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Significance of leaf morphological variations within some *Bauhinia* L. species

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Abstract
Leaf characters of 15 Egyptian *Bauhinia* species and two forms, investigated using both the eye lens and scanning electron microscope. Variations within the leaf shapes are recorded and all obvious morphological characters are subjected to statistical analyses. These analyses were restricted to the characters noticed by the eye lens only. Density, type and wall ornamentation of the hairs considerably varied between the studied taxa. Most of the species have epicuticular wax depositions with different shapes on the periclinal walls. Characters of both the periclinal and anticlinal walls, seen from SEM investigations are insignificant, while the hair type, density and wall ornamentations shows great variations within the taxa. This study supports the division of the *Bauhinia* species into two subgenera with five sections. Identification key and evolutionary line postulated within the studied species according to leaf macro-morphological characters.

Keywords: *Bauhinia*, division, evolution, leaf, morphology, taxonomy

Introduction
The pantropical genus *Bauhinia* L. has been the subject of a number of taxonomical treatments in which it has been recognized either as a single genus with several subgenera or as several distinct genera. *Bauhinia* was named after the two Swiss botanist's brothers Jean Bauhin (1541–1613) and Gaspard Bauhin (1560–1624), suggesting a brotherly relationship in its commonly bilobate leaves [1]. Genus *Bauhinia* L. considered from the largest genera belonging to family Fabaceae, subfamily Cercidoideae tribe Bauhinieae, subtribe Bauhiniinae as given by the Legume Phylogeny Working Group [2]. The division of the species under this genus has been faced with many controversial opinions [1,3,4,5,6,7]. This genus contains ca 350-400 species worldwide, except the Pacific islands [8]. Species belonging to this genus are cultivated, ornamental woody trees, shrubs or lianas characterized by the bilobed leaves. The division of the *Bauhinia* species has given by [9], who recognized four subgenera under the genus: *Barklya* (1 species), *Bauhinia* (140 species), *Elayuna* (6 species), and *Phanera* (150 species). The latter subgenus characterize by tendril-bearing species, while the three former taxa comprise tree or shrubby species.

In fact the classification of the species under this genus is complicated, and it has been recognized either as a large genus by [1,3,7,9,10,11], or as 8-9 distinct genera by [12,13,14]. Recent studies on molecular analyses suggest the division of the Bauhinia species into Bauhinia s.s and other independent [15,16,17,18]. Most of the above mentioned taxonomic divisions relayed on minor morphological differences in leaf and fruit characters. Larsen & Larsen in [19] concluded "that Bauhinia in the sense of Linnaeus, Bentham, De Candolle, Taubert and Hutchinson is an evolutionary unit and a very natural genus". Larsen and Larsen in [19] noted that *Bauhinia s.l.* presents a reticulate pattern of variation across its pantropical range. While this is undoubtedly true if the genus is considered as all-inclusive, recent studies of legume distributions have revealed repeated patterns of generic distribution which appear to be duplicated by at least some of the segregates of *Bauhinia*. Accordingly this investigation carried out to study the leaf macro- and micro-morphological characters, within the cultivated *Bauhinia* species cultivated in the Egyptian roads and gardens. Meanwhile, this study traces the evolutions within the studied species.

Materials and Methods
Fifteen species and two forms, commonly cultivated in the Egyptian roads and gardens, were subjected in this study. Herbarium sheets examined from the mentioned botanical gardens in Cairo, Egypt (table 1). Leaves from, at least 10 branches, were examined carefully by eye lens to observe the leaf surfaces and texture. Ten leaves measured by ruler for their lengths and width (widest part) and L/W calculated. Leaf morphological characters examined carefully from ten leaves, and photographed using ordinary camera. Terminology used in the description of the morphological characters is that of [20].

Sem Investigation
Parts of the dry leaves were stuck onto the Aluminum stubs using double cello tape. The stubs were coated with 30 nm gold in a polaron JFC-1100E coating unit, then examined and photographed under 15Kev, with JEOL JSM-IT200 SEM in the electron microscopes unit, Faculty of Science, Alexandria University, Egypt. Terminology used according to [21].

Data Analysis
The measured characters are subjected to SPSS program to calculate the standard error of the mean, standard deviation and variance. Similarity index and Pearson Coefficient have been calculated using the same program. Principal Component Analyses carried out between the studied leaf

characters to estimate the relationship between the characters in each category as well as clustering dendrogram between the studied taxa using PAST program v.3.

Table 1: Studied species, information of the herbarium sheets, source of materials, confirmation of nomenclature and synonyms.

