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Genetic Variation In Morphological Characters And Yield Related Traits Of Taro Collections {*Colocasia Esculenta L*. (Schott)} In Kenya

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Abstract:** Determination of genetic variability in morphological characters of taro collections Colocasia esculenta L. (Schott) were scored based on the key International Plant Genetic Resources Institute (IPGRI) descriptors for taro (IPGRI, 1999). Twenty-five taro germplasm from Kenya were used for this research study. These characteristics were as follows: Suckers and yields; taro leaf characters and yields, taro petiole character and yields; corms and yields amongst Kenya taro accessions. Shannon's Diversity Index was used to calculate the diversity for the quantitative characters that showed polymorphism in various traits. A two-way analysis of variance (ANOVA) was used to analyze genotypic agronomic performance of quantitative characters and yields. The application of analysis of variance test at (p>0.00) revealed a significant difference between morphological quantitative characters and yields of taro accessions with reference to taro genotype performance characters and yields. These findings have shown that variations morphological characters are important diagnostic features for distinguishing genotypes and these phenotypic characteristics could serve as the best genetic markers which is of fundamental importance for crop improvement and breeding purposes.

***Keywords:** Taro (Colocasia esculenta), Genetic variation, Leaf and Petiole Phenotypic characters, taro accessions*

I. INTRODUCTION

Taro *Colocasia esculenta* (L.) *Schott* var. *esculenta* belongs to the genus *Colocasia*, and monocotyledonous family Araceae (Deo *et al.*, 2009; Purseglove, 1972). Taro yields in Kenya are largely unknown compared to those of West Africa countries (Akwee, Palapala and Netondo, 2016). Taro being one of these underutilized crop, it has great untapped potential to support taro rural farmers by improving their food production systems, food nutritional security and income. This would go hand in hand towards sustaining taro genetic resources to cope with environmental challenges (Padulosi *et al.*, 2013 and Macharia et. al. 2014). Morphological characters that have a direct influence on yields and yield related traits have a greater influence on the overall genotype agronomic performances. Morphological quantitative characters could have a direct effect on genotype yield per plant at the genotypic level. In order to realize desirable maximum food production systems amongst taro rural farmers in Kenya, there is need to clearly bring out the desirable morphological characters and yield related traits to the attention of rural taro farmers. Little information about the genetic variation in morphological characters and yield related traits has had undesirable impacts to a great number of these underutilized and neglected crops including taro. This gives a clear indication of Kenyan taro genotype agronomic performances is extremely low that could not be even counted among taro producers in Africa (Jianchu *et. al.*, 2001; Akwee *et. al.*, 2016). Phenotypic characters are vital diagnostic features for distinguishing taro genotypes (Tafadzwanashe and Modi, 2013; Garcia *et al.*, 2006). They may serve as genetic bench markers that could facilitate selection of suitable taro germplasm variety for crop improvement (Saidia *et al.*, 2012; Elibariki *et al.*, 2013). This reinforces the suitability of

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agronomic characters in selecting genotypes (Garcia *et al.*, 2006; Dwevedi and Sen, 1999).

In terms of taro cultivation by Kenyan small holder farmers, there was a clear indication of lack of clear understanding of genetic variability towards identification of morphological characters that have desirable traits related to yields performances are fundamentally critical for taro crop productivity and breeding. Akwee et. al (2016) reported that, despite several strides undertaken by various stakeholders and constraints limiting sustainable taro production are still unknown leading to unrealized agronomic potential of taro in addressing perennial food security in the country. This could be attributed to a lack of understanding and awareness of farmers, about the magnitude of the food security problem which underlies the very concept of sustainable development.

Taro could be an economically viable crop in Kenya but its agronomic potential has largely remained unknown for many decades because it has remained unexploited and underutilized crop. This study was therefore conceived to establish the genetic variation with reference to morphological characters and yield related traits of taro collections {*Colocasia esculenta L*. (Schott)} in Kenya.

