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Research Article

Numerical taxonomic studies of some members from four tribes of the family Araceae in south western Nigeria

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Abstract

Sixteen taxa belonging to four tribes in the family Araceae were grouped based on numerical data generated from the coding of 16 morphological and 44 anatomical characters with the aim of inferring phenetic relationships among them. The data from these two fields of evidence were subjected to Paired Group Cluster Analysis (PGCA) and Principal Components Analysis (PCA). From the results, two groups emerged. The first group consists of members of genera *Alocasia*, *Colocasia* and *Xanthosoma* which are acaulescent herbs in that their stem(s) are subterranean and are also corm producers while the members of genera *Aglaonema* and *Dieffenbachia* which are caulescent herbs exhibiting decumbent character and non-corms producers constitute the second group. Twenty-nine (29) characters comprising of 15 morphological characters and 14 anatomical characters had high component loadings and can be employed in the delimitation of the taxa. The importance of these characters in the delimitation of the Araceae taxa was discussed.

Key words: Anatomy, Araceae, Habit, Numerical taxonomy, Morphology, Cluster analysis

Introduction

Family Araceae, also referred to as Arum family with members called aroids is a large family of monocotyledonous flowering plants with diverse morphological structures (Bown, 2000). Hutchinson and Dalziel (1968) reported 107 genera and over 3700 species for the family, but in a recent review, Boyce and Croat (2018) reported 3,645 species from 144 genera. Some highlights of the morphology of members of the family Araceae as described by authors include the roots of its members being majorly adventitious, stems being aerial or subterranean, decumbent or erect (Mayo *et al*., 1997). Aerial stems can be climbing or not while the subterranean stems can be rhizomatous or tuberous (Ray, 1987). The leaves of Araceae are known to be expanded blade with midrib, petiole and petiole sheath towards the base of the petiole, though there may be some exceptions (Mayo *et al*. 1997). The inflorescence is usually a spike, known as spadix, bearing numerous but minute flowers and usually surrounded by a colourful bract or modified leaf, known as spathe and fruits are juicy berries (Bown, 2000; Christenhusz and Byng 2016).

The diverse morphological forms observed in the family Araceae have imposed some complexity and problems in its taxonomy (Ngoka, 1997; Green and Oguzor, 2009) which are being solved by different authors (Onwueme, 1978; Burkill, 1985; Gill, 1988; Hirai *et al*. 1989; Mayo *et al*., 1997; Hesse *et al*., 1999; Bown, 2000; Keating, 2003; Chen *et al*., 2004; Hesse, 2006; Cabrera *et al*., 2008; Green and Oguzor, 2009; Osuji and Nwala, 2015; Arogundade and Adedeji, 2016; 2017). There is no known work in which numerical methods were applied to members of the family Araceae in order to understand their pattern of relationships.

The importance of numeric taxonomic methods in classifying and delimiting plant species has been stressed by many authors as it has been variously employed in resolving taxonomic problems among organisms at both higher and lower ranks. For example, Bello *et al.* (2013) employed this tool in resolving some taxonomic problems in the genus *Solanum*. Feng and Xie (2013) were able to solve the taxonomic identification problem that existed in the genus *Mallomonas* (Chrysophyta) from China using numerical taxonomy. Other numerical taxonomic works include those of Illoh *et al.* (1991) on the genus *Sida* Linn.; Arogundade and Adedeji (2012) on genus *Ocimum*; Rahman *et al*. (2013) on genus *Senna*. This work, therefore, intends to use numerical methods in grouping 16 taxa from the family Araceae based on their character states from the fields of Morphology and Anatomy.

Materials and Methods

Sixteen members from five genera belonging to four tribes of family Araceae were worked on in this study. The genera are: *Colocasia*, *Xanthosoma*, *Alocasia*, *Dieffenbachia* and *Aglaonema*. Genera *Colocasia* and *Alocasia* are from tribe Colocasieae; genus *Xanthosoma* is from the tribe Caladieae; genus *Dieffenbachia* is from tribe Dieffenbachieae while genus *Aglaonema* is from tribe Aglaonemateae. The species, varieties and cultivar worked were: *Colocasia esculentum* (L.) Schott var. *esculentum*, *Colocasia esculentum* var. *antiquorum* (L.) Schott, *Xanthosoma mafaffa* Schott (white variety), *Xanthosoma mafaffa* Schott (red variety), *Xanthosoma saggitifolium* Schott, *Dieffenbachia picta* Schott, *Dieffenbachia senguine* (Jacq) Schott, *Dieffenbachia senguine* cultivar candida Schott, *Dieffenbachia oerstedii* Schott, *Alocasia plumbea (*Schott) G. Don, *Alocasia cucullata* (Lour.) Schott, *Alocasia macrorrhiza* (L.) G. Don, *Aglaonema commutatum* Schott, *Aglaonema brevispathum* Schott (Engl.) Engl., *Aglaonema rotundum* Schott and *Aglaonema pictum* Schott. The plant samples were collected from different locations in the South Western part of Nigeria (Table 1).

