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IMPLICATION OF LEAF ARCHITECTURE AND ITS TAXONOMIC SIGNIFICANCE IN DELIMITATION OF SOME SELECTED TAXA OF THE FAMILY MALVACEAE *s. l.*

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Abstract: ***Malvaceae s. l. "Core Malvales" is an expanded paraphyletic family that undergoes several taxonomic treatments, however, there is a considerable variation in its circumscription. In this context, leaf architecture, a morphological character reported to be genetically fixed, is considered a significant taxonomic tool in taxa identification and delimitation. Herein, eleven taxa namely, Abutilon hirtum, Hibiscus × rosa- sinensis, Hibiscus sabdariffa, Hibiscus schizopetalus, Hibiscus syriacus, Hibiscus tiliaceus, Hibiscus trionum, Malvaviscus arboreus, Sida alba, Dombeya burgessiae, and Dombeya tiliacea. were investigated morphologically based on leaf architecture including (leaf blade macromorphological characters, major veins orders, and minor veins orders) for each taxon to estimate the applicability of leaf architectural features in the taxa identification and delimitation. A phenetic relationship between the taxa under investigation based mainly on the major vein categories was constructed using UPGMA and PCA plotting analysis. The resulting clustering dendrograms segregated the eleven studied taxa into two main clusters, sharing a set of character states. The first one encompasses five taxa of tribe Hibisceae with a degree of similarity to Malvaviscus arborous that represents tribe Malvavisceae. The second cluster encompasses Sida alba, Abutilon hirtum, Dombeya burgessiae and Dombeya tiliacea, besides Hibiscus tiliaceus. The clustered taxa per each cluster authenticate that there are shared lines between the different taxa not only at triable level but also at sub-familial level. The resulted dendrogram emphasized the taxonomic significance of leaf architectural characteristics in taxa identification, and delimitation at the species level that could be harnessed in solving some taxonomic confusions for species substitutions at tribal level.***

Keywords: Leaf architecture, Numerical analysis, Family Malvaceae, UPGMA analysis, Taxa delimitation.

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I.INTRODUCTION

Malvaceae *sensu* APG II & III (alternatively Mallow family) is a large widely distributed expanded family that includes the four traditional families of "Core Malvales"; Malvaceae *s. s.*, Bombacaceae, Sterculiaceae and Tiliaceae to become Malvaceae *s. l.* forming a natural grouping **(APGII 2003; APGIII. 2009; Bayer et al. 1999; Bayer et al. 2003; Judd and Manchester 1997)**. The family has a diverse array of herbaceous, shrubs, and sometimes tree genera encompassing about 6133 known species of 339 genera **(Christenhusz and Byng 2016)**. It has long been known to be of great economic importance more than usual for cotton as well as its vegetables, horticultural members, and for medicinal applications **(Thorne 1992)**. In the recent systems of classifications, the enlarged family 'Malvaceae *s. l.* was subdivided into nine subfamilies named Bombacoideae, Brownlowioideae, Byttnerioideae, Dombeyoideae, Grewioideae, Helicteroideae, Malvoideae, Sterculioideae, and Tilioideae, based on molecular, morphological and biogeographical data and nine tribes according to APG. Subfamily Malvoideae, part of the broader Malvaceae *s.l.* **(Alverson et al., 1999; Bayer et al., 1999; Whitlock et al., 2001)**, includes the traditional Malvaceae *sensu stricto* (the Malows or Eumalvoideae), which comprises 78 genera and about 1,700 species **(Baum et al. 2004)**, both Malvoideae and Bombacoideae were defined as a well-supported clade termed Malvatheca.

Leaf venation pattern is a considerable interesting taxonomic evidence in angiosperms due to the distinct and pronounced hierarchical network of its veins to be exploited in distinguishing species from each other based on the high degree of interspecific variation on the entire venation, **(Ellis et al. 2009; Hickey 1973; Hickey and Taylor 1991)**. It has a potential in the identity of taxonomically confusing taxa, evolutionary lineages in the woody dicotyledonous plants, and species delimitation, it extends to include ferns as well. Genetically leaf architecture was evaluated as one of the most fixed morphological attributes aligned with molecular approaches **(Huiet et al. 2018)**. It has been assayed as a precious taxonomic tool at different hierarchical levels and represents a good tool for plant identification especially in the lack of reproductive parts such as flowers and fruits **(Buot Jr 2020; Escalona and Buot 2023a; Escalona et al. 2023; Fuller and Hickey 2005; Masungsong et al. 2019).** By surveying the botanical literature leaf architecture and venation patterns were implicated as taxonomic tools for the circumscription of different dicotyledonous families, e.g., Solanaceae **(Hamed et al. 2004; Inamdar 1978)**, Apocynaceae **(Kapoor and Mitra 1979; Mohan and Inamdar 1982)**, and even monocotyledonous families **(Inamdar et al. 1983)**. For the Malvaceae taxa, the literature review concerning leaf architecture is little, however, **(Bhat 1995)** studied13 species of the genus *Hibiscus*, **(Escalona and Buot 2023b)** implicated the leaf architecture at the variety level of *Hibiscus* × *rosa-sinesis*. **(Abdelfattah et al, 2024)** documented that the leaf vein categories as a synapomorphy feature are helpful in species delimitation of five *Hibiscus* species. **(Laraño and Buot Jr 2010)** described some species of Malvaceae *sensu* APG and constructed dichotomous key based solely on leaf veins attributes to evaluate its taxonomic significance in species delimitation**,** while this study mainly depended on herbarium specimens and did not introduce meticulous descriptions for the studied species. Leaf architecture and anatomy of *Tilia* species were recognized by **(Ramírez-Díaz et al. 2024).** In the present work, the leaf architectures of eleven taxa were harnessed by concerning the major veins categories for constructing a phenetic relationship based on meticulously discrete characters, and to evaluate its implication as a taxonomic tool in taxa delimitation helpful in understanding the placement of the taxa in the Malvaceae family in its broad circumscription.

