

## LEAF MICROMORPHOLOGICAL FEATURES OF THE GENUS *Cordia* L. (BORAGINACEAE) FROM EGYPT

WAFAA AMER, RIM HAMDY<sup>1</sup> AND RIHAM MAHDY<sup>2</sup>

*Department of Botany & Microbiology, Faculty of Science, Cairo University, Giza 12613, Egypt*

**Keywords:** *Cordia*; Trichomes; Stomata; SEM; Egypt.

### Abstract

Foliar epidermal characters of nine *Cordia* L. species found in Egypt are investigated. Glandular trichomes are observed in *C. boissieri* A. DC. and *C. cylindristachya* (Ruiz & Pav.) Roem. & Schult., while eglandular trichomes are predominant in all studied species. Different stomatal characters were examined including: shape, size, rims, stomatal level, aperture, cuticular deposition and wax ornamentation. The retrieved results showed a great variation among the studied species. The observed trichomes and stomata were used to construct two different taxonomic keys.

### Introduction

*Cordia* L. is a large pantropical genus growing across the tropical and subtropical areas of America, Africa, Asia and Oceania (Al-Shehbaz, 1991) with 320 species of trees and shrubs. The genus is represented in the flora of Egypt by eight cultivated and one wild species.

*Cordia myxa* L. was recorded in ancient Egypt (Täckholm, 1961; Lucas, 1962; Darby *et al.*, 1977 and Manniche, 1989). Its fruit was eaten fresh and used to make wine. It may also have been raised for the production of birdlime (Van der veen, 2011). *Cordia sinensis* Lam. is the only relict species in its wild form; traced in moist ground in oases and Gebel Elba (Täckholm, 1974; Boulos, 2009). It was also raised in the Israel-Palestine area and in the Arabian Peninsula (Feinbrun-Dothan, 1978).

Taxonomic treatments of *Cordia* L. have long been recognized by many workers (Johnston, 1930; Kazmi, 1970; Taroda and Gibbs, 1986; Al Nowaihi *et al.*, 1987; Warfa, 1988; Verdcourt, 1991; El Mahi, 2012 and Mehrabian *et al.*, 2014). Metcalfe and Chalk (1950) described the general anatomical properties of the family including some details of the genus *Cordia* and underlined the taxonomic value of trichomes and stomata and their involvement in systematics.

The micromorphological characters of the epidermal system (stomata, trichomes, epidermal wax deposits) have been received much attention in the recent past years. According to Rejda (1991); monographs are considered incomplete without micromorphology of the epidermis. In the context, however, little attention was given to the genus *Cordia*. Recently Ventrella and Marinho (2008) studied foliar micromorphological of *C. verbenacea* DC from Brazil, Sharma *et al.* (2013) made identification of *Cordia macleodii* Hook. through stomatal index. As the earlier studies confirmed the importance of epidermal micromorphology in taxonomy (Stockey and Taylor 1978 a, b; Stace, 1984; Palmer and Gerbeth-Jones, 1986 and 1988; Yoon 1994; Hassan, 2004; Özcan, 2002). It reveals that foliar epidermal characters are important in taxonomic identification and species relationships in *Cordia* species. Despite the previous studies, genus *Cordia* L. received very little attention in Egypt. Therefore, the present study was undertaken to evaluate the features

<sup>1</sup>Corresponding author: Email: rimhamdy@yahoo.com

<sup>2</sup>Timber Trees and Forestry Department, Horticulture Research Institute, Agriculture Research Center, Giza, Egypt.

of foliar trichomes and stomata in the genus *Cordia* L. growing in Egypt and to assess these characters for specific and interspecific delimitation. It was also aimed to construct two differential keys on the trichomes and stomatal characters to identify *Cordia* species from Egypt.

### Materials and Methods

Nine species of *Cordia* used in this study are *C. africana* Lam., *C. boissieri* A. DC., *C. crenata* Delile, *C. cylindristachya* (Ruiz & Pav.) Roem. & Schult., *C. dentata* Poir., *C. dichotoma* G. Forst., *C. myxa* L., *C. sebestena* L. and *C. sinensis* Lam.

The localities of these species along with the voucher numbers are appended in Table 1. Fresh specimens collected and studied from different gardens as well as herbarium specimens deposited in Cairo University Herbarium (CAI), The Agriculture Research Centre, Flora of Phytotaxonomy Herbarium (CAIM) and Orman garden herbarium. Leaf material was examined by Scanning Electron Microscopy (SEM). Small pieces (c. 7 mm<sup>2</sup>) of dried mature leaf material were fixed to SEM stubs using double-sided adhesive tape, coated with gold in a sputter coat (SPI-Module), examined and photographed with a Jeol (JSM-5500 LV) using high vacuum mode at the Electron Microscope Unit, Regional Center of Mycology and Biotechnology at Azhar University, Cairo (Egypt).

Terminology of trichomes used are according to Al-Shammery and Gornell (1994); Bigazzi *et al.* (1999) and Taia (2006), while for stomata terminology Wilkinson (1983 & 1992) and El Hadidy (2004) were followed.

