Research Article

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Response of Thirteen Tannia Accessions to Variations in Planting Date in the Humid Tropics

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Abstract: The objectives of the study were to assess the inter-relationship between growth, yield, nutritional and anti-nutritional responses of thirteen tannia (*Xanthosoma sagittifolium* L.) accessions to planting date (May, June and July) in the humid tropics. Tannia corms and leaves are veritable sources of dietary fibre and starch, also essential minerals and vitamins; hence its value for security and as a cash crop for people in the humid tropics. A two-year 13-genotype × 3 planting date factorial arranged rain-fed field experiment in randomized complete block design with three replications was carried out during the 2014 and 2015 cropping seasons at Michael Okpara University of Agriculture, Umudike, Nigeria. The results indicated that planting date and accession influenced growth and yield of tannia, an indication of differential responses of the thirteen accessions to the planting dates (May, June and July). The results suggest that May is the most appropriate planting date; accessions planted during this month had the highest yields. The interaction between planting date and tannia accession was significant for some traits (number of leaves per plant and cormel weight per plant) in both years and significant for plant height, pseudo-circumference and corm weight (2014); leaf area and tannia yield (2015). The correlation analysis showed good selection characters in plant height, pseudo-stem circumference, leaf area, number of leaves per plant, corm weight, corm circumference, cormel weight and cormel circumference for high yielding varieties, while nutritional analysis (crude protein, carbohydrate, phosphorus, potassium, calcium, tannin and oxalate) exhibited lower concentrations in processed corms relative to unprocessed. The corm yield of the tannia accessions ranged from 1.49 to 13.48 $Mt.ha^{-1}$ in 2014 and 2.72 to 8.50 $Mt.ha^{-1}$ in 2015 and best four accessions judged by interaction between tannia accession and date of planting was 13 (*Ikaro*) > 12 (*Idoani*) > 3 (*Ehor*) > 10 (*Idasen*) in May 2014 compared to accessions 6 (*Ewu*) >10 (*Idasen*) > 12 (*Idoani*) > 1 (*Ikpoba*) planted in June 2015. The differences in sequence suggest that both environment and genetic constitution contribute to Tannia yield.

Keywords: Tannia corm yield, nutritional composition, phyto-chemical analysis, proximate analysis

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1 Introduction

Tannia (*Xanthosoma sagittifolium*), which belongs to the family Araceae is a staple food security crop with rich economic and nutritional qualities for many people living in Sub-Sahara Africa, south east Asia and the Malayan archipelagos (Onwueme 1999; Lebot 2009). Tannia is ranked sixth in the world for root crop production after cassava, potato, sweetpotato, yam and taro (Ramesh et al. 2007; Perez 2010).

According to Green (2003) and Chukwu and Nwosu (2008) the highly calorific corms of tannia are rich in carbohydrates and are nutritionally superior to other roots and tubers in terms of digestible crude protein and minerals such as calcium, magnesium, and phosphorus. The starch contained in the large corms is about 98.8 % digestible (Vinning 2003) thereby making it a veritable source of carbohydrate with low potassium and protein. Furthermore, the phyto-chemicals in tannia corms and leaves are toxic or anti-nutritional because of their acridity, a natural defensive against grazing animals (Lebot 2009).

The yield for tannia has remained low (5 to 7 t ha^{-1}) in Africa principally due to seasonal weather variability (Mulualem and WeldeMichael 2013). According to Lebot et al. (2006), one cardinal avenue to increase or at least maintain crop yield in the face of a changing climate is to adjust planting dates of crops. Thus appropriate planting date is one of the most effective and zero cost means of increasing crop yields. Khan et al. (2003) and Yadav et al.

(2007) demonstrated that an ideal planting date is one that maximizes yield by avoiding those stages of growth that coincide with periods of crop sensitivity to temperature or moisture stress. Specific knowledge of crop response to different planting dates within the ecosystem is therefore important to determine the most appropriate planting time for the crop. Lu et al. (2001), Lal (2009) and Jianchu et al. (2001) in their studies submitted that the yield of taro is largely affected by planting date with temperature being the most important factor, though this varies according to accession and the agro-ecology of the area. Studies by Mbouobda et al. (2007) have shown that genetic diversity of tannia is still poorly characterized, although studies on morphological and agronomic characterization tend to suggest a narrow genetic base.

The nutritional importance of any food product depends not only on the nutrient composition but also on the presence of anti-nutritional factors such as tannins and oxalate among others (Agueguia et al. 1992; Onokpise et al. 1999). Processing tannia corms has been reported to improve digestibility, promote palatability, improve keeping quality and also makes corms, roots and tubers safe to eat (FAO 1990; Albihn and Savage 2001). However, there is dearth information on the nutritional status of processed and unprocessed tannia corms in the humid tropics of southern Nigeria. The objectives of this study were, therefore, to determine the growth, yield and yield-component responses of thirteen tannia accessions to three planting dates and the inter-relationships among corm yield and other traits as well as the nutritional and anti-nutritional composition of the accessions.

2 Materials and methods

The experiment was conducted at the Department of Agronomy, Michael Okpara University of Agriculture, Umudike teaching and research farm (Lat. 05° 29′ N; Long. 07° 33′ E; Alt. 122 m) in 2014 and 2015 cropping seasons. Umudike is in the humid tropics and has a mean rainfall of about 2177 mm with mean air temperature of about 26°C per annum. The mean sunshine hours during the cropping season (April to December) was 4.2 per day while the relative humidity ranged from 34 to 88 % across the two cropping seasons (Table 1). The rainfall pattern is bimodal and characterized by a long wet season from April to July, which is interrupted by a short dry spell in August and then followed by another short rainy season from September to October tailing into early November. The dry season stretches from early November to March. Meteorological data covering rainfall, temperature, relative humidity and daily sunshine at the experimental site during 2014 and 2015 cropping seasons are shown in Table 1.

Prior to planting, composite top-soil samples to a depth of 20cm were collected the experimental units using a soil auger at a depth of 0 – 20 cm. These samples

Table 1: Agro-meteorological data of the experimental site in 2014 and 2015 cropping seasons

Month	2014							2015						
	Rainfall amount (mm)	Temperature (°C)		Relative Humidity (%)		Sunshine (Hrs)		Rainfall amount (mm)	Temperature (°C)		Relative Humidity (%)		Sunshine (Hrs)
		Max	Min	0900 Hrs	1500 Hrs				Max	Min	0900 Hrs	1500 HrsS	
April	78.7	32.2	23.5	79	66	5.5	61.7	33.4	23.8	78	58	5.18
May	249.2	31.9	23.4	81	69	5.2	246.8	32.7	23.4	81	63	5.88
June	281.8	30.5	24.2	81	74	4.9	346.2	29.8	23.5	87	76	2.2
July	114.9	30.0	24.0	86	79	2.8	129.2	27.3	22.4	88	81	2.2
August	444.2	29.6	23.3	85	78	3.1	366.2	29.0	24.0	87	80	2.3
September	405.3	29.8	22.9	85	79	2.8	276	29.0	23.0	87	78	2.74
October	165.1	31.0	23.6	82	71	4.2	380.2	31.0	24.0	84	74	4.63
November	147.4	31.6	23.5	81	66	3.3	49.7	33.0	24.0	80	60	6.09
December	0.0	32.7	21.8	65	47	5.9	0.0	29.5	22.9	35	34	6.23
Total	1886.6	-	-	-	-	37.7	1856	-	-	-	-	37.5
Mean	209.2	31.0	23.4	80.5	69.9	4.2	206.2	30.5	20.7	78.5	67.1	4.2

Source: National Root Crops Research Institute Agro-Meteorological Station, Umudike Abia State Nigeria.

were analysed following standard soil science procedures (Table 2). The soil has been classified as sandy loam Ultisol (paleustalt) (USDA classification).

