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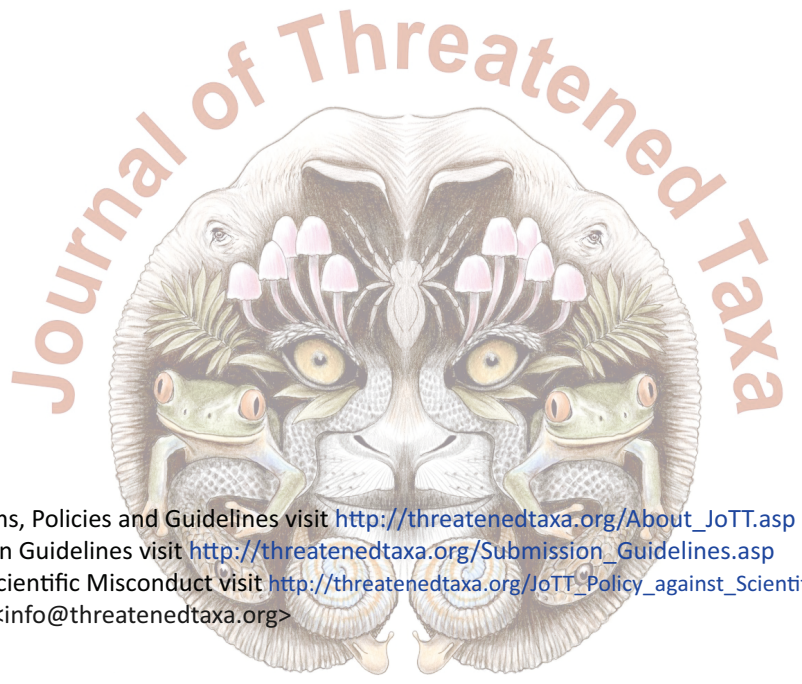

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Numerical taxonomy of *Berlinia* species (Caesalpinioideae: Leguminosae) and their distribution in Nigeria

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Abstract: A morphometric study was performed on six *Berlinia* species of the Nigerian flora. Individual specimens deposited at Forest Herbarium Ibadan and University of Ibadan Herbarium formed the units of study. Twenty morphological characters were assessed and analyzed following conventional taxonomic practice. Results showed a close resemblance between *B. craibiana* and *B. grandiflora,* which share affinity with *B. bracteosa* and *B. confusa*, while *B. coriacea* appears to be distantly related. Species distribution studies revealed that *B. grandiflora* exists in savanna and forest regions while other members of the genus are found only in forest zones. While suggesting practical measures for conserving endangered Nigerian flora, we also recommend that further taxonomic studies be carried out on the genus *Berlinia* and its related allies to ascertain their placement within the Caesalpiniodeae.

Keywords: *Berlinia,* Caesalpinioideae, distribution, morphometrics, taxonomy.

French Abstract: Résumé: Une étude morphométrique a été effectuée sur six espèces de la flore *Berlinia* Nigérians. Spécimens déposés à Forest Herbier Ibadan et de l'Université d'Ibadan Herbier formées les unités d'étude. Vingt caractères morphologiques ont été évaluées et analysées conformément à la pratique conventionnelle taxonomique. Les résultats ont montré une étroite ressemblance entre *B. craibiana* et *B. grandiflora*, qui partagent des affinités avec *B. bracteosa* et *B. confusa*, tandis que *B. coriacea* semble être parent éloigné. Études de répartition des espèces ont révélé que *B. grandiflora* existe dans les régions de savane et de forêt tandis que d'autres membres du genre ne se trouvent que dans les zones forestières. Tout en suggérant des mesures concrètes pour la conservation de la flore Nigérians en voie de disparition, il est également recommandé que d'autres études taxonomiques effectuées sur le genre *Berlinia* et ses alliés connexes pour déterminer leur placement dans le Caesalpiniodea.

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Author Details: Emmanuel C. Chukwuma is a Research Scientist at Forestry Research Institute of Nigeria. Abiodun E. Ayodele is a Professor with the University of Ibadan. Michael O. Soladoye is also a Professor with Southwestern University Nigeria. Deborah M. Chukwuma is a Lecturer with Federal University Oye-Ekiti. All the authors are plant taxonomists, and actively engaged in taxonomic research and conservation of Nigerian flora.

Author Contribution: CEC initiated the research. CEC and DMC performed the bench work. CEC performed the data analysis. All the authors contributed to the write-up. AEA and MOS corrected the final manuscript.

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INTRODUCTION

Berlinia is a member of the angiosperm family Leguminosae. It was first described by Hooker & Bentham in 1849 from three different collections (*Smeathmann* s.n., *Ansell* s.n. and *Heudelot* 886), which were ascribed to a single species (*B. acuminata* Sol. ex Hook.f. & Benth.). The currently accepted narrow circumscription of *Berlinia* was established by Leonard (1957) based on Harms' sections *Euberlinia* and *Macroberlinia.* The genus belongs to the tribe Detarieae *sensu lato* of Caesalpinioideae, and comprises 10 species in West Africa, with eight found in Nigeria (Hutchinson & Dalziel 1958; Keay 1989; Soladoye & Lewis 2003; Ayodele & Yang 2012).

