Morpho-agronomic characterization of Lake Victoria Basin taro genotypes

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Abstract

An on-farm experiment was conducted in Kenya to assess the agro-morphological diversity of taro cocoyam accessions based on phenotypic characters. One hundred and seventy accessions of taro collected from the Lake Victoria basin of Kenya and Uganda were evaluated-morphologically using the IPGRI descriptors. 18 qualitative and 17 quantitative characters were studied. Hierarchical cluster analysis identified two major clusters each with various subgroups. Most qualitative and quantitative descriptors displayed considerable variability. Diversified qualitative taro characters were leaf margin color, lower leaf color, petiole color and leaf surface glossiness while growth habit, exterior corm surface texture, corm shape and corm exterior color were monomorphic. Most divergent quantitative parameters were observed in corm weight, plant span and height and petiole length while low variability was seen in the ability to produce sucker above ground, corm length and diameter. Pearson's correlation revealed significant correlation between corm weight, corm length and corm diameter and some qualitative and quantitative taro characters. Euclidean proximity similarity matrix for all the tested taro samples was 82.1% for quantitative parameters. These data indicate significant genetic variation exists within the genotypes used in this study and that the germplasm would be of great value as a genetic resource in breeding programs.

Keywords: Cocoyam; Germplasm; Colocasia esculenta; Descriptors.

Introduction

Cocoyam (*Colocasia esculenta)* a perennial herb with origins in South Central Asia and presently grown widely grown around the world, *is* among the major crops grown in the wetlands and uplands of Lake Victoria basin of East Africa (Talwana et. al., 2009; Serem et al. 2008). Taro belongs to the genus *Colocasia*, within the sub-family Colocasioideae of the monocotyledonous family Araceae. Because of a long history of vegetative propagation, there is considerable confusion in the taxonomy of the genus *Colocasia (*Onwueme, 1999). Cultivated taro is classified as *Colocasia esculenta*, but the species is considered to be polymorphic. There are at least two botanical varieties (Purseglove, 1972):Globally, cocoyam is the 14th most consumed vegetable in the world (FAO, 1998). It is highly nutritious and the leaves are consumed because they are rich in protein and vitamins while the root is rich in carbohydrates and minerals (Dako, 1981; Dura and Uma, 2003). The crop offers a high potential for alleviating food insecurity and can be promoted to contribute to food diversity and improved livelihoods.

In spite of various efforts to achieve food security in East Africa, the status remains unattained and malnutrition is prevalent in many communities around the Lake Victoria basin. While there are concerted efforts to increase the production of high value crops including maize, wheat and rice, contrasting emphasis is placed on indigenous crops including taro and tannia (*Xanthosoma sagittifolia*) cocoyam among other crops. However, for various reasons that include culture, low costs of production and environmental adaptability, small scale rural farmers rely on these marginalized food crops (Chumo, 2007). Opportunities to promote and support the use of alternative food crops can make a major contribution to the food security of farmers in the tropics particularly in East Africa.

In the Lake Victoria basin, taro is popular and successfully grown due to its adaptability to a wide range of soil and climatic conditions (Chumo, 2007). The crop is thus adaptable to varied environmental factors for survival in ecological zones. The interplay between diverse cultivation practices, biotic and abiotic factors may have resulted in the development or modification of taro landraces and inherent allelic frequencies of desirable traits in the region. Since the extent of genetic variability in the crop as well as genotype performance remains unknown indicates a vast and largely untapped potential for research on cocoyam in the region.

Since characterization of germplasm and search for desirable traits are important in crop productivity and breeding, there is therefore, the need to fully investigate, identify and correlate taro landraces to their agronomic and physiological performances. This study is a first step towards understanding the genetic variability of taro in the region. The objective of the study was to identify the extent of phenotypic variability in quantitative and qualitative traits within the Lake Victoria taro landraces.

Material and methods

The plant material was made up of 170 taro cocoyam accessions collected from a wide range of agricultural zones in the Lake Victoria basin. This comprised 153 Kenya (Accession numbers 1-153) and 17 Uganda taro accessions (numbers 154-170) (Data not shown). Corm suckers were planted as upland cocoyam in 2008 and 2009 at the Masinde Muliro University experimental field in Kakamega, Kenya. The cocoyam accessions were planted at a distance of 2m x 2m between rows and plants. A field experiment was conducted at the Makerere University Agricultural Research Institute Kabanyolo (MUARIK), located about 14 km North East of Kampala, at an elevation between 1250m and 1320m above the sea level. The soils at MUARIK are deep, highly weathered with a pH of 5.0 – 6.0; the climate is tropical, with annual rainfall of about 1300mm, divided into two peaks: abroad peak in March to May and a narrow peak in October to November. The daily maximum temperatures vary from 26^0C in July to 28.5^0C in January and daily minimum temperatures vary from 15.5^0 C in July/August to 17.4^0 C in April.