All tannia (*Xanthosoma saggittifolium*) accessions tested were collected from farmers in thirteen communities across five local governments in Edo State and two from Ondo State (Table 3). The experiment was a 13 × 3 factorial arranged in a randomized complete block design and the treatments comprised thirteen tannia accessions and three planting dates (May, June and July). There were thirty nine treatment combinations with three replications. The experimental field was cleared, ploughed, harrowed and ridged using a tractor. Planting was done May 10th, June 12th and July 15th (2014) and May 16th, June 12th and July 10th (2015). The plot size used was 3 x 3 m (9 m^2) and the corms were planted at 1 x 1 m intra- and inter- spacing (10,000 plants ha^{-1}). The plots were kept weed free by manual weeding starting three and seven weeks after planting (WAP). 8 WAP mixed fertilizer (N:P:K:Mg 12:12:17:2) was applied at the recommended rate of 400 kg ha^{-1} , meaning that 48 kg N, 48 kg P, 68 kg K and 8 kg Mg were applied.

2.1 Data collection

Growth data as follows were randomly collected from a sample of four plants per plot 15 weeks after planting (WAP). This included plant height, measured by meter ruler as the distance from the ground level to the attachment point between the leaf petiole and the lamina of the

Table 2: Soil physico-chemical properties of experimental sites in 2014 and 2015 cropping seasons

Soil properties	2014	2015
Texture	Sandy clay loam	
Physical properties		
Sand (%)	76.40	67.20
Silt (%)	7.40	9.00
Clay (%)	14.20	23.80
Chemical properties		
pH (H_2O)	4.65	5.20
Total nitrogen (%)	0.15	0.18
Organic carbon (%)	1.69	0.50
Organic matter (%)	2.91	0.87
Phosphorus ($mg \cdot kg^{-1}$)	35.20	67.80
Calcium ($cmol \cdot kg^{-1}$)	2.00	2.80
Magnesium ($cmol \cdot kg^{-1}$)	1.20	1.60
Potassium ($cmol \cdot kg^{-1}$)	0.07	0.078
Sodium ($cmol \cdot kg^{-1}$)	0.24	0.19
Exchangeable acidity ($cmol \cdot kg^{-1}$)	1.28	2.16
ECEC ($cmol \cdot kg^{-1}$)	4.79	6.82
Base saturation (%)	73.24	68.35

Source: Soil Science Laboratory, National Root Crops Research Institute, Umudike, Nigeria.

Table 3: Thirteen (13) tannia accessions and their geographical origin (community and geographical coordinates) of the area

Accessions	Town of provenance	LGA	State	Longitude	Latitude
Acc. 1 (*Ikpoba*)	Ikpoba	Ovia South	Edo	5˚18′ E	6˚15′ N
Acc. 2 (*Isokponba*)	Isokponba	Ovia South	Edo	5˚18′ E	6˚15′ N
Acc. 3 (*Ehor*)	Ehor	Uhumwode	Edo	5˚54′ E	6˚34′ N
Acc. 4 (*Uhimwento*)	Uhimwento	Uhumwode	Edo	5˚54′ E	6˚34′ N
Acc. 5(*Irrua*)	Irrua	Esan Central	Edo	6˚80′ E	6˚45′ N
Acc. 6 (*Ewu*)	Ewu	Esan Central	Edo	6˚80′ E	6˚45′ N
Acc. 7 (*Evbukhu*)	Evbukhu	Oredo	Edo	5˚30′E	6˚35′ N
Acc. 8 (*Ekae*)	Ekae	Oredo	Edo	5˚30′ E	6˚35′ N
Acc. 9 (*Uselu*)	Uselu	Egor	Edo	6˚14′ E	7˚15′ N
Acc. 10 (*Idasen*)	Idasen	Owo	Ondo	5˚59′ E	7˚19′ N
Acc. 11 (*Uso*)	Uso	Owo	Ondo	5˚59′E	7˚19′ N
Acc. 12 (*Idoani*)	Idoani	Ose	Ondo	5˚78′ E	6˚95′ N
Acc. 13 (*Ikaro*)	Ikaro	Ose	Ondo	5˚78′ E	6˚95′ N

highest leaf; the number of leaves per plant, obtained by counting the mean number of leaves on each plant within each 9 m^2 plot and leaf area, obtained by measuring the length from the sinus to widest point of individual leaves and calculated as follows:

Y = K (LW), where, Y (leaf area), K = constant (0.628), L (length of leaf) and W (width of leaf) according to (ReyesCastro et al. 2005).

Pseudo-stem circumference of the plants was taken with the aid of a flexible measuring rule.

At harvest, the yield parameters assessed from each 9 m^2 plot included weight of cormel and corm, circumference of cormel and corm, and fresh corm yield (Mt ha^{-1}). Proximate (protein and carbohydrate), mineral (phosphorus, potassium and sodium) and phyto-chemical (tannin and oxalate) status of the cormels from each tannia accession were also carried out.

2.2 Nutritional composition

Protein content was determined by the kjeldahl method as described by Chang (2003). Briefly, 0.5 g aliquots of raw (unprocessed) or boiled (processed) corm of each tannia accession were scooped out and mixed with 10 mL of concentrated H_2SO_4 in a digestion flask. A tablet of selenium catalyst was added prior to heating in a fume cupboard. The resulting digest was then diluted to 100 mL in a volumetric flask prior to analysis which involved mixing 10 mL of the digest with an equal volume of 45 % NAOH solution in a kjeldahl distillation apparatus. The distillate was collected into 10 mL of 4 % boric acid containing 3 drops of indicator (3 methyl red). A total of 50 mL of these distillates were collected and titrated against 0.02 N ethylenediaminetetraacetic acid (EDTA) to a green to deep red end point. A reagent blank was similarly digested, distilled and titrated. The total N_2 was determined and the protein content was calculated using the formula below:

% Protein = % N × 6.25,

where,
% N = $(100 / W \times N \times 14/1000 \times V_t / V_a)$ T B;
where W = Weight of tannia corm scoop (0.5 g),
N = Normality of the titrant (0.02 N H_2SO_4),
V_t = Total digest volume (100 mL),
V_a =Volume of digest analyzed (10 mL),
T = Titre value,
B = Blank titre value.

The carbohydrate contents of the tannia corm of the accessions were calculated using the formula below (James 1995).

% Carbohydrate = 100 - % (protein + fat + fibre + ash + moisture content).

2.3 Mineral composition

Phosphorus in the sample was determined by the vanado-molybdate (yellow) spectrometry method (James 1995). A one millilitre sample extract was dispensed into a test tube. Identical volumes of a standard phosphorus solution or water, were put into other test tubes to serve as standard and blank, respectively. The tube contents were mixed with an equal volume of vanado-molybdate colour reagent. They were left to stand for 15 minutes at room temperature before their absorbance was measured using a Jenway electronic spectrophotometer at wave length 420 nm. Measurements were taken with the blank at zero.

Phosphorus content was given by the formula:

$$P\ (mg / 100\ g) = ((100 / W) \times (A_u / A_s) \times C \times (V_f / V_a)),$$

where,
W = Weight of sample,
A_u = Absorbance of the test sample,
A_s = Absorbance of standard solution,
V_f = Total volume of filtrate,
V_a = Volume of filtrate analysed,
C = Concentration of the standard in mg / mL.