II.MATERIAL AND METHODS

1. Specimen collection and identification

Eleven taxa belonging to 5 genera within 5 tribes included in 2 subfamilies of the family Malvaceae *s.l.* "Core Malvales" were collected from Egypt; collections localities, as well as the taxa systematy, are shown in Table 1. Identification and authentication of the specimens were carried out by standard literature **(Bayer and Kubitzki 2003)** for cultivated taxa and **(Täckholm, 1974)** for the two wild ones. For identification, the voucher herbarium specimens were prepared and matched against authentic ones at the Orman Botanical Garden, Giza, Egypt. The scientific names of the plants were verified according to the websites of the International Plant Names Index: www.ipni.org./ipni/query_ipni.html.

The collected cultivated taxa are *Abutilon hirtum*, *Hibiscus* × *rosa- sinensis*, *Hibiscus sabdariffa*, *Hibiscus schizopetalus*, *Hibiscus syriacus*, *Hibiscus tiliaceus*, *Malvaviscus arboreus*, *Dombeya burgessiae*, and *Dombeya tiliacea.* The two wild taxa are *Hibiscus trionum* and *Sida alba.*

2. Specimen fixation for light microscopy (LM) investigations.

The collected mature leaves were fixated in F.A.A. (5 ml Formaldehyde (40%): 5 ml Glacial Acetic Acid: 90 ml Alcohol (70%)] and subsequently preserved in 70% ethyl alcohol until further analysis.

3. Leaf architecture investigations.

The fresh mature expanded leaves were decolorized by immersing the leaves in domestic bleach (sodium hypochlorite) for 3h, then being rinsed three times with tap water before being transferred to 50% ethyl alcohol and stained with 1% Safranine. Excess stain was washed with 50% alcohol, the leaves were dried and pressed between filter papers and were examined and photographed by the dissecting microscope. The outcomes were described according to leaf architecture characters and terminologies of the *Manual of Leaf Architecture* **(Ellis et al. 2009; Hickey (1973)**.

4. Statistical analysis.

Nine-character states of major veins orders of primary, secondary, and tertiary categories besides the occurrence of agrophic veins of primary and secondary laterals were constructed in a data matrix on Microsoft Excel and were subjected to the Past4.09_32.exe software program. The multistate characters were transformed into two-state characters in coding **(Sneath and Sokal 1973)**. Each of all characters was treated as a binary character in a

data matrix; the presence coded 1, and the absence coded 0. Unweighted pair group method (UPGMA) phenogram clustering and Principal Component Analysis (PCA) were assayed to demonstrate a phenetic circumscription among the studied taxa, in addition to assaying the weight of the characters taxonomically to be applicable as a synapomorphic trait at a wide range of taxa for their identification and delimitation.

Table 1 The localities, and Systematy of the studied taxa of family Malvaceae *s. l.* according to **APG II & III (2003& 2009)**

No.	Locality	Taxa	Tribe	Subfamily
1	Orman Botanical Garden, Giza, Egypt	*Abutilon hirtum* (Lam.) Sweet	Abutileae	Malvoideae
2	Orman Botanical Garden, Giza, Egypt	*Hibiscus* × *rosa-sinensis* L.	Hibisceae	
3	Kafr El-Shaikh Province, Egypt	*Hibiscus sabdariffa* L.		
4	Orman Botanical Garden, Giza, Egypt	*Hibiscus schizopetalus* (Mast) Hook.f.		
5	Orman Botanical Garden, Giza, Egypt	*Hibiscus syriacus* L.		
6	Orman Botanical Garden, Giza, Egypt	*Hibiscus tiliaceus* L.		
7	Kafr El-Shaikh Province, Egypt	*Hibiscus trionum* L.		
8	Orman Botanical Garden, Giza, Egypt	Malvaviscus *arboreus* Dill.	Malvavisceae	
9	Kafr El-Shaikh Province, Egypt	*Sida alba* L.	Malveae	
10	Orman Botanical Garden, Giza, Egypt	*Dombeya burgessiae* Gerrard ex Harv.	Dombeyeae	Dombeyoideae
11	Orman Botanical Garden, Giza, Egypt	*Dombeya tiliacea* (Endl.) Planch		

III.RESULTS AND DISCUSSION

1. **RESULTS**

i. *Abutilon hirtum* (Lam.) Sweet. Fig. 1 (a1-5)

Leaf blade macromorphology: orbiculate-cordate with cordate base and straight acuminate tips. The position of the petiolar arrangement is marginal eccentric from abaxial surface. Three orders teeth (3º) of dentate margin. **Vein order categories** primary major veins (1º) are 3 basal actinodromous diverging radially, the two laterals are curved. Secondary major veins (2º) are craspedodromous. Compound agrophic veins of a lateral 1° and 2° present. Tertiary major veins (3º) are mixed opposite alternate percurrents. The highest veins order (4º) and (5º) are polygonal reticulate.

ii. *Hibiscus* × *rosa-sinensis* L. Fig. 1 (b1-4)

Leaf blade macromorphology: ovate shaped with convex base and straight acute tips. The position of the petiolar arrangement is marginal. One order tooth (1º) of dentate margin. **Vein order categories:** primary major veins (1º) are 3 basal actinodromous patterns diverging radially, the two laterals are slightly curved. Secondary

major veins (2º) are festooned semi-craspedodromous. Agrophic veins are absent. Tertiary major veins (3º) are alternate percurrents. The highest (minor) vein order (4º) and (5º) are polygonal reticulate.

