International Journal of Scientific Advances
ISSN: 2708-7972
Volume: 2 | Issue: 6 | Nov - Dec 2021 Available Online: www.ijscia.com
DOI: 10.51542/ijscia.v2i6.20

Morphological Variability and Storage Root Productivity of Some Sweet Potato (*Ipomoea Batatas* (L.) Lam) Genotypes in An Ultisol

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ABSTRACT
Ten sweet potato (Ipomoea batatas (L.) Lam) genotypes sourced from National Root Crops Research Institute, Umudike were evaluated under rainfed condition in 2020 and 2021 cropping seasons at the Teaching and Research Farm of the University of Uyo, Uyo, Akwa Ibom State to ascertain variability among ten sweet potato genotypes and identify traits which are positively and significantly associated with yield and also identify genotypes with high yield potential for cultivation on an ultisol of Akwa Ibom State, Nigeria. The ten genotypes: TIS87/0087, Naspoy-12, Umuspo-4, Umuspo-1, Naspoy-11, Lourdes, Erica, Delvia, Ex-Igbariam and Umuspo-3 were used as treatments and the experiment was laid out in a randomized complete block design with three replications. Data collected were subjected to analysis of variance, correlation and principal component analysis. The genotype differs significantly ($P \leq 0.05$) for number of marketable roots, weight of marketable roots and fresh roots yield. UMUSPO-3 was superior over all the other genotypes for the following character; number of marketable roots, weight of marketable root yield and fresh root yield. Umuspo-3 produced the highest storage root yield (28.78t/ha, 27.09t/ha) in 2020 and 2021 cropping seasons, respectively. The result of the correlation analysis also revealed that vine length, number of marketable roots, weight of marketable were highly significantly and positively ($P<0.01$) correlated with fresh root yield. Principal component analysis (PCA) had four main principal components explaining 81.55% of the total variation with number of marketable roots, weight of marketable tuber and storage root yield contributing the most to the first PCA. Umuspo-3 outperformed the other nine sweet potato genotypes in yield and yield related characters. Therefore, Umuspo-3 been a high yielding genotype adaptable to Uyo agro-ecology, could be recommended to sweet potato growers for fresh storage root production.

Keywords: genotypes; morphological; storage root yield; sweet potato; variability

INTRODUCTION

Sweet potato (*Ipomoea batatas* (L.) Lam) is a crop herbaceous dicotyledonous tuber crop belonging to the morning glory family called Convolvulaceae. Predominately, sweet potato is cultivated in the tropical and warm temperate regions of the world (Allemann *et al.* 2004), and it is widely grown staple crop across the different agro-ecology of Nigeria (Njoku et al., 2009). It ranks as the seventh most important food crop (FAO, 2013). Compared to yam and cassava, sweet potato is enriched with higher protein content in terms of its nutritional benefits. Protein content varies from 1-2.5%. Carotenes, precursors of vitamin A production are also present in yellow varieties (Mukhtar *et al.,* 2010).

In the tropics, the average yield potential of sweet potato ranges from 20 – 50 t/ha and the annual world production is 131 million tons, on approximately 9 million hectares with mean estimated yields of 13.7 t/ha. Estimated yields of sweet potato among small holders' farmers in Nigeria are comparatively minimal, 2.6t/ha compared with average sweet potato yield in Africa (9.6t/ha) and the world's yield average (15.9t/ha). This lowering trend could be attributed to a number of factors, including inappropriate agronomic practices and prolonged usage of local accessions with diminishing yield potentials and limited circulation of the improved varieties (Karanja *et al.,* 2013).

White fleshed sweet potato varieties are predominately cultivated and consumed and these white fleshed varieties containing a minimal quantity of beta carotene. Beta carotene is a major source of vitamin A, which is remedy for vitamin A deficiency (Omiat *et al*., 2005).

Sweet potato's short gestation period of about four or five months, depending on the variety, is a major factor that has contributed immensely to its vast cultivation in Nigeria. When planted between the months of April and July, it attains harvest maturity before the onset of dry season (Nwankwo *et al.,* 2012). It is a crop that easily adaptable to varying environmental conditions and can endure the tough of the weather to grow on soils with minimal fertility status drought resistant, hence, contributing to food security (Mukherjee, 2010).