Potassium and sodium were determined by flame photometry method (James 1995). The photometer was set up according to the manufacturer's instruction. One millilitre of prepared potassium and sodium standard solutions were aspirated into the machine and sprayed over the non-luminous butane gas flame. The potassium and sodium emissions (having been appropriately filtered) from different test concentrations were recorded to construct a standard curve. Subsequently, the optical density emissions recorded from each of the samples were compared against those in the curve to extrapolate the quality of potassium and sodium in the sample.

2.4 Phyto-chemical composition

The tannin content of the corm was determined using the Folin Dennis spectro-photometric method (Pearson 1976) in which 2 g of the powdered sample was mixed with 50 mL of distilled water and shaken for 30 minutes. The mixture was filtered and 5 mL of the filtrate measured into a 50 mL volumetric flask and diluted with 3 mL of distilled water. Similarly 5 mL of standard tanuric acid solution and 5 mL of distilled were added separately. 1 ml of Folin-Dennis reagent was added to each of the flasks followed by 2.5 mL of saturated sodium carbonate solution. The content of each flask was made up to mark and incubated for 90 minutes at room temperature. The absorbance of the developed colour was measured at 760 nm wavelength with the reagent blank at zero. The process was replicated in triplicate to obtain the mean. The tannin content was calculated as shown below.

$$\% \text{ tannin} = ((100 / W) \times (A_u / A_s) \times (C / 100) \times (V_f / V_a)) \times D,$$

where,
W = weight of sample analyzed,
A_u = Absorbance of the test sample,
A_s = Absorbance of standard solution,
C = Concentration of standard in mg / mL,
V_f = Total volume of filtrate,
V_a = Volume of filtrate analysed,
D = Dilution factor where applicable.

The level of oxalate in the corms of the thirteen tannia accessions was determined following the titrimetric method of Day and Underwood (1986) in which 150 mL of 15 N H_2SO_4 was added to 5 g of the pulverized sample and the solution was gently stirred intermittently with a magnetic stirrer for 30 minutes and then filtered using Whatman No. 1 filter paper. Twenty five mL of filtrate was collected and titrated against 0.1 N $KMnO_4$ solution until a faint pink colour appeared and persisted for 30 seconds.

2.5 Statistical Procedures

The variables assessed were subjected to analyses of variance using SAS statistical software (SAS Institute 2007) to estimate accession and planting date main effects. Interactions between crop characters were measured with tannia accession and planting date as fixed variables in each year analysis. The differences in means were tested with F-tests (LSD) at $P \leq 0.05$ according to Obi (2002). Pearson correlation coefficients between tannia corm yield and other plant attributes were calculated using the PROC CORR of SAS (SAS Institute 2007) and the significance between them tested by referring to the standard table (Snedecor and Cochran 1980) with n - 2 degrees of freedom, where n is the total number of observations.

Ethical approval: The conducted research is not related to either human or animal use.

3 Results

Analysis of variance in both years (Table 4) indicated that the main effects (planting date and tannia accession) were generally affected all the tested variables (plant height, number of leaves/plant, leaf area and pseudo-stem circumference) in both seasons; the only exceptions being pseudo-stem circumference in 2014, and plant height /leaf area in 2015 that were non-significantly ($P>0.05$) affected by tannia accessions. The interaction between accession and planting date affected all the tested variables except leaf area (2014) and plant height and pseudo-stem circumference (2015). Across the planting date as a main factor; plant height, number of leaves per plant, and pseudo-stem circumference of tannia in both cropping seasons were highest when tannia accessions were planted in May compared with the other planting dates. Plant height ranged from 41.25 to 51.01 cm (2014) and 29.3 to 46.41 cm (2015); accession 10 (*Idasen*) had the highest number of leaves per plant and leaf area in 2014 cropping season. but this trend was not apparent n the 2015 cropping season. In both years, there was significant variation in pseudo-stem circumference with accession 1 (*Ikpoba*), exhibiting the biggest values amongst the different accessions.

3.1 Plant height and pseudo-stem circumference

The interaction between tannia accessions and planting date (Table 5) significantly ($P<0.05$) affected plant height of tannia in 2014. Tannia accessions planted in May were taller compared with same accessions planted in June or July. Accession 3 (*Ehor*) closely followed by Accessions 7 (*Evbukhu*) and 4 (*Uhimwento*) planted in May were the tallest tannia accessions among the thirteen evaluated in the study while accession 13 (*Ikaro*) planted in July gave the shortest plants. The same trend was recorded in pseudo-stem circumference with accession 3 (*Ehor*) under May planting exhibiting the largest pseudo-stem circumference compared with the other treatments, especially accession 9 (*Uselu*) under July planting date.

Table 4: Genotype and planting date effect on vegetative growth of tannia at 15 WAP[1] in 2014 and 2015 cropping seasons

	2014				2015			
Treatment	**Plant height (cm)**	**Number of leaves/ plant**	**Leaf area (cm²)**	**pseudo-stem circum-ference (cm)**	**Plant height (cm)**	**Number of leaves/ plant**	**Leaf area (cm²)**	**pseudo-stem circum-ference (cm)**
Planting date (PD)								
May	55.21	10.24	870	18.78	46.93	5.500	809	19.18
June	42.39	4.67	354	11.82	43.28	5.135	616	15.86
July	36.65	4.59	303	10.14	31.13	4.081	344	10.97
Mean	44.75	6.50	509	13.58	40.45	4.905	589	15.34
$LSD_{(0.05)}$	3.199	0.643	119.6	2.978	5.560	1.1028	278.9	4.713
Tannia Accessions (TA)								
Acc. 1 (*Ikpoba*)	42.26	5.74	459	12.86	**48.84**	5.806	684	19.37
Acc. 2 (*Isokponba*)	46.18	4.85	539	13.75	41.25	4.806	782	17.32
Acc. 3 (*Ehor*)	51.01	7.67	434	14.62	46.41	5.472	656	17.63
Acc. 4 (*Uhimwento*)	47.76	6.76	401	13.40	41.34	5.028	555	15.06
Acc. 5(*Irrua*)	44.98	5.96	507	12.52	44.78	5.278	701	16.96
Acc. 6 (*Ewu*)	43.42	4.72	412	12.13	39.80	5.583	525	15.66
Acc. 7 (*Evbukhu*)	46.31	4.43	508	14.17	43.71	5.833	570	17.23
Acc. 8 (*Ekae*)	44.46	6.85	543	13.02	43.10	5.250	603	15.27
Acc. 9 (*Uselu*)	43.55	5.56	443	13.13	41.21	5.000	589	14.76
Acc. 10 (*Idasen*)	41.25	7.84	623	14.12	29.30	4.222	529	13.51
Acc. 11 (*Uso*)	42.42	8.20	529	13.79	32.38	3.583	411	10.82
Acc. 12 (*Idoanî*)	46.90	9.50	562	14.46	33.45	3.686	418	11.1
Acc. 13 (*Ikaro*)	41.89	6.41	657	14.57	40.25	4.222	636	14.69
Mean								
$LSD_{(0.05)}$	6.495	2.245	157.5	ns	ns	0.9494	ns	4.379
PD x TA	11.040	3.762	Ns	4.713	ns	1.7783	436.4	ns
ANOVA								
Main effects								
PD	***	***	***	**	***	*	*	*
TA	*	***	*	ns	ns	***	ns	**
Interaction effects								
PD x TA	*	**	Ns	*	ns	*	*	ns

Data analyzed with Least Squares Means and means separated with LSD.