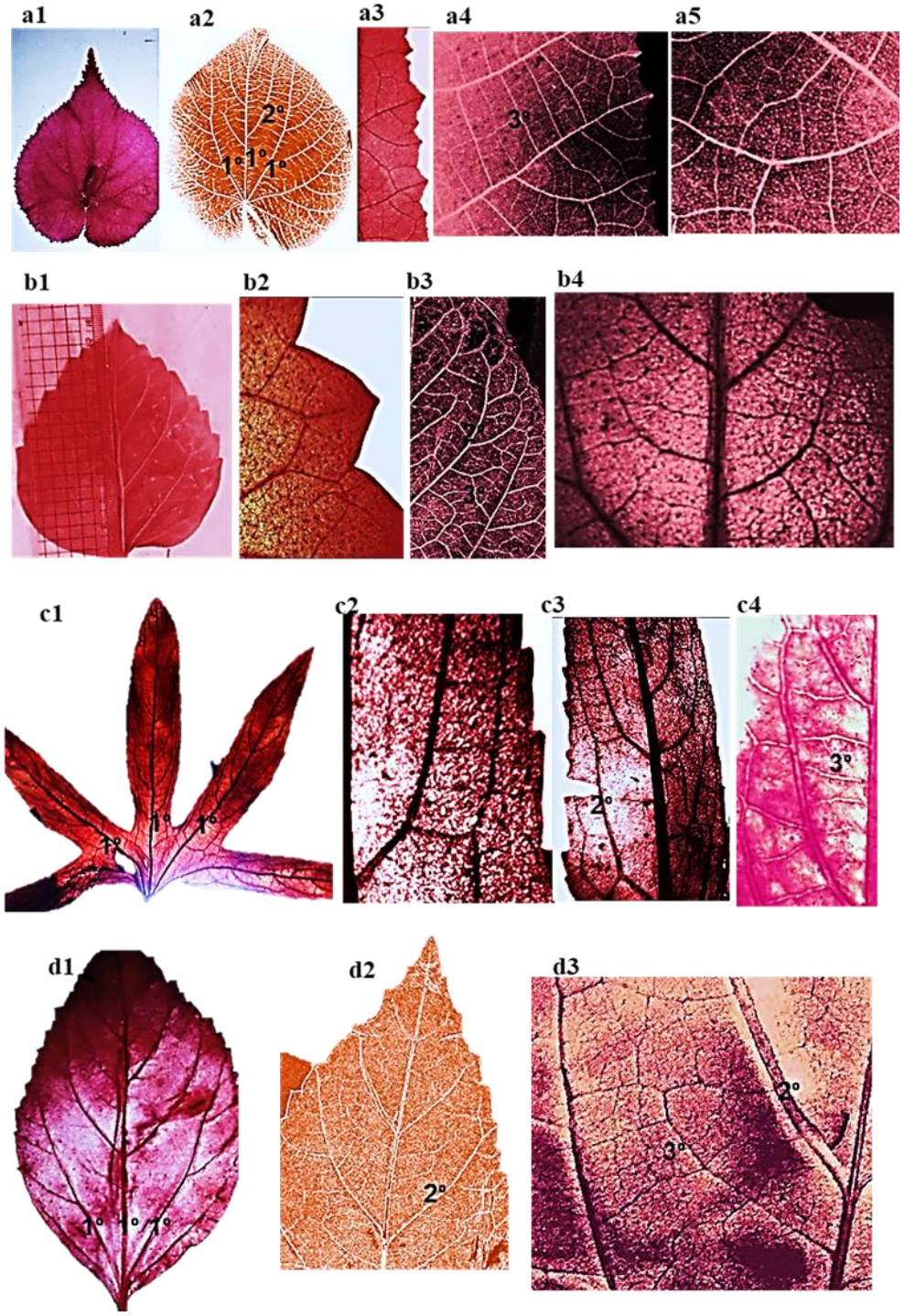

Fig. 1 LM photographs of the leaf macromorphology and the vein order categories of the eleven studied taxa. a1-5: *Abutilon hirtum.* b1-4: *Hibiscus* × *rosa-sinensis*. c1-4: *Hibiscus sabdariffa*. d1-3: *Hibiscus schizopetalus*.

iii. *Hibiscus sabdariffa* L. Fig. 1 (c1-4)

Leaf blade macromorphology: palmately sect of 5-7 lobes, each elliptical with a convex base and straight acute tips. The position of the petiolar arrangement is marginal. One order tooth (1º) of serrate margin. **Vein order categories:** primary major veins (1º) are 3 basal actinodromous diverging radially, the two laterals are slightly curved. Secondary major veins (2º) are festooned semi-craspedodromous. Agrophic veins are absent. Tertiary major veins (3º) are alternate percurrent. The highest vein orders are obscured.