Taro basal stems (the apical 1-2 cm of the corm with the basal 15-20 cm of the petioles attached) collected from neighbouring farmers' fields were planted out in the field in August 2007 and March 2008 and arranged in a split – split – plot design with three replications

Phenotypic descriptors of taro as described by IPGRI (1999) were evaluated at four months after planting wile corm characteristics were recorded after six months. The quantitative characters evaluated were: Plant span; Plant height; No. of sprouting cormel suckers; Cormel sucker length; Leaf lamina length; Leaf lamina width; Petiole length; Leaf sheath length; Midrib length; Denuding angle; Collecting vein number; Number of leaves; Corm weight; Corm length; Corm diameter; No. of cormels/corm and Plant span. Qualitative descriptors recorded were: Growth habit; Interior sheath color; Petiole attachment; Lamina orientation; Leaf shape; Leaf margin color; Leaf sinus denuding; Leaf surface glossy; Leaf margin type; Leaf vein color; Upper leaf color; Lower leaf color; Petiole color; Vein pattern

To illustrate variability among individual accessions descriptive statistics (mean, standard error of mean, variance, standard deviation and range), correlation and cluster analysis were computed. Pearson's correlation bivariate analysis was carried between qualitative and quantitative parameters on one hand and corm weight, corm length and corm diameter on the other at P=0.01 significance level. Correlation distance (proximity similarity matrix) for taro accessions was calculated using binary Euclidean distance for qualitative and quantitative parameters separately. A hierarchical cluster dendogram was generated using proximity matrix (rescaled distance of the average linkage) between accessions. For this matrix, Pearson correlation coefficients were generated from all quantitative morphological data using SPSS Version 11.5 software package programme.

Results and discussions

For the qualitative morphological characters evaluated, considerable morphological variations were observed for most parameters of taro (Table 1). There was uniformity in most qualitative parameters including the leaf shape, lamina position, corm flesh color while the quantitative parameters were highly variable. Slight variation was observed some characters. 97.6% of accessions had a yellow interior leaf sheath color. In most accessions, variability in qualitative characters was significant. For example, leaf attachment was peltate (in 65.3% of accessions), subpeltate (32.4%) or nonpeltate (2.4%) while lamina orientation was either in downward plane

(77.1%), erect plane (5.9%) or cup-shaped (17.1%). Leaf shape was either without basal bodies (1.8%), hastate (22.9%), sagittate with entire leaf (44.2%), sagittate with basal bodies (5.4%). The leaf margin color was concolorous in 39.4%, purple/red (60%) or clear edge (0.6%) of accessions. For leaf sinus, denuding was either absent (15.3%), slightly present (84.1) or totally present (0.6%). Leaf surface was glossy in 87.1% and not glossy (12.6%). The upper leaf color of tested taro accessions ranged from being light green (37.6%), medium green (46.5%), dark green (12.9%) or reddish/purple green (2.9%) while the lower leaf color was light green in 26.5%, medium green (26.5% or green streaked with red/purple (47.1%). Most taro accessions (71.2%) had petiole color as red/purple color while light green and green streaked with red/purple were in 25.9% and 2.9% respectively. All taro accessions had Y-shaped (85.9%) or V-shaped (14.1%) vein pattern or yellow (7.1%), orange (16.5%) or purple (70.6%) colored veins. Leaf margins were entirely smooth (53.5%) or undulate (46.5%). The proportion of taro with purple corm interior color was 89.4% either while those with white were 10.6%. From these results the most diversified qualitative taro characters were leaf margin color, lower leaf colour, petiole colour and leaf surface glossiness. However, all tested accessions had acaulescent growth form, fibrous corm exterior surface/texture, elliptical corm shape and dark brown corm exterior colour.