Ns, non-significant; *, significant at $P < 0.05$; **, significant at $P < 0.01$; ***, significant at $P < 0.001$. WAP[1] = Weeks after planting.

3.2 Number of leaves and leaf area

The interaction between tannia accession and planting date (Table 6) significantly affected the number of leaves per plant in both cropping seasons but leaf area in 2015 only. The number of leaves per tannia plant ranged from 2.83 to 7.00 (2014) and 2.56 to 16.44 (2015) while leaf area ranged from 170 to 1053 per cm² in 2015 cropping season. Accession 1 (*Ikpoba*) planted in June had the highest number of leaves per plant in 2014 while accession 3 (*Ehor*) had the highest number of leaves per plant under May planting in 2015. However, accession 3 (*Ehor*) had a small leaf area(smaller by 32.4% than that for accession 1 (*Ikpoba*), which exhibited the highest leaf area when planted in June 2015. Furthermore leaf area, of the

Table 5: Effect of interaction between planting date and tannia accessions on plant height and pseudo-stem circumference of corm in 2014 cropping season

Tannia accessions	Plant height (cm)				Pseudo-stem circumference (cm)			
	Planting date							
	×	May	June	July	×	May	June	July
Acc. 1 (*Ikpoba*)		57.5	35.13	34.15		19.80	8.94	9.83
Acc. 2 (*Isokponba*)		54.78	42.45	41.31		17.49	12.93	10.84
Acc. 3 (*Ehor*)		63.81	44.61	44.61		21.79	10.11	11.96
Acc. 4 (*Uhimwento*)		58.76	44.19	40.35		17.89	12.37	9.94
Acc. 5(*Irrua*)		56.94	41.09	36.90		19.60	10.12	7.82
Acc. 6 (*Ewu*)		54.30	40.68	35.28		17.70	9.34	9.33
Acc. 7 (*Evbukhu*)		58.99	41.97	37.96		19.99	11.30	11.22
Acc. 8 (*Ekae*)		51.08	44.45	37.85		15.90	10.93	12.23
Acc. 9 (*Uselu*)		55.25	39.04	36.37		18.97	11.87	8.54
Acc. 10 (*Idasen*)		50.27	39.97	33.52		19.02	12.26	11.08
Acc. 11 (*Uso*)		46.46	46.04	34.75		15.01	14.99	11.36
Acc. 12 (*Idoani*)		55.61	45.98	39.11		20.78	12.88	9.71
Acc. 13 (*Ikaro*)		53.94	45.50	26.22		20.17	15.61	7.94
		$LSD_{(0.05)} = 11.04$				$LSD_{(0.05)} = 4.713$		

Data in interaction analyzed with Least Squares Means and means separated with LSD. Two-way ANOVA

Table 6: Effect of interaction between planting date and tannia accessions on number of leaves/plant in 2014 and 2015, and on leaf area in 2015 cropping seasons

Tannia accessions	Number of leaves/plant								Leaf area (cm²)			
	2014				2015				2015			
	Planting date											
	x	May	June	July	x	May	June	July	x	May	June	July
Acc. 1 (*Ikpoba*)		6.00	7.00	4.42		9.56	3.34	4.33		773	1053	226
Acc. 2 (*Isokponba*)		5.42	5.58	3.42		7.33	2.67	4.56		1003	901	444
Acc. 3 (*Ehor*)		6.00	6.25	4.17		16.44	3.33	3.22		712	924	333
Acc. 4 (*Uhimwento*)		5.25	5.50	4.33		12.11	3.11	5.04		585	657	422
Acc. 5(*Irrua*)		4.83	5.67	5.33		10.22	4.11	3.55		710	843	552
Acc. 6 (*Ewu*)		6.75	4.42	5.58		7.89	3.05	3.22		900	316	360
Acc. 7 (*Evbukhu*)		5.42	6.25	5.83		7.00	2.61	3.67		515	670	526
Acc. 8 (*Ekae*)		5.08	5.83	4.83		12.00	2.56	6.00		974	398	438
Acc. 9 (*Uselu*)		6.33	5.50	3.17		10.22	2.78	3.67		881	682	204
Acc. 10 (*Idasen*)		5.58	3.83	3.25		8.89	8.44	6.18		1001	409	178
Acc. 11 (*Uso*)		4.42	3.50	2.83		9.44	8.55	6.61		584	395	255
Acc. 12 (*Idoani*)		5.00	3.08	2.97		11.34	10.56	6.61		822	263	170
Acc. 13 (*Ikaro*)		5.417	4.333	2.917		10.67	5.56	3.00		1054	494	360
		$LSD_{(0.05)} = 1.7783$				$LSD_{(0.05)} = 3.762$				$LSD_{(0.05)} = 436.4$		

Data in interaction analyzed with Least Squares Means and means separated with LSD. Two-way ANOVA.

Table 7: Effect of interaction between planting date and tannia accessions on cormel weight/plant and corm weight/plant in 2014 and 2015 cropping seasons

Tannia accessions	Cormel weight/plant (g)								Corm weight/plant (g)							
	2014				2015				2014				2015			
	Planting date															
	x	May	June	July	x	May	June	July	x	May	June	July	x	May	June	July
Acc. 1 (*Ikpoba*)		78.8	20.2	21.1		71.7	74.7	24.6		356	291	273		325.6	347.6	178.7
Acc. 2 (*Isokponba*)		71.7	59.5	24.4		128.9	81.8	55.8		450	484	387		271.5	230	173.6
Acc. 3 (*Ehor*)		69.8	39.6	34.2		88.8	72	52.3		422	359	234		254.7	321.7	202.7
Acc. 4 (*Uhimwento*)		43.3	31.2	23.6		38.8	37.4	65.5		533	345	293		154.6	229.6	212.7
Acc. 5(*Irrua*)		74	21.1	24.8		73.6	96.8	29.8		533	244	244		294.4	208.1	200.7
Acc. 6 (*Ewu*)		85.2	26	20.6		77.1	37.2	35.4		706	133	106		283.9	162.6	203.8
Acc. 7 (*Evbukhu*)		64	36.9	22.4		53.3	41.8	35.7		572	254	234		359.8	201.4	164.5
Acc. 8 (*Ekae*)		86.1	42.8	43.2		90.4	32.7	22		567	263	260		170	140.3	115.2
Acc. 9 (*Uselu*)		60.7	28.6	31		63.8	73.6	33.9		544	295	227		341.1	197.6	114.6
Acc. 10 (*Idasen*)		110.2	55.2	46.1		129.3	67.4	22.2		550	185	204		268.4	158	51.5
Acc. 11 (*Uso*)		107	53.8	18.5		78.6	12.9	18.9		400	251	143		232.7	87.3	56.6
Acc. 12 (*Idoani*)		156.8	32.9	29.5		117.5	24.3	19.8		**756**	175	125		233.2	95.9	74.9
Acc. 13 (*Ikaro*)		119.6	62.5	15.3		126.7	43.9	35.2		683	274	250		270.8	135	144.1

$LSD_{(0.05)}$, Planting date (PD) = 25.30** = 33.59* = 93.20*** = ns
$LSD_{(0.05)}$, Tannia accessions (TA) = 20.56*** =25.63*** = ns = 68.96***
$LSD_{(0.05)}$, Interaction, PD x TA = 39.06** =49.53** = 219.60* = ns

Data in interaction analyzed with Least Squares Means and means separated with LSD. Two-way ANOVA.

accessions planted in July were low compared with May and June planting dates.