Leaflets 2–6 pairs, usually fairly large and symmetrical at the base. Flowers are borne on stout stalk and there are 10 prominent free stamens with small anthers attached in the middle. Petals of *B. bracteosa* and *B. occidentalis* are more or less subequal in length and inflorescence is a stout terminal simple raceme while those of other West African species are very unequal in length and their inflorescence in a cluster of racemes or sparingly branched panicles (Hutchinson & Dalziel 1958; Keay 1989). Of the eight Nigerian species, *B. congolensis* and *B. hollandii* have been reported to be rare within the region (Keay 1989). Hutchinson & Dalziel (1958) and a recent monograph by Mackinder & Pennington (2011), reported only four specimens of *B. congolensis* in Nigeria, and these were collected from two locations (3 from Shasha Forest reserve on $07^0$05'N & $04^0$30'E and 1 from Eket on $04^0$39'N & $07^0$56'E) as far back as 1935. These areas however, have been greatly disturbed and availability of this species can no longer be guaranteed. Similarly, only two collections of *B. hollandii* were gathered (from Cross River state), between 1897 and 1898 by John Henry Holland who was the Curator of The Calabar Botanic Garden (Hepper & Neate, 1971); and as suggested by Mackinder & Pennington (2011), this species may have disappeared.

Mackinder (2001) noted that identification and curation of *Berlinia* collections can be problematic due to lack of consensus over genus and species limits, in some cases confounded by nomenclatural confusion which have led to conflicting taxonomic treatments in regional African floras. A poor understanding of the phylogenetic relationships within and among *Berlinia* species and its supposed allies is also a big problem. Nevertheless, a number of generic systems have been proposed for *Berlinia sensu stricto* and its presumed allies (Leonard 1965; Cowan & Polhill 1981), and this has rendered the taxonomic position of *Berlinia* uncertain.

The need to classify plants based on morphological characters (e.g., of leaf, flower, fruit and seed) while assigning equal importance to such attributes as proposed by Adanson (1763) brought about the establishment of Numerical Taxonomy (Sneath & Sokal 1963). Over the last 20 years the field has developed rapidly, to the extent that we now distinguish between traditional morphometrics (Marcus 1990) and recent geometric morphometrics (Adams et al. 2004), which are not widely used in plant systematics (Jensen 2003; Henderson 2006). Plant morphometric studies (Gomez-Campo et al. 2001; Sonibare et al. 2004; El-Gazzar & Rabei 2008; Soladoye et al. 2010) have been very useful in delimiting species at generic and infra-generic levels.

This study employs a morphometric approach to the delimitation of West African *Berlinia* species occurring in Nigeria, based on external morphology of some vegetative and reproductive characters. We also report the availability of species within the region and thus present the basis for a distribution map (Fig. 1).

MATERIALS AND METHODS

This study was performed between July 2013 and February 2015. The existing voucher specimens of *Berlinia auriculata* Benth., *B. bracteosa* Benth., *B. confusa* Hoyle, *B. coriacea* Keay, *B. craibiana* Baker f. and *B. grandiflora* (Vahl) Hutch. & Dalziel, deposited at the Forest Herbarium Ibadan (FHI) and University of Ibadan Herbarium (UIH) (Holmgren et al. 1990) were used for this study. Some of these are detailed in Table 1. Vouchers for *B. congolensis* and *B. hollandii* were not deposited in these herbaria by the collectors. Several efforts to locate fresh specimens were also futile due to continuous deforestation and other human activities within the reported locations of original collections. Prior to data collection, the available specimens were carefully examined and the choices of characters were determined.

Morphological studies

For each species, 20 morphological characters comprising 10 quantitative and 10 qualitative macro-characters were assessed from the available specimens (Tables 2 and 3). All quantitative characters were measured using a thread and rule. Measurements were obtained from specimens deposited at FHI and UIH, thus individual specimens formed the units of study (Image 1). Leaflet length and width were obtained by spreading the

