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Diversity of Yam (*Dioscorea spp.*) Populations in South Western Region of Cameroon

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Abstract: Yams are Dioscoreaceae grown in the tropics and sub-tropics and used as food and for related pharmaceutical properties. The South Western Region of Cameroon is a major yam producing zone. This study which evaluates morphological variability between ten linguistically different yam types grown in South Western Cameroon will serve as a necessary step for subsequent genetic study of the species. The yams, collected from nine sites, were planted in a completely randomized design in four locations. Analysis of data on nine morphological vines traits reveals that, the yam types constituted five main clusters. Cluster 1 with 61.3% similarity consists of five accessions of *D. rotundata* - *Ikom, Calabar, White, Agar* and *Igbo* yams. This cluster has three sub-groups with 84.9% similarity. Cluster 2 consists of *Yellow* yam (*D. cayenensis*) with 48.5% similarity to members of Cluster 1. *Ghana Water* yam and *Swệt* yam constitute Cluster 3 with 83.4% similarity while *Sugar* yam and *Water* yam constitute the 4th and 5th clusters respectively. The ten yam types are actually five cultigens – *rotundata, rotundata-cayenensis complex, cayenensis, dumetorum* and *alata;* and the significant variability ($P<0.05$) observed with respect to the morphological characters evaluated may be the basis for the linguistic polymorphism noticed in the naming of the different yam types. Although genetic analysis is recommended to determine firm similarities, the establishment of clear links remains problematic because of the high hybridisation noticed among members of the Dioscoreaceae; and considering that yams types were introduced in the zone from different lands over many centuries.

Keywords: Dioscoreaceae, Clusters, Linguistic Polymorphism, Similarities, Morphometric Analysis

1. Introduction

The Dioscoreaceae are vine plants that produce underground or aerial tubers. They are found principally in tropical and sub-tropical regions in the world. The family contains four genera: *Dioscorea*, *Stenomeris*, *Tacca* and *Trichopus* [1] and that several segregate genera have been merged into *Dioscorea* [2]. The edible types are harvested [3] or cultivated in a wide scale as a major source of food, medicine and income to the farmers. It is established [4] that in economic terms, medicines have been an important product of *Dioscorea* than food as many species are rich in steroidal compounds. However, [5] assert that tropical roots and tubers are the most important food crops in the world after cereals and legumes; and [2] [6] asserts that yams (*Dioscorea spp.*) rank as the fourth most important tuber crop after potatoes, cassava and sweet potatoes.

Although the Dioscoreaceae show features of dicotyledonous plants such as reticulate venation of leaves, they are actually monocots of the order Dioscoreales [4]. The yam genus, *Dioscorea* L is the most diverse and important member of Dioscoreales, with over 600 botanically accepted species [7]. According to [8] and [9], there are only eight edible types among which are three major cultigens: the winged yam (*D. alata* L.), the guinea yams (*D. cayenensis* Lam./ *D. rotundata* complex (Poir.)) and the lesser or Asiatic yam *D. esculenta* (Lour.) [10].

Yams are of great economic and social importance in Sub-Saharan Africa where more than 95% of the world's yams are produced [11]. Cameroon is ranked the sixth highest producer of yam in the world after Nigeria, Ghana, Côte D'Ivoire, Benin and Togo [12]. It is reported that Cameroon is the African country with the highest diversity of rainforest wild yam species with seventeen specific to the country [13]. This is supplemented by studies carried out by [14] indicating high diversity of the Dioscoreaceae in the Guineo-Congolian basin. Two wild *Dioscorea spp.* - *D. bulbifera* L and *D. oppositifolia* are very common in South Western Cameroon. Though their exploitation for food is minimal, they still play an important role in meeting family food needs in rural areas especially during the period of food gaps.

Due to the socio-economic importance of yam, the cultivation of the crop in the country is gaining more grounds within the farming communities with production estimated at more than 350.000 tons in 2010 as against 215.5 tons and 225.6 tons in 2007 and 2008 respectively [15]. The most cultivated species in the South Western region of Cameroon are *D. alata* L., *D. esculenta* Bork., *D. dumetorum* Pax and *D. rotundata/D. cayenensis* complex (Guinea yam). Various cultigens of Guinea yam exist in the zone and the tubers are most preferred in the markets because of their shape and taste.