Table 1. Variability of some qualitative parameters within taro accessions

Parameter	Mean±S.E	Standard deviation	Variance
Interior sheath color	2.05 ±0.023	0.305	0.093
Petiole attachment	1.37±0.041	0.531	0.283
Lamina orientation	2.11±0.036	0.467	0.218
Leaf shape	2.82±0.045	.593	0.351
Leaf margin color	2.25±0.091	1.187	1.409
Leaf sinus denuding	1.850±0.28	0.371	0.138
Leaf surface glossy	0.94±0.065	0.844	0.712
Leaf margin type	1.46±0.038	0.500	0.250
Leaf vein color	3.75±0.051	0.669	0.447
Upper leaf color	1.81±0.059	0.769	0.592
Lower leaf color	2.68±0.100	1.304	1.669
Petiole color	2.54±0.071	0.924	0.854
Vein pattern	2.72±0.054	0.698	0.488
Corm interior color	1.11±0.02	0.309	0.095

N=170

Few taro traits displayed positive correlation with corm weight, diameter and length (Table 2). However, a strong positive correlation was observed between corm weight and leaf margin type, petiole color. As expected the highest correlations were observed between the corm weight and corm dimensions. Significant negative correlation was seen between corm weight and petiole attachment, lamina orientation and leaf surface glossiness. Interestingly, petiole and lamina parameters that were quite divergent also showed very high correlation with corm weight.

Quantitative characters were highly variable for all tested taro accessions (Table 3). Greatest variation was observed in corm weight, plant span and height and petiole length while low variability was observed in ability to produce sucker above ground, corm length and diameter. While 99.8% of the tested accessions did not sprout cormel suckers above the ground, most harvested corms possessed cormels. The corm weight, plant span and denuding angle were the most divergent characters and would be useful parameters in gauging biodiversity variation among cultivated taro.

Correlation analysis revealed that the Euclidean proximity similarity matrix for all the tested taro samples was 82.1% for quantitative parameters. Pearson's correlation revealed significant correlation between corm weight, corm length and corm diameter and some qualitative and quantitative taro characters. After four months of cultivation, significant positive correlation between corm weight/yield and some vegetative characters including plant span, plant height, number of leaves, lamina width and height, midrib length and leaf sheath length

(Table 4). Garcia et al., (2006) and Dwevedi and Sen (1999) showed significant correlations between yield and several vegetative traits. This reinforces the suitability of agronomic characters in selecting genotypes.

Table 2. Pearson-Correlation between taro corm characters and qualitative parameters

Parameters	Corm weight	Corm length	Corm diameter
Interior sheath color	-0.068	-0.189*	0.015
Petiole attachment*	-0.190*	-0.130	-0.180*
Lamina orientation	-0.188*	-0.380**	0.018
Leaf shape*	0.098	0.377**	-0.165*
Leaf margin color*	0.220**	0.111	0.152*
Leaf sinus denuding	0.004	-0.299**	0.009
Leaf surface glossy	-0.172*	0.048	-0.110
Leaf margin type	0.358**	0.123	-0.001
Leaf vein color	0.161*	0.149	-0.046
Upper leaf color	0.054	0.085	0.344**
Lower leaf color	-0.054	0.101	-0.198**
Petiole color	0.221**	0.297*	0.048
Vein pattern	0.124	0.343**	0.030
Corm interior color	0.049	0.223**	0.168*

Computed at P=0.1 except for * where P=0.05

Table 3. Variability of some qualitative parameters of taro cocoyam accessions

Parameter	Mean±S.E	Standard deviation	Min.	Max.	Variance	Range
Plant span (cm)	61.28 ±1.40	18.23	14.00	130.00	332.23	116
Plant height (cm)	42.95 ±0.99	13.04	14.00	83.00	169.95	69
No. of sprouting cormel suckers*[1]	1.50 ± 0.50	0.70	1	2	0.50	1
Cormel sucker length*[2](cm)	22.10±3.90	5.51	18.2	26.00	30.42	7.80
Leaf lamina length (cm)	29.45±0.65	8.50	7.50	50.00	72.39	42.50
Leaf lamina width (cm)	20.65 ± 0.58	7.55	6.20	78.00	57.03	71.80
Petiole length (cm)	34.15 ±0.93	12.07	12.80	72.00	145.81	59.20
Leaf sheath length (cm)	17.17 ±0.64	8.32	2	49.00	69.37	47
Midrib length (cm)	17.93 ±0.38	4.98	5.50	30.20	24.79	24.70
Denuding angle (°)	57.33±1.26	16.47	10	110.00	271.21	100
Collecting vein number	9.8 ±0.55	7.15	5	99.00	51.12	94
Number of leaves	5.72 ±0.09	1.16	2	9.00	1.35	7
Corm weight (g)	198.25±10.78	140.50	19.39	927.00	19741.05	908.35
Corm length (cm)	12.43±0.43	5.56	1	25.50	3.96	24.50
Corm diameter (cm)	3.76±0.09	1.13	1	6.70	1.28	5.70
No. of cormels/corm	3.44±0.22	2.91	0	16.00	8.46	16