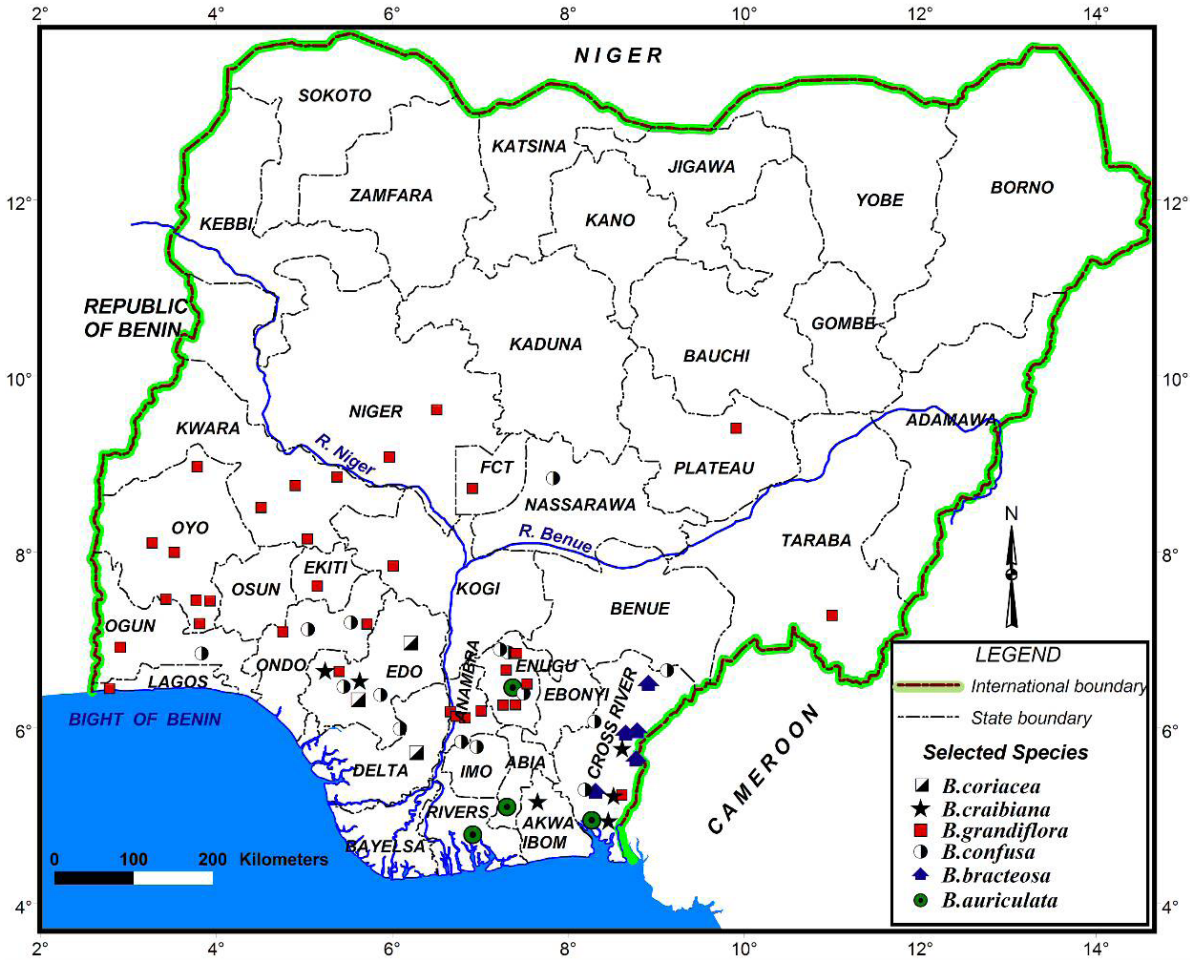

Figure 1. Distribution of *Berlinia* species in Nigeria.

middle leaflet on a flat surface on the laboratory bench to ensure uniformity (Olowokudejo 1999; Soladoye et al. 2010). Some characters (e.g., number of lateral nerves, number of leaflet pairs) were counted and carefully recorded while others (qualitative) were observed either with the naked eyes or hand lens where necessary. The mean and standard error for each measured character were calculated; all data were coded and thereafter subjected to statistical analysis using Minitab 17.0 and supported by IBM SPSS Statistics 20.0.

Species distributional study

This was based on existing collections deposited at the aforementioned herbaria. For each *Berlinia* species, place and date of collection were adequately recorded from all available specimens, and the derived data used to produce a distributional map for Nigeria using Arc GIS 9.3 at the Department of Geography, University of Ibadan, Ibadan, Nigeria.

RESULTS AND DISCUSSION

Herbarium collections showed *B. grandiflora* to be more abundant than the other species studied. While it extends from the wet zones to the drier parts of Nigeria, others are confined to the rain forest region except for *B. confusa,* which was also collected from the savanna of Nassarawa State (Fig. 1). Observations from this study revealed that *B. bracteosa* is restricted to the rich forests of Cross River State and *B. coriacea* in Edo and Delta states. Nonetheless, *B. auriculata* spreads from Port Harcourt (Rivers State) to Enugu-Ogbeti (Enugu State) and to Calabar (Cross River State). In general, all of the *Berlinia* species studied except *B. coriacea* are found in Cross River State. This state has been known for its rich biodiversity. The occurrence of *B. grandiflora* in both savanna and rain forest ecosystems is also an indication that it can survive in either environment unlike other members of the genus examined. This result also agrees with the earlier work of Ayodele & Yang (2012) who

