Micromorphological Variability of the Leaf epidermis in some Ornamental Taxa of Genus *Ficus* L. (Moraceae) in Egypt

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ABSTRACT

A study of the epidermal leaf traits of 12 cultivated taxa of the genus *Ficus* (Moraceae) representing five subgenera and nine sections has been made with the SEM. The study revealed important micromorphological characters which exhibit interesting variations at the infrageneric level. The characters found to be of valuable use in distinguishing groups of taxa are: pattern of anticlinal walls of adaxial epidermal cells; nature of trichomes as the presence or absence of eglandular simple unbranched or complex branched ones, as well as, elliptic and elongate glandular hairs; presence or absence of hydathodes on both surfaces and its type adaxially; absence of lithocysts on both surfaces and its presence abaxially and/or adaxially; stomata outline, size, distribution and presence of sunken stomata with peristomatal cuticular thickening; cuticle architecture and epicuticular wax. Clustering analysis of the studied taxa has been done to assess the taxonomic identification and the phenetic relationships among the taxa.

Keywords: *Ficus* - Moraceae - epidermal features - scanning electron microscope (SEM)- taxonomy.

INTRODUCTION

Moraceae Link has always been associated with Urticaceae (Berg, 1989a) and other families commonly placed in the Urticales. These are all placed in Rosales (APGII, 2003). The family is divided into five tribes: *Moreae*, *Dorstenieae*, *Castilleae*, *Ficeae* and *Artocarpeae*. The tribe *Ficeae* is only represented by the genus *Ficus* (Heywood et al., 2007). *Ficus* L. is considered the largest genus in the Moraceae with approximately 750-1000 species in different habitats throughout tropical and warm-temperate regions, but mostly in Asia and Australia (Corner, 1965; Berg, 1989b, 1991; Berg & Corner 2005; Heywood et al., 2007).Economically, *Ficus* is important for its edible fruit (figs), timber, fibers, folk medicine, and some are cultivated as large tropical shade trees or smaller house plants (Heywood et al., 2007).In the genus *Ficus*, the leaves are characterized by the presence of crystals with calcium carbonate (cystoliths), calcium oxalate or silica. These crystals are produced in special enlarged epidermal cells called "lithocysts". These crystals are also widespread in the normal epidermal cells or in trichomes (Esau, 1965).From a taxonomical perspective, based on geographical distribution and morphological traits, the genus *Ficus* has recently been divided into six subgenera with 19 sections and 27 subsections (Berg & Corner, 2005). In 2015, Pederneiras et al. reviewed the genus and revised its nomenclature. His revision resulted in the displacement of three subgeneric (*Ficus* subg.*Terega*, *F.* subg.*Sycomorus*, *F.* subg.*Spherosuke*) and four sectional names (*F.* sect.*Cordifoliae*, *F.* sect.*Pogonotrophe*, *F.* sect.*Platyphyllae*, *F.* sect.*Urostigma*) that have the priority over others which have long been used. In this study, the updated

nomenclature of Pederneiras et al. (2015) has been adopted. Anatomically, considerable works have been done on epidermal and lamina characteristics in the family Moraceae or in some members of *Ficus* such as: trichomes and stomata (Metcalfe & Chalk, 1950; Shah & Kachroo, 1975; Gangadhara & Inamder, 1977; Theobald et al., 1979; Klimko & Truchan, 2006; Ogunkunle, 2013); laminar hydathodes and leaf anatomy (Lersten & Peterson, 1974; Van Greuning et al., 1984; Sonibare et al., 2005; Klimko & Truchan, 2006; Chantarasuwan et al., 2014; Giordano et al., 2020). All these selected traits were studied on plants from their natural localities, but only few researchers who used cultivated members in their research among them Sosnovsky (2014), who studied the leaf architecture.

For Egypt, there is a lack of literature on *Ficus* due to its enormous diversity in vegetative, floral and fruit characteristics. Boulos (2009) has enumerated four wild species; while a few numbers of studies on *Ficus* leaf architecture (Loutfy et al., 2005) and palynology (Taleb & Salah -El-din, 2014). For the cultivated species in the Egyptian gardens, Diwan et al. (2004) mentioned 6 species; while Heneidy (2010) reported15 species. Later in 2021, Soliman et al. have reported for the first time 33 species (41 taxa; 4 subspecies and 4 varieties) classified into 5 subgenera. Anatomically, no work has been done except the leaf anatomy and its molecular characteristics of the 12 Ficus taxa (Binnoubah et al., 2023).

The present study aims to: analyze leaf microscopic structure, provide additional data, and identify valuable traits for identification and delimitation of the studied cultivated *Ficus* taxa.

MATERIALS AND METHODS

1. Plant material:-

Fresh samples were collected from six gardens in Cairo, Giza and Aswan Governorates for the in vivo study. Voucher specimens were deposited in the Cairo University Herbarium (CAI). Identification is confirmed using the contribution sources of Corner (1977), Ghafoor (1985), Berg & Hijman (1989), Berg (1991), Soliman et al., (2021), the online sites (The Plant list, 2013; IPNI, 2021; and Van Noort & Rasplus, 2021) with the authentic sheets deposited in Cairo University Herbarium (CAI) and Mazhar Botanic Garden Herbarium (MAZHAR). Voucher information of the collected specimens is presented in Table (1).

2. For SEM Microscopy:-

Prepared samples of selected segments of leaf (adaxial and abaxial surfaces) were fixed to labelled Aluminum stubs with double-sided adhesive tape. Each sample was coated with gold in a JEOL JFC-1100E ion sputtering device. The samples examined and photographed using JEOL JSM-IT200 scanning electron microscopy accelerated by a voltage of 20 KV at SEM Unit, Faculty of Science, Alexandria University, Egypt.

In this presentation, the terminology of Theobald et al. (1979) have been adopted for trichome description; while that of Payne (1978), Wilkinson (1979) and Barthlott et al. (1998) for stomata and epicuticular wax; respectively.

3. Data analysis:-

Thirty-one micromorphological epidermal leaf traits (Table 4) were analyzed and scored as binary and multistate characters to construct the data matrices. Cluster analyses were provided to generate a dendrogram to evaluate the interrelationships among taxa and to assess the phenetic relationships using PAST program version3.

Table 1: Voucher information of plant material used in this study.

