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ARTICLE

The leaf architecture and its taxonomic significance in Capparaceae from Egypt

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ABSTRACT The paper deals with the leaf architecture of **19** species belonging to **7** genera ***(Capparis, Cadaba, Boscia, Maerua, Dipterygium, Cleome*** and ***Gynandropsis)*** of the family Capparaceae ***sensu lato*** (including Cleomaceae) from Egypt. A comprehensive description of leaf architecture for the studied taxa was provided, including venation pattern, areolation, and marginal ultimate venation. The venation pattern showed mostly pinnate brochidodromous or craspidododromous. Aeroles may be well or poorly developed. Taxonomically significant leaf features of the examined taxa showed great diversity in leaf or leaflet form, leaf surface, leaf base, leaf persistence, main venation pattern, secondary vein angle, inter secondary veins, number of veins on either side of midrib, free ending ultimate veins and marginal ultimate venation. A new free ending ultimate venation (F.E.V.S) branched with swollen ends was reported. On the basis of leaf architecture, we advocate the recognition of two separate families Capparaceae ***sensu lato*** and Cleomaceae. Multivariate analysis was carried out with the aim of solving some of the taxonomic problems existing in the family using **21** characters including **74** character states. Based on the comparison of leaf architecture, we supported the taxonomic treatment of the family Capparaceae. We supported retaining ***Gynandropsis gynandra*** as ***Cleome gynandra*** of the family Capparaceae, as it clearly nested within ***Cleome.*** Leaf architecture helped to distinguish all the species investigated and accordingly a key was provided for this purpose.
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KEY WORDS

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Cleomaceae
leaf architecture
leaf venation
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taxonomy

Family Capparaceae *sensu lato* is a fairly large (45 genera and 675 species), mainly subtropical being most conspicuous in tropical seasonally dry habitats with diversity in floral structure (Mabberley 1987). Except in some species of *Capparis,* it has a great constancy in the number and position of sepals and carpels (Pax and Hoffmann 1936; Jacobs 1965). It also shows great diversity in the morphology and number of petals and stamens (Endress 1992). Many genera that were considered in Capparaceae by Pax and Hoffmann (1936) have been elevated to familial level or included in unrelated families. The two major subfamilies of Capparaceae: Cleomoideae (about 8 genera and 275 species) and Capparoideae (about 25 genera and 440 species) are quite distinct, and have been elevated to familial status by some authors (e.g., Airy Shaw 1965; Hutchinson 1967). In both subfamilies the type genus is by far the largest and houses the majority of the species: *Cleome* (200 species) for the former and *Capparis* (150-200 species) for the latter. However, Pax and Hoffman (1936) described the most comprehensive taxonomic treatment of *Capparis* to date in which they recognized 45 genera (20 monotypic) to be included in eight subfamilies.

Capparaceae are represented in the Egyptian flora by 7 genera, 21 species and *4* varieties of wide ecological and geographical range of distribution (Boulos 1999). They vary considerably in their growth forms from small trees *(e.g.Boscia)* or shrubs (e.g. *Capparis)* to annual (e.g. *Gynandropsis gynandra)* or perennial herbs (e.g. *Cleome).* Therefore, their vegetative characters range from woody perennials to annual herbs. The Egyptian taxa of Capparaceae belong to the xerophytic communities (Zahran and Willis 1992; Abd El-Ghani and Marei 2006), except for *Gynandropsis gynandra* that is common among the weed flora of the arable fields (Boulos and El-Hadidi 1984). The taxonomic treatment of the family in Egypt focused mainly on seed morphology (Al-Gohary 1997), leaf anatomy (Al-Gohary 1982) and pollen morphology (Khafagi and Al-Gohary 1998). The systematic revision of the native species of Capparaceae (excluding *Cleome)* revealed the uncertain occurrence of *Boscia angustifolia,* while *Capparis spinosa* is represented by 3 varieties viz.: *spinosa, inermis* and *deserti* (El-Karemy 2001). Separation from Cleomaceae may be unsustainable, since difficulties are encountered in assigning the genera. Precise comparative data on gynoecium and fruit structure are elusive or non-existent. Actually, the taxonomic affinities between Capparaceae and Cleomaceae are still of debate. Täckholm (1974) distinguished between the two families according to gland struc-

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Table **1**. List ofthe studied Egyptian taxa arranged into subfamilies and tribes according to Pax and Hoffman (1936).

No	Taxon	Subfamily	Tribe	Numberofexamined individuals
1	Capparis decidua Edgew.	Capparoideae	Cappárideae	20
2	Capparis sinaica Veill.	Capparoideae	Cappárideae	30
3	Capparis spinosa L. var. spinosa	Capparoideae	Cappárideae	30
4	Capparis spinosa L. var. canescens Coss.	Capparoideae	Cappárideae	15
5	Capparis spinosa L. var. inermis Turra	Capparoideae	Cappárideae	20
6	Capparis spinosa L. var. deserti Zohari	Capparoideae	Cappárideae	25
7	Cadaba glandulosa Forssk.	Capparoideae	Cappárideae	5
8	Cadaba farinosa Forssk.	Capparoideae	Cappárideae	7
9	Cadaba rotundifolia Fords	Capparoideae	Cappárideae	10
10	Boscia senegalensis Poir.	Capparoideae	Cappárideae	8
11	Boscia angustifolia A. Rich.	Capparoideae	Cappárideae	7
12	Maerua oblongifolia (Forssk.) A. Rich.	Capparoideae	Maerueae	5
13	Maerua crassifolia Forssk.	Capparoideae	Maerueae	5
14	Dipterygium glaucum Decne.	Dipterygioideae		10
15	Cleome droserifolia (Forssk.) Delile	Cleomoideae		30
16	Cleome chrysantha Decne	Cleomoideae		12
17	Cleome arabica L.	Cleomoideae		15
18	Cleome brachycarpa DC.	Cleomoideae		5
19	Cleome hanburyana Penz.	Cleomoideae		10
20	Cleome paradoxa R. Br. ex DC.	Cleomoideae		10
21	Cleome amblyocarpa Barratte& Murb.	Cleomoideae		40
22	Gynandropsis gynandra (L.) Briq.	Cleomoideae		20

ture, fruit type, and development of a gynophore, whereas Zohary (1966) included the intriguing genus *Cleome* in the subfamily Cleomoideae of Capparaceae. The Capparaceae in Boulos (1999), however, included both Cleomaceae and Capparaceae. On the species level, Täckholm (1974) recognized 8 species of *Capparis,* whereas Boulos (1999) classihed the genus as 3 species and 4 varieties.