Table 1. Some of the voucher specimens of *Berlinia* species studied

Species	Voucher No.	Collector	Locality	Date of collection
B. auriculata	FHI78659	Daramola, Macauley & Oguntayo	Oban FR, Calabar, Cross River State	9.x.1975
	FHI 56377	Daramola, B.O.	Oban FR, Calabar, Cross River State	4.ix.1965
	FHI 60332	Okafor, J.C.	Port-Harcourt-Aba Road, Abia State	12.viii.1966
	FHI 6169	Jones, A.P.D.	Aba, Portharcourt, Rivers State	9.i.1943
	FHI 63136	Emwiogbon, J.A.	Enugu-Ogbeti, Enugu State	
B. bracteosa	FHI 28153	Keay, R.W.J.	Cross River North Forest, Ikom	7.xii.1950
	FHI 55577	Daramola, B.O.	Awi-Akampa Rd, Cross River State	19.v.1965
	FHI 17340	Jones, A.P.D. & Onochie, C.F.A.	Ikom, Cross River State	2.iv.1946
	FHI 17336	Jones, A.P.D. & Onochie, C.F.A.	Ikom, Cross River State	29.v.1946
	FHI 99895	A.L. Gentry & George Pilz	Ekang, Cross River State	20.vi.1981
B. confusa	FHI 22649	Adekunle, A.O.	Usonigbe Fr, Edo State	26.v.1949
	FHI 68514	Emwiogbon & Onyeachusim	Ihiala, Anambra State	5.v.1972
	FHI 3150	Jones, A.P.D.	Owo Fr, Owo, Ondo State	14.iv.1943
	FHI 72154	Okeke & Macauley	Uboma/Orlu Rd, Imo State	24.i.1975
	FHI 33148A	Emwiogbon, J.A.	Enugu, Enugu State	24.iv.1972
B. coriacea	FHI 2728	Kenndey, J.	Sapoba FR, Edo State	viii.1931
	FHI 17031	Jones, A.P.D. & Onochie C.F.	Omo Forest Reserve, Ogun State	23.iii.1946
	FHI 60854	Emwiogbon, J.A.	Ukpe-Sabo FR, Delta State	6.iii1968
	UIH21054	Lowe, R.G.	Omo Forest Reserve, Ogun State	4.vi.1985
	UIH21046	Lowe, R.G.	Omo Forest Reserve, Ogun State	6.vi.1985
B. craibiana	FHI 58461	Emwiogbon, J.A.	Sapoba FR, Edo State	23.iv.1966
	FHI 37021	Keay, R.W.J.	Usonigbe FR, Edo State	22.v.1957
	FHI 56035	Okafor, J.C. & Latilo, M.G.	Ikot-Ekpene- Abakaliki Rd, Akwa-Ibom State	24.i.1966
	FHI 38901	Richards, P.W.	Calabar, Cross River State	11.iii.1955
	UIH15210	Lowe, J.C.	Sapoba FR, Edo State	10.i.1974
B. grandiflora	FHI 37337	Keay, R.W.J. & de Wt, H.C.D.	Olokemeji FR, Abeokuta, Ogun State	15.i.1958
	FHI 73701	Chapman, J.D.	Sardauna Province, Mambilla, Taraba State	18.xii.1972
	FHI 2747	Kennedy, J.D.	Sapoba FR, Edo State	i.1928
	UIH10199	Gledhill, D.	Ife-Ilesha Rd, Osun State	5.iv.1968
	UIH21798	Apejoye, F. & Madunagu	Onne, Rivers State	9.ii.1992

noted that the Nigerian species of *Berlinia* are found only in the rain forest zones, except *B. grandiflora* which occurs both in the savanna and forest regions of the country. In fact, the species of *Berlinia* studied in this work can be said to be sympatric.

Results from the macro-characters assessed showed that mean leaflet length and leaflet width ranged from 10.6cm and 4.9cm in *B. confusa* to 22.7cm and 10.7cm in *B. coriacea.* This variation was also observed for lamina length and distance between nodes, which ranged from 13.5cm and 3.3cm in *B. confusa* to 28.0cm and 5.8cm in *B. coriacea,* respectively. Petiolule length was least in *B. grandiflora* (0.5cm) but highest in *B. coriacea* (1.1cm) (Table 2) however.

As observed in Table 4, there is high positive correlation between leaflet length and lamina length, leaflet width and lamina length, fruit length and fruit width, lamina length and distance between nodes. Others include leaflet length and leaflet width, leaflet width and distance between nodes, leaflet length/leaflet width ratio and length of bract, amongst others. High negative correlation also exists between lamina length/ petiolule length ratio and leaflet base, distance between nodes and number of leaflet pairs, petiolule length and