No	Taxa	Collectors & date of collection	Source of materials	Confirmation of nomenclature	Synonyms
1	*B. acuminata L.*	Reham Mahdy 5/7/2021	Giza:Mazhar botanical garden	"ILDIS LegumeWeb entry for Bauhinia"; USDA, ARS, National Genetic Resources Program; "The Plant List entry for Bauhinia",IPNI	*B. linnaei* Ali *B. acuminata* Vell.
2	*B. blackeana* Dunn.(hybrid)	Reham Mahdy 5/3/2021	Giza:Mazhar botanical garden	The national flowers of Hong Kong. Lau *et al.* (2005).	No
3	*B. forficata* J.H.F.	Reham Mahdy 13/9/2020	Giza:Mazhar botanical garden	"ILDIS LegumeWeb entry for Bauhinia"; USDA, ARS, National Genetic Resources Program; "The Plant List entry for Bauhinia"	*B. candicans* Benth. *B. breviloba* Benth. *B. forficata subsp. forficata Basionym Pauletia forficata* (Link) A. Schmitz
4	*B. galpinii* N.E. Br.	Reham Mahdy and Al-Shaarawy 12/7/2021	Al-Abeed Agriculture Farm	"ILDIS LegumeWeb entry for Bauhinia"; USDA, ARS, National Genetic Resources Program; "The Plant List entry for Bauhinia"	*B.galpinii var. galpinii Perlebia galpinii* (N.E.Br.) A.Schmitz
5	*B.glabra* Jack	Reham Mahdy 12/3/2021	Giza:Mazhar botanical garden	Catalogue of life check list, The NY Bot. Gard.	*B.heterophylla* Kunth *Schnella glabra* (Jacq.) Dugand
6	*B. grandidieri* Baill	Reham Mahdy 5/7/2021	Giza:Mazhar Bot.Gard.	"ILDIS LegumeWeb entry for Bauhinia"; USDA, ARS, National Genetic Resources Program; "The Plant List entry for Bauhinia"	No
7	*B. grevei* Drake	Reham Mahdy 5/7/2021	Giza:Mazhar botanical garden	"ILDIS LegumeWeb entry for Bauhinia"; USDA, ARS, National Genetic Resources Program; "The Plant List entry for Bauhinia"	No
8	*B. hookeri* F. Muell.	Reham Mahdy and Al-Shaarawy 12/7/2021	Al-Abeed Agriculture Farm	IPNI-The International Plant Names Index.	*Lysiphyllum hookeri* (F.Muell.) Pedley
9	*B.madagascariensis* Desv.	Reham Mahdy 5/7/2021	Giza:Mazhar botanical garden	"ILDIS LegumeWeb entry for Bauhinia"; USDA, ARS, National Genetic Resources Program; "The Plant List entry for Bauhinia"	*B.commersonii* Scott-Elliot
10	*B.monandra* Kurz	Reham Mahdy 22/11/2020	Giza: Orman botanical garden	"ILDIS LegumeWeb entry for Bauhinia"; USDA, ARS, National Genetic Resources Program; "The Plant List entry for Bauhinia"	No
11	*B. purpurea* L.	Reham Mahdy 7/3/2021	Giza:Mazhar botanical garden	"ILDIS LegumeWeb entry for Bauhinia"; USDA, ARS, National Genetic Resources Program; "The Plant List entry for Bauhinia"	*B.platyphylla* Zipp. ex Span. *B.triandra* Roxb. *B.castrata* Blanco
12	*B.roxburghiana* Voigh	Reham Mahdy 15/9/2021	Giza:Mazhar botanical garden	IPNI (International Plant Names Index). Govaerts (1996) World Checklist of Seed Plants.	*B.emarginata* G.Don
13	*B. tomentosa* L.	Reham Mahdy 5/7/2021	Giza:Mazhar botanical garden	"ILDIS LegumeWeb entry for Bauhinia"; USDA, ARS, National Genetic Resources Program; "The Plant List entry for Bauhinia"	No
14	*B. vahlii* Wight & Arn	Reham Mahdy 8/3/2021	Giza:Mazhar botanical garden	"ILDIS LegumeWeb entry for Bauhinia"; USDA, ARS, National Genetic Resources Program; "The Plant List entry for Bauhinia"	*B.racemosa* Vahl *Phanera vahlii* (Wight & Arn.) Benth.
15	*B.variegata* (L.) Benth.	Reham Mahdy 7/5/2021	Giza:Mazhar botanical garden	Plants of the world on line	*Phanera varigata* (L.) Benth.
16	*B.variegata* (L.) alba	Reham Mahdy 8/3/2021	Doki: near Russian Center	"ILDIS LegumeWeb entry for Bauhinia"; USDA, ARS, National Genetic Resources Program; "The Plant List entry for Bauhinia"	No

Results

1. 1-Morphological Variations According to Eye Examination

Leaves of fifteen species, with two forms belonging to genus *Bauhinia* are investigated using both eye lenses and SEM. The life form of the studied taxa is mostly trees or shrubs, lianas are found in both *B.glabra* and *B. vahlii*. The stipules of the leaves are usually andante to the stem enclosing the axillary buds, or free as small linear leafy structures, except in *B.forficata* they are small spines at each side of the leaf base. The leaves are petiolate in all the studied taxa, with different lengths (table 2 and Plate 1). The variability within the leaf blades is noticeable within all the studied taxa. The base of the leaf blades is straight or convex and mostly simple, with orbicular or cordate shapes. In *B.glabra, B.grandidieri and B. grevei* the leaf blades are oblong or nearly ovate and bifoliate. The leaf texture is papyraceus, coriaceus, or scariosus except in *B. vahlii* it is spongiousus (table 2 & Plate 1). The veins in the leaf surface appearance are rectinervis, curvinervis or nervosus, with different numbers of main veins, from 1 to 15 (table 2 cont.). The main midrib length differs according to the deepness of the apical notch and the leaf length. The venation of the leaves is palmiformis either eureticulodromous or brochidodromous, except in both *B.grandidieri and B. grevei* the venation is rectinervis, eureticulodromous in the former and uninervouss brochidodromous or trinervous eureticulodromous. The leaf blade apices take variable wide of the V-shapes, it varied from the narrow V-shaped to the very wide V-shaped, except in *B. roxyburghiana* the apices are nearly obtuse (table 2 cont. & Plate 1).

Table 2: Vegetative morphological characters of the studied species examined by eye lens

Char.→Taxa↓	Life form	Stipules	Petiole L	Blade						
				form	base	L	W	L/W	Shape	texture
B.acuminata	shrub	free	2.7-4 (3.2)	Sim	Str	7.6-11.7 (9.30)	7.0-12.0 (9.20)	1.0-1.1 (1.02)	Orb	Coriaceus
B. blakeana	tree	adnate	3.3-4.4 (3.76)	Sim	Cv	8-13.6 (9.66)	8.9-14.2 (10.84)	0.8-1.0 (0.89)	Cor	Scariosus
B.forficata	tree	spiny	2-3 (2.56)	Sim	Str	6.5-9 (8.28)	4.8-6.7 (5.96)	1.3-1.5 (1.39)	Cor	Papyraceus
B.galpinii	shrub	adnate	0.5-0.8 (0.66)	Sim	Cv	2.5-3.6 (2.94)	3.5-5.2 (4.22)	0.6-0.8 (0.7)	Cor	Scariosus
B.glabra	liana	adnate	1.2-2 (1.68)	Bifol	Cv	1.2-3.8 (2.54)	1.05-1.8 (1.42)	1.1-2.5 (1.75)	Obl.	Papyraceus
B. grandidieri	shrub	free	0.6-0.8 (0.7)	Bifol	Str	0.8-1.2 (1.0)	0.4-0.7 (0.56)	1.6-2.0 (1.81)	Obl	Coriaceus
B. grevei	shrub	adnate	1.1-1.5 (1.28)	Bifol	Str	2.3-2.6 (2.48)	1.2-1.5 (1.3)	1.7-2.2 (1.92)	Obl	Papyraceus
		adnate	0.7-0.9 (0.8)	Sim	Str	3.1-3.4 (3.2)	1.4-2.0 (1.6)	1.6-2.3 (2.03)	Ovate	Papyraceus
B. hookeri	tree	free	1.2-2.3 (1.74)	Sim	Str	1.8-2.8 (2.34)	1.4-2.7 (2.16)	0.9-1.3 (1.11)	Orb	Coriaceus
B.madagascariensis	shrub	adnate	2.6-4.8 (3.86)	Sim	Str	6.2-9.2 (7.74)	5.8-7.8 (6.68)	1.1-1.3 (1.15)	Orb	Papyraceus
B.monandra	Shrub	free	2.7-5.2 (3.92)	Sim	Cv	6.5-15 (9.94)	7.2-14-8 (10.52)	0.91.0 (0.93))	Orb	Papyraceus
B. purpurea	tree	adnate	3.8-5.3 (4.52)	Sim	Cv	8.5-11 (9.54)	9.7-12.0 (10.66)	0.8-1.0 (0.9)	Orb	Coriaceus
B.roxburghiana	tree	adnate	5.6-6.8 (6.16)	Sim	Cv	10.5-14.8 (12.56)	13.0-18.5 (15.58)	0.8-0.9 (0.81)	Cor	Papyraceus
B.tomentosa	tree	free	1.5-2 (1.64)	Sim	Str	2.1-2.5 (2.2)	1.2-3.2 (2.62)	0.7-1.8 (0.95)	Orb	Scariosus
B. vahlii	liana	free	3.7-6.2 (5.1)	Sim	SCv	11.0-14.0 (12.38)	14.2-15.0 (14.68)	0.8-1.0 (0.84)	Cor	Spongiousus
B.variegata L.	tree	free	2.7-4.2 (3.52)	Sim	Cv	8.5-12.3 (10.16)	9.2-13 (10.66)	0.9-1.0 (0.95)	Orb	Coriaceus
B. variegata alba	tree	free	2.3-2.9 (2.7)	Sim	Str	8.6-13.6 (11.38)	10.0-14.4 (12.52)	0.8-1.0 (0.9)	Orb	Coriaceus