Although flower and fruit characters have proved very useful in identification and delimitation of the genera and species, there are situations in which these organs are not available for study as in Capparaceae. The study of the reproductive characters of this group is problematic for different reasons, amongst others; the difficulty of preserving the flowers in some genera as in *Capparis* (Hedge and Lamond 1970), the striking variability in their size and shape at the individual level species (Mabberley 1987), and many long-lived tropical plant flowers are infrequent and irregular (LAWG 1999). So, there is a great need to identify and classify plants using vegetative characters.

Ettingshausen (1861) made the first comprehensive effort to systematize the description of the vegetative leaf architecture with his classification of venation patterns. Leaf architectural characters have proved valuable taxonomic and systematic data both in fossil and living plants (Hickey 1973; Dilcher 1974; Hickey and Wolfe 1975). Leaf architecture and venation pattern studied in different families of dicotyledons; amongst others, Compositae (Banerjee and Deshpande 1973), Solanaceae (Inamdar and Murthy 1978), Bignoniaceae (Jain 1978), Hamamelidaceae *sensu lato* (Li and Hickey 1988), Leguminosae (Sun et al. 1991), Amaranthaceae (Shanmuka et al. 1994), Ulmaceae (Wang et al. 2001), Lagaceae (Luo and Zhou 2002), and in some monocots (Inamdar et al. 1983). The present work was undertaken to give comprehensive account of the venation pattern and leaf architecture in 7 genera and 19 species of the Capparaceae (including Cleomaceae) as no report exists on the subject. It is a contribution towards better understanding the systematic treatment of the Egyptian Capparaceae verifying the role of leaf architecture, assessing the range of variation among species by applying multivariate analysis.

Materials and Methods

During the growing seasons in 2005-2006, fresh material of 7 genera *(Capparis, Cadaba, Boscia, Maerua, Dipterygium, Cleome* and *Gynandropsis)* and 19 species were collected from their natural habitats and field observations were made from several localities of the Mediterranean region, and in the western Desert, Eastern Desert, Mountains of Sinai and Elba (Fig. 1). In addition, leaves were obtained from herbarium specimens in Cairo University (CAI), Ministry of Agriculture (CAIM) and National Research Centre (CAIRC). In order to broadly sample the variation, the studied taxa were represented by a number of collections (herbarium specimens or fresh material or both) from different localities in Egypt (Table 1). Plant identifications were according to Zohary (1966), Täckholm (1974), Thulin (1993) and Boulos (1999).

Mature leaves were cleared following Thakur (1988), but with modified procedure to suit investigation. Accord-

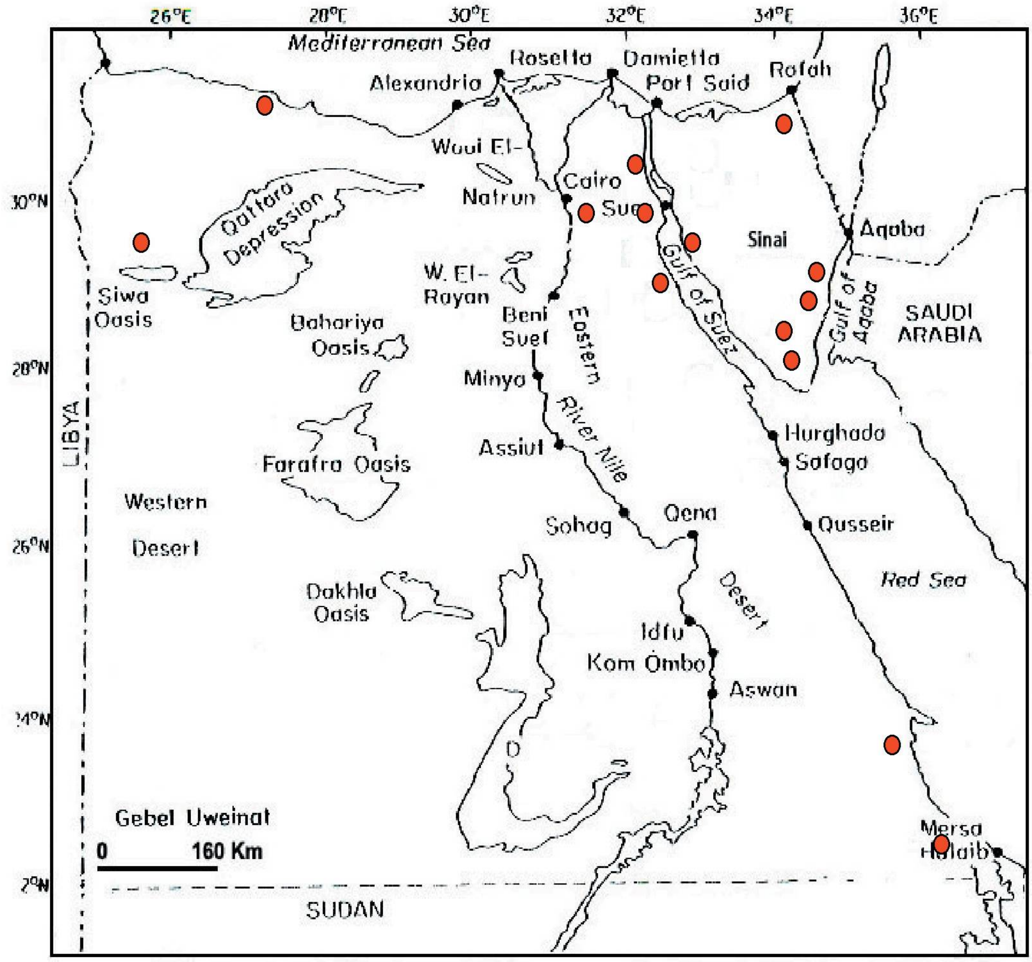

Figure 1. Location map showing the collecting sites.

