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Evaluation of Organic and Inorganic Fertilizers for Orange-Fleshed Sweetpotato Production under Humid Tropical Conditions of South East Nigeria

Wisdom Ezechi[1,2], Dominic Okpara[1], Charity Nwadinobi[1], and Chinedu Eze[1]

[1]Department of Agronomy, Michael Okpara University of Agriculture, Umudike, Abia State Nigeria
[2]Sahel Consulting Agriculture and Nutrition Limited, Nigeria.
Corresponding author's email: wisdom.ezechi@gmail.com

Abstract
Sweetpotato, especially the orange-fleshed type, is an important crop that is now receiving greater attention in Nigeria. This has generated demand for information on management practices such as fertilization aimed at optimizing growth and yield under local smallholder conditions. Given this, a field study was conducted in a humid tropical ultisol at Umudike, south-eastern Nigeria to evaluate organic and inorganic fertilizer application on the growth and yield of three orange-fleshed sweetpotato varieties. The experiment was laid in a 5 x 3 factorial arranged in a randomized complete block design (RCBD) with three replications. The organic and inorganic fertilizer rates were zero application, 4t/ha poultry manure, 4t/ha cow dung, a combination of poultry manure and cow dung at 2t/ha each, and 400kg/ha NPK (15:15:15) fertilizer; while the sweetpotato varieties were Umuspo 1, Umuspo 3 and Umuspo 4. The result showed that, in both the year 2020 and 2021 cropping seasons, the application of poultry manure alone at 4t/ha produced a significantly greater leaf area index compared to other fertilizer treatments. Organic and inorganic fertilizer application did not significantly (P>0.05) influence storage root yields likely due to the fairly fertile soils used, but the application of poultry manure at 4t/ha gave significantly higher dry matter content of the storage roots than other treatments. Orange-fleshed sweetpotato varieties Umuspo 1 and Umuspo 3 had similar root yields of 11.2t/ha and 13.3t/ha respectively, but significantly higher yields than Umuspo 4 (3.9 t/ha); while shoot biomass was comparable in Umuspo1 and Umuspo 4 but higher than that of Umuspo 3. Interaction effects showed that the highest dry matter content (35.5%) of the storage roots was obtained from Umuspo 1 received 4t/ha poultry manure while the highest carotene content (78.9 ug/g) of storage roots was obtained from Umuspo 3 variety at zero application. Based on financial returns, the highest profit (gross margin) of 3,400 was obtained from the application of poultry manure at 4t/ha on Umuspo 3, followed by Umuspo 1 variety. Overall, the results illustrate the importance of the choice of variety and fertilization in improving sweetpotato productivity and providing higher income to the farmers.
Keywords: Economic returns, orange-fleshed, root yield, sweetpotato, and variety

Introduction

Sweetpotato *(Ipomoea batatas)* is a storage root crop that belongs to the family of *Convolvulaceae*. Sweetpotato is the 6[th] most important food crop after rice, wheat, maize, and cassava. But in developing countries, it is the 5[th] most important food crop (Tortoe, 2010). More than 105 million metric tons are produced globally each year; 95% of which are grown in developing countries (CIP, 2014). Sweetpotato comes in varieties with skin and flesh colours that range from white to yellow, orange, and deep purple. Orange-fleshed sweetpotato is an important source of beta-carotene, the precursor to Vitamin A. The strategy of increasing orange-fleshed sweet potato consumption helps to alleviate vitamin A deficiency (Anderson *et al.*, 2007). Vitamin A is very vital to the diet of the rural poor and its deficiency causes night blindness, a serious public health problem in many developing countries (WHO, 1995). Sweet potatoes are now being used in Africa to combat a widespread vitamin A deficiency in 250,000 – 500,000 children. The roots are also a source of industrial material for the production of starch and alcohol (Ukom *et al.*, 2009).

Sweetpotatoes are usually consumed without special processing. It is a starchy root crop containing vitamins, particularly vitamin A, and minerals comparable to those of various fruits (Truong, 1987) while its edible leaves contain about 34.5% crude protein (Nwinyi, 1988) and could be fed to an animal as forage. The fresh tuber is boiled, roasted, baked, or fried as chips, which may be sold as snacks or salted and eaten as potato crisps in most parts of Nigeria. Sweet potatoes are fed to livestock or processed industrially into alcohol, starch, noodles, candy, desserts and flour (Umoh, 2013).