Improvement of a particular character of crop in field evaluation translates to simultaneous improvement of all the positively correlated characters (Nnungu and Uguru, 2014). Selection of suitable genotypes from existing ones could be an important aspect of improvement of sweet potato, especially, if their physiological characters and yield components correlate with tuber yield (Gargi et al., 2013).

Sweet potato is widely accepted and consumed in Akwa Ibom State but its production and supply are not commensurate with the rate of consumption since it is not extensively cultivated. Presently, the rate of production is abysmally low. Akwa Ibom State is among the least sweet potato producing states in Nigeria and the local demands is only satisfied by imports from other states in Nigeria (Roberts, 2012).

There is a need to evaluate different genotypes of sweet potato in Akwa State to identify genotypes that are suitably adapted to the environment with high yield. For selection of genotypes with high yield potentials, plant breeders' takes advantage of correlation analysis to determine characters that positively correlates with yield.

Hence, the objective of the study was to ascertain variability among ten (10) sweet potato genotypes and identify traits which are positively and significantly associated with yield and also identify genotypes with high yield potential vis-a-vis the national checks for cultivation in an ultisol of Akwa Ibom State, Nigeria.

MATERIALS AND METHODS

Experimental site, cropping history and field layout

The present study was conducted at the University of Uyo Teaching and Research Farm in Uyo, Akwa Ibom State, Nigeria during 2020 and 2021 early cropping seasons. Uyo is located in the south-south part of Nigeria and it is situated within the humid tropical rainforest zone. The area lies within latitude 4°33′ and 5°33′ North and longitude 7°55′ and 8°25′ East of the Greenwich meridian. The mean annual rainfall ranges from 2680.8 – 2700.1mm with a mean monthly relative humidity of 79.8% while the mean monthly atmospheric temperature range is 26.88 – 27.00°C (Ndaeyo, 2003). The field experiment was laid out in a randomized complete block design (RCBD) with three replications per treatment. Each replication was marked out into plots of $6m^2$ (2m x 3m). There were 5 plots per block and the total land size of $180m^2$.

Planting materials

The planting materials (treatments) were ten (10) genotypes of sweet potato vine cuttings were obtained from National Root Crops Research Institute (NRCRI), Umudike, Abia State, Nigeria.

Agronomic practices

The land was mechanically ploughed, harrowed and ridged 1m apart. The plots were marked out using measuring tape, pegs and ropes. Sweet potato vines were cut 25cm long with four nodes. The vine cuttings were sown 30cm intra-row and 100cm inter-row on the crest of ridges, and 10cm below the soil surface on raised beds. Poultry manure was incorporated at a recommended rate of 8.6t/ha two weeks before planting (County, 1996). Organic manure (poultry dung) should be incorporated into the soil during land preparation for sweet potato production if the soil is found to be of low fertility status (Saviour *et al.,* 2013). Planting was done on 21st May, 2020 and 21st May, 2021, using 10 vines per plot. The crop was rain-fed. Weeding was done at 4, 8 and 12 weeks after planting (WAP). Fertilizer (NPK: 15:15:15) was applied 400kg//ha 4 weeks after planting (WAP), immediately after first weeding (Nwankwo *et al.,* 2012). Five plants per plot were randomly selected and tagged for data collection. Data on growth parameters was collected at 6th, 9th and 12th week respectively. Parameters include; vine length, vine girth, number of branches, leaf area, number of leaves. Harvesting was done 120 days after planting (DAP). Each plots were harvested by uprooting six plants from the middle of each plot. Vines were first cut with cutlasses and the storage roots were uprooted with fork.

Statistical analysis

Data were taken on the following characters; number of marketable, non-marketable tubers per plot, marketable root weight (kg/ha), unmarketable root weight (kg/ha) and fresh tuber yield (t/ha). Harvest data were collected and introduced into Statistical package for social scientists (SPSS) software (Version 22) for analysis of variance (ANOVA) and means were separated using Duncan's new Multiple-Range Test at 5% level of probability. Pearson's correlation analysis was done to show association among yield and yield related components of sweet potato genotypes. Principal component analysis was done for the yield related traits.