II. MATERIALS AND METHODS

The study was conducted in a farm field station at Masinde Muliro University of Science and Technology (MMUST) Main campus, located 00^{O} 17.30’ North and $34^{o}45$’ East (GPS receiver) in Kakamega, Kenya. Twenty-five taro germplasm collections were collected from part of Nyanza, Western, Central and Rift valley parts of Kenya and were used for this research study. A completely randomized design was employed for this study and it involved grouping similar experimental accessions into different taro genotypes in each block. Each experimental accession was as uniform as possible; there was no application of fertilizer or manure. Each block of the experimental unit consisted of twelve replications of each taro genotype. Each replicate of the taro accession was randomized separately and had the same probability of being assigned to a given experimental block within a replicate. Developed key descriptors for International Plant Genetic Resources Institute (IPGRI, 1999) for taro *(Colocasia esculenta)* were used for scoring morphological characters. Shannon’s Diversity Index *(H)* and a two-way analysis of variance (ANOVA) were used to calculate the diversity for the qualitative characters that showed polymorphism in various traits. The analyses of variance were tested at 0.05 level of significance.

These characteristics were as follows: Corm shape, Corm cortex color; Corm flesh color; Number of sprouting suckers; Corm sucker length; Corm weight; Corm length; Corm diameter; Number of cormels; Corm branching and root color.

Shannon Diversity Index (H) formula:

$$SDI_i = -\sum_{J=1}^{d_i} P_{ij} \log P_{ij}$$

Where

SDI= Shannon’s Diversity Index for the I^{th} qualitative character; d_i being the character state for ith character, and the proportion of accessions for j^{th} character state of ith character .P_i = the proportion of the character state of accessions i.

S/No	Genotype variety	Kenya Accession Number	Region
1	Kigoi	KCT/GHT/31	Central-Kenya
2	Kigirigasha	KCT/KGI/32	Central-Kenya
3	Ngirigacha	KCT/NGC/33	Central-Kenya
4	Lukuywa	KWK/LKW/13	Western Kenya
5	Ishwa	KWK/ISW/14	Western Kenya
6	Shitao	KWK/SHT/12	Western Kenya
7	KakamegaT15	KWK/KAK/15	Western Kenya
8	KakamegaT16	KWK/KAK/16	Western Kenya
9	Kakamega T17	KWK/KAK/17	Western Kenya
10	AmakTar72	KWK/BSA/42	Western Kenya
11	Eluhya	KMM/ELU/73	Western Kenya
12	MumiasT75	KMM/ENG/75	Western Kenya
13	Enduma	KMM/END/74	Western Kenya
14	Mumias T78	KMM/MMU/78	Western Kenya
15	Mumias T79	KMM/MMU/79	Western Kenya
16	Kiminini	KRT/KTL/61	Riftvalley Kenya
17	Siaya	KNY/SYA/51	Nyanza Kenya
18	Kisii T81	KNY/KIS/81	Nyanza Kenya
19	Kisii T 82	KNY/KIS/82	Nyanza Kenya
20	Kisumu	KNY/NYA/52	Nyanza Kenya
21	Lake VictoriaT21	KNY/LVT/21	Nyanza Kenya
22	Lake VictoriaT22	KNY/LVT/22	Nyanza Kenya
23	Amagoro Busia	KWK/BSA/41	Western Kenya
24	Kakamega T12	KWK/KAK/12	Western Kenya
25	Lake Victoria	KWK/LVT/23	Nyanza Kenya

Table 1: Germplasm Collections Passport Data on the general description

III. RESULTS

Majority of morphological phenotypic characters showed polymorphism amongst the taro germplasm collections. The character with the highest genetic diversity was the number of suckers with diversity index of 0.901 as shown on table 2. Twenty per cent of taro genotypes produced 5 to 10 suckers, sixty-four percent of them produced a range of 1 to 5 suckers while sixteen per cent from 10 to 20 suckers. The diversity indices for plant height were similar for both taro germplasm accessions with a value of 0.439. A total of eighty-eight per cent of taro variety lacked stolons. The Shannon’s genetic diversity indices were of relatively low value of 0.501 for the taro genotypes.