Although the development and introduction of new varieties of orange-fleshed sweetpotato have resulted in a tremendous increase in production in Nigeria, sustainable production is constrained by prevailing poor soil fertility (Njoku *et al*., 2001, Okpara *et al*., 2011, Akpaninyang *et al*., 2013, 2015). Therefore, for farmers to benefit and realize higher yields and economic returns from the newly released orange-fleshed sweetpotato varieties, there is a need to explore the effect of fertilizer types or combinations on the crop. Most small-scale farmers, however, lack the financial resources to procure inorganic fertilizers, which are usually expensive and sometimes hardly available when required. With the intensive use of land for agriculture and the heavy rainfalls that cause the leaching of nutrients in southern Nigeria, the use of fertilizers is becoming mandatory to achieve high yields (Muoneke *et al*., 2011). This paper evaluated the effect of organic and inorganic fertilizers on the growth and yield of three varieties of orange-fleshed sweetpotato. The work also sought to evaluate the effect of organic and inorganic fertilizer combinations on dry matter and beta-carotene contents of the root tubers and financial returns in gross margin.

Materials and Methods

The experiment was conducted in two consecutive cropping seasons at Michael Okpara University of Agriculture, Umudike research farm in south eastern Nigeria. Umudike is located at latitude 05˚ 29´ N, longitude 07˚ 33´ E and 122m above sea level altitude. The soil of the experimental site is an utisol and was texturally loamy sand in 2020 and sandy clay loam in 2021. The soil chemical characteristics were 5.9 pH, 4.1% Organic Manure (OM), 0.22% Nitrogen (N), 47.8mg/kg Phosphorus (P) and 0.38Cmol/kg Potassium (K) in 2020, and 5.7 pH, 3.38% OM, 0.18% N, 43.0mg/kg P and 0.17Cmol/kg K in 2021. The total annual rainfall was 2292.8mm in 2020 and 2838.92mm in 2021. In each cropping season, the experimental site was slashed, ploughed, harrowed and ridges made 1m apart. The experiment was laid in a 4 x 3 factorial arranged in a randomized complete block design (RCBD) with three replications. Treatments comprised four fertilizer types (0t/ha (control), 4t/ha poultry manure, 4t/ha cow dung, 2t/ha each of poultry manure and cow dung, and 400kg/ha NPK fertilizer) and three varieties of orange-fleshed sweetpotato (Umuspo 1, Umuspo 3 and Umuspo 4). The plot was 3 X 2m ($6m^2$) and each treatment combination was randomly allocated to the plots. The poultry manure and cow dung were thoroughly incorporated into appropriate plots after ridging. In both years 2020 and 2021, the following treatment was used: poultry manure had 9.52pH, 55.82% OM, 2.31% N, 0.575% P and 0.725% K while cow dung had 10.26Ph, 54.55%OM, 1.79% N, 0.61% P and 0.70% K. Vine cuttings of the sweetpotato varieties each measuring 20cm in length were planted on 22nd May 2020 and 27th June 2021. The supply of dead stands was done at 4 weeks after planting (WAP). Hoe weeding was done at 4 and 8 WAP. Records were taken on leaf area index (LAI) at 6, 8, 10 and 12 WAP, and on shoot biomass and storage root yield at 18WAP. The leaf area used for LAI was determined according to Ramanuyan and Indira's (1978) method. The data were subjected to analysis of variance using GenStat (2007) statistical package.