Abbreviations: BCord=broadly cordatus, Bifor= Biforked, Cor=Cordatus Cv=Convex, L/W=Length/Width, Ren=ReniformisSCv=Strong convex, Obl= Oblongus, Orb=Orbicularis, Sim=Simple, STR=Straight.

Table 2 Cont.: Vegetative morphological characters of the studied species examined by eye lens

No	Char.→ Taxa↓	Surface	No of main veins	Midrib Length (cm.)	Leaf L./Midrib L.	veining	Apex	Notch depth
1	*B.acuminata* L.	Rectinervis	9	3.9-7.1 (5.44)	0.96-1.10 (1.02)	Palmiformis Eureticulodromous	Vsh	3-4.7 (4.0)
2	*B. blakeana* Dunn	Curvinervis	11	4.2-7.2 (5.10)	0.83-0.96 (0.89)	Palmiformis Eureticulodromous	WVsh	3.7-6.4 (4.6)
3	*B.forficata* Link	Nervosus	9	3.1-4.0 (3.74)	1.3-1.5 (1.39)	Palmiformis Eureticulodromous	Ysh	3.4-5 (4.5)
4	*B.galpinii* N.E.Br.	Nervosus	5	1.8-2.9 (2.32)	0.6-0.8 (0.71)	Palmiformis Eureticulodromous	WVsh	0.4-0.7 (0.6)
5	*B.glabra*Jacq.	Curvinervis	3	0	0	Palmiformis Brochidodromous	Vsh	0
6	*B grandidieri* Baill.	Rectinervis	2 in each	0	0	Rectinervis, Eureticulodromous	DVsh	0
7	*B. grevei* Drake	Nervosus	1	0	0	Uninervous, Brochidodromous	Acute	0
		Nervosus	3	0.2-0.5 (0.38)	6.4-15.5 (9.23)	Trinervous, Eureticulodromous	DVsh	2.7-3.0 (2.8)
8	*B. hookeri* F. Muell.	Nervosus	9	1.2-2.1 (1.64)	1.3-1.5 (1.36)	Palmiformis Brochidodromous	WVsh	0.3-0.6 (0.4)
9	*B.madagascariensis* Desv.	Nervosus	7	1.8-3.6 (2.74)	2.5-3.44 (2.91)	Palmiformis Eureticulodromous	NVsh	4.1-5.6 (5.0)
10	*B.monandra* Kurz	Nervosus	9	2.5-9.5 (5.6)	1.58-2.6 (1.95)	Palmiformis Brochidodromous	Vsh	2.9-5.5 (4.3)
11	*B. purpurea* L.	Curvinervis	11	4.5-6.4 (5.56)	1.62-1.89 (1.72)	Palmiformis Eureticulodromous	Vsh	3.6-4.6 (4.0)
12	*B.roxburghiana*Voigt	Nervosus	9	9-11.5 (10.18)	1.13-1.35 (1.23)	Palmiformis Brochidodromous	Obtuse	1.5-3.8 (2.9)
13	*B.tomentosa*L.	Rectinervis	7	0.5-0.9 (0.66)	2.33-4.2 (3.51)	Palmiformis Eureticulodromous	Vsh	1.2-1.7 (1.5)
14	*B.a vahlii* Wight &Arn.	Nervosus	13 or 15	5-7.5 (6.25)	1.57-2.7 (2.03)	Palmiformis Eureticulodromous	Ysh	4-8.5 (6.1)
15	*B.variegata L.*	Curvinervis	11	6.5-11 (8.4)	1.09-1.38 (1.22)	Palmiformis Eureticulodromous	NVsh	1-2.5 (1.8)
16	*B. variegata alba*	Rectinervis	13	6.5-11 (8.66)	1.24-1.39 (1.32)	Palmiformis Eureticulodromous	WVsh	2.1-3.7 (2.7)

Abbreviations: DVsh=Deep V-shaped, NVsh=Narrow V-shaped, Vsh=V-shaped, WVsh=wide V-shaped, Ysh=Y-shaped

2. Morphological Variations According to Sem Examination

The observed features under the SEM are summarized in table 3 and illustrated in plate 2. The leaf surfaces within the studied taxa are mostly hairy, except in *B.hookeri* and *B.roxburghiana* they are glabrous (Photos 15 and 22). The hairs are distributed all over the leaf surfaces, except in *B.galpinii, B.glabra* and *B.grevei* the hairs are restricted in the margins only (Photos 8 & 13). The hairs are of one type in all the studied taxa, except *B. vahlii*, two types of hairs recorded, multicellular uniserriate pointed and globular hairs (Photos 25 & 26). The hairs, when present, are of different densities and types (table 3). The multicellular, uniserriate pointed appeared woolly, while the densely hairy are mostly unicellular pointed or tabular. The multicellular uniserriate glandular hairs present sparsely in *B. galpinii* only in the

leaf margins. There are globular unicellular hairs covering the leaf blade of *B.madagascariensis* and present on *B.vahlii* (Photos 16, 17, 25 & 26). The hair basal cells are unicellular except in *B.galpinii, B.glabra* they are multicellular. The hair walls are either smooth or furniture by echinae, granules or scales (table 3 & Photos 4, 7, 12, 19, 21, 24, 26 & 30).

The shape of the epidermal cells are nearly isodiametric or elongated except in *B.madagascariensis*, they are triangular (Photo17). The periclinal walls are mostly grooved, straight or sinuate except in *B.forficata, B. monandra* and *B. vahlii*, the periclinal walls are superficial and straight. The anticlnal walls are convex, except in those species with superficial periclinal walls, the anticlinal walls are flat.