On taro suckering phenotypic ability and stolons presence amongst Kenya taro genotypes, number of suckers was one of the characters with the highest genetic diversity indices with a value of (H’) 0.901 (Table 2). This shows that, most taro accessions could produce suckers as a clear indicator of good taro production in terms of corm yields. Stolon formation was one of the phenotypic characters with the lowest diversity index value of (H’) 0.464 as indicated on result table 2.

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Character	IPGRI descriptors	% frequency	*SDI (H´)-*	Total *H´*
Plant span	Medium Wide	64 36	0.286 0.368	0.653
Plant height,	Medium Wide	44 56	0.146 0.293	0.439
Stolon formation	Absent Present	88 12	0.112 0.352	0.464
Number of stolons	None Short Long	88 4 8	0.112 0.129 0.202	0.443
Number of suckers	1to 5 24 5 to 10: 72 10 to 20 6	64 20 16	0.286 0.322 0.293	0.901

Table 2: Frequency distribution and Shannon's Diversity Indices (SDI) on qualitative phenotypic characters based on IPGRI Descriptors of taro accessions from Kenya Accessions

On taro corms and cormel phenotypic characteristics, the corms and cormels shapes were morphologically variable from both regions. Four of the corm qualitative characters assessed showed higher polymorphism rate among the taro accessions. The qualitative corm/cormels morphological characteristics with the highest Shannon's diversity indices value were as follows: The corm shape (1.399), corm cortex color (1.204) and corm flesh color (0.973) for Kenyan taro accessions as shown on table 3. Most of the taro genotypes showed conical, cylindrical and dumb-bell shapes. The corms flesh color showed whitish purple and grayish white in color as shown on Table 3

Character	IPGRI descriptors	% Frequency	*SDI(H´)*	Total *(H´)*
Corm shape	Conical Elliptical Round Cylindrical Dumb-bell shaped	40 4 12 28 16	0.367 0.129 0.254 0.356 0.293	1.399
Corm cortex color	Light Brown Brown Dark Brown Blackish	32 40 24 4	0.365 0.367 0.343 0.129	1.204
Corm flesh color	White Whitish purple Grayish white	12 48 40	0.254 0.352 0.367	0.973
Corm branching	Branched Unbranched	76 24	0.209 0.343	0.552
Corm root color	White Brown	16 84	0.293 0.147	0.44
Corm length	Intermediate Long Short	8 88 4	0.202 0.112 0.202	0.516

Table 3: Frequency distribution and Shannon's Diversity indices (SDI) on qualitative phenotypic characters based on IPGRI descriptors of taro accessions

Leaf phenotypic characters displayed high polymorphic rate within taro germplasm collections. Taro genotype accessions displayed greater phenotypic diversity in terms of leaf blade color with Shannon's diversity indices (H') of 1.279, followed by vein junction color with value of (H') 1.039, leaf lamina margin with diversity indices with a value of H' (0.971). In terms of petiole phenotypic variation, the petiole characters displayed by taro genotypes collections showed greater genetic diversity. The qualitative characters that showed higher Shannon's diversity index were as follows: petiole junction color (H':1.317); for Kenya; petiole junction pattern (H': 1.051) and petiole basic color (H': 0.833) respectively as shown on Table 4.

