COMBINATIONS OF ORGANIC AND INORGANIC FERTILIZERS FOR VINE, CAROTENE AND ROOT YIELDS OF ORANGE-FLESHED SWEETPOTATO AT UMUDIKE, SOUTHEASTERN NIGERIA

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ABSTRACT

Field experiment was conducted during 2013 and 2014 cropping season at Umudike, southeastern Nigeria, to evaluate the effect of fertilizer combinations (poultry manure, NPK (15:15:15) and agrolyser) on two varieties of orange-fleshed sweetpotato (*Ipomoea batatas*). The experiment was a split-plot laid out in randomized complete block design (RCBD) with three replications. Combined application of 2.5 t/ha poultry manure + 200 kg NPK produced significantly higher leaf area index of 3.3, shoot biomass of 31.9 t/ha and multiplication ratio of 1:48than the control or application of NPK or agrolyser alone. Application of 2.5 t/ha poultry manure + 200 kg NPK also produced significantly higher average storage root yield of 29.1 t/ha than no fertilizer or agrolyser application, and also gave higher carotenoid level than application of NPK or the control. Umuspo 1 suppressed weeds more and significantly produced 598% higher shoot biomass and 125% higher average storage root yield than Umuspo 3. Umuspo 3 variety however, had a carotenoid level of 2268.1mg/g, which was higher than that of Umuspo 1 by 1860%. The highest net monetary returns from the cultivars accrued from a combined application of 2.5t/ha poultry manure and 200 kg NPK while the lowest return was from where no manure was applied or where agrolyser was applied alone.

Keywords: Carotene, fertilizer combinations, orange-fleshed, *Ipomoea batatas,* yields

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INTRODUCTION

Sweetpotato ranks fifth in importance after rice, wheat, maize and cassava in developing countries (Som, 2007). The crop is valued for its roots which can be boiled, fried, baked and roasted for humans or fed to livestock as a source of energy. The roots are also a source of industrial material for the production of starch and alcohol (Ukom *et al,* 2009) while the leaves are used as vegetables (Nwinyi, 1988). Orange-fleshed sweetpotatoes are particularly rich in pro-vitamin A and can contribute significantly to vitamin A nutrition in humans. Vitamin A is very vital to the diet of the rural poor and its deficiency is a serious public health problem in many developing countries (WHO, 1995). Low soil fertility is a major constraint to sweet potato production in the ultisols of south eastern Nigeria (Njoku *et al.,* 2001). Chemical fertilizers are commonly used to improve soil fertility (FAO, 2000). Research has shown that application of inorganic fertilizer increases root yields (Njoku *et al.,* 2001) but hampers sweet potato quality (Nedunchezhiyan *et.al*., 2003) and aggravates soil degradation (Mbah, 2008).

Poultry manure contains both macro and micro nutrients and, in contrast to inorganic fertilizer, adds organic matter to improve soil structure, soil aeration, nutrient retention, soil moisture holding capacity and water infiltration (Amanullah *et al.,* 2010). Appropriate poultry manure management is essential to ensure maximum crop nutrient utilization and reduce risk of negative environmental impact. The slow release of nutrients from organic manures can be complemented by enriching them with inorganic nutrients which are easily available to boost crop growth (Uwah *et al.,* 2011). The objective of the study was to determine the optimum combinations of poultry manure, NPK and agrolyser for vine, carotene and monetary yields of orange fleshed sweet potato varieties in a humid location of south eastern Nigeria.