TABLE 1: Description of the five-orange fleshed sweet potato varieties used as planting materials

Genotypes	Shape of central leaf lobe	Storage root shape	Predominant skin colour	Predominant flesh colour	Source
TIS87/0087 (National check)	Toothed	Round	Dark purple	White	NRCRI, Umudike
Naspoy-12	Triangular	Elliptic	Purple red	Intermediate orange	NRCRI, Umudike
Umuspo-4	Lanceolate	Round	Purple red	Intermediate orange	NRCRI, Umudike
Umuspo-1	Lanceolate	Long irregular	Purple red	Pale orange	NRCRI, Umudike
Naspoy-11	Triangular	Elliptic	Purple red	White	NRCRI, Umudike
Lourdes	Oblanceolate	Long elliptic	Dark purple	Pale orange	NRCRI, Umudike
Erica	Oblanceolate	Long elliptic	Dark purple	Pale orange	NRCRI, Umudike
Delvia	Linear	Long elliptic	Dark purple	Cream	NRCRI, Umudike
Ex-Igbariam	Toothed	Long irregular	Cream	Cream	NRCRI, Umudike
Umuspo-3	Toothed	Round	Orange	Dark orange	NRCRI, Umudike

RESULTS AND DISCUSSION

Soil physical and chemical properties

The soil of the experimental site was texturally classified as sandy loam in 2020. The soil was very low in nitrogen, and acidic. The soil organic matter was low and the available Phosphorus was high (Table 2). The sandy loam soil of the experimental site was ideal and the rainfall was substantially high during the time of crop growth in May through October. The soil had 0.06%N which was lower than the critical value of 0.15%N reported by Chude et al (2004). The soil of the experimental site moderately deep and has a sandy-loam texture. The percentage of sand was 89.06% in the top-soil. Silt fraction was 4.08% on the top soil while the clay fraction was 6.86% on the top soil (Table 2). Soils within the location of this experiment are predominately acidic with pH values of 5.40 and 5.50 in the top-soil and sub-soil respectively. The soil was acidic with a pH of 6.55 in 2021. Sweet potatoes are tolerant of soil pH of 5.6 – 6.8. However, the preferable soil pH for high yields of sweet potato is 5.8 – 6.0 (Lynn et al., 2017).

Variability among morphological characters

The results of the current study presented in Table 3 showed that some important yield and yield related characters of the evaluated sweet potato genotypes differed significantly ($p<0.05$). However, the ANOVA revealed that some of the morphological characters investigated did not differ significantly among the genotypes ($p<0.05$) for the morphological and agronomic characters investigated in 2020 and 2021 cropping seasons (Table 3). The current finding is in agreement with Omiat et al. (2005), who indicated that varietal effect had a significant influence on the variability of marketable tuberous root yield as well as total storage root yield of sweet potato. Similarly, Kathabwalika et al. (2013) also observed significant differences in storage root yield among sweet potato varieties in their trial.

In 2020 and 2021 cropping seasons, variability was recorded for vine length among the genotypes ($p<0.05$) as the longest vine length was produced by Umuspo-3 (252.80cm, 246.35cm) followed by Umuspo-4 (234.41cm, 227.35cm) and Ex-Igbariam (230.33cm, 212.85cm), respectively while the shortest was found in Naspoy-12 (126.47cm, 118.08cm) as presented in Table 3.

Variability for vine girth per plant ($p< 0.05$) was observed in 2020 and 2021 cropping seasons. Umuspo-4 produced the highest vine girth, followed by Umuspo-1, Lourdes and Ex-Igbariam, respectively while Delvia recorded the lowest vine (Table 3). However, no significant differences were observed between Umuspo-4 and Umuspo-1 in 2020 cropping season. Also, there was no significant difference between Naspoy-12, Naspoy-11 and Lourdes in 2020 and 2021 cropping seasons, respectively.

The sweet potato genotypes differed significantly in number branches per plant ($p<0.05$). In both cropping seasons, Lourdes produced the highest number of branches, followed by Umuspo-3, Umuspo-4 and Umuspo-1, respectively, while the least number of branches was observed with Delvia (Table 3). However, no significant differences were observed between Umuspo-4 and Umuspo-1 and between Delvia and Ex-Igbariam for the character.

