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Growth and yield responses of high-density coverage sweet potato to liming and fertilizer combinations for sandy-loam Ultisols at Nsukka, southeastern Nigeria

[1]Nnadi A.L., [2]Nnanna P.I., [1]Onyia V.N., [*2]Obalum S.E. and [2]Igwe C.A.

[1]Department of Crop Science & [2]Department of Soil Science, Faculty of Agriculture, University of Nigeria, Nsukka, Enugu State, Nigeria

Abstract

Low productivity characterizes farming on acid, nutrient-poor soils in fragile agroecosystems of tropical Africa. Sweet potato (*Ipomoea batatas* L.), a trailing and tuberizing annual, is viewed as a food-security crop not only because, as a cover crop, it is drought-tolerant and can thrive in impoverished soils, but also because of its fairly short growth cycle. Considering that its foliar coverage also shields nutrients against losses to excessive rainfall, the crop may respond to fertility management of coarse-textured soils in humid environments. Soil fertility trials with a high-density coverage sweet potato (UMUSPO-2) were, therefore, initiated on sandy-loam Ultisols at humid Nsukka in southeastern Nigeria in the 2018 rainy season. The objective was to evaluate the effects of lime and fertilizer types on the soil using this variety. Treatments were inorganic lime (CaO-88%) at 10 and 0 t/ha, each with poultry droppings at 20 t/ha (PD_{20}), NPK 15-15-15 at 0.40 t/ha ($NPK_{0.40}$), half doses of PD_{20} and $NPK_{0.40}$ (PD_{10}+$NPK_{0.20}$), and no-fertilizer amendments (control) in 2.25-m^2 plots. Lime-×-fertilizer and lime effects were not as evident as fertilizer effects. Generally, PD_{20} and/or PD_{10}+$NPK_{0.20}$ enhanced most of the growth traits (as sampled at 3, 6 and 9 weeks after planting) relative to the control and/or $NPK_{0.40}$. Vine biomass per plot, weight of tubers per plot and mean tuber length followed a similar pattern; 11.99 kg/plot, 5.59 kg/plot and 22.44 cm, respectively in PD_{40}-amended plots, and 6.06 kg/plot, 2.90 kg/plot and 16.79 cm, respectively in control plots. Vine biomass and weight of tubers correlated with leaf area, petiole length, vine length and numbers of nodes and branches, with weight of tubers also correlating with numbers of leaves and internodes. From agronomic standpoint, liming before manuring with poultry droppings at 20 t/ha appears the best soil nutrient management option for UMUSPO-2. This option could produce similar effects as growing without liming the soil but with a partial combination of poultry-droppings manure and inorganic fertilizer. This inference needs to be supported with data on treatment effects on physico-chemical fertility indices of the soil.

Key words: coarse-textured tropical soils, soil fertility management, nutrient-loaded manures, high-density coverage, tuberizing cover crops

*Corresponding Author's E-mail Address: sunday.obalum@unn.edu.ng: Phone: +234803 968 8755
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1.0 Introduction

Sweet potato (*Ipomoea batatas* L. (Lam.)) belongs to the morning glory (Convolvulaceae) family (Woolfe, 1992). It has a short growing period of 3-5 months depending on the variety, and this permits 2-3 crop cycles in a year. It is a widely grown staple food crop in most parts of the tropical and subtropical regions of the world, and is ranked seventh among the world's major food crops (FAO, 2004). Sweet potato is grown mainly for its starchy, sweet-tasting tuberous roots. It is now a prominent tuber crop in sub-Saharan Africa with both domestic and industrial uses (Law-Ogbomo and Osaigbovo, 2017). The tubers are consumed directly by humans (Odebode *et al*., 2008) or used as livestock feed (Ojeniyi and Tewe, 2003). Also, they often serve as raw materials in the production of starch and alcohol (Prian *et al*., 1997) and confectioneries (Igbokwe *et al*., 2005; Odebode *et al*., 2008). Sweet potato tubers contain carbohydrates, proteins, minerals and vitamins (Ishida *et al.*, 2000), with nutritional values far exceeding those of yam, cassava and cocoyam, while also possessing medicinal properties (Loebenstein, 2009). The leaves could be eaten by humans and animals including fishes (Okposhen *et al*., 1996; Madugba *et al*., 2005). Sweet potato thus offers an enormous potential for the enhancement of food security and prevention of malnutrition in the developing world.