The detailed morphological and anatomical studies of all the species, varieties and cultivars were carried out following standard procedures. Morphological parameters studied on the taxa include the plant habits, leaf shape, leaf base, leaf apex, leaf margins, veins and petiole of the leaves. Measurements of quantitative morphological characters - leaf length, leaf breadth, and petiole length were made for all the collections. For the anatomical studies, the scraping technique of Metcalfe (1960) adopted by Arogundade and Adedeji (2016) was used to obtain the epidermal peels of both the adaxial and abaxial surfaces of the leaves. Sections were made from the three regions of the petiole – proximal, median and distal regions. Leaf clearing method described by Olatunji (1983) was employed in clearing the leaf portions for venation studies. Sixteen (16) morphological parameters and 44 anatomical parameters which were qualitative and quantitative were employed in this study, making 60 characters altogether. The basic data matrix of 60 × 16 was prepared by coding for the presence or absence of characters. Data were standardized using the method recommended by Sokal and Sneath (1963) (Table 2). The quantitative anatomical characters were first subjected to the Duncan Multiple Range Test for mean separation before being coded. The data generated were then analysed using Paired Group Cluster Analysis (PGCA) and Principal Components Analysis (PCA) in Paleontological Statistics software package (PAST).

Results and Discussion

Table 3 is showing the Duncan Multiple Range Test (DMRT) result of the mean values of the quantitative foliar anatomical features studied where means with the same alphabet along the columns are not significantly different at $P \leq 0.05$. The dendrogram resulting from the cluster analysis of the Araceae taxa is presented in Fig. 1 while the Principal Components Analysis (PCA) scatter plots are presented in Figs 2 and 3. The results from these two analyses provided some basis on which the Araceae taxa can be delimited. Two main clusters emerged from the dendrogram's first grouping which also agrees largely with their tribal classification (Cabrera *et al*., 2008).

The clustering is in consonant with the habits of the taxa, implying that habit is a major character that can be employed in their grouping. The taxa belonging to genera *Alocasia*, *Colocasia* and *Xanthosoma* which are acaulescent, corm producing herbs were grouped together in the first main cluster while the members of *Aglaonema* and *Dieffenbachia* which are caulescent, decumbent and non-corm producing herbs were grouped together in the second cluster (Fig. 1). Leaf shape is another character identified as responsible for this grouping. Reniform, cordate and saggitate leaf shapes were observed in the genera *Alocasia*, *Colocasia* and *Xanthosoma,* while three other types of leaf shape; lanceolate, oblong and elliptic, were observed in the genera *Aglaonema* and *Dieffenbachia*. Cordate and reniform leaf shapes observed in genera *Alocasia*, *Colocasia* and *Xanthosoma*, as well as the acaulescent growth habit, have been reported to be primitive characters in the plant kingdom (Grayum, 1990), suggesting that members of genera *Aglaonema* and *Dieffenbachia* are more advanced than genera *Alocasia*, *Colocasia* and *Xanthosoma*.

In the first main cluster of the dendrogram where the corm producing members were grouped, *Alocasia cucullata* was separated from the other corm producers. This same species was also observed to be an outlier from the PCA results as shown in Figs. 2 and 3. *Alocasia cucullata* is the only species among the corm-producers with acuminate leaf apex, angular collenchyma in the three regions of its petiole and singly diverged veinlet ending. Further still on this first cluster, *Alocasia macrorrhiza*, *Colocasia esculentum* var. *esculentum*, *Xanthosoma maffafa* white variety and *Xanthosoma sagittifolium* were all clustered together but *Colocasia esculentum* var. *esculentum*, *Xanthosoma maffafa* white variety were clustered together at a higher similarity level. The reason behind this is most likely quantitative rather than qualitative since there is no significant difference between the values of the epidermal area and stomata index on their abaxial surfaces. Interestingly, *Alocasia plumbea, Colocasia esculentum* var. *antiquorum* and *Xanthosoma maffafa* red variety were also further clustered together.

Table 1. Sites and locations of collection

Sample	**Place of Collection**	**Coordinate**
Aglaonema brevispathum	Rainbows Q Gardens, Ibadan, Oyo state	N07º24.148' E003º57.726'
Aglaonema commutatum	Rainbows Q Gardens, Ibadan, Oyo state	N07º24.149' E003º57.731'
Aglaonema pictum	Parks and Garden, O.A.U., Ile-Ife, Osun State	N07º31.335' E004º31.829'
Aglaonema pictum	Rainbows Q Gardens, Ibadan, Oyo state	N07º24.150' E003º57.732'
Aglaonema rotundum	Rainbows Q Gardens, Ibadan, Oyo state	N07º24.147' E003º57.731'
Dieffenbachia picta	Rainbows Q Gardens, Ibadan, Oyo state	N07º24.148' E003º57.728'
Dieffenbachia picta	Biological Gardens, O.A.U., Ile-Ife, Osun State	N07º31.354' E004º31.418'
Dieffenbachia picta	Parks and Garden, O.A.U., Ile-Ife, Osun State	N07º31.335' E004º31.829'
Dieffenbachia picta	Oladapo Estate, Ondo, Ondo State	N07º06.762' E004º47.898'
Dieffenbachia oerstedii	Rainbows Q Gardens, Ibadan, Oyo state	N07º24.149' E003º57.730'
Dieffenbachia oerstedii	Line 1, Ajebamidele, Ile-Ife, Osun State	N07º29.847' E004º29.980'
Dieffenbachia senguine	Rainbows Q Gardens, Ibadan, Oyo state	N07º24.150' E003º57.729'
Dieffenbachia senguine	Parks and Garden, O.A.U., Ile-Ife, Osun State	N07º31.237' E004º31.720'
Dieffenbachia senguine	Catholic Church Compound, O.A.U., Ile-Ife, Osun State	N07º30.659' E004º30.971'
Dieffenbachia senguine cult. *Candida*	Rainbows Q Gardens, Ibadan, Oyo state	N07º24.148' E003º57.729'
Alocasia cucullata	Yellow House, O.A.U., Ile-Ife, Osun State	N07º31.156' E004º31.221'
Alocasia cucullata	Parks and Garden, O.A.U. Ile-Ife	N07º31.342' E004º31.834'
Alocasia cucullata	Rainbows Q Gardens, Ibadan, Oyo state	N07º24.182' E003º57.799'
Alocasia macrorrhiza	Ondo Road, Modakeke, Osun State	N07º28.986' E004º32.156'
Alocasia macrorrhiza	Gbongan, Osun State	N07º28.046' E004º21.321'
Alocasia macrorrhiza	Ikire, Osun State	N07º22.754' E004º10.893'
Alocasia macrorrhiza	Igbara Odo, Ekiti State	N07º29.959' E005º03.996'
Alocasia macrorrhiza	Rainbows Q Gardens, Ibadan, Oyo State	N07º24.161' E003º57.782'
Alocasia plumbea	Oladapo Estate, Ondo, Ondo State	N07º06.758' E004º47.885'
Alocasia plumbea	Igbara Odo, Ekiti State	N07º30.160' E005º03.601'
Alocasia plumbea	Rainbows Q Gardens, Ibadan, Oyo State	N07º24.151' E003º57.726'
Colocasia esculentum var. *antiquorum*	Central Science Laboratory, O.A.U., Ile-Ife	N07º31.237' E004º31.720'
Colocasia esculentum var. *antiquorum*	Chemical Engineering Department, O.A.U., Ile-Ife, Osun State	N07º31.200' E004º31.647'
Colocasia esculentum var. *antiquorum*	O.A.U.T.H.C., Ile-Ife, Osun State	N07º30.365' E004º34.362'
Colocasia esculentum var. *antiquorum*	Erefe, via Ile-Ife, Osun State	N07º24.983' E004º33.990'