ingly, the mature leaves were cleared by keeping them in 5% NaOH solution at 25°C for two or three days, rinsed in water and transferred to acetic acid, hydrogen peroxide and lactophenol (Subrahmanyan 1999) in 1:1:1 ratio for three or four days. The cleared leaves were stained with 1% safranin, and mounted on slides with glycerine (Plates 1-3). A total of 21 characters were measured in each studied specimen, comprising 3 quantitative and 18 qualitative characters. Seven of the qualitative characters were scored as binary and the rest were scored as multistate characters (Table 2). The measurements for all specimens of a taxon were averaged into one score for each of the characters. Scores for quantitative characters were averages of measurements of at least 20 specimens (where possible). Because herbarium specimens cannot be considered to be a random sample of the species, we followed Wieringa (1999) by calculating the mean of the minimum and maximum measurement. When some of the characters for a certain species were lacked, these omissions were coded as missing data (-999). The complete data matrix is available upon request from the hrst author. Leaf architectural terminology was largely from Hickey (1973, 1977 and 1991), Levin (1986) and Leaf Architecture Working Group (LAWG 1999).

To avoid the effects of different scales of measurement for different characters, the values for each character were standardized prior to analysis using the default option in SYSTAT version 5.02 for Windows software (SYSTAT Inc, USA). Two types of analyses were performed with Community Analysis Package (CAP version 1.2, Pisces Conservation Ltd, UK). Firstly, we performed three different procedures of agglomerative cluster analysis (complete linkage, average linkage and minimum variance) using Euclidean distance to a data matrix of 22 taxa and 21 characters. Secondly, we performed a principal components analysis (PCA).

Results

Leaf was persistent in most of the studied species, but it was deciduous in only two species; *Capparis decidua* and *Dip-*

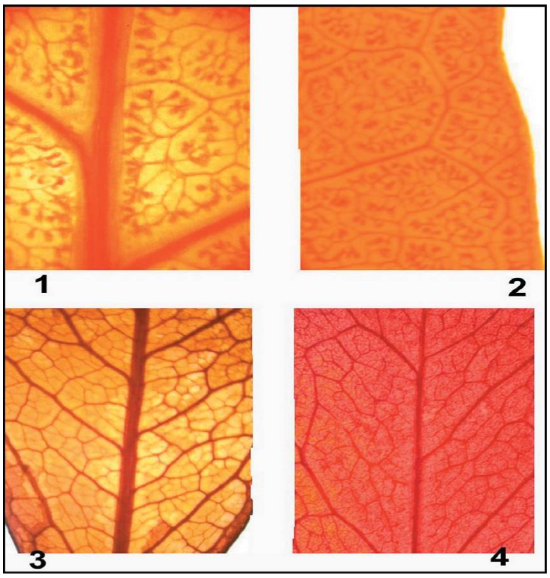

Plate (1). Figure 1: *Capparis spinosa*Mar. *inermis(xAO),* pinnate venation pattern, F.E.V.Sfree ending ultimate veins three branched with swollen dots; Figure 2: *Capparis sinaica* (x40) brochidodromous, incomplete margin; Figure 3: *Boscia senegalensis(x*40), absence of F.E.V.S, random reticulate of third and fourth vein category, prismatic attached vein angle; Figure 4: *Maerua crassifolia* (x40), five or more sided aeroles, tapering branched F.E.V.S.

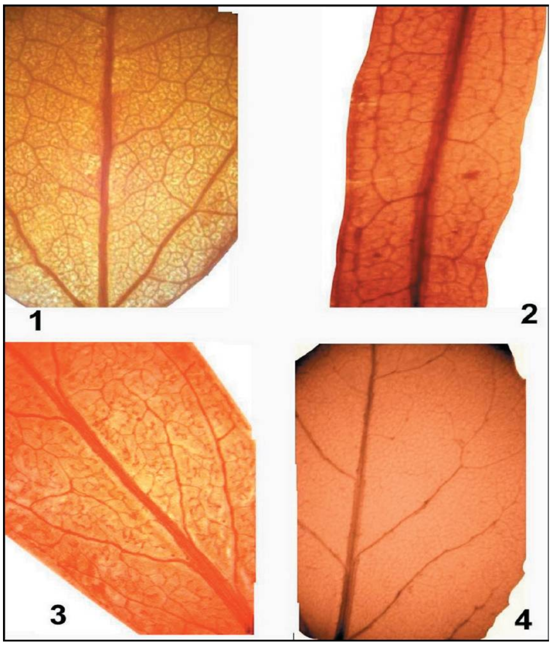

Plate (3). Figure 1: *Boscia angistifolia* (x40), one acute pair secondaries, random reticulate fourth vein category, no F.E.V.S.; Figure 2: *Capparis decidua* (x25), marginal arcuate venations looped arcuate, perpendicular third vein angle to the primary; Figure 3: *Dipterygium glaucum* (x 40) poorly developed aerolation. Figure 4: *Gynandropsis gynandra,* cladododromous, excurrent vein branched.