*[1] Mean computed with reference to only accessions with cormel suckers present (N=2)

*[2] Computed as the horizontal ground distance between a main corm plant (stem) and its relative sucker sprout (N=2)

Table 4. Pearson-Correlation between taro corm and quantitative characters

Plant characteristics	Corm weight	Corm length	Corm diameter
Plant span	0.444**	0.039	0.398**
Plant height	0.570**	0.149	0.490**
No. of sprouting cormel suckers	1.000**	1.000**	1.000**
Cormel sucker length	-1.000**	-1.000**	1.000**
Leaf lamina length	0.478**	-0.035	0.418**
Leaf lamina width	0.444**	0.135	0.342**
Petiole length	0.559**	-0.294**	0400**
Leaf sheath length	0.560**	0.102	0.541**
Midrib length	0.545**	-0.055	0.475**
Denuding angle	-0.034	-0.381**	0.163*
Collecting vein number	-0.038	-0.197*	0.010
Number of leaves	0.243**	0.189*	0.212**
Corm weight	-	0.199**	0.732**
Corm length	0.199**	-	-
Corm diameter	0.732**	0.030	-
No. of cormels/corm	0.447**	0.152**	0.465**

Computed at P=0.05

On the basis of quantitative traits, the hierarchical classification of the collected taro biodiversity showed similarity between groups. Two major groups were categorized (dendogram not shown). One group comprising only one plant (Acc. 126) was very unique. On the basis of quantitative traits, the hierarchical classification of the collected taro biodiversity showed similarity and differences between groups. Two major groups were categorized. One group comprising only one plant (Acc. 126) was very unique from a clade which had further two major subcategories comprising a smaller group and a larger group. In all, nine distinct taro subgroups were identified. These nine taro subgroups may be cultivar lines within the large taro population present in East Africa. Within the latter group there was a high degree of variability and it is here that the Ugandan taro accessions were located. However, no distinct geographical clades were observed signifying the relatedness of taro germplasm populations in the region. This high variability of intra-specific productivity in cultivated cocoyam has been shown in tannia (Tambong et al., 1997).

All taro accessions in the region had monomorphic trait loci for growth habit, corm exterior surface texture, corm shape and corm exterior color. The corm weight, plant span and height and petiole length were the most divergent quantitative traits and could be used to select agronomically important accessions for breeding and cultivation. The correlation between corm weight and other morphological traits is could be a tool for selecting taro accessions for agronomic purposes. However, there is need to determine genetic variability since it has been shown that morphological variability in taro does not necessarily translate into a variable genetic base (Lebot and Aradhya, 1991).

The genetic variation displayed by the cluster dendogram, highlights an important biodiversity pool for genetic resources that could be harnessed for better agricultural exploitation of cocoyam germplasm in the region. Given the neglected and underutilized status of taro cocoyam in Africa, for a sustainable breeding program whose mandate would be to develop well adapted and cultivars with increased crop productivity, it will be important to build taro conservation strategies in the region. It will be interesting to develop genetic markers linked to the discussed phenotypic traits. This will be important in defining the genetic relatedness and biodiversity of taro cocoyam, and in cloning genes of agronomic importance (quantitative trait loci; QTL). In this study, biodiversity variation was not linked to geographical distribution. There would be need to critically assess and determine the degree of genetic variation in the constituent East African countries.

Conclusion

The analysis of phenotypic variability and agronomic assessment of 170 accessions in the East Africa Lake basin region indicate that significant phenotypic variation exists among taro cocoyam populations and that, traits like corm weight, plant span and denuding angle are quite divergent parameters and would be useful parameters in gauging biodiversity variation among cultivated taro in the region. Our aim is to establish a biological database for the conservation of taro in the region and selection of high yielding genotypes for distribution to farmers. According to the correlation matrix, the most important vegetative characters corresponding to increased productivity (corm weight) we can focus our selection on traits such as plant span and height, and leaf lamina height and size. To maximize utility of taro germplasm resources in the region, however, there will be need to correlate results from the morphological evaluation with a genetic analysis as a strategy towards selecting germplasm for breeding.

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