Secondary ornamentations on the anticlinal walls take different shapes; they are striate in *B. galpinii*, pitted in *B.grandidieri*, echinate in *B.monandra* and either smooth or granulate in the rest of the studied species (table 3). The tertiary sculpture is in the form of epicuticular secretions which present in different densities and shapes or completely absent in *B. galpinii, B.grevei, B.monandra* and *B.roxyburghiana*. The epicuticular secretions takes the shapes of needle, flakes, globules or rosette star shapes (Photos 10,12,15,17,19,21 & 24).

Table 3: Vegetative morphological characters of the studied species examined by SEM

No	Char.→ Taxa↓	Trichomes					Shape of Epid. cell					Epicuticular secretions	
		P	*H*	D	T	*Ba*	W		Per W.	Ant W	Or	*D*	*T*
1	*B.acuminata* L.	Al	Is	Wo	MUP	Uc	Sm	osI	StG	vC	--	++++	Ne
2	*B. blakeana* Dunn	Al	Is	HD	MUP	Uc	Sc	osI	GtS	vC	---	++++	Ne
3	*B.forficata* Link	Al	Is	Wo	MUP	Uc	Sm	osI	SS	Fl	Gr	+	Gl
4	*B.galpinii* N.E.Br.	M	Is	HS	GUM	Mc	Sm	lE	SG	vC	tS	---	---
5	*B.glabra*Jacq.	M	Is	SH	TMM	cM	Sm	osI	GtS	vC	---	++++	Ro
6	*B grandidieri* Baill.	Al	Is	DH	UT	Uc	Sc	Iso	Gs	Cv	Pi	++++	Gl
7	*B. grevei* Drake	M	Is	SH	UP	Uc	Gr	osI	GtS	vC	Gr	---	---
		M	Is	SH	UP	Uc	Gr	Iso	StG	Cv	Gr	---	---
8	*B. hookeri* F. Muell.	---	---	G	---	---	---	Iso	SG	Cv	Sm	++	Ne
9	*B.madagascariensis* Desv.	Al	Is	H	Gl	Uc	Sm	Tr	SG	Cv	Sm	++	Ne
10	*B.monandra* Kurz	Al	Is	DH	UT	Uc	Ec	El	SS	Fl	Ec	---	---
11	*B. purpurea* L.	Al	Is	DH	UP	Uc	Sc	Iso	Gs	Cv	Gr	+	Gl
12	*B.roxburghiana*Voigt	---	---	G	---	---	---	El	SG	Cv	Sm	---	---
13	*B.tomentosa*L.	Al	Is	DH	UP	Uc	Ec	Iso	Gs	Cv	Gr	++++	Ro
14	*B. vahlii* Wight &Arn.	Al	H	Wo	MUP& Gl	Uc	Sm	El	SS	Fl	Sm	++++	Fc
15	*B.variegata L.*	Al	Is	DH	UP	Uc	Sm	El	Gs	Cv	Sm	++	Gl
16	*B. variegata alba*	Al	Is	DH	UP	Uc	Sm	El	Gs	Cv	Sm	++	Gl

Abbreviations: Al=All over the surface, AntW=Anticlinal wall, Bc=Basal cells, Cv=Convex, D= Density, DH=Densely hairy, Ec=echinate, El=Elongated, Fc=flakes, Fl=Flat, G=glabrous, Gl=Globular, Gs=grooved sinuate, Gr=Granulate, H=heterogenous, H=Homogeneity, Is=Isogenous, Iso= Isodiametric, M=Margin, Mc=multicellular, MMT= Multicellular multiserriate tabular, MMU=Multicellular multiseriate glandular, MUG=multicellular uniseriate glandular, MUP=multicellular uniserriate pointed, Ne=Needle, Or=ornamentation, P=position, Per W.=periclinal wall,Pi=pitted, Ro=Rosette, Sc=Scally, SH=Sparsely hairy, SS=straight superficial, St=Straite, Sm=Smooth, StS=straight superficial, T=type, Tr=triangular, Uc=unicellular, UT= unicellular tabular, W=Wall Wo=Woolly.

Identification key for the studied taxa

I-Spiny stipules----------*B.forficata*
I-Leafy stipules
II-Bifoliate leaves
III-Number of main midribs in each leaflet 3-------*B.glabra*
III-Number of main midribs in each leaflet 2--*B.grandidieri*
III-Number of main midribs in each leaflet 1---*B.grevei* I
II-Simple leaves
III-Number of main midribs 3----------*B.grevei* II
III-Number of main midribs in each leaflet 5----*B.galpinii*
III-Number of main midribs in each leaflet 7
IV-Leaves small, their lengths 2.1-2.5 cm------*B.tomentosus*
IV-Leaves big, their lengths 6.2-9.2 cm----*B.madagascariensis*
III-Number of main midribs 9
IV-Leaves small, their lengths 1.8-2.8 cm-----*B.hookeri*
IV-Leaves big, their lengths more than 6.5 cm
V-Leaf apex obtuse----------*B.roxyburghiana*
V-Leaf apex notched
VI-Leaf venation Eureticulodromous--------*B.acuminata*
VI-Leaf venation Brochidodromous------*B.monandraa*
III-Number of main midribs 11
IV-Leaves big, their lengths more than 8.0 cm
V-Leaf apex shallow notched 1.0-2.5 cm-----*B.variegata*
V-Leaf apex deep notched more than 3.5 cm
VI-Leaf venation Eureticulodromous
VII-Leaf blades covered with very dense needle shaped wax depositions-*B.Blakeana*
VII-Leaf blades covered with sparse globular wax depositions----------*B.purpurea*
III-Number of main midribs more than 11
IV-Leaves big, their lengths more than 8.0 cm
V-Leaf apex shallow notched 2.1-3.7 cm---*B.variegata alba*
V-Leaf apex shallow notched 4.0-8.5 cm-----*B.vahlii*

3. Data Analysis

The data analyses were according to the observable results as they give obvious variation between the studied taxa. The fifteen characters listed in tables 4 & 5 are subjected to statistical analyses as resulted in tables 6 & 7 and illustrated

in Figs 1 & 2. All the characters are measured as separate ones and the mean, standard error and deviation, mode, variance, range, maximum, minimum and the summation of the entire item are presented in table 6. Correlation analyses of the fifteen characters indicated that the leaf length, width, number of veins, length of the main midrib and apical notch dept are highly correlated as well as both the leaf type and form. In the second category of +ve correlation are the petiole length and the leaf blade base; the leaf length, width and texture with the leaf blade base; venation type and leaf state (bifoliate versus simple); Main midrib length with the apical notch depth. On the other hand, the leaf length and width beside the number of veins and length of the main midrib are –vely correlated the leaf blade form. Also the type of venation and the depth of the apical notch beside the main midrib length are –vely correlated. The third category is the highly –ve correlated characters, which are the leaf blade form with both the number of veins and apical notch depth as well as the venation type with the number of veins (table 7).