MATERIALS AND METHODS

The study was conducted during the 2013 and 2014 cropping seasons at the National Root Crops Research Institute at Umudike farm, south eastern Nigeria. Umudike is located between latitude 05^0 29'N and longitude 07^0 33'E and at an elevation of 122m above sea level. The soil is an ultisol and was texturally sandy loam. Soil properties of the site in 2013 were: sand 78.8%, silt 10.0%, clay 11.2%. pH (H_20) 4.7, organic matter 1.59%, N 0.08%, P 32.1mg/kg and K 0.35 cmol/kg. In 2014, soil properties of the site were sand 75.9%, silt 11.6%, clay 12.5%, pH 4.5, organic matter 2.22%, N 0.09%, P 43.6 mg/kg and K 0.20 cmol/kg. The experiment was a split plot arranged in randomized complete block design with three replications. The main plot treatments were two orange-fleshed sweet potato varieties (Umuspo 1 and Umuspo 3). Umuspo 1 is erect with thick vines, lobed leaf, pink root skin and light orange root flesh while Umuspo 3 is a creeper with purplish thin vines, triangular leaf without lobe, orange root skin and orange root flesh. The sub plot treatments were nine fertilizer combinations (0, 5.3 kg/ha agrolyser, 400 kg/ha NPK, 5 t/ha poultry manure 10 t/ha poultry manure, 200 kg/ha NPK + 2.7 kg agrolyser, 2.5 t/ha poultry manure + 200 kg NPK, 5 t/ha poultry manure + 200 kg NPK and 2.5 t/ha poultry manure + 200 kg NPK +2.7 kg agrolyser). Chemical analyses showed that the poultry manure had pH 7.06, N 2.17%, P 1.06% and K 0.62% in 2013. In 2014, the poultry manure had pH 7.26, N 2.31%, P 0.84% and K 0.66%. The poultry manure rates were applied into appropriate plots after ridging while the NPK fertilizer (15:15:15) and for plots with agrolyser and NPK 15:15:15, agrolyser was thoroughly mixed with the compound fertilizer for ease of application. Rates were applied 4 weeks after planting (WAP) by band placement. Each plot (subplot) measured 3 m X 2 m ($6m^2$). The agrolyser contained secondary and micronutrients (Ca 20.14%, Na 1.04%, Zn 0.11%, Mg 0.19%, Cu 0.19, S 2.12%).

Sweetpotato vine cuttings of 20 cm length with a least 4 nodes were planted at a spacing of 1 m X 0.3 m along the crest of the ridges on 23 June in 2013 and on 31 May in 2014. This gave a plant population of 33333 plants/ha for each year. Supply of dead stands was done at 4 WAP. Hoe weeding was done at 4 and 8 WAP. Weeds were sampled with 1m X 1m quadrat at 8 WAP and oven dried at 70^0C for 72 hours. Measurements taken included leaf area index (LAI), fresh shoot weight, multiplication ratio, carotene, storage root yield and net returns. LAI was calculated using the formula (Hunt, 1978): LA/P, where LA = total leaf area and P = land area occupied by plant. Leaf area used in leaf area index calculation was determined by the disc method according to the procedure of Kelm *et al* (2001). Carotene determination was by the methods described by Rodrigues-Amaya (1999). Net returns were determined by multiplying the yield of crop with prevailing market price of the commodity minus the total cost of production within the location (Eke Okoro *et al*., 2005). Multiplication ratio (MR) was determined with the formula: MR = Weight of harvested biomass/Weight of planting material (Onwueme, 1978).The data were subjected to analysis of variance using GenStat (2007) statistical package.

RESULTS

There were significant effects of fertilizer combinations and variety on weed density and growth (Table 1). The combined application of 2.5 or 5 t/ha poultry manure and 200 kg NPK, or application of 2.5 t/ha poultry manure and 200 kg NPK + 2.7 kg agrolyser produced significantly lower weed density than other fertilizer treatments except 10 t/ha poultry manure. Umuspo 1 significantly reduced weed population compared to Umuspo 3 variety. Weed dry matter was lowest with combined application of 2.5 t/ha poultry manure and 200 kg NPK + agrolyser while application of 400 kg/ha NPK produced the highest weed dry weight. Weed dry matter was significantly lower in Umuspo 1 than in Umuspo 3. Interactions were significant, with Umuspo 1 variety producing lower weed population and growth at all fertilizer treatments except combined application of 2.5 t/ha poultry manure + 200 kg NPK + agrolyser. Data on leaf area index and shoot biomass are presented in Table 2. At 12 WAP, combined application of 2.5 t/ha poultry manure + 200 kg NPK significantly produced higher leaf area index than other treatments. Similarly, Umuspo 1 variety produced higher LAI than Umuspo 3. Interaction effects were such that combining 2.5 or 5 t/ha poultry manure + 200 kg NPK with Umuspo 1 produced the highest LAI.