Taxonomic groups and taxa	Geographic coordinates	Voucher specimens
Subgenus *Ficus*		
Section *Ficus*		
F. carica L.	30° 03' 07" N, 31° 14' 49" E	Giza: Groppi garden, 18-8-2022, *R. Mahdy*, s.n.(CAI)
F. palmata Forssk.	30° 01' 44" N, 31° 12' 46" E	Giza: Orman botanic garden, 16-5-2022, *R. Mahdy*, s.n.(CAI)
Section *Eriosycea*(Miq.) Miq.		
F. hirta Vahl	24° 05' 37" N, 32° 53' 13" E	Aswan: Aswan botanic garden, 9-5-2022, *H. Rofaeel*, s.n.(CAI)
Subgenus *Terega* Raf.		
Section *Sycidium* (Miq.) Miq.		
F. aspera G. Forst.	30° 03' 35" N, 31° 08' 41" E	Giza: Mazhar botanic garden, 24-4-2022, R. Mahdy, s.n.(CAI)
Subgenus *Sycomorus* Raf.		
Section *Sycomorus* (Raf.) Miq.		
F. sycomorus L.	30° 01' 44" N, 31° 12' 46" E	Giza: Orman botanic garden, 16-3-2022, *R. Mahdy*, s.n.(CAI)
F. racemosa L.	30° 02' 29" N, 31° 13' 38" E	Cairo: Qasr El Quba garden, 7-6-2022, *T. Labib*, s.n.(CAI)
Section *Sycocarpus* Miq.		
F. hispida L.f.	30° 03' 35" N, 31° 08' 41" E	Giza: Mazhar botanic garden, 24-4-2022, *R. Mahdy*, s.n. (CAI)
Subgenus *Synoecia* (Miq.) Miq.		
Section *Pogonotrophe* (Miq.)Miq.		
F. pumila L. var. *pumila*	30° 03' 35" N, 31° 08' 41" E	Giza: Mazhar botanic garden, 24-4-2022, *R. Mahdy*, s.n.(CAI)
Subgenus *Spherosuke* Raf.		
Section *Americanae*(Miq.) Corner		
F. nymphaeifolia Mill.	30° 02' 38" N, 31°13' 43" E	Cairo: Zohriya garden, 7-6-2022, *R. Mahdy*, s.n.(CAI)
Section *Platyphyllae* Mildbr. & Burret		
F. saussureana DC.	30° 01' 44" N, 31° 12' 46" E	Giza: Orman botanic garden, 16-5-2022, *R. Mahdy*, s.n.(CAI)
Section *Cordifoliae* G. Don		
F. drupacea Thunb. var. *pubescens* (Roth) Corner	30° 01'40" N, 31°12' 57" E	Giza: Zoo garden 18-8-2022, *R. Mahdy*, s.n.(CAI)
Section *Urostigma* (Endl.) Griseb.		
F. macrophylla Desf. ex Pers.	30° 01' 44" N, 31° 12' 46" E	Giza: Orman botanic garden, 16-3-2022, *R. Mahdy*, s.n.(CAI)

RESULTS AND DISCUSSION

The study of the epidermal leaf traits of *Ficus* revealed number of important micromorphological characters which exhibit interesting interspecific variations. These are of diagnostic value for taxa identification and delimitation.

Trichomes

Plant trichomes are of great interest for the species description. Trichome types with their distribution among the studied species are summarized in Table (2).

A. Eglandular trichomes

Based on branching patterns, eglandular trichomes can be divided into simple, unbranched trichomes and complex branched ones (Table 2; Plate 1a Figs.1-11).

I. Simple, unbranched trichomes

Micromorphological investigation showed that these are uniseriate, unicellular or multicellular and quite variable in length and shape. Moreover, multicellular trichomes are more common than unicellular ones.

The body is erect-suberect, falcate, arcuate or bent; with acute apex or curved near the tip; with or without bulbous base surrounded by many epidermal cells forming a rim, and sometimes with cystoliths at the trichome base. The outer wall is thin or thick, the lumen is broad at the base and narrowed above, and the surface is either smooth or papillate (micro- or coarsely). According to the shape and number of cells, these are further subdivided into 8 types:

1. **Papilla**: unicellular and can be differentiated into two subtypes:

a. ± lobed papillae: Only the abaxial epidermal cells of two species (*F. hirta* Vahl and *F. aspera* G. Forst.) are papillose.

b. Papilla-like lithocyst: unicellular, nipple-like trichome with fully enlarged base containing cystolith. It was observed on both surfaces of *F. palmata* and *F. hirta*, while only on abaxial surface of *F. carica*, *F. aspera*, *F. sycomorus*, *F. racemosa*, *F. hispida*, *F. pumila* var. *pumila*, and *F. drupacea* var. *pubescens*.

2. Prickle: bristle-like and can be differentiated into:

a. Unicellular: This was observed only on the abaxial surface of *F. sycomorus* and *F. drupacea* var. *pubescens*.

b. Prickle-like lithocyst: unicellular, either appressed or curved to suberect, stiff, with fully enlarged base. Occurred on both surfaces in *F. palmata*, *F. hirta*, and *F. hispida*; while only on the abaxial surface of *F. carica*, *F.* aspera, *F. sycomorus*, *F.* racemosa, *F. pumila* var. *pumila* and *F. drupacea* var. *pubescens*. In *F. racemosa*, prickle-like enlarged into a trichome on the abaxial leaf.

3. Acicular (slender): It is formed of one-celled on the abaxial surface of *F. sycomorus*; or multicellular, uniseriate with 3-10-celled arranged in a single row in 9 species related to different subgenera and sections. These were distributed on both surfaces in 7 species (*F. carica*, *F. palmata*, *F. hirta*, *F. aspera*, *F. hispida*, *F. pumila* var. *pumila* and *F. drupacea* var. *pubescens*); while only on the abaxial surface of *F. sycomorus* and *F. racemosa*.

4. Conical: with the figure of a cone; narrowly deltoid in outline. This was observed as unicellular on abaxial surface of *F. sycomorus*; or multicellular, uniseriate with 3-8-celled in 9 species. These were observed on both surfaces of 7 species (*F. palmata*, *F. hirta*, *F. aspera*, *F. sycomorus*, *F. racemosa*, *F. hispida* and *F. pumila* var. *pumila*); while only on the adaxial surface of *F. carica* or on the abaxial surface of *F. drupacea* var. *pubescens*.

5. Hooked (uncinate): with a hooked tip. Only multicellular, uniseriate formed of 4-8-celled and only restricted to the abaxial surface of 6 species (*F. carica*, *F. palmata*, *F. aspera*, *F. sycomorus*, *F. racemosa* and *F. drupacea* var. *pubescens*).

