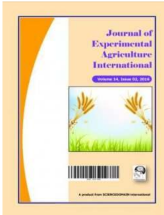

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Variability and Inter-Relationships between Yield and Associated Traits in Taro (*Colocasia esculenta* (L.) Schott)

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Authors' contributions

This work was carried out in collaboration between authors CEE and GEN. Both authors contributed equally from the design of the study to the final approved manuscript.

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ABSTRACT

The genetic variability and inter-relationships between yield and associated traits in some taro (*Colocasia esculenta* (L.) Schott) genotypes were investigated in two years across two locations. The experiment was laid out as randomized complete block design with three replications in each location. Data were collected on the growth and yield attributes of taro. The genetic variability of the attributes measured in both locations was studied to estimate the genotypic (GCV) and phenotypic (PCV) coefficients of variation, broad sense heritability (h^2b) and genetic advance (GA). Considering GCV, h^2b and GA simultaneously as the best estimators of the amount of advance expected from selection, number of secondary shoots/plant and number of leaves/plant gave the highest values in each of the locations. This shows that a satisfactory selection program for improvement of these genotypes through these traits is possible at each specific location. Correlation analysis showed that all the traits measured were significantly and positively correlated with taro yield except corm and cormel lengths. Number of cormels/plant had the strongest positive correlation with taro yield (r = 0.699**) followed by cormel weight (r = 0.624**). Path-coefficient analysis and stepwise multiple regression analysis revealed cormel weight and number of

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cormels/plant as the biggest determinants of taro yield, both contributing about 72% of the total variation in yield. This suggests that these two characters are important selection indices for taro yield improvement.

Keywords: Yield; field evaluation; path analysis; heritability; genetic advance.

1. INTRODUCTION

Taro (*Colocasia esculenta* (L.) Schott) is an important traditional staple crop in rural African countries especially in Nigeria. It is cultivated by small-scale, resource-poor farmers, mostly women [1]. Nigeria is an important producer of taro in the world, with an estimated annual production of 4.46 million metric tons [2] but in recent years (2008 – 2012), production has declined drastically due to the incidence of the taro leaf blight (TLB) in the country (FAO, 2013). Taro is used as food, prepared the same way as potatoes. Its flour is considered good for baby food because it is easily digestible, helps with digestive problems and acts as iron supplements [3-6].

Variability in germplasm determines the level of success in the improvement of such germplasm through selection. Success in crop improvement demands that characters should be highly heritable as progress due to selection depends on heritability, selection intensity and genetic advance [7]. Understanding the level of heritability and genetic advance that exist in crop characters will facilitate the choice of selection methods [7,8]. The main thrust in any crop improvement program is to enhance yield. Yield is a complex trait and is dependent on many other ancillary characters which are mostly inherited quantitatively [9]. Understanding the relative contribution of each trait to yield may be accomplished using correlation studies but simple correlation does not provide adequate information about the contribution of each factor towards yield. Hence, path coefficient analysis that untangles correlation coefficients into direct and indirect effects is the most effective means to determine the contributions of the causal factors of association among the different variables to yield. Path coefficient analysis can discriminate between the realistic (genetic effects) and inflated (environmental effects) correlations [10]. Hence, the knowledge of direct and indirect effects of different components on yield is of prime important in selection of high yielding genotypes. Plant height and leaf area are important factors correlated with taro yield [11]. Information on the path analysis of yield components of taro is scanty in literature. Generally, knowledge of the quantitative genetics of important agronomic traits for taro is scarce. Hence, the present study was undertaken to gather useful information on genetic variability, character association and path analysis of yield components in eight genotypes of taro.

2. MATERIALS AND METHODS

The trials were conducted at the Michael Okpara University of Agriculture teaching and research farm, Umudike (Latitude 05º29'N; Longitude 07º33'E; Alt. 122 m) and the National Root Crops Research Institute's farm at Igbariam (Latitude 06°15'N; Longitude 06°52'E; Alt. 81 m) in 2013 and 2014 cropping seasons. Umudike is in the humid tropics with an annual average temperature of about 26°C. It has a bimodal rainfall pattern with a total of about 2177 mm per annum. A long wet season from April to July is interrupted by a short "August break" followed by another short rainy season from September to October/early November. Dry season stretches from early November to March. The predominant vegetation type is rain forest [12], and the soil has been classified as sandy loam ultisol [13]. Igbariam temperature is relatively constant during the year and its vegetation is classified as a derived savanna, with a tropical moist forest biozone. The soil in the area is high in acrisols, alisols, plinthosols (ac), acid soil with clay-enriched lower horizon and low base saturation (www.chinci.com).

