Uganda Journal of **Agricultural Sciences**
ISSN: 1026-0919 (Print); 2410-6909 (Online)
Volume 21 Number 2 (2023) pp. 31 – 40
DOI: http://dx.doi.org/10.4314/ujas.v21i2.3

https://www.ajol.info/index.php/ujas

Effect of Spent Mushroom Substrate and NPK Fertilizer on White and Orange-Fleshed Sweet Potato Varieties in South Eastern Nigeria

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Abstract. Spent mushroom substrate (SMS) and NPK (15:15:15) fertilizer were assessed under field conditions for their comparative effects on white and orange-fleshed sweet potato varieties in Umuahia southeastern Nigeria. The experiment was a split-split plot in randomized complete block design with three replicates. The main plot treatments were two sweet potato varieties (white-fleshed TIS87/0087 and orange-fleshed Umuspo 3). The split plot treatments were five NPK fertilizer rates (0, 100, 200, 300 and 400kg/ha) while the split-split plot treatments were three SMS levels (0, 2 and 4t/ha). Averaged across sweet potato varieties and NPK fertilizer, SMS significantly increased leaf area index, shoot biomass and storage root yield. Application of NPK fertilizer increased leaf area index and shoot biomass in both years and storage root yield in 2019. The white-fleshed TIS87/0087 variety produced significantly higher shoot biomass than Umuspo 3 in both years. TIS87/0087 had higher root yield than Umuspo 3 in 2018, but in 2019, the latter out yielded the former. Three-way interactions were significant for shoot biomass in 2018 and for storage root yield in both years. The highest shoot biomass (28.70 – 30.0t/ha) in 2018 was obtained from TIS87/0087 at moderate rates of 2t/ha SMS and 300kg/ha NPK fertilizer and from Umuspo 3 at 2t/ha SMS and 200kg/ha NPK fertilizer. The highest storage root yield 30.0t/ha was obtained from TIS87/0087 at 4t/ha SMS alone in 2018 and 37.1t/ha yield from Umuspo 3 at 4t/ha SMS only in 2019. The results showed that 4t/ha SMS was sufficient to promote high root yields in sweet potato in the area.

Keywords: Spent mushroom substrate, NPK fertilizer, sweet potato, root yield.

Introduction

Sweet potato (*Ipomoea batatas* (L.) Lam) is traditionally cultivated for food as a root crop while the leaves are used as vegetable and the top as valuable forage for livestock in many developing countries (Ruiz, 1981; Giang *et al.,* 2004). The tuberous roots and leaves are excellent sources of carbohydrates, proteins, iron, vitamins and fiber Smart and Simmods (1995). Traditionally in countries like Uganda and Nigeria, fresh sweet potato is consumed boiled and eaten with stew, boiled and pounded with boiled cassava or yam, roasted, fried or boiled with beans and vegetables Mwanga *et al.,* (2003). The white-fleshed and orange-fleshed cultivars are commonly grown, with the latter having good antioxidant properties because of the high content of carotenoids.

Although the development and introduction of some varieties of sweet potato have resulted in improved yields in Nigeria, sustainable production is constrained by prevailing poor soil fertility (Njoku *et al.*, 2001; Akpaninyang *et al.,* 2013; 2015). The poor yields obtained from farmers' fields make fertilization inevitable for sweet potato production, if high yields are to be realized. The common method of increasing crop productivity is by use of inorganic fertilizer. Most small holder farmers however can hardly afford the high costs of inorganic fertilizers, which are also scarce. Moreover, the productivity of many tropical soils cannot be sustained by use of inorganic fertilizer alone, as this may result in long term deterioration of soil physical properties and depletion of soil organic matter (Nambiar, 1995; Mbah, 2008).

To address the unsustainable production system involving the use of inorganic fertilizers Ambos and Calipusan (2017) recommended the use of locally available organic materials such as spent mushroom wastes as an alternative to reduce the cost of farm input. On the other hand, Ogoke *et al* (2009) stressed the need for integrated use of organic materials and inorganic fertilizers to improve yields.