Results and Discussion

Results

The effect of organic and inorganic fertilizer application on leaf area index showed increased progressive differences from 6 to 12 weeks after planting (Table 1). Generally, poultry manure applied at 4t/ha consistently produced the highest LAI of 4.7 while the application of cow dung alone gave the lowest 2.2 LAI across ages. Umuspo 1 had significantly (P<0.05) higher LAI than Umuspo 3 and Umuspo 4 varieties across sampling dates. The two varieties (Umuspo 3 and Umuspo 4) produced statistically significant (P<0.05) similar LAI values. Shoot biomass in both cropping seasons was not affected by the application of organic and inorganic fertilizers (Table 2). Umuspo 1 and Umuspo 4 varieties had similar above-ground biomass of 18.1t/ha and 17.4t/ha respectively but significantly (P<0.05) higher values than Umuspo 3. Fertilizer and variety interaction effects were not significant (P>0.05) on top yield in both seasons. The result of the table showed higher values of 18.2t/ha for storage root yield with poultry manure at 4t/ha. There was no significant (P>0.05) difference between the result of the organic and inorganic fertilizer application in both cropping seasons (Table 3). However, the highest storage root yield was obtained from sweetpotato variety Umuspo 3, followed closely by Umuspo 1 while the lowest yield was from Umuspo 4 in 2020. In 2021, the yield of storage roots did not differ significantly (P>0.05) between Umuspo 3 and Umuspo 1 varieties, but both had higher root yields than Umuspo 4. Interactions of fertilizer and variety did not significantly influence storage root yield in both seasons. There were significant (P<0.05) effects of fertilizer, variety and interactions of both factors on dry matter of storage roots (Table 4). Poultry manure application at 4t/ha produced the highest dry matter content, followed by inorganic NPK fertilizer and the least dry matter was from a combination of Cow dung and Poultry Manure, while Umuspo 1 variety had the highest dry matter content, followed by Umuspo 3. Interactions showed that Umuspo 1 which received 4t/ha poultry manure gave the highest dry matter content of 34.4% on average. There were significant (P<0.05) effects of fertilizer, variety and interactions of both factors on dry matter of storage roots (Table 4). Poultry manure application at 4t/ha produced the highest dry matter content, followed by inorganic NPK fertilizer, while the Umuspo 1 variety had the highest dry matter content, followed by Umuspo 3. Interactions showed that Umuspo 1 which received 4t/ha poultry manure gave the highest dry matter content of 34.4% on average. The effect of organic and inorganic fertilizer application varied significantly on the carotene content of storage roots, with zero application producing the highest values (66.1 ug/g), followed closely by combined application of poultry manure and cow dung (65.6 ug/g) and poultry manure alone with61.1 ug/g. (Table 5). The lowest carotene yield (57.5 ug/g) was from the application of cow dung alone. For the varieties, Umuspo 3 produced significantly the highest carotene content of 73.7 – 74.6 ug/g, followed by

Umuspo 4 (66.8 – 67.7 ug/g) while Umuspo 1 (44.4 – 44.6 ug/g) had the least. There were also significant interaction effects, with Umuspo 3 at zero application or a combination of poultry and cow dung at 2t/ha each, producing the highest carotene content (77.8 – 79.1 ug/g) of storage roots. The average result across two cropping seasons of the revenue (N2,874.4), gross margin (N2,374) and return per naira invested (N5.2) were highest in Umuspo 3 variety with poultry manure application, followed by the same variety that received NPK fertilizer (Table 6). The least revenue (N1,066.2), gross margin (N605.4) and return per naira invested (N1.6) were mostly Umuspo 4 that received especially a combination of poultry manure and cowdung.

Discussion

Application of poultry manure alone at 4t/ha consistently produced a higher leaf area index than inorganic NPK fertilizer, cow dung or the control across ages, especially due to the chemical characteristics of the former. Muoneke *et al.* (2013) obtained similar results and attributed manure-treated treated plots to the nitrogen content of the manure. The chemical composition of the manures showed poultry manure to have higher total nitrogen of 2.31 – 2.35% while cowdung had lower values of 1.75 – 1.79% N. Despite the greater leaf area index with poultry manure, fertilizer application did not impact proportionately on storage root yield, primarily due to the native soil nutrient status which was high in organic matter (3.4 – 4.1%), nitrogen (0.18 – 0.22%), phosphorus (43.0 – 47.8 mg/kg) and potassium (0.17 – 0.38 Cmol/kg), with a high pH of 5.7 to 5.9. However, for a slightly lower potassium content in 2021, these values were above the critical values reported by Fairhurst (2012). With the high fertility of the soil, the application of poultry manure encourages luxuriant growth at the expense of storage root bulking, since older and shaded leaves in the lower parts of the canopy reached their light compensation point and became sinks rather than sources of current assimilate (Hay and Walker, 1989). However, organic and inorganic fertilizer applications still exerted considerable influence on dry matter and carotene contents of storage roots and economic returns. On average, the highest dry matter content was obtained from the application of poultry manure alone at 4t/ha while the highest carotene content was from zero application. The high dry matter content obtained with poultry manure application may be attributed to an adequate supply of nitrogen and potassium by the manure, as both elements are critical for root production (Okpara *et al,* 2014). On the other hand, the higher carotene content from zero application may be a result of reduced nutrient dilution from lower yield or dry matter production. Okpara and Omaliko (1995) made similar observations in the nutrient concentration of herbage. Like the results for dry matter content, economic analysis showed that profit was maximized with the application of poultry manure at 4t/ha since it had the highest gross margin and return per naira invested.