Pre-planting composite soil samples were collected at the two locations using soil auger of 5cm diameter at a depth of 0 - 20cm and analyzed for their physicochemical properties. Particle-size analysis was carried out for textural class using the hydrometer method [14]. Soil pH was determined in a soil/water (1:2) suspension using a digital electronic pH meter. The Walkley and Black procedure was used to determine the soil organic carbon by wet oxidation using chromic acid digestion [15]. Total N was determined using micro-Kjeldahl digestion and distillation techniques [16]; available P was determined using Bray II method as outlined in [17]. Exchangeable K, Ca and Mg were extracted with a 1M NH_4OAc, pH 7 solution. Thereafter, K was analysed with a flame photometer and Ca and Mg were determined with an atomic absorption spectrophotometer [18].

Eight (8) genotypes of taro (*Colocasia esculenta* L. Schott) obtained from National Root Crops Research Institute, Umudike were used (Table 1).

Table 1. The genotypes and their common/local names

S/N	Genotype	Common/local name
1	NCe 001	Cocoindia
2	NCe 002	“Ede ofe” green
3	NCe 003	“Ede ofe” purple
4	NCe 005	“Ukpong”
5	NCe 010	“Akiri”
6	NCe 011	“Akpahiri”
7	NCe 012	“Akiri mgbawa”
8	-	“Ede Orba”

The experiment was laid out as a Randomized Complete Block Design with three replications at both locations. Each plot measured 4 m by 4 m, consisting of 4 rows with plant spacing of 100 cm by 50 cm (inter and intra respectively giving 20, 000 plants/ha).

Planting was carried out in Umudike and Igbariam on 11^{th} and 16^{th} May in 2013 and on 15^{th} and 21^{st} May in 2014 respectively. Weed control was carried out manually. Basal fertilizer application was done at 6 weeks after planting (WAP) using NPK 15:15:15.

Data on taro growth and yield were collected on the twelve (12) plants from the two middle rows for assessment at 6, 8, 10 and 12 weeks after planting (WAP). The data collected were subjected to Analysis of Variance using the GenStat Discovery 12^{th} edition [19]. Genotypic, phenotypic and error variances were estimated using the formulae of [20,21]:

$$VG = (MSG-MSE)/r; \quad VP = MSG/r; \quad VE = MSE/r$$

Where: MSG, MSE and r are the mean squares genotypes, mean squares error and number of replication respectively. The phenotypic (PCV) and genotypic (GCV) coefficients of variations were estimated by the methods of [22,23] as:

$$PCV = (\sqrt{VP} \times 100)/\overline{X} \quad GCV = (\sqrt{VG} \times 100)/\overline{X}$$

Where: VP, VG and $\overline{X}$ are phenotypic and genotypic variances and grand mean respectively for the traits under consideration. Broad sense heritability (h^2B) was expressed as the percentage of the ratio of VG to VP on genotypic mean basis as described by [24]. Genetic advance was estimated using the method of [25] as $GA = k(Sp)h^2B$ where k is a constant (2.06 at 5% selection pressure), Sp is the phenotypic standard deviation, $\sqrt{VP}$, h^2B is the broad sense heritability. GA was calculated as a percentage of the mean.

Correlations and multiple regression (stepwise) were calculated to examine inter character relationships among the traits and their contributions to yield, respectively, using SPSS for Windows version 16.0. Path coefficient analysis was done to determine direct and indirect effects of each trait to yield according to the procedure of Dewey and Lu [26].

3. RESULTS AND DISCUSSION

The soil physicochemical properties of the experimental sites are presented in Table 2. The result showed that the soil texture of both locations was sandy loam. The pH ranged from 4.65 – 5.10 with the soil of Umudike being more acidic than that of Igbariam in both years. Available phosphorus (mg/kg) was higher at Umudike in 2013 but in 2014, Igbariam had higher available phosphorus. Similar trend was observed for total nitrogen in both years. Umudike soil had higher organic carbon and organic matter contents in both years. In both years, Igbariam soil had higher proportion of calcium, magnesium, potassium and sodium. Exchange acidity was higher at Umudike in both years while the effective cation exchange capacity was higher at Igbariam also in both years. The result also indicated that the percentage base saturation of Igbariam soil was higher than that of Umudike in both years.

The average monthly rainfall at Umudike and Igbariam over 2013 and 2014 are presented in Figs. 1 and 2. The total rainfall at Umudike was 2210.0 mm in 2013 and 2068.5 mm in 2014 while the total rainfall at Igbariam was 1912.8 mm in 2013 and 1823.4 mm in 2014. At Umudike in 2013, the highest rainfall was recorded in May while in 2014, it was recorded in August. At Igbariam in 2013, the rainfall pattern was bimodal with peaks in June and September. In 2014, the highest rainfall at Igbariam was recorded in the month of September.