Unlike LAI data, application of 5 t/ha poultry manure produced the highest shoot biomass at 16 WAP while no fertilizer application or application of agrolyser alone gave lowest shoot yield. Among the varieties, Umuspo 1 produced 698% higher shoot yield than Umuspo 3. Interaction effects showed that Umuspo 1 had significantly higher shoot biomass than Umuspo 3 at all fertilizer combinations. The effects of fertilizer combinations and sweet potato variety on multiplication ratio and carotene yield are shown in Table 3. At 16 WAP, multiplication ratio was significantly highest with application of 5t/ha poultry manure the lowest was produced where no fertilizer was applied or where agrolyser or NPK was applied alone. Umuspo 1 variety had a multiplication ratio of 1:78 and this was remarkably higher by 710% than that of Umuspo 3. Interaction effects showed that application of poultry manure at 5 t/ha with Umuspo 1 produced the greatest multiplication ratio. Combined application of 200 kg/ha NPK + 2.7 kg agrolyser produced significantly the highest carotene yield of 1589.5 mg/g, followed by the application of 5 t/ha poultry manure or 2.5 t/ha poultry manure +200 kg NPK. The lowest carotenoid levels of 869.3 – 981.0 mg/g were produced where agrolyser was applied alone or where 5 t/ha poultry manure + 200 kg NPK or 2.5 t/ha poultry manure + 200 kg NPK + agrolyser were applied. Unlike the data on sweet potato growth, Umuspo 3 variety significantly produced 1860% higher carotene yield than Umuspo 1. Interactions were not significant on carotene yield.

Although storage root yields mostly followed the same pattern in response to nutrient management in both years, significant effects were produced in 2013 only (Table 4). Across the years, storage root yield obtained from combined application of 2.5 t/ha poultry manure + 200 kg NPK was 29.1 t/ha and this was significantly higher than the yields from the control or from application of agrolyser or 200 kg/ha NPK + agrolyser (Table 5). Similarly, Umuspo 1 had average storage root yield of 29.3 t/ha which was more than double the yield of Umuspo 3. Fertilizer combination and variety did not produce significant interaction effect in both years on storage root yield. Economic analysis showed that the highest net monetary returns were obtained from combined application of 2.5 t/ha poultry manure + 200 kg NPK while the lowest returns were from no fertilizer or agrolyser application, on average (Table 5). Umuspo 1 variety produced higher net monetary returns than Umuspo 3.

DISCUSSION

In this study, combined application of 2.5 t/ha poultry manure + 200 kg NPK favoured crop growth and suppressed weed as it produced greater leaf area index and shoot biomass compared to the control or application of NPK alone. The crop canopy closure may have developed much earlier in the former which had a high LAI of 3.3, resulting in shading that reduced weed population. Muoneke *et al* (2013) obtained similar results and attributed the production of more leaves in manure treated plots to the nitrogen content of the manure. However, application of 5t/ha poultry manure or combined application of 5 t/ha poultry manure + 200 kg NPK produced the highest shoot biomass and multiplication ratio but did not improve storage root yield compared to the lower rate of 2.5 t/ha poultry manure + 200 kg NPK. This indicates that high manure rate 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).

Combined application of 2.5 t/ha poultry manure + 200 kg NPK also produced higher storage root yield over no fertilizer or agrolyser application on the average. Agrolyser had no positive effect on the crop, and the poor yields obtained from its application may probably be due to antagonistic effects or nutrient imbalance arising from non-application of the primary nutrients. For example, agrolyser had calcium which precipitates inorganic phosphorus, restricts magnesium uptake and translocation as well as copper which inhibits uptake of zinc and displaces other ions from root exchange sites (Mengel and Kirkby, 2001). The average storage root yield of 29.1 t/ha obtained from application of 2.5 t/ha poultry manure + 200 kg NPK was higher than the yield values from no fertilizer application or application of agrolyser alone by 89% and 133%, respectively. Of interest also is the carotenoid level of 1368.2mg/g obtained from application of 2.5 t/ha poultry manure + 200 kg NPK, which was remarkably higher than those of the control or the higher rate of 5t/ha poultry manure + 200 kg NPK or application of NPK or agrolyser alone. Overall, the highest net monetary return was obtained from application of 2.5 t/ha poultry manure + 200 kg NPK. This highlights the advantage of mixing organic and inorganic fertilizers at lower rates and the benefits of manure in improving soil quality and crop yields as reported by Sangakkara *et al* (2014).

For the cultivars, Umuspo 1 was more effective in suppressing weed growth and had more sweetpotato top and storage root yield, as well as higher net monetary returns than Umuspo 3. Lack *et al* (2011) and Sakariyawo *et al* (2014) in their studies on rice observed genotypic variability on yield and attributed such differences to the inherent ability of the cultivars to adapt, utilize and response to applied input and local stresses. Umuspo 1 produced shoot biomass of 51.9 t/ha and average storage root yield of 29.3 t/ha, which were higher than those of Umuspo 3 by 698% and 125%, respectively. Although yields were generally lower in 2013, Umuspo 3 was more adversely affected due to mainly the use of some viral infected vines in that year. High average storage root yields of 47.4 t/ha for Umuspo 1 and 19.6 t/ha for Umuspo 3 were obtained in 2014 but the carotenoid level was much lower in the former. Umuspo 3 variety had a carotenoid content of 2268.1 mg/g, which was 1860% higher than that of Umuspo 1.