iv. ***Hibiscus schizopetalus*** (Mast.) Hook.f. **Fig. 1 (d1-3)**

Leaf blade macromorphology: elliptical with convex base and straight apiculate tips. The position of the petiolar arrangement is marginal. One order tooth (1º) of dentate-serrate margin. **Vein order categories:** primary major veins (1º) are 3 basal actinodromous diverging radially, the two laterals are slightly curved. Secondary major veins (2º) are craspedodromous. Agrophic veins are simple. Tertiary major veins (3º) are alternate percurrent. The highest (minor) vein orders are obscured.

v. ***Hibiscus syriacus*** **L. Fig. 2 (e1-3)**

Leaf blade macromorphology: Palmately fid of 3 lobes, each is elliptic in shape with a rounded base and straight acuminate tips. The position of the petiolar arrangement is marginal. One order tooth (1º) of dentate-serrate margin. **Vein order categories:** primary major veins (1º) are 3 basal actinodromous diverging radially, the two laterals are moderate straight. Secondary major veins (2º) are festooned semi-craspedodromous. Agrophic veins are absent. Tertiary major veins (3º) are alternate percurrent. The highest (minor) vein orders (4º) and (5º) are polygonal reticulate.

vi. ***Hibiscus tiliaceus*** **L. Fig. 2 (f1-3)**

Leaf blade macromorphology: cordate shaped with cordate base and straight acute tips. The position of the petiolar arrangement is marginal. One order tooth (1º) of crenate margin. **Vein order categories:** primary major veins (1º) are 3 basal actinodromous diverging radially, curved. (2º) are festooned brochidodromous. Agrophic veins type is compound. Tertiary major veins (3º) are mixed opposite alternate percurrent. The highest (minor) vein order (4º) and (5º) are polygonal reticulate.

vii. ***Hibiscus trionum*** **L. Fig. 2 (g1-3)**

Leaf blade macromorphology: Palmately–pinnately sect of 3 parts, each is elliptical in shape with a rounded base and blunt tips. The position of the petiolar arrangement is marginal. One order tooth (1º) of dentate-serrate margin. **Vein order categories:** primary major veins (1º) are 3 basal actinodromous diverging radially, the two laterals are straight. Secondary major veins (2º) are craspedodromous besides interior veins as inter-secondaries. Agrophic veins are absent. Tertiary major veins (3º) are alternate percurrent. The highest (minor) veins are obscured.

viii. ***Malvaviscus arboreus*** **Dill. ex Cav. Fig. 2 (h1-3)**

Leaf blade macromorphology: elliptical shaped with convex base and straight acute complex of three tips, shallowly lobed. The position of the petiolar arrangement is marginal. One orders teeth (1º) of dentate-crenate margin. **Vein order categories:** primary major veins (1º) are 3 basal actinodromous diverging radially, the two laterals are straight. Secondary major veins (2º) are festooned brochidodromous. Agrophic

ix. ***Sida alba*** **L. Fig. 3 (i1-4)**

Leaf blade macromorphology: Ovate shaped with cordate base and straight acute-blunt tips. The position of the petiolar arrangement is marginal. One orders teeth (1º) of dentate margin. **Vein order categories:** Primary major veins (1º) are 3 basal actinodromous diverging radially, the two laterals are curved. Secondary major veins (2º) are craspedodromous. Compound agrophic veins type of 1° and 2° laterals is compound. Tertiary major veins (3º) are mixed opposite alternate percurrent. The highest (minor) vein orders (4º) and (5º) are polygonal reticulate.

x. ***Dombeya burgessiae*** **Gerrard ex Harv. Fig. 3 (j1-4)**

Leaf blade macromorphology: Ovate shaped with cordate base and straight acute tips. The position of the petiolar arrangement is peltate-eccentric. Two orders teeth (2º) of dentate-serrate margin. **Vein order categories:** Primary major veins (1º) are 3 basal actinodromous diverging radially, the two laterals are curved. Secondary major veins (2º) are craspedodromous. Compound agrophic veins type of 1° and 2° laterals is compound. Tertiary major veins (3º) are mixed opposite alternate percurrent. The highest (minor) vein orders (4º) and (5º) are polygonal reticulate.

xi. ***Dombeya tiliacea*** **(Endl.) Planch. Fig. 3 (k1-4)**

Leaf blade macromorphology: Ovate shaped with cordate base and straight acuminate tips. The position of the petiolar arrangement is marginal. Two orders teeth (2º) of dentate-serrate margin. **Vein order categories:** Primary major veins (1º) are 3 basal actinodromous diverging radially, the two laterals are straight. Secondary major veins (2º) are craspedodromous. Compound agrophic veins type of 1° and 2° laterals is compound. Tertiary major veins (3º) are mixed opposite alternate percurrent. The highest (minor) vein orders (4º) and (5º) are polygonal reticulate.