Table 2. Soil physicochemical properties of experimental sites in 2013 and 2014

Soil properties	2013		2014	
	Umudike	**Igbariam**	**Umudike**	**Igbariam**
Texture	**Sandy loam**	**Sandy loam**	**Sandy loam**	**Sandy loam**
Sand (%)	71.80	75.80	76.40	72.40
Silt (%)	11.40	11.40	7.40	11.40
Clay (%)	16.40	12.40	14.20	16.20
pH (H_20)	4.70	4.80	4.65	5.10
Phosphorus (Mg/Kg)	33.40	25.40	35.20	38.40
Total Nitrogen (%)	0.028	0.042	0.146	0.077
Organic Carbon (%)	0.54	0.24	1.69	0.89
Organic matter (%)	0.93	0.41	2.91	1.53
Calcium ($Cmolkg^{-1}$)	3.20	4.80	2.00	2.40
Magnesium ($Cmolkg^{-1}$)	1.20	1.60	1.20	1.60
Potassium ($Cmolkg^{-1}$)	0.137	0.219	0.065	0.438
Sodium ($Cmolkg^{-1}$)	0.278	0.287	0.243	0.348
Exchange Acidity ($Cmolkg^{-1}$)	1.52	0.64	1.28	0.88
ECEC ($Cmolkg^{-1}$)	6.34	7.55	4.79	5.67
Base Saturation (%)	75.95	91.47	73.24	84.41

Source: NRCRI Soil Science Laboratory

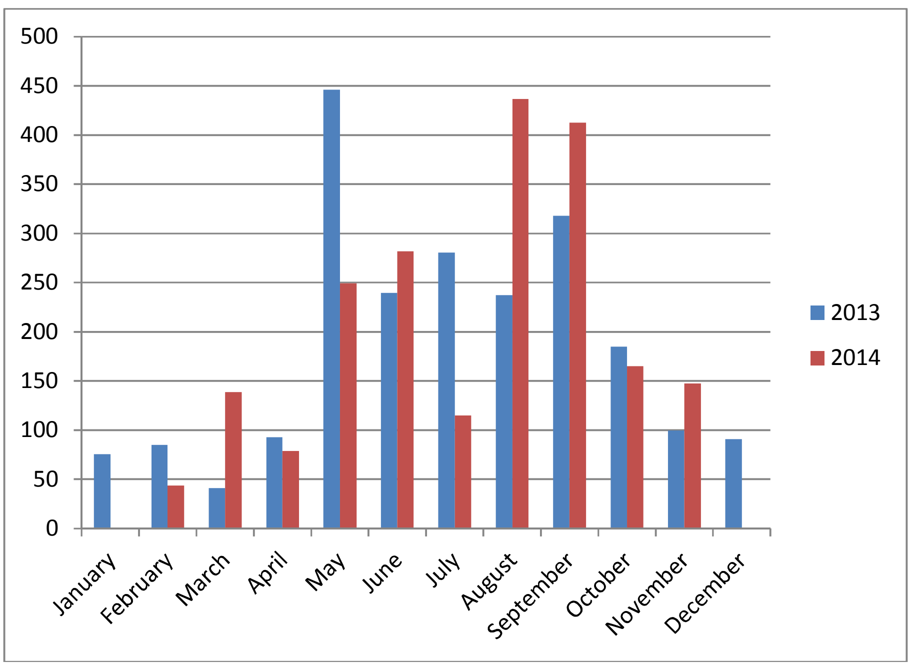

Fig. 1. Average monthly rainfall (mm) at Umudike in 2013 and 2014
(Source: NRCRI meteorological station)

The estimates of the variance components for all the traits showed that phenotypic and genotypic variances were close to each other at both locations in two years. The error variance was relatively lower than the genotypic variance for all traits. Similar results of higher genotypic variance than error variance for some characters were reported by [27] for *Vernonia galamensis*, [28] for Egusi Melon, [29] for Cowpea and [30] for Sorghum. These lower error variances indicate that the genotypic component was the major contributor to the total variance for these characters in each of the two locations. It can be concluded that most of the variability observed in the phenotype for the different characters has more of a genetic than non-genetic basis. The variability due to genotypic variance indicates considerable scope for selection. It is difficult to compare the variances among the range of various characters because they are not unit free [31], thus, the phenotypic coefficient of variability (PCV), genotypic coefficient of variability (GCV), broad sense heritability (h^2b) and genetic advance (GA) were estimated.

The Estimates of phenotypic coefficient of variability, genotypic coefficient of variability, heritability (in broad sense) and genetic advance, as a percentage of mean, measured in Umudike are shown in Table 3. In 2013, PCV ranged from 12.28 to 69.04 and from 7.71 to 62.51 in 2014 while GCV ranged from 11.69 to 60.19 in 2013 and 7.09 to 54.13 in 2014. In both years, the highest and lowest PCV values were observed in number of secondary shoots/plant and corm circumference respectively. Although GCV provides information on the genetic variability present in various quantitative characters, it is not possible to determine the amount of the variation that was heritable from only the genotypic coefficient of variation. In 2013, broad sense heritability estimates ranged from 75.53% (number of leaves/plant at 8 WAP) to 96.88% (number of leaves/plant at 12 WAP) (Table 3). In 2014, broad-sense heritability estimates ranged from 68.08% for plant height to 96.21% for taro tuber yield. Genetic advance (GA) as percentage of mean ranged from 22.92% for corm circumference to 108.10% for number of secondary shoots/plant in the first year. However, in the second year, GA varied from 13.43% for corm circumference to 96.54% for number of secondary shoots/plant. Considering heritability and GA together in both years, most of the traits had high heritability and high genetic advance but corm circumference had high heritability with low Genetic advance.