In 2020 and 2021 cropping seasons, the sweet potato genotypes differed significantly in number branches per plant ($p<0.05$). The largest leaf area per plant was produced by Lourdes, followed by Umuspo-1, Naspoy-12 and Naspoy-11, respectively, while the smallest leaf area per plant was noticed for TIS87/0087 (Table 3).

The sweet potato genotypes differed significantly in number of leaves per plant ($p<0.05$). In both cropping seasons, Umuspo-4 produced the highest number of leaves, followed by Umuspo-3 and Umuspo-1, respectively, while the least number of leaves was observed with Delvia (Table 3). However, no significant differences were observed between TIS 87/0087 and Lourdes and between Naspoy-12 and Ex-Igbariam for the character.

TABLE 2: Soil physio-chemical properties of the experimental sites in 2020 cropping season

Physical properties	0-30cm
Sand (%)	89.06
Silt (%)	4.08
Clay (%)	6.86
Textural class	Sandyloam
Chemical properties	
pH (H_2O)	6.55
Available P (mg/kg)	66.50
Total Nitrogen (%)	0.06
Organic carbon (%)	1.29
Organic matter (%)	2.65
Calcium (cmol/kg)	2.16
Magnesium (cmol/kg)	2.06
Sodium (cmol/kg)	0.12
Potassium (cmol/kg)	0.09
Exchange acidity (cmol/kg)	4.74
ECEC (cmol/kg)	6.15
Base saturation (%)	68.04

TABLE 3: Mean square values for growth characters of ten sweet potatoes genotypes in 2020 and 2021 cropping seasons in Uyo, Nigeria.

Genotypes	VL		VG		NB		LA		NL	
	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
TIS87/0087	143.92^{b}	138.20^{b}	3.06^{bc}	2.19^{bc}	4.40^{b}	4.17^{b}	62.49^{e}	57.25^{d}	101.20^{bcd}	95.73^{bcd}
Naspoy-12	126.47^{b}	118.08^{b}	3.59^{abc}	2.82^{abc}	3.53^{b}	3.30^{b}	115.01^{ab}	110.08^{a}	77.87^{cd}	73.47^{cd}
Umuspo-4	234.41^{a}	227.35^{a}	4.29^{a}	3.58^{a}	6.80^{ab}	6.50^{ab}	65.80^{e}	60.70^{d}	153.87^{a}	149.53^{a}
Umuspo-1	140.07^{b}	132.59^{b}	4.27^{a}	3.40^{ab}	6.73^{ab}	6.53^{ab}	115.58^{ab}	110.60^{a}	128.20^{abc}	123.20^{ab}
Naspoy-11	128.00^{b}	121.75^{b}	3.60^{abc}	2.82^{abc}	4.07^{b}	3.80^{b}	106.67^{abc}	101.84^{ab}	86.53^{bcd}	81.53^{bcd}
Lourdes	147.66^{b}	142.35^{b}	3.81^{ab}	2.94^{abc}	8.53^{a}	8.23^{a}	124.48^{a}	119.11^{a}	101.80^{bcd}	97.67^{bcd}
Erica	153.73^{b}	146.25^{b}	3.10^{bc}	2.27^{bc}	5.00^{b}	4.80^{ab}	98.18^{abcd}	92.63^{abc}	93.27^{bcd}	88.47^{bcd}
Delvia	148.33^{b}	141.28^{b}	2.59^{c}	1.73^{c}	3.52^{b}	3.27^{b}	77.21^{cde}	71.66^{cd}	73.87^{d}	68.87^{d}
Ex-Igbariam	220.33^{a}	212.85^{a}	3.24^{abc}	2.37^{abc}	3.93^{b}	3.63^{b}	87.65^{bcde}	82.10^{bcd}	82.80^{cd}	78.33^{cd}
Umuspo-3	252.80^{a}	246.35^{a}	3.70^{abc}	2.91^{abc}	8.20^{a}	8.07^{a}	85.49^{cde}	80.13^{bcd}	137.73^{ab}	132.67^{bc}
Grand mean	169.57	162.70	3.52	2.70	5.47	5.23	93.86	88.61	103.71	98.95
SD	52.88	52.94	0.71	0.77	2.46	2.51	24.37	24.41	34.86	34.76

Values with the same letter(s) across each column do not differ significantly ($p \leq 0.05$). VL = Vine length, VG = Vine girth, NB = Number of branches, LA = Leaf area, NL = Number of leaves, NMT = Number of marketable tubers.