Character	IPGRI descriptors	% frequency	*SDI* (H)*	Total *H*
Predominant position (shape) of leaf lamina surface	Erect Apex down Erect Apex down Semi horizontal	64 4 32	0.286 0.129 0.365	0.78
predominant shape of lamina	Cup shaped Drooping edge Flat	80 4 16	0.179 0.129 0.293	0.601
Leaf lamina margin	Undulate Erect apex up	60 40	0.307 0.367	0.674
Leaf lamina colour	Yellow Green Dark green	28 44 12	0.356 0.361 0.254	0.971
Leaf blade colour	Green Yellow green Yellow Purple Green	40 16 12 32	0.367 0.293 0.254 0.365	1.279
leaf lamina variegation	Absent Present	72 28	0.237 0.356	0.593
Vein junction color	Green Yellow Green Purple	48 20 32	0.352 0.322 0.365	1.039
Petiole Basic color	Green; Yellow Purple green	48 4 48	0.352 0.129 0.352	0.833
Petiole Attachment	Peltate Sub peltate	84 16	0.147 0.293	0.44
Petiole junction color	Green Red purple Dark purple Yellow	56 8 24 12	0.352 0.368 0.343 0.254	1.317
Petiole junction color of the top third	Purple Yellow Green	32 4 64	0.365 0.129 0.286	0.78
Petiole Junction pattern and sinus	Small Medium Large	36 20 44	0.368 0.322 0.361	1.051

**Figures in parenthesis are the Shannon's Diversity Indices for the entire character*

Table 4: Frequency distribution and Shannon's Diversity indices (SDI) on qualitative phenotypic characters based on IPGRI descriptors of taro accessions from Kenya accessions

Taro genotype performance characters exhibited direct effect on yield per plant at the genotypic level. Analysis of variance of genotype performance characters and yields for taro collections has revealed a significant difference with reference to yields performances at $^{**}p<0.05$ (Table 5). These genotypes characters such as the plant height, plant span, petiole length, leaf length and breadth, number of suckers, cormel weight, number of cormels, cormel breadth had the direct effects on yields as revealed by multivariate analysis tests[a] effects among taro accessions. Western Kenya taro genotypes had the highest yields potential were: KakamegaT16, KakamegaT15, MumiasT75, Ishwa, Shitao, and Eluhya. Nyanza Kenya taro genotypes that had higher were KisiiT81 and Siaya and followed by central Kenya (Kigoi and Ngirigacha genotypes) while Kiminini taro genotype (KT61) from Rift valley Kenya had the lowest yielding genotype (Table 5). Based on the results, there exists a high significant difference between taro genotype agronomic characters and yields of taro collections. The application of multivariate analysis tests by Tukey HSD test at (p>0.00) revealed a significant difference between taro accessions with reference to yield performances. At 95% confidence level interval, the hypothesis test results in a P-value, statistically, there is a significant difference between genotype performance characters and yields. This could mean that the selection of taro genotypes could be based on these genotype characters as a benchmark for selecting key characters to efficiently maximize taro productivity. Therefore, the selection of taro genotype accessions could be pegged on key desirable heritable characters with high genetic diversity, its adaptability to agrozones and yield potential towards improving taro productivity.

Genotype performance characters and yields	Sum of Squares	Mean Squares	Df	Error	F	Sig.
Corms circumference	5821.706	4704.888	24	477.677	236.388	.05
Plant height	73244.275	68748.545	24	2171.012	759.998	.05
Leaf length	17899.37	16806.04	24	471.644	855.154	.05
Number of suckers	545.853	227.527	24	191.763	28.476	.05
Corms and yields	2588.395	2219.379	24	179.268	297.126	.05
Cormels and yields	863.905	139.98	24	216.060	15.549	.001

Table 5: Analysis of Variance of Morphological Characters and Yields Related Traits for amongst Kenyan taro accessions

IV. DISCUSSION OF THE FINDINGS

Generally, phenotypic characters showed polymorphism amongst the taro germplasm collections. Genetic variation in morphological characters and yield related traits of taro collections. The phenotypic characterization results show that there exists a wide genetic variation amongst taro collections with regard to phenotypic characters and yield related traits amongst taro genotypes in Kenya. The phenotypic characters showed distinct polymorphic variations from various qualitative characters and their Shannon's genetic diversity indices within the total taro genotypes were high.