In Nigeria, many varieties of sweet potato differ not only phenotypically but also in yield potential and food and nutritional values. Its national average yield is in the range of 6.0-9.8 t/ha (BNARDA, 2008; FAOSTAT, 2012), which is low and below the African and world averages, put at 7 and 15 t/ha, respectively (FAOSTAT, 2012). The low yields of this crop in Nigeria can be attributed to low soil nutrient status and unproductive cultural practices, among other factors (CRI, 2002). The low soil nutrient status is as a result of dominance of low-activity clays (Obalum and Obi, 2014; Uzoh *et al*., 2015), continuous cropping (Agbede and Adekiya, 2011), low organic matter and excessive leaching of the soil (Zingore *et al*., 2003). Use of fertilizers is an important option left to farmers for yield improvement in most soils. Fertilizer application in its singularized form may increase the yield of sweet potato in impoverished soils by up to 32% and nearly double it under better soil conditions (Stathers *et al*., 2005). The use of N, P and K fertilizers in sweet potato production has been reported to improve soil quality and increase the yield of the crop under West African conditions (Dapaah *et al.*, 2004; Idigbor *et al*., 2010).

However, inorganic fertilizers have their shortcomings in scarcity and high cost. They also often have deleterious effects on the quality and shelf life of the crop produced (Data *et al*., 1989), as well as on human health and the environment (Basel and Atif, 2008). Organic fertilizers (manures), on the other hand, are known to be effective in the maintenance of adequate supply of soil organic matter with attendant improvements in physicochemical fertility status of the soil and crop performance (Mbagwu, 1992; Nwite, 2016). In terms of nutrient load and release, poultry droppings is about the most efficacious among animal manures (Uzoh *et al*., 2015), but its use either alone or in combination with inorganic fertilizers for high-density coverage sweet potato has not received adequate research attention in southeastern Nigeria. Owing to the climate of high-intensity rainfall and the coarse texture of the dominant Ultisols in this region, both driving the aforementioned excessive leaching which causes increases in soil acidity, there is a need for field studies in this regard.

Indications are that liming and combined use of organic and inorganic fertilizers in the so-called integrated soil fertility management (ISFM) could be a way to improve crop yields in acid, low-fertility tropical soils. Therefore, there has been research advocacy to develop appropriate ISFM-based systems for enhancing agronomic production in these soils. For sweet potato, this effort entails the choice of a variety with potential for high above-ground biomass that could amply shield the soil from climatic adversities during the crop growth phase, thereby complementing the soil fertility management practices in place. The objective of this study was to determine the effects of inorganic lime and fertilizer type (poultry droppings, NPK fertilizer and their partial combination) in well-drained soil on the growth and yield of high-density coverage sweet potato during the rainy season at Nsukka in southeastern Nigeria. The aim was to identify the role of soil fertility management involving lime-fertilizer combination in optimizing sweet potato production in this environment.