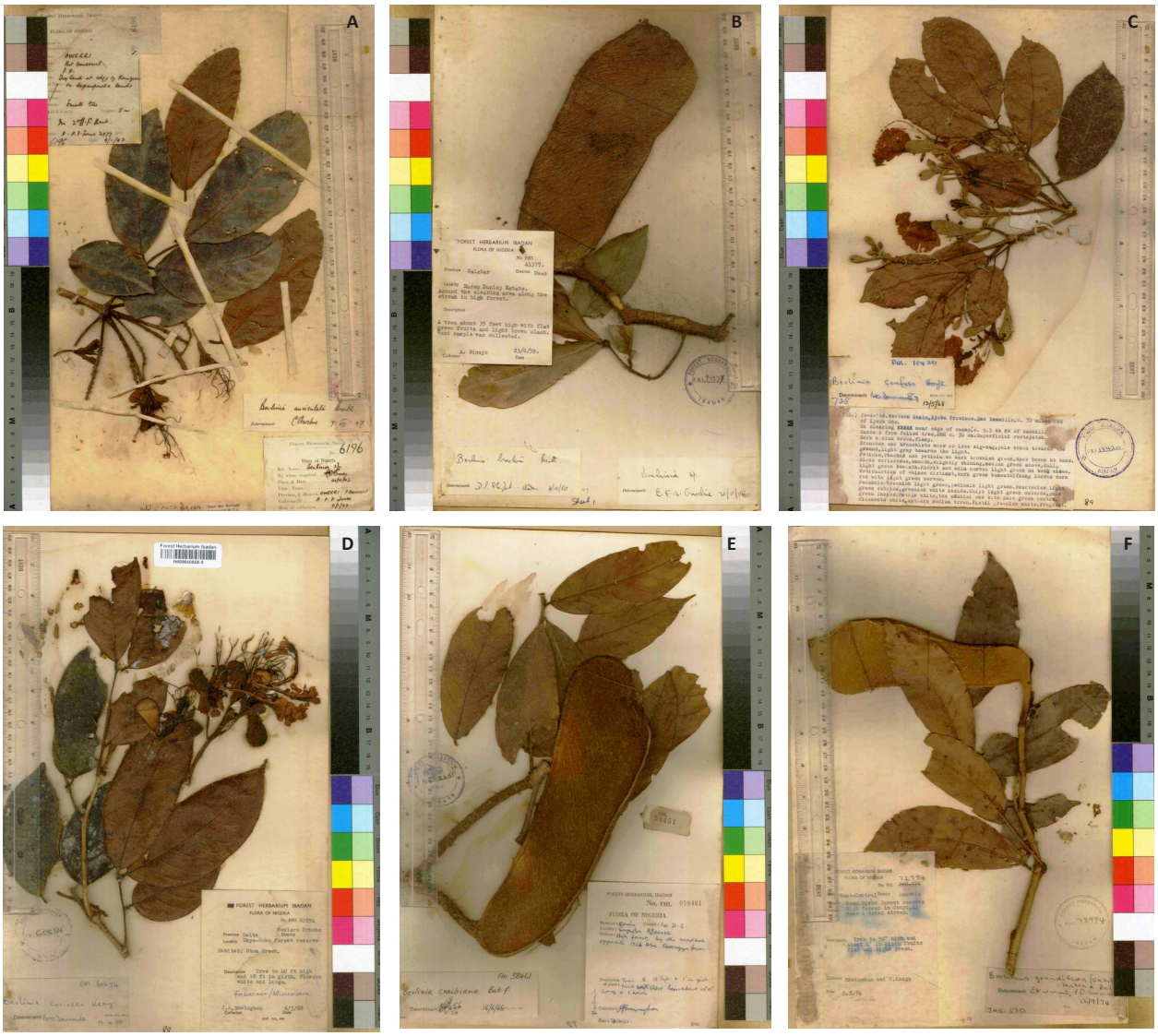

Image 1. Herbarium specimens of *Berlinia* species in Nigeria.
(A - *B. auriculata;* B - *B. bracteosa;* C - *B. confusa;* D - *B. coriacea;* E - *B. craibiana;* F - *B. grandiflora*)

fruit texture, leaflet width and fruit length etc. While characters with positive correlations may be more useful in distinguishing the *Berlinia* species studied, those with negative correlations when combined may not be suitable for species delimitation.

Principal component analysis (PCA) revealed that only three components contributed 92% of the total variance. Other extracted components were ignored as uninformative. Component 1 accounts for approximately 48%, while the other two constitute the remaining 44% (Table 5). These three components all have eigen values greater than 1, reflecting their reliability in the present study. Furthermore, the first component is most highly correlated with leaflet width and petiolule length. Leaflet width is a better representative, because it is less correlated with the other two components. For the second component, length of the bract is a better choice while pedicel length may be preferred for the third component (Table 6). This suggests that these three characters (leaflet width, bract length and pedicel length) could be focused on in further studies.

The cluster analysis (Table 7) shows that the distance measure between species 5 (*B. craibiana*) and species 6 (*B. grandiflora*) is the least while that between species 1 (*B. auriculata*) and species 4 (*B. coriacea*) is the highest. This result implies that the degree of affinity existing between species *B. craibiana* and *B. grandiflora* is the highest (with a very strong similarity level - 83.1601) while species *B. auriculata* and *B. coriacea* are the most distantly related taxa (similarity level - 13.3992). This is

Table 2. Vegetative and reproductive macro-morphological characters of *Berlinia* species examined. All measurements in cm and presented as min (mean±standard error) max