For the varieties, Umuspo 1 was superior in crop growth (LAI and biomass) while optimum storage root yields and economic benefits were obtained from the less vegetative Umuspo 3, followed by the more vegetative Umuspo 1. Both Umuspo 3 and Umuspo 1 varieties have been reported as top yielders (Akpaninyang *et al*., 2015; Ogbologwung *et al*., 2016). Besides producing higher root yields and economic returns, Umuspo 3 gave the highest beta-carotene content in tuberous roots while Umuspo 1 had the highest dry matter content in storage roots. Generally, Umuspo 4 had a high shoot yield but the lowest storage root yield and financial returns, indicating poor adaptation to the Umudike environment in southeastern Nigeria, even though it may serve in erosion control due to the ground cover. Correspondingly, interaction effects showed that Umuspo 1 at 4t/ha poultry manure produced the highest dry matter content, while Umuspo 3 at zero application gave the highest beta-carotene content of storage roots. In all, the response of sweetpotato to 4t/ha poultry manure was substantial, confirming the importance of the manure for sweetpotato production even in fairly fertile soil in southeastern Nigeria, where the sandy loam utisols are subject to high leaching due to high rainfalls. With high costs of chemical fertilizer, poultry manure would provide a low-cost supply of nutrients and organic matter with which farmers improve soil productivity, sweetpotato yield and income. There is evidence indicating that poultry manure has significant effects on soil productivity through residual effects or slow release of nutrients and through its influence on soil physical and chemical properties (Muoneke *et al*., 2011; Ndukwe *et al*., 2011). Root yield was higher by 30.1% in 2020 than in 2021, due probably to infection by virus, especially on the Umuspo 3 variety. Similar to the results for root yield, profit was maximized in Umuspo 3 with the application of 4t/ha poultry manure which had the highest revenue, gross margin and return per naira invested, followed by the same variety that received 400kg/ha NPK (15:15:15) fertilizer.

Conclusion

The findings in the results suggest that poultry manure application at 4t/ha is important for improving sweetpotato yield, dry matter content and farmer's income under the humid tropical conditions of southeastern Nigeria. Of the varieties, Umuspo 3 is a top yielder, followed by Umuspo 1 and both varieties are recommended for improved food and nutritional security and improved income for farmers in the region.

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Table 1: Effect of organic and inorganic fertilizers and varieties on the Leaf area index (LAI) at different sampling dates in 2020 and 2021 cropping seasons

Fertilizer treatment	**Weeks after planting**			
	6	**8**	**10**	**12**
Control	1.8	3.1	3.4	3.7
400kg/ha NPK	1.6	2.7	3.0	3.4
4t/ha Poultry Manure (PM)	2.5	3.8	4.3	4.7
4t/ha cow dung (CD)	1.1	1.6	2.0	2.2
2t/ha PM + 2t/ha CD	2.1	2.7	3.2	3.4
Mean	1.8	2.8	3.2	3.5
LSD (0.05)	**0.7**	**0.7**	**0.9**	**0.9**
Variety				
Umuspo 1	2.0	4.0	4.4	4.7
Umuspo 3	1.3	2.1	2.6	2.9
Umuspo 4	1.4	2.2	2.5	2.8
Mean	1.8	2.8	3.2	3.5
LSD (0.05)	**0.7**	**1.6**	**1.7**	**1.7**

Table 2: Effect of organic and inorganic fertilizers on shoot biomass (t/ha) of three varieties of orange-fleshed sweetpotato in 2020 and 2021 cropping seasons

Fertilizer treatment	**Variety**			
	Umuspo 1	**Umuspo 3**	**Umuspo 4**	**Mean**
Control	16.6	11.5	16.4	14.9
4t/ha Cow dung (CD)	14.7	9.0	15.8	13.2
4t/ha Poultry Manure (PM)	22.1	13.1	16.3	17.2
2t CD + 2t/ha PM	20.6	7.2	17.4	15.1
400kg/ha NPK	16.2	8.5	20.8	15.1
Mean	18.1	9.9	17.4	
LSD (0.05) for fertilizer (F) means = NS				
LSD (0.05) for variety (V) means = 3.98				
LSD (0.05) for F * V means = NS				

Table 3: Effect of organic and inorganic fertilizers on storage root yield (t/ha) of three varieties of orange-fleshed sweetpotato in 2020 and 2021 cropping seasons