2.0 Materials and Methods

2.1 Site description

The study was conducted at the Teaching and Research Farm of the Faculty of Agriculture, University of Nigeria (UNN), Nsukka. The experimental site is located at latitude 06° 52'N and longitude 07º 24'E, and is on an elevation of ca. 447 m above sea level. The site lies in the Derived Savanna agro-ecological zone in southeastern Nigeria. The climate is humid tropical with two distinct seasons (rainy and dry). Mean annual rainfall is about 1600 mm, while mean minimum and maximum daily temperatures are 21 and 31ºC, respectively. Relative humidity can be highly variable yearly, often in the range of 55-90%. The soil at the experimental site is deeply weathered, brownish red, coarse-textured (sandy loam) and hence well drained. The key physicochemical properties of the top-(0-20 cm) soil from a nearby field some 100 m away have been presented elsewhere (Obalum *et al.*, 2017); showing average sand, silt and clay contents of 750, 70 and 180 g/kg, respectively as well as acidic soil pH in water of 4.8, soil organic carbon concentration of 17.88 g/kg, total nitrogen of 0.56 g/kg, and cation exchange capacity of 12.40 cmol/kg.

2.2 Experimental design

The field study involved two factors namely lime status of the soil and fertilizer type used as soil amendment. Two lime statuses were involved namely liming at 10 t/ha and no liming. Four fertilizer types were involved including sole application of poultry droppings at the rate of 20 t/ha, designated PD_{20}; sole use of NPK 15-15-15 at 0.40 t/ha, designated $NPK_{0.40}$; poultry droppings at 10 t/ha plus NPK 15-15-15 at 0.20 t/ha, designated PD_{10}+$NPK_{0.20}$; and no-fertilizer amendments (control). The study was executed as a 2 × 4 factorial laid out as split-plots in a randomized complete block design (RCBD) replicated three times. The high-density coverage variety of sweet potato, UMUSPO-2, used for the trial was sourced from the National Root Crop Research Institute (NRCRI), Umudike, Abia State, Nigeria. Poultry droppings was sourced from the Poultry Unit of Animal Science Section of the UNN Teaching and Research Farm. The NPK 15-15-15 fertilizer and inorganic lime (CaO-88%) were sourced from an agro-chemical dealer in Ogige Market, Nsukka.

2.3 Cultural practices

The site for the study was previously under fallow for three years. It was manually cleared and demarcated into plots for the treatments using bunds. The size of each plot was 1.5 m × 1.5 m (2.25 m^2). Considering the creeping nature of sweet potato and to minimize interference among treatment plots, a 0.75-m space was left between every two adjoining plots in a block. The separation between blocks was 1.5 m. Topsoil samples were randomly collected and used to determine the soil pH and for the calibration of the quantity of lime to be added. After this, lime was applied surficially to plots meant to receive it at an equivalent rate of 10 t/ha. The poultry droppings was cured by air drying, homogenized, crushed and sieved before use. It was applied surficially also to the relevant plots on the same day as lime.

The plots were then tilled by hoeing to ca. 20 cm depth, incorporating the amendments into the soil and making flatbeds. The sweet potato vines were cut into 20-25 cm vines and planted on the beds to a depth of 10-15 cm and at a plant spacing of 75 cm × 37.5 cm, giving six plants per plot. This plant spacing and the ensuing plant density was similar to 30 cm × 90 cm (37,000 stands per hectare) recommended for sweet potato grown on sandy-loam soils in humid tropical environments (Adubasim *et al*., 2017). The planting was done three weeks after applying the lime and poultry droppings. Application of NPK 15:15:15 was by topdressing whereby 90 and 45 g were applied to plots receiving 0.40 t/ha (full) and 0.20 t/ha (half), respectively. Band placement and split application of this N-containing inorganic fertilizer was adopted, as split application may be better than single dosing of N-rich fertilizers in the study environment (Oko and Asiegbu, 2001), a notion recently supported by Umezinwa *et al*. (2020). The NPK was applied at 1, 4 and 7 weeks after planting (WAP). Since the application was spread over three growth stages of the crop, one-third of the NPK rate adopted here was added to the soil at each stage. Thus, at each stage of NPK application, 30 and 15 g were added to plots for full and half doses, respectively. Routine cultural practices were carried out. For instance, the plots were weeded manually by hand picking at two-week intervals; no pesticide or herbicide was applied in the course of the experiment.