Most taro collections had their phenotypic characters with the highest genetic diversity index such as suckers, corms/cormels, leaf and petiole just to mention a few of them. This shows that, most taro accessions could produce suckers as a clear indicator of good taro production in terms of corm yields. Taro suckering ability is a heritable characteristic that exists amongst taro genotypes (Cheema *et al.*, 2006; Dwivedi and Sen, 1999). Paul and Bari (2011) and Sivan (1980) found out that, the number and size of suckers produced by each taro genotypes determines corm shape, corm yields for taro production system.

Stolon formation was one of the phenotypic characters with the lowest genetic diversity indices.

The presence of stolons is often found to be co-related with undesirable traits amongst taro accessions. This confirmed that it's one of the specific trait that could be observed for selection by taro breeders. This result for this character is a clear indicator or pointer of good taro production in terms of corm yields. Studies by Paul and Bari (2011) on taro yields reported that absence of stolon formation is a clear indication of desirable heritable traits amongst taro accessions like corm yields and corm shape. This has confirmed that the stolon phenotypic characterization is a heritable trait amongst taro genotypes that could be potentially be considered for selection of taro genotypes. The presence of stolons among taro genotypes contributes significantly to yield production.

Paul and Bari (2011) and Solomon *et. al.* (2014) found out that corm length (0.6153); corm weight (0.2273); plant height (0.197); petole length (0.34) had direct and indirect effect at the yield per plant at the phenotypic and genotypic level. Solomon *et al.* (2014) reported that cormel fresh weight (47.68%), number of cormels per plant (49.43%), corm dry matter (43.59%), cormel dry matter (43.15%), cormel length (26.85%), corm diameter (22.37%) and corm length (32.87%) among Ethiopian genotypes displayed high morphological variation between genotypes. This means that these phenotype characters a better opportunity and potential for further utilization of its genetic improvement through selection and hybridization.

On corms/cormels and suckering characteristics, the phenotypic characters with the highest genetic Shannon's diversity index were corm shape and suckering ability. This could mean that corm shape and yields is dictated by number of suckers produced by each taro genotype. The higher number of stolons the lower the corm yield per taro genotype (Paul and Bari (2011). Majority of the Kenya taro genotypes exhibited short; intermediate; long stolon characterization. This explained the fact the taro farmers have very limited information in high yielding varieties from different parts of the country due to uncoordinated and limited taro researches. This assertion is also true because of decreased taro production in Kenya as a result of poor selection of quality planting materials and taro variety /cultivating with low suckering and stolon ability for both upland and lowland taro production in Kenya.

This corroborated by similar study by Sivan (1977) and (1980) who found out that the number of suckers produced is influenced to a large extent by the production system and cultural practices given that suckering ability is highly inheritable. Assessment of the genetic diversity of germplasm of many crops including taro would be very vital for development of specific traits.

Bucker *et al.*, (2006) and Elameen *et al.*, (2008) reported that the diversity analysis of germplasm can be performed using data from morphological levels. Similar studies by Dudly and Moll (1969) on heritable traits also found out that any breeding program for improving the genetic pattern of crop depends on the nature and magnitude of variability and the extent to which the desirable characters are heritable. These findings could mean that low taro yields are determined by its suckering ability or heritable character. Therefore, the phenotypic suckering ability character is a key selection factors for taro germplasm accessions to improve its yields.

Leaf and petiole phenotypic characters have demonstrated clearly that both of them have direct and indirect effects on taro genotype performance in terms of yield stability per plant at the genotypic level. Findings by Bertan *et al.* (2007) and Garcia *et al.* (2006) were similar to these results and they found that significant correlations exist between several phenotypic vegetative traits and yield of a plant. Leaf blade color, vein junction color and lamina margin color predominant shape of lamina and predominant shape of leaf lamina surface, and leaf lamina variegation hold highest criteria for selection by taro breeders. The findings are in agreement with several authors who reported that the knowledge of genetic diversity can also aid in the dissection of population subsets selected for specific traits (Verma and Cho, 2004; Mohammadi and Prasanna, 2003).