The clustering dendrogram divided the studied taxa into two main categories at similarity index of 33.33. The first group, which has two subgroups A & B, includes the species, *B.acuminata, B., B.blackena, B.monandra, B. purpurea* , the two *varigata* forms, *B.vahli* and *B.roxyburghiana.* These two later species are separated from the rest of the group, at similarity index 49.90 in subgroup B, while the rest of the species in subgroup A. The second group has both *B.forficata* and *B.madagascariensis* in subgroup Cat similarity matrix 34.62 and *B.galbenii, B.glabra, B.glandidieri,* and the two *B.grevei* at group D. *B.hookeri* and *B.tomentosa* came together in subgroup Eat similarity index of 58.62 (Fig. 1).

Table 4: Characters employed in data and numerical analysis

Taxa	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Acum.	2	2	3.2	1	1	1	9.3	9.2	2	2	1	9	5.4	1	4.0
Blak.	1	1	3.8	1	1	2	9.7	10.8	3	3	2	11	5.1	1	4.6
Forf	1	3	2.6	1	1	1	8.3	6.0	1	5	3	9	3.7	1	4.5
Galb	2	2	0.7	1	1	2	4.2	0.7	3	3	3	5	2.3	1	0.6
Glab	3	2	1.9	1	2	2	2.5	1.4	1	2	2	3	0	2	0
Gran	2	1	0.7	1	2	1	1.0	0.6	2	4	1	2	0	5	0
Grev 1	2	1	1.3	2	2	1	2.9	1.3	1	6	3	1	0	4	0
Grev 2	2	1	0.8	2	1	1	3.2	1.6	1	4	3	3	0.4	3	2.8
Hook	3	2	1.7	1	1	1	2.3	2.2	2	3	3	9	1.6	2	0.4
Madg	2	1	3.9	1	1	1	7.7	6.7	1	1	3	7	2.7	1	5.0
Mon	2	2	3.9	1	1	2	9.9	10.5	1	2	3	9	5.6	2	4.3
Purp	1	1	4.5	1	1	2	9.5	10.7	2	2	2	11	5.7	1	4.0
Roxy	1	1	6.2	1	1	2	12.6	15.6	1	7	3	9	10.1	2	2.9
Tome	1	2	1.6	1	1	1	2.2	2.6	2	2	1	7	0.7	1	1.5
Vah	3	2	5.1	1	1	3	12.4	14.7	4	5	3	13	6.3	1	6.1
Var	1	2	3.5	1	1	2	10.2	10.7	2	1	2	11	8.4	1	1.8
V.alba	1	2	2.7	1	1	1	11.4	12.5	2	3	1	13	8.7	1	2.7

Table 5: Characters types and states employed in numerical analyses

No.	Character	Type	States
1	Life form	Multistate qualitative unordered	1-tree , 2-shrub , 3-liana
2	stipules	Multistate qualitative unordered	1-adnate , 2-free, 3-spiny
3	Petiole length	Continuous	
4	Leaf blade state	Binary	1-one type , 2- two types
5	Leaf blade form	Binary	1-simple , 2-bilobed
6	Leaf blade base	Multistate qualitative ordered	1-straight , 2-convex , 3-strong convex
7	Leaf blade length	Continuous	
8	Leaf blade width	Continuous	
9	Leaf blade texture	Multistate qualitative unordered	1-papyraceus , 2- coriaceus , 3- scariosus, 4- spongiousus
10	Leaf blade apex	Multistate qualitative ordered	1-narrow V-shaped , 2-V-shaped , 3- wide V-shaped , 4-deep V-shaped, 5-Y-shaped , 6-acute, 7-obtuse
11	Leaf blade surface	Multistate qualitative unordered	1- rectinervis , 2- curvinervis, 3-nervosus
12	Number of veins	Continuous	
13	Length of main mid rib	Continuous	
14	Venation	Multistate qualitative unordered	1- Palmiformis Eureticulodromous , 2- Palmiformis Brochidodromous , 3-Trinervous, Eureticulodromous , 4- Uninervous, Brochidodromous , 5-Rectinervis, Eureticulodromous
15	Notch deep	Continuous	

Table 6: Statistical data of the 15 characters subjected to numerical analyses

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Mean	1.7647	1.6471	2.8294	1.1176	1.1765	1.5294	7.0176	6.9294	1.8235	3.2353	2.2941	7.7647	3.9235	1.7647	2.6588
Std. Error of Mean	0.1825	0.14706	0.3947	0.08055	0.09531	0.15141	0.9777	1.27111	0.21412	0.41595	0.20588	0.91366	0.80154	0.29116	0.4831
Mode	1.00[a]	2.00	0.70[a]	1.00	1.00	1.00	1.00[a]	10.70	1.00[a]	2.00	3.00	9.00	0.00	1.00	0.00
Std. Deviation	0.75245	0.60634	1.62741	0.33211	0.39295	0.62426	4.03117	5.24092	0.88284	1.71499	0.84887	3.76712	3.30483	1.20049	1.99188
Variance	0.566	0.368	2.648	0.110	0.154	0.390	16.250	27.467	0.779	2.941	0.721	14.191	10.922	1.441	3.968

Range	2.00	2.00	5.50	1.00	1.00	2.00	11.60	15.00	3.00	6.00	2.00	12.00	10.10	4.00	6.10
Minimum	1.00	1.00	0.70	1.00	1.00	1.00	1.00	0.60	1.00	1.00	1.00	1.00	0.00	1.00	0.00
Maximum	3.00	3.00	6.20	2.00	2.00	3.00	12.60	15.60	4.00	7.00	3.00	13.00	10.10	5.00	6.10
Sum	30.00	28.00	48.10	19.00	20.00	26.00	119.30	117.80	31.00	55.00	39.00	132.00	66.70	30.00	45.20

Table 7: Similarity index between the 15 Characters

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1														
2	0.081	1													
3	-0.249	-0.103	1												
4	0.118	-0.402	-0.412	1											
5	0.361	-0.247	-0.448	0.31	1										
6	0.149	0.029	0.568*	-0.319	-0.15	1									
7	-0.384	0.097	0.877**	-0.37	-0.578*	0.503*	1								
8	-0.363	0.005	0.918**	-0.394	-0.531*	0.524*	0.97**	1							
9	0.122	0.11	0.113	-0.351	-0.265	0.52*	0.222	0.251	1						
10	-0.003	-0.156	0.098	0.387	0.213	0.052	0.067	0.09	-0.053	1					
11	0.311	-0.029	0.174	0.313	-0.165	0.278	0.082	-0.003	-0.177	0.379	1				
12	-0.329	0.317	0.703**	-0.576*	-0.73**	0.402	0.825**	0.838**	0.457	-0.175	-0.094	1			
13	-0.473	0.101	0.802**	-0.424	-0.566*	0.439	0.934**	0.935**	0.199	0.061	-0.038	0.815**	1		
14	0.281	-0.465	-0.473	0.544*	0.756**	-0.324	-0.579*	-0.505*	-0.336	0.423	0.011	-0.745**	-0.518*	1	
15	-0.203	0.06	0.709**	-0.238	-0.637**	0.325	0.763**	0.714**	0.209	-0.045	0.189	0.663**	0.525*	-0.558*	1