2.4 Data collection and analysis

Crop growth data were collected on two middle plants in a plot at three-week intervals starting from 3 WAP. These included leaf area, petiole length and vine length which were determined by linear measurements. The leaf area was assessed from the lengths and widths of the largest leaves of the two sampled plants in a plot. Leaf area was calculated as length × width × 0.45 (Ogoke *et al*., 2003). Other growth traits determined by counting were numbers of branches, leaves, nodes and internodes per plant.

At crop maturity and harvest some 12 WAP, yields were assessed on fresh weight basis, measuring vine biomass per plot (vine yields) alongside weight of tubers per plot (tuber yields) as obtained from all plants in the whole 2.25-m^2 plot. Data were also collected on some tuber yield components including mean length of tubers, mean girth of tubers, marketable yield per plot, number of tubers per plot, and marketable number of tubers per plot.

Data were analyzed using the software GenStat Discovery Edition 4. The data were subjected to one-way analysis of variance (ANOVA), selecting the appropriate procedure for field experiments with a split-plot design in RCBD. Significantly different treatment means were separated and compared using Fisher's least significant difference (F-LSD) procedure at 5% level of probability ($P < 0.05$). Pearson correlation was performed between all the growth attributes, vine biomass per plot, weight of tubers per plot and tuber yield components of the crop using the software Statistical Package and Service Solution (SPSS) version 22.

3.0 Results

3.1 Treatment effects on some growth variables of UMUSPO-2 sweet potato variety

The interaction effects of soil lime status and fertilizer type used on some growth variables of the UMUSPO-2 variety of sweet potato at 3, 6 and 9 WAP are presented in Table 1. Leaf area and petiole length differed among treatments at 3 WAP, whereas vine length differed among them at 9 WAP, all three variables showing highest values in limed/$NPK_{0.40}$ and no-lime/PD_{10}+$NPK_{0.20}$ plots. These two treatments produced similar effects as no-lime/PD_{20} only for vine length. Notably, the lowest values were always obtained in no-lime/control and no-lime/$NPK_{0.40}$ plots. The data for numbers of branches, leaves, nodes and internodes of the UMUSPO-2 at 3, 6 and 9 WAP show that treatment had no effects on these growth variables.

3.2 Treatment effects on yields and yield components of UMUSPO-2 sweet potato variety

The interaction effects of lime status and fertilizer type on vine biomass and weight of tubers per plot including tuber yield components of the UMUSPO-2 sweet potato variety are shown (Table 2). Of all the yield variables assessed, only fresh vine biomass differed among the treatments. The highest values were due to treatment limed/PD_{20}, followed by the trio of limed/PD_{10}+$NPK_{0.20}$, no-lime/PD_{20} and no-lime/PD_{10}+$NPK_{0.20}$ all three for which values were similar. The treatments limed/control and no-lime/$NPK_{0.40}$ gave the lowest values. Fresh weight of tubers and the yield components such as mean tuber length, marketable number and marketable yield tended to follow the same trend.

3.3 Main effects of lime status and fertilizer type on growth and yield indices of UMUSPO-2

The main effects of lime status on some growth traits of the UMUSPO-2 variety of sweet potato showed higher leaf area in the limed plots than no-lime ones at 3 WAP (24.60 and 21.74 cm^2, respectively) and also at 6 WAP (51.40 and 38.60 cm^2, respectively). Apart from this observation, liming to overcome to soil acidity did not affect the growth attributes of this variety of sweet potato.

The main effects of fertilizer type on the growth attributes of the UMUSPO-2 are shown in Table 3. The results show an interesting trend in the differences in the growth traits of the crop due to the application of poultry droppings and NPK 15:15:15 and their partial combination. The fertilizer types affected the growth variables at the different growth stages; the only clear exception was at 9 WAP when, notably, there were no differences in leaf area and numbers of leaves, nodes and internodes per plant. Overall, the trend shows enhanced growth of the UMUSPO-2 in PD_{20}-fertilized plots, with PD_{10}+$NPK_{0.20}$-fertilized ones as very close substitutes. The poorest growth of this sweet potato variety was always recorded in the non-fertilized plots serving as the control, and occasionally, in the NPK_{40}-amended plots.