In Nigeria, farms producing fresh mushrooms are springing up in some urban centers because of the new impetus to agriculture Adedokun *et al* (2016a). The large quantities of spent mushroom substrate generated in these farms could profitably be used for fertilizing crop lands. Farmers living close to the mushroom farms usually collect these wastes for application to crops. Organic wastes, which accumulate become ecological hazards while high doses of waste application could lead to toxic levels of compounds such as soil sulphate and ground water pollution (Mba, 2008; Smith, 1996).

There are no data from any planned investigation to indicate the optimum levels of spent mushroom wastes for sweet potato production in Nigeria, where the nutrient requirements have mainly been with inorganic fertilizers or animal manures (Okpara *et al.,* 2009; 2001; Njoku *et al.,* 2011; Akpaninyang *et al.,* 2013). The objective of this study was to determine the effects of spent mushroom substrate and NPK fertilizer on white-fleshed and orange-fleshed sweet potato productivity in southeastern Nigeria.

Materials and Methods

Field studies were conducted during 2018 and 2019 cropping seasons at the Forestry Research Institute of Nigeria (FRIN), Humid Forest Research Station farm, Umuahia, southeastern Nigeria, to assess the growth and yield responses of two sweet potato varieties to spent mushroom substrate and NPK fertilizer.

Umuahia is located on latitude $5^0$32'N, longitude $7^0$31'E and 149m above sea level altitude. The soil is a sandy loam ultisol. The soil characteristics were 75.0% sand, 8.8% silt, 16.2% clay, 5.3 pH (water), 3.2% organic matter (om), 0.182% N, 40.3mg/kg P and 0.148 Cmol/kg K in 2018 and 79.0% sand, 6.8% silt, 14.2% clay, 5.7 pH (water), 3.0% organic matter (om), 0.14% N, 38.6 mg/kg P and 0.139 Cmol/kg K in 2019. Total annual rainfalls in 2018 and 2019 were 2028.6mm and 2953mm, respectively.

In each cropping season, the experimental site was slashed, ploughed, harrowed and ridged 1m apart. The treatments were arranged as split-split plot in randomized complete block design with three replications. The main plots were assigned to the two sweet potato varieties (white-fleshed TIS87/0087 and orange-fleshed Umuspo 3), NPK (15:15:15) fertilizer treatments (0, 100, 200, 300 and 400kg/ha) were assigned to the subplots and spent mushroom substrate rates

(0. 2 and 4t/ha) were assigned to the sub-plots. The sub sub-plots measured 3m X 2m (6m^2) each. The spent mushroom substrate at the three rates was applied to appropriate plots at the time of ridging on 10 June, 2018 and 14 May 2019. The chemical characteristics of the spent mushroom substrate were pH (water) 7.0, 15.5% om, 1.54% N, 0.55% P, 0.35% K, 2.4% Ca and 1.10% Mg in 2018 and 7.1 pH, 65.4% om, 1.75% N, 0.50% P, 0.25% K, 2.61% Ca and 1.15% Mg in 2019.

Vine cuttings of the sweet potato varieties measuring about 20cm long with at least 4 nodes were planted at the crest of the ridges on 23 June, 2018 and on 26 May, 2019. Supply of vacant stands was done at 2 weeks after planting (WAP). Hoe weeding was done at 4 and 8 weeks after planting (WAP). NPK fertilizer (15:15:15) at the different rates was done to the appropriate plots at 4 WAP by banding.

Records were taken on leaf area index at 8, 10 and 12 WAP and shoot biomass (t/ha) and storage root yields (t/ha) at 18 WAP. Leaf area for leaf area index determination was estimated by the disc method according to Kelm *et al* (2001). Leaf area index was calculated as L = LA/P, where L=leaf area index, LA = total leaf area per plant, P = land area occupied by the plant. The data obtained were subjected to analysis of variance using GenStat Discovery Edition 3 Statistical Package (2007).

Results

Across sweet potato varieties, leaf area index at 8 and 10 WAP in 2018 was significantly higher at 4t/ha spent mushroom substrate than at the lower rate of 2t/ha or no application (Table 1).