**Table 1. List of species of *Cordia* L. along with voucher specimens used in the present study.**

No.	Species	Voucher specimens
1	<i>Cordia africana</i> Lam.	Aswan: Aswan botanic garden, 20. 2. 1996, H. Rafeel 29135 (CAIM) Giza: Mazhar botanic garden, Baragile, 24. 8. 2014, R. Mahdy s.n. (CAI)
2	<i>C. boissieri</i> A. DC.	Giza: Villa El Maghraby, 30. 4. 2004, T.Labib (Orman garden herbarium) Giza: Mazhar botanic garden, Baragile, 24. 8. 2014, R. Mahdy s.n. (CAI)
3	<i>C. crenata</i> Delile	Sudan: Jebel Dambobei, Karora, 25. 12. 1966, M. Kass, M. Mobarak & H. Omar 1166 (CAI)
4	<i>C. cylindristachya</i> (Ruiz & Pav.) Roem. & Schult.	Giza: Faculty of Agriculture, 5. 6. 1976, B. Diwan s.n. (Orman garden Herbarium)
5	<i>C. dentata</i> Poir.	Giza: Orman garden, 5. 6. 1933, Khattab g1349 (CAIM) Giza: Zoological garden, 22. 5. 2014, R. Mahdy s.n. (CAI)
6	<i>C. dichotoma</i> Forst.f.	Giza: Mazhar botanic garden, Baragile, 6. 5. 2011, M. El Said s.n. Mazhar Herbarium Giza: Mazhar botanic garden, Baragile, 24. 8. 2014, R. Mahdy s.n. (CAI)
7	<i>C. myxa</i> L.	Aswan: Aswan botanic garden, 12. 5. 1998, H. Rafeel, 29366 (CAIM) Giza: Zoological garden, 22. 5. 2014, R. Mahdy s.n. (CAI)
8	<i>C. sebestena</i> L.	Giza: Orman garden, 28.7. 2007, Mostafa (Orman garden herbarium) Giza: Mazhar botanic garden, Baragile, 24. 8. 2014, R. Mahdy s.n. (CAI)
9	<i>C. sinensis</i> Lam.	Giza: Orman garden, 10.7.1933, J. Shabetaig1354 (CAIM) Giza: Zoological garden, 22. 5. 2014, R. Mahdy s.n. (CAI)

## Results and Discussion

The genus *Cordia* offers different types of trichomes and stomata are summarized in Tables 2 and 3. Both glandular and eglandular trichomes are found in *Cordia* (Table 2). Glandular trichomes are observed only in *C. boissieri* (40-46  $\mu\text{m}$ , Fig.1A) and *C. cylindristachya* (33-38  $\mu\text{m}$ , Fig.1B); the earlier possess clavate head while the later possess globular head. Eglandular trichomes are evident in all species, however they vary in density and distribution; presence or absence of basal part (cell), with circular rim or pluricellular, shape of upper part (apical cell); with cylindrical, flattened or conical, their length and ornamentation.

The eglandular trichomes are simple unbranched; the majorities are medium-long sized upper part. Their length ranges from 108-833  $\mu\text{m}$ . These eglandular trichomes may be without basal part as in *Cordia dichotoma* (Fig. 1C) or with basal part. The basal part either in circular rim as in *C. africana* (Fig. 1D), in one pluricellular (*C. myxa* Fig. 2F and *C. crenata* Fig. 2A, B), or in more than one row of cells as shown in *C. dentata* (Fig. 2G). The eglandular trichomes in the studied taxa appeared cylindrical in *C. africana* (Fig. 1D), or flattened in *C. dentata* (Fig.1F), rarely cone-like as in *C. crenata* (Fig. 2A). Trichome surface in the studied taxa appeared with variable surface namely: smooth (in *C. dichotoma*, Fig. 1C), granulate (in *C. africana*, Fig.1D), scaly (in *C. dentata*, Fig. 1F) or echinate (in *C. boissieri*, Fig. 1E).

Trichomes of the upper leaf surface of the studied taxa ranges from sparse (number of hairs /  $1\text{cm}^2$ , <300) in *Cordia africana*, *C. myxa*, *C. dichotoma* and *C. dentata* (Table 2). *Cordia sinensis* and *C. sebestena* possess moderate ( $\geq 300$ -600). The dense ( $\geq 600$ ) appeared in *C. boissieri*, *C. cylindristachya* and *C. crenata*, while in the lower surface trichomes appeared dense in most of the studied species, sparse in *C. dentata* and very dense in *C. boissieri* (Table 2).

The following key was constructed on the basis of trichome features of the studied *Cordia* species as shown under SEM:

1	Eglandular and glandular present	2
-	Only eglandular trichomes present	3
2	Glandular with clavate head	<i>C. boissieri</i>
-	Glandular with globular head	<i>C. cylindristachya</i>
3	Basal part absent	<i>C. dichotoma</i>
-	Basal part present	4
4	Formed of circular rim	<i>C. africana</i>
-	Formed of pluricellular cells	5
5	Pluricellular base formed of more than two rows	<i>C. dentata</i>
-	Pluricellular base formed of one row	6
6	Distinct in cylindrical upper part	<i>C. crenata</i>
-	Not distinct in cylindrical upper part	7
7	Scaly upper part	<i>C. myxa</i>
-	Granulate upper part	8
8	Granules coarse	<i>C. sinensis</i>
-	Granules fine	<i>C. sebestena</i>

The epidermal and stomatal features of the studied *Cordia* species are summarized in Table 3. Stomata as seen under SEM showed high diversity in stomatal shape: round (L= 1-1.2W) in *C. africana*, *C. boissieri* and *C. cylindristachya* (Fig. 3A, B & Fig. 4C, D, E, F); narrowly elliptic

Table 2. Trichomes features of the studied *Cordia* species.

<i>Cordia</i> species	Trichome Density (average number/cm <sup>2</sup> )		Glandular	With Basal part				Without Basal part						
	Upper epidermis (U)	Lower epidermis (L)		Circular Rim Base		Pluricellular Base		Hair Length/ $\mu$ m	Ornamentation	Number of Rows	Ornamentation	Hair Length/ $\mu$ m	Shape	Ornamentation
				Shape	Ornamentation	Shape	Ornamentation							
<i>C. africana</i>	+	+++	-	186	Cylindrical (L)	Granulate	-	-	-	-	464-528	Flattened (L)	Scaly	
<i>C. boissieri</i>	+++	+++	+	82-126	Cylindrical (U/L)	Echinate	-	-	-	-	400-692	Flattened (U/L)	Smooth	
<i>C. crenata</i>	+++	+++	-	-	-	-	208-280	Cylindrical (L)	One	Granulate	-	-	-	
<i>C. cylindristachya</i>	+++	+++	+	-	-	-	76-96	Conical (U)	-	-	-	151-360	Flattened (L)	Smooth
<i>C. dentata</i>	+	+	-	400-700	Flattened	Scaly	152-346	Cylindrical (U/L)	More than two	Granulate	152-346	Cylindrical (U/L)	Granulate	
<i>C. dichotoma</i>	+	+++	-	-	-	-	-	-	-	-	210-371	Cylindrical	Granulate	
<i>C. myxa</i>	+	+++	-	108-233	Cylindrical (L)	Granulate	331-446	Cylindrical (U/L)	One	Scaly	-	-	-	
<i>C. sebestena</i>	++	+++	-	-	-	-	292-417	Cylindrical (U/L)	One	Granulate	-	-	-	
<i>C. sinensis</i>	++	+++	-	-	-	-	117-167	Cylindrical (U/L)	One	Granulate	-	-	-	

Hair density: average number of hairs: Sparse=+ (<300 hairs/cm<sup>2</sup>), Moderate=++ (300-600 hairs/cm<sup>2</sup>), Dense=+++ (≥600 hairs/cm<sup>2</sup>), and very dense=++++ (hairs uncountable). Hair distribution: (U)= upper epidermis, (L)= lower epidermis and (U/L)=in both upper & lower epidermis.