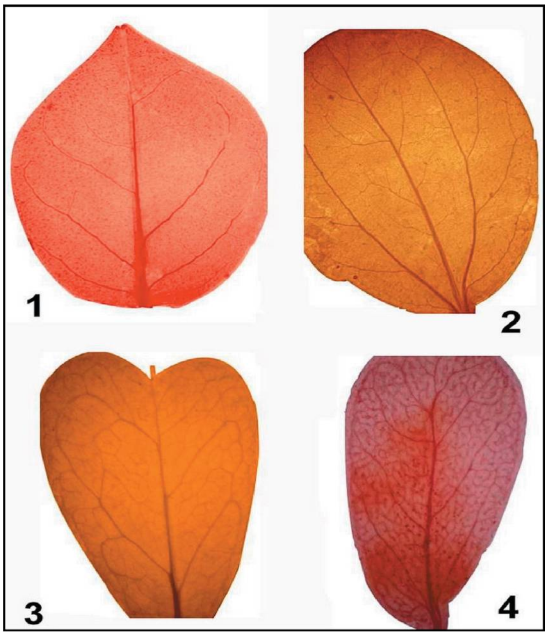

Plate (2). Figure 1: *Capparis spinosa* (x 40), brochidodromous, 4 veins on either side of midrib; Figure 2: *Cleome arabica,* actinododromous, one vein on either side of midrib, cladododromous; Figure 3: *Maerua crassifolia* (x25), secondary vein spacing increasing toward base, secondary vein angle decreasing toward base, marginal ultimate venation of incomplete loops. Figure 4: *Dipterygium glaucum* (x25), cladododromous, agrophic, excurrentvein branched.

terygium glaucum. Taxonomically significant leaf features of the examined taxa showed great diversity in leaf or leaflet form, leaf surface, leaf base, leaf persistence, main venation pattern, secondary vein angle, inter-secondary veins, number of veins on either side of midrib, free ending ultimate veins and marginal ultimate venation. As in the case with other taxonomic characters, great care must be taken when using leaf venation.

A survey of venation of Egyptian Capparaceae (Plates 1-3) showed that venation pattern is mostly pinnate, but it was actinododromous in *Cleome arabica* and *C. droserifolia.* Secondary vein category was brochidodromous in the majority of the studied taxa, while it was cladododromous in *Cleome arabica, Dipterygium glaucum* and *Gynandropsis gynandra',* craspedodromous secondary vein were present in four species of *Cleome* viz., *Cleome brachycarpa, C. droserifolia, C. chrysantha* and *C. hanburyana',* semicraspidodromous was restricted only to *Cleome amblyocarpa.* Most taxa had irregular vein spacing and rarely regular, e.g. *Cleome paradoxa,* or increasing towards base as in *Cleome droserifolia.* The second vein angle varied greatly between the studied taxa, so it has no taxonomic value to differentiate between rare taxa. The number of veins on either side of midrib had a significant taxonomic value among different taxa; where *Capparis decidua* was characterized by 7-8 veins on either

Table 2. Characters and character states used in morphometric analysis of Capparaceae.

Character	Character state	Code
1. Leaf or leaflet form	Obovate	1
	Narrow oblong	2
	Orbicular	3
	Ovate	4
	Oblanceolate	5
	Elliptic	6
	Linear	7
2. Leaf apex	Mucronate spiny	1
	Mucronulate	2
	Obtuse	3
	Acute	4
	Retuse	5
	Accuminate	6
3. Leaf margin	Entire	1
	Denticulate	2
4. Leafcomposition	Simple	1
	Trifoliate	2
	Petafoliate	3
5. Leaf surface	Glabrous or pubescent	1
	Glandular hairy	2
	Farinose	3
	Scabrous	4
	Pilose	5
	Viscid	6
6. Leaf base	Cuneate	1
	Acute	2
	Obtuse	3
	Subcordate	4
	Decurrent	5
7. Leaf persistence	Deciduous	1
	Persistent	2
8. Venation pattern	Pinnate	1
	Actinododromous	2
9. Secondary vein category	Brochidodromous	1
	Cladododromous	2
	Craspedodromous	3
	Semicraspedodromous	4
10. Secondary vein spacing	Irregular	1
	Regular	2
	Increasing toward base	3
11. Secondary vein angle	Uniform	1
	Increasing toward base	2
	Decreasing toward base	3
	One pair acute secondaries	4
	Two pair acute secondaries	5
12. Inter-secondary veins	Present	1
	Absent	2
13. Number of veins on either side of midrib	1	1
	4-6	2
	7-8	3
14. Third vein category	Random reticulate	1
	Dichotomous	2
15. Third vein angle to the primary	Acute	1
	Perpendicular	2
16. Fourth vein category	Random reticulate	1
	Dichotomously branched	2
17. Fifth vein category	Absent	1
	Random reticulate	2
	Dichotomously branched	3

Table 2. Continued.

Character	Character state	Code
18. Areolation	5-ormoresided	1
	Poorly or moderately developed	2
19. Free Ending UltimateVeinsofthe leaf (F.E.V.S)	Three branched with swollen dots	1
	One branched tapering	2
	Three branched diffuse	3
	Three branched tapering	4
	Absent	5
20. Attached vein angle	Prismatic	1
	Truncatetriangle	2
21. Marginal ultimate venation	Incomplete loops	1
	Fimbrial arcuate	2
	Fimbrial simple	3
	Excurrentveinbranched	4

side of midrib, *Cleome arabica* and *C. droserifolia* were characterized by one vein on either side of midrib. The third vein category was reticulate and mostly meets the primary veins at acute angles. Quaternary venation was mostly dichotomized branching, while fifth vein category is mostly absent, and, if present, it may be random or dichotomizing branched.

Areolation were usually well developed. In addition, the free ending ultimate veins of the leaf (F.E.V.S.) could be distinguished by having one, two or three branched tapering or swollen ends. Marginal ultimate venation had incomplete loops in genera of *Capparis* (except *Capparis decidua)* and *Maerua;* while fimbrial arcuate was characterized to *Cadaba* and *Boscia.* Branched excurrent vein was characteristic to genus *Cleome,* except *Cleome chrysantha,* which had fimbrial arcuate marginal vein.