Thus, although authors, [8] and [9] have reported only 8 edible species of yam, there are many more than these in the South West Region of Cameroon, based on the nomenclature applied. It is unclear whether the observed differences in cultivated yams in the region are sufficient to delimit species. The Dioscoreaceae, like most other plants, show a lot of morphological variability and polymorphism due to the effect of hybridisation which is widely noticed among plants of this family; and the fact that yams have been introduced in many communities over a long time and from different sources. While the morphological characters exhibited by tubers have been widely applied in the naming of yam types, vine characteristics are equally important in taxonomic considerations at all levels and evaluating linkages between various yam types. In this respect, morphometric techniques can be effectively applied in determining the level of true polymorphism in the yams cultivated in the region. Hence, this study was to evaluate certain morphological properties in ten yam types cultivated in the South Western Region of Cameroon based on collected cultigens planted and observed in field plots across four sites in order to identify the traits that have a discriminative effect and then verify if these had the same effect on all samples irrespective of the environment.

2. Materials and Methods

2.1. Area of Study

The study was carried out in the South Western Region of Cameroon. This area is made up of the South West and Littoral Regions of Cameroon and is located between longitude 9 - 11^0 E and latitude 3 - 6^0 N [16]. The zone covers an estimated area of 44,810 Km^2 [17]. This is a humid forest zone with a yearly mono-modal rainfall pattern that stretches over a 5 - 7 month period with mean annual range of 2000 to 10,000mm along the coast. The highest rainfall comes between July and September with amounts ranging from 400 to 500mm and temperature range of 18 to 30°C. The relative humidity ranges between 70 – 80% [18]. Based on these climatic conditions, this zone is classified under agro-ecological zone IV. Soils in the zone show marked variations with ferrallitic and volcanic soil types being predominant. The fertile soils and combined with the climatic conditions favour the growth of luxuriant vegetation, diversity in plant and animal species and is one of the major yams producing zones in the country.

2.2. Yams Collection and Treatment

Yam types were collected from nine sites in the study area (Table 1). Leather hand gloves were worn in the process of collecting tubers and vegetative materials to prevent peeling, cuts and injuries from spikes. Yams were collected between November 2012 and May 2013 in the study area and were differentiated by their local names and/or morphological structures. Each yam type was put in a plastic bag and labelled accordingly. Tubers of ten cultivated yam types were selected and kept on shelves in a well ventilated room to break dormancy. Once sprouting was noticed, the tubers were cut into setts of average weight 350 g. The cut setts were soaked in a solution of Aliette (Fosetyl-AI: $C_6H_{18}AlO_3P_3$) fungicide at 100 g/15 L of water for 15 minutes, removed and air-dried for 48 hrs. The setts were then treated with an insecticide – Dursban 4E (chlorpyriphos – ethyl) at 90ml/15 L water, air-dried for 24 hr before planting.

2.3. Site Selection, Plot Preparation, Layout, and Planting of Yams

Four sites in the zone of study were selected for the field planting of yam types (Table 2). The choice of sites was based on soil type and climatic conditions. Site geographical coordinates were recorded using a GPS instrument (model GPSMAP 60 CSX).

The land at each site was cleared using machetes and raked. Each site was marked out into 30 experimental plots. Each plot measured 35 x 35m giving 1225 m^2 per plot and 36750 m^2 per site. A turn-around boarder of 1.0 m was left round and in the middle of each site. Mounds were made at 1 x 1m spacing and plant matter excluding twigs raked from the plots was ploughed back to increase soil organic matter. Planting was done in March – April 2003 and 2014 for the tubers collected in 2012 and 2013. Attribution of yam types in the plots was randomly done using a random number table. Each yam type had three replicates of 35 setts per site. Thus, 105 setts of each yam type were planted at each site using the randomized complete block experimental designed.