A: Umuspo-4
(Shape of central leaf lobe: Lanceolate)

B: Umuspo-1
(Shape of central leaf lobe: Lanceolate)

C: Naspoy-11
(Shape of central leaf lobe: triangular)

D: Lourdes
(Shape of central leaf lobe: Oblanceolate)

FIGURE 1: Morphological variation observed in the leaves of different sweet potato genotypes

Variability in yield and yield characters
The result of this study showed that the ten (10) sweet potato genotypes do different significantly (P≤0.05) in the number of marketable roots per plot in 2020 and 2021 cropping seasons (Table 4). The highest mean number of marketable root per plot (34.78, 32.47) was recorded in Umuspo-3, followed by Ex-Igbariam (26.14, 23.31) and Erica (22.23, 19.93), in 2020 and 2021 cropping seasons, respectively. The lowest mean number of marketable roots per plot (16.95, 14.22) were recorded by Delvia in both 2020 and 2021 cropping season, respectively (Table 4). The difference perceived among the sweet potato genotypes in number of marketable roots per plot could be attributed to the differences in their genotypic composition. Genotype Umuspo-3 had the highest number of marketable roots per plant and this is one important factor for selection of sweet potato varieties and serves as indicator of adaptability of the crop to the study area (Nwankwo *et al*., 2012).

Unmarketable root number and unmarketable root weight:
The result of this study showed that the ten (10) sweet potato genotypes do not different significantly (P≤0.05) in the number of unmarketable roots per plot in 2020 and 2021 cropping seasons. TIS 87/0087 and Delvia recorded the highest number of unmarketable root per plot (7.33, 5.83), respectively in both cropping seasons while Lourdes recorded the least number of unmarketable roots (4.67, 3.17) in both cropping season (Table 4). Delvia recorded the highest unmarketable root weight in 2020 and 2021cropping seasons while TIS 87/0087 recorded the least weight of unmarketable roots. Similarly, Nwankwo *et al*. (2012) also observed none significant differences in number of unmarketable root number per plot among sweet potato varieties in their study.

Fresh storage root yield:
The result of this study showed that in 2020 and 2021 cropping seasons, significant differences were observed among the genotypes for fresh tuber yield (t/ha). Umuspo-3 produced the highest storage root yield (28.78t/ha, 27.09 t/ha) in both 2020 and 2021 cropping seasons, respectively, followed by Umuspo-1 (17.33t/ha, 15.50t/ha) and Ex-Igbariam (15.83t/ha, 13.93t/ha) (Table 4). The results further showed that the genotypes Umuspo-4 produced the least fresh storage root yield (4.50t/ha, 2.52t/ha) in 2020 and 2021 cropping seasons, respectively (Table 4).

The results of this study in 2020 cropping season showed that two genotypes out of the ten sweet potato genotypes evaluated produced tuber yields higher than the world average of 15.9t/ha, namely, Umuspo-3 (28.78t/ha) and Umuspo-1 (17.33t/ha).

The current result agrees with the findings of Andrade *et al.* (2009), who reported that the total storage root yields of five sweetpotato varieties from Sub-Saharan Africa ranged between 0.5 and 65 t / ha. Consistent with the results of this study, Mcharo and Ndolo (2013) and Nedunchezhiyan *et al.* (2007) reported large differences between sweetpotato clones in terms of root yield due to genetic variation. Consistent with the results of this study, Wassu *et al.* (2015) reported significant variations between 116 sweetpotato genotypes that included the genotypes tested in this experiment, with a mean total storage root yield from storage of 10.74 (t /ha) and a range of 2.26 to 28.46 t/ha. The differences in fresh storage root yield could be attributed to genetic differences among the sweet potato genotypes (Antiaobong, 2007). This result is in line with Amare *et al.* (2014), who also found significant differences in total tuberous root yield among varieties in their trial.