Analysis of venation in the Capparaceae indicated that the

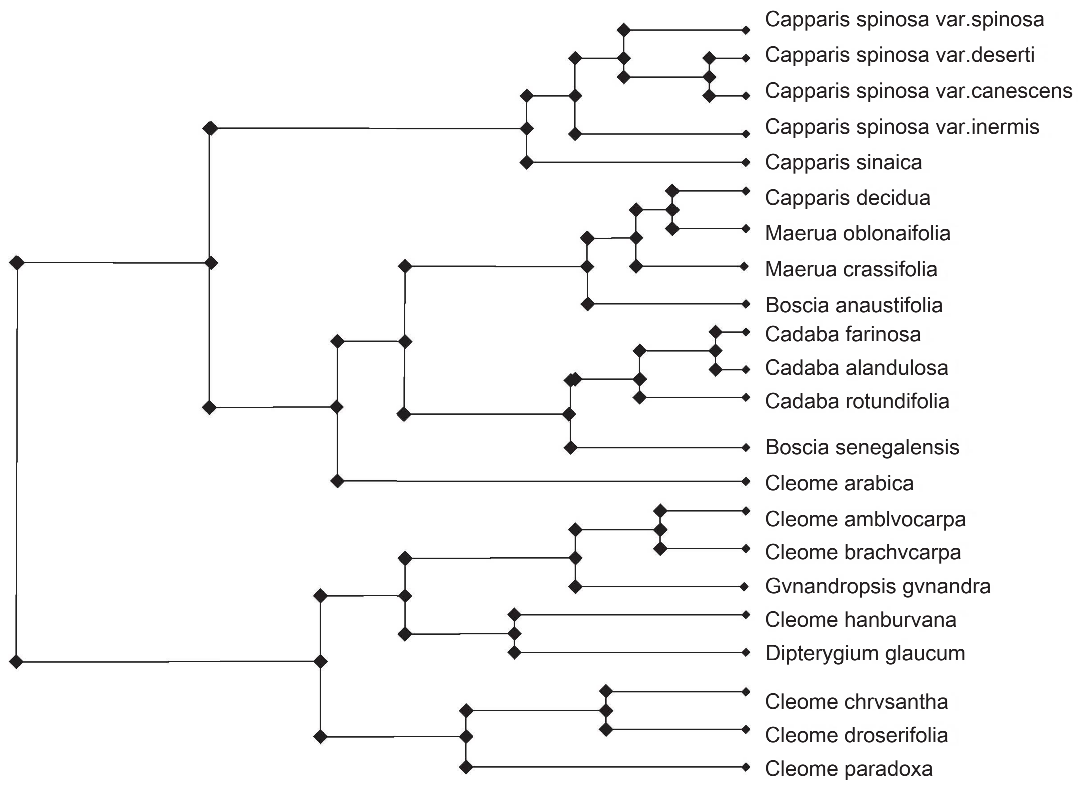

Figure 2. Complete linkage

following characteristics were helpful in the identihcation of the studied taxa: leaf composition, leaf surface, major venation pattern, secondary vein category, number of veins on either side of midrib, areolation, free ending ultimate veins and marginal ultimate venation. Therefore, based on the aforementioned results, the following key can be presented for the identihcation of the Capparaceae:

1. Venation pattern actinododromous
2. Marginal ultimate venation is incomplete loop *Cleome arabica*
2. Marginal ultimate venation is branched excurrent vein............... *Cleome droserifolia*
1. Venation pattern pinnate
3. Number of veins on either side of midrib 7-8 *Capparis decidua*
3. Number of veins on either side of midrib otherwise 4
4. Marginal ultimate venation with excurrent vein branched............................ 5
5. Secondary vein category brochidodromous................................ .... *Cleomeparadoxa*
5. Secondary vein category semi-craspedododromous ………… .... *Cleome amblyocarpa*
5. Secondary vein category cladododromous 6
6. Secondary vein angle decreasing toward base and areolation poorly developed.................................... *Diptery-gium glaucum*
6. Secondary vein angle uniform, areolation well developed 5 or more sided.. *Gynandrop-sis gynandra*
5. Secondary vein category craspedodoromous 7
7. Marginal ultimate venation hmbrial arcuate and secondary vein spacing increasing toward base.................... .... *Cleome chrysantha*
7. Marginal ultimate venation with excurrent vein branched and irregular secondary vein spacing 8
8. Secondary vein angle with one pair acute secondaries *Cleome hanburyana*
8. Secondary vein angle decreasing towards base .... *Cleome brachycarpa*
4. Marginal ultimate venation with hmrial arcuate 9
9. Free ending ultimate veins (F.E.V.S.) absent 10
10. Secondary vein spacing increasing toward base and secondary vein angle with one pair acute secondaries *Boscia angustifolia*
10. Secondary vein angle with two pair acute secondaries and irregular vein spacing................... ....*Boscia senegalensis*
9. Free ending ultimate veins with three branched and tapering 11
11. Secondary vein angle decreasing towards base *Cadabafarinosa*
11. Secondary vein angle with one pair acute secondaries *Cadaba glandulosa*
11. Secondary vein angle with two pair acute secondaries *Cadaba rotundifolia*
4. Marginal ultimate venation with incomplete loops 12
12. Free ending ultimate veins with three branched diffuse 13
13. Leaf oblanceolate..*Maerua crassifolia*
13. Leaf narrow oblong...................................*Maerua oblongifolia*
12. Free ending ultimate veins with three branched and swollen dots... 14
14. Inter-secondary veins absent 15
15. Secondary vein angle uniform................................ ....*Capparis spinosa* var. *deserti*
15. Secondary vein angle increase towards base ....*Capparis spinosa* var. *inermis*
14. Inter-secondary vein present 16
16. Third vein angle to the primary is perpendicular *Capparis spinosa* var. *spinosa*
16. Third vein angle to the primary is acute................. 17
17. Secondary vein angle increasing towards base ……………………………………. .... *Capparis spinosa* var. *canescens*
17. Secondary vein angle with two pair acute secondaries *Capparis sinaica*