Table 3. The epidermal and stomatal features of the studied *Cordia* species.

<i>Cordia</i> species	Epidermal Features			Stomata			Stomatal Aperture			Stomatal Rim	
	Cuticular Deposition	Wax Ornamenatation	Level	Length (µm)	Width (µm)	Shape	Length (µm)	Width (µm)	Shape	Number	Width
<i>C. africana</i>	Rims + Striations	Absent	Raised	15-18-20	13-15-17	Round	8-9-9	1-2-3	Short & Wide	One	Wide
<i>C. boissieri</i>	Rims + Striations	Absent	Raised	15-17-18	16-17-18	Round	8-9-9	3-4-4	Short & Wide	Two	Wide
<i>C. erenata</i>	Striations	Granules & Particles	Leveled	23-26-28	15-16-17	Broadly elliptical	10-14-17	2-3-3	Long & Slit-Like	Two	Narrow
<i>C. cylindristachya</i>	Ridges	Particles	Raised	15-18-20	13-16-18	Round	9-11-13	3-4-5	Long & Slit-Like	One	Wide
<i>C. dentata</i>	Striations	Flakes & Granules	Leveled	18-20-22	12-14-15	Broadly elliptical	7-8-9	2-3-3	Short & Wide	Two	Wide
<i>C. dichotoma</i>	Ridges	Filaments & Granules	Leveled	26-29-32	11-16-20	Narrowly elliptical	15-16-17	3-4-4	Long & Wide	Two	Narrow
<i>C. myxa</i>	Ridges	Flakes & Particles	Leveled	25-29-33	15-16-17	Narrowly elliptical	15-17-18	2-3-3	Long & Wide	One	Wide
<i>C. saebstenia</i>	Striations	Particles	Leveled	15-18-20	11-11-12	Broadly elliptical	6-9-11	1-2-2	Short & Narrow	One	Narrow
<i>C. sinensis</i>	Striations	Particles	Leveled	17-21-25	8-11-13	Narrowly elliptical	8-10-12	1-2-2	Long & Slit-Like	One	Narrow

Stomata shape: Round=(L= 1-1.2W), Narrowly elliptical=(L= 1.8-1.9W), Broadly elliptical=(L=1.4-1.6W). Aperture shape: Long: (aperture length average >10 µm), Short: (aperture length average ≤10 µm). Length and Width cited as average value in the middle figure.

( $L=1.8-1.9W$ ) in *C. sinensis*, *C. myxa* and *C. dichotoma* (Fig. 3E, F & Fig. 5A,B,C,D); while broadly elliptic ( $L=1.4-1.6W$ ) in *C. sebestena*, *C. crenata* and *C. dentata* (Fig. 3C,D, Fig. 4A, B & Fig. 5E,F).

The stomatal size ranged from 15-33  $\mu\text{m}$  long and 8-20  $\mu\text{m}$  wide. The largest in *C. myxa* and *C. dichotoma* while the smallest in *C. sebestena*. Some of the stomata show raised level as in *C. africana*, *C. boissieri* and *C. cylindristachya*, while other species are in the same level.