6. Bracket: a bent trichome with flat-topped apex.Only multicellular, uniseriate with 3-9-celled. It was frequently observed on the abaxial surface of 7 species (*F. carica*, *F. palmata*, *F. hirta*, *F. sycomorus*, *F. hispida*, *F. pumila* var. *pumila* and *F. drupacea* var. *pubescens*); while on both surfaces in *F. aspera* and *F. racemosa*.

7. Flagelliform: a whip-like trichome with delicate terminal cell. It is multicellular, uniseriate formed of 3-7-celled. It occurred on both surfaces of *F. palmata*; while only on the abaxial surface of *F. sycomorus* and *F. racemosa*.

8. Tortuosus: These are weak, unicellular trichomes and twisted in different directions. These are only characteristic to *F. drupacea* var. *pubescens*.

II. Complex, branched, multicellular eglandular trichomes

These were restricted to subg. *Spherosuke* with the four species related to different sections: *F. nymphaeifolia* (sect. *Americanae*), *F. saussureana* (sect.*Platyphyllae*), *F. drupacea* var. *pubescens* (sect.*Cordifoliae*) and *F. macrophylla* (sect.*Urostigma*). Two types were seen:

1. 2-Armed (T-shaped): a trichome in which the apical cell is oriented transversely with regard to the stalk (1-2-celled). The two arms are equal or unequal. *Ficus macrophylla* lacks this type from both surfaces; present on the adaxial surface of *F. saussureana* and *F. drupacea* var. *pubescens*; while only restricted to the abaxial surface of *F. nymphaeifolia*.

2. Dendroid: a tree-like trichome with branches or rays, along the stalk, with smooth wall. These are either:

a. Forked-Dendroid: weak, multicellular, ribbon- like trichomes which are divided terminally into two branches with an axis (stalk) of 1-2-celled. The branches are either with or without septa. These were seen in all the species of subg.*Spherosuke*. but differs in its presence either on the abaxial/or the adaxial surface of lamina. It was observed on the abaxial surface of *F. nymphaeifolia* and *F. macrophylla*; while on the adaxial surface of both taxa: *F. saussureana* and *F. drupacea* var. *pubescens*.

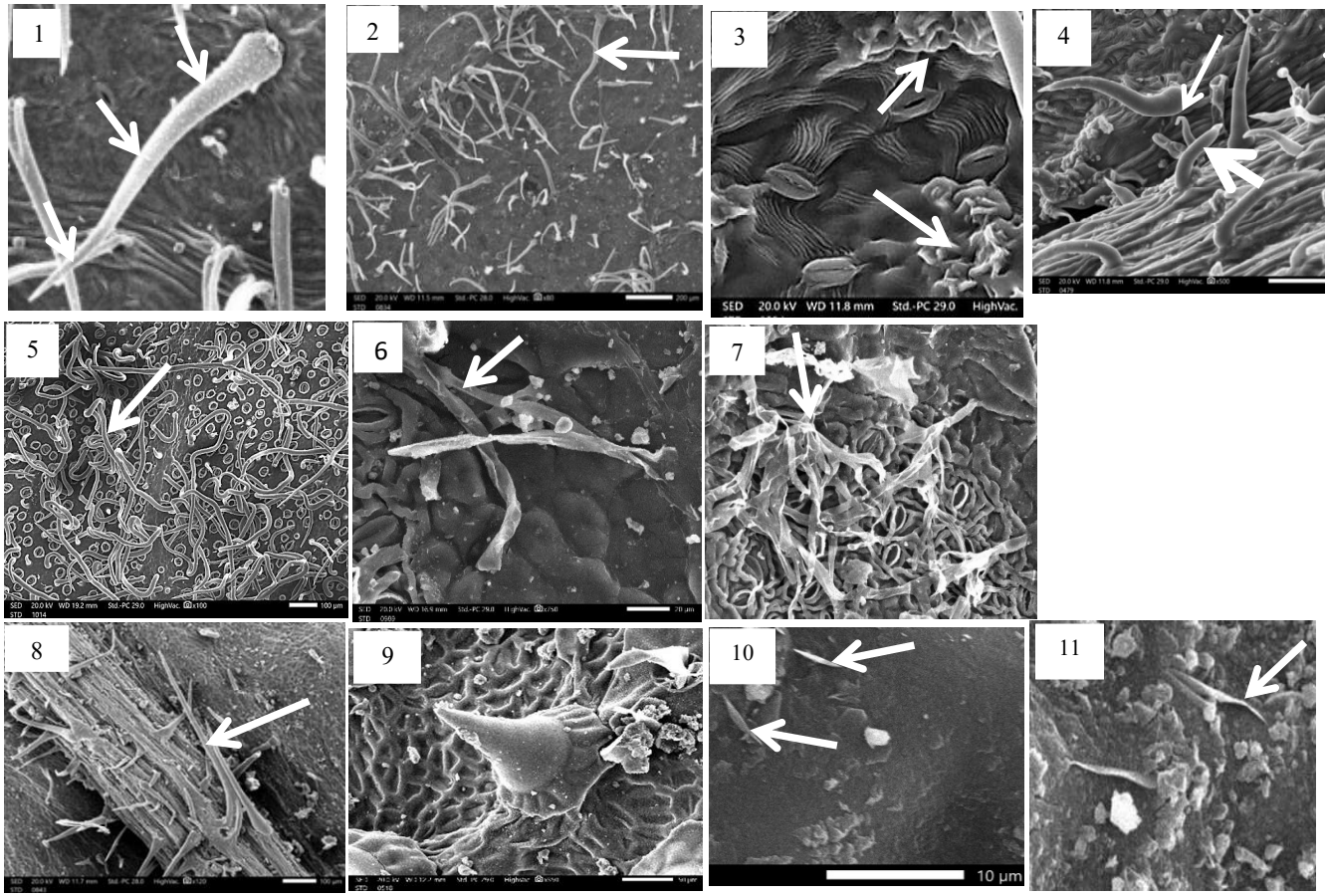
b. Cladose-Dendroid: multicellular, uniseriate with few to several branches randomly distributed, and with 1-2-celled stalk. These were observed on the adaxial surface of *F. saussureana* and abaxial of *F. macrophylla*.

Table 2: Glandular and eglandular trichomes with its distribution among the studied taxa.