On the basis of leaf architecture, cluster analysis was used to solve some of the problems met within this family such as: (a) the segregation of *Cleome* species from the *Capparis* group, *i.e.,* into two distinct families or not, (b) whether *Dipterygium* is better placed in Capparaceae than Brassicaceae (Hedge et al. 1980), and (c) the treatment of *Gynandropsis* as separate genus or its restoration as *Cleome gynandra.*

The dendrograms resulted from the cluster analysis are shown in Figures (2-4). Differences between methods arose

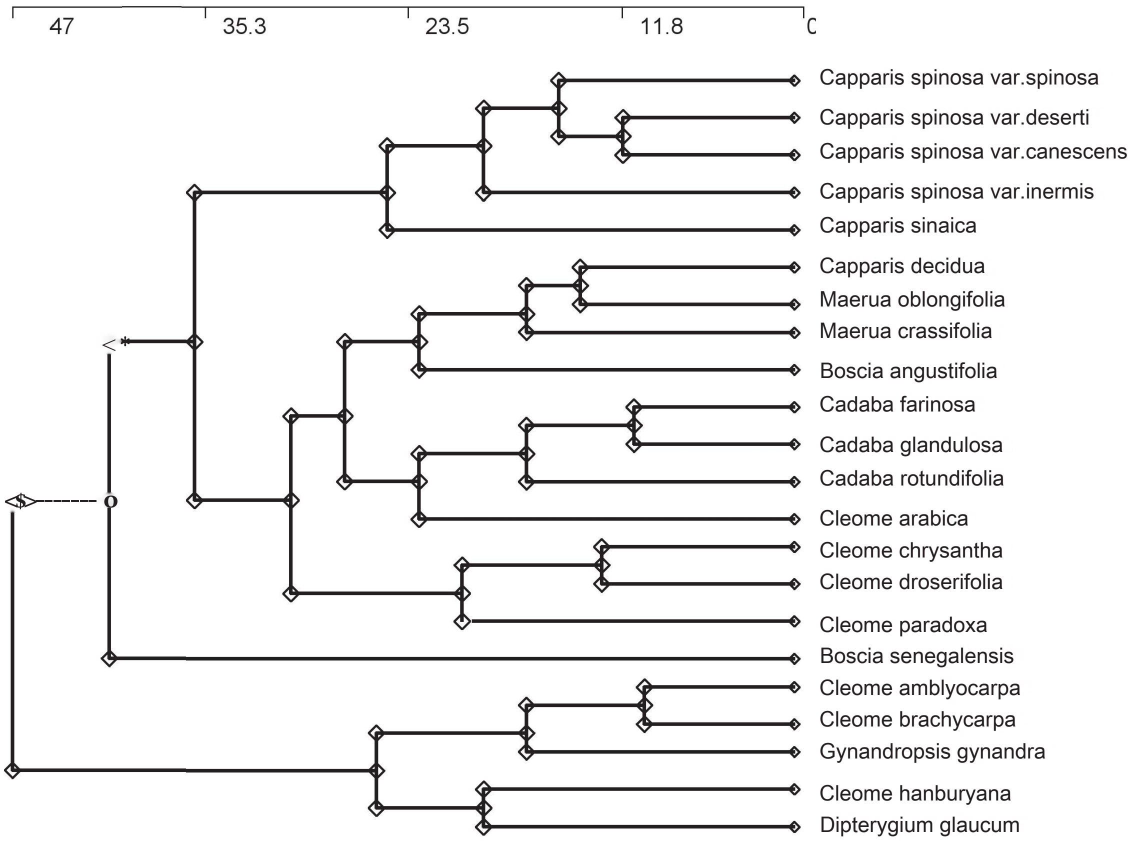

Figure 3. Average linkage

because of the differences in the ways of defining distance (or similarity) between individuals, and a group containing several individuals. All the dendrograms showed that three main clusters can be distinguished: (1) a cluster comprised most of the *Capparis* species; (2) a cluster divided into three subgroups: the first comprises all *Maerua* species, *Capparis decidua* and *Boscia angustifolia,* the second comprises *Cadaba* species and *Boscia senegalensis,* and the third with *Cleome arabica;* and (3) a cluster comprises most of *Cleome* species, *Gynandropsis gynandra* and *Dipterygium glaucum.*

Principal Components Analysis (PCA) reflected which characters were important on the axes; and indicated the significant characters based on the highest factor loading (Table 3). Therefore, it becomes clear which characters caused the separation between groups and can be useful to distinguish taxa. Generally, the results showed congruence between classification and ordination analyses in suggesting the following groups:

1- *Capparis* group (Tribe Capparideae): On the basis of leaf and venation characters, results of PCA confirmed that the studied taxa of *Capparis* formed a well-distinguished group characterized by: (a) simple ovate leaf, (b) irregular secondary vein spacing, (c) random reticulate third vein category and (d) branched free ending ultimate veins with swollen dots.

2- *Boscia* group (Tribe Capparideae): This group characterized by the absence of free ending ultimate veins. Phylogenetically and based on morphological and molecular data, Hall et al. (2002) revealed that there was less supported resolution within the terminal clades of Capparoideae, and still unresolved but comprise five well supported clades.

3- *Cadaba* group (Tribe Capparideae): This group is characterized by: (a) three branched with tapering end of free ending ultimate ends and (b) absence of intersecondary veins. Hall et al. (2002) indicated that genus *Cadaba* is well supported as a natural genus based upon the presence of large adaxial glands in flowers, and thus it can be supported as monophyletic group.

4- *Maerua* group (Tribe Maerueae): This group included the taxa of genus *Maerua.* It is differentiated on the basis of: (a) simple leaf, (b) pinnate venation pattern and (c) three branched diffuse of free ending ultimate veins of the leaf.