Species	lflt lgth	lflt wdt	lflt lgth/ lflt wdt	lam lgth	ptl lgth	lam lgth/ ptl lgth	dst bt nds	frt lgth	frt wdt	pdcl lgth	no ltrl nrv	no lflt prs
B. auriculata	12.0 (15.8±1.8) 22.1	5.3 (6.9±0.9) 9.3	1.6 (2.4±0.3) 3.5	13.3 (19.2±2.5) 27.2	0.7 (0.9±0.1) 1.0	14.8 (22.7±2.8) 34.0	3.0 (5.3±0.8) 6.6	21.0 (24.8±3.8) 28.6	5.3 (6.7±1.4) 8.0	12.0 (15.5±3.5) 19.0	9 (13±1.1) 17	2 (2±0.2) 3
B. bracteosa	12.6 (19.7±2.6) 33.0	4.1 (6.7±1.1) 13.1	2.3 (3.1±0.2) 4.3	14.3 (21.5±2.6) 34.3	0.6 (0.8±0.1) 1.0	14.7 (28.9±4.4) 42.9	2.4 (4.7±1.5) 9.0	19.4 (21.0±1.5) 22.5	6.7 (7.4±0.7) 8.0	4.8 (5.2±0.4) 5.6	11 (15±1.3) 20	3 (3±0.2) 4
B. confusa	5.9 (10.6±0.7) 16.4	3.4 (4.9±0.4) 7.4	1.7 (2.2±0.1) 2.6	6.4 (13.5±1.0) 19.9	0.3 (0.8±0.2) 1.0	5.0 (22.5±2.9) 56.0	1.8 (3.3±0.2) 4.7	8.5 (22.0±2.9) 31.3	1.5 (5.0±0.7) 8.8	3.0 (3.6±0.5) 5.0	9 (11±0.5) 14	3 (4±0.2) 5
B. coriacea	14.8 (22.7±2.4) 41.1	6.2 (10.7±1.0) 16.8	2.0 (2.1±0.1) 2.7	18.0 (28.0±2.3) 42.7	0.8 (1.1±0.1) 1.5	16.3 (25.9±2.0) 38.8	2.3 (5.8±0.8) 10.2	0	0	0	8 (12±0.7) 15	2 (2±0.2) 3
B. craibiana	8.9 (15.5±0.7) 19.8	4.1 (5.9±0.2) 7.5	1.7 (2.6±0.1) 3.3	12.1 (17.5±0.7) 23.0	0.4 (0.6±0) 0.8	18.6 (31.0±1.6) 40.5	3.0 (4.2±0.2) 6.8	2.7 (20.3±5.1) 32.5	1.2 (5.6±1.3) 8.3	1.6 (3.6±0.6) 6.6	7 (10±0.4) 13	4 (4±0.1) 5
B. grandiflora	8.7 (13.0±0.9) 20.4	4.0 (5.5±0.4) 9.3	1.9 (2.4±0.1) 3.0	1.1 (15.9±1.1) 27.0	0.3 (0.5±0) 0.8	17.5 (33.7±2.0) 46.3	2.3 (3.6±0.2) 5.0	13.0 (17.8±2.6) 22.0	4.0 (5.3±0.7) 6.0	2.5 (2.4±0.4) 3.6	8 (12±0.4) 14	3 (4±0.1) 4

Key: Lflt Lgth - Leaflet Length; Lflt Wdt - Leaflet Width; Lflt Lgth/Lflt Wdt - Leaflet Length/Leaflet Width ratio; Lam Lgth - Lamin Length; Ptl Lgth - Petiolule Length; Lam Lgth/Ptl Lgth - Lamina Length/Petiolule Length ratio; Dst bt Nds - Distance between Nodes; Frt Lgth - Fruit Length; Frt Wdt - Fruit width; Pdcl Lgth - Pedicel Length; No Ltrl Nrv - No. of Lateral Nerves; No Lflt Prs - No. of Leaflet Pairs

Table 3. Some qualitative characters for the identification of *Berlinia* species

Species	Petal length	No. of leaflet pairs	Leaflet apex	Leaflet base	Leaflet margin	Leaflet shape	Leaflet arrangement	Fruit texture	Bract
B. auriculata	Very unequal in length	2–3	Acute to short acuminate	Acute to round	Entire	Ovate to elliptic	Opposite/ sub-opposite	Glabrous	<6mm long
B. bracteosa	More or less equal in length	3–4	Short acuminate	Acute to obtuse	Entire	Oblanceolate to narrowly elliptic	Opposite/ sub-opposite	Glabrous	>25mm long
B. confusa	Very unequal in length	3–5	Acute to acuminate	Cuneate or rounded	Entire	Elliptic	Opposite/ sub-opposite	Slightly pubescent	<6mm long
B. coriacea	Very unequal in length	2–3	Acute	Obtuse	Entire	Elliptic	Opposite/ sub-opposite	Glabrous	<6mm long
B. craibiana	Very unequal in length	4–5	Acuminate	Obtuse or cuneate	Entire	Elliptic or ovate	Opposite/ sub-opposite	Pubescent	<6mm long
B. grandiflora	Very unequal in length	3–4	Short acuminate	Obtuse to round	Entire	Ovate to elliptic	Opposite/ sub-opposite	Pubescent	<6mm long