Sample	**Place of Collection**	**Coordinate**
Colocasia esculentum var. *antiquorum*	SAO City Estate, Ondo, Ondo State	N07º07.005' E004º48.086'
Colocasia esculentum var. *antiquorum*	Ile-Oluji, Ondo, Ondo State	N07º07.300' E004º51.939'
Colocasia esculentum var. *esculentum*	Ajebamidele, Ile-Ife, Osun State	N07º29.759' E004º29.925'
Colocasia esculentum var. *esculentum*	Rainbows Q Gardens, Ibadan, Oyo State	N07º24.151' E003º57.771'
Colocasia esculentum var. *esculentum*	SAO City Estate, Ondo, Ondo State	N07º07.005' E004º48.086'
Colocasia esculentum var. *esculentum*	Igbara Odo, Ekiti State	N07º30.114' E005º03.993'
Xanthosoma mafaffa (Red)	Botany Department, O.A.U., Ile-Ife, Osun State	N07º31.149' E004º31.555'
Xanthosoma mafaffa (Red)	O.A.U.T.H.C., Ile-Ife, Osun State	N07º30.352' E004º34.317'
Xanthosoma mafaffa (Red)	Oke-irorun, Gbongan, Osun State	N07º28.062' E004º21.594'
Xanthosoma mafaffa (Red)	Ikire, Osun State	N07º22.854' E004º11.044'
Xanthosoma mafaffa (Red)	Rainbows Q Gardens, Ibadan, Oyo State	N07º24.181' E003º57.788'
Xanthosoma mafaffa (Red)	Igbara Odo, Ekiti State	N07º30.089' E005º03.999'
Xanthosoma mafaffa (Red)	Ogotun-Ekiti, Ekiti State	N07º30.401' E004º59.427'
Xanthosoma mafaffa (White)	O.A.U.T.H.C., Ile-Ife, Osun State	N07º30.371' E004º34.340'
Xanthosoma mafaffa (White)	SAO City Estate, Ondo, Ondo State	N07º06.927' E004º48.028'
Xanthosoma mafaffa (White)	Ikeji Ile, Osun State	N07º28.805' E004º55.269'
Xanthosoma mafaffa (White)	Rainbows Q Gardens, Ibadan, Oyo State	N07º24.175' E003º57.794'
Xanthosoma mafaffa (White)	Bamikemo village, Ondo State	N07º18.328' E004º52.659'
Xanthosoma mafaffa (White)	Ogotun Ekiti, Ekiti, State	N07º30.401' E004º59.427'
Xanthosoma saggitifolium	Aye-Coker, Osun State	N07º17.934' E004º36.285'
Xanthosoma saggitifolium	SAO City Estate, Ondo, Ondo State	N07º06.927' E004º48.028'

