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Morphological variability within the Kenyan yam (*Dioscorea spp.*)

Mwirigi, P.N*., Kahangi, E. M., Nyende, A. B. and Mamati, E.G.
Department of Horticulture, Jomo Kenyatta University of Agriculture and Technology, P.O. Box 62000-00200, Nairobi

Corresponding author e-mai: mwirigip@yahoo.com

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ABSTRACT
Objective: To characterize 43 Kenyan yam cultivars using morphological characters.
Methodology and results: Yam cultivars were collected in the major yam growing districts in Kenya. Data of 17 morphological variables measured on these accessions were subjected to multivariate analysis using Principal Component Analysis (PCA) and clustering criterion. The results indicated that the characters contributing most to variability were twining direction, stem colour, spine shape, leaf type and presence or absence of flowering for above ground plant parts; and tuber flesh colour, skin colour, shape of the tuber, hardness of the tuber when cooked, and presence or absence of roots on the tuber surface for the parts below ground. The pruned dendogram generated through agglomerative hierarchical clustering based on the similarity matrix revealed four main groups of this species. One group had only one cultivar which was collected in only one locality in Meru. This is possibly a newly discovered cultivar that has not been previously documented.
Conclusion and potential application of findings: This study has showed that there is wide variability in the major yam cultivars grown in Kenya and this can be used to breed higher yielding varieties or screen for cultivars resistant to pests and diseases. The results would also be useful for conservation planning and genetic improvement of the crop. Nevertheless further confirmatory research is required using molecular tools to analyze the diversity detected.

Key words: Characterization, dendogram, *Dioscorea spp.,* morphology, multivariate analysis

INTRODUCTION

Yam (*Dioscorea spp*) is important for food security in East and West Africa where 95% of the world production occurs (FAO, 1991). It is a source of food and cash income for many small scale farmers, including women who are involved as producers, processors and traders. High market value and consumer demand make yam a perfect candidate for a market-driven intensification of production. The major factors affecting production include lack of knowledge on appropriate production methods, poor germplasm that is highly susceptible to pest damage, chronic lack of healthy planting material and lack of supporting policies (Maina, 2008). In the Central highlands of Kenya where considerable yam production still occurs around Mt. Kenya, yams are grown in a near perennial manner, leaving the mother tuber in the soil for prolonged periods before new yam is planted on fresh ground. This practice results in poor quality vines, low yield, and serious attacks especially by soil borne pests and pathogens (Maina, 2008). Policies tilted in favour of cereal grains, especially maize and cash crops, e.g. coffee or tea are other factors that have led to a decline in productivity. Yam, compared to maize, is less vulnerable to variations in climate effects, e.g. rainfall, and therefore food security would not be so heavily compromised when rains fail. Yam harvesting, unlike maize, can also be staggered to varying times of the year without seasonal limitation, thus assuring households of some reliable source of food.

Compared to other major staple crops, e.g. cassava, maize, rice and sorghum, yam is an under-researched crop. Available information indicates that Kenyan yam diversity is represented by a number of cultivars within *D. bulbifera, D. minutifolia* and *D. dumetorum* species (Maundu *et al*., 1999). They are grown for food mainly by elderly farmers in Eastern, Central, Western and Coastal regions of the country. *D. minutiflora* was the most commonly grown yam in Kenya but its use as food has declined rapidly in recent decades. It is now rarely cultivated, and is almost invariably maintained by elderly women as a matter of tradition in their small farms (Maundu *et al*., 1999).

The identification of variability among accessions is pivotal to the maintenance, utilisation and further acquisition of germplasm resources. Various numerical taxonomic techniques have been successfully used to classify variation patterns at both intra and inter-specific levels (Sneath & Sokal, 1973; Chheda & Fatokun, 1982; Ariyo, 1991).