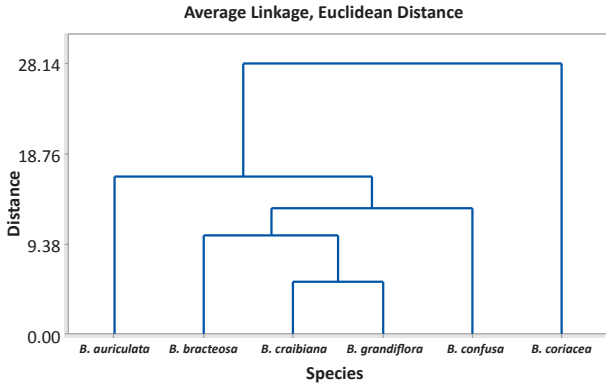

Figure 2. Dendrogram of Nigerian *Berlinia* species examined

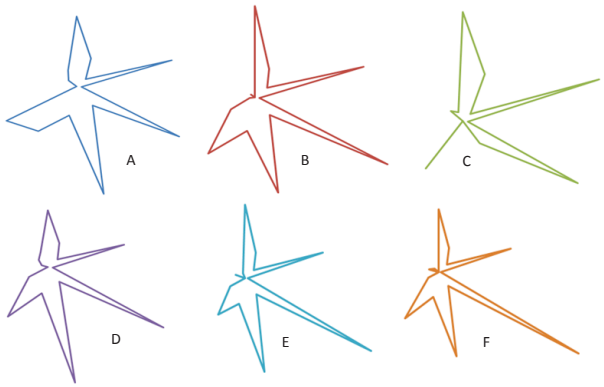

Figure 3. Polygonal chart derived from measured characters of the studied species.
(A - *B. auriculata;* B - *B. bracteosa;* C - *B. coriacea;* D - *B. confusa;* E - *B. craibiana;* F - *B. grandiflora*)

Table 4. Correlation coefficient of the macro-morphological characters of *Berlinia* species studied

Correlation	Lflt Lgth	Lflt Wdt	Lflt Lgth/ Lflt Wdt	Lam Lgth	Ptl Lgth	Lam Lgth/ Ptl Lgth	Dst bt Nds	Frt Lgth	Frt Wdt	Pdcl Lgth	No Ltrl Nrv	No Lflt Prs	Brct Lgth	Frt Tx	Lflt Apx	Lflt Bs
Lflt Lgth	1.000	.889	.188	.975[a]	.641	.021	.873	-.674	-.455	-.159	.451	-.722	.388	-.624	.332	-.174
Lflt Wdt		1.000	-.279	.968[a]	.791	-.183	.883	-.859	-.760	-.200	.199	-.794	-.016	-.604	.646	.115
Lflt Lgth/Lflt Wdt			1.000	-.028	-.324	.393	-.037	.459	.710	.168	.598	.133	.872	-.076	-.643	-.574
Lam Lgth				1.000	.733	-.076	.902[a]	-.781	-.611	-.179	.364	-.784	.215	-.642	.503	-.045
Ptl Lgth					1.000	-.726	.770	-.540	-.552	.107	.281	-.841	.038	-.873	.848	.554
Lam Lgth/Ptl Lgth						1.000	-.285	-.064	.121	-.457	-.065	.499	.156	.656	-.686	-.900[b]
Dst bt Nds							1.000	-.523	-.403	.244	.385	-.940[b]	.109	-.737	.501	.261
Frt Lgth								1.000	.943[a]	.637	.098	.401	.184	.226	-.564	.123
Frt Wdt									1.000	.591	.342	.327	.450	.140	-.650	-.122
Pdcl Lgth										1.000	.328	-.412	.014	-.363	.012	.587
No Ltrl Nrv											1.000	-.492	.806	-.689	.166	-.190
No Lflt Prs												1.000	-.083	.862	-.679	-.457
Brct Lgth													1.000	-.415	-.234	-.500
Frt Tx														1.000	-.679	-.415
Lflt Apx															1.000	.584
Lflt Bs																1.000

[a] = positivey significant values; [b] = negatively significant values

Key: Lflt Lgth - Leaflet Length; Lflt Wdt - Leaflet Width; Lflt Lgth/Lflt Wdt - Leaflet Length/Leaflet Width ratio; Lam Lgth - Lamin Length; Ptl Lgth - Petiolule Length; Lam Lgth/Ptl Lgth - Lamina Length/Petiolule Length ratio; Dst bt Nds - Distance between Nodes; Frt Lgth - Fruit Length; Frt Wdt - Fruit width; Pdcl Lgth - Pedicel Length; No Ltrl Nrv - No. of Lateral Nerves; No Lflt Prs - No. of Leaflet Pairs; Brct Lgth - Bract Length; Frt Tx - Fruit Texture; Lflt Apx - Leaflet Apex; Lflt Bs - Leaflet Base

further illustrated in Fig. 2 showing the dendrogram of the examined species. *B. coriacea* could be considered as the outlier, as members of the genus are divided into three main groups: *B. craibiana, B. grandiflora, B. bracteosa* and *B. confusa* as a more united group (group 1), *B. auriculata* as a monospecific group having some common ancestral characteristics with group 1, and *B. coriacea* existing as an entirely different mono-specific group with less degree of affinity with other members. The above observations reflect the statistical rule that, the less the coefficient value, the more the degree of affinity existing between any two species. Nonetheless, the extent of similarity measured by the correlation coefficient of cluster existing between *B. craibiana* and *B. grandiflora* may suggest a monophyletic origin of these species.