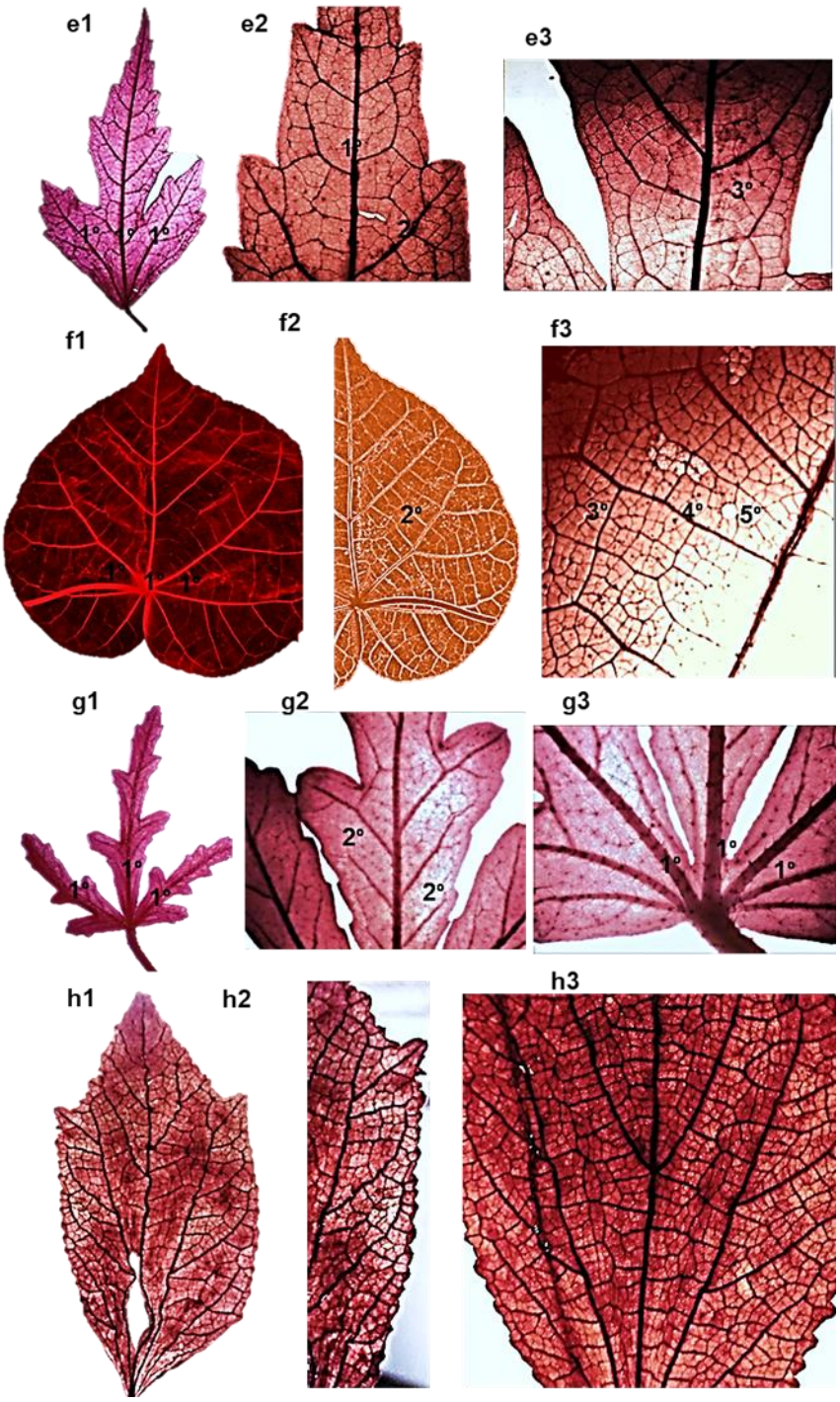

Fig. 2 LM photographs of the leaf macromorphology and the vein order categories of the eleven studied taxa. e1-3*: Hibiscus syriacus*. f1-3: *Hibiscus tiliaceus.* g1-3: *Hibiscus trionum.* h1-3: *Malvaviscus arborous.*