Similarly, Wariboko and Ogidi (2014) also concluded that improved orange fleshed sweet potato varieties were higher in total tuberous root yield. However, the result of this study strongly disagrees with the findings of Bassey (2017), who reported that Umuspo-3 was generally vegetative and unproductive sweet potato genotype. In this study, Umuspo-3 was the superior in fresh storage root yield. This could be attributed to application of organic fertilizer (manure) before planting to augment the application of NKP 15:15:15 fertilizer to the soil to improve the soil fertility status. Umuspo-3 and Umuspo-1 could be recommended for cultivation in Uyo agro-ecology for high storage root yield. The result from this study showed that Umuspo-3 been the highest yielding genotype in the study area, could be beneficial to sweet potatoes farmers, since yield is an important factor which determines choice of sweet potato varieties for cultivation (Njoku *et al.,* 2009). For advancement to multi-locational trials, only Umuspo-3 and Umuspo-1 satisfied the selection criteria of securing higher yields. Ragassa *et al.* (2015) opined that improvement of sweet potato genotypes can be achieved by crossing with superior genotypes in a given environment. Genotypes with tuber yields below 20t/ha could be crossed with the top yielder (Umuspo-3).

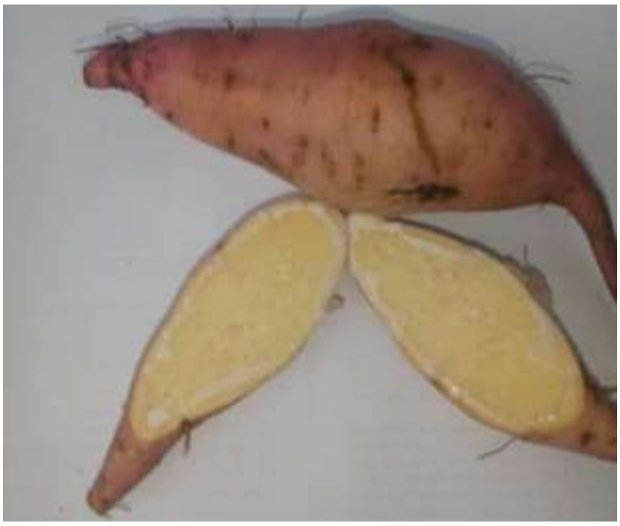
TABLE 4: Mean square values for yield and yield components of ten sweet potatoes genotypes in 2020 and 2021 cropping seasons in Uyo, Nigeria.

	NMT		NUT		WMT		WUT		Yield (t/ha)	
	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
TIS87/0087	17.22^{d}	17.67^{cd}	7.33^{a}	5.83^{a}	4.27^{de}	2.85^{d}	1.40^{a}	0.98^{a}	7.11^{de}	5.18^{de}
Naspoy-12	16.95^{d}	14.22^{de}	6.67^{a}	5.17^{a}	8.00^{c}	6.53^{bc}	1.60^{a}	1.34^{a}	13.33^{c}	11.46^{c}
Umuspo-4	12.39^{e}	9.55^{e}	5.00^{a}	3.50^{a}	2.70^{e}	1.25^{d}	1.63^{a}	1.13^{a}	4.50^{e}	2.52^{e}
Umuspo-1	17.33^{d}	14.44^{de}	6.00^{a}	4.50^{a}	10.40^{b}	8.13^{b}	2.13a	1.66^{a}	17.33^{b}	15.50^{b}
Naspoy-11	18.32^{d}	15.99^{cd}	5.33^{a}	3.83^{a}	4.13^{de}	2.62^{d}	2.07^{a}	1.65^{a}	6.89^{de}	5.18^{de}
Lourdes	19.62^{cd}	16.62^{cd}	4.67^{a}	3.17^{a}	5.33^{d}	3.86^{cd}	1.93^{a}	1.42^{a}	8.89^{d}	6.93^{d}
Erica	22.33^{c}	19.93^{bc}	6.00^{a}	4.50^{a}	8.53^{bc}	7.11^{b}	2.07^{a}	1.65^{a}	14.22^{bc}	12.66^{bc}
Delvia	6.64^{f}	3.72^{f}	7.33^{a}	5.83^{a}	3.70^{de}	2.29^{d}	2.30^{a}	1.82^{a}	6.17^{de}	4.25^{de}
Ex-Igbariam	26.14^{b}	23.31^{b}	6.33^{a}	4.83^{a}	9.50^{bc}	7.95^{b}	1.73^{a}	1.30^{a}	15.83^{bc}	13.93^{bc}
Umuspo-3	34.78^{a}	32.47^{a}	5.33^{a}	3.83^{a}	17.27^{a}	16.06^{a}	2.17^{a}	1.70^{a}	28.78^{a}	27.09^{a}
Grand mean	19.17	16.79	6.00	4.50	7.38	5.86	1.90	1.46^{a}	12.31	10.47
SD	7.45	7.78	2.23	2.23	4.35	4.44	0.51	0.54	7.25	7.34