Table 2. Character and character states investigated

S/No	Characters	No of States
1	**Habit of plant** – Acaulescent and non-decumbent/ Caulescent and Decumbent	2
2	**Leaf colour** – Green/ Green and Off-white/ Deep green and light green/ Green and grey/ Green and White/ Green and purple	6
3	**Leaf margin** – Entire/ Sinuate	2
4	**Leaf shape** – Lanceolate/ Oblong/ Elliptic/ Reniform/ Cordate/ Saggitate	6
5	**Leaf apex** – Caudate/ Acuminate/ Cirrhose/ Acute/ Mucronate	5
6	**Leaf base** – Obtuse/ Acute/ Cordate/ Saggitate	4
7	**Venation type** – Pinnate/ Palmate-pinnate	2
8	**Venation pattern** – Eucamptodromous/ Brochidodromous / Craspedodromous	3
9	**Petiole shape** – Concave/ Round	2
10	**Petiole colour** – Green/Green and white/ Green and off-white/ White and off-white/ Green and purple/ Purple	6
11	**Stem type** – Aerial decumbent/ Aerial erect/ Subterranean	3
12	**Stem colour** – Green/ Brown and white/ Brown and pinkish-purple/ Brown, white and purple/ Brown and Pink/ Brown and yellow	6
13	**Leaf length** (cm)- 0-30/ 31-60/ above 60	3
14	**Leaf breath** (cm) –0-20/21-40/ above 40	3
15	**Vein number** – 0-5/6-10/ above 10	3
16	**Petiole Length** (cm)- 0-50/ 51-100/ above 100	3
17	**Adaxial epidermal cell shape** – Polygonal/ Polygonal to Irregular/ Irregular	3
18	**Abaxial epidermal cell shape** - Polygonal/ Polygonal to Irregular	2
19	**Adaxial anticlinal wall pattern** – Wavy/ Wavy to Undulating/ Undulating/ Straight	4
20	**Abaxial anticlinal wall pattern** – Straight to Wavy/ Straight	2
21	**Adaxial stomata shape** – Elliptic/ Elliptic and Circular	2
22	**Abaxial stomata shape** - Elliptic/ Elliptic and Circular	2
23	**Adaxial surface stomata** – Present/ Absent	2
24	**Adaxial stomata type** – Brachyparacytic/ Brachyparacytic and Anomocytic/ Brachyparacytic and Anisocytic	3
25	**Abaxial stomata type** – Brachyparacytic/ Brachyparacytic and Anomocytic/ Brachyparacytic and Anisocytic	3
26	**Scales on adaxial surface** - Present/ Absent	2
27	**Papillae on adaxial surface** - Present/ Absent	2
28	**Cuticular striations on adaxial surface** - Present/ Absent	2
29	**Raphides and druses** - Present/ Absent	2
30	**Mucilaginous cells** - Present/ Absent	2
31	**Cuticular striations on abaxial surface** - Present/ Absent	2
32	**Papillae on abaxial surface** - Present/ Absent	2
33	**Number of veinlet ending** – 0/ 0-2/ 0-3	3
34	**Veinlet ending branching** – None/Singly/ Singly and Bifurcated/ Singly and Forked/ Singly, forked and Bifurcated	5
35	**Venation inclusions** – None/ Druses/ Druses and Raphides	3

S/No	Characters	No of States
36	**Adaxial epidermal cell area (µm)** – 301-600/601-900/901-1200/1201-1500/ above 1500	5
37	**Abaxial epidermal cell area (µm)**– 0-500/501-1000/ 1001-1500/ above 1500	4
38	**Adaxial stomata area (µm)**– 0-200/201-400/401-600/above 600	4
39	**Abaxial stomata area (µm)**– 100-300/ 301-500/ 501-700/ above 700	4
40	**Adaxial stomata index (µm)** – 0-4.0/ above 4.0	2
41	**Abaxial stomata index (µm)** – 0-10.0/ above 10	2
42	**Areole area (µm)**– 0-2000/ 2001-4000/ 4001-6000/ above 6000	4
43	**Midrib collenchyma cell type** – Angular/ Angular and Lamella/ Lamellar/ Lacunar	4
44	**No. of palisade mesophyll layer** – 1/ 1-2/ 1-3	3
45	**Outline of adaxial surface of petiole proximal region** – Concave/ Flat/ Flat to Convex/ Convex/ Round	5
46	**Layers of parenchyma in petiole proximal region** – 0-2/ 1-4/ 1-6	3
47	**Proximal region collenchyma type** – Angular/ Angular and Lamellar/ Lacunar/ Lamellar	4
48	**Raphide in petiole proximal region** – Present/ Absent	2
49	**Druses in petiole proximal region** - Present/ Absent	2
50	**Tannins in petiole proximal region** - Present/ Absent	2
51	**Outline of adaxial surface of petiole median region** – Concave/ Round/ Flat to Convex/ Convex	4
52	**Layers of parenchyma in petiole median region** – 0-2/ 1-4/ 1-6	3
53	**Median region collenchyma type** - Angular/ Angular and Lamellar/ Lacunar/ Lamellar	4
54	**Tannins in petiole median region** - Present/ Absent	2
55	**Outline of adaxial surface of petiole distal region** – Concave/ Convex	2
56	**Layers of parenchyma in petiole distal region** - 0-3/ 4-6/ >6	3
57	**Distal region collenchyma type** – Angular/Lamellar/ Lacunar	3
58	**Raphide in petiole distal region** – Present/ Absent	2
59	**Tannins in petiole distal region** – Present/ Absent	2
60	**Trichome** - Present/ Absent	2

Morphologically, the leaves and petioles of these three taxa are green and purple. The purple colour may cover an entire surface as observed on the adaxial surface of *Alocasia plumbea* or appear like a tape around the margin, at the upper part of the petiole or as a dot at the point of attachment of the leaf lamina to the petiole as observed in *Colocasia esculentum* var. *antiquorum* and *Xanthosoma maffafa* red variety. *Alocasia plumbea* and *Colocasia esculentum* var. *antiquorum* were grouped at a higher similarity level indicating their close relatedness. This closeness may be due to mucronate leaf apex and similar divergence of the veinlet endings which they have in common. These two also belong to the same tribe, Colocasieae.