Table 1: Interaction effects of lime status and fertilizer types on leaf area, petiole length, vine length and number of branches of UMUSPO-2 variety of sweet potato at 3, 6 and 9 weeks after planting (WAP) in the rainy season in well-drained soil at Nsukka, southeastern Nigeria

Lime status	Fertilizer type	Leaf area (cm^2)			Petiole length (cm)			Vine length (cm)		
		3WAP	6WAP	9WAP	3WAP	6WAP	9WAP	3WAP	6WAP	9WAP
Limed	Control	16.49	40.30	47.40	4.65	12.23	15.81	20.60	46.20	94.00
	PD$_{20}$	29.53	55.10	66.90	6.83	19.62	23.84	25.80	79.80	108.30
	NPK$_{0.40}$	31.01	51.80	81.10	8.32	12.50	18.95	16.60	60.60	122.50
	PD$_{10}$+NPK$_{0.20}$	21.35	58.50	56.70	6.30	16.10	16.68	19.40	67.10	118.20
No Lime	Control	11.01	33.40	56.80	4.75	11.23	15.47	19.50	50.90	80.20
	PD$_{20}$	29.73	53.30	66.70	6.67	17.97	18.45	22.90	85.00	125.40
	NPK$_{0.40}$	14.52	21.80	56.30	4.05	11.16	13.27	20.60	45.90	89.20
	PD$_{10}$+NPK$_{0.20}$	31.70	45.80	62.40	7.65	17.78	16.42	19.50	85.20	127.90
	F-LSD$_{(0.05)}$	*6.32*	*ns*	*ns*	*1.19*	*ns*	*ns*	*ns*	*ns*	*33.42*

PD$_{20}$ - poultry droppings at 20 t/ha, NPK$_{0.40}$ - NPK 15-15-15 at 0.40 t/ha, PD$_{10}$+NPK$_{0.20}$ - poultry droppings at 10 t/ha + NPK 15-15-15 at 0.20 t/ha

Table 2: Interaction effects of lime status and fertilizer type on yields and some yield components of UMUSPO-2 variety of sweet potato grown during the rainy season in well-drained soil at Nsukka, southeastern Nigeria

Lime status	Fertilizer type	VB	WOT	MTL	MTG	MY	UMY	MN	UMN
		(kg/plot)		(cm)		(kg/plot)		per plot	
Limed	Control	5.68	2.77	17.51	22.74	2.35	0.65	6.33	11.70
	PD$_{20}$	13.87	5.90	21.09	22.71	5.04	1.03	10.67	15.30
	NPK$_{0.40}$	7.93	3.28	17.58	22.60	2.89	0.68	8.00	13.00
	PD$_{10}$+NPK$_{0.20}$	10.38	4.91	19.78	20.87	3.02	1.33	10.00	11.70
No Lime	Control	6.44	3.04	16.08	24.94	1.78	0.83	5.67	13.70
	PD$_{20}$	10.12	5.28	23.79	20.11	3.58	1.50	11.00	16.00
	NPK$_{0.40}$	4.72	3.06	17.24	22.76	2.13	0.83	6.67	13.00
	PD$_{10}$+NPK$_{0.20}$	9.67	5.20	20.68	23.62	3.87	1.14	7.67	15.30
	F-LSD$_{(0.05)}$	*2.15*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*

PD$_{20}$ - poultry droppings at 20 t/ha, NPK$_{0.40}$ - NPK 15-15-15 at 0.40 t/ha, PD$_{10}$+NPK$_{0.20}$ - poultry droppings at 10 t/ha + NPK 15-15-15 at 0.20 t/ha, VB - vine biomass, WOT - weight of tubers, MTL - mean tuber length, MTG - mean tuber girth, MY - marketable yield, UMY - unmarketable yield, MN - marketable number, UMN - unmarketable number, WAP - weeks after planting, ns - not significant