Ficus Taxa	Glandular trichomes		Eglandular Trichomes															
			Simple; unbranched												Complex; branched multicellular			
	Adaxial	Abaxial	Unicellular								Multicellular uniseriate				2-armed	Dendroid		
			Pa	Pa litho	Pr	Pr litho	Ac	C	Br	Tor	Ac	C	Ho	Br	Flag	T-shaped	F-D		Cl-D
F. carica	-	Ca $_{(H4,St1)}$ Cl $_{(H3,St1)}$,P	-	Ab	-	Ab	-	-	-	-	Ad,Ab	Ad	Ab	Ab	-	-	-		-
F. palmata	Cl $_{(H3,St1)}$,P	Ca $_{(H6,St1)}$ Cl $_{(H3-4,St1)}$ El $_{(H1,St1)}$,P	-	Ad,Ab	-	Ad,Ab	-	-	-	-	Ad,Ab	Ad,Ab	Ab	Ab	Ad,Ab	-	-		-
F. hirta	Cl $_{(H4,St1)}$ E $_{(H2,St2)}$,P	E $_{(H2,St2)}$ El $_{(H1,St1)}$,P	Ab	Ad,Ab	-	Ad,Ab	-	-	-	-	Ad,Ab	Ad,Ab	-	Ab	-	-	-		-
F. aspera	Ca $_{(H6,St1)}$ El $_{(H6,St1)}$,P	Ca $_{(H6,St1)}$ El $_{(H6,St1)}$,P	Ab	Ab	-	Ab	-	-	-	-	Ad,Ab	Ad,Ab	Ab	Ad,Ab	-	-	-		-
F. sycomorus	Ca $_{(H4,St1)}$ E $_{(H4,St2)}$,P	Ca $_{(H2,St3)}$ E $_{(H2/3,St1/2)}$,P	-	Ab	Ab	Ab	Ab	Ab	-	-	Ab	Ad,Ab	Ab	Ab	Ab	-	-		-
F. racemosa	P	Ca $_{(H4,St1)}$ E $_{(H2,St1)}$,P	-	Ab	-	Ab	-	-	-	-	Ab	Ad,Ab	Ab	Ad,Ab	Ab	-	-		-
F. hispida	Ca $_{(H1,St1)}$ P	Ca $_{(H2,St1)}$ E $_{(H2,St1)}$,P	-	Ab	-	Ad,Ab	-	-	-	-	Ad,Ab	Ad,Ab	-	Ab	-	-	-		-
F. pumila var. *pumila*	P	P	-	Ab	-	Ab	-	-	-	-	Ad,Ab	Ad,Ab	-	Ab	-	-	-		-
F. nymphaeifolia	P	E $_{(H3,St1)}$ El $_{(H1,St1)}$,P	-	-	-	-	-	-	-	-	-	-	-	-	-	Ab	Ab		-
F. saussureana	P	E$_{(H2,St3)}$,P	-	-	-	-	-	-	-	-	-	-	-	-	-	Ad	Ad		Ad
F. drupacea var. *pubescens*	P	P	-	Ab	Ab	Ab	-	-	-	Ad,Ab	Ad,Ab	Ab	Ab	Ab	-	Ad	Ad		-
F. macrophylla	P	E $_{(H3,St1)}$ El$_{(H2,St3)}$,P	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Ab		Ab

Abbreviations: Ab=Abaxial; Ac=Acicular; Ad=Adaxial; Br=Bracket; C=Conical; Ca=Capitate; Cl=Clavate; Cl-D=Cladose-Dendroid; E=Ellipsoid; El=Elongate; F-D=Forked-Dendroid; Flag=Flagelliform; H=Head; Ho=Hooked; P=Peltate; Pa= Papilla; Palitho= Papilla lithocyst; Pr= Prickle; Pr litho= Prickle lithocyst; St=Stalk; Tor=Tortuosus.

Plate (1a): Some types of eglandular trichomes with its distribution among *Ficus* taxa.



Figs. (1-7) abaxial:(1) *F. carica*: acicular, multicellular; (2) *F. palmata*: flagelliform, multicellular; (3) *F. hirta*: papillose epidermis (±lobed); (4) *F. sycomorus*:prickle, unicellular (head-arrow)- acicular, unicellular (thick-arrow)-hooked, multicellular (thin-arrow); (5) *F. drupacea* var. *pubescens*: tortuosus, unicellular; (6) *F. macrophylla*: forked-dendroid; (7) *F. macrophylla*: cladose-dendroid.

Figs. (8-11) adaxial:(8) *F. aspera*: bracket, multicellular; (9) *F. hirta*: conical, multicellular (surrounded by pluricellular epidermal cells); (10) *F. drupacea* var. *pubescens*: T-shaped.(11) *F. saussureana*: cladose-dendroid.

B. Glandular Trichomes:-

The body of the trichome is differentiated into foot, stalk and head. The foot is simple and sometimes sunken in the epidermal cells. The types of glandular trichomes with its distribution are presented in Table 2; Plate 1b Figs. (12-20).

***Types of glandular trichomes*:**

1. *Capitate*: globose or spherical head with either:

a. Unicellular stalk with unicellular head. This was only observed on the abaxial surface of *F. hispida*.

b. Unicellular stalk with bicellular head. This was only seen on the abaxial surface of *F. hispida*.

c. Unicellular stalk with multicellular head (4-6-celled). This was observed on the abaxial surface of *F. carica*, *F. palmata*, and *F. racemosa*; on the adaxial surface of *F. sycomorus*; while on both surfaces of *F. aspera*.

d. Uniseriate stalk (3-celled) with bicellular head. This was only seen on the abaxial surface of *F. sycomorus*.

2. *Clavate*: club-shaped head with broadest part towards the apex. This was only observed in 3 species. The species possess unicellular stalk with multicellular head (3-or 4-celled). This was seen on the abaxial surface of *F. carica*; on the adaxial surface of *F. hirta*; while on both surfaces of *F. palmata*.

3. *Ellipsoid*: It is provided with:

a. Unicellular stalk with bicellular head. This was seen on the abaxial of *F. sycomorus*, *F. racemosa* and *F. hispida*.

b. Unicellular stalk with multicellular head (3-celled). This was seen on the abaxial surface of *F. nymphaeifolia* and *F. macrophylla.*

c. Uniseriate stalk (2-3-celled) with bi-or multicellular head (3-or 4-celled). These were observed on both surfaces of *F. hirta*, *F. sycomorus*; while on abaxial of *F. saussureana*.

4. *Elongate*: ±cylindrical head with either:

a. Unicellular stalk and unicellular head: This was seen on abaxial surface of *F. palmata*, *F. hirta* and *F. nymphaeifolia.*

b. Unicellular stalk and multicellular head (6-celled). This occurred on both surfaces of one species: *F. aspera*.

c. Uniseriate stalk (2-celled) and bicellular head. This was observed on the abaxial of *F. macrophylla*.