Table 3. Duncan Multiple Range Test of the mean values of the quantitative foliar anatomical features

Species	**Epidermal Area Adaxial (μm^2)**	**Epidermal Area Abaxial (μm^2)**	**Stomata Area Adaxial (μm^2)**	**Stomata Area Abaxial (μm^2)**	**Stomata Index Adaxial (%)**	**Stomata Index Abaxial (%)**	**Areole Area (μm^2)**
Aglaonema brevispathum	1703.81^{BA}	1151.65^{C}	671.70^{B}	586.98^{C}	2.70^{I}	11.14^{CB}	5986.9^{CB}
Aglaonema commutatum	1371.97^{C}	1268.47^{CB}	447.30^{E}	549.44^{D}	2.99^{I}	8.58^{FG}	3581.5^{EF}
Aglaonema pictum	1760.93^{A}	1757.66^{A}	786.53^{A}	859.52^{A}	3.21^{HI}	9.98^{ED}	6113.5^{CB}
Aglaonema rotundum	947.51^{D}	1117.24^{C}	Nil	581.40^{C}	Nil	7.88^{G}	6398.0^{B}
Dieffenbachia picta	876.93^{ED}	891.07^{D}	520.74^{D}	530.94^{D}	4.95^{DE}	10.22^{D}	5024.8^{CD}
Dieffenbachia oerstedii	1261.67^{C}	1422.70^{B}	531.49^{D}	592.01^{C}	2.62^{I}	8.87^{F}	3501.4^{F}
Dieffenbachia senguine	1583.86^{B}	1349.12^{B}	566.44^{C}	579.77^{C}	3.10^{HI}	9.25^{FE}	7437.9^{A}
Dieffenbachia senguine cult. candida	1570.94^{B}	1892.44^{A}	700.26^{B}	802.26^{B}	4.20^{FG}	10.32^{CD}	3070.9^{GF}
Alocasia cucullata	720.12^{GF}	768.94^{D}	275.81^{G}	274.31^{F}	3.64^{HG}	9.24^{FE}	4592.1^{ED}
Alocasia macrorrhiza	532.85^{IH}	489.74^{FE}	229.98^{H}	244.53^{G}	7.41^{A}	10.34^{CD}	5244.6^{CD}
Alocasia plumbea	526.32^{IH}	565.22^{FE}	217.87^{H}	282.61^{F}	5.40^{DC}	10.82^{CBD}	4619.6^{ED}
Colocasia esculentum var. antiquorum	581.67^{GH}	446.62^{FEG}	177.07^{I}	197.67^{H}	4.75^{FE}	11.31^{B}	3377.6^{F}
Colocasia esculentum var. esculentum	349.38^{J}	269.86^{H}	140.66^{J}	171.56^{I}	6.87^{BA}	10.52^{CBD}	2770.4^{GF}
Xanthosoma mafaffa (Red)	416.30^{IJ}	219.64^{H}	239.22^{H}	219.64^{H}	6.56^{B}	13.39^{A}	3402.9^{F}
Xanthosoma mafaffa (White)	455.33^{IHJ}	207.54^{H}	216.65^{H}	207.54^{H}	5.66^{C}	10.78^{CBD}	2176.0^{GH}
Xanthosoma saggitifolium	778.19^{EF}	313.21^{E}	308.45^{F}	313.21^{E}	5.66^{C}	13.67^{A}	1453.9^{H}