Values with the same letter(s) across each column do not differ significantly (p < 0.05). NUT = Number of unmarketable tubers, WMT = Weight of marketable tubers, WUT = Weight of unmarketable tubers

A: TIS 87/0087 (White flesh)

B: Lourdes (Orange flesh)



C: Delvia (Orange flesh)

Umuspo 1: (Orange flesh)

FIGURE 2: Morphological diversity observed in the storage root of different sweetpotato genotypes

Correlation among yield and yield related characters of ten sweet potato genotypes

In the present study correlation analysis among yield and yield related characters was done and revealed positive and negative associations among the studied yield and yield related characters of OFSP varieties evaluated in the study (Table 5). Vine length was positively was significantly and positively correlated (R = 0.60*) with number of leaves. Vine length was highly significantly and positively correlated (R = 0.44**) with number of marketable roots. Storage root yield was positively was highly significantly and positively correlated (R = 0.72**) with vine length. Fresh storage root yield was highly significantly and positively correlated (R = 0.81**) with number of marketable roots (Table 4). Similarly, yield also highly significantly and positively correlated (R = 0.99**) with weight of marketable roots.

Also, yield was highly significantly and positively correlated (R = 0.25) with number of leaves. Fresh storage root yield was highly positively correlated (R = -0.17) with number of leaf area. In line with the result of our current study, Nedunchezhiyan *et al*. (2007) also found that number of tuberous roots per plant was strongly related to total tuberous root yield. Likewise, marketable tuberous root yield is also highly significantly and positively correlated (R = 0.97**) with total tuberous root yield. In line with the current study, Stathers *et al*, (2003) and Islam *et al*. (2002) showed that vine length and number of roots were positively and significantly correlated with root yield (total root weight). Tsegaye *et al.,* (2006) reported positive yet

TABLE 5: Correlation of growth characters, yield and yield of ten sweet potatoes genotypes in 2020 and 2021 cropping seasons in Uyo, Nigeria

	VL	VG	NB	LA	NL	NMT	NUT	WMT	WUT	Yield (t/ha)
PH										
VG	0.216									
NB	0.383**	0.491**								
LA	-0.265*	0.272*	0.197							
NL	0.603**	0.625**	0.710**	-0.006						
NMT	0.449**	0.153	0.313*	0.110	0.205					
NUT	-0.043	-0.093	-0.403**	0.014	-0.268*	-0.153				
WMT	0.395**	0.211	0.334**	0.155	.0256*	0.822**	-0.106			
WUT	0.109	0.335**	0.312*	0.237	0.278*	0.191	-0.237	0.358**		
Yield (t/ha)	0.392**	0.187	0.329*	0.174	0.250	0.819**	-0.106	0.992**	0.330**	

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

VL = Vine length, VG = Vine girth, NB = Number of branches, LA = Leaf area, NL = Number of leaves, NMT = Number of marketable tubers, NUT = Number of unmarketable tubers, WMT = Weight of marketable tubers, WUT = Weight of unmarketable tubers.

significant root girth among thirty sweetpotato genotypes. Selection of correlated traits influences each other thus allowing simultaneous selection in plant breeding programmes (Rukundo *et al*, 2013). Similarly, Yohhanes *et al.,* (2010) reported that total storage root yield had significant and positive association with marketable storage root yield and average storage root weight. Gunjan (2012) also reported that marketable tuberous root yield was positively correlated with total tuberous root yield. This indicates that yield is an important agronomic index which shows adaptability of a genotype to its growing environment (Antiaobong and Bassey, 2008) and hence genotype Umuspo-3 can be identified as the highest tuberous root yielding and adaptable genotype to the study area and also number of marketable roots and marketable root weight can be used as important factors for selection of sweet potato to growers aimed at producing sweet potatoes for tuber production and serves as an indicator of adaptability of the crop to the local growing conditions (Nwankwo *et al*., 2012).