5. *Peltate trichomes*: These are with horizontal rays fused along much of their length forming a flat disk-shaped with an apical portion atops a peltately attached stalk. These consist of one basal epidermal cell, one neck cell and 5-6 secretory cells. These were seen on both surfaces of the studied species except *F. carica* (only on the abaxial).

Lithocysts

In this study, types of lithocysts (Papilla, Prickle or trichome-like) with their distribution among *Ficus* species are presented in Table 2; Plate 2, Figs. (1-3). Lithocysts are completely absent in most species of subgenus *Spherosuke* (*F. nymphaeifolia*, *F. saussureana*and*F. macrophylla*). These species are related to different sections. *Ficus palmata* (subg. *Ficus* sect.*Ficus*) and *F. hirta* (subg. *Ficus* sect.*Eriosycea*) possess lithocysts on both surfaces; while lithocysts are only restricted to the abaxial surface in six species: *F. carica* (subg. *Ficus*sect. *Ficus*), *F. aspera* (subg.*Terega* sect. *Sycidium*), *F. racemosa* (subg. *Sycomorus* sect. *Sycomorus*), *F. hispida* (subg. *Sycomorus* sect.*Sycocarpus*), *F. pumila* var. *pumila* (subg.*Synoecia* sect.*Pogonotrophe*) and *F. drupacea* var. *pubescens* (subg. *Spherosuke* sect.*Cordifoliae*).

This shows that the presence or absence of lithocysts and their distribution among the species on the adaxial and/or abaxial surface are applicable to specific identification within infrageneric groupings. Our results corroborated previous studies (Van Greuning *et al*., 1984; Berg, 2003; Klimko & Truchan, 2006).

Laminar hydathodes

In the studied species, there is an important epidermal structure called ″laminar hydathode‟. The hydathode is a structure through which water is secreted in the liquid form, mainly on leaves. These occur on leaf lamina between the midrib and the margin, and around which a thin film of dried excretion can generally be seen. These are either sparse or dense. Little data have been published on the hydathodes of some taxa in *Ficus* (e.g. De-Barry, 1884; Sonibare *et al*., 2005; Klimko & Truchan, 2006; Sosnovsky, 2014).

In the studied species, three types of laminar hydathodes were recognized: pit-, wart-and stomata-like hydathodes. Types with its distribution among the taxa are presented in (Table 4; Plate 2, Figs.4-6).

Stomata-like hydathodes were confined to the abaxial surface; while that of pit- and wart-ones were observed on the adaxial surface. This fits the observation of Sosnovsky (2014).

Hydathodes were completely absent in the leaves of four species: *F. carica*, *F. palmata*, *F. hirta* and *F. racemosa*; while the rest had hydathodes on the adaxial and/or abaxial surface.

Hydathodes occurred on both surfaces in five taxa (*F. sycomorus*, *F. hispida*, *F. pumila* var. *pumila*, *F. nymphaeifolia* and *F. drupacea* var. *pubescens*; two species possessed only stomata-like hydathodes on the abaxial surface (*F. aspera* and *F. macrophylla*); while *F. saussureana* with only wart-like hydathodes on the adaxial surface.

In this study, dense hydathodes were noticed in *F. saussureana*. Our result corroborated previous study of De-Barry (1884), while contradicts with that of Sonibare *et al*. (2005).

Epidermal cells

The conducted SEM observations showed that the adaxial epidermal cells located between veins were commonly polygonal (regular or irregular) or rarely associated with rectangular ones, and with straight to arched or undulated cell walls (Table 4, Plate3, Figs 1-5,7)

Shape: epidermal cells were irregularly polygonal in nine species (*F. palmata* and*F. hirta* in subg. *Ficus*; *F. sycomorus*, *F. racemosa* and *F. hispida* of subg.*Sycomorus*; and all the taxa of subg.*Spherosuke* except for *F. macrophylla*); three species with regular polygonal(*F. carica*, *F.pumila* var. *pumila* and *F. macrophylla*); while irregular polygonal and rectangular ones were only seen in *F. aspera* in subg.*Terega.*

Plate (1b): Some types of glandular trichomes with its distribution among *Ficus* species.

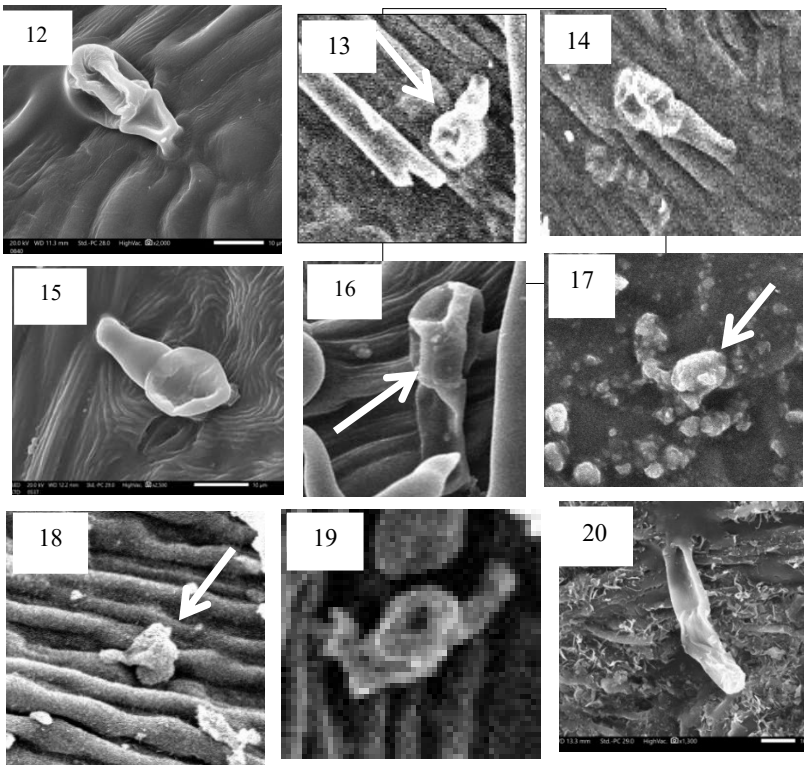
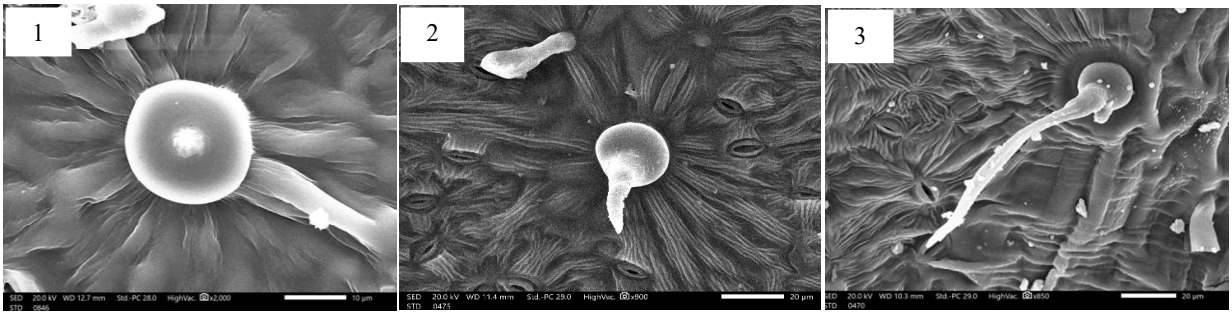
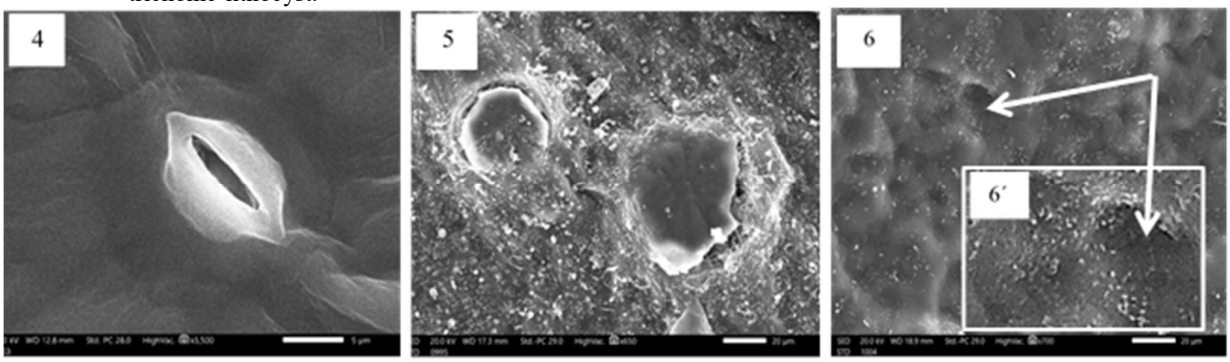