** Means with the same letter along columns are not significantly different at $P \leq 0.05$.

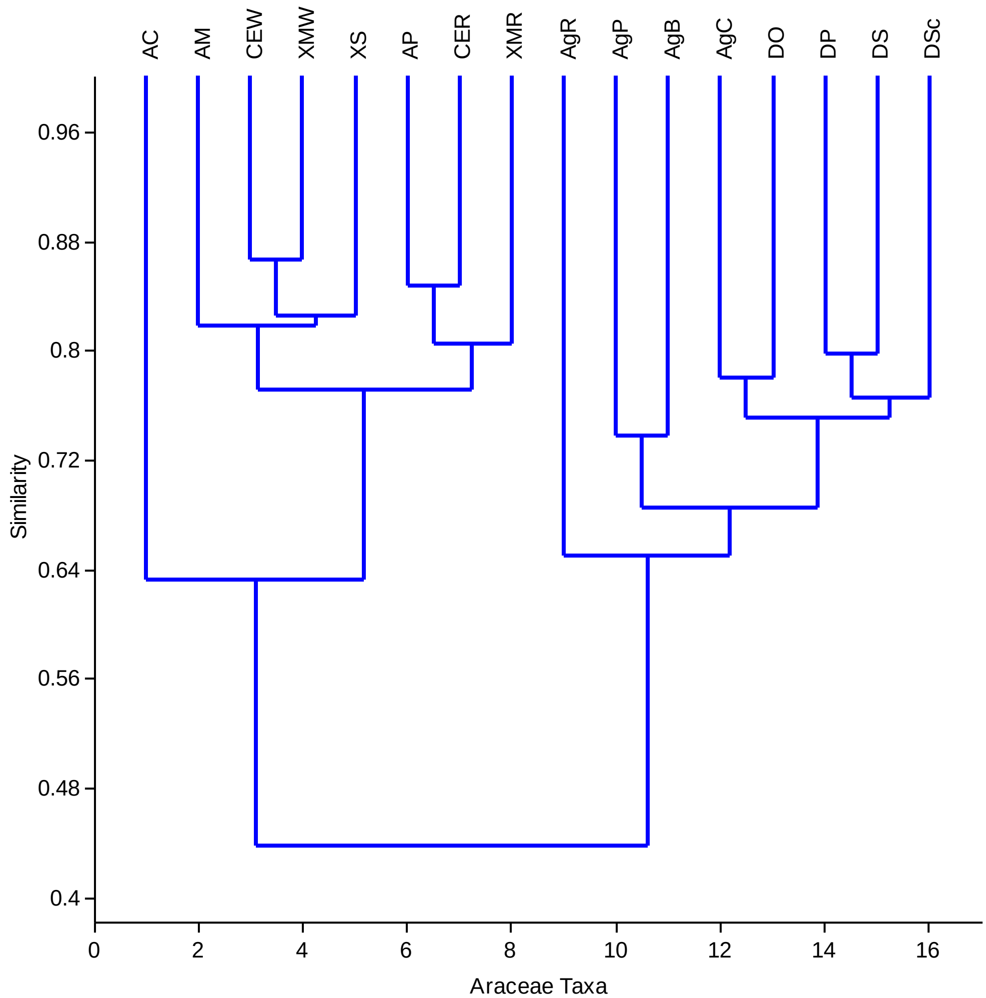

Figure 1. Dendrogram of Cluster Analysis showing relationships of Araceae taxa.

Legend:
AgB - *Aglaonema brevispathum*; AgC - *Aglaonema commutatum*; AgP - *Aglaonema pictum*; AgR - *Aglaonema rotundum*; DO - *Dieffenbachia oerstedii*; DP - *Dieffenbachia picta*; DS - *Dieffenbachia senguine*; DSC - *Dieffenbachia senguine* cult. candida; AC - *Alocasia cucullata*; AM - *Alocasia macrorrhiza*; AP - *Alocasia plumbea*; CER - *Colocasia esculentum* var. *antiquorum*; CEW - *Colocasia esculentum* var. *esculentum*; XMR - *Xanthosoma mafaffa* (Red); XMW - *Xanthosoma mafaffa* (White); XS - *Xanthosoma saggitifolium*.

In the second main cluster, *Aglaonema rotundum* was clearly separated from the other non-corm producing herbs as an outlier. From the foliar anatomical research conducted on the taxa, *A. rotundum* is the only species with hypostomatic leaves (Arogundade and Adedeji, 2016) and this demarcates *A. rotundum* from the other members of Araceae in this study which are all amphistomatic. The clustering together of *Aglaonema pictum* and *Aglaonema brevispathum* seems to be based more on quantitative rather than qualitative characters. *Aglaonema commutatum* observed to be clustering together with members of genus *Dieffenbachia* - *D. oerstedii*, *D. picta*, *D. senguine* and *D. senguine* cult. candida, is most likely due to the divergence of the veinlet endings observed in them. Veinlet ending as a character separated the members of the genus *Aglaonema* in that the only species with veinlet ending, though singly diverged, is *A. commutatum*, no veinlet endings were observed in the other three species. The clustering together of *Dieffenbachia picta* and *Dieffenbachia senguine* at a higher similarity level is worthy of note. These two species have cirrhose leaf apex in common as well as green with patches of cream colour in their petiole. Some schools of thought believe these two are the same and that one is just a variant of the other (Aigbokhan, 2014). However, some morphological characters of the leaves can be readily employed in separating them. The leaf shape is oblong with obtuse leaf base in *D. picta* while it is elliptic with cordate leaf base in *D. senguine*. Also, the leaf colour in *D. picta* is green with white patches whereas, it is cream/light green with dark green colour at the margin and midrib in *D. senguine*. The separation of *D. senguine* cult. candida from *D. picta* and *D. senguine* confirms the fact that these two species are most likely the parent plants, though acuminate leaf apex, cuticular striations and flat to slightly concave adaxial petiole outline were unique to the cultivar.

The graphs or scatter plots of the PCA are those of the first three components (Figs 2 and 3). Fig. 2 is based on components 1 and 2 while Fig. 3 is based on components 1 and 3. These first three components accounted for a cumulative percentage of 75.08% of the total variation among the taxa, but the first nine components accounted for 93.53% of the total variation. Component 1 alone accounted for 53.40% of the total variation; components 1 and 2 accounted for 68.26% variation while components 1 and 3 accounted for 60.22% (Table 4).

The characters that were responsible for the variations and groupings observed in the Araceae taxa are as presented in Table 5. Twenty-nine (29) out of the 60 characters employed in this study had high component loadings of which 15 are morphological characters while the remaining 14 are anatomical characters. The high component loading is a reiteration of the fact that all those characters can be employed in the identification and separation of the Araceae taxa and so they are diagnostic characters. Of the 29 diagnostic characters, 26 characters which include morphological and anatomical characters were in the first Axis of ordination. Axis II only had two characters which are leaf colour and petiole colour while Axis III consists of the vein number only.