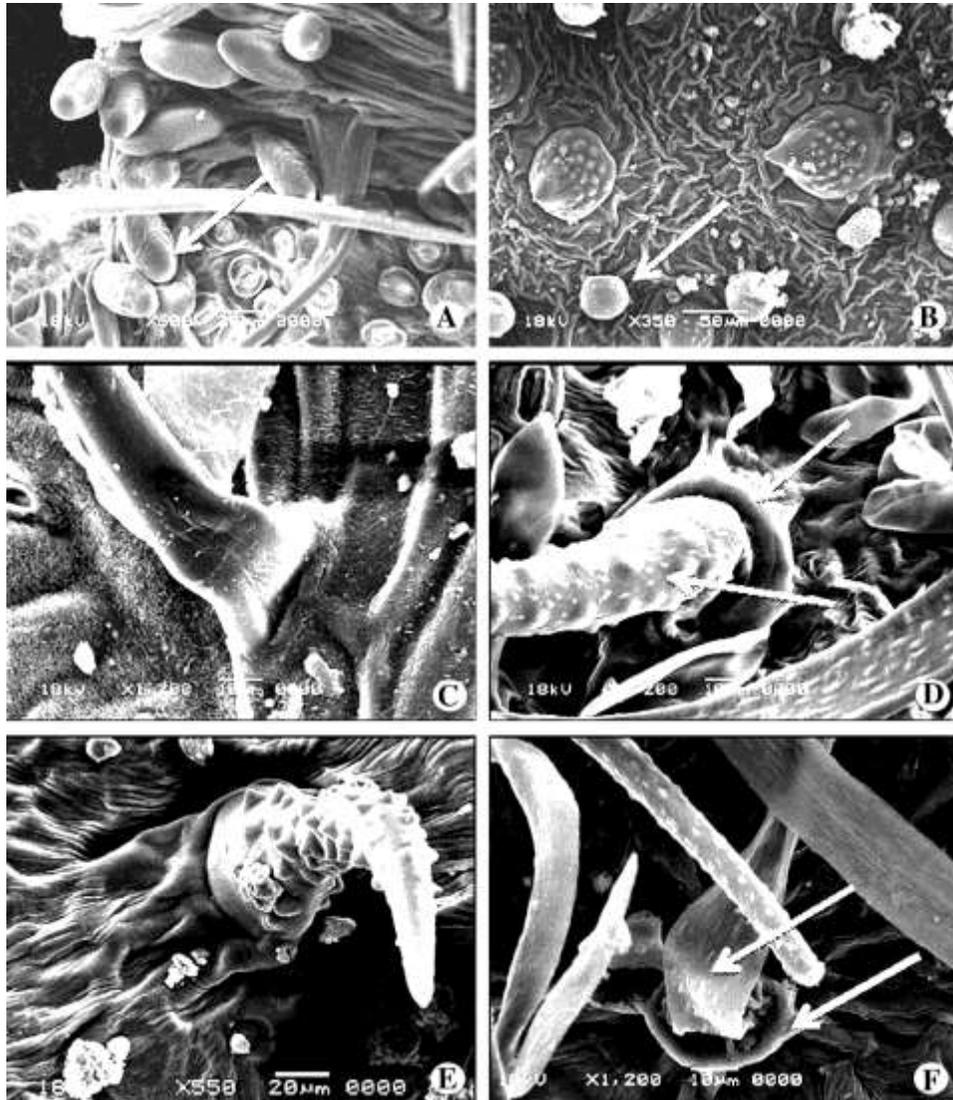


Fig. 1. SEM micrographs showing foliar trichomes in *Cordia* species. A-B Glandular trichomes: A. Clavate head of *C. boissieri*. and B. Globular head of *C. cylindristachya*. C-F Eglanular trichomes: C. Without basal part, cylindrical upper part of *C. dichotoma*, with smooth surface. D-E circular rim basal part: D. Cylindrical upper part of *C. africana*, with granulate surface, E. *C. boissieri*, with echinate surface. F. Flattened upper part of *C. dentata* with scaly surface.

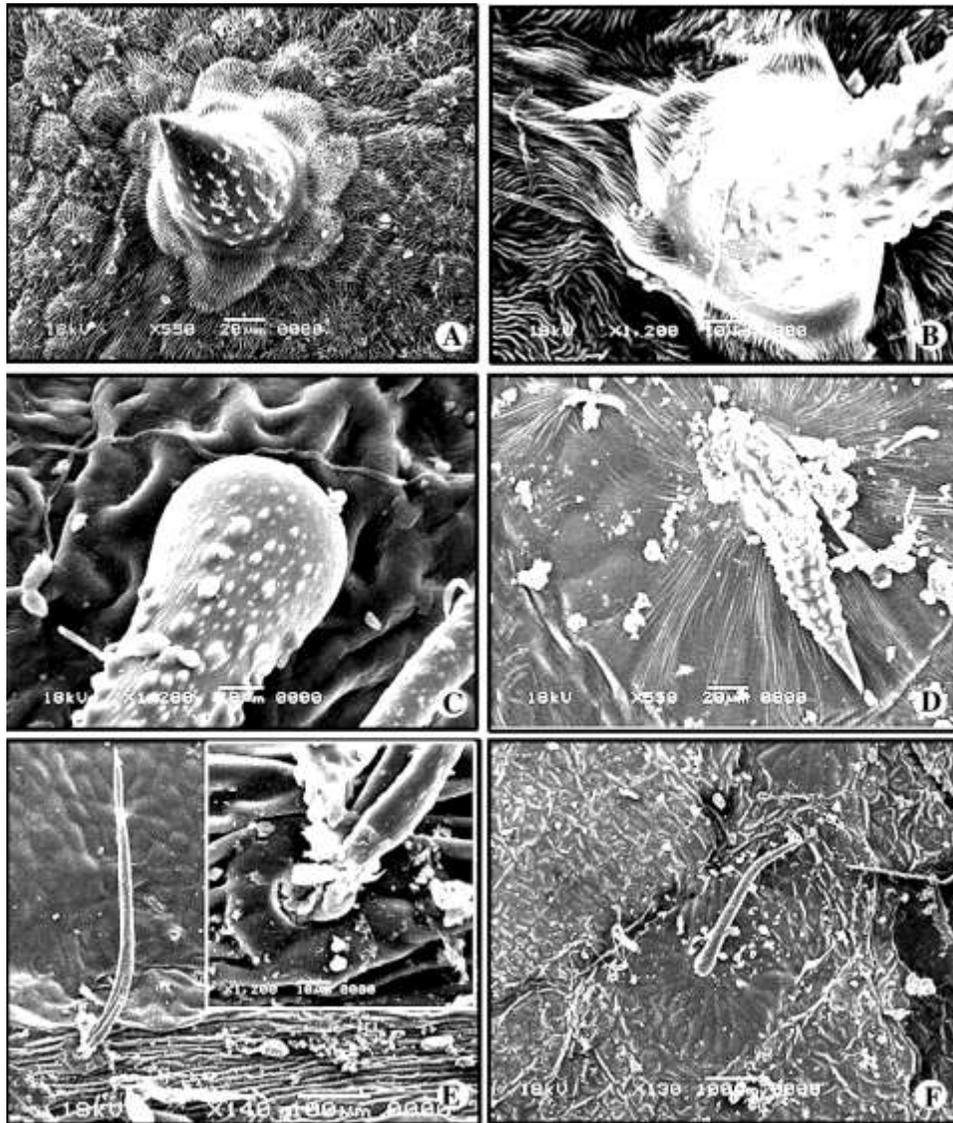


Fig. 2. SEM micrographs showing foliar trichomes in *Cordia* species. A-G eglanular trichomes with pluricellular basal part: A-F. In one row cells, A, B. *C. crenata*, A. conical upper part, B. cylindrical upper part, C. cylindrical upper part of *C. sebestena*, D. cylindrical upper part of *C. sinensis*, with granulate surface, E, F Cylindrical upper part of *C. myxa*, with scaly surface and G. pluricellular basal part in more than two rows of *C. dentata*.

The presence of stomatal rim is a diagnostic feature: single in *C. africana* (Fig. 3B), *C. sebestena* (Fig. 3D), *C. sinensis* (Fig. 3F), *C. cylindristachya* (Fig. 4F), *C. myxa* (Fig. 5B) and double in *C. crenata* (Fig. 4A), *C. boissieri* (Fig. 4D), *C. dichotoma* (Fig. 5D) and *C. dentata* (Fig. 5F).