3.3 Corm and cormel weight

Analysis of variance (Table 7) indicated that tannia accession and planting date main effects as well as their interaction effect exhibited various degrees of significance on cormel weight per plant in 2014 cropping season while the interaction effect indicated that accession 12 (*Idoani*) planted in May had the heaviest cormels (156.80 g) closely followed by accessions 13 and 10 (*Ikaro* and *Idasen*) that were also planted in the same month. The trend indicated that in both years, a May planting date increased cormel weight per plant compared to the other planting dates (June and July). Tannia accession by planting date interaction was significant ($P^{<}0.05$) in 2014 but not in 2015. Accession 12 (*Idoani*) planted in May 2014 had the heaviest corm per plant(heavier by 86% relative to accession 6 (*Ewu*)) the lightest corm weight per plant following a July, 2014 planting date. With the exception of tannia accession, planting date and interaction between accession and planting date were non-significant (P>0.05) in 2015. Among the accessions, accession 7 (*Evbukhu*) exhibited the highest corm weight per plant in 2015 closely followed by accessions 1 (*Ikpoba*) and 9 (*Uselu*) .

3.4 Corm yield

The effect of planting date and tannia accession on corm yield (Table 8) indicated that planting date significantly affected corm yield in both years in contrast to tannia accession and the interaction effects that affected yield only in the 2015 cropping season. Tannia accessions planted in the month of May gave greater corm yield compared to other planting dates studied, with accession 13 (*Ikaro*) followed by accessions 12 (*Idoani*), 3 (*Ehor*) 10 (*Idasen*) and 7 (*Evbukhu*) in decreasing order in 2014 and accession 6 (*Ewu*) followed by accessions 10 (*Idasen*), 12 (*Idoani*), 1 (*Ikpoba*) and 2 (*Isokponba*) in decreasing order in the (2015) cropping season exhibiting the highest corm yield. The interaction between accession and planting date indicated that accession 11 (*Uso*) planted in July had the lowest corm yield, (lower by 68 % compared with

Table 8: Effect of interaction between planting date and tannia accessions on yield (Mt·ha) of tannia accessions in 2014 and 2015 cropping seasons

Tannia accessions	2014				2015			
	Planting date				Planting date			
	x	May	June	July	x	May	June	July
Acc. 1 (*Ikpoba*)		7.75	2.04	2.16		7.54	6.67	2.96
Acc. 2 (*Isokponba*)		7.78	5.14	3.12		7.41	4.56	3.22
Acc. 3 (*Ehor*)		11.61	2.64	2.63		6.65	6.74	3.37
Acc. 4 (*Uhimwento*)		5.52	2.84	2.54		5.35	4.22	4.78
Acc. 5(*Irrua*)		8.67	2.62	2.27		6.39	5.00	3.96
Acc. 6 (*Ewu*)		9.94	1.49	1.50		8.50	3.15	4.11
Acc. 7 (*Evbukhu*)		10.33	2.43	2.19		5.37	4.83	3.37
Acc. 8 (*Ekae*)		8.07	2.67	3.15		7.11	3.96	3.17
Acc. 9 (*Uselu*)		8.05	2.42	2.28		6.91	4.57	3.11
Acc. 10 (*Idasen*)		11.44	3.68	3.02		8.14	3.87	2.78
Acc. 11 (*Uso*)		8.74	2.74	2.14		4.87	2.83	2.72
Acc. 12 (*Idoani*)		12.15	2.95	1.89		7.85	2.83	2.80
Acc. 13 (*Ikaro*)		13.48	4.09	2.66		6.89	3.02	4.00
$LSD_{(0.05)}$, Planting date (PD)	= 2.291**				= 1.143**			
$LSD_{(0.05)}$, Tannia accessions (TA)	= ns				= 1.084*			
$LSD_{(0.05)}$, Interaction, PD x TA	= ns				= 1.990***			

accession 6 (*Ewu*) planted in May 2015 which had the highest corm yield.

3.5 Inter-relationships between growth and yield characters

The correlation matrix between yield and other attributes (Table 9) indicated that with the exception of corm weight and cormel weight in 2014, corm yield exhibited a highly significant ($P \leq 0.001$) and positive association with all the other measured variables (plant height, pseudo-stem circumference, leaf area, number of leaves/ plant, corm weight, corm circumference, cormel weight, cormel circumference and corm yield). The correlation coefficients for the same variables ranged from 0.59 to 0.82 and 0.27 to 0.79 in 2014 and 2015 cropping seasons, respectively. The trend was similar amongst all the other variables with the exception of the relationship between corm yield and these variables (corm circumference, cormel weight and cormel circumference), as well as cormel weight and cormel circumference in 2014 and corm circumference and corm weight in 2015.

3.6 Nutritional characteristics of corm accessions

The nutritional and anti-nutritional status of the accessions (Table 10) indicated significant difference ($p^{<}0.05$) in proximate, mineral and phyto-chemical compositions of unprocessed and processed tannia accessions with unprocessed tannia corms exhibiting greater values in all the attributes analysed relative to the processed accessions. Among the unprocessed accessions, accession 1 (*Ikpoba*) had the highest amount of crude protein and potassium and tannin compared with the other accessions. Tannia accessions 6 (*Ewu*), 7 (*Evbukhu*) and 9 (*Uselu*) showed carbohydrate amounts that were higher than 38 mg 100 g^{1} raw corm while the lowest amount of phosphorus and sodium were seen in accession 5 (*Irrua*). The oxalate content ranged from 2.35 to 4.55 mg 100 g^{1} raw corm with accession 4 (*Uhimwento*) exhibiting highest values.

The crude protein content in the processed tannia accessions, ranged from 3.46 to 4.89 mg 100 g^{1} processed corm, with accession 12 (*Idoani*) producing the highest amount of crude protein compared with the other accessions. Among the processed tannia corms, accession 7 (*Evbukhu*) had the highest carbohydrate content, higher

Table 9: Correlation coefficients between different growth and yield attributes of tannia accessions (above diagonal) in 2014 and (below diagonal) 2015 cropping seasons

Year	Plant characteristics	Plant height (cm)	Pseudo-stem circum-ference (cm)	Leaf area (cm²)	No. of leaves /plant	Corm weight (g)	Corm circum-ference (cm)	Cormel weight (g)	Cormel circum-ference (cm)	Corm Yield (Mt·ha)	Year
2015	Plant height (cm)	**1.00**	0.85**	0.75**	0.61**	0.59**	0.67**	0.51**	0.49**	0.65**	**2014**
	Pseudo-stem circumference (cm)	0.88**	**1.00**	0.87**	0.67**	0.61**	0.71**	0.64**	0.57**	0.78**	
	Leaf area (cm^{-2})	0.84**	0.91**	**1.00**	0.68**	0.64**	0.72**	0.69**	0.59**	0.82**	
	No. of leaves/plant	0.83**	0.89**	0.75**	**1.00**	0.37**	0.52**	0.46**	0.41**	0.59**	
	Corm weight (g)	0.63**	0.74**	0.71**	0.65**	**1.00**	0.04ns	-0.06ns	-0.04ns	0.01ns	
	Corm circumference (cm)	0.69**	0.77**	0.72**	0.72**	0.17ns	**1.00**	0.63**	0.45**	0.79**	
	Cormel weight (g)	0.53**	0.65**	0.73**	0.48**	0.29**	0.60**	**1.00**	-0.05ns	-0.01ns	
	Cormel circumference (cm)	0.49**	0.57**	0.62**	0.49**	0.27**	0.55**	0.54**	**1.00**	0.85**	
	Corm Yield (Mt.ha)	0.65**	0.78**	0.79**	0.64**	0.27**	0.74**	0.71**	0.74**	**1.00**	