Fertilizer treatment	Variety			
	Umuspo 1	Umuspo 3	Umuspo 4	Mean
Control	10.4	10.8	4.5	8.6
4t/ha Cow dung (CD)	9.4	11.0	4.2	8.2
4t/ha Poultry Manure (PM)	11.4	18.2	3.7	11.1
2t CD + 2t/ha PM	13.0	10.4	2.2	8.5
400kg/ha NPK	11.8	16.1	4.5	10.9
Mean	11.2	13.3	3.9	
LSD (0.05) for fertilizer (F) means = NS				
LSD (0.05) for variety (V) means = 3.4				
LSD (0.05) for F * V means = NS				

Table 4: Effect of organic and inorganic fertilizers on the dry matter content (%) of three varieties of orange-fleshed sweetpotato in 2020 and 2021 cropping seasons

Fertilizer treatment	**Variety**			
	Umuspo 1	**Umuspo 3**	**Umuspo 4**	**Mean**
Control	35.2	21.9	21.9	26.5
4t/ha Cow dung (CD)	32.6	22.7	21.8	25.7
4t/ha Poultry Manure (PM)	35.5	23.2	20.9	26.5
2t CD + 2t/ha PM	30.0	19.8	17.0	22.3
400kg/ha NPK	31.4	22.9	25.9	26.8
Mean	32.9	22.1	21.5	
LSD (0.05) for fertilizer (F) means = 0.02				
LSD (0.05) for variety (V) means = 0.02				
LSD (0.05) for F * V means = 0.04				

Table 5: Effect of organic and inorganic fertilizers on the carotene content (ug/g) of storage roots of three varieties of orange-fleshed sweetpotato in 2020 and 2021 cropping seasons

Fertilizer treatment	**Variety**			
	Umuspo 1	**Umuspo 3**	**Umuspo 4**	**Mean**
Control	48.7	78.9	70.9	66.1
4t/ha Cow dung (CD)	40.4	69.3	62.4	57.5
4t/ha Poultry Manure (PM)	45.3	70.7	67.4	61.1
2t CD + 2t/ha PM	47.4	78.8	70.6	65.6
400kg/ha NPK	41.5	70.3	62.5	58.1
Mean	44.6	73.7	66.8	
LSD (0.05) for fertilizer (F) means = 0.04				
LSD (0.05) for variety (V) means = 0.03				
LSD (0.05) for F * V means = 0.06				

Table 6: 2–Year mean economic analysis of the effect of fertilizer types on three orange-fleshed sweetpotato varieties (2020 and 2021) Naira (x1000/ha)

					Um 1 (₦)					Um 3 (₦)					Um 4 (₦)
Item/ha	**CTR**	**NPK**	**PM**	**CD**	**PM+CD**	**CTR**	**NPK**	**PM**	**CD**	**PM+CD**	**CTR**	**NPK**	**PM**	**CD**	**PM+CD**
Land preparation	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Vines (334 bundles)	167.0	167.0	167.0	167.0	167.0	167.0	167.0	167.0	167.0	167.0	167.0	167.0	167.0	167.0	167.0
NPK fertilizer (8 bags)		88.0	20.0	20.0	20.0		88.0	20.0	20.0	20.0		88.0	20.0	20.0	20.0
Planting	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5
Weeding (twice)	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0
Fert/manure Application		22.5	22.5	22.5	22.5		22.5	22.5	22.5	22.5		22.5	22.5	22.5	22.5
Harvesting	49.5	49.5	49.5	49.5	49.5	49.5	49.5	49.5	49.5	49.5	49.5	49.5	49.5	49.5	49.5
Transportation	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0
Cost of production	453	563	495	495	495	453	563	495	495	495	453	563	495	495	495
Yield (t/ha)	8.19	9.94	9.1	9.48	10.31	9.17	14.16	15.59	9.68	8.88	4.06	5.39	3.99	4.25	3.34
Revenue	2,047	2,483	2,275	2,301	2,579	2,293	3,538	3,896	2,427	2,218	1,014	1,347	1,071	1,063	836
Gross margin	1,594	1,920	1,779	1,805	2,084	1,840	2,975	3,400	1,932	1,723	562	784	576	576	529
Return per ₦ invested	4.02	3.91	4.09	4.15	4.71	4.57	5.78	7.36	4.39	3.98	1.74	1.89	1.67	1.65	1.19