The estimates of phenotypic coefficient of variability (PCV), genotypic coefficient of variability (GCV), heritability (in broad sense) and genetic advance as a percentage of mean were also evaluated and compared for all the traits measured in Igbariam for both years as shown in Table 4. The PCV ranged from 9.89 for corm circumference to 65.98 for number of secondary shoots/plant at 10WAP in 2013 and from 5.76 for cormel circumference to 82.58 for number of secondary shoots/plant at 8WAP in 2014. The GCV ranged from 8.78 for corm circumference to 65.67 for number of secondary shoots/plant at 10WAP in 2013 while in 2014, it ranged from 5.19 for cormel circumference to 71.82 for number of secondary shoots/plant at 8WAP. In 2013, broad sense heritability ranged from 64.86% for corm weight to 99.06% for number of secondary shoots/plant at 10 WAP while in 2014, broad-sense heritability values ranged from 66.99% for number of cormels/plant to 96.66% for cormel length (Table 4). Genetic advance (GA) as percentage of mean ranged from 15.88% for corm length to 134.63% for number of secondary shoots/plant at 10 WAP in the first year. In the second year, GA varied from 9.64% for cormel circumference to 128.68% for number of secondary shoots/plant at 8 WAP. Considering heritability and GA together in both years, most of the traits combined high heritability with high genetic advance.

The phenotypic coefficient of variability (PCV) was generally higher than the genotypic coefficient of variability (GCV) for all the traits in each location but the differences were quite small. The same trend was reported by [32] for taro, [27] for *Vernonia galamensis* and [33] for cowpea. This suggests that environmental effects constitute a portion of the total phenotypic variation in the traits. High GCV together with high heritability and high genetic advance will give good information than each parameter alone [34]. In this study, for traits with high values of GCV, heritability and GA such as number of secondary shoots/plant and number of leaves/plant, there is a possibility of improving these genotypes through direct selection for the aforementioned traits at each specific location.

Trait association studies in the present investigation revealed that all the traits measured were significantly and positively correlated with taro yield except corm length and cormel length. Corm length was positively but non-significantly correlated with yield while cormel length was negatively and non-significantly correlated with yield. Number of cormels/plant had the strongest positive association with taro yield (r = 0.699**). Cormel weight (r = 0.624**), cormel circumference (r = 0.597**) and number of secondary shoots/plant (r = 0.534**) were also strongly and positively correlated with yield. Significant and positive association was also observed between yield and plant height (r = 0.258*) while negative and non-significant relationship exists between yield and cormel length (r = -0.128) (Table 5). [35] reported that mean weight of cormels/ plant, number of cormels/plant and leaf area were positively and significantly correlated with yield. [36] observed that yield in taro was significantly and positively correlated with leaf area, number of secondary shoots/plant, weight of cormels, number of cormels/plant, weight of cormels and yield per plant. [37] estimated genotypic and phenotypic correlation coefficients of taro (*Colocasia esculenta* (L.) Schott) for 19 characters, they found among others that corm length and cormel length were significantly and positively correlated with yield in both genotypic and phenotypic levels. This disagrees with the findings of this investigation for both corm and cormel length. The strong correlation of these traits with taro yield suggests that they could be used as selection indices for yield improvement of taro in this agro-ecological zone.

The result also showed that most of the traits were significantly and positively correlated with each other except for cormel length which had negative and significant relationship with number of secondary shoots/plant, number of leaves/plant, number of cormels/plant, plant height, and circumference of pseudostem. Corm length also had negative and significant correlation with number of leaves/plant and number of secondary shoots/plant (Table 5). This suggests that a selection for an increase in one trait will likely and simultaneously lead to increase in most of the other traits as significant and positive association between two characters under consideration indicates that these characters can be improved simultaneously in a selection programme while a selection for an increase in cormel length will likely and simultaneously lead to decrease in number of secondary shoots/plant, number of leaves/plant, number of cormels/plant, plant height, and circumference of pseudostem. Similar situation would also be observed with corm length. Strongest, positive and significant relationships were observed between corm weight and corm circumference (r = 0.862**), leaf area and plant height (r = 0.759**), and leaf area and circumference of pseudostem (r = 0.722**). The relationship between corm weight and corm circumference; leaf area and plant height found in this study agrees with that reported by [37].