**$P \leq 0.01$, ns = not significant (2-tailed).

by 23% relative to accession 8 (*Ekae*) which had the smallest amount of carbohydrate. Among the mineral attributes evaluated, potassium was the most abundant ranging from 138.62 to 154.62 mg 100 g^{1} of processed corm with accession 10 (*Idasen*) having the highest but lowest sodium content. Phosphorus content ranged from 21.94 to 32.84 mg 100 $g^{1,}$ with accession 1 (*Ikpoba*) having the highest amount compared to the others. Results from the phyto-chemical analysis of the tannia accessions indicated that accession 10 (*Idasen*) had the least tannin (0.06 mg 100 g^{1}) relative to others, however, it exhibited the highest oxalate content (0.45 mg 100 g^{1}), which was higher by 87% relative to accession 11 (*Uso*) that also had the lowest oxalate content.

4 Discussion

Previous studies by Lebot et al. (2006) and Omenyo et al. (2013) showed that yield differences due to planting date can be ascribed to variation in weather conditions. This study confirms that rainfall was more abundant in the months of May and June than in July for both 2014 and 2015 cropping season.

Also, plants sown earlier had more time for growth under suitable moisture and temperature that tannia required for increased corm yield. Similar studies on two potato cultivars (Kawakami et al. 2006) showed that delaying planting date reduced tuber yield mainly because of a shortened growing period. Furthermore, Balali et al. (2008) who had compared three three planting dates (November, December and February) on mini-tuber production of *Marfona* potato (*Solanum tuberosum cv. Marforna*) in South Africa, reported that November was optimal and delay reduced mini-tuber yield significantly.

Although plant height was higher after a May planting date for both years, there wasn't a very wide difference compared to June planting. Deblonde and Ledent (2001) reported that the taller potato plants observed with May and June planting dates when rainfall was high confirmed that plant height was sensitive to moderate drought conditions and found that plants exposed to low water stress were tallest.

The increased corm and cormel weights aftrer May planting may be attributed to the early increased leaf growth as a result of higher rainfall, temperature and relative humidity during the period. Higher significant leaf area accrued, implies more area of photosynthetic activity hence increased corm formation. In 2014, the leaf area after May planting was almost doubled that of June and July planting dates. These results are in agreement with previous findings by Bussell and Bonin (1998) from their studies on taro (*Colocasia esculenta*) in New Zealand; (Mcfarland and Barko 1990) on cocoyam in India, and Rinaldi (2003) on sugar beet (*Beta vulgaris*) in Italy who suggested that increased leaf area due to earlier planting may be associated with higher and amount and longer duration of rainfall, warmer air temperature and higher relative humidity experienced during the juvenile growth period of the crops, which invariably influenced corm yields. Furthermore, the present findings indicate that corm and cormel weight over 2 consecutive years decreased delayed planting. Similarly, studies by Lu et al. (2001) on taro, Khan et al. (2003) on some potato

Table 10: Proximate, mineral and phyto-chemical analysis of unprocessed (raw) and processed (boiled) tannia accession corms

Tannia accession	Proximates		Minerals			Phyto-chemicals	
	Crude Protein	Carbohy-drate	Phosphorus	Potassium	Sodium	Tannia	Oxalate
				Unprocessed (Raw)			
Acc. 1 (*Ikpoba*)	5.74	36.81	38.73	145.84	13.57	0.84	3.77
Acc. 2 (*Isokponba*)	4.93	34.84	36.68	165.56	11.57	0.58	4.47
Acc. 3 (*Ehor*)	3.85	32.96	37.87	152.71	18.29	0.81	3.46
Acc. 4 (*Uhimwento*)	4.14	36.89	36.63	149.21	14.79	0.73	4.55
Acc. 5(*Irrua*)	4.87	34.99	35.80	180.39	10.69	0.58	3.89
Acc. 6 (*Ewu*)	3.73	38.04	41.72	174.69	12.78	0.69	3.15
Acc. 7 (*Evbukhu*)	4.17	38.33	40.79	158.63	11.88	0.84	2.86
Acc. 8 (*Ekae*)	3.63	37.11	41.71	172.71	11.37	0.65	2.90
Acc. 9 (*Uselu*)	4.68	38.74	45.80	170.49	12.80	0.71	3.62
Acc. 10 (*Idasen*)	4.65	35.49	41.85	171.77	13.75	0.57	2.35
Acc. 11 (*Uso*)	3.93	36.40	48.25	168.77	12.77	0.35	3.35
Acc. 12 (*Idoani*)	4.75	37.13	43.82	165.87	13.67	0.37	2.77
Acc. 13 (*Ikaro*)	3.79	37.97	47.59	167.81	14.72	0.30	2.81
$LSD_{(0.05)}$	0.0491	0.1456	0.2452	0.3016	0.151	0.0223	0.0568
				Processed (Boiled)			
Acc. 1 (*Ikpoba*)	4.26	25.93	32.84	140.73	10.75	0.14	0.33
Acc. 2 (*Isokponba*)	4.31	25.77	30.26	143.85	10.75	0.07	0.43
Acc. 3 (*Ehor*)	3.46	22.59	31.31	138.77	11.35	0.11	0.28
Acc. 4 (*Uhimwento*)	3.87	25.68	29.62	141.31	9.53	0.09	0.37
Acc. 5(*Irrua*)	4.14	22.11	28.43	153.28	8.64	0.08	0.28
Acc. 6 (*Ewu*)	3.49	26.08	29.77	149.72	9.31	0.09	0.22
Acc. 7 (*Evbukhu*)	3.86	28.69	31.45	138.62	8.76	0.12	0.19
Acc. 8 (*Ekae*)	3.47	22.07	30.54	145.23	8.58	0.09	0.15
Acc. 9 (*Uselu*)	4.33	26.17	31.62	153.62	8.76	0.08	0.20
Acc. 10 (*Idasen*)	4.17	24.53	29.80	154.62	7.84	0.06	0.45
Acc. 11 (*Uso*)	3.48	26.36	34.18	152.31	8.47	0.07	0.06
Acc. 12 (*Idoani*)	4.89	25.62	25.82	149.30	9.17	0.07	0.39
Acc. 13 (*Ikaro*)	3.82	25.96	21.94	153.64	9.42	0.07	0.13
$LSD_{(0.05)}$	0.0419	0.3873	0.0348	0.0366	0.04142	0.0056	0.0151

(*Solanum tuberosum*) cultivars and Scheffer et al. (2005) on Japanese taro indicated that there was a strong and positive association between weight of corms and tubers on water availability and temperature, which was directly related to planting date. The variation in yield and yield attributes seen among accessions in the present work corroborates the findings of Ogbonna et al. (2015) in their studies on Nigerian taro.

Looking at the inter-relationships between characters in the present work indicated that most exhibited highly significant and positive correlations in both 2014 and 2015. Similarly, Pandey et al. (1996), Fantaw et al. (2014) as well as Paul and Bari (2015) in studies on cocoyam reported a positive and highly significant correlation between growth characters.. Also, the strong correlation between these traits suggests that they could be used as selection indices for yield improvement. Further observations by Pandey et al. (2009) and Paul and Bari (2011) on cocoyam, which are corroborated in the present study showed that selection for an increase in one trait will most likely lead to an increase in other traits as significant and positive association between two characters under consideration indicates that these characters can be improved simultaneously in a selection programme.