5- The mixed group: which included *Cleome* species, *Dipterygium glaucum* and *Gynandropsis gynandra* that characterized by their leaf margin and leaf persistence.

The present results showed some degree of similarity

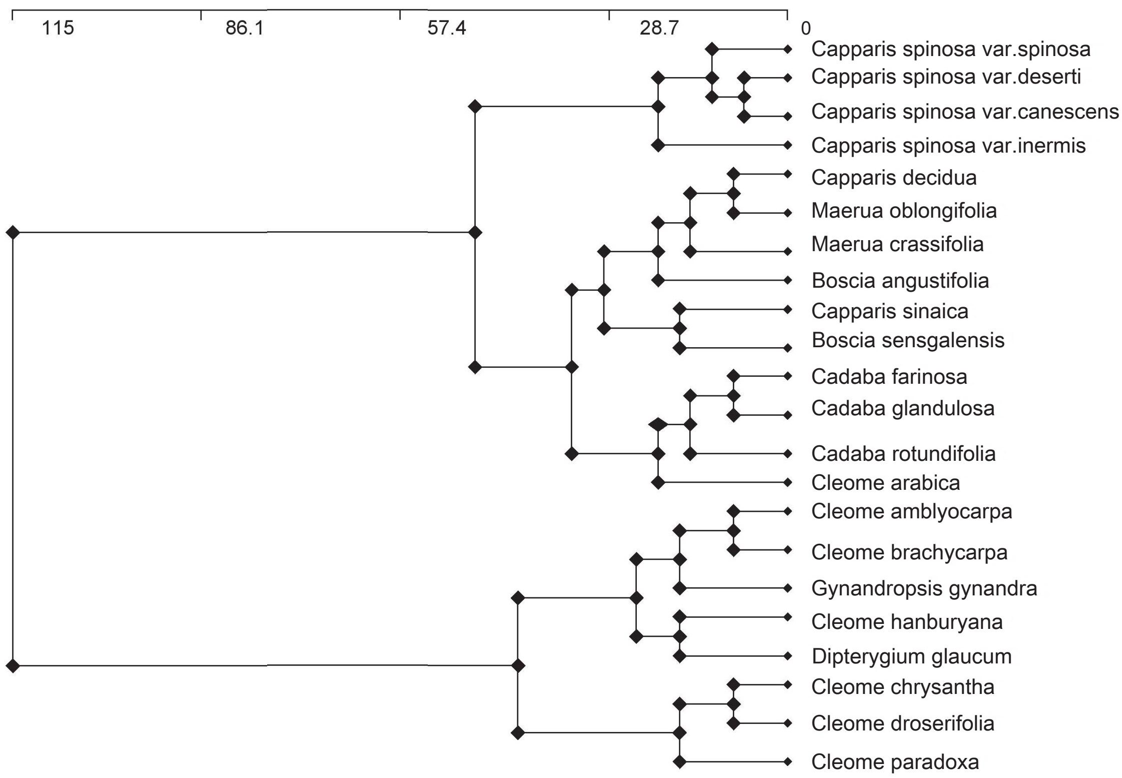

Figure 4. Minimum variance

among the taxa of Dipterygioideae and Cleomoideae based on: (a) the number of veins on either side of midrib and (b) secondary vein category (either cladodromous or craspidodromous).

Table 3 and Figure 5 showed that the main characters explaining this separation were leaf or leaflet form (1), leaf surface (5), leaf base (6), leaf persistence (7), main venation pattern (8), secondary vein angle (11), inter-secondary veins (12), number of veins on either side of midrib (13), free ending ultimate veins (19) and marginal ultimate venation (21).

Discussion

Leaf venation in angiosperm varies both in pattern (Hickey 1973) and regularity (Hickey and Doyle 1972). According to Pray (1954), the veins of first, second and third order form major venation pattern and those of subsequent orders constitute minor venation patterns. Hickey and Wolf (1975) based most of their conclusions on a survey of dicotyledonous leaf architecture made in the course of over ten years' study. They established the first framework for a systematic summary of dicotyledonous leaf architectural features. Because most taxa of dicots possess consistent patterns of leaf architecture, this rigorous method of describing the features of leaves is of immediate usefulness in both modern and fossil taxonomic studies. In addition as a result of this method, it is anticipated that leaves will play an increasingly important part in phylogenetic and ecological studies.

Based on the present study the Capparaceae *sensu lato* manifest two principal types of venation pattern: pinnate and actinododromous. According to Hickey and Wolf (1975), leaves (or leaflets) of the studied taxa of Capparaceae were basically simple, margin entire, venation pinnate, secondary veins were strongly brochidodromous. The free ending ultimate veins of the leaf (F.E.V.S) are a diagnostic character in the Capparaceae. The present observations were in accordance with those of Hickey and Wolf (1975) except the formation of a three-branched free ending ultimate vein with swollen dots (in *Capparis* species, except *C. decidua),* which was not recorded earlier. Whereas it was absent in the studied species of *Boscia,* three branched tapering or diffuse ending was recorded in genera of *Maerua,* and *Cleome arabica.* The remaining *Cleome* species were characterized by one-branched tapering endings.