Furthermore, the descriptive chart presented in Fig. 3 supports the result from the PCA and dendrogram generated from analysis. This result tends to clearly separate *B. coriacea* and *B. auriculata* from other members of the genus, with uniquely different polygonal shapes while uniting *B. craibiana, B. grandiflora, B. bracteosa* and *B. confusa* with somewhat similar shapes.

We observed that leaflet shape and sizes varied within populations, which may be attributed to variations in light intensity affecting growth (Aborg 1943), or other environmental and genetic factors. In general, variations in the vegetative and floral organs are important diagnostic tools, which could be used in the delimitation of taxa, and the importance of these morphological features in taxonomic classification of plant species was noted by Nwachukwu (1997) and Stern (2000). Numerical taxonomy has also been reflected in parallel taximetrics and orthodox studies in *Crotalaria* (Bisby & Polhill 1973), the phenetic classification of

Table 5. Principal component analysis of the examined characters (Total variance explained)

Component	Initial Eigen values			Extraction Sums of Squared Loadings		
	Total	% of V	C %	Total	% of V	C %
1	7.625	47.658	47.658	7.625	47.658	47.658
2	3.774	23.585	71.243	3.774	23.585	71.243
3	3.331	20.816	92.059	3.331	20.816	92.059

Extraction Method: Principal Component Analysis.
% of V - % of Variance; C% - Cumulative %

Table 6. Component matrix of the eleven quantitative characters of *Berlinia* species studied

	Component		
	1	2	3
Leaflet Length	.801	.384	-.413
Leaflet Width	**.938***	-.038	-.319
Leaflet Length/Leaflet Width	-.304	**.926**	-.116
Lamina Length	.893	.202	-.376
Petiolule Length	**.942**	-.042	.222
Lamina Length/Petiolule Length	-.486	.208	-.769
Distance Between Nodes	.894	.234	-.008
Fruit Length	-.700	.331	.626
Fruit Width	-.646	.609	.451
Pedicel Length	.029	.310	**.846***
No. of Lateral Nerves	.323	.844	.128
No. of Leaflet Pairs	-.909	-.206	-.251
Bract Length	.024	**.919***	-.133
Fruit Texture	-.814	-.398	-.363
Leaflet Apex	.807	-.339	.242
Leaflet Base	.371	-.422	**.815**

Extraction Method: Principal Component Analysis. 3 components extracted.

Table 7. Cluster analysis based on average linkage between *Berlina* species studied

Stage	Similarity level	Distance level	Clusters joined		New cluster	No. of observations in new cluster
			Cluster 1	Cluster 2		
1	83.1601	5.4726	5	6	5	2
2	68.3388	10.2891	2	5	2	3
3	59.6305	13.1191	2	3	2	4
4	49.4879	16.4152	1	2	1	5
5	13.3992	28.1432	1	4	1	6

Table 8. Conservation status of the *Berlinia* species studied

Species	Assessment	Reference
B. auriculata	Not Threatened	Roskov et al. 2016
B. bracteosa	Not Threatened	Roskov et al. 2016
B. confusa	Least Concern	Contu 2012
B. coriacea	Least Concern	IUCN 2016
B. craibiana	Near threatened	Mackinder & Pennington 2011
*B. grandiflora**	Least Concern	Mackinder & Pennington 2011; Chukwuma, E.C (pers. obs.)

* - This species is the most widely distributed member of the genus.

Baphia species (Soladoye 1982), and delimitation of Nigerian species of *Sterculia* and *Eribroma* (Soladoye et al. 2011) to mention but a few. Thus its application in the present work has in no little way contributed to the existing taxonomic information regarding *Berlinia* species occurring in Nigeria. However, it is important to note that morphometric analysis is not sufficient to delimit taxa, even though it has greatly benefited plant systematic studies. Further studies in *Berlinia* are recommended in order to overcome challenges in the identification of species, especially in sterile or fragmentary states.

CONCLUSION

All the Nigerian *Berlinia* species studied can be said to be hygrophilous, except *B. grandiflora,* which is often found in forest-savanna boundaries. This work supports the co-existence of the *Berlinia* species examined, since they share many overlapping vegetative and floral characteristics. Some of these include: number of leaflet pairs (2(3)-5), leaf type (paripinnate), leaf margin (predominantly entire), leaflet arrangement (opposite/ sub-opposite) and fruit shape (oblong).

The conservation of our rich but endangered forest regions, particularly in Cross River State which is home to many indigenous plant species (regarded endemic), is also of great concern as this would ensure the availability and sustainable collection of many indigenous flora species including those of *Berlinia*.

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