Table 1. *Sites from which yam types were collected in South Western Region of Cameroon.*

Yam type (local name)	Cultigene	Collection site	Coordinates *		Altitude* (m)	Temperature (°C)
			Latitude	Longitude		
Agar	rotundata	Bonakana	4°22'N	9º27'E	915	18
Igbo yam (sand paper)	rotundata-cayenensis complex	Bombe	4°45'N	9º46'E	124	28
Swệt/Elephant yam	rotundata	Boubou - Loum	4°43'N	9º44'E	293	26
Calabar yam (Amular)	rotundata	Bombe	4°45'N	9º46'E	124	28
Sugar yam	dumetorum	Mabonji	4° 33'N	9º11'E	72	28
Yellow yam	cayenensis	Melong	5°11'N	9º95'E	790	26
Ghana water yam	alata	Mbalangi	4°50'N	9º46'E	98	27
Ikom yam	rotundata-cayenensis complex	Banga -Bakundu	4°49'N	9º38'E	124	28
Water yam	alata	Sokelle	3°46'N	10º31'E	171	27
White yam	rotundata	Bomono Ba Mbengue	4°14'N	9º59'E	0	33

Source: * GPSMAP 60 CSX field record.

Table 2. *Geographical and soil types of planting sites in South Western Region of Cameroon.*

Site	Soil type	Latitude*	Longitude*	Altitude* (m)	Mean annual temperature (°C)	Mean annual rainfall (mm/year)
Bombe	Sandy loam	4°45'N	9°46'E	124	28	2500
Bova	Volcanic	4°11'N	9°15'E	912	18	3050
Dibanda	Sandy-volcanic	4°13'N	9°30'E	390	23	2800
Bomono Ba Mbengue	Sandy	4°14'N	9°59'E	0	31	2778

Source: * GPS field record.

The sprouted yams were staked; and weeding and mulching done at two monthly intervals. Harvesting was done in January 2014 (for 2013 planting) and January 2015 (for 2014 planting).

2.4. Data Collection and Analysis

Morphological observations and data collection started at six weeks after planting and continued on a monthly basis for six months. Data was collected from fifteen tagged stands per replicate of each yam type at each site. This gives a total of 45 stands sampled per yam type per site; and 180 stands per yam type for the four sites. Features on which data was collected are those outlined by [19], which included collar diameter, internode length, number of internodes, number of leaves and leaf area. Measurements of vine diameter was done using a vernier caliper while leaf measurements - length and width of ten randomly selected leaves along a 2 m vine length for each tagged plant per replicate were done using a 30 cm metre rule and the relative leaf area calculated using the formula L x W. Vine internodes length and vine length were measured using a meter rule. The number of spikes, internodes, branches and leaves were counted along a one meter length on the vine from ground level. Data was keyed-in on MS- Excel version 2007 and analyzed using Minitab Statistical Package Version 16 (Minitab Inc., USA). Similarity indices were compared. Analysis of Variance for randomized complete block was conducted on morphological parameters following tests for normality; and homogeneity of variance and means were separated using the Friedman's Statistical Test. Cluster analysis with complete linkage and Euclidean distance was done to determine the phenotypic relationships between the different yam types. Where necessary, α was set at 0.05.

3. Results

3.1. Variability in Phenotypic Characters in Yam Types

The variability in the phenotypic characters examined in all the ten yam types is presented in Table 3. From all the study sites, each yam type expressed variable morphological characteristics. It was noted that leaf length, number of internodes, collar diameter and internode length varied significanly across sites. All vine characteristics showed significant differences with respect to species.

It was observed that *Agar* yam, *Ikom* yam and *Yellow* yam are similar in terms of number of spikes, leaf length, leaf width and collar diameter. Leaf area, number of leaves per metre and internode length were the most similarity expressed characters across most species. The number of internodes and number of branches per metre were the characters which showed most variability for all the yam types. Based on differential expression of characters across sites, each yam type segregated into a number of morphoforms.

3.2. Grouping of Different Yam Types

Graphical similarities of the different yam types based on the morphological characters under consideration and the sites are presented in Figures 1. In Figure 1A, the *Ikom* yam expresses three morphoforms. The same yam grown in Bombe is markedly different from that grown in Bomono Ba Mbengue and Dibanda, which are also different from that grown in Bova. The *Ikom* yam expresses 67% morphological similarity in Bomono Ba Mbengue and Dibanda.