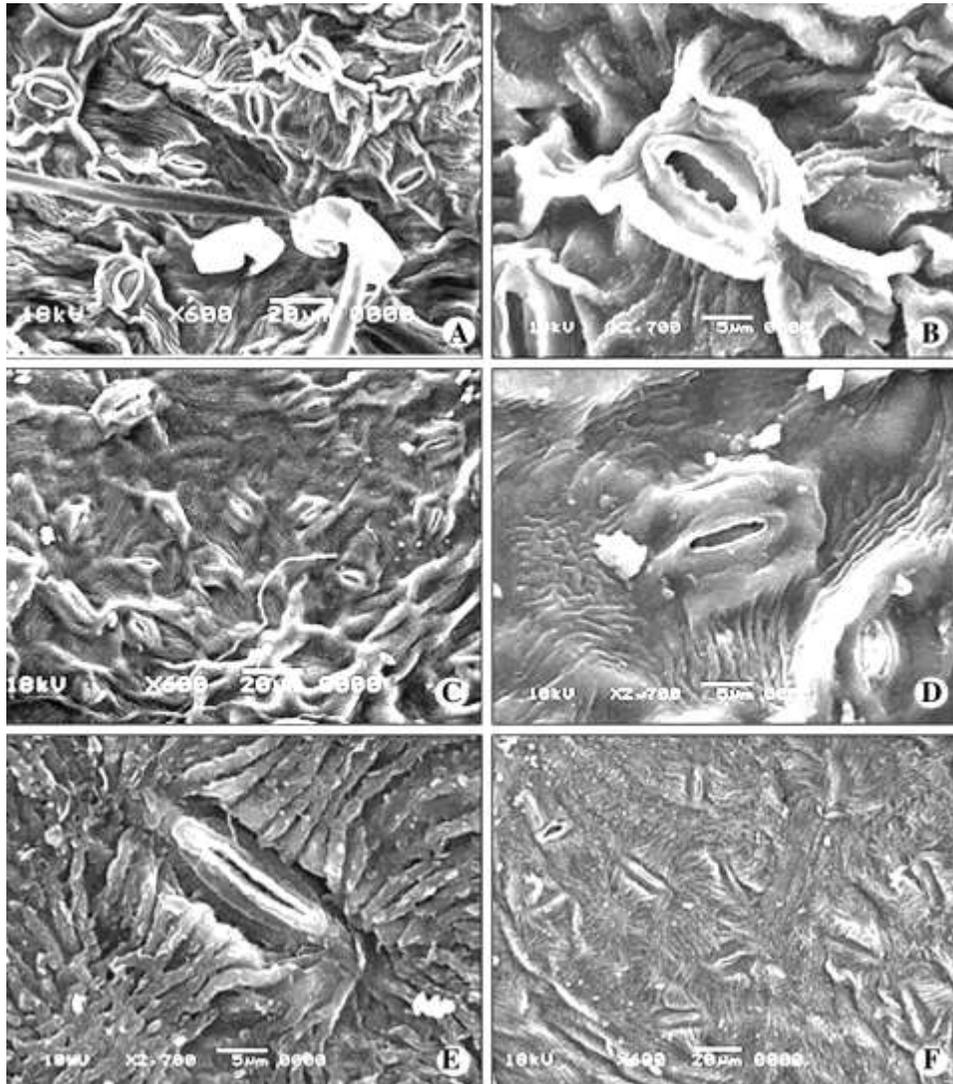


Fig. 3. SEM micrographs showing the stomatal pattern and magnified stomium in *Cordia* species. A, B: *C. africana*, C, D: *C. sebestena*, E, F: *C. sinensis*.

Stomatal opening (aperture) is variable among the studied taxa: long (average length  $>10\ \mu\text{m}$ ) in *C. dichotoma*, *C. myxa*, *C. crenata*, *C. cylindristachya* and *C. sinensis*; short (average length  $\leq 10\ \mu\text{m}$ ) in *C. africana*, *C. boissieri*, *C. dentata* and *C. sebestena*.

Cuticular deposits are observed in the form of striations or ridges; striations forming lateral wings perpendicular to the long axis of the subsidiary cells are observed in *C. sinensis* (Fig. 3E, F). Sometimes these striations radiating extend across more than one epidermal cell as in *C. sebestena* (Fig. 3C,D) and *C. dentata* (Fig. 5E,F). Striations distinguished *C. crenata* (Fig. 4A, B) and *C. sinensis* (Fig. 3E, F) from the rest of the studied species. However in *C. africana* the stomata are enclosed by undulated rim. Also striations extend across more than one epidermal

cells (Fig. 3A, B). These striations sometimes form short lateral wings perpendicular to the long axis of the subsidiary cells in *C. boissieri* (Fig. 4C, D). *Cordia cylindristachya* can be distinguished from the other studied species with the presence of stomata located on epidermal ridges forming lateral wings perpendicular to the long axis of the stomatal cells (Fig. 4E, F). These ridges are crescentic and mostly parallel (occasionally perpendicular) to the long axis of the subsidiary cells as observed in *C. myxa* (Fig. 5A, B) while appears crescentic perpendicular to the long axis of the subsidiary cells in *C. dichotoma* (Fig. 5 C, D).