Principal component analysis (PCA) is a descriptive technique which reveals the pattern of character variation among individual accessions. It reduces a set of multivariate data into units or components that account for meaningful amounts of variation in a population (Atchley & Bryant, 1975). Another technique commonly used is canonical analysis, which unlike PCA, separates and forms two sets of variates from which highly correlated variables are separated to form a new unit of within and between groups (Lawley & Maxwell, 1971). Cluster analysis decreases the number of individual variable units by classifying such variation into groups which are translated into a dendogram using the coefficient of similarity (Sneath & Sokal, 1973; Tatineni *et al*., 1996).

In the present study, the major cultivars grown in selected yam growing regions of Kenya were determined and multivariate analysis of principal components and cluster analysis based on morphological traits performed to determine the level of variability and the relationship among the accessions.

MATERIALS AND METHODS

The study area covered Meru Central (Eastern Kenya), Teso, Bungoma-West and Hamisi (Western Kenya) and Nyeri North and South districts (Central Kenya).

A house hold level survey covering the six districts was conducted from August 2007 to February 2008. A stratified sampling procedure was followed to define the sampling units. The area was first stratified in terms of geographical distance to cover the approximate ecological range of yams so that valid generalizations could be drawn from the findings. Consultation with the district agricultural officers and key informants knowledgeable with the area enabled accurate identification of the farmers growing yams.

Data was collected through personal interviews with members in each household responsible for management of yam fields using structured and semi-structured questionnaires. The semi-structured questionnaire was included to enable full consideration of the open-ended questions such as how farmers evaluate and identify the different landraces.

The number of landraces in each farm was recorded on-farm, where each farmer was asked to distinguish, name and describe the different landraces he/she was growing. This was then accompanied by physical recording of the selected morphological characters. This was conducted during the time of the year when yams were still growing in the field to aid identification of the different morphotypes.

Data recording: Data for morphological characteristics was observed directly on living plants under field conditions. Initially, 22 characteristics were considered but later pruned to 17 agro-morphological traits (Table

1). The characters observed and methods of data recording were as previously described (IPGRI, 1997), with slight modification. The data was recorded either directly from the measurements using a scale of 1-9 or as a binary recording (1=present; 0=absent).

Data analysis: All data were standardized and then subjected to Agglomerative Cluster analysis using unweighted pair-group average method. Principal component analysis was performed using the XLSTAT software version 2008.4.02. In the PCA, the data was used to generate Eigen values, percentage of the variation accumulated by the PCA and the load coefficient values between the original characters and respective PCA. The first two principal components which accounted for the highest variation were used to plot the two-dimensional dispersion or scatter diagram of the accessions. A similarity matrix was used to generate a morphological distance plot among the accessions using Euclidean similarity coefficients and then used to generate an Agglomerative Hierarchical (AHC) dendogram through unweighted pair-group average (UPGA) using XLSTAT 2008.4.02software. This analysis is used to study patterns of variance and relationships among accessions where accessions that are close genetically are placed in close proximity in the dendogram.

Table 1: Morphological traits used to describe Kenyan yam (*Dioscorea* Spp.) accessions.

Code	Characters	Score Code-Descriptor State
1	Twining direction	0-Anticlockwise;
2	Stem colour	1-Light green; 2-Deep green; 3-Grey; 4-Dark brown; 5-Green; 6-Yellow
3	Spines on the stem base	1-Many; 2-Few; 0-Absent
4	Spine shape	1-Straight; 2-Curved down; 3-Curved up; 0-Absent
5	Leaf position	1-Alternate; 0-Opposite
6	Leaf colour	1-Light green; 2-Deep green; 5-Green; 3-Grey
7	Flowering	1-Flowering; 0-Not flowering
8	Tuber flesh colour at central transverse cross-section	1-White; 6-Yellow; 4-Brown; 7-Red; 3-Grey; 8-purple
9	Tuber skin colour (beneath the bark)	6-Yellow; 3-Grey; 4-Brown; 7-Red; 8-Purple; 1-White
10	Tuber shape	2-Irregular; 3-Oval; 4-Oblong; 1-Straight; 5-Round
11	Roots on the tuber surface	2-Few; 1-Many; 0-Absent
12	Hardness of the tuber (when cooked)	1-Hard; 2-Soft; 3-Medium

RESULTS

A total of 43 yam accessions were collected from six selected regions in Kenya (Table 2). Meru district had the highest number of different landraces according to local names followed by Nyeri while Western Kenya had the least. Most of these local names represented the same cultivars and this became quite clear after analysis (dendogram, Fig. 3).