Move cells= highly +ve correlated characters, Orange cells= +ve correlated, Blue cells= highly –ve correlated, Green cells= -ve correlated characters

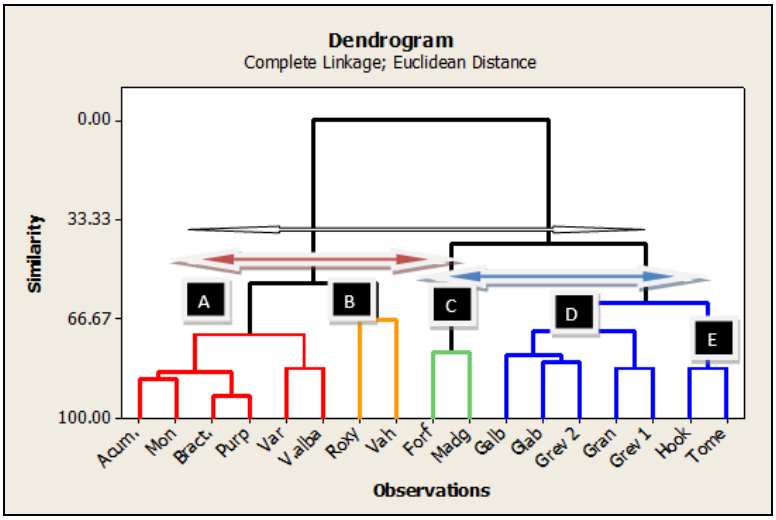

Fig 1: Clustering analysis of the studied taxa according to macro-morphological characters

Discussion

Leaf morphology consider from the most important vegetative parts in plant identifications. Most of the world floras relay on the leaf variations in the identification keys. Not only the macro-morphological characters, but also the micro-morphological features aid in the taxonomical decisions [21, 22, 23, 24]. found that the type and density of stomata in both the abaxial and adaxial surfaces in 12 species and 3 varieties of *Bauhinia* are able to categorize these taxa into four groups. Genus *Bauhinia* Linn. belonging to the tribe Cercideae, subfamily Caesalpinoideae, family Leguminosae Juss. faced with many taxonomical opinions as mentioned before. According to Wunderlin *et al.* [3, 25], species within this genus classified under four subgenera; the mostly arborescent or shrubby subgenera *Bauhinia*, *Elayuna* and *Barklya*, beside the lianas subgenus *Phanera*. In a way to trace the relationship between the *Bauhinia* species, this investigation carried out. The sixteen Egyptian road trees *Bauhinia* species subjected for leaf examinations and according to the macro- and micro-morphological characters taxonomical identification key constructed. From the clustering analysis of the fifteen characters, two well recognized groups identified (Fig.1). These groups did not separate the lianas, shrubs from the trees as they gather eight species; *B.acuminata*, *B.*, *B.blackena*, *B.monandra*, *B. purpurea*, the two *varigata* forms, *B.vahli* and *B.roxyburghiana*; in the first group. The second group has the other eight species, with the two *B.grevei* forms; *B.forficata* and *B.madgascariensis*, *B.galbenii*, *B.glabra*, *B.glandidieri*, the two *B.grevei*, and *B.hookeri* and *B.tomentosa*. These two groups based according to the similarities in leaf macro-morphological characters. Each of these two groups is subdivided into two or three categories. These divisions favored the recognition of the *Bauhinia* species as large genus, as proposed by [1,3,7,10,11]with two subgenera and five sections. The most significant +ve correlated leaf characters are the petiole length, leaf blade length, width, base, state, and texture as well as the apical notch, number of palmate nerves, length of the main midrib and type of venation. These characters are simply recognized by eye-lens investigation, and were evaluated by [26]. These characters can give postulated line of evolution

within the studied species. Larsen & Larsen in [19] concluded "that *Bauhinia* in the sense of Linnaeus, Bentham, De Candolle, Taubert and Hutchinson is an evolutionary unit and a very natural genus". Larsen and Larsen [19] noted that Bauhinia *s.l.* presents a reticulate pattern of variation across its pantropical range. [4] mentioned that genus *Bauhinia* is paraphyletic with the monospecific genus *Brenierea* clustered within it. This genus, usually described as sister to *Bauhinia s.l.*, forms a clade with *Bauhinia s.s.* and other genera. But tracing the evolutionary line within the *Bauhinia s.l.* species did not mentioned. From the obvious leaf macro-morphological characters, we can postulate that the simple leaf blades with shallow apical notch or rounded apex, with many palmate nerves are the primitive species, while the deepest apical notch or bifoliate leaves with few nerves can be considered as more advanced. Line of evolution of the studied taxa according to macro-morphological characters is postulated in Fig.2.

In spite of the importance of the micro-morphological characters in taxonomy, in this study gave limited role in the grouping of the genus. The most important micro-morphological characters are the hair type, wall and epicuticular depositions. The presence of globular unicellular hairs in both *B. madagascariensis* and *B.vahlii* was recorded by [27] and called it cavicated secretory hairs.