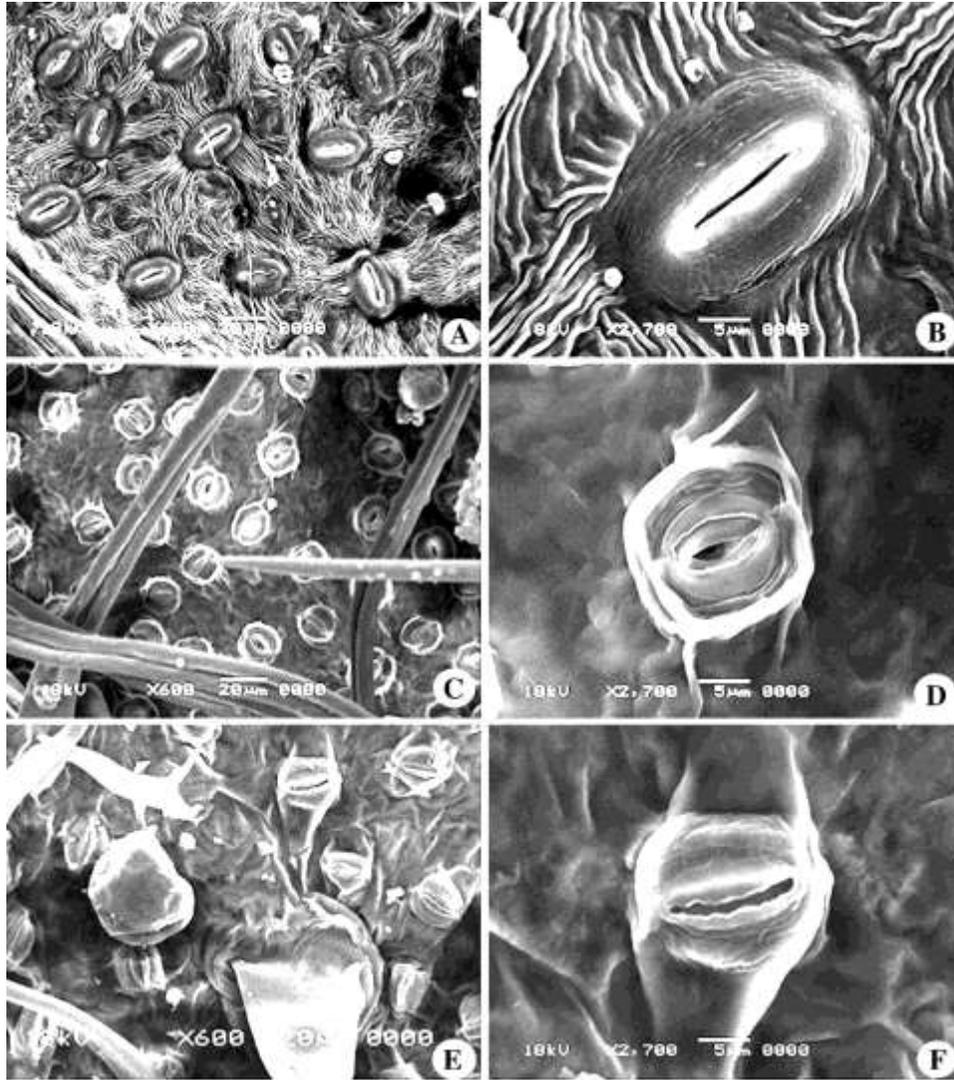


Fig. 4. SEM micrographs showing the stomatal pattern and magnified stomium in *Cordia* species. A, B: *C. crenata*, C, D: *C. boissieri*, E, F: *C. cylindristachya*.

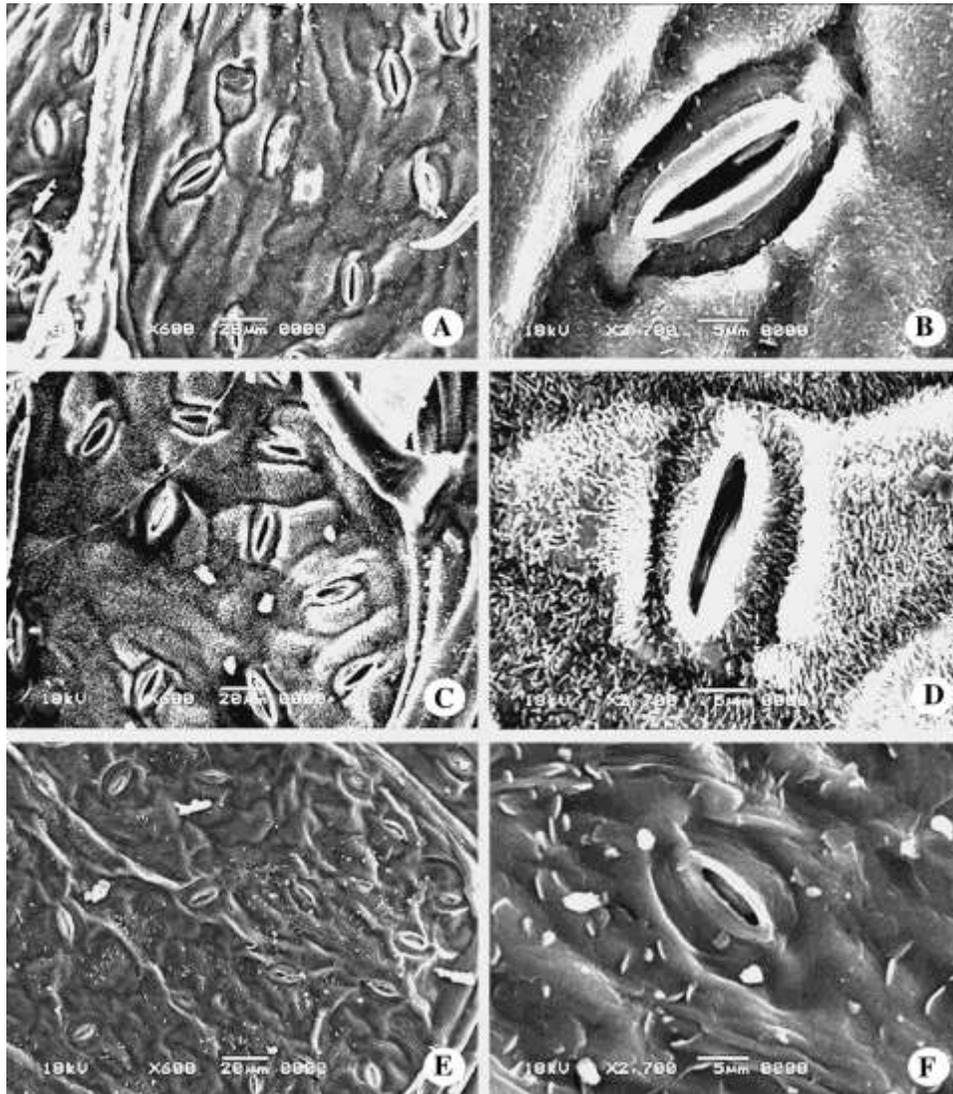


Fig. 5. SEM micrographs showing the stomatal pattern and magnified stomium in *Cordia* species. A, B: *C. myxa*, C, D: *C. dichotoma*, E, F: *C. dentata*.