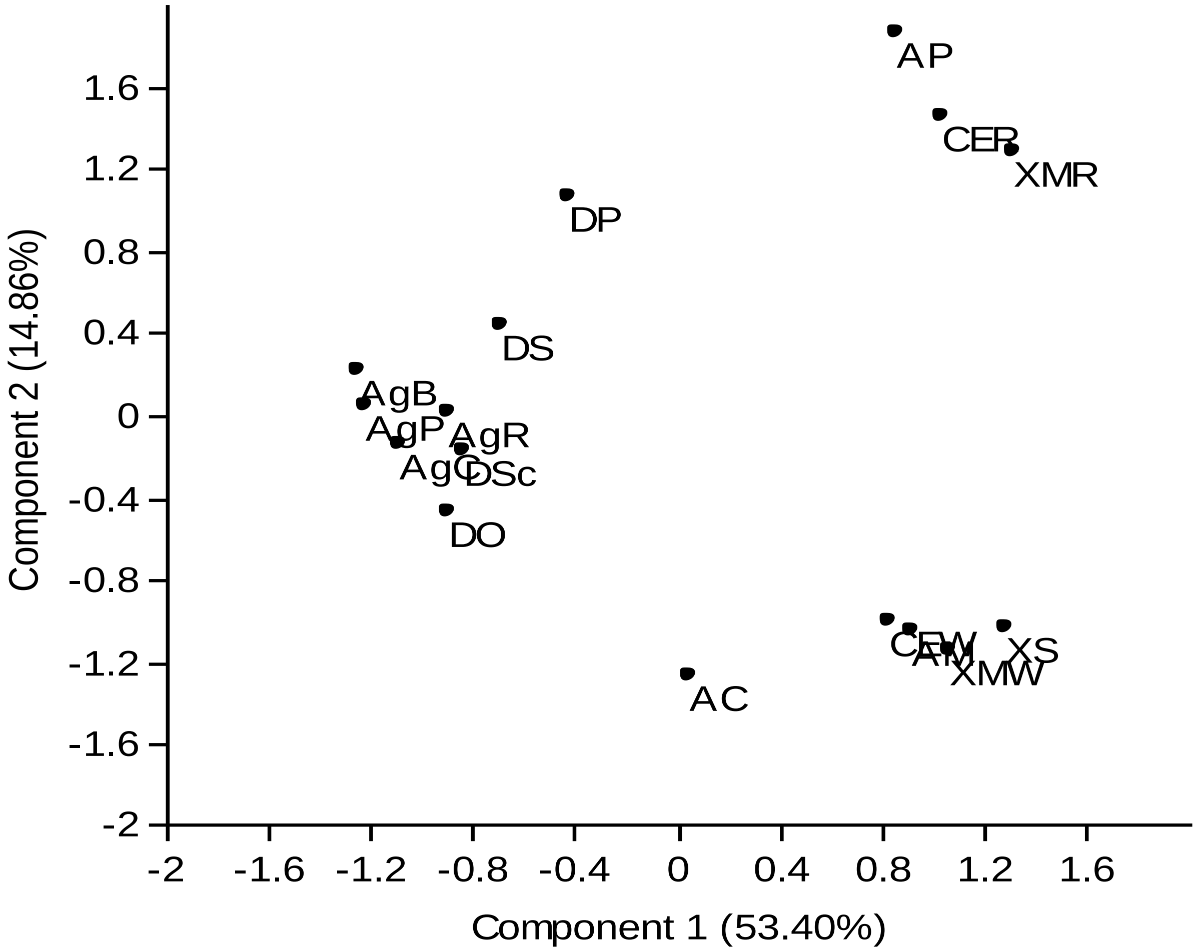

Figure 2. Two dimensional components space showing relationships among Araceae taxa based on Components 1 and 2

Legend:
AgB - *Aglaonema brevispathum*; AgC - *Aglaonema commutatum*; AgP - *Aglaonema pictum*; AgR - *Aglaonema rotundum*; DO - *Dieffenbachia oerstedii*; DP - *Dieffenbachia picta*; DS - *Dieffenbachia senguine*; DSC - *Dieffenbachia senguine* cult. candida; AC - *Alocasia cucullata*; AM - *Alocasia macrorrhiza*; AP - *Alocasia plumbea*; CER - *Colocasia esculentum* var. *antiquorum*; CEW - *Colocasia esculentum* var. *esculentum*; XMR - *Xanthosoma mafaffa* (Red); XMW - *Xanthosoma mafaffa* (White); XS - *Xanthosoma saggitifolium*.