Principal component among yield and yield related characters of ten sweet potato genotypes:

Three main component axes (PC1 PC2 PC3and PC4) were obtained in the principal component analysis in all ten (10) agro-morphological traits were studied (Table 5). PC analysis had eigen values up to 1.0, explaining cumulative variance of 81.55% of the total variation among the genotypes (Table 6). The traits of importance for the first component involved root traits of commercial interest. Principal component one (PC1), with eigen value of 3.95, contributed 39.54% of the total variability. PC2, with eigen value of 1.78, accounted for 17.86% of total variability. PC3, with eigen value of 1.40, accounted for 14.09%, PC4, with eigen value of 1.00, accounted for 10.05% (Table 6). In PC1, the traits that accounted for most of the 39.54% observed variability among the ten sweet potato genotypes included number of vine length, with vector loading of 0.61, number of branches (0.78), number of marketable tubers (.075), weight of marketable tubers (0.82), yield (0.81) (Table 6). PCA is a technique to identify which plant traits is the most contributing to the observed variation. Afuape *et al.* (2011), who reported a cumulative variance of 76.00% for the first three axes in the evaluation of twenty-one sweetpotato genotypes, found important traits to be the genotypes they worked with. Four main components (PC) were identified, accounting for 67.22% of the total variation between accessions (Koussao *et al*., 2014). Placide *et al*., (2015) also used PCA to study the variability between 54 sweetpotato genotypes and found the cumulative variance of 77.83% from the first seven major component axes.

TABLE 6: Principal component analysis of ten sweet potatoes genotypes in 2020 and 2021 cropping seasons in Uyo, Nigeria

	Component			
	PCA 1	PCA 2	PCA 3	PCA 4
PH	0.610	-0.043	-0.640	0.188
VG	0.542	-0.533	0.209	0.387
NB	0.708	-0.478	0.006	-0.096
LA	0.200	-0.039	0.837	0.211
NL	0.679	-0.586	-0.267	0.150
NMT	0.757	0.509	-0.057	-0.051
NUT	-0.322	0.318	-0.036	0.845
WMT	0.828	0.514	0.065	-0.004
WUT	0.505	-0.159	0.414	-0.164
Yield (t/ha)	0.819	0.526	0.067	-0.006
Total	3.955	1.786	1.409	1.006
% of Variance	39.547	17.860	14.095	10.056
Cumulative %	39.547	57.406	71.501	81.557

PH = Plant height, VG = Vine girth, NB = Number of branches, LA = Leaf area, NL = Number of leaves, NMT = Number of marketable tubers, NUT = Number of unmarketable tubers, WMT = Weight of marketable tubers, WUT = Weight of unmarketable tubers.

CONCLUSION

The current results showed high level of variability among the ten sweet potato genotypes for most important yield and yield related characters: number of marketable root per plot, weight of marketable tuber and fresh storage tuber in both cropping seasons. Umuspo-3 produced the highest marketable root weight per plot and storage tuber yield. Based on these results, Umuspo-3 recorded the best performance in the majority of yield and yield related characters. Yield is considered an important factor which determines choice of sweet potato genotype for cultivation. Hence, genotype Umuspo-3 can be identified as the highest storage root yielding and adaptable genotype to the study area under the rain fed condition. Therefore, Umuspo-3 can be utilized as the superior genotype with maximum yield and highest adaptability in Uyo agro-ecology of Akwa Ibom State. Umuspo-4, Naspoy-11 and Delvia could be eliminated from sweet potato list of the environment. Sweet potato genotypes with yields below 20t/ha could be crossed with Umuspo-3 to improve their productive capacities for the environment. Breeding strategies for characters that correlate with fresh tuber yield, would improve yield in sweet potato.

DECLARATION OF CONFLICTING INTERESTS

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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