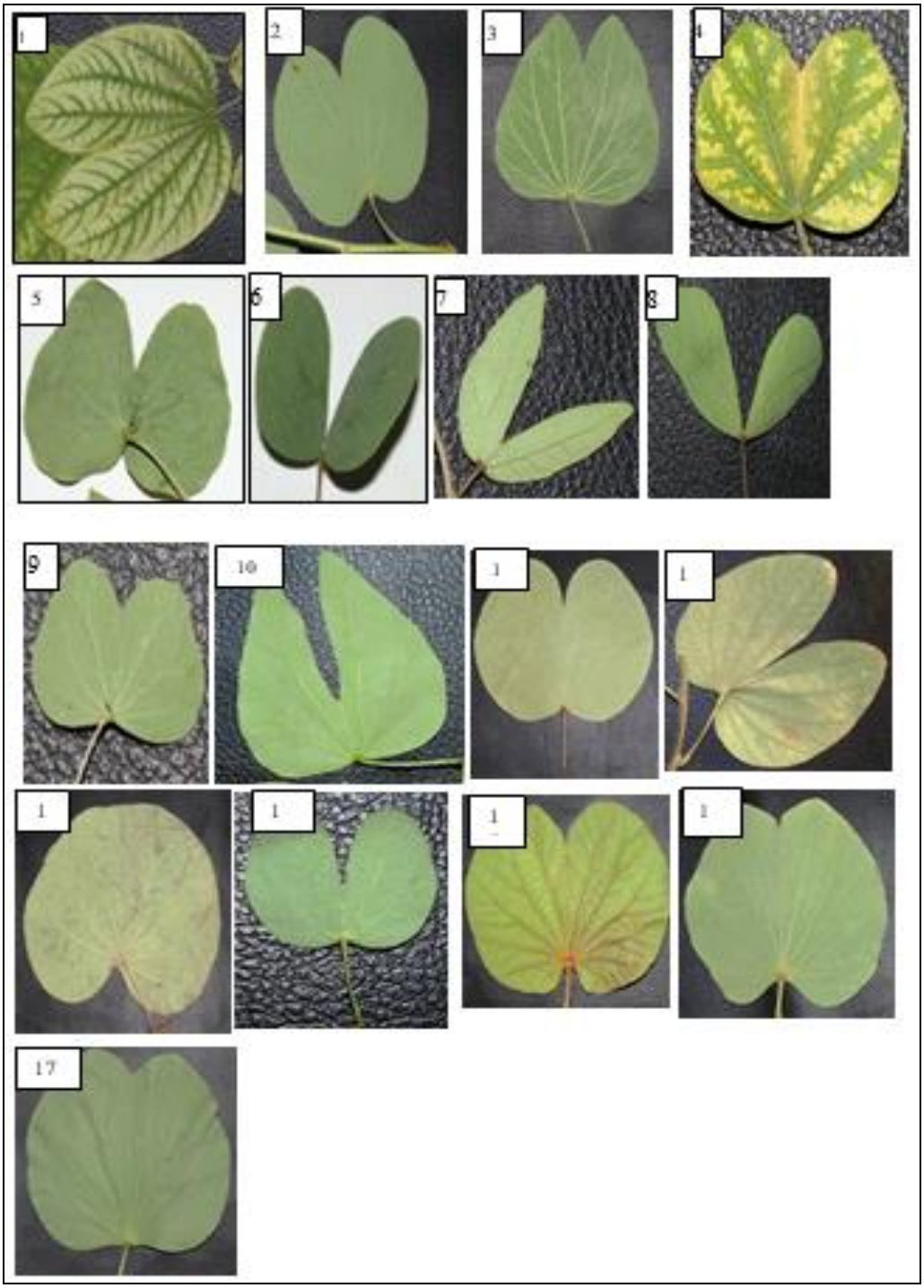

Plate 1: Photographs of *Bauhinia* species: 1- *B. acuminata, 2- B.blakeana, 3-B.forficata, 4- B.galpinii, 5- B. glabra, 6- B.grandidieri, 7&8- B. grevei, 9- B.hookeri, 10- B.madagascariensis, 11- B. monandra, 12- B.purpurea, 13- B. roxburghiana, 14- B.tomentosa, 15- B.vahlii, 16- B.variegata, 17- B. varigata alba.*

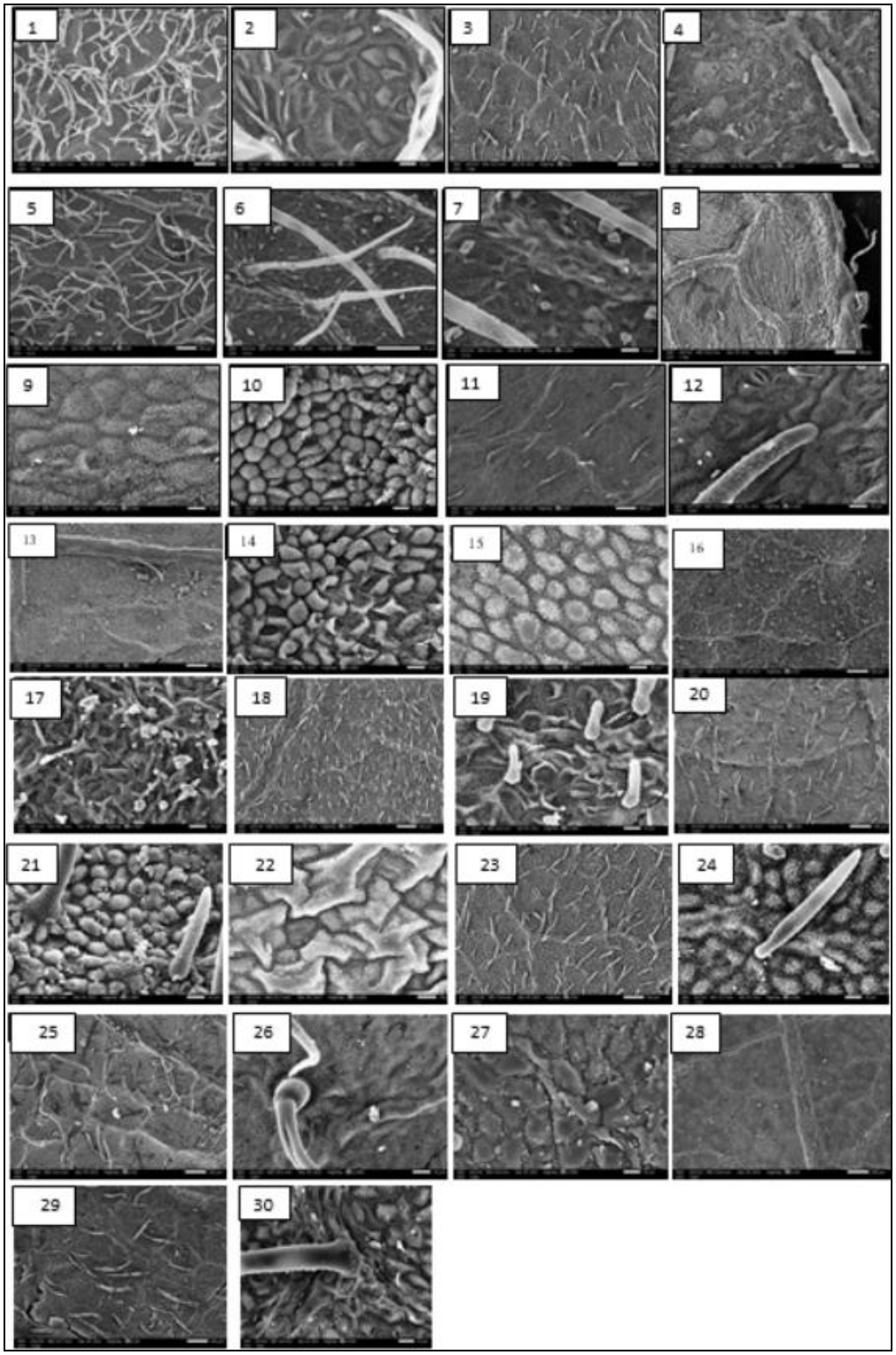

Plate 2: SEM Photographs in the leaf surfaces of *Bauhinia* species: 1&2 *B. acuminata*, 3&4*B.blakeana*, 5,6 &7*B.forficata*, *8&9 B.galpinii, 10 B. glabra*, 11&12*B.grandidieri,13&14 B. grevei, 15- B.hookeri, 16&17B.madagascariensis, 18&19 B. monandra, 20&21B.purpurea, 22- B. roxburghiana, 23&24- B.tomentosa, 25&26 B.vahlii, 27&28B.variegata, 29&30 B. varigata alba.*

Conclusion

This study supports the previous work of considering genus *Bauhinia* a large genus with the division of its species under two subgenera and five sections. Species within the genus show an evolutionary line as the simple leaves with rounded apices, in *B. roxyburghiana*, considered the most primitive ones.