Cleomoideae and Capparoideae were previously included in Capparaceae (Cronquist 1981, 1988; Thorne 1976, 1983; Dahlgren 1975; Takhtajan 1980, 1976). However, the two subfamilies of Capparaceae (Cleomoideae and Capparoideae) have already been elevated to familial status by some taxonomists (Airy Shaw 1965; Hutchinson 1967). Morphological and molecular studies (Radman 1991a, 1991b; Radman

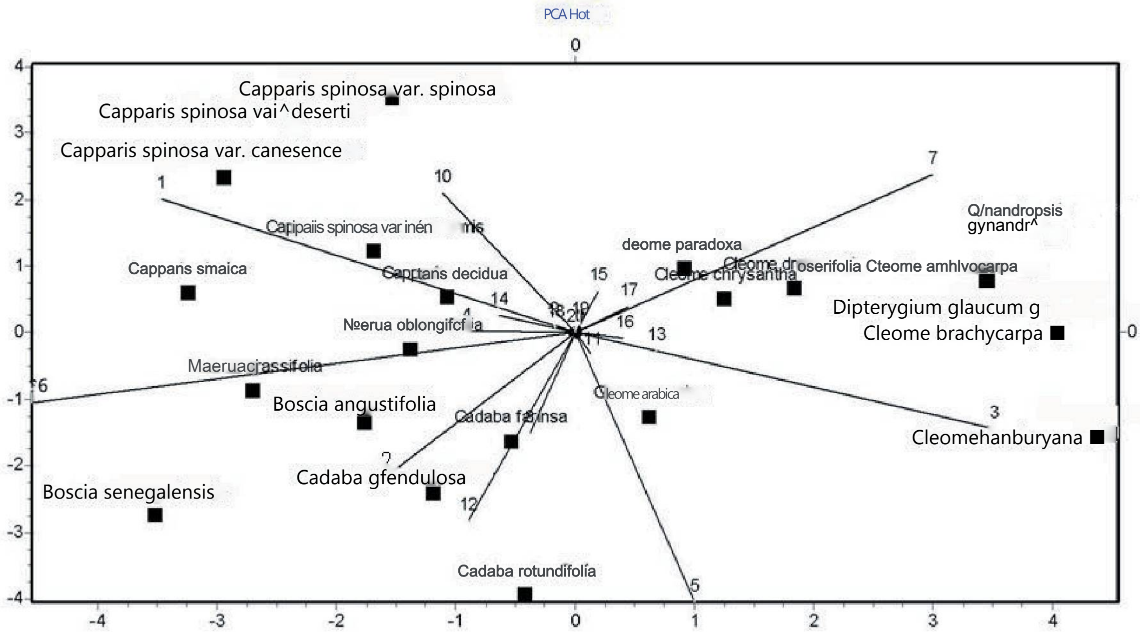

Figure 5. Principal Components Analysis (PCA) biplot showing characters (arrows) and species (dark squares). For character numbers, see Table 2.

et al. 1993; Judd et al. 1994) suggested that Capparoideae form a paraphyletic grade sister to a monophyletic Cleomoideae plus Brassicaceae. Based on these analyses, the two families have been merged into one family: the Brassicaceae *sensu lato* (APG 1998). However; based on molecular data; Cleomoideae, Capparoideae and Brassicaceae all form three well-supported monophyletic clades (Hall and Sytsma 2000; Hall et al. 2002) and could be recognized as three separate families, the Capparaceae, Cleomaceae, and Brassicaceae, a course of action recommended by some recent authors (Hall et al. 2002). On the basis of leaf architecture study, we advocate the recognition of two separate families Capparaceae and Cleomaceae. In this investigation most vein orders of leaf architecture were shown to be of great importance in the taxonomy of Capparaceae and Cleomaceae. They allowed in many instances clear separation between various taxa even at the very lower levels (species level) of the taxonomic hierarchy. Thus, their use to complement macro characters for taxonomic purposes is highly advisable. So for, there is no study devoted to the minor venation pattern, in the Capparaceae and Cleomaceae, the major and minor venation patterns are useful for the identihcation of the species. Our result revealed that leaf architecture has a signihcant value in differentiation between species; however, there is no differentiation at the variety level. We will investigate these tribes and genera with both morphological and molecular data in a separate account.

The present numerical analysis generally in agreement with earlier classification though it has suggested some amendments on generic level. litis (I960), De Wolf (1962), Ernst (1963) and Al-Gohary (1997) adopted the treatment of *Gynandropsis* as separate genus, but this had been contradicted with Täckholm (1974) and Boulos (1999). The cladistic

Table 3. Morphological characters showing highest factor loadings on the first three axes of PCA. For character numbers, see Table 2.

Character Number	Axis 1	Axis 2	Axis 3
1	-1.44	6.25	-1.60
2	-4.36	-2.48	0.058
3	3.28	-0.20	0.61
4	2.12	-1.37	-0.05
5	-0.46	-4.89	-3.07
6	-2.88	-0.61	-0.04
7	-0.45	1.13	-1.31
8	2.88	-0.27	0.95
9	0.56	-2.96	-0.79
10	-0.11	0.42	2.72
11	-5.87	2.21	0.34
12	0.09	0.09	0.24
13	-0.56	1.58	-0.94
14	3.37	0.05	0.83
15	3.02	0.48	0.98
16	-0.21	-0.92	1.04
17	2.55	3.79	-3.68
18	3.00	0.02	0.97
19	-4.52	1.14	248
20	1.94	0.39	1.56
21	-1.92	-3.90	-1.31

analysis of leaf architecture presented in this study supported the concept adopted by some authors as El Hadidi and Fayed (1994/95) and Boulos (1995) who retained *Gynandropsis gynandra* as *Cleome gynandra* of the family Capparaceae, as it clearly nested within *Cleome* (Figures 2-4). Comer (1976) also stated that the seeds of some species of *Cleome* seem to be resemble those of *Gynandropsis* e.g. *Cleome chelidonii.* Our results also added further evidence for the suggestion of Pax and Hoffman (1936), Ernst (1963) and Khafagi and Al-Gohary (1998) that *Gynandropsis gynandra* is closely related to *Cleome hanburyana.*

Although, Täckholm (1974) maintained *Dipterygium* in Cruciferae (Brassicaceae), yet Hedge et al. (1980) and Boulos (1999) favoured better placement in Capparaceae *sensu lato* than in the Cruciferae. This investigation had reinforced evidence for the suggestion of Hedge et al. (1980) for maintaining *Dipterygium* in Cleomaceae. Based on molecular and morphological data, Hall et al. (2002) demonstrated also a strong relationship within the clade including *Cleome* spp., *Dipterygium glaucum* and *Gynandropsis gynandra.*

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