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EFFECT OF PLANTING DATE ON GROWTH, CAROTENE AND ROOT YIELD OF THREE SWEETPOTATO VARIETIES [*Ipomoea batatas* (L.) Lam.] IN SOUTH-EAST NIGERIA

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Abstract
There is paucity of information on the effect of time of planting on sweetpotato in South-East Nigeria and hence the need for this study; where four planting dates were assessed under field conditions for their comparative effects on growth, carotene, and root yield of orange-fleshed sweetpotato varieties at the National Root Crops Research Institute, Umudike, Nigeria in 2013 and 2014 cropping seasons. The experiment was a split-plot laid out in randomized complete block design with three replications. The main plot treatments were three sweetpotato varieties (Umuspo 1, Umuspo 3, and Ex-Igbariam), while the sub-plot treatments were four planting dates (April, May, June, and July). Results indicated that delayed planting from April to other planting dates significantly reduced orange-fleshed sweetpotato fresh shoot biomass and dry matter. Similarly, planting in April, 2013 produced significantly ($p<0.05$) higher storage root yield than planting later in May, June, and July by 75%, 92%, and 149%, respectively. In contrast, delayed planting up to June produced a carotene yield of 1267.7µg/g, which was higher than those of April and May by 180% and 82%, respectively. On average, Umuspo 1 produced significantly greater biomass of shoot and root. In 2013, Umuspo 1 also produced higher storage root yield than Umuspo 3 and Ex-Igbariam by 61% and 46%, respectively. However, Umuspo 3 produced significantly highest carotene yield (1918.0µg/g), followed by Umuspo 1 (582.0µg/g), while Ex-Igbariam had the lowest value (296.5µg/g). There were no significant interaction effects on root yield in both years, but there was a significant interaction on carotene yield, which was highest in Umuspo 3 in July, followed by the June planting date. For high fresh shoot and storage root yields, planting Umuspo 1 in April is recommended, while for high carotene yield, planting Umuspo 3 in June or July is recommended.

Keywords: Carotene, orange-fleshed sweetpotato, planting date, root, varieties, yield

Introduction
Sweetpotato [*Ipomoea batatas* (L.) Lam]; a perennial plant usually grown as an annual (Woolfe, 1992), is a dicotyledonous plant that belongs to the family Convolvulaceae (Purseglove, 2009 and Woolfe, 2008). Sweetpotato is one of the world's food crops and an important staple food crop in Nigeria (Ukpabi, 2009). It is a low input crop and used as a vegetable, desert, source of starch and animal feed (Odebode, 2004). In Nigeria, sweetpotato is eaten as a substitute for yam, because of its lower cost of production. Sweetpotato is an important food in many enclaves in Nigeria (FAO, 2009), though it is one of the crops whose potential is not well known of all the major crops, in-spite of its nutritive and agronomic characteristics (Woolfe, 1992). It is drought tolerant and has short growth periods (Amare *et al*., 2014). It is high-yielding with limited inputs on relatively marginal soils (Oduro *et al*., 2000). Farmers in sub-Saharan Africa produce below 10 tonnes per hectare fresh weight on the average, while farmers in Nigeria have the lowest average yields of less than 3.1 tonnes per hectare (FAO, 2009). Sweetpotato roots grow from underground stem nodes as it produces trailing and twisting vines that can be as long as 6m. Woodward (2003), and *Kyte and Kleyn* (1996), have reported that roots grow where stem nodes touch the ground, and most develop into the edible storage roots, usually, 4 to 10 storage roots *per* plant.