The notched apices with different depths are steps in the evolution toward the bifoliate leaves in *B.grevei*, which considered the most advanced species within the studied taxa. This work needs further molecular and phylogenetic works to assess the relationship within the taxa.

References

1. Lewis GP, Forest F. Tribe Cercideae. Legumes of the world. Edited by Edited by: Lewis G, Schrire B, Mackinder B, Lock M., Kew: The Royal Botanic Gardens, 2005, 57-68.
2. The Legume Phylogeny Working Group (LPWG). "A new subfamily classification of the Leguminosae based

on a taxonomically comprehensive phylogeny". *Taxon*.,2017:66(1):44-77.
3. Wunderlin P, Larsen K, Larsen SS. Reorganization of the Cercideae (Fabaceae: Caesalpinioideae). Biol. Skr,1987:28:1-40.
4. Sinou C, Forest F, Lewis GP, Bruneau A. The genus Bauhinias.l. (Leguminosae): aphylogeny based on the plastidtrnL–trnF region. Botany,2009:87(10):947-960. DOI: 10.1139/B09-065.
5. Wunderlin RP. Revision of the arborescent Bauhinias (Fabaceae: Caesalpinioideae: Cercideae) native to Middle America. Ann. Miss. Bot. Gard.,1983:70:95-127.
6. Wunderlin RP. Revision of Bauhinia subgenus Bauhinia section Amaria (Cercideae, Caesalpinioideae, Fabaceae). Sida,2006:22(1):97-122.
7. Wunderlin RP. Revision of Bauhinia subgenus Bauhinia section Pauletia (C ercideae, Caesalpinioideae, Fabaceae). J. Bot. Res. Inst. Texas,2009:3(2):629-637.
8. Juarez P, Flores R, Blanco MA. Bauhinia proboscidea (Fabaceae: Cercidoideae), a new species from Costa Rica and Panama, with notes on B. beguinotii, B. gorgonae and B. pansamalana. Phytotaxa,2018:361(1):025-040. DOI: https://doi.org/10.11646/phytotaxa.361.1.2.
9. Duarte-Almeida JM, Negri G, Salatino A. Volatile oils in leaves of Bauhinia (Fabaceae Caesalpinioideae). Biochemical Systematics and Ecology,32(8):747-753.
10. Zhang DX. A cladistic analysis of Bauhinia L. (Leguminosae). Chin J Bot.,1995:7:52-64.
11. Wunderlin RP. Reorganization of the Cercideae (Fabaceae: Caesalpinioideae). Phytoneuron,2010:48:1-5.
12. Chen TC. Bauhinia Linn. Flora Reipublicae Popularis Sinicae, Tomus 39. Edited by: Wu TL, Chen PY, Wei CF, Chen TC., Beijing: Science Press, 1988, 145-203.
13. Hao G, Zhang DX, Zhang MY, Guo LX, Li SJ. Phylogenetics of Bauhinia subgenus Phanera (Leguminosae: Caesalpinioideae) based on ITS sequences of nuclear ribosomal DNA. Bot Bull Acad Sin,2003:44:223-228.
14. Chen TC, Zhang DX, Larsen K, Larsen SS. Bauhinia Linnaeus. Flora of China, vol. 10. Edited by: Wu ZY, Raven PH, Hong DY., Beijing: Science Press & St. Louis: Missouri Botanical Garden Press, 2010, 6-21.
15. Bruneau A, Forest F, Herendeen PS, Klitgaard BB, Lewi GP. Phylogenetic relationships in the Caesalpinioideae (Leguminosae) as inferred from chloroplast trnL intron sequences. Syst. Bot,2011:26:487-514.
16. Doyle JJ, Luckow MA. The rest of iceberg: legume diversity and evolution in a phylogenetic context. Pl Physiol,2003:131:900-910. 10.1104/pp.102.018 150.
17. Bruneau A, Mercure M, Lewis GP, Herendeen, PS. Phylogenetic patterns and diversification in the caesalpinioid legumes. Botany,2008:86:697-718. 10.1139/B08-058.
18. Wang QZ, Song Y, Chen S, Shen ZL. Leaves and fruits of Bauhinia (Leguminosae, Caesalpinioideae, Cercideae) from the Oligocene Ningming Formation of Guangxi, South China and their biogeographic implications. BMC Evolutionary Biology,2014:14:88-104.
19. Hou D, Larsen DHK, Larsen SS.Caesalpinaceae, Flora Melesiana Series 1, Kalkman, C. et al, 1996, 409-784.
20. Stearn WT. Botanical Latin. 3rd. ed. David & Charles, Newton Abot, London, North Promftrt (Vt), 1986.
21. Stace CA. The taxonomic importance of the leaf surface. In: Heywood VH and Moore DM (eds.) Current concepts in plant taxonomy, Academic Press, London, U.K, 1984.
22. Kathiresan P, Karar P, Siva H. Comparative micromorphological and phytochemical studies on the roots of three Viburnum (Caprifoliaceae) species. Turkish Journal of Botany,201135:663-670.
23. Taia WK, Shehata AA, Ibrahim MM, El-Shamy I. Vegetative Morphological Variations within Some Egyptian Amaranthus L. Species. Jordon Journal of Biological Sciences (JJBS),2020:13(5):137-146.
24. Kotresha K, YN Seetharan YN. Epidermal studies in some species of Bauhinia L. (Caesalpinoideae). Phytomorphology,1995:45(1-2):127-137.
25. Wunderlin RP, Larsen K, Larsen SS. Cercideae Bronn (1822). Advances in legume systematics, part 1. Edited by: Polhill RM, Raven PH., Kew: The Royal Botanic Gardens, 1981, 107-116.
26. Sutarn SS, Salunka RJ. Study of leaf venation in some species of genus Bauhinia L. Journal of Phytocognosy and Phytochemistry,5(4):122-124.
27. Marinho CR, Oliviera RB, Teixeira SP. The uncommon cavitated secretory trichomes in Bauhinia s.s. (Fabaceae): the same roles in different organs. Botanical Journal of the Linnean Society,2016:180:104-122.