The *White* yam shows three distinct morphological types across the four sites. In Bombe and Bomono Ba Mbengue, the yam expresses similar phenotypes (69% similarity) but different by more than 33% from those grown in Dibanda and Bova (Fig. 1B).

There were two distinct phenotypes of *Yellow* yam across sites. The *Yellow* yam in Bombe and Dibanda formed a cluster (31.1% similarity) while that in Bomono Ba Mbengue and Bova formed a second cluster with 34.5% similarity (Fig. 1 C).

The *Agar* yam (Fig. 1 D) expresses three morphoforms across the four sites. The *Agar* yam planted in Bombe and Bomono Ba Mbengue form a cluster with 59.2% similarity while the Bova group is unique and links to the first (Bombe and Bomono Ba Mbengue cluster) with a 41.0% similarity. The *Agar* yam grown in Dibanada is entirely unique from the other clusters.

With respect to *Ghana Water* yam (Fig.1 E), there were three unique morphoforms across the four sites. The *Ghana Water* yams grown in Bombe and Bova were 83.0% morphologically similar thus forming the first cluster while the one grown in Bomono Ba Mbengue formed a second cluster in terms of the morphological characters observed. It was 60.0% similar to the first cluster. The ones grown in Dibanda were completely different from the first two clusters.

Swệt yam grown across the sites expresses two main morphoforms resulting in two clusters. The yams in Bombe and Dibanda formed Cluster 1 (82.0% similarity) while that in Bomono Ba Mbengue and Bova formed the second cluster (79.23%). The two clusters were completely dissimilar (Fig. 1 F).

Phenotypical characterisation showed that there were three main clusters of *Igbo* yam across the sites (Fig. 1 G). The yam grown in Bombe and Bomono Ba Mbengue formed the first cluster (74.6% similarity) while those grown in the Bova and Dibanda sites formed the second and third clusters respectively. The Dibanda cluster is completely unique from the other two clusters.

With regards to *Sugar* yam, the one grown in Bombe and Dibanda showed morphological similarity of 82.9% thus constituting the first cluster while a second cluster was formed by yams grown in Bomono Ba Mbengue and Bova having 55.7% morphological similarity (Fig. 1 H). The *Water* yam grown in the four sites manifested morphological variations which grouped into three clusters. In Bombe, the *Water* yam expressed morphological characters which were unique from the rest of the sites. The *Water* yams planted in Bomono Ba Mbengue and Bova were highly similar (92.2%) and are linked to the Dibanda cluster at 71.0% similarity (Fig. 1 I).

There were three distinct morphoforms of *Calabar* yam across the four sites. The Bombe cluster is unique from the rest. *Calabar* yam grown in Bomono Ba Mbengue and Dibanda were highly similar (81.0% similarity) and linked to the Bova cluster at 28.1% similarity (Fig. 1 J).

When considered together across sites, all the yam types constituted five main clusters (Fig. 2). Cluster 1 consists of *Ikom, Calabar, White, Agar* and *Igbo* yams with an overall within-cluster similarity of 61.3%. Within this cluster, there are three sub-groups: *Ikom* and *Calabar* yams are most similar (84.9% similarity), likewise *White* and *Agar* yams (87.3% similarity).

A second cluster consists of *Yellow* yam which is only 48.5% similar to members of cluster 1. Cluster 3 consists of *Ghana Water* yam and *Swệt* yam (83.37% similarity). The fourth cluster is made up of *Sugar* yam while *Water* yam makes the fifth cluster. As indicated in Figure 2, clusters 4 and 5 are 54.2% similar while clusters 3 and 4 are 10.18% similar and completely dissimilar from clusters 1 and 2. Based on within-cluster similarities, the results indicated that the 10 yam types could actually be grouped under 5 morphoforms.