Table 6 shows the multiple regression stepwise, coefficient of determination (R^2) and R^2 change (ΔR^2). The result showed that three attributes, namely; number of cormels/plant, cormel weight and number of leaves/plant were the largest contributors to yield. These three attributes significantly predicted and explained approximately 75% of the yield variation observed. Number of cormels/plant was the largest single contributor and accounted for 49% of the total variation in yield (B = 0.699; P<0.001), cormel weight accounted for 23% while number of leaves/plant accounted for 2.6%. Number of cormels/plant as the largest contributor to taro yield is therefore, an important indicator for estimating and improving taro yield. This also suggests that improvement of yield through selection of this trait would have good impact on taro yield.

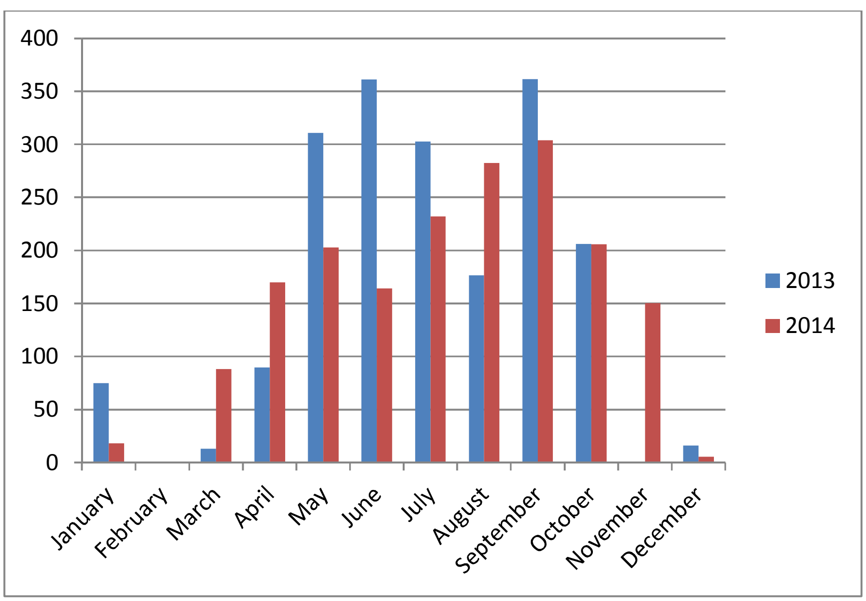

Fig. 2. Average monthly rainfall (mm) at Igbariam in 2013 and 2014
(Source: NRCRI meteorological station)

Table 3. Phenotypic coefficient of variability (PCV), genotypic coefficient of variability (GCV), broad sense heritability (h^2b) and genetic advance (GA) of the taro attribute measured in Umudike in two years

Attribute	2013						2014					
	Mean	Range	PCV	GCV	H^2b	GA	Mean	Range	PCV	GCV	H^2b	GA
PH (6wap)	14.51	7.16-18.80	21.65	20.81	92.46	41.23	22.07	11.84-38.83	25.83	23.36	81.80	43.52
PH (8wap)	24.35	10.47-33.79	22.48	21.41	90.69	42.00	30.00	16.20-46.10	23.97	21.58	81.01	40.01
PH(10wap)	41.40	15.70-57.56	23.44	22.19	89.61	43.26	44.50	23.58-65.46	21.73	18.69	73.98	33.12
PH(12wap)	50.35	26.00-68.14	20.35	19.64	93.17	39.06	50.50	25.68-72.24	19.45	16.05	68.08	27.29
LA (6wap)	273.80	56.98-388.70	31.85	30.50	91.68	60.15	365.00	90.70-603.50	36.79	33.19	81.39	61.69
LA (8wap)	383.00	120.60-631.60	30.97	29.44	90.31	57.62	524.00	112.00-894.60	32.83	27.87	72.08	48.75
LA(10wap)	860.00	232.30-1399.00	31.34	28.36	81.85	52.85	889.00	201.30-1410.00	-	-	-	-
LA(12wap)	1042.00	458.50-1543.00	27.91	26.66	91.22	52.45	1014.00	243.20-1562.00	-	-	-	-
COP(6wap)	5.11	2.75-6.54	17.84	16.92	90.00	33.07	6.79	4.23-9.56	21.80	19.88	83.10	37.33
COP(8wap)	6.50	2.78-8.79	22.14	21.03	90.25	41.16	9.21	5.00-12.50	21.20	18.70	77.83	33.99
COP(10wap)	10.81	4.53-15.27	21.79	20.26	86.49	38.82	12.46	7.18-17.13	20.32	17.87	77.35	32.37
COP(12wap)	12.57	6.45-16.50	19.24	18.47	92.08	36.50	15.16	8.03-32.31	-	-	-	-
NSS (8wap)	0.39	0.00-1.42	69.04	60.19	76.01	108.10	0.92	0.00-2.30	62.51	54.13	74.97	96.54
NSS(10wap)	2.24	0.00-4.58	57.13	53.88	88.96	104.68	2.87	0.42-5.67	44.57	37.51	70.83	65.03
NSS(12wap)	4.15	0.33-7.66	44.85	41.88	87.16	80.53	5.28	1.67-8.92	33.11	27.64	69.70	47.54
NOL (6wap)	4.35	2.16-6.83	27.58	27.13	96.74	54.97	4.05	2.33-5.92	15.61	13.74	77.43	24.90
NOL (8wap)	4.73	2.80-8.00	23.09	20.07	75.53	35.93	5.16	3.30-6.90	18.48	16.86	83.22	31.69
NOL(10wap)	5.77	2.41-12.41	39.36	37.92	92.83	75.27	8.72	4.08-15.25	34.39	29.62	74.19	52.55
NOL(12wap)	8.59	2.42-13.25	38.16	37.56	96.88	76.17	11.73	4.42-22.58	38.57	34.66	80.77	64.17
Ncormel	10.29	3.42-16.50	34.57	32.04	85.88	61.17	17.33	6.60-28.83	27.37	25.95	89.87	50.67
Wcorm	137.80	49.25-230.00	30.10	28.34	88.69	54.99	136.20	74.00-188.10	22.64	21.96	94.03	43.86
WPCML	32.10	22.08-43.73	-	-	-	-	39.00	28.00-61.95	17.43	14.84	72.48	26.03
CM L	6.37	4.58-8.07	12.94	12.21	89.04	23.74	6.15	4.40-8.23	12.88	12.21	89.76	23.82
CML L	6.09	4.38-13.22	29.36	27.52	87.89	53.16	6.58	5.20-11.00	22.22	21.30	91.88	42.06
CM C	19.82	15.04-24.29	12.28	11.69	90.62	22.92	19.95	16.95-22.68	7.71	7.09	84.61	13.43
CML C	10.77	8.70-12.24	-	-	-	-	11.01	9.30-12.75	-	-	-	-
Y (t/ha)	6.47	2.63-9.88	30.73	29.94	94.95	60.10	11.52	6.93-16.40	22.12	21.70	96.21	43.85