The SEM of the epidermal system showed the presence of special wax structures (filaments, particles, flakes and granules, Table 3) in the studied taxa. Particles are observed in *C. cylindristachya*, *C. sebestena* and *C. sinensis*. These particles mixed with flakes in *C. myxa* (Fig. 5 B) or mixed with granules in *C. crenata* (Fig. 4B), while flakes and granules are observed in *C. dentata* (Fig. 5F) filaments and granules in *C. dichotoma* (Fig. 5D). The following key was constructed on the basis of the stomatal and epidermal features of the studied taxa as shown under SEM.

1	Obvious epidermal striations	2
-	Obscure epidermal striations	5
2	Stomata with cuticular rim	<i>C. africana</i>
-	Stomata without cuticular rim	3
3	Cuticular deposition with unobvious striations extending across more than one epidermal cell	<i>C. sebestena</i>
-	Cuticular deposition with conspicuous striations, not extending across more than one epidermal cell	4
4	Striations only perpendicular to the long axis of the subsidiary cells	<i>C. sinensis</i>
-	Striations radiating all over the stomata	<i>C. crenata</i>
5	Stomata round	6
-	Stomata elliptic	7
6	Stomata on ridge without stomatal rim	<i>C. cylindristachya</i>
-	Stomata not on ridge, with stomatal rim	<i>C. boissieri</i>
7	Stomata broadly elliptic	<i>C. dentata</i>
-	Stomata narrowly elliptic	8
8	Epidermis with dense waxy filaments	<i>C. dichotoma</i>
-	Epidermis not so	<i>C. myxa</i>

In our study *Cordia myxa* and *C. dichotoma* have been found closely related (Verdcourt, 1991) as attested by the following shared characters: lamina broadly ovate to suborbicular, inflorescence dichotomous branching, flowers salverform and white, stigma flattened and subfoliaceous with irregular or erose-denticulate margin, fruit yellowish orange. However the epidermal features do not support a close association between them, using micromorphological characters during this study to distinguish both species; the eglandular trichomes without basal part is observed in *C. dichotoma* (Fig. 1C) while basal part is pluricellular in *C. myxa* (Fig. 2F). Also wax ornamentation is formed of particles in addition to flakes in *C. myxa* (Fig. 5A, B) and filaments and granules in *C. dichotoma* (Fig. 5C, D).

Stomata in *Cordia* are usually confined to lower side (Metcalf and Chalk, 1950). The results outlined in Table (3), indicate that stomatal rim and wax ornamentation is found to be significant characters; stomatal rim was double in *C. boissieri*, *C. crenata*, *C. dentata* and *C. dichotoma* and single in *C. africana*, *C. cylindristachya*, *C. myxa*, *C. sebestena* and *C. sinensis* (Figs.3, 4,5). Wax ornamentation is formed of particles and granules in *C. crenata* (Fig. 4A, B), *C. myxa* with particles and flakes (Fig. 5A, B), *C. dichotoma* with filament and granules (Fig. 5C, D) while *C. dentata* characterized flakes and granules (Fig. 5E, F). These results are in accordance with that of Akcin *et al.*, (2013), who claimed that, the stomatal rims and wax ornamentations are important characters for delimiting fourteen species of *Onosma* L.

*Cordia cylindristachya* was distinguished from other species, by stomata located on epidermal ridge (Fig. 4E, F) which was confirmed earlier by Metcalfe and Chalk (1950) on some *Cordia* species.

Finally, we conclude that the micromorphological characters of *Cordia* species such as presence of eglandular and glandular trichomes, presence or absence, shape and ornamentation of

basal trichome part, stomatal rim and wax ornamentation possess diagnostic taxonomic value which can delimit *Cordia* species.

### References

- Akçin Ö.E., Şenel G. and Akçin, Y. 2013. Leaf epidermis morphology of some *Onosma* (Boraginaceae) species from Turkey. *Turk. J. Bot.* **37**: 55-640.
- Al-Nowaihi, A.S., Khalifa, S.F. and Hamed, K. 1987. A contribution to the taxonomy of Boraginaceae. *Phytologia* **62**: 107-125.
- Al-Shammary, K.I.A., and Gornall, R.J. 1994. Trichome anatomy of the Saxifragaceae. I. from the southern hemisphere. *Bot. J. Linn. Soc.* **114**: 99-131.
- Al-Shehbaz, I.A. 1991. The genera of Boraginaceae in the Southeastern United States. *J. Arnold Arb. Suppl.* **1**: 1-169.
- Bigazzi, M., Selvi, F. and Fiorini, G. 1999. A reappraisal of the generic status of *Gastrocotyle*, *Hormuzakia* and *Phyllocara* (Boraginaceae) in the light of micromorphological and karyological evidence. *Edinb. J. Bot.* **56**(2): 229-251.
- Boulos, L. 2009. Flora of Egypt Checklist, El Hadara Publishing, Cairo, Egypt, 410p.
- Darby, W., Ghalloungui, P., Griffith, L. 1977. Food: The gift of Osiris. Vol. **1 & 2**, Academic press, London, New York, San Francisco.
- Dasti, A.A., Bokhari, T.Z., Malik, S.A. and Akhtar, R. 2003. Epidermal morphology in some members of family Boraginaceae in Baluchistan. *Asian J. Plant Sci.* **2**(1): 42-47.
- El Hadidy, A.M.H. 2004. Morphological studies on fruits and seeds of the genus *Lotus* L. in Egypt, Proceedings of First International Conference on Strategy of Egyptian Herbaria March 9-11, 2004; Giza, Egypt. 129-159.
- El Mahi, H.O.A. 2012. Taxonomic revision of the family Boraginaceae in Sudan. Ph.D. Thesis, Botany Department, Faculty of Science, University of El Khartoum.
- Feinbrun-Dothan, N. 1978. Boraginaceae, Flora Palaestina, Vol. **3**, Israel Academy of Science and Humanities, Jerusalem.
- Hassan, S.A. 2004. Stomatal diversity in certain species of Apocynaceae and its bearing on taxa delimitation. *Taeckholmia* **24** (1): 21-31.
- Johnston, I.M. 1930. Studies in Boraginaceae. VIII. *Contrib. Gray Herb. Harvard Uni.* **92**: 1-89.
- Johnston, I.M. 1935a. Studies in Boraginaceae. X. The Boraginaceae of Northeastern South America. *J. Arnold Arb.* **16**: 1-64.
- Johnston, I.M. 1935b. 3. New or otherwise noteworthy species. *J. Arnold Arb.* **16**: 173-181.
- Johnston, I.M. 1937. Studies in the Boraginaceae. XII - 1. *Trigonotis* in Southwestern China. 2. Novelties and Critical Notes. *J. Arnold Arb.* **18**: 10-13.
- Johnston, I.M. 1940. Studies in Boraginaceae. XV. Notes on some Mexican and Central American species of *Cordia*. *J. Arnold Arb.* **21**: 336-355.
- Johnston, I.M. 1948. Studies in the Boraginaceae. XVI - Species chiefly from Mexico and Western United States. *J. Arnold Arb.* **29**: 227-240.
- Johnston, I.M. 1949a. Studies in the Boraginaceae. XVII. A. *Cordia* section *Varronia* in Mexico and Central America. *J. Arnold Arb.* **30**: 85-106.
- Johnston, I.M. 1949b. Studies in the Boraginaceae. XVII. Boraginaceae of the Southern West Indies. *J. Arnold Arb.* **30**(2): 111-138.
- Johnston, I.M. 1951. Studies in the Boraginaceae. XX. Representatives of three subfamilies in Eastern Asia. *J. Arnold Arb.* **32**(2): 1-26.
- Johnston, I.M. 1956. Studies in the Boraginaceae. XXVIII. New or otherwise interesting species from America and Asia. *J. Arnold Arb.* **37**: 288-306.