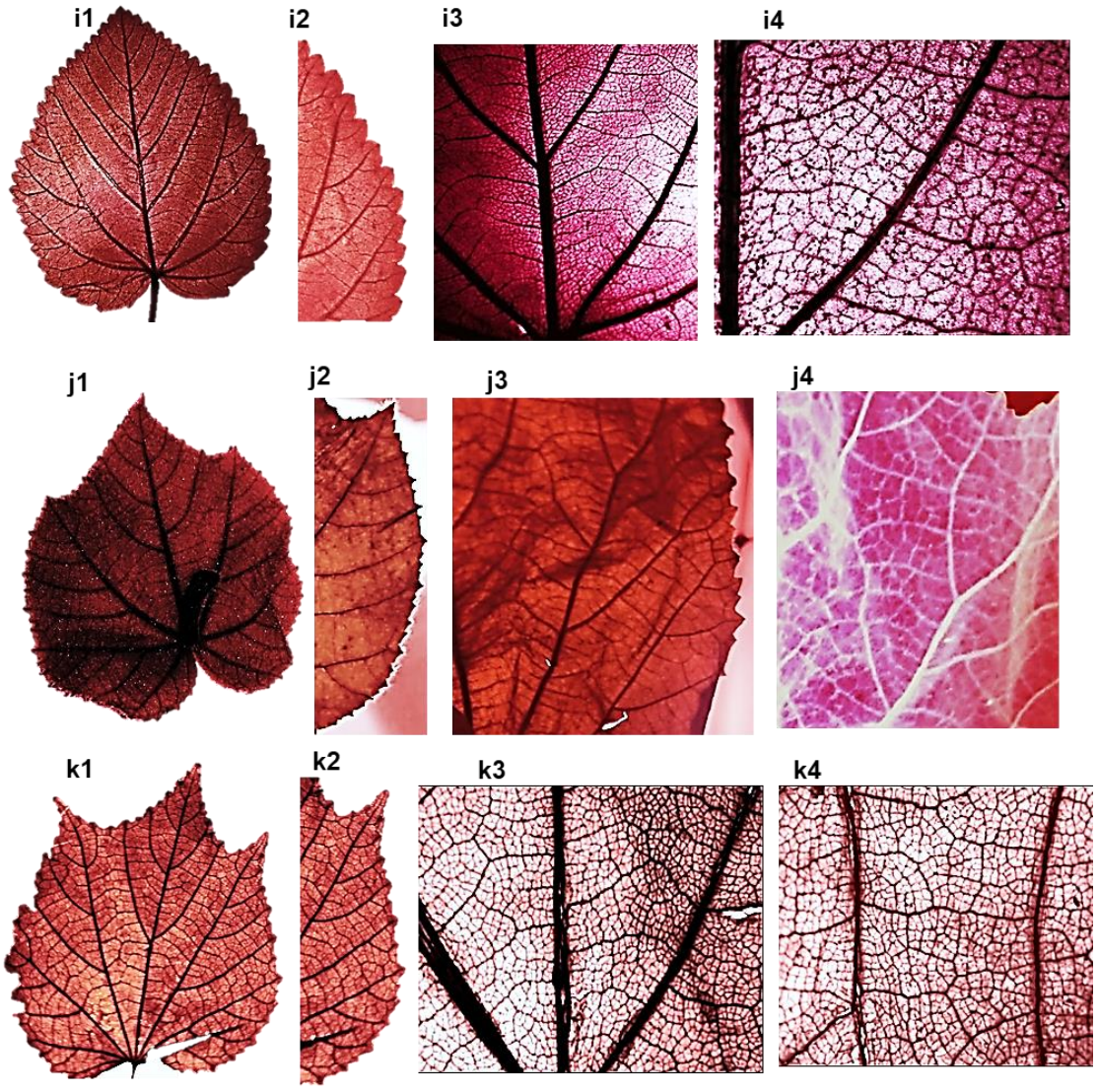

Fig. 3 LM photographs of the leaf macromorphology and the vein order categories of the eleven studied taxa. i1-4: *Sida alba*. j1-4: *Dombeya burgessiae*. k1-4: *Dombeya tiliacea*.

Table 2 leaf architectural characteristics of eleven selected species of family Malvaceae *s. l.*

No	Characters Species	Leaf organization						Vein order categories				
		Laminar shape	Base shape	Petiolar attachment	Apex feature	Margin type	Lobation	1°	2°	3°	4°	Agrophic veins
i.	***Abutilon hirtum***	Orbiculate-cordate	Cordate	Peltate-eccentric	Straight acuminate	Dentate-crenate	Unlobed	Ba	C	M/opp/alt	Polygonal reticulate	Compound
ii.	***Hibiscus × rosa-sinensis***	Ovate	Convex	Marginal	Straight acute	Dentate	Unlobed	Ba	Fsc	Ap	Obscured	Absent
iii.	***Hibiscus sabdariffa***	Elliptical	Convex	Marginal	Straight acute	Serrate	Palmately sect 5-7 lobes	Ba	Fsc	Ap	Obscured	Absent
iv.	***Hibiscus schizopetalus***	Elliptical	Convex	Marginal	Straight acute	Dentate-serrate	Unlobed	Ba	C	Ap	Obscured	Present
v.	***Hibiscus syriacus***	Elliptical	Rounded	Marginal	Straight acuminate	Dentate-serrate	Palmately fid 3 lobes	Ba	Fsc	Ap	polygonal reticulate	Absent
vi.	*Hibiscus tiliaceus*	Cordate	Cordate	Marginal	Straight acute	Crenate	Unlobed	Ba	Fb	M/opp./alt.	4° and 5° polygonal reticulate	Compound
vii.	*Hibiscus trionum*	Elliptic	Rounded	Marginal	Straight	Dentate – serrate	Palmately – pinnately sect	Ba	C& In	Obs	Obscured	Absent
viii.	Malvaviscus *arboreus*	Elliptic	Convex	Marginal	Complex	Dentate-serrate	Shallowly lobed	Ba	Fb	Ap	polygonal reticulate	Absent
ix.	*Sida alba*	Ovate	Cordate	Marginal	Straight	Dentate	Unlobed	Ba	C	Mixed opp./ alt.	4° and 5° polygonal reticulate	Compound
x.	*Dombeya burgessiae*	Ovate	Cordate	Peltate-eccentric	Complex	Dentate-serrate	Shallowly lobed	Ba	C	Ap	polygonal reticulate	Compound
xi.	*Dombeya tiliacea*	Ovate	Rounded	Marginal	Complex	Dentate	Shallowly lobed	Ba	C	Ap	polygonal reticulate	Compound

Ap: Alternate percurrent, Ba: Basal actinodromous, C: craspedodromous, Fb: Festooned brochidodromous, Fsc: Festooned semi-craspedodromous, M/opp/alt: Mixed opposite alternate percurrent, In: interior as intersecondaries