PH = Plant Height (cm); LA = Leaf Area (cm^2); NSS = Number of Secondary Shoots; COP = Circumference of Pseudostem (cm); NOL = Number of Leaves; nCormel = Number of Cormels; wCorm = Weight of Corm (g); WPCML = Weight per Cormel (g); CM L = Corm Length (cm); CML L = Cormel Length (cm); CM C = Corm Circumference (cm); CML C = Cormel Circumference (cm); Y (t/ha) = Yield (t/ha); "-" = not significant; wap = weeks after planting

Table 4. Phenotypic coefficient of variability (PCV), genotypic coefficient of variability (GCV), broad sense heritability (h^2b) and genetic advance (GA) of the taro attribute measured in Igbariam in two years

Attribute	2013						2014					
	Mean	Range	PCV	GCV	H^2b	GA	Mean	Range	PCV	GCV	H^2b	GA
PH (6 wap)	18.45	11.20-26.87	24.21	23.12	91.17	45.47	23.44	10.87-33.14	22.58	20.76	84.52	39.32
PH (8 wap)	29.02	19.19-42.10	23.09	22.45	94.54	44.96	31.05	13.67-44.58	24.99	23.71	89.97	46.32
PH(10 wap)	39.28	28.20-53.10	18.38	18.09	96.90	36.69	45.01	31.36-57.49	15.19	13.59	80.10	25.06
PH(12 wap)	48.57	32.13-64.28	15.15	14.81	95.61	29.84	55.80	39.88-74.03	-	-	-	-
LA (6 wap)	429.00	165.50-728.90	36.15	33.72	87.00	64.79	402.00	139.00-753.90	37.77	35.97	90.71	70.57
LA (8 wap)	533.00	234.60-907.00	35.80	34.30	91.78	67.69	547.00	222.6-1072.00	36.00	34.14	89.93	66.68
LA(10 wap)	688.00	345.2-1150.00	33.10	31.52	90.68	61.82	1000.00	363.8-1672.00	31.20	28.58	83.88	53.91
LA(12 wap)	889.00	488.1-1391.00	29.42	28.41	93.30	56.53	1052.00	391.4-1728.00	30.37	28.46	87.81	54.93
COP(6 wap)	3.44	1.20-6.00	24.84	22.07	78.99	40.41	6.62	3.83-9.36	20.80	19.53	88.18	37.78
COP(8 wap)	4.82	2.40-7.60	26.22	24.91	90.22	48.73	8.75	4.64-12.00	22.21	20.85	88.15	40.32
COP(10 wap)	9.15	6.30-12.60	19.87	19.14	92.76	37.97	12.97	7.04-17.58	21.32	19.94	87.46	38.42
COP(12 wap)	11.37	7.40-15.50	18.66	18.04	93.50	35.94	13.99	8.63-17.83	19.42	18.14	87.32	34.92
NSS (8 wap)	0.44	0.00-1.80	64.00	51.91	65.81	86.75	0.54	0.00-2.00	82.58	71.82	75.64	128.68
NSS(10 wap)	2.45	0.03-5.25	65.98	65.67	99.06	134.63	2.97	0.75-6.08	51.24	47.98	87.70	92.57
NSS(12 wap)	4.67	1.13-7.57	45.11	44.77	98.50	91.52	5.11	1.83-10.16	36.18	32.50	80.67	60.13
NOL (6 wap)	3.28	2.10-5.40	19.96	17.80	79.57	32.71	3.71	2.50-4.92	15.48	14.20	84.13	26.83
NOL (8 wap)	3.67	2.40-5.60	19.98	16.83	71.00	29.22	3.97	2.92-6.25	13.42	11.19	69.51	19.21
NOL(10 wap)	5.56	3.00-8.80	30.26	27.87	84.86	52.89	4.72	3.67-6.00	10.82	10.15	87.98	19.60
NOL(12 wap)	8.75	4.40-11.80	27.00	26.07	93.23	51.86	12.70	3.91-23.17	53.50	52.19	95.18	104.90
nCormel	11.06	4.09-25.17	34.35	29.31	72.78	51.50	13.66	5.33-21.75	23.64	19.35	66.99	32.63
wCorm	98.70	30.00-180.20	23.77	19.14	64.86	31.76	118.50	53.40-166.10	22.23	20.85	87.96	40.28
WPCML	23.66	11.50-33.96	17.57	14.72	70.21	25.40	28.20	20.00-38.03	17.40	16.27	87.39	31.33
CM L	5.62	3.77-7.96	10.89	9.16	70.76	15.88	6.19	4.53-8.18	10.49	9.84	88.13	19.04
CML L	6.00	3.38-12.66	36.88	35.81	94.27	71.62	6.47	3.87-12.33	32.95	32.39	96.66	65.60
CM C	18.29	13.76-21.73	9.89	8.78	78.83	16.05	19.26	14.97-22.30	8.27	7.57	83.63	14.25
CML C	10.05	7.32-12.50	-	-	-	-	10.20	8.88-12.04	5.76	5.19	81.24	9.64
Y (t/ha)	4.69	0.63-9.99	39.44	34.15	74.98	60.92	5.69	1.25-9.56	36.20	33.76	87.00	64.87