Most African varieties have white, cream, or yellow flesh, which are low in provitamin A (Omiat *et al*., 2005), while few have orange flesh which are high in provitamin A. While white-to yellow coloured sweetpotatoes have been reported to contain little or no provitamin A, orange-fleshed sweetpotatoes contain good qualities, principally of β-carotene (Kosambo *et al*., 1998). Vitamin A deficiency is a serious public health problem in many developing countries, including most of the countries of Eastern, Central, and Southern Africa (WHO, 1995). It mainly affects young children (6 months to 6 years of age) and pregnant women (Radhika *et al*. 2002) in poor countries. This is because the breast milk of lactating mothers with vitamin A deficiency contains little vitamin A, which provides the breast fed child with too little vitamin A (McLaren and Frigg, 2001). World Health Organization (WHO, 1995) estimated that 13.8million children have some degree of visual loss related to vitamin A deficiency (VAD). Orange-fleshed sweetpotato therefore, can be used to combat the widespread vitamin A deficiency in Africa that results in blindness and even death of young children (Feliciano, 2007).

One approach to increased food availability and tackling vitamin A deficiency would be to grow and utilize orange-fleshed sweetpotato varieties (Low *et al*., 1997). Promoting consumption of locally available vitamin A-rich foods that can be grown in home gardens holds great promise in many places (Low *et al*., 2007), due to its technical feasibility and cost-effectiveness. Orange-fleshed sweetpotato can be a very suitable crop for this approach (Low *et al*., 1997; Woolfe, 1992). In the 1990's, scientists at the International Potato Centre (CIP), identified a group of orange-fleshed sweetpotato varieties with high content of β-carotene and sufficient dry matter to satisfy consumer preferences and tastes. Subsequent studies demonstrated that the consumption of just small amounts of foods derived from the new orange-fleshed sweetpotato varieties could eliminate or greatly reduce vitamin A deficiencies in both young children, pregnant and lactating women (Feliciano, 2007).

Apart from varietal effects, time of planting has been identified as one of the most important factors affecting the growth, yield, and quality of roots (Nedunchezhiyan and Byju, 2005). Planting dates have also been reported to influence the yield and chemical composition of crops (Bastidas *et al*. 2008). Planting dates can also affect many crop diseases; early planting increases the risk of seedling disease and some other soil-borne pathogens, but for some diseases, there is a risk of greater yield loss with late planting date (Munkvold and Yang, 1999). The increased risk associated with late planting occurs because plants are at an earlier growth stage at the onset of disease (Hahn and Anota, 1981). Plants infected earlier in their development suffer greater yield reductions. Anioke (1996) indicated the need to review the production technologies, including the time of planting in South-East Nigeria following the release of new sweetpotato varieties by National Root Crops Research Institute (NRCRI), Umudike. In South-East Nigeria, the common production practice is to plant major crops such as yam, cassava, and maize early in the cropping season; April through June, with the result that other crops are often planted later (Ojikpong *et al*., 2007). In recent times, rainfall patterns have been erratic due to climatic change, such that rains may not stabilize until May/June (Kohler *et al*., 2010; Marston, 2008) compared with March/April previously reported (Van Rheeneen, 1973). The general approach is to relate the planting date to the length of the rainy season of the region (Akchurst and Screedharan, 1965). Sweetpotato is sensitive to photoperiod with a change in planting date having a marked effect on plant development and growth (Marcos *et al*., 2011). Consequently, planting dates after July reduce yields because early tuber initiations with short days cause a big reduction in vegetative growth and resulting in poor tuber enlargement (Shiwachi *et al*., 2002). Therefore, the objectives of this work were to determine the effect of planting date and variety on the root yield and carotenoid content of orange-fleshed sweetpotato. We hypothesized that varying planting dates may not have an effect on the growth and yield of orange-fleshed sweetpotato.