2. DISCUSSION

1. Leaf blade macromorphology and the veins order categories

The architectural features of the leaf were investigated; the focus was on the most accurate detail traits including qualitative macromorphological characteristics of the leaf, including two main sections. Section I: leaf organization that includes laminar shape, base shape, position of petiolar arrangement, apex shape, margin type, and leaf incisions (lobation). Section II: vein orders that include primary, secondary, and tertiary vein categories as major types in addition to minor vein orders including fourth order when observed in any of the studied taxa. The salient comparative features among the studied taxa were recorded in **Tables 2 and Fig. (1-3)**. The macromorphological characteristics of the leaf blade of the investigated taxa were tabulated as an identifiable feature not for taxa delimitation because of the great variation in its morphology. The basal actinodromous pattern of three primary veins; diverging radially from the leaf base; is the chief and the only pattern for all the studied taxa. The diagnostic variances were reported in the secondary and tertiary vein categories, where there are three categories of secondary veins were recorded; craspedodromous, festooned semi-craspedodromous, and festooned brochidodromous. Alternate percurrent and mixed opposite alternate percurrent tertiaries were the chief venation patterns of tertiaries. 2° craspedodromous and 3° mixed opposite alternate percurrent are the characteristic venation patterns in *Abutilon hirtum, Sida alba*, and the two taxa of *Dombeya*. *Hibiscus trionum* is distinguished by craspedodromous pattern besides interiors as inter-secondaries, while its tertiaries percurrent are obscured. *Malvaviscus arboreus* and *Hibiscus tiliaceus* are delimited by the 2° festooned brochidodromous pattern, while their tertiaries are alternate in the first and mixed opposite alternate in the second. The remaining four species of *Hibiscus* share 2° festooned semi-craspedodromous pattern and alternate percurrent tertiaries.

2. Numerical analysis.

Multivariate clustering dendrogram based on the UBGMA method using the Jaccard coefficient **(Sneath and Sokal 1973)** and Principal component analysis (PCA) using PC1 for (X) axis that represents the most variable component and PC2 for (Y) axis that represents the second component in the variability of (9) character states of the three major veins of the leaf blade, primary, secondary and tertiary veins orders categories, besides the presence or absence of agrophic veins to decern its taxonomic significance in taxa delimitation. The minor veins categories were not included in the analysis due to only a reticulate polygonal pattern was recorded besides the obscured pattern in some of the investigated taxa. The resulting clustering dendrogram **(Fig. 4)** separates the eleven studied taxa into two main clusters. The first cluster encompasses five taxa of tribe Hibisceae with a degree of similarity to *Malvaviscus arborous* that represent tribe Malvavisceae. This agrees with the previous treatment of the rapidly expanded genus *Hibiscus* that contained a diverse assemblage of morphologically distinct species groups, e.g., *Malvaviscus genus* that segregated into a separate tribe**(Hanes et al. 2024; Pfeil et al. 2002)**. This cluster initially branched into two sub-clusters at similarity index (0.6%), the first included *Malvaviscus arborous* as a sister taxon to *Hibiscus* × *rosa-sinensis, Hibiscus syriacus, and Hibiscus sabdariffa* that are separated at the same line. The second sub-cluster includes *Hibiscus schizopetalus*, and *Hibiscus trionum*. The second cluster encompasses *Sida alba, Abutilon hirtum, Dombeya burgessiae*, and *Dombeya tiliacea*, besides *Hibiscus tiliaceus*. The second cluster undergoes further branching into two sub-clusters separated at about (0.5 %) similarity index, the first sub-cluster represents the two *Dombeya* species. The second sub-cluster branched into two branches at (0.6 %) similarity index; the first included *Sida alba* and *Abutilon hirtum* at the same line. and this agrees with Linnaeus's broad system including uniovulate species referable to *Sida with* multi-ovulate species treated as *Abutilon* in addition at the generic level those two genera were reported to be allied ones **(Aguilar et al. 2003; Pejhanmehr 2022)**. The second branch encompasses *Hibiscus tiliaceus*. Through the **PCA** plotting analysis, the plotting dendrogram (**Fig. 5)** visualizes the most variable components (PC1 and PC2) reflecting the relationship between the studied taxa and their degree of closeness. The first two PCs construct a reliable relationship between the eleven studied taxa and authenticate the same results of multivariate clustering which can be summarized as follows: the two *Dombeya* species (*Dombeya burgessiae. and Dombeya tiliacea*) are pointed in a single point like *Sida alba* and *Abutilon hirtum*. Furthermore, (*Hibiscus rosa-sinensis, Hibiscus sabdariffa, and Hibiscus syriacus*) are plotted at the same point. On the other hand, *Hibiscus trionum* and *Hibiscus schizopetalus* are plotted as two points sharing a set of similar characters. *Malvaviscus arboreus* is separated as a plot closely related to the three grouped species of *Hibiscus* **Fig. 3**. *Hibiscus tiliaceus* is plotted as a separate point intermediate the main two clusters.