Figure 3 shows the expression of all vine characters measured across sites. These are necessary as a guide to explaining the observed patterns in Figure 2. Vine characters segregated into five main clusters as well. Spikes form a cluster, as they are unique to some yam types, few in some and absent in others (Table 3). Number of branches and number of leaves form a second set of determinants of morphological patterns observed. Leaf width, leaf length and leaf area form a third cluster of morphological variability, number of internodes a fourth while collar diameter and internode length a fifth cluster (Figure 3). For all types, variability with respect to yam type is highly significant for spikes, leaf length, leaf area, number of internodes, number of branches/meter and number of leaves/meter.

Table 3. *Variability in expressed phenotypic characters of 10 yam types in South Western of Cameroon.*

Yam type	No. of spikes	Leaf length (cm)	Leaf width (cm)	Leaf area (cm^2)	No. of internodes	No. of branches Per metre	No. of leaves per metre	Collar diameter (mm)	Inter-node length (cm)
Yellow yam	125.7 ^{a}	12.5 ^{ab}	10.2 ^{ab}	131.2 ^{b}	5.4 ^{cd}	2.4 ^{d}	56.0 ^{b}	5.3 ^{b}	10.7 ^{ab}
Agar yam	107.0 ^{ab}	9.2 ^{b}	9.0 ^{bcd}	110.1 ^{b}	9.0 ^{ab}	6.1 ^{a}	105.9 ^{a}	6.8 ^{ab}	11.5 ^{ab}
Ikom yam	98.2 ^{ab}	9.6 ^{b}	7.4 ^{bcd}	71.5 ^{b}	5.4 ^{cd}	3.2 ^{bcd}	87.6 ^{ab}	6.9 ^{ab}	11.9 ^{a}
White yam	91.4 ^{bc}	11.7 ^{ab}	8.3 ^{bcd}	98.4 ^{b}	7.1 ^{bc}	4.2 ^{abcd}	99.8 ^{ab}	7.5 ^{a}	12.1 ^{a}
Calabar yam	74.7 ^{bc}	10.4 ^{b}	7.0 ^{cd}	75.3 ^{b}	5.0 ^{d}	4.7 ^{abc}	82.1 ^{ab}	5.9 ^{ab}	12.3 ^{a}
Igbo yam	60.2 ^{c}	12.1 ^{ab}	9.3 ^{bcd}	117.8^{b}	8.3 ^{b}	5.0 ^{abc}	106.4^{a}	6.2 ^{ab}	12.3 ^{a}
Sugar yam	14.6 ^{d}	16.1 ^{a}	12.6 ^{a}	208.0 ^{a}	4.4 ^{d}	2.3 ^{d}	60.2 ^{ab}	6.6 ^{ab}	11.7 ^{ab}
Water yam	0.0 ^{d}	12.9 ^{ab}	10.1 ^{abc}	135.8 ^{b}	10.7 ^{a}	2.8 ^{cd}	53.4 ^{b}	5.6 ^{b}	8.8 ^{b}
Ghana water yam	0.0 ^{d}	9.7 ^{b}	6.9 ^{d}	70.2 ^{b}	10.8 ^{a}	5.5 ^{ab}	105.0 ^{a}	7.6 ^{a}	12.7 ^{a}
Swệt yam	0.0 ^{d}	10.9 ^{b}	7.8 ^{bcd}	85.8 ^{b}	5.2 ^{cd}	3.1 ^{cd}	83.8 ^{ab}	6.8 ^{ab}	12.2 ^{a}

For each morphological character, yam type with the same indexed alphabet are significantly similar at $P_{< 0.05}$ along the same colunm.