Owing to the emphasis placed on the nutritional value of tannia, the present findings show that there were variations between accessions on their proximate, mineral and phyto-chemical analyses. Previous studies by Agueguia (2000) showed that the presence of minuscule bundles of crystals of calcium oxalate in tannia corms creates an irritating effect when consumed. Hence it is imperative that corms and cormels must be processed by boiling, roasting or baking before consumption. Comparing results of the accessions analysed in the unprocessed and processed states, indicates that processing can uniformally decrease proximate, mineral and phyto-chemical . These findings corroborate previous crop yield analyses by FAO (2013) in which they reported that cooking may reduce the nutritional value of crops as a result of losses and changes in the major nutrients during cooking. This implies that there is need to develop tannia processing technologies that can reduce anti-nutritional properties while retaining nutritional qualities. Also, in contrast to the low nutritional and anti-nutritional values obtained by Sefa-Dedeh and Agyir-Sackey (2004) in their analyses on the chemical composition of *Xanthosoma sagittifolium* and *Colocasia esculenta* cormels; the proximate, mineral and phyto-chemical values obtained from this study were relatively higher. Furthermore, findings by Muniat et al. (2009) in their analytical works on cooked and uncooked accessions of *Colocasia esculenta* exhibited higher nutritional values contrary to the results obtained in this study.

The strong variations observed in the mineral contents of the accessions is in agreement with work by Fennema (1988) and Quero-Garcia et al. (2004) in which they submitted that such variations may be due to the difference in the genetic potential of each accession to obtain nutrients from the soil. Other factors might include the concentration of minerals in the soil and the age of the plant. This indicated uniformity in soil and age of tannia plants in the experiment. The most abundant mineral element in the corms was potassium, which was in consonance with FAO (1990) analysis of nutrients in cocoyam. The ratio of sodium (Na) to potassium (K) was less than unity, which implied that consumption of processed tannia corms may contribute to reduction in high blood pressure because Na:K was less than one as recommended by Food and nutrition board, Institute of Medicine (FND 2002). This study indicated that corm processing regardless of accession type, reduced concentrations of phyto-chemicals such as oxalate.. The results agreed with Albihn and Savage (2001), Owusu-Darko et al. (2014) as well as Boakye et al. (2017) who reported from their various studies that maximal reduction in oxalate content in cocoyam occurred after processing, which resulted in considerable cell rupture thereby facilitating the leakage of soluble oxalate into the processing solution. Furthermore, Albihn and Savage (2001) submitted that processing oca tubers (*Oxalis tuberosa*) by boiling considerably reduced the oxalate concentration in the whole tuber.

5 Conclusions

The planting date significantly affected growth, yield and yield components of tannia. Hence, May planting seems to be best in the farming systems present in the hot, humid tropical lowlands of south-east Nigeria. The interaction between planting date and tannia accession was significant for some of the plant attributes studied, an indication that the accessions exhibited differential responses to different planting date in both years in the agro-ecological region.

In both years, the highest weighted yields were recorded after a May planting date while accessions 13 (*Ikaro*), closely followed by 12 (*Idoani*), were superior in yield characterisctics. The correlation indicated that all the attributes (plant height, pseudo-stem circumference, leaf area, number of leaves per plant, corm weight, corm circumference, cormel weight and cormel circumference exhibited good selection characteristics for developing high yielding varieties of the crop. Also, crude protein, carbohydrate, phosphorus, potassium and sodium of tannia showed that processed corms exhibited low nutritional qualities and very low tannin and oxalate relative to the unprocessed corms, hence farmers are encouraged to cook the corms prior to eating. Further work is also warranted to develop processing technologies that will maximize the nutritional value of tannia and at the same time minimize any anti-nutritional effects.

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References

Agueguia A., Fatokun C.A., Haln S.k., Protein analysis of ten cocoyam, *Xanthosoma sagittifolium* (L.). Schott and *Colocasia esculenta* (L.) Schott genotypes. Root crops for food security in Africa. Proc. of the 5th Triennial Symp., Kampala, Uganda, 1992, p. 348

Agueguia A., Importance and uses of cocoyam in Cameroonian diets. In: Nakatani, M., Komaki, K. (Eds.), Proceedings of the 12th International Soc. for Tropical Root Crops (ISTRC) Symposium on Potential of Root Crops for Food and Industrial Resources, Tsukuba, Japan, 2000, p. 550–560

Albihn P.B.E., Savage G.P., The effect of cooking on the location and concentration of oxalate in three cultivars of New Zealand grown oca (*Oxalis tuberosa* Mol.). J. Sci. Food Agric., 2001, 81, 1027-1033

Balali G.R., Hadi M.R., Yavari P., Bidram H., Naderi A.G., Eslami A., Effect of pot size, planting date and genotype on minituber production of *Marfona* potato cultivar. African J. Biotechnol., 2008, 7(9), 1265-1270

Boakye A.A., Gudjónstdoltir M., Skytte J.L., Chronakis L.S., Wireko-Manu F.D., Oduro I., Characteristics of *Xanthosoma sigittifolium* roots during cooking, using physiochemical analysis, uniaxial compression, multispectral imaging and low field NMR spectroscopy. J. Food Sci. and Technol., 2017, 54(9), 2670-2683, doi:10.1007/S13197-017-2704-7

Bussell W.T., Bonin M.J., Effects of high and low watering levels on growth and development of taro. New Zealand J. Crop and Hort. Sci., 1998, 26(4), 313-317, doi: 10.1080/01140671.1998.9514069

Chang S.K.C., Protein Analysis. In: Food Analysis. (Ed.) Nielsen, S.S. Kluwer Academic Publishers, New York. 2003

Chukwu G.O., Nwosu K.I., Cocoyam rebirth, the renaissance of a giant crop. National Root Crops Research Institute, Umudike. Annual Report, 2008, p. 34

Day J.R.A., Underwood A.L., Quantitative Analysis 5th Ed., Prentice-Hall publications, London. 1986, p. 701

Deblonde P.M.K., Ledent J.F., Effects of moderate drought conditions on green leaf number, stem height, leaf length and tuber yield of potato cultivar. European J. Agron., 2001, 14, 31-41

Fantaw S., Amsalu N., Tewodros M., Correlation and path coefficient studies of yield and yield related characters in Tannia (*Xanthosoma sagittifolium* (L.) Schott) genotypes. Intern. J. Plt. Breed. and Genet., 2014, 8, 241-254

Fennema, O., Effects of freeze preservation on nutrients. In: Nutritional Evaluation of Food Processing (Ed. by E. Karmas and R.S. Harris). Van Nostrand Reinhold, New York, USA. 1988, p. 269-317

FND (Food and Nutrition Board, Institute of Medicine. National Academy of Sciences). Dietary reference Intake for Energy, Carbohydrate, Fibre, Fat, Fatty Acids, Cholesterol, protein and Amino acid (micronutrients). 2002, ww.nap.edu

FAO (Food and Agricultural Organization). Roots, tubers, plantain and bananas in human nutrition. Food and Agriculture Organization of the United Nations, Rome. Food and Nutrition Series, 1990, 24, 182 p.

FAO (Food and Agricultural Organization). Food and Agricultural Organization of the United Nations, Rome. Production statistics. 2013, 94 p.