Table 1. Effect of spent mushroom substrate on leaf area index of two sweet potato varieties

Year	Mushroom substrate (t/ha)	Weeks after planting		
		8	*10*	*12*
2018	0	0.12	0.23	1.06
	2	0.13	0.33	4.87
	4	0.32	0.49	3.35
	Mean	**0.19**	**0.35**	**3.09**
	LSD $_{(0.05)}$	**0.06**	**0.11**	**NS**
2019	0	0.15	0.22	2.13
	2	0.17	0.28	2.49
	4	0.93	0.38	3.26
	Mean	**0.42**	**0.29**	**2.63**
	LSD $_{(0.05)}$	**NS**	**0.07**	**0.20**

LSD = least significant difference

NS = not significant

At 10 and 12 WAP in 2019, leaf area index at 4t/ha spent mushroom substrate was also higher than the values at the lower application rates. Leaf area index also increased significantly with increased application of NPK fertilizer up to the highest rate of 400kg/ha at 8 and 10 WAP in 2018 and at 10 and 12 WAP in 2019 (Table 2).

Table 2. Effect of NPK fertilizer on leaf area index of two sweet potato varieties

Year	NPK (kg/ha)	Weeks after planting		
		8	*10*	*12*
2018	0	0.05	0.13	1.38
	100	0.08	0.16	5.49
	200	0.13	0.26	1.89
	300	0.21	0.39	2.79
	400	0.48	0.81	3.92
	Mean	**0.19**	**0.35**	**0.39**
	LSD $_{(0.05)}$	**0.08**	**0.18**	**NS**
2019	0	0.13	0.18	2.03
	100	1.31	0.19	2.05
	200	0.81	0.30	2.07
	300	0.21	0.34	3.28
	400	0.25	0.45	3.69
	Mean	**0.42**	**0.29**	**2.63**
	LSD $_{(0.05)}$	**NS**	**0.09**	**0.25**

LSD = least significant difference

NS = not significant

In both years, fresh shoot biomass was significantly influenced by spent mushroom substrate, NPK fertilizer and sweet potato variety (Table 3). Application of 2t/ha spent mushroom substrate significantly increased shoot biomass, but a further increase to 4t/ha did not further increase above ground biomass in 2018. However, in 2019, increasing spent mushroom substrate rate up to 4t/ha resulted in progressively higher biomass yield.

Table 3. Effect of spent mushroom substrate, NPK fertilizer and genotype on fresh shoot biomass of two sweet potato varieties

		Shoot biomass (t/ha)	
		2018	*2019*
Spent mushroom substrate (t/ha)	0	13.0	11.0
	2	20.0	18.9
	4	20.0	33.2
	Mean	**17.7**	**21.0**
	LSD $_{(0.05)}$	**1.8**	**0.8**
NPK fertilizer (F) (kg/ha)	0	9.2	12.9
	100	13.4	14.4
	200	19.9	18.0
	300	19.5	24.7
	400	26.4	35.1
	Mean	**17.7**	**21.0**
	LSD $_{(0.05)}$ Variety (V)	**1.7**	**1.3**
Genotype	TIS87/0087	21.4	21.7
	Umuspo 3	13.9	20.3
	Mean	**17.7**	**21.0**
	LSD $_{(0.05)}$	**1.9**	**0.4**

LSD = least significant difference

There were significant increases in shoot biomass as the level of NPK fertilizer increased up to 400kg/ha on average. The white-fleshed TIS87/0087 produced higher shoot biomass than the orange-fleshed Umuspo 3 variety in both cropping seasons. Three-way interactions were significant in 2018, with the highest above ground biomass (28.7 – 30.8t/ha) obtained mostly from TIS87/0087 at 300 or 400kg/ha NPK fertilizer with or without spent mushroom substrate or from Umuspo 3 at 2t/ha spent mushroom substrate and 200kg/ha NPK fertilizer (Table 4).