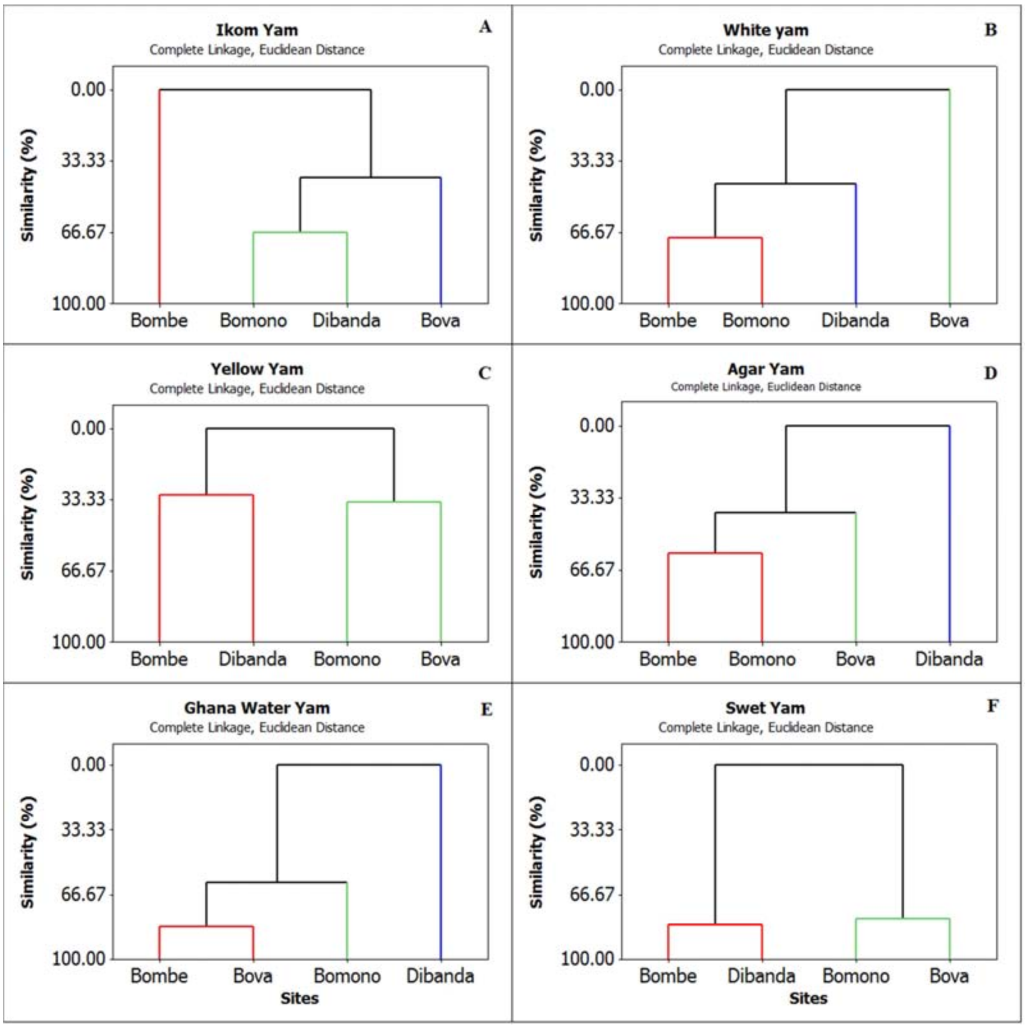

Figure 1. *Similarities of yam types based on morphological characters and sites in South Westen Region of Cameroon.*