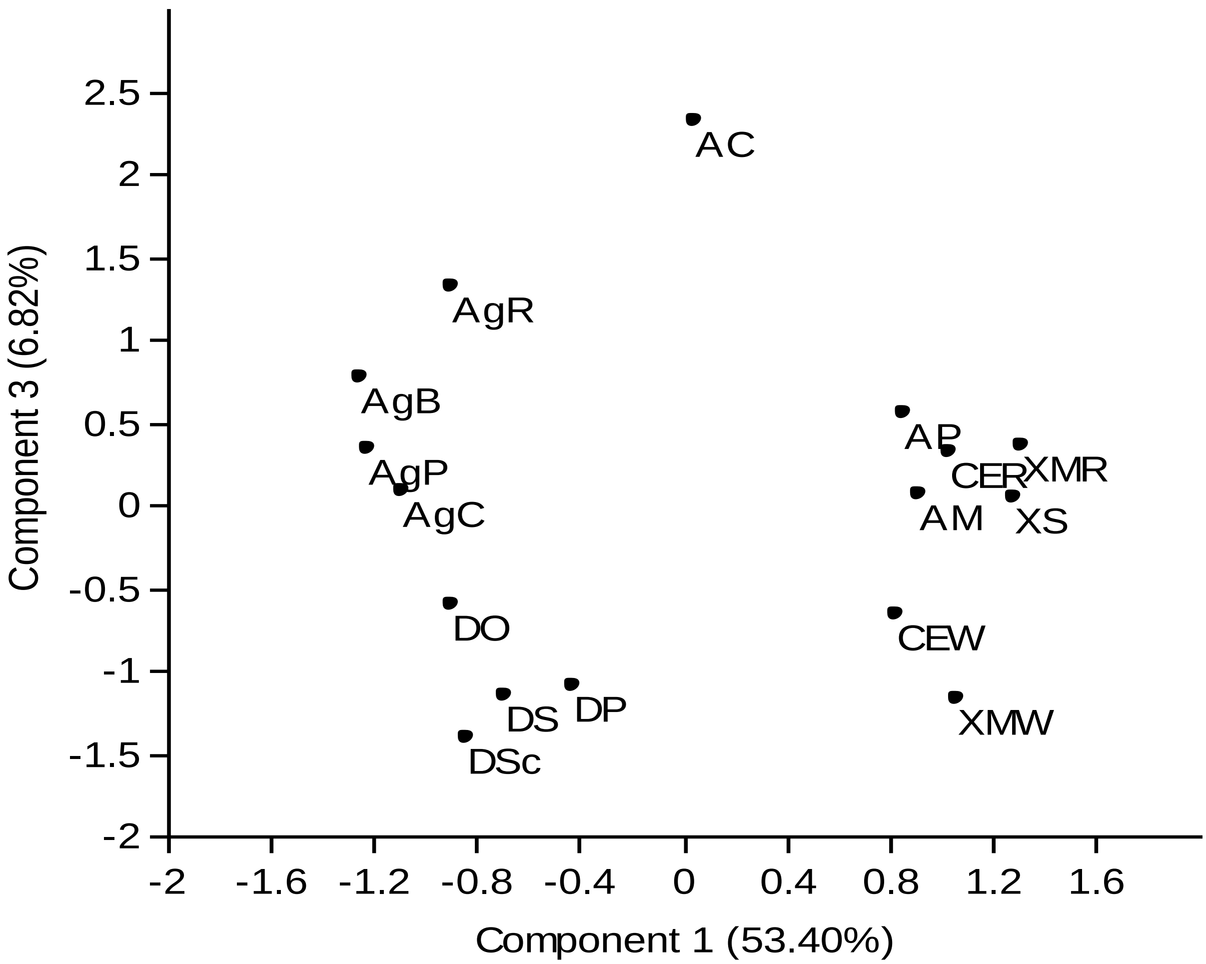

Figure 3. Two dimensional components space showing relationships among Araceae taxa based on Components 1 and 3

Legend:

AgB - *Aglaonema brevispathum*; AgC - *Aglaonema commutatum*; AgP - *Aglaonema pictum*; AgR - *Aglaonema rotundum*; DO - *Dieffenbachia oerstedii*; DP - *Dieffenbachia picta*; DS - *Dieffenbachia senguine*; DSC - *Dieffenbachia senguine* cult. candida; AC - *Alocasia cucullata*; AM - *Alocasia macrorrhiza*; AP - *Alocasia plumbea*; CER - *Colocasia esculentum* var. *antiquorum*; CEW - *Colocasia esculentum* var. *esculentum*; XMR - *Xanthosoma mafaffa* (Red); XMW - *Xanthosoma mafaffa* (White); XS - *Xanthosoma saggitifolium*.

Table 4. Eigenvalues and percentage of total variation accounted for by the first nine Principal Component Axes of the Ordination of the members of the family Araceae.

Principal component axis	Eigen-value	Percentage of total variation	Cumulative percentage
1	26.4786	53.40	53.40
2	7.36813	14.86	68.26
3	3.37969	6.82	75.08
4	2.36916	4.78	79.86
5	1.89041	3.81	83.67
6	1.48638	2.30	85.97
7	1.34636	2.72	88.69
8	1.27088	2.56	91.25
9	1.12989	2.28	93.53

In conclusion, data generated from the morphological and anatomical studies of the Araceae taxa in this study were indeed useful in inferring phenetic relationship among the taxa. The morphological characters which include the habit, leaf architecture such as leaf shape, leaf base and apex, leaf colour will provide first-hand information as regards their identification on the field. However, research into the ploidy level of the cultivar and varieties studied is highly recommended as this will guide the conclusion into whether they can stand as separate species or not.

Table 5. Characters with high component loading

Characters	
Axis 1	**Factor Score**
Habit	-0.9438
Leaf Shape	0.9199
Leaf Apex	0.8132
Leaf Base	0.8621
Venation Type	0.9438
Venation Pattern	0.9105
Petiole Shape	0.9438
Stem Type	0.9135
Stem Colour	0.8105
Leaf Length	0.8097
Leaf Breadth	0.9047
Petiole Length	0.9044
Abaxial Epidermal Cell Shape	-0.7672
Adaxial Anticlinal Wall Pattern	0.8809
Papillae on Abaxial Surface	-0.7672
Veinlet Ending Branching Type	0.7673
Adaxial Epidermal Cell Area	-0.895
Abaxial Epidermal Cell Area	-0.9237
Abaxial Stomata Area	-0.8796
Adaxial Stomata Index	0.7816
Midrib collenchyma cell type	0.802
Number of palisade mesophyll layer	0.9141
Outline of adaxial surface of petiole proximal region	0.803
Proximal region collenchyma type	0.9391
Outline of adaxial surface of petiole median region	0.7666
Median region collenchyma type	0.9391
Axis II	
Leaf Colour	0.9398
Petiole Colour	0.8763
Axis III	
Vein Number	-0.744

Conflicts of Interest

There are no conflicts of interest between the Authors.

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