Green B.O., Taxonomic and nutritional analysis of certain tuber crops in the Niger Delta of Nigeria. African J. Environ. Studies, 2003, 4, 120-122

James C.S., Analytical Chemistry of Foods. 1st Edn., Chapman and Hall, New York. 1995, 178 p.

Jianchu X., Yongping Y., Yingdong P., Ayad W.G., Eyzagnire P., Genetic diversity in taro (*Colocasia esculenta* Schott, Araceae) in China: An ethnobotanical and genetic approach. Econ. Bot., 2001, 55, 14-31

Kawakami J., Iwama K., Jitsuyama Y., Soil water stress and the growth and yield of potato plants grown from microtubers and conventional seed tubers. Field Crops Res., 2006, 95(1), 89-96

Khan I.A., Deadman M.L., Al-Nabhani H.S. and Al-Habsi K.A., Interactions between temperature and yield components in exotic potato cultivars grown in Oman. Acta Hort., 2003, 619, 353-359

Lal R., Soil degradation as a reason for inadequate human nutrition. Food Security, 2009, 1, 45–57

Lebot V., Ivancic A., Quero-García J., Comparative performance of local and introduced cultivars of taro (*Colocasia esculenta* (L.) Schott) in Vanuatu. In: Proceedings of the 14th Symposium of the International Soc. for Tropical Root Crops. Thiruvananthapuram, Kerala, India, 20–26 November, 2006 (ISTRC)

Lebot V., The tropical root and tuber crops: cassava, sweet potato, yams and aroids. Crop Prod. Sci. Hort., Series 2009, 17, CABI, UK, 432 p.

Lu H.Y., Lu CT., Chan L.F., Wei M.L., Seasonal variation in linear increase of taro harvest index explains by growing degree days. Agron. J., 2001, 93, 1136-1141

Mbouobda H.D., Boudjeko T., Djocgoue P.F., Tsafack T.J.J., Omokolo D.N., Morphological characterization and agronomical evaluation of cocoyam (*Xanthosoma sagittifolium* (L.) Schott) germplasm in Cameroon. J. Biological Sci., 2007, 7, 27-33

Mcfarland D.G., Barko J.W., Temperature and daylenght effects on growth and tuber formation in Hydrilla. J. Aquat. Plt. Manage., 1990, 28, 15–19

Muniat N.L., Patrick O.A., Anthony J.A., Effect of cooking on the mineral and anti-nutrient contents of the leaves of seven accessions of *Colocasia esculenta* (L.) Schott growing in South Africa. J. Food Agric. & Environ., 2009, 7(3 and 4), 359-363

Mulualem T., WeldeMichael G., Study on genotypic variability estimates and interrelation-ship of agronomic traits for selection of taro (*Colocasia esculenta* (L.) Schott) in Ethiopia. Sky J. Agric. Res., 2013, 2(11), 154–157

NEST (Nigeria Environmental Study Action /Team). Nigeria's Threatened Environment: A National Profile. Nigeria: NEST 1991

Obi I.U., Statistical methods of detecting differences between treatment means and research methodology. issues in laboratory and field experiments. Nsukka: AP Express Publishers VED. 2002, 117 p.

Ogbonna P.E., Orji K.O., Nweze N.J., Opata P.I., Effect of planting space on plant population at harvest and tuber yield in taro (*Colocasia esculenta* L). African J. Agric. Res., 2015, 10(5), 308-316

Omenyo E.L., Quain M.D., Moses E., Asumadu H., Acheampong P.P., Ankomah A.A., Farmer Participatory Development of Cocoyam (*Xanthosoma sagittifolium*, Linn, Schott) Cultivars. International J. Sci. Innovation and Discoveries Res., 2013, 3(1), 74-85

Onokpise O.U., Wutoh J.G., Ndzana X., Tambong J.T., Meboka M.M., Sama A.E., Nyochembeng L., Agueguia A., Nzietchueng S., Wilson J.G., Bursn M., Evaluation of macabo cocoyam germplasm in Cameroon. In: Janick, J., (ed.) Perspectives on News Crops and New Uses. ASHA Press, Alexandra, 1999, p. 394–396

Onwueme I., Taro cultivation in Asia and Pacific: RAP Publication 1999/16. Bangokok, Thailand: Food and Agriculture Organisation of the United Nations regional office for Asia and the Pacific. 1999

Owusu-Darko P.G., Paterson A., Omenyo E.L., Cocoyam (corms and cormels) – an underexploited food and feed resource. J. Agric.Chem.and Environ.,.2014, 03(01), 22-29, doi:10.4236/jacen,2014.31004

Pandey G., Dhobal V.K., Sapra R.L., Genetic variability, correlation and path analysis in Taro. (*Colocasia esculenta*). J. Hill. Res., 1996, 9(2), 299-302

Pandey V.S., Ojha M., Singh P., Genetic variability and correlation studies in arvi (*Colocasia esculenta* L. var. *Antiquarum*). Vegetable Sci., 2009, 36, 431-434

Paul K.K., Bari M.A., Studies on direct and indirect effects of different plant characters on yield of Taro (*Colocasia esculenta* L. Schott) Var. *Antiquarum.* Agriculturists, 2011, 9, 89-98

Paul K.K., Bari M.A., Correlation and path coefficient studies of Cocoyam (*Xanthosoma sagittifolium* L.) Bangladesh J. Sci. Ind. Res., 2015, 50(1), 47-52

Pearson D., The Chemical Analysis of Foods. 7th Edn., Churchill Livingstone, London, 1976, p. 7-11, ISBN: 0443014116

Perez P.J., Cocoyam: In Quality declared planting material protocols and standards for vegetatively propagated crops, FAO plant production and protection, Rome Italy. 2010, 195, 41-48

Quero-Garcia J., Noyer J., Perrier X., Marchand J.L., Lebot V., A germplasm stratification of taro (*Colocasia esculenta*) based on agro-morphological descriptors, validation by AFLP markers. Euphytica, 2004, 137, 387-395

Ramesh V., John K.S., Ravindran C.S., Edison S., Agro-techniques and plant nutrition of tannia (*Xanthosoma* spp.): An overview. J. Root Crops, 2007, 33(1), 1-11

ReyesCastro G., Nyman M., Rönnberg-Wästljung A.C., Agronomic performance of three cocoyam (*Xanthosoma violaceum* Schott) genotypes grown in Nicaragua. Euphytica, 2005, 142, 265-272

Rinaldi M., Variation in specific leaf area for sugar beet depending on sowing date and irrigation. Italian J. Agron., 2003, 7, 23-32

SAS Institute Inc., SAS/STAT® users' Guide, Ver. 8, 4th ed., Scholars Academic and Scientific Publishers, SAS Institute, Cary, North Caroline, U.S.A., 2007

Scheffer J.J.C., Douglas J.A., Triggs C.M., Factors affecting the production and quality of Japanese taro cormels. Acta Hortic., 2005, 670, 167-172

Sefa-Dedeh S., Agyir-Sackey E.K., Chemical composition and the effect of processing on oxalate content of cocoyam; *Xanthosoma sagittifolium* and *Colocasia esculenta* cormels. Food Chem., 2004, 85, 479- 487

Snedecor G.W., Cochran W.G., Statistical methods, 7th edn. Iowa State University Press, Ames., 1980

Vinning G., Select markets for taro, sweet potato and yam. RIRDC Project No. UCQ 2003, 13A

Yadav R.K., Rai N., Yadav D.S., Sanwal S.K., Correlation, Path coefficient and genetic diversity pattern in *Colocasia* (*Colocasia esculenta*) genotypes. Vegetable Sci., 2007, 34, 153-156