Fig. (12-20): (12) *F. palmata*: clavate, multicellular head(abaxial); (13) *F. aspera*: capitate, multicellular head (abaxial); (14) *F. aspera*: elongate multicellular head (abaxial); (15) *F. sycomorus*: elliptic, bicellular head (abaxial); (16) *F. sycomorus*: elliptic, multicellular head (abaxial); (17) *F. sycomorus*: peltate, surface-view (adaxial); (18) *F. racemosa*: peltate, longitudinal-section (abaxial); (19) *F. hispida*: capitate, unicellular head (abaxial); (20) *F. nymphaeifolia*: elongate, unicellular head(abaxial).

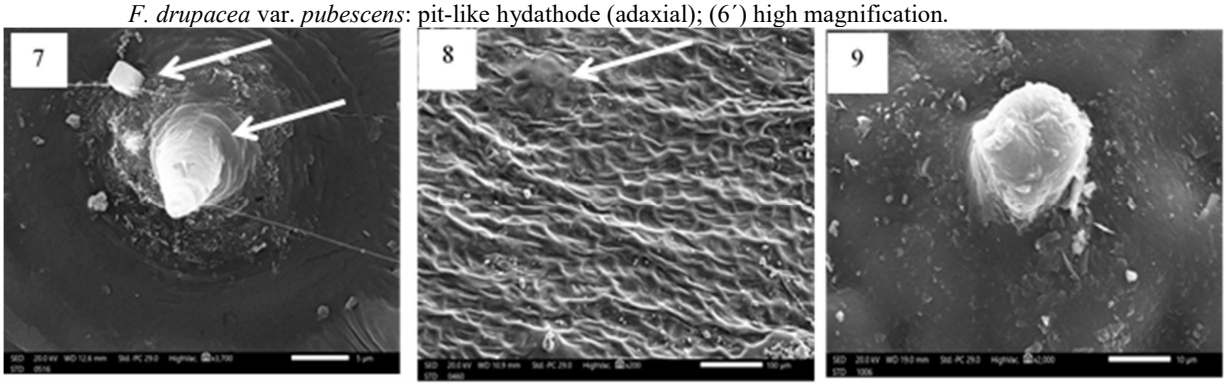
Plate (2): Epidermis of *Ficus* leaves with lithocysts, hydathodes and waxy glandular spots among the studied species.



Figs. (1-3): SEM microphotographs showing types and distribution of lithocysts among *Ficus* leaves in abaxial surface:(1) *F. aspera*: papillate-lithocyst; (2) *F. sycomorus*: prickle-lithocyst; (3) *F.racemosa*: trichome-lithocyst.



Figs. (4-6): SEM microphotographs showing types and distribution of hydathodes among *Ficus* leaves: (4) *F. aspera*: stomata-like hydathode (abaxial); (5) *F. saussureana*: wart-like hydathode (adaxial); (6) *F. drupacea* var. *pubescens*: pit-like hydathode (adaxial); (6´) high magnification.



Figs. (7-9): SEM microphotographs showing shapes of waxy glandular spots and their distribution among *Ficus* species: (7) *F.carica*: abaxial; (8) *F.racemosa* : adaxial; (9)*F. drupacea* var. *pubescens*: abaxial.

Pattern of anticlinal cell walls: straight to arched were observed in six species (*F. palmata*, *F. hirta*, *F. aspera*, *F. sycomorus*, *F. racemosa* and *F. hispida*); only undulated in *F. macrophylla*; while two types were seen in the rest.

Periclinal surface: It was concave in all of the studied species except for *F. hirta* and *F. racemosa*, both showed flat surfaces.

This shows that the pattern (straightness) of anticlinal cell wall is valuable in infrageneric grouping and can be applicable with the periclinal surface in specific delimitation within the grouping. However, Metcalf & Chalk (1950), Van Greuning et al. (1984), Sonibare et al. (2005) emphasized that the shape of epidermal cell walls can be a good diagnostic feature for the specific delimitation on the basis of leaf anatomy.