Table 2: Local names and collection site (district) of the yam accessions studied.

Cultivar (Local Names)	District
Baribate; Barimutwa; Kambo; Karukwaji; Kijara; Kimwere; Majara; Mbeu Iguru; Mbeu mpuria; Mbeu nkuru; Mbeu ruguru; Mbeuku; Mbithi; Murijo; Murungwa; Mweru; Mwezi I; Mwimba Iguru; Nakirima; Nalo; Ndera ngutu; Ndiathi; Ndiua na thi; Ngundu; Nkandau; Nkone; Ntigania; Ntokinyoni; Nyaara; Air potato (*Dioscorea bulbifera*)	Meru
Emondo	Teso
Embame	Bungoma
Kihama	Hamisi
Nkwa njiru, Njuhi, Muchara, Ichara, Gichara, Muchuka	Nyeri North
Ngiriri, Mwezi II, Unknown, Borani	Nyeri South

Principal component analysis (PCA)

The first five principal components (PCs) with coefficient values greater than 1.0 together explained 66.2% of the total variance present in the data set (Table 3). Scores on the first principal component (PC-1) which accounted for 20% of the total variation were highly correlated (correlation coefficient >0.3) to characters related to twining direction, presence or absence of spines on the stem, position of the leaf on the stem, presence or absence of flowering and presence or absence of roots on the tuber surface (Table 4). The second principal component (PC-2) explained 13.7% of the total variation and was highly associated with the stem colour, presence of spines on the stem, hardness of the tuber when cooked and presence or absence of flowering.

The third component (PC-3) which explained 12.5% of the variation was mainly correlated to characters related to the stem colour, spine shape, leaf colour and tuber flesh colour. The fourth component (PC-4) explained 10.8% of the variation and was determined by the stem colour, tuber skin colour and hardness of the tuber when cooked. The fifth component (PC-5) was related to the twining direction, spine shape and tuber skin colour and accounted for 9.1% of the total variability. Principal component six (PC-6) was dominated by the stem colour, leaf position, leaf colour and the shape of the tuber. The component explained a total of 7.9% of the variation. PC-7, PC-8 and PC-9 explained an additional 7.2, 5.3 and 4.8% of the total variation. PC-7 was correlated to characters related to the spine shape and hardness of the tuber when cooked. PC-8 was dominated by characters that included twining direction, leaf position and tuber flesh colour while PC-9 was correlated to characters such as tuber shape and presence or absence of roots on the tuber surface (Table 4). PC-10, 11, and 12 had variations of less than 4% and were considered to be of less significance to the overall variability.

Table 3: Eigen values and the cumulative variability of the different principal components.

Principal Component	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8
Eigen value	2.406	1.645	1.505	1.294	1.095	0.947	0.875	0.634
Variability (%)	20.053	13.708	12.544	10.780	9.123	7.892	7.291	5.287
Cumulative %	20.053	33.761	46.304	57.085	66.208	74.100	81.390	86.678

Table 4: Correlations between variables and factors

Character	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9
Twinning Direction	0.307*	-0.551	0.106	0.221	0.566	0.044	-0.055	0.336	0.179
Stem Colour	-0.187	0.525	0.342	0.328	0.298	0.369	-0.305	0.219	-0.167
Spines on the Stem	0.410	0.636	-0.402	-0.113	0.210	-0.087	-0.078	0.014	-0.048
Spine Shape	0.241	0.209	0.402	-0.544	0.343	0.159	0.364	-0.215	0.293
Leaf Position	0.406	0.126	-0.606	-0.166	0.003	0.375	0.299	0.342	0.026
Leaf Colour	0.289	0.026	0.606	0.270	-0.311	0.442	0.291	-0.023	-0.083
Flowers	0.546	0.570	0.245	-0.088	-0.097	-0.162	-0.327	-0.018	0.114
Tuber Flesh Colour	-0.548	0.107	0.417	-0.391	-0.026	-0.308	-0.008	0.427	0.140
Tuber Skin Colour	-0.562	0.221	-0.149	0.418	0.474	0.000	0.109	-0.291	0.195
Tuber Shape	-0.599	0.167	-0.242	0.040	-0.381	0.358	-0.148	0.068	0.457
Roots on Tuber Surface	0.713	-0.257	0.044	0.234	-0.136	-0.040	-0.317	-0.075	0.357
Hardness of Tuber (when cooked)	0.149	0.348	0.033	0.580	-0.169	-0.434	0.474	0.179	0.134

*Values in bold indicate the most relevant characters (>0.3) that contributed most to the variation of the particular component.

The distribution of variates based on the PC-1 and PC-2 shows the phenotypic variation among the accessions and how widely dispersed they are along both axes (Fig 1).The two components explain a cumulative variability of 33.76%. Based on the distribution of variates, cultivars Mbeuku (12) and Nakirima (19) are the most distantly related to that group while the second group shows cultivars Kijara (5) and Nkone (26) to be the least similar to the group. The most distant in the third quarter are the cultivars Murungwa (15) and Emondo (21). The last quarter is made up of Mwezi II (17) and Murijo (14) that are least similar to the group (Fig 1).

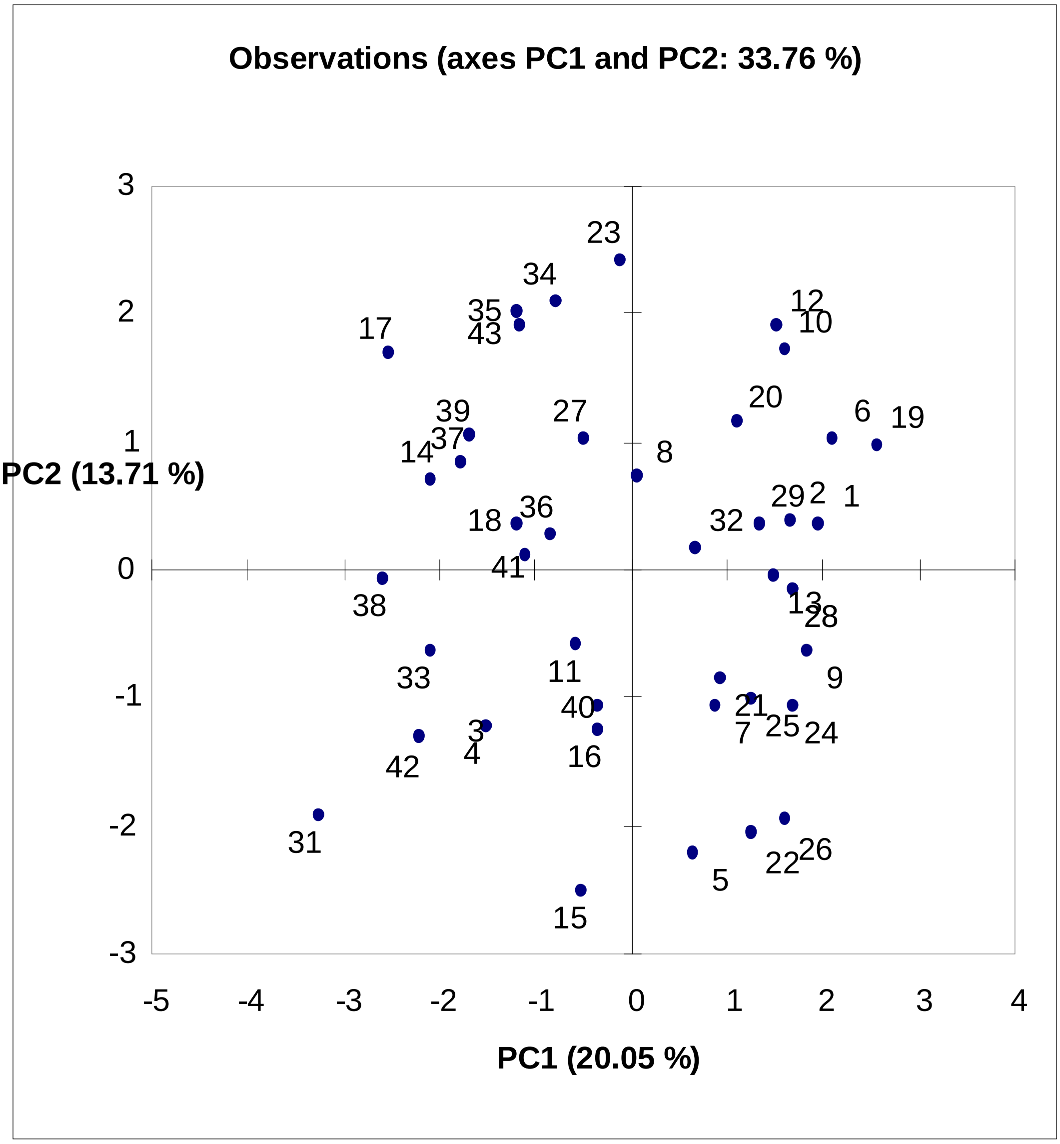

Figure 1: Distribution of variates among accessions in PC-1 and PC-2.

The correlation among characters shows three main clusters of characters (Fig. 2) The first cluster comprised of traits associated with presence or absence of spines on the stem, hardness of the tuber when cooked, spine shape, presence or absence of flowering, leaf position and the leaf colour; the second cluster comprised of traits associated with the twining direction and presence or absence of roots on the tuber surface; the third cluster comprised of characters related to stem colour, tuber skin colour, tuber shape and the tuber flesh colour.

Cluster analysis: The agglomerative hierarchical clustering dendogram illustrates the relationship among the accessions (Fig 3). At 0.92 level of similarity, almost all the 43 accessions were distinct from each other while at 0.72 levels, almost half of the accessions were similar to each other. The cluster analysis separated the 43 accessions as different genotypes with Euclidean similarity distance ranging from 0.99 to 0.42. The pruned dendogram at similarity distance=0.42 identified four main clusters A, B,C &D according to the local names and the major morphological characters associated with them. The first three clusters contained between 13 and 16 accessions per cluster. The first group (A) had only one accession and this could possibly be a new cultivar that has not been documented previously or a rare cultivar grown only in a few areas (Fig. 3). One cultivar was accurately identified in the field as *Dioscorea* bulbifera (air potato) hence was omitted from the analysis (Table 2).

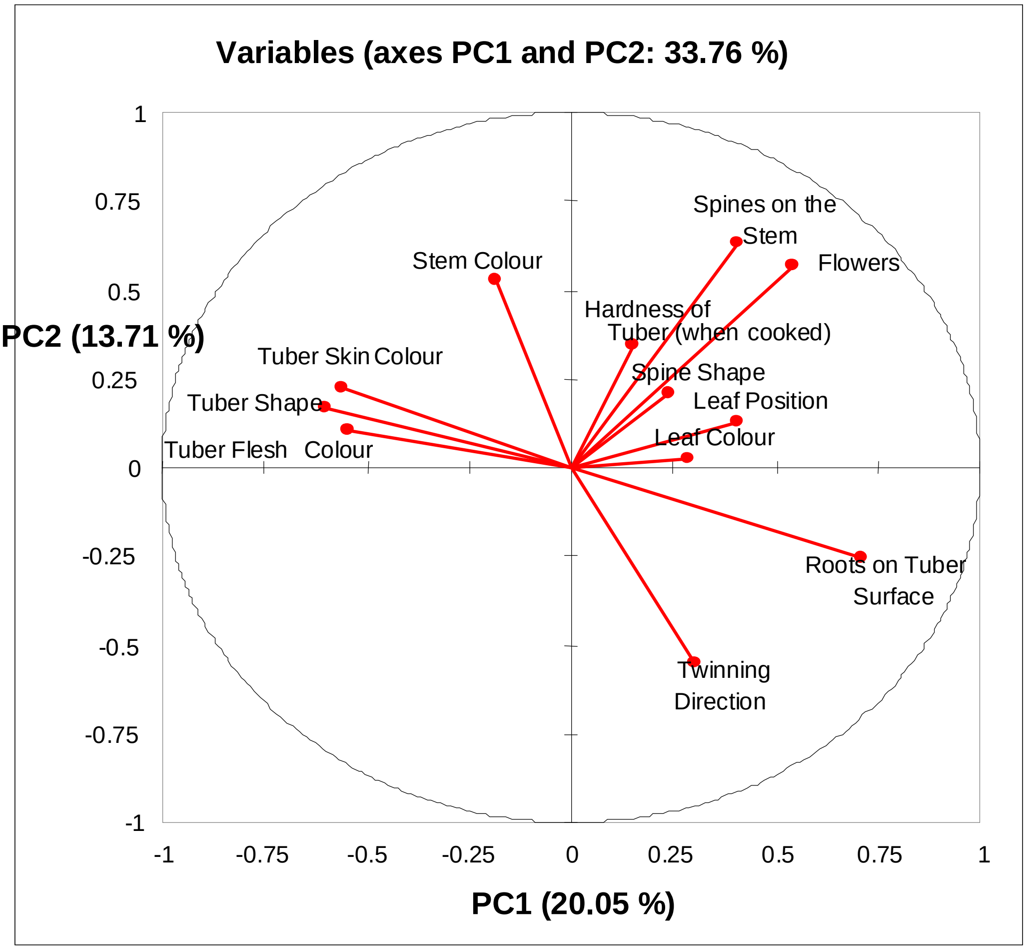

Figure 2: Correlation among characters associated with the first and second principal components. (The closer the attributes are to each other in the PCA plot, the higher the correlation i.e. the smaller the angle between the attributes, the higher the correlation)

DISCUSSION

Multivariate analysis assumes inclusion of genotypes with maximum genetic divergence (Bhatt, 1970; Amurrio *et al*., 1995). Variability was obtained in all the 17 measured characteristics indicating presence of a high degree of morphological polymorphism among the cultivated varieties of yams in Kenya. This indicates the presence of diverse morphotypes at the individual genotype level pointing to ample possibilities of obtaining desirable trait combinations in specific cultivars. This would be crucial in meeting the diverse demands of farmers, researchers and consumers of this crop.

Substantial morphological variation within and between the various accessions may be attributed to cross-pollination and sexual recombination, and perhaps mutation followed by intensive selection by isolated human communities in diverse environments (Martin, 1976). Mutation and intensive human selection for example could have resulted in the emergence of the rather uncommon cultivar (Nkone), which was present only in one farm in Meru district.

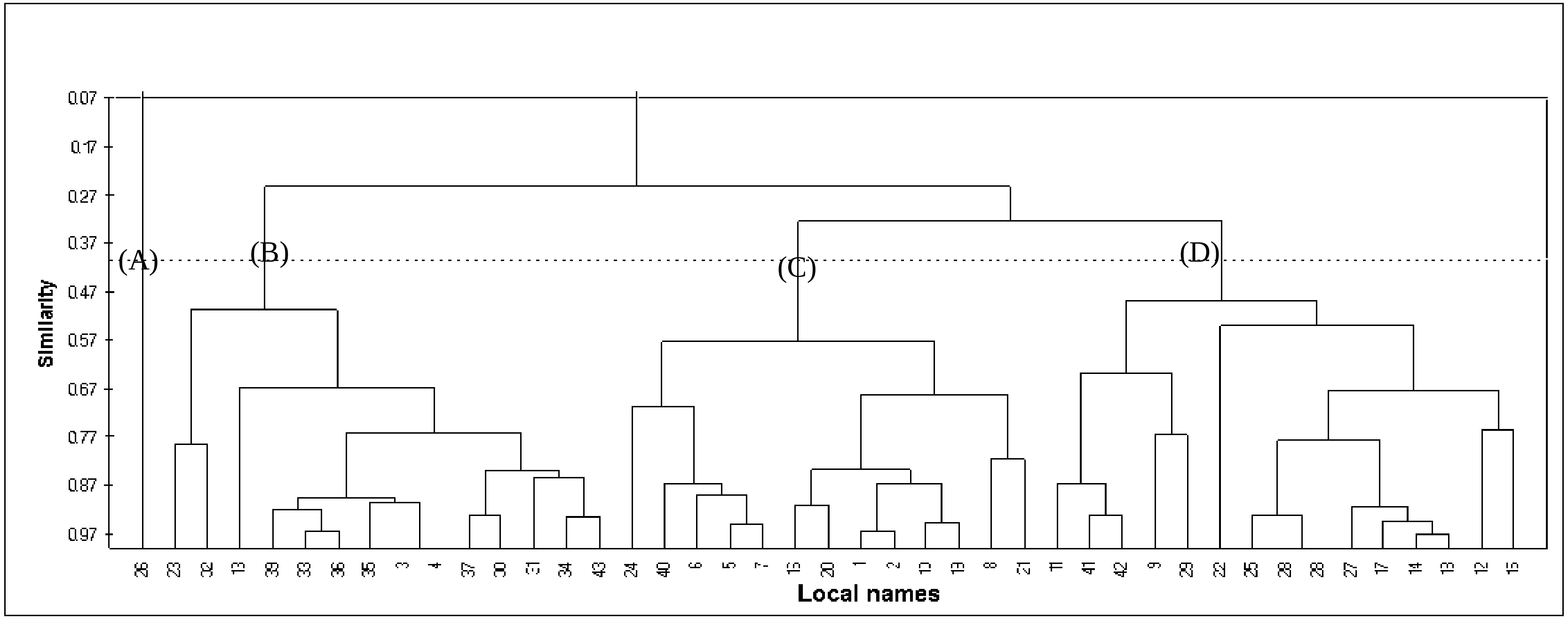

Figure 3: Dendogram constructed based on morphological characters of yams in the major growing areas

Key of local names

Code	Local name	Code	Local name	Code	Local name	Code	Local name	Code	Local name	Code	Local name	Code	Local name	Code	Local name
1	Baribate	6	Kimwere	11	Mbeu ruguru	16	Mweru	21	Ndera ngutu	26	Nkone	32	Embame	37	Ichara
2	Barimutwa	7	Majara	12	Mbeuku	17	Mwezi I	22	Ndiathi	27	Ntigania	33	Kihama	38	Gichara
3	Kambo	8	Mbeu Iguru	13	Mbithi	18	Mwimba Iguru	23	Ndiua na thi	28	Ntokinyoni	34	Nkwa njiru	39	Muchuka
4	Karukwaji	9	Mbeu mpuria	14	Murijo	19	Nakirima	24	Ngundu	29	Nyaara	35	Njuhi	40	Ngiriri
5	Kijara	10	Mbeu nkuru	15	Murungwa	20	Nalo	25	Nkandau	31	Emondo	36	Muchara	41	Mwezi II
42	Unknown	43	Borani												

From the dendogram, it was not possible to group all the cultivars from the different zones into their specific groups but it was clear that majority are related. For example, the first cluster (Fig 3) shows that most of the cultivars from Nyeri are related to one particular cultivar (Karukwaji) from Meru. The other groups are evenly distributed showing there was a possibility of frequent exchange of planting materials among and between farmers from different zones. It is also likely that continuous vegetative propagation and selection have contributed to the wide phenotypic variability of this crop.

The analysis suggests that when numerous characters are considered simultaneously, Principal Component Analysis (PCA) alone may not give an adequate character representation in terms of their relative importance and hence it needs to be complemented with other techniques such as Single Linkage Cluster Analysis (SLCA) which provides a clear and more informative display of the relative positions of the accessions.

Complementary studies, for example using genetic characterization are needed to further accurately identify and classify the major yam cultivars grown in Kenya. In many cases crop germplasm resources are threatened with loss through genetic erosion due to environmental, social, political and economic challenges in the country. Thus genetic conservation and improvement based on the selected materials should be encouraged with an aim to prevent and/or reverse this erosion. Such activities would also maximize the use of these resources.

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