Similarly, these phenotypic characters are in accordance to the findings of Paul and Bari (2011) who found out that the phenotype characters such as plant height, petiole length and numbers of suckers have direct effect on yield per plant at the genotypic level. Offori and Bernett-larteg (1995) reported that morphological characters are important diagnostic features for distinguishing genotypes. These results are supporting this fact of phenotypic characteristics serving as genetic markers. This is in agreement with what was reported by Barrett and Kidwell (1998) that the knowledge of genetic diversity with any set of germplasm is very vital towards the selection of parental combinations for development of mapping populations with maximum genetic variability. Therefore, phenotypic characters hold the highest criteria to be selected in taro crop breeding programme towards improving it. This emphasizes the need of embracing the concept of taro client oriented breeding approach that encourages efficient production system in many crops. This brings closer the research based knowledge information to the rural farmers on efficient and proper utilization of taro crop like any other dominated cash crops in the mainstream farming.

In terms of total taro yields production potential, the Kenyan taro genotypes have clearly demonstrated a greater production potential. With estimation of taro cultivation in one hectare, taro accessions could produce 5.8 ton/ ha^{-1} of yields as per the findings. This result shows a clear indication of very good genotypes performances in terms of yields potential. Singh *et al.* (2012) found out that taro could produce an average of 6 ton/ ha^{-1}. The higher yielding great potential of Kenyan taro genotypes. This is in agreement with what Goenaga and Chardon (1993) and (1995) who reported that taro crop could yields 34000 and 20000 kgha-1. This analysis of taro genotypic agronomic characters performance has revealed the potential characters determining yields among taro accessions. In order to maximize taro genotypes yields performance, the selection of accessions could be based on such characters including the weight of cormels, the plant height, plant span, petiole length, leaf length and breadth, number of cormels, cormel breadth among others. These results are in agreement with Cheema *et al.* (2007) who observed a clear correlation between the numbers of cormel per plant. They observed that the corm weight and length or circumference had direct positive effects on total yields per plant accession. Similarly, Paul and Bari (2011) also reported that in order to efficiently maximize the cormels yield in taro; the selection can be based on corm weight and higher girth of main sucker. This could mean the selection of taro genotypes be based on such characters to efficiently maximize the cormels yields in taro.

Findings by Bertan *et al.* (2007), Cheema *et al.* (2006), Dwivedi and Sen (1999), Paul and Bari (2011) and Palapala *et. al.*, (2009) have also reported that phenotypic and genotypic characters such as petiole, leaf and corm characteristics holds higher merits to be selected for taro breeding programme towards improving its production. They reported that these characters exhibited direct effects on yield per plant at the genotypic level. Bertan *et al.* (2007) and Palapala *et. al.*, (2005) also found that the phenotypic performance for specific traits, adaptability to certain agrozones and yield stability are some of different methods employed by breeders towards classification of germplasm into heterotic groups. This concurs with Baig *et al.*, 2009 who reported that knowledge of genetic variation and genetic relationship among genotypes is an important consideration for classification, utilization of germplasm resources and breeding.

V. CONCLUSIONS

The phenotypic characters showed distinct polymorphic genetic variations amongst taro collections. Most Kenyan taro genotypes produced suckers but lacked stolon. The suckering phenotypic ability and stolon formation ability are good phenotypic indicators of desirable heritable traits that are important for taro crop productivity and breeding in terms of yields. Genetic variation that exists in phenotypic characters' holds higher criteria for selection by taro breeders. Phenotypic characterization of taro genotypes could be used as a benchmark for selection and identifying heritable desirable traits towards improving food security in terms of taro productivity, germplasm diversification and breeding.

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