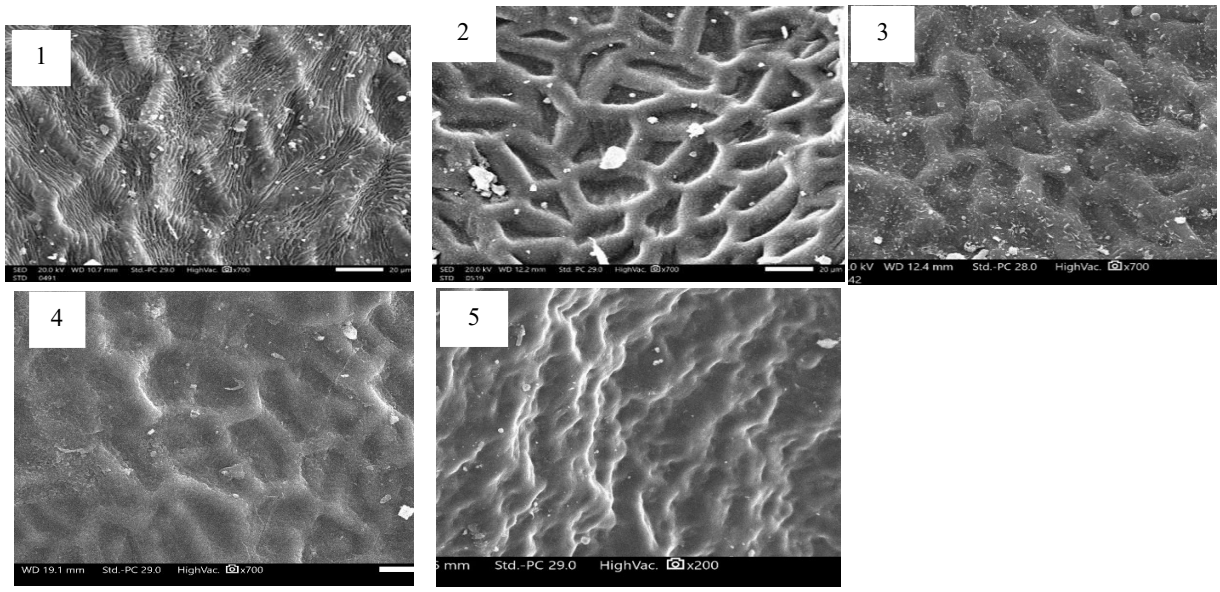
Epicuticular wax

In this presentation, wax morphology remains constant on adaxial and abaxial surfaces, but its density may be different. Detailed SEM observations showed that the epicuticular wax is of valuable taxonomic significance at the infrageneric groups; while of less taxonomic significance at the specific level. So far, only wax from the adaxial surface has been described.

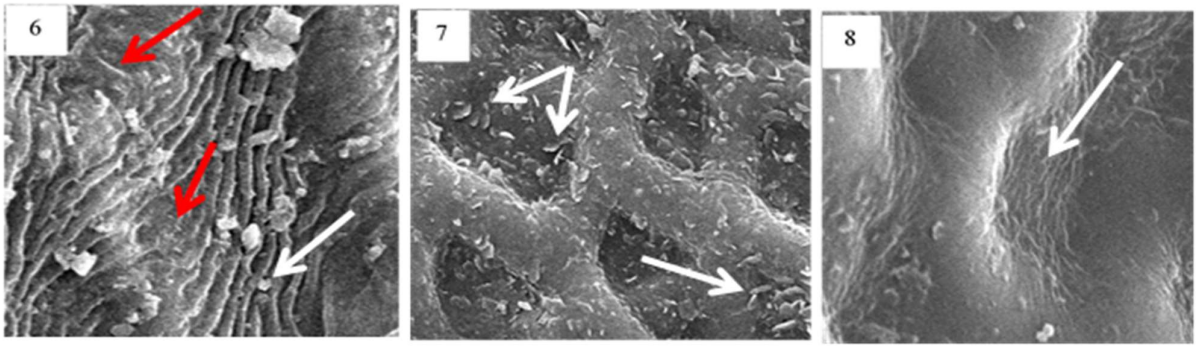
Adaxially, wax usually occurs in the form of mixed coatings in all the studied taxa (Table4; Plate3, Figs. 6-8).

Granules were observed in all the taxa, and accompanied with flakes (scattered, sprinkling and minute to small variously shaped). These were observed in all species of subg.*Sycomorus*, most species ofsubg.*Ficus* and *F. pumila* var. *pumila* (subg.*Synoecia*). On the other hand, granules with only platelets or with platelets and wax threads. *Ficus palmata* (subg.*Ficus*), and *F. aspera* (subg.*Terega*) had granules with platelets, as well as, *F. saussureana* and *F. drupacea* var. *pubescens* of subg.*Spherosuke*. Wax threads were of rare occurrence. These were only observed in*F. Macrophylla* and *F. nymphaeifolia* of subg.*Spherosuke*. The last species had abaxially a plate of wax (dense covering of platelets with distinct edges).Wax morphology is particularly useful as an additional diagnostic character (Wilkinson, 1979).

Plate (3): SEM micrographs showing some variations in the epidermal cells and epicuticular wax on the adaxial surface among *Ficus* species.



Figs.(1-5): Some variations in the epidermal cells.(1) *F. carica*; (2) *F. hirta*;(3) *F. aspera*; (4) *F. nymphaeifolia*; (5) *F. macrophylla*.



Figs. (6-8): Some variations in the epicuticular wax. (6) *F. carica*: flakes (red-arrow) - granules (white-arrow); (7) *F. aspera*: platelets (note rectangular epidermal cells); (8) *F. macrophylla*: wax threads.

Waxy glandular spots

These are epidermal patches with various shapes and markedly elevated above the leaf surface (Plate 2, Figs. 7-9).

Metcalf & Chalk (1950); Rohwer (1993); and Berg (2003 & 2004) emphasized that *Ficus* species are characterized by the presence of these waxy glandular spots mainly on the abaxial leaf surface, which are distributed singly either on the midrib or in the angles between lateral veins.

In this study, these were found singly on the lateral veins and in between on both surfaces, and not only restricted to the abaxial leaf surface. Our result is consistent with that of Klimko & Truchan (2006) who mentioned that the waxy glandular spots were found not only near veins on abaxial surface, but also on both leaf surfaces and on the leaf margin.

Cuticular architecture: abaxial varies from ± smooth to very striate. In all the studied species except those of subg.*Spherosuke* (Plate 4; Figs.1-8), it is striate; fine striae extended as lateral wings from ordinary stomata, radiating ones from primary (giant) stomata and short radiating ridges from hair bases and lithocysts. In *F. carica* (Plate 4; Fig.1), also few ± concentric striae arranged around the stomata.