PH = Plant Height (cm); LA = Leaf Area (cm^2); NSS = Number of Secondary Shoots; COP = Circumference of Pseudostem (cm); NOL = Number of Leaves; nCormel = Number of Cormels; wCorm = Weight of Corm (g); WPCML = Weight per Cormel (g); CM L = Corm Length (cm); CML L = Cormel Length (cm); CM C = Corm Circumference (cm); CML C = Cormel Circumference (cm); Y (t/ha) = Yield (t/ha); "-" = not significant; wap = weeks after planting.

Table 5. Correlation matrix between yield (t/ha) and other attributes of some taro genotypes in two locations over two years

	PH	LA	COP	NSS	NOL	NCML	WC	WCML	CM L	CML L	CM C	CML C	YLD(t/ha)
PH	-	0.759**	0.675**	0.535**	0.393**	0.403**	0.370**	0.043	0.001	-0.275**	0.488**	0.217*	0.258*
LA		-	0.722**	0.405**	0.232*	0.322**	0.573**	0.214*	0.311**	-0.045	0.644**	0.279**	0.326**
COP			-	0.509**	0.388**	0.485**	0.353**	0.214*	0.024	-0.226*	0.494**	0.255*	0.467**
NSS				-	0.588**	0.524**	0.078	0.181	-0.253*	-0.425**	0.200	0.405**	0.534**
NOL					-	0.476**	-0.004	0.115	-0.316**	-0.388**	0.022	0.367**	0.479**
NCML						-	0.332**	0.231*	-0.125	-0.323**	0.426**	0.477**	0.699**
WC							-	0.542**	0.679**	0.232*	0.862**	0.435**	0.415**
WCML								-	0.429**	0.307**	0.365**	0.632**	0.624**
CM L									-	0.652**	0.508**	0.044	0.030
CML L										-	0.048	-0.170	-0.128
CM C											-	0.428**	0.441**
CML C												-	0.597**
YLD(t/ha)													-

*Note: PH = Plant height (cm) at 12WAP (Weeks after planting), LA = Leaf area (cm^2) at 12 WAP, COP = Circumference of pseudostem (cm) at 12 WAP, NSS = Number of secondary shoots at 12 WAP, NOL = Number of leaves at 12 WAP, NCML = Number of cormels, WC = Corm weight (g), WCML = Cormel weight (g), CM L = Corm length (cm), CML L = Cormel length (cm), CM C = Corm circumference (cm), CML C = Cormel circumference (cm), YLD (t/ha) = Yield (t/ha). ** = correlation is significant at the 0.01 level, * = correlation is significant at the 0.05 level*

Table 6. Multiple Regression (B, Stepwise), Coefficient of Determination (R^2), R^2 Change (ΔR^2) between yield (t/ha)and other attributes of some taro genotypes in two locations over two years