- Kazmi, S.M.A. 1970. A revision of the Boraginaceae of West Pakistan and Kashmir. *J. Arnold Arb.* **51**: 133–184.
- Lucas, A. 1962. Ancient Egyptian materials and industries. Fourth edition, Revised by J.R. Harris, E. Arnold, London.
- Manniche, L. 1989. An ancient Egyptian herbal, British Museum Publications, Austin.
- Mehrabian, A.R., Sheidai, M. and Mozaffarian, V. 2014. Micromorphology of leaf trichomes in *Onosma* (Boraginaceae) and their systematic relevance in Iran. *Phytol. Balcan.* **20** (1): 33- 48.
- Metcalf, C.R. and Chalk, L. 1950. Anatomy of Dicotyledons, Second edition, Clarendon Press, Oxford.
- Özcan, T. 2002. SEM observation on petals and fruits of some Turkish endemic *Buplerum* L. (Umbelliferae) species. *Bot. J. Linn. Soc.* **138** (4): 441-449.
- Palmer, P.G. and Gerbeth-Jones, S. 1986. A scanning electron microscope survey of the epidermis of East African grasses IV. *Smithson. Contr. Bot.* **49**: 1-120.
- Palmer, P.G. and Gerbeth-Jones, S. 1988. A scanning electron microscope survey of the epidermis of East African grasses V and West African supplement. *Smithson. Contr. Bot.* **67**: 1-153.
- Rejdali, moh.F.L.S. 1991. Leaf micromorphology and taxonomy of North African species of *Sideritis* L. (Lamiaceae). *Bot. J. Linn. Soc.* **107**(1): 67-77.
- Sharma, A., Acharya, R.N., Shukla, V.J., Harisha, C.R. and Gupta, S.K. 2013. Identification of *Cordia macleodii* Hook. through DNA finger printing and stomatal index. *Universal Journal of Pharmacy - UJP* **2**(3): 98-101.
- Stace, C.A. 1984. The taxonomic importance of the leaf surface. *In: Heywood, V.H., Moore, D.F. (Eds), Current Concepts of Plant Taxonomy.* Academic Press, London, pp. 31–39.
- Stockey, R.A. and Taylor, T.N. 1978a. Scanning electron microscopy of epidermal patterns and cuticular structure in genus *Araucaria*. *Scan. Electron Microsc.* **2**: 223-228.
- Stockey, R.A. and Taylor, T.N. 1978b. Cuticular features and epidermal patterns in the genus *Araucaria* de Jussieu. *Bot. Gaz.* **139**: 490-498.
- Täckholm, V. 1961. Botanical identification of the plants found at the Monastery of Phoebammon. *In: Bachatly, C. (Ed.) La Monastère de Phoebammon dans la Thébaïde.* Cairo.
- Täckholm, V. 1974. Student's flora of Egypt, second edition, Cairo University, Beirut.
- Taia, W.K. 2006. Family Boraginaceae: Hair variations and their significance in the systematic of the Genera. *Asian J. Plant Sci.* **5**(3): 441-454.
- Taroda, N. 1984. Taxonomic studies on Brazilian species of *Cordia* L. (Boraginaceae). Ph.D. Thesis, University of Saint Andrews, Saint Andrews. pp. 1-232.
- Taroda, N. and Gibbs, P. 1986. Studies of the genus *Cordia* L. (Boraginaceae) in Brazil. 1. A new infrageneric classification and conspectus. *Rev. Bras. Bot.* **9**: 31-42.
- Van der Veen, M. 2011. Consumption, trade and innovation. *Journal of African Archaeology Monograph series (JAAMs)* **6**: 1-313.
- Ventrella, M.C. and Marinho, C.R. 2008. Morphology and histochemistry of glandular trichomes of *Cordia verbenacea* DC. (Boraginaceae) leaves. *Rev. Bras. Bot.* **31**(3): 457-467.
- Verdcourt, B. 1991. Boraginaceae. *In: Polhili, R.M. (Ed.), Flora of Tropical East Africa.* A. A. Balkema, Rotterdam, Brookfield, Netherlands, 124 p.
- Warfa, A.M. 1988. *Cordia* (Boraginaceae) in NE Tropical Africa and Tropical Arabia. *Acta Universitatis Upsaliensis - Comprehensive Summaries of Uppsala Dissertations from the Faculty of Science* **174**: 1-80.
- Wilkinson, H.P. 1983. Leaf anatomy of *Gluta* (L.) Ding Hou (Anacardiaceae). *Bot. J. Linn. Soc.* **86**: 375-403.
- Wilkinson, H.P. 1992. Leaf anatomy of the Pittosporaceae R. Br. *Bot. J. Linn. Soc.* **110**: 1-59.
- Yoon, C.Y. 1994. A taxonomic study on the genus *Angelica* L. in Korea and adjacent region. Ph.D. Thesis, Korea University, Korea.