Table 4. Effect of interaction of mushroom substrate (M), NPK fertilizer (F) and variety (V) on shoot biomass

Year	Variety		Spent mushroom substrate (t/ha)		
		NPK rate (kg/ha)	*0*	*2*	*4*
2018	TIS87/0087	0	4.6	21.2	18.3
		100	4.0	19.3	23.6
		200	13.1	22.2	27.4
		300	19.2	29.4	30.2
		400	29.9	28.2	30.8
	Umuspo 3	0	1.7	5.6	3.8
		100	1.4	11.4	20.4
		200	23.1	28.7	24.9
		300	10.7	13.6	13.8
		400	22.6	24.4	26.7
2019	TIS87/0087	0	3.2	8.4	29.8
		100	6.2	9.9	31.9
		200	7.2	16.0	34.3
		300	11.1	25.8	37.3
		400	27.3	35.0	42.5
	Umuspo 3	0	2.8	7.3	26.2
		100	3.3	7.6	27.3
		200	5.2	15.9	29.4
		300	12.8	27.1	34.0
		400	30.8	35.8	39.4

	2018	2019
LSD $_{(0.05)}$ for M × F × V means	= 2.32	NS

LSD = least significant difference

NS = not significant

M = mushroom

F = fertilizer

V = variety

The effects of spent mushroom substrate, NPK fertilizer and sweet potato variety were significant on storage root yield in both 2018 and 2019 cropping seasons (Table 5). There was an increase in storage root yield as the level of spent mushroom substrate increased up to 2t/ha in 2018. However, in 2019, storage root yield increased significantly as the spent mushroom rate was raised up to 4t/ha. The effect of NPK fertilizer was inconsistent in 2018, whereas in

2019, application of NPK fertilizer at 400kg/ha significantly produced the highest storage root yield.

Table 5. Effect of spent mushroom substrate, NPK fertilizer and genotype on storage root yield of two sweet potato varieties

		Storage root yield (t/ha)	
		2018	*2019*
Mushroom (M) substrate (t/ha)	0	7.7	11.0
	2	12.8	11.4
	4	10.3	22.0
	Mean	**10.3**	**14.6**
	LSD $_{(0.05)}$	**1.0**	**0.6**
NPK fertilizer (F) (kg/ha)	0	13.3	13.0
	100	8.5	15.1
	200	13.0	16.0
	300	9.0	14.2
	400	7.4	17.2
	Mean	**10.3**	**14.6**
	LSD $_{(0.05)}$	**1.1**	**0.6**
Variety (V)	TIS87/0087	11.8	12.3
	Umuspo 3	8.7	17.0
	Mean	**10.3**	**14.6**
	LSD $_{(0.05)}$	**0.8**	**0.7**

LSD = least significant difference

NS = not significant

M = mushroom

F = fertilizer

V = variety

The white-fleshed TIS87/0087 variety had higher storage root yield than orange-fleshed Umuspo 3 in 2018, but in 2019, Umuspo 3 produced significantly higher storage root yield than TIS87/0087. Three-way interactions were significant on storage root yield in both years (Table 6).

Table 6. Effect of interaction of mushroom substrate, NPK fertilizer and genotype on storage root yield of two sweet potato varieties

Year	Variety		Spent mushroom substrate (t/ha)		
		NPK rate (kg/ha)	*0*	*2*	*4*
2018	TIS87/0087	0	5.3	24.2	30.0
		100	5.5	15.4	8.9
		200	7.7	18.5	14.5
		300	8.9	10.7	8.6
		400	9.4	5.6	4.4
	Umuspo 3	0	6.3	8.1	5.9
		100	5.6	10.3	5.5
		200	9.7	15.9	11.8
		300	8.5	10.2	7.2
		400	10.3	9.0	5.5
2019	TIS87/0087	0	3.5	4.7	30.7
		100	4.4	7.9	21.6
		200	4.9	7.1	21.6
		300	7.9	13.0	12.1
		400	21.0	12.3	11.7
	Umuspo 3	0	8.2	11.6	37.1
		100	8.9	12.5	20.5
		200	10.6	12.7	33.7
		300	12.3	13.2	14.6
		400	32.7	12.3	13.4

	2018	2019
LSD $_{(0.05)}$ for M × F × V means =	1.4	1.6

LSD = least significant difference
NS = not significant
M = mushroom
F = fertilizer
V = variety

In 2018, white-fleshed TIS87/0087 at 4t/ha spent mushroom substrate without NPK fertilizer produced the highest yield of 30.0t/ha. In 2019, however, orange-fleshed Umuspo 3 at 4t/ha spent mushroom substrate without NPK fertilizer also produced the highest storage root yield of 37.1t/ha.