CONCLUSION

In conclusion, the results showed that combined application of 2.5 t/ha poultry manure + 200 kg NPK produced significantly greater leaf area index and greater shoot biomass compared to the control or application of NPK or application of agrolyser alone. Average root yield was also higher with the application of 2.5 t/ha poultry manure + 200 kg NPK than with the control or application of agrolyser. The carotenoid level obtained from combining 2.5 t/ha poultry manure + 200 kg NPK was higher than those of the control or application of NPK or agrolyser alone. Although Umuspo 1 was more weed competitive and produced higher leaf area index, shoot biomass and storage root yield than Umuspo 3, the latter gave higher carotene yield than the former. Highest monetary yields accrued from combined application of 2.5 t/ha poultry manure + 200 kg NPK. Combining organic and inorganic fertilizers at the lower rates of 2.5 t/ha poultry manure + 200 kg NPK is therefore recommended for orange-fleshed sweet potato production in south eastern Nigeria.

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Table 1: Effect of fertilizer combination and variety on weed density and growth in 2014

Variety	0	5.4kgAg	400kg NPK	200kg NPK + 2.74Ag	5t PM	10t PM	5tPM+ 200kg NPK	2.5tPM + 200kg NPK	2.5tPM + 200kg NPK+Ag	Mean
	Fertilizer Combination									
	Weed density (number/m^2)									
Umuspo 1	34.0	33.0	46.7	42.3	40.3	45.3	31.0	34.3	36.4	38.2
Umuspo 3	174.0	159.3	94.3	103.0	95.0	85.0	69.3	81.3	47.7	101.0
Mean	104.0	96.2	70.5	72.7	67.7	65.2	50.2	57.8	42.0	
	Weed dry matter (g/m^2)									
Umuspo 1	98.7	63.1	80.1	39.5	118.0	211.8	29.4	35.5	39.5	79.4
Umuspo 3	205.4	114.6	320.5	101.7	181.0	173.5	119.4	291.1	34.3	171.3
Mean	152.1	88.9	200.3	70.6	149.5	192.7	74.4	163.4	36.9	

		Weed density	Weed dry matter
LSD $_{(0.05)}$ for two fertilizer (F) means	=	8.1	6.5
LSD $_{(0.05)}$ for two variety (V) means	=	12.3	12.9
LSD $_{(0.05)}$ for two (F X V) means	=	12.5	11.1

Table 2: Effect of fertilizer combination and variety on leaf area index at 12 WAP and fresh shoot biomass at 16WAP in 2014

Variety	0	5.3kgAg	400kg NPK	200kg NPK + 2.74Ag	5t PM	10t PM	5tPM+ 200kg NPK	2.5tPM + 200kg NPK	2.5tPM + 200kg NPK+Ag	Mean
	Fertilizer Combination									
	Leaf area index									
Umuspo 1	1.6	1.4	5.3	3.1	5.4	4.4	6.3	5.9	4.3	4.2
Umuspo 3	0.4	0.4	0.4	0.5	0.4	1.3	1.2	0.6	0.6	0.6
Mean	1.0	0.9	2.9	1.8	2.9	2.9	3.8	3.3	2.5	
	Shoot biomass (t/ha)									
Umuspo 1	31.2	29.9	39.1	36.3	83.9	50.4	76.5	56.4	62.9	51.9
Umuspo 3	4.3	4.0	6.5	5.2	10.0	8.7	7.0	7.0	5.8	6.5
Mean	17.8	16.9	22.8	20.7	47.0	29.5	41.8	31.9	34.3	

		LAI	Shoot biomass
LSD $_{(0.05)}$ for two fertilizer (F) means	=	0.04	5.1
LSD $_{(0.05)}$ for two variety (V) means	=	0.03	27.7
LSD $_{(0.05)}$ for two (F X V) means	=	0.05	22.3

Table 3: Effect of fertilizer combination and variety on multiplication ratio and carotene yield in 2014