Attributes	Multiple regression (B)		Coefficient of determination	R^2 change
	B	VR	R^2	ΔR^2
No of cormels	0.699	89.862***	0.489	0.489
Cormel weight (g)	0.845	116.472***	0.715	0.226
No of Leaves at 12wap	0.861	87.900***	0.741	0.026

*Note: *** = significant at 0.001 level of probability.*

Table 7. Path analysis showing direct and indirect effects of other attributes on taro yield in two locations over two years

	PH(12wk)	LA(12wk)	NOL(12w)	nCormel	wCORM	WPCML	CM L	CML L	CM C	CML C	Y(t/ha)
PH(12wk)	**-0.249411**	0.104323	0.090453	0.161992	-0.033725	0.025141	-0.005551	0.015265	0.165651	-0.020743	0.253395
LA(12wk)	-0.190472	**0.136604**	0.055518	0.134536	-0.055381	0.144069	-0.074712	0.002177	0.231024	-0.035032	0.348331
NOL(12w)	-0.102404	0.034425	**0.220303**	0.187255	-0.001930	0.075790	0.058978	0.021336	0.009796	-0.049049	0.454500
nCormel	-0.104179	0.047388	0.106371	**0.387818**	-0.037722	0.154294	0.002324	0.013405	0.168835	-0.064416	0.674120
wCORM	-0.082789	0.074460	0.004186	0.143988	**-0.101602**	0.376206	-0.163403	-0.013335	0.326111	-0.067289	0.496534
WPCML	-0.009858	0.030940	0.026250	0.094074	-0.060092	**0.636077**	-0.105772	-0.015066	0.159300	-0.095294	0.660558
CM L	-0.006078	0.044808	-0.057045	-0.003957	-0.072890	0.295383	**-0.227769**	-0.033418	0.214601	-0.013517	0.140118
CML L	0.072191	-0.005639	-0.089126	-0.098576	-0.025689	0.181710	-0.144328	**-0.052739**	0.042065	0.015666	-0.104465
CM C	-0.110970	0.084765	0.005797	0.175869	-0.088995	0.272159	-0.131288	-0.005959	**0.372308**	-0.063727	0.509959
CML C	-0.032817	0.030356	0.068544	0.158466	-0.043367	0.384499	-0.019530	0.005241	0.150502	**-0.157646**	0.544247
Residual											0.206677

Note: PH = Plant height (cm) at 12 WAP, LA = Leaf area (cm^2) at 12 WAP, COP = Circumference of pseudostem (cm) at 12 WAP, NSS = Number of secondary shoots at 12 WAP, NOL = Number of leaves at 12 WAP, NCML = Number of cormels, WC = Corm weight (g), WPCML = Cormel weight (g), CM L = Corm length (cm), CML L = Cormel length (cm), CM C = Corm circumference (cm), CML C = Cormel circumference (cm), Y(t/ha) = Yield (t/ha)

Path coefficient analysis is used to untangle cause and affect relationship that is confounded by correlation coefficients [28]. It was carried out to estimate the direct and indirect contributions of various component traits to yield for recommending a reliable selection criterion. Cormel weight had the highest positive direct effect on taro yield (0.636) while number of cormels/plant had the strongest total positive influence on yield (0.674). Positive direct effects were also obtained for number of cormels/plant (0.388), corm circumference (0.372), number of leaves/plant (0.220) and leaf area (0.137). Plant height at 12WAP and corm length had moderate and negative direct effects on taro yield while cormel circumference, corm weight and cormel length had weak and negative direct effects on taro yield. Though, cormel circumference and corm weight had weak and negative direct effects on yield, they had high indirect effects through cormel weight. Apart from cormel length whose total effect on taro yield is negative, the total effects of most of the traits were high and positive and this was due to their high direct effects and moderate indirect effects through cormel weight (Table 7).The residual effect (0.207) is relatively low indicating that the characters considered in this analysis successfully explained variation existing in the taro genotypes. Positive and high total effects of these traits to yield reveals their importance in determining taro yield and is an indication that improvement of yield in taro is linked with these traits, therefore, selection of these traits might have positive outcome on taro yield. This result is comparable to what was reported by [38] and [39].

4. CONCLUSION

In conclusion, this study indicates the presence of genetic variabiltiy among the genotypes for the different traits under consideration and suggests direct selection for number of secondary shoots/plant and number of leaves/plant as a means of improving this crop. Correlation analysis, stepwise multiple regression and path analysis showed number of cormels/plant and cormel weight as the most important contributors to taro yield. They should therefore be considered as important selection indices for taro improvement aimed at developing high yielding varieties in these zones.

DISCLAIMER

This manuscript was presented in the conference.

Conference name: “The International Society of Tropical Root Crops this week”
Conference link is -
http://www.ediblearoids.org/portals/0/Newsletters/2016/January/Text/ISTRC.pdf
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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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