Materials and methods

The experiment was conducted during the 2013 and 2014 planting seasons from April to July at the National Root Crops Research Institute, Umudike, South-East, Nigeria, located on longitude 07° 33′E, latitude 05° 29′N and altitude 122m above sea level. The soil is classified as sandy loam, acidic, and characterized as an ultisol (Eke-Okoro, 2001). Typically rainforest vegetation, characterized by a long duration of rainfall (7 – 12 months) and a short period of dry season (NRCRI, 2012). The soils of the experimental sites were texturally sandy loam in 2013 and sandy clay loam in 2014 cropping seasons. The soils were low in nitrogen (0.06 – 0.12 %) and acidic in reaction (pH 5.0 - 5.3). A split-plot in a randomized complete block design was used. The main plot treatments were the three varieties of sweetpotato (Umuspo 1, Umuspo 3, and Ex-Igbariam), while, the sub-plot treatments consist of four planting dates: 24th April, 22nd May, 20th June, and 18th July in 2013. The planting dates in 2014 were; 16th April, 14th May, 11th June, and 9th July. The variation in date between the two cropping seasons was a result of challenges encountered with land acquisition. The twelve treatments were randomly allocated to the plots in each of the blocks. The treatments were replicated three times. Each plot consist of four rows with a spacing of 1m x 0.3m to give a plant population of 33,333plants/ha. Sweetpotato vines sourced from a 10 weeks old NRCRI Umudike sweetpotato nursery were cut into lengths of 20 – 25cm containing at least four nodes. Planting was done at the stipulated dates and missing stands supplied 2 weeks after planting (WAP). Weeding and roughing were done manually at 6 and 12 WAP respectively. NPK- 15:15:15 was applied at the rate of 400kg/ha at 4WAP using band placement. Data were taken on fresh shoot biomass, number of roots per plant, root weight (g), root yield (t/ha), and total carotenoid (µg/g) which was determined in the NRCRI Umudike laboratory. Total carotenoid was calculated (after extracting carotene from the root using acetone, the carotene extract separated using the chromatographic method and the samples read with spectrometer) thus;

$$\text{Total carotenoid} = \frac{\text{absorbance} \times 10000 \times \text{Volume}}{\text{Constant} \times \text{sample weight}}$$

Where, volume = 25ml, constant = 2592, sample weight = 5g.

Analysis of Variance was used to determine if there was a significant difference or not in the effects of planting date and variety on growth, yield, and carotenoid content of OFSP using Genstat (2007) statistical package. The means that differed were separated using Fisher's least significant difference at 5% probability level.

Table 1: Treatment combinations

Varieties (V)	Planting Dates			
	D_1	D_2	D_3	D_4
V_1	V_1D_1	V_1D_2	V_1D_3	V_1D_4
V_2	V_2D_1	V_2D_2	V_2D_3	V_2D_4
V_3	V_3D_1	V_3D_2	V_3D_3	V_3D_4

Results and Discussion

Meteorological data

The total annual rainfall in 2013 and 2014 was 2210.0mm and 2068.5mm, respectively (Table 1). There was rainfall in all the months of the 2013 cropping season. However, in 2014, there was no rainfall in January and December. A high amount of rainfall was observed in May through September in both cropping seasons, although in July, 2014, there was a clear reduction in the amount of rainfall. The mean maximum monthly temperature for 2013 and 2014 was 31.6°C and 31.7°C respectively, while, the minimum temperature was 22.6°C and 23.2°C in 2013 and 2014 respectively.

Table 2: Agrometerological data of the experimental site for 2013 and 2014

	2013			2014		
	Rainfall (mm)	Temp.(°C)		Rainfall (mm)	Temp.(°C)	
	Amt.	Max.	Min.	Amt.	Max.	Min.
Jan	75.4	32	18.4	0.0	33.4	21.5
Feb	84.8	33	21.3	43.7	33.9	23.2
March	40.8	33	40.0	138.8	33.2	23.4
April	92.8	32	23.3	78.7	32.2	23.5
May	466.1	31	22.7	249.2	31.9	23.4
June	239.4	29	22.4	281.8	30.5	24.2
July	280.5	30	22.6	114.9	30.0	24.0
August	237.1	34	22.5	436.5	29.6	23.3
Sept	318.0	30	22.9	412.4	29.8	22.9
Oct	184.8	30	29.9	165.1	31.0	23.6
Nov	99.5	32	23.2	147.4	31.6	23.5
Dec	90.8	32	21.6	0.0	32.7	21.8
Total	2210.0	378.0	271.0	2068.5	379.8	278.3
Mean		31.6	22.6		31.7	23.2