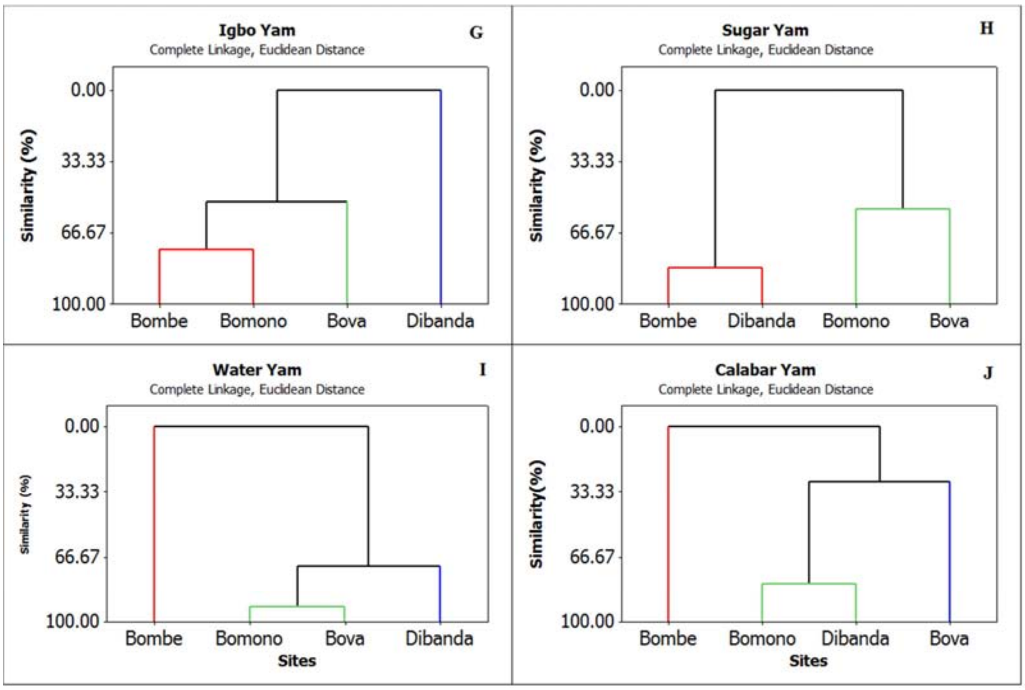

Figure 1. *Continuous.*

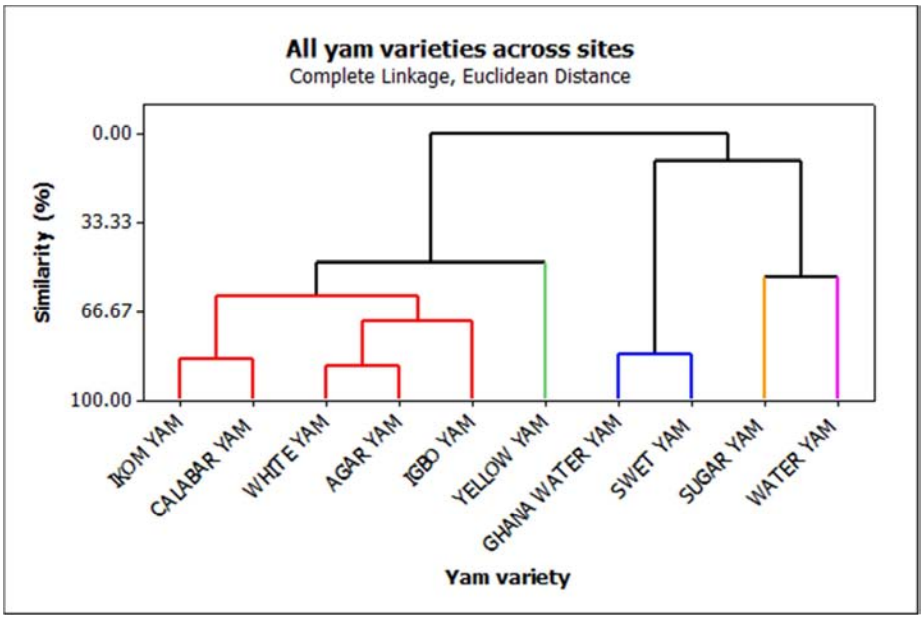

Figure 2. *Cluster analysis showing associations of 10 yam types based on phenotypical expression across all sites in South Western Region of Cameroon.*

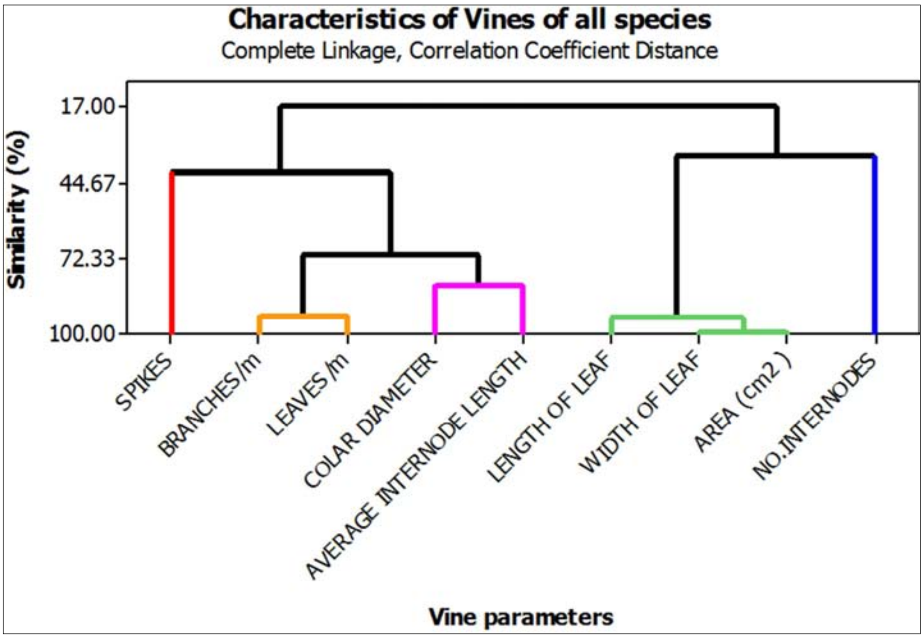

Figure 3. *Relationship between parameters measured from the different yam types across sites in South Western Region of Cameroon.*

4. Discussion

The issue of morphological variability among cultivars of yams has lead researchers to develop keys and classification systems [20]. A study carried out by [21] on morphological variation in 100 cultivars of yams in New Caledonia based on 20 characters, regrouped these cultivars into four major groups of morphotypes. A similar study conducted by [22] on 140 local cultivars from India using 22 morpho-agronomic descriptors identified fifteen groups while in the study by [14] four varieties and seven morpho-species were grouped from four thousand and eighty-seven dioscorea specimens collected from 2895 localities. Similarly, as revealed in this study, the different yam types show varying morpho-structural characteristics for the characters investigated. These characters variability is also noticed for the same yam types planted in the different sites. This could be attributed to the existence of many intermediate forms especially of *D. rotundata* and *D. cayenensis* as stated by [23] and differences in environmental factors whose influence on morphological variation is unreliable for conclusive comparison to be made.

The presence of spikes on vines of the *Dioscoreaceae* is not a characteristic of all types. Of the ten yam types evaluated, seven have spikes present in varying degrees on their vines. Those with spikes are of the *rotundata, cayenensis*, *rotundata - cayenensis* complex cultigenes and *D. dumetorum*. Yams of the *D. alata* group did not exhibit spiky vine features. Hence, the presence or absence of spikes is due to genetic constitution and not by environmental factors although, spikes are among the characters considered in differentiation of morphotypes.

Variability for five out of the nine phenotypic characters evaluated is not significant with respect to site considerations. These attributes are genetically influenced [24]. The level of significance of these individual phenotypic characters between yam types, buttresses the similarities or dissimilarities between the yams types studied. In addition, ten yam types were studied and the characters regrouped into five clusters and two main groups, highlighting the characters responsible for the morphological variations observed. Similar results of morphological variability among yam types collected from different regions were obtained in Kenya [25]; [26]. The variations in the characters observed cannot be used in any concrete sub-division of the different yam types based on either site or morphological grounds only. According to [20], germplasm collection of vegetatively propagated species such as *D. alata,* frequently contain accessions which although morphologically similar, have different genetic origins and vice versa. It has been opined that yam being a vegetatively propagated crop strongly exhibit the existence of duplicated accessions [27]. Identical cultivars often have different names in different communities and countries due to the numerous vernacular languages. The results thus suggest that the 10 yam types called different names across the region are actually morphoforms of 5 main cultigens. The significant differences observed for these characters could be caused by interactions between environment and genetic factors. However, the within cluster similarity is low and the yam types can be considered as five unique landraces.

5. Conclusion

The ten yam types collected and planted in four sites in the zone of study exhibit morpho-phenotypic variability in different degrees. The *Ikom* yam and *Calabar* yam show strong similarities in all characters and are considered as the same yam type; and same applies to *White* yam and *Agar* yam. These are called differently due to linguistic polymorphism. The significant variability observed in the characters between the yam types is due to inherent nature of each yam type which can be determined by genetic analysis. Even with this method, the high hybridisation noticed among members of the Dioscoreaceae and considering that yams are among the crops introduced in different lands over many centuries of human migration, still makes the establishment of clear links problematic.

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