Discussion

Differences in leaf area index and shoot biomass between plants that received spent mushroom substrate or NPK fertilizer and those that received no fertilizer were large, suggesting that fertilization enhanced sweet potato growth. The increase in these parameters with application of spent mushroom substrate or inorganic fertilizer is consistent with literature reports under the tropical humid conditions with nutrient leaching of the coarse textured soil (Okpara *et al.,* 2014; Akpaninyang *et al.,* 2005). While mineral fertilizers are associated with quick release of nutrients for early crop growth, spent mushroom substrate has been shown to be a good source of nutrients which are gradually and steadily released for the improvement of growth and yield of crops (Adedokun *et al.,* 2016a; Adedokun and Orluchukwu, 2013; Orluchukwu and Adedokun, 2014).

For sweet potato, nitrogen and potassium are critical elements, with nitrogen reported to increase dry matter, leaf area index and the distribution ratio of above ground to underground parts (Tsuno and Fujise, 1964). Abundant potassium supply has been reported to favor primary process of photosynthesis and adenosine triphosphate (ATP) production, promote carbon dioxide assimilation and the synthesis and translocation of carbohydrate from the leaves to tubers (Uwah *et al*., 2011; Iwuagwu *et al*., 2019).

The white-fleshed TIS87/0087 variety had consistently greater shoot biomass than orange-fleshed Umuspo 3, but the storage root yield responses of the varieties differed in both cropping seasons. The higher above ground biomass of TIS87/0087 did not necessarily result in higher root yield in 2019. This is in agreement with Okpara *et al* (2009) that conditions that maximize biomass production may not be conducive to high yield because of excessive competition for resources between the shoot and root sinks or differences in assimilate partitioning at the disadvantage of the root yield potential. In 2018, TIS87/0087 had 35.6% higher root yield than Umuspo 3, while in 2019, the orange-fleshed Umuspo 3 variety out yielded white-fleshed TIS87/0087 by 44.2%. The lower yield from Umuspo 3 in 2018 could be attributed to the use of poor-quality vines, as the variety is susceptible to virus infection (Akpaninyang, 2019).

The three-way interactions showed the highest storage root yield of 30.0t/ha was obtained from white-fleshed TIS87/0087 at 4t/ha spent mushroom substrate alone in 2018, whereas in 2019, highest root yield of 37.1t/ha was obtained from orange-fleshed Umuspo 3 at 4t/ha spent mushroom substrate without NPK fertilizer. The increase in root yield for spent mushroom substrate in 2019 could possibly be due to the higher organic matter of the spent mushroom substrate used in 2019 compared with that of 2018.The response of root yield to 4t/ha spent mushroom substrate alone was substantial, confirming the importance of spent mushroom substrate in production of sweet potato in the forest zone of southeastern Nigeria.

With the exorbitant costs of chemical fertilizers, spent mushroom substrate would therefore be an alternative low-cost supply of nutrients and organic matter which farmers can use to improve soil productivity and sweet potato yield. Like other organic wastes, there is evidence indicating that spent mushroom substrate has tremendous effects on soil productivity through residual effects or slow release of nutrients and through its influence on soil organic matter and related soil physical, chemical and biological properties (Adedokun *et al.,* 2016; Orluchukwu and Adedokun, 2019). Unlike storage root yield, top yield (biomass) in 2018 was highest at the moderate rates of 2t/ha spent mushroom substrate and 200kg/ha NPK fertilizer for Umuspo 3 or 2t/ha spent mushroom substrate and 300kg/ha NPK fertilizer for TIS87/0087.

In all, judicious use of both spent mushroom substrate and fertilizer at the lower rates of 2t/ha spent mushroom substrate and 200kg/ha NPK fertilizer for orange-fleshed Umuspo 3 or 300kg/ha NPK fertilizer for white-fleshed TIS87/0087 produced highest top yields. However, storage root yield response to 4t/ha spent mushroom substrate alone was sufficient to give high root yields of sweet potato in the forest zone of southeastern Nigeria.

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