Source: NRCRI, 2014

Yield and yield components

Orange-fleshed sweetpotato fresh shoot biomass in 2013 decreased significantly when planting was delayed until July (Table 3). Planting in April produced shoot yield of 8.2t/ha and this was higher than in May, June, and July planting by 44%, 67%, and 382% respectively. In both years, Umuspo 1 consistently produced significantly ($p<0.05$) highest shoot biomass, followed by Ex-Igbariam, while, Umuspo 3 had the lowest shoot yield. Interactions of planting dates and variety were significant in 2013, with Umuspo 1 variety producing the highest shoot biomass in April planting date. The July planting date had the lowest yield regardless of sweetpotato variety. The number of storage roots harvested per plant in 2013 decreased significantly with delay in planting i.e., July (Table 4). Conversely, planting in June produced more storage roots than planting early in April and May or later in July in 2014. Umuspo 1 had a significantly ($p<0.05$) higher number of roots per plant than other varieties in 2013. However, in 2014, the highest number of roots was produced by Umuspo 3 when planting was done in June. At harvest i.e., 16 WAP, planting date did not produce any significant difference on storage root weight in both cropping seasons (Table 5). There was also no significant effect of variety and interaction of both factors on the weight of storage roots per plant. In 2013, planting in April produced significantly higher storage root yield than planting in May, June, and July by 75%, 92%, and 149% respectively (Table 6). Storage root yields obtained from the May through July planting dates did not vary significantly ($p<0.05$). Among the varieties, Umuspo 1 produced significantly higher root yields than Umuspo 3 and Ex-Igbariam by 61% and 46%, respectively. In 2014, however, planting date and orange-fleshed sweetpotato variety did not significantly affect root yield. Similarly, in both years, interactions between planting date and variety did not significantly influence storage yield. Delaying planting to June resulted in increases in the carotenoid content of orange-fleshed sweetpotato but beyond this date, no significant improvement occurred (Table 7). The carotenoid level of 1267.7µg/g obtained at June planting date was higher than those of April and May by 180% and 82%, respectively. Delaying planting to July slightly increased the carotenoid content by 3% than planting in

June. The Umuspo 3 orange-fleshed sweetpotato variety produced significantly highest carotenoid content of 1918.0µg/g, followed by Umuspo 1 (582.0µg/g), while, Ex-Igbariam had the least value (296.5µg/g). Interactions between planting date and variety showed that the highest carotenoid level of 3066.2µg/g occurred in Umuspo 3 in July, followed closely by the June planting date with 2783.0µg/g.

Table 3: Effect of planting date and variety on fresh shoot biomass (t/ha) of orange-fleshed sweetpotato in 2013 and 2014 cropping seasons

		Variety		
Planting date	**Umuspo 1**	**Umuspo 3**	**Ex-Igbariam**	**Mean**
		2013		
April	16.1	1.8	6.7	8.2
May	7.3	3.7	6.1	5.7
June	6.5	2.1	6.1	4.9
July	2.8	1.0	1.4	1.7
Mean	8.2	2.2	5.1	
		2014		
April	22.2	2.1	8.5	10.9
May	12.0	2.1	7.7	7.3
June	21.0	3.5	9.2	11.2
July	10.9	1.5	6.8	6.4
Mean	16.5	2.3	8.1	
		2013	**2014**	
LSD (0.05) for two planting date (D)		2.8	NS	
LSD (0.05) for two variety (V)		2.4	3.0	
LSD (0.05) for two D x V		4.5	NS	
*NS = Not significant				

Table 4: Effects of planting date and variety on the number of storage roots per plant of orange-fleshed sweetpotato in 2013 and 2014 cropping seasons