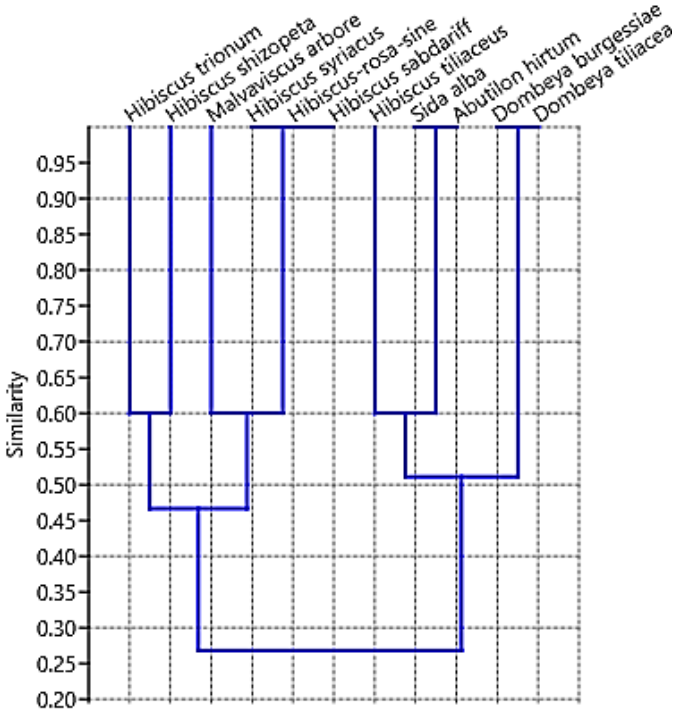

Fig. 4 Hierarchical multivariate clustering dendrogram of morpho-anatomical approach using Algorism (UPGMA) and Jaccard similarity index of the eleven studied taxa based on the major vein categories attributes.

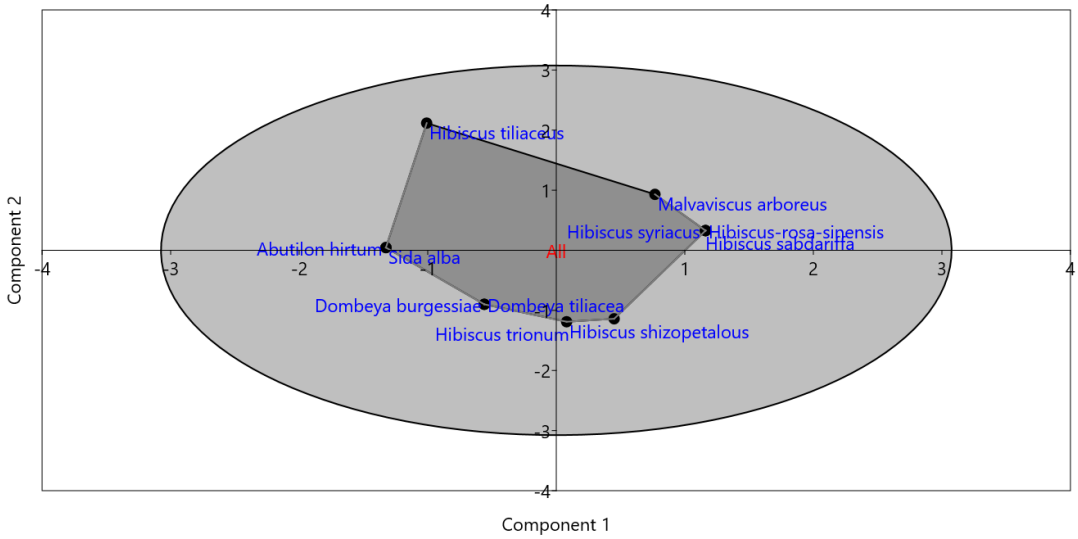

Fig. 5 Scatter plotting of multivariate ordination approach of the principal component analysis (PCA) of PC1 1nd PC2 for the eleven studied taxa based on the major vein categories attributes.

IV.CONCLUSION

The present study discussed the implementation of leaf architecture through comparative investigations of the leaf blade macromorphological features and the vein order categories of eleven taxa *of the* Malvaceae *family*, namely: *Abutilon hirtum*, *Hibiscus* × *rosa- sinensis*, Hibiscus *sabdariffa*, *Hibiscus schizopetalus*, *Hibiscus syriacus*, and *Hibiscus tiliaceus*, *Hibiscus trionum*, *Malvaviscus arborous*, *Sida alba*, *Dombeya burgessiae*, *and Dombeya tiliacea*. The results revealed that the macromorphological features could be exploited in the taxa identification per each taxon separately and were not included in the numerical analysis due to the variation in the recorded states. On the other hand, the vein order categories mainly the major types represented the discrete states harnessed in the numerical analysis to discern its taxonomic significance for taxa delimitation through

building a phenetic circumscription. Furthermore, the multivariate clustering and plotting analysis exhibited remarkable similarities and a degree of variances in the character states between the studied taxa. Craspedodromous secondaries and alternate percurrent of tertiaries are the chief types besides the basal actinodromous primaries. However, there are some attributes loads in minor range as the brochidodromous, festooned semi-brochidodromous, intersecondaries of the secondary vein orders, and mixed opposite alternate percurrent of tertiaries. The variance in the character states helped in drawing the meticulous relationship between the taxa under investigation. UPGMA clustering dendrogram separated the studied taxa into two main clusters. The first encompasses five taxa of tribe Hibisceae with a degree of similarity to *Malvaviscus arborous* that represent tribe Malvavisceae. The second cluster encompasses *Sida alba*, *Abutilon hirtum*, *Dombeya burgessiae and Dombeya tiliacea*, besides *Hibiscus tiliaceus*. The clustered taxa per each cluster authenticate that there are shared lines between the different taxa at not only the triable level but also the sub-familial level. It can be concluded that the architectural characteristics concerning the leaf vein patterns can be harnessed taxonomically as a synapomorphy trait, help in understanding the phylogenetic lineages in a broad sense, and could be harnessed in the taxa identification and delimitation at the species level. However, we recommend additional integrated aspects in addition to the present applied approach to delimit the taxa at the triable level.

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