In *F. saussureana* and *F. drupacea* var. *pubescens*, abaxial ± smooth, although stomata with peristomatal cuticular rims were seen in both, and with a few short radiating ridges from hair bases and lithocysts in *F. drupacea* var. *pubescens*. In *F. nymphaeifolia*, short irregular thick striae randomly oriented throughout the leaf surface, a few radiating ones from primary stomata and narrow peristomatal cuticular thickenings were observed. In *F. macrophylla*, abaxial with densely aggregated striae where stomata are crowded. Thick, ± undulated striae over epidermal cells, while some stomata with peristomatal cuticular striae and probably a few with wings of striae.

Stomata-complex

The characteristic features of the stomata are shown in Table 3&4; Plate 4; Figs. 1-12 & Plate 5; Figs. 1-3.

Distribution: Stomata were dense and aggregated in all the species of subg. *Spherosuke*; while evenly distributed throughout the abaxial surface of the lamina between the veins in the rest. This agrees with Klimko & Truchan (2006) and Sosnovsky (2014).

Outline: stomata were ± suborbicular or widely -elliptical in the taxa of subg. *Spherosuke* except for *F. macrophylla*; while elliptical or narrowly - elliptical in the rest. Results from our present study is at variance with the observation of Sosnovsky (2014).

Size: ranges from the smallest in *F. aspera* at 8-18 um long and 5.0-7.5 um wide to the largest in *F. drupacea* var. *pubescens* at 30-40 um long and 20-30 um wide and *F. nymphaeifolia* at 25-33 um long and 20 -27.78 um wide. Mean stomatal length fell within the range 12.67-33.92 um; while mean length of less than 15 um was recorded in four taxa (*F. palmata*, *F. hirta*, *F. aspera* and *F. racemosa*). Likewise to our results, length and width of stomata significantly separate subg.*Spherosuke* from the others (Sosnovsky, 2014). However, the quantitative features of stomata don't agree with both Klimko & Truchan (2006) and Sosnovsky (2014).

***Location*:** stomata were slightly raised in a few species (*F. hirta* and *F. aspera*); sunken in the taxa of subg. *Spherosuke* (except for *F. saussureana*); while leveled with the epidermal cells in the rest.

Rims: stomatal rims are raised in most of the species except for *F. hirta*, *F. aspera* and *F. nymphaeifolia* (in which curved and flat).

Cuticular thickening around the stomata: only in the studied taxa of subg. *Spherosuke*, the stomata were surrounded with a cuticular thickening, which formed a characteristic rim in *F. nymphaeifolia* and *F. saussureana* or polygonal in *F. drupacea* var. *pubescens* and *F. macrophylla*.

Primary (giant) stomata: seen in all the studied species except for *F. saussureana*. These stomata were surrounded by radiating striae/ridges.

Plate (4): Variations in the cuticular architecture, stomata-complex and epicuticular waxes among *Ficus* species on abaxial surface.

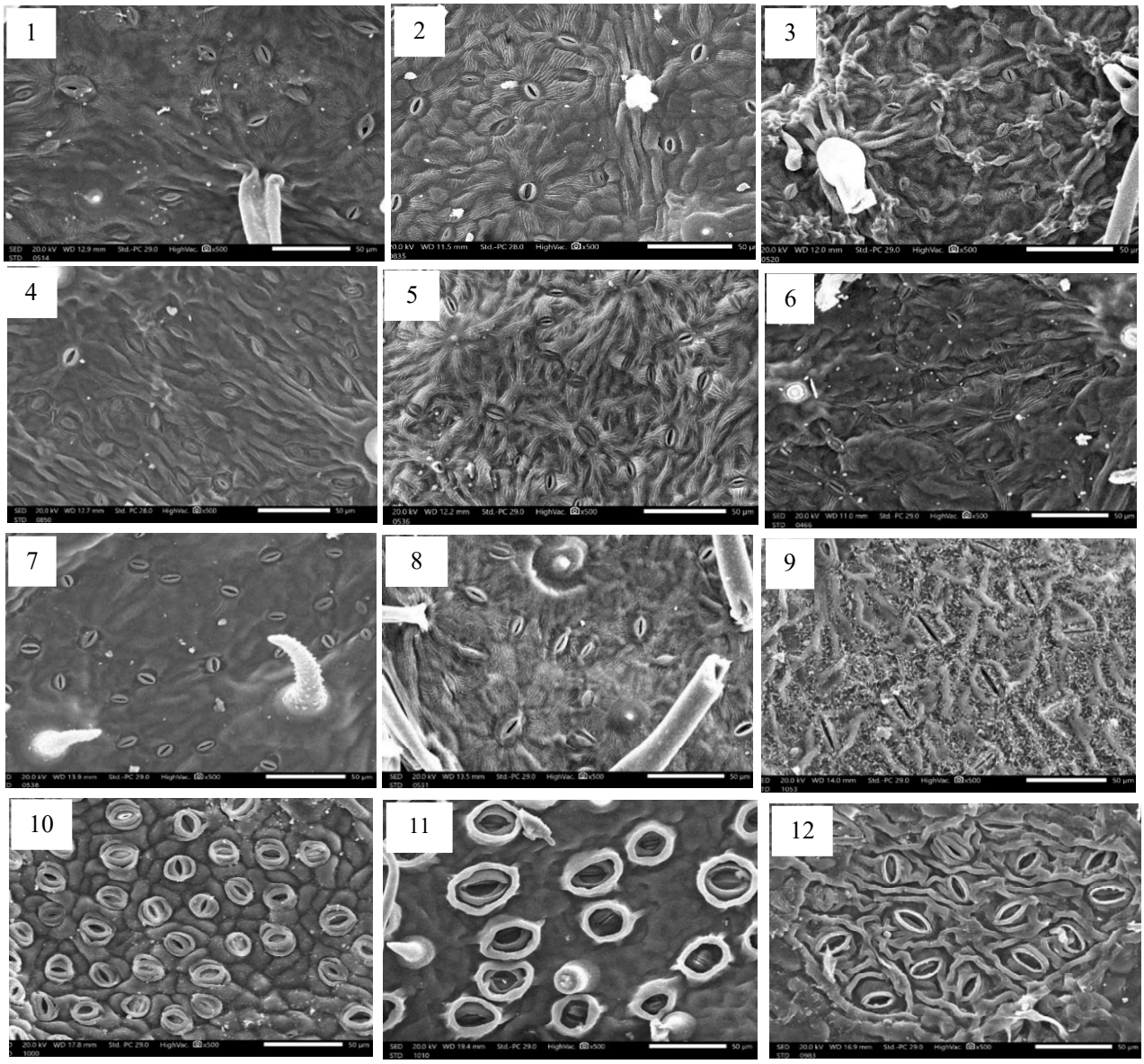