Table 3: Main effects of fertilizer type on some growth traits of UMUSPO-2 variety of sweet potato grown during the rainy season in well-drained soil at Nsukka, southeastern Nigeria

	Leaf area (cm^2)			Petiole length (cm)			Vine length (cm)		
	3WAP	6WAP	9WAP	3WAP	6WAP	9WAP	3WAP	6WAP	9WAP
Control	13.75	36.80	52.10	4.70	11.73	15.64	20.10	48.50	87.10
PD$_{20}$	29.63	54.20	66.80	6.75	18.79	21.15	24.30	82.40	116.90
NPK$_{0.40}$	22.76	36.80	68.70	6.18	11.83	16.11	18.60	53.30	105.80
PD$_{10}$+NPK$_{0.20}$	26.53	52.20	59.60	6.97	16.94	16.55	19.40	76.10	123.00
F-LSD$_{(0.05)}$	*5.14*	*12.31*	*ns*	*1.50*	*1.82*	*2.62*	*ns*	*15.11*	*18.22*

	Number of branches			Number of leaves			Number of nodes			Number of internodes		
	3WAP	6WAP	9WAP	3WAP	6WAP	9WAP	3WAP	6WAP	9WAP	3WAP	6WAP	9WAP
Control	2.25	3.41	10.35	9.08	19.20	34.30	8.58	20.23	26.42	6.17	17.92	25.50
PD$_{20}$	3.67	5.92	17.75	13.33	26.80	34.30	11.75	22.76	32.08	9.17	26.50	30.33
NPK$_{0.40}$	2.75	3.10	8.33	9.92	19.20	32.40	9.08	23.83	32.72	7.33	21.15	32.17
PD$_{10}$+NPK$_{0.20}$	3.08	6.25	18.08	11.42	30.10	38.40	10.67	26.31	34.22	7.67	25.37	32.22
F-LSD$_{(0.05)}$	*0.98*	*2.22*	*5.09*	*2.03*	*6.18*	*ns*	*1.61*	*3.75*	*ns*	*1.31*	*4.38*	*ns*

PD$_{20}$ - poultry droppings at 20 t/ha, NPK$_{0.40}$ - NPK 15-15-15 at 0.40 t/ha, PD$_{10}$+NPK$_{0.20}$ - poultry droppings at 10 t/ha + NPK 15-15-15 at 0.20 t/ha, WAP - weeks after planting, ns - not significant

Again, liming had no effects on any of the vine biomass per plot, weight of tubers per plot and tuber yield components of the UMUSPO-2. The main effects of fertilizer type on these yield indices, however, showed some significant differences among treatments (Table 4). The differences in fresh vine biomass and weight of tubers were such that PD_{20} and $PD_{10}+NPK_{0.20}$ were similar and out-yielded NPK0.40 and control for which values were similar too. For mean tuber length, this order was observed except that $PD_{10}+NPK_{0.20}$ produced tubers with mean length similar to those from $NPK_{0.40}$. Both marketable number and unmarketable number of tubers indicated a pattern of differences among treatments similar to that of weight of tubers; however, the differences were significant only for the unmarketable number of tubers.

3.4 Relationships between yield indices and growth traits of UMUSPO-2 sweet potato variety

The relationships existing between some yield indices and the various growth traits of the UMUSPO-2 variety of sweet potato were examined by the coefficients of their correlations. For each growth trait, these coefficients are shown only for two out of the three sampling stages when the correlations were consistently significant; 6 and 9 WAP for petiole length, vine length and number of branches, and 3 and 6 WAP for the rest (Table 5). The results show that all three indices of yield (i.e., vine biomass per plot, weight of tubers per plot, and the tuber yield components) were positively influenced by the crop growth traits to varying degrees at the respective growth stages. Notably, the number of growth variables influencing vine biomass per plot was smaller than the number influencing weight of tubers per plot. The outstanding influence of petiole and vine lengths at 6 WAP and of number of nodes at 3 WAP on weight of tubers is also noteworthy.

The matrix of coefficients of the correlations among the yield indices of the UMUSPO-2 variety of sweet potato is also presented (Table 6). The results show that all the crop yield indices included in these linear correlations had positive influence on one another.

Table 4: Main effects of fertilizer type on fresh vine biomass and weight of tubers per plot and tuber yield components of UMUSPO-2 variety of sweet potato grown during the rainy season in well-drained soil at Nsukka, southeastern Nigeria

Fertilizer type	VB	WOT	MTL	MTG	MY	UMY	MN	UMN
	(kg/plot)		(cm)		(kg/plot)		per plot	
Control	6.06	2.90	16.79	23.84	2.06	0.74	6.00	12.70
PD_{20}	6.32	3.17	17.41	22.68	2.51	0.75	7.33	13.00
$NPK_{0.40}$	11.99	5.59	22.44	21.41	4.31	1.26	10.83	15.70
$PD_{10}+NPK_{0.20}$	10.02	5.06	20.23	22.24	3.45	1.23	8.83	13.50
F-LSD(0.05)	*1.49*	*1.35*	*3.01*	*ns*	*ns*	*0.48*	*ns*	*ns*

PD_{20} - poultry droppings at 20 t/ha, $NPK_{0.40}$ - NPK 15-15-15 at 0.40 t/ha, $PD_{10}+NPK_{0.20}$ - poultry droppings at 10 t/ha + NPK 15-15-15 at 0.20 t/ha, VB - vine biomass, WOT - weight of tubers, MTL - mean tuber length, MTG - mean tuber girth, MY - marketable yield, UMY - unmarketable yield, MN - marketable number, UMN - unmarketable number, ns - not significant

Table 5: Coefficients of the correlations between some yield indices and growth traits of the UMUSPO-2 variety of sweet potato during the rainy season in well-drained soil at Nsukka, southeastern Nigeria (n = 8)

	Leaf area		Petiole length		Vine length		Number of branches		Number of leaves		Number of nodes		Number of internodes	
	3WAP	6WAP	6WAP	9WAP	6WAP	9WAP	6WAP	9WAP	3WAP	6WAP	3WAP	6WAP	3WAP	6WAP
VB	0.710*	0.805*	0.932**	0.903**	0.880**	0.673	0.881**	0.816*	0.701	0.698	0.755*	0.367	0.513	0.638
WOT	0.713*	0.679	0.977**	0.712*	0.924**	0.722**	0.859**	0.881**	0.801*	0.784*	0.906**	0.534	0.717*	0.813*
MTL	0.721*	0.623	0.890**	0.545	0.898**	0.757*	0.614	0.729*	0.934*	0.779*	0.955**	0.571	0.867**	0.897**
MY	0.819*	0.661	0.930**	0.843**	0.849**	0.713*	0.795*	0.773*	0.832*	0.699	0.861**	0.331	0.655	0.610
MN	0.683	0.767*	0.834*	0.763*	0.818*	0.730*	0.742*	0.701	0.764*	0.651	0.777*	0.568	0.733*	0.880**

VB - vine biomass, WOT - weight of tubers, MTL - mean tuber length, MTG - mean tuber girth, MY - marketable yield, UMY - unmarketable yield, MN - marketable number, UMN - unmarketable number, WAP - weeks after planting * and ** - significant at $P \leq 0.05$ and 0.01 respectively

Table 6: Matrix of coefficients of correlations among yield indices of the UMUSPO-2 variety of sweet potato during the rainy season in well-drained soil at Nsukka, southeastern Nigeria (n = 8)

	VB	WOT	MTL	MY	MN
VB	-				
WOT	0.931**	-			
MTL	0.735*	0.875**	-		
MY	0.920**	0.902**	0.764*	-	
MN	0.849**	0.854**	0.867**	0.774*	-

Abbreviations and notations are as explained in Table 5.

4.0 Discussion

This field study was conducted with the objective of determining the suitability of liming and its compatibility with organic and inorganic fertilizers and their partial combination for coarse-textured and hence well-drained soils for the production of high-density coverage sweet potato in humid tropical locations. The choice of a good fertilizer management practice is important to ensure good crop development and yields (Okpara *et al*., 2004). The effects of the inorganic lime used in the present study on the vegetative growth, vine and tuber yields, and yield components were generally not pronounced. Our data show that liming before application of organic and/or inorganic fertilizers would be necessary only if the agronomic goal is to increase vine biomass productivity of the UMUSPO-2 variety of sweet potato used in this study.

The lime was compatible with PD_{20} but not $NPK_{0.40}$ in enhancing vine biomass production. On the other hand, PD_{20} as organic fertilizer was more efficacious in limed compared to no-lime plots. These results partially agree with Laxminarayana *et al*. (2011) who reported that the combination of lime with inorganic and organic fertilizer sources in an Alfisol produced a positive effect on total biomass of sweet potato, and that the effect of the organic sources was more pronounced where they were co-applied with lime rather than applied solely. The combined use of manurial amendment and inorganic fertilizer gave similar values of vine biomass in both limed and no-lime plots, making it a soil fertility management option to adopt under poorly buffered soil pH conditions.

The efficacy of combining liming with PD_{20} as regards vine biomass production in the sandy-loam Ultisols of this study could be linked to the inorganic nature of the lime (Nwite *et al.*, 2013). In their agronomic evaluation of some soil amendments for sandy-loam Ultisols elsewhere in southeastern Nigeria, Nwite *et al.* (2013) reported that co-applying poultry droppings with rice-husk ash was less effective in increasing leaf yield of *Telfairia occidentalis* (fluted pumpkin) than co-applying NPK 15-15-15 with this organic lime. From their data and ours here, it seems that, in terms of biomass productivity, organic fertilizers are more compatible with inorganic than organic lime in these soils, while the reverse is true for inorganic fertilizers.

The data further show that the deeply weathered and well-drained Ultisols of the study, whether limed or not, can support increased growth and yields of the high-density coverage UMUSPO-2 if the soil fertility is managed with sole application of nutrient-rich organic fertilizer or by the ISFM strategy combining organic and inorganic fertilizers. Such a combination has been reported to be efficacious in these soils (Unagwu *et al.*, 2013; Ogumba *et al.*, 2020). The lowest values of weight of tubers per plot (of size 2.25 m^2) in the control plots translate into 12.89 t/ha. This exceeds the crop's Nigerian upper average yield put at 9.8 t/ha (FAOSTAT, 2012), thus showing that the UMUSPO-2 is truly a high-yielding variety. Among other implications, the results of the correlations suggest that soil fertility management practices that lead to longer petioles and vines and/or more nodes can ultimately increase the yields of this high-density coverage variety of sweet potato.

5.0 Conclusion

The study has demonstrated the agronomic importance of appropriate soil fertility management of coarse-textured and well-drained Ultisols in humid tropical environments for sweet potato production. The high-yielding UMUSPO-2 and other sweet potato varieties with potential for greater surface coverage can be grown in the rainy season in such environments after amending the soil with inorganic lime and manure. Alternatively, the crop could be grown without liming but with a partial combination of poultry-droppings manure and inorganic fertilizer. Future research should dwell on the optimum rates and combining ratios of these soil amendments for sweet potato varieties, as well as the amendment-induced changes in physicochemical fertility indices of the soil and their broad and specific contributions to the agronomic performance of the crop.

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