		Variety		
Planting date	**Umuspo 1**	**Umuspo 3**	**Ex-Igbariam**	**Mean**
		2013		
April	3.4	1.7	3.0	2.7
May	1.8	1.3	1.4	1.5
June	1.5	1.3	1.0	1.3
July	1.3	1.1	1.0	1.1
Mean	2.0	1.4	1.6	
		2014		
April	1.4	1.3	1.6	1.4
May	1.0	1.1	1.1	1.1
June	1.8	2.6	1.0	1.8
July	1.4	1.4	1.2	1.3
Mean	1.4	1.6	1.2	
		2013	**2014**	
LSD (0.05) for two planting date		0.4	0.3	
LSD (0.05) for two variety (V)		0.4	NS	
LSD (0.05) for two D x V		NS	0.6	
*NS = Not significant				

Table 5: Effect of planting date and variety on weight (kg) of orange-fleshed sweetpotato tubers per plant in 2013 and 2014 cropping seasons

Planting date	Umuspo 1	Variety Umuspo 3	Ex-Igbariam	Mean
		2013		
April	0.147	0.119	0.119	0.128
May	0.134	0.140	0.126	0.134
June	0.153	0.148	0.111	0.138
July	0.129	0.126	0.120	0.125
Mean	0.141	0.133	0.119	
		2014		
April	0.111	0.114	0.116	0.114
May	0.352	0.131	0.166	0.216
June	0.143	0.106	0.152	0.134
July	0.148	0.134	0.202	0.161
Mean	0.188	0.121	0.159	
		2013	**2014**	
LSD (0.05) for two planting date (D) means =		NS	NS	
LSD (0.05) for two variety (V) means =		NS	NS	
LSD (0.05) for two D x V means =		NS	NS	
*NS = Not significant				

Table 6: Effect of planting date and variety on storage root yield (t/ha) of orange-fleshed sweetpotato in 2013 and 2014 cropping seasons

Planting date	Umuspo 1	Variety Umuspo 3	Ex-Igbariam	Mean
		2013		
April	16.5	6.7	11.8	11.7
May	8.1	5.9	6.1	6.7
June	7.8	6.6	3.9	6.1
July	5.6	4.5	4.1	4.7
Mean	9.5	5.9	6.5	
		2014		
April	4.9	5.0	5.8	5.2
May	11.7	4.6	6.1	7.5
June	8.5	9.2	5.1	7.6
July	6.7	6.1	8.2	7.0
Mean	7.9	6.2	6.3	
		2013	**2014**	
LSD (0.05) for two planting date (D)		3.7	NS	
LSD (0.05) for two variety		2.4	NS	
LSD (0.05) for two D x V		NS	NS	
*NS = Not significant				

Table 7: Effect of planting date and variety on the total carotenoid content (µg/g) of orange-fleshed sweetpotato in 2014 cropping season

Planting date	Umuspo 1	Variety Umuspo 3	Ex-Igbariam	Mean
		2014		
April	389.2	916.3	53.0	452.8
May	695.4	906.2	489.0	697.0
June	682.2	2783.0	338.0	1267.7
July	560.0	3066.2	306.0	1311.0
Mean	582.0	1918.0	296.5	
LSD (0.05) for planting date (D)	219.7			
LSD (0.05) for variety	130.1			
LSD (0.05) for D x V	254.5			