Variety	0	5.3kgAg	400kg NPK	200kg NPK + 2.74Ag	5t PM	10t PM	5tPM+ 200kg NPK	2.5tPM + 200kg NPK	2.5tPM + 200kg NPK+Ag	Mean
							Multiplication ratio			
Umuspo 1	46.8	44.8	58.7	54.5	125.8	75.5	114.8	85.2	94.3	77.8
Umuspo 3	6.5	6.0	8.3	7.8	15.0	13.0	10.5	10.5	8.7	9.6
Mean	26.7	25.4	31.2	33.5	70.4	44.3	62.7	47.8	51.5	
							Carotene yield (mg/g)			
Umuspo 1	116.1	138.7	96.9	113.3	161.1	68.7	83.9	110.6	152.6	115.7
Umuspo 3	1916.0	1823.2	2396.6	3065.6	2714.5	2433.1	1654.7	2625.8	1783.5	2268.1
Mean	1016.1	981.0	1246.8	1589.5	1437.8	1437.8	869.3	1368.2	968.1	

		LAI	Shoot biomass
LSD $_{(0.05)}$ for two fertilizer (F) means	=	7.7	116.3
LSD $_{(0.05)}$ for two variety (V) means	=	42.0	38.1
LSD $_{(0.05)}$ for two (F X V) means	=	33.8	NS

Table 4: Effect of fertilizer combination and variety on storage root yield (t/ha) of orange-fleshed sweet potato in 2013and 2014

Variety	0	5.3kgAg	400kg NPK	200kg NPK + 2.7Ag	5t PM	10t PM	5tPM+ 200kg NPK	2.5tPM + 200kg NPK	2.5tPM + 200kg NPK+2.7kg	Mean
							2013			
Umuspo 1	7.7	7.6	12.5	9.1	10.8	8.6	14.0	16.7	14.2	11.2
Umuspo 3	2.2	1.9	12.0	3.4	8.4	8.5	5.6	8.0	7.3	6.4
Mean	4.9	4.8	12.3	6.3	9.6	8.5	9.8	12.3	10.7	
							2014			
Umuspo 1	39.0	33.9	49.1	46.8	41.0	43.7	51.1	67.1	54.6	47.4
Umuspo 3	11.8	7.2	27.1	16.0	18.1	18.4	23.6	27.7	24.2	19.6
Mean	25.8	20.2	38.1	31.4	29.6	31.1	37.3	48.4	39.4	

		2013	2014
LSD ($_{0.05}$) for two fertilizer (F) means	=	5.0	NS
LSD ($_{0.05}$) for two variety (V) means	=	NS	29.1
LSD ($_{0.05}$) for two (F X V) means	=	NS	NS

Table 5: Effects of fertilizer combination and variety on mean storage root yield (t/ha) of orange-fleshed sweet potato (mean of 2013and 2014)

	Fertilizer Combination									
Variety	0	5.3kg Ag	400kg NPK	200kg NPK + 2.7Ag	5t PM	10t PM	5tPM+ 200kg NPK	2.5tPM + 200kg NPK	2.5tPM + 200kg NPK+2.7kg	Mean
Umuspo 1	23.8	20.4	30.8	28.0	25.9	26.1	33.9	40.5	34.4	29.3
Umuspo 3	7.0	4.6	19.6	9.7	13.3	13.4	15.8	17.7	15.7	13.0
Mean	15.4	12.5	25.2	18.8	19.6	19.8	24.8	29.1	25.1	

LSD $_{(0.05)}$ for fertilizer (F) means = 10.9
LSD $_{(0.05)}$ for variety (V) means = 5.1
LSD $_{(0.05)}$ for F X V means = NS

Table 6: Net monetary returns (₦ million/ha) of fertilizer combination and variety of storage roots of orange-fleshed sweet potato in 2013and 2014

	Fertilizer Combination									
Variety	0	5.3kg Ag	400kg NPK	200kg NPK + 2.7Ag	5t PM	10t PM	5tPM+ 200kg NPK	2.5tPM + 200kg NPK	2.5tPM + 200kg NPK+2.7kg	Mean
							2013			
Umuspo 1	1.45	2.07	2.45	1.73	2.11	1.59	2.80	3.39	2.91	2.28
Umuspo 3	0.22	0.14	2.34	0.46	1.57	1.58	0.94	1.46	1.28	1.11
Mean	0.84	1.11	2.40	1.10	1.84	1.59	1.87	2.43	2.10	
							2014			
Umuspo 1	8.54	7.09	10.58	10.1	8.82	9.40	11.04	14.69	11.80	10.23
Umuspo 3	2.36	1.31	5.69	3.26	3.73	3.78	4.81	6.29	5.04	4.03
Mean	5.45	4.20	8.14	6.68	6.28	6.59	7.93	10.49	8.42	