The results showed that delaying planting from April to May, June, and July in 2013 resulted in a marked reduction in orange-fleshed sweetpotato storage root yield by 42.7%, 47.9%, and 59.8%, respectively. Across the two cropping seasons, reductions in yield following delayed planting from April to May, June, and July were 16%, 18.9%, and 30.8%, respectively. The greater reduction in yield following delayed planting may in part be due to the longer vegetative phase associated with early planting dates; the heavier rainfall of later planting dates which caused cloudy skies and reduced radiation or more nutrient losses due to runoff, leaching and sediment transport arising from rainfall intensity (Yang *et al.,* 2020) . Marcos *et al*. (2011) reported that the length of the vegetative phase is of crucial importance for plant growth and later tuber filling because a great proportion of the leaf area is produced before tuber filling, while, Marcos *et al*. (2009) noted that photoperiod and secondarily temperature played a major role in tuber initiation and thus in the length of vegetative phase. Optimum yields were obtained when the orange-fleshed sweetpotato was planted in late April, which received 93mm rainfall in 2013. Yields were however lower in May to July planting dates which had higher monthly rainfalls of 239 to 466 mm. This agrees with the observations by Anioke (1996), that best yields were obtained when 62 to 95mm of rain falls within two weeks after planting. According to Nwinyi, (1992) the sunlight hour is positively correlated with the yield of sweetpotato and inversely correlated to rainfall. Generally, delayed planting coincided with increased rainfall and cloud cover, which affected the sunlight hours and consequently the photosynthetic activities of the plants. The April planting date which produced the highest storage root yield also gave higher fresh shoot biomass than planting in May, June, and July by 48%, 19%, and 134%, respectively, on average. Similar reductions in shoot biomass of African yam bean and soybean have been reported following a delay in planting date (Okpara *et al*., 2005). Although planting early in April increased vine and root yields, planting in June and July substantially increased the carotenoid content of the root tubers over the former. Planting in July increased the carotenoid level than planting in June, May, and April by 3%, 88%, and 190%, respectively. Similarly, planting in June produced a higher carotene yield than planting in May and April by 82% and 180%. The improved carotenoid level observed when planting was delayed to June or July may probably be due to the greater availability of nutrients at this time which coincided with when the rain had stabilized. Ukom *et al*. (2009) had reported increased β – carotene yield with increased availability of nitrogen. Selection for higher yield has been the major focus for crop improvement in Africa but gains from such selection have been low due to large genotype and environmental interactions (Nigam and Dwivedi 1991). Dugje *et al*. (2009) noted that the choice of any variety suitable for an agro-ecological zone should be based on the maturity period and yield potentials. The result obtained in this study showed that Umuspo 1 produced higher storage root yield and shoot biomass than other varieties, probably due to the tendency to have a strong ability to accommodate more assimilates in the storage root by the high yielder (Bhagsari and Harmon, 1982). 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 respond to applied input and local stresses. On average, storage root yield was higher by 43% and 37% in Umuspo 1 than in Umuspo 3 and Ex-Igbariam. Similarly, average fresh shoot biomass was higher by 449% and 88% in Umuspo 1 than in Umuspo 3 and Ex-Igbariam varieties, respectively. Although vine and root yields were higher in Umuspo 1, Umuspo 3 was superior in carotene yield. On average, the carotene yield of Umuspo 3 was 1918μg/g and this was higher than those of Umuspo 1 and Ex-Igbariam by 230% and 548%, respectively. Similar observations were made by Akpaninyang *et al*. (2015) who reported higher carotene but lower vine and root yields in Umuspo 3. The shoot and root yields obtained in this study were generally lower than the values reported by Akpaninyang *et al*. (*ibid*). The mean storage root yields of 8.7t/ha for Umuspo 1 and 6.1t/ha for Umuspo 3 were much lower than the average yields of 30.8t/ha for Umuspo 1 and 19.7t/ha for Umuspo 3 reported by Akpaninyang *et al*. (*ibid*) and the yields of 25.1t/ha for Umuspo 1 and 17.5t/ha for Umuspo 3 reported by Ogbologwung *et al*. (2014) when NPK fertilizer was applied at the same nutrient rate of 400kg/ha. The disparities in response reported could be related to differences in edaphic factors and erosion and the high prevalence of virus-infected planting materials in the present study which was initiated early in the season. Agboola and Unanma (1994) also reported that low soil fertility is one of the constraints in the production of sweetpotato in Nigeria.

Conclusion

Based on the results, it is concluded that high storage root yield of orange-fleshed sweetpotato could be realized by planting in late April, while high carotenoid yield could be obtained by delaying planting to June or July. On the other hand, Umuspo 1 variety gave the highest storage root yield compared to the other varieties and also had an appreciable carotenoid content; making it a better variety for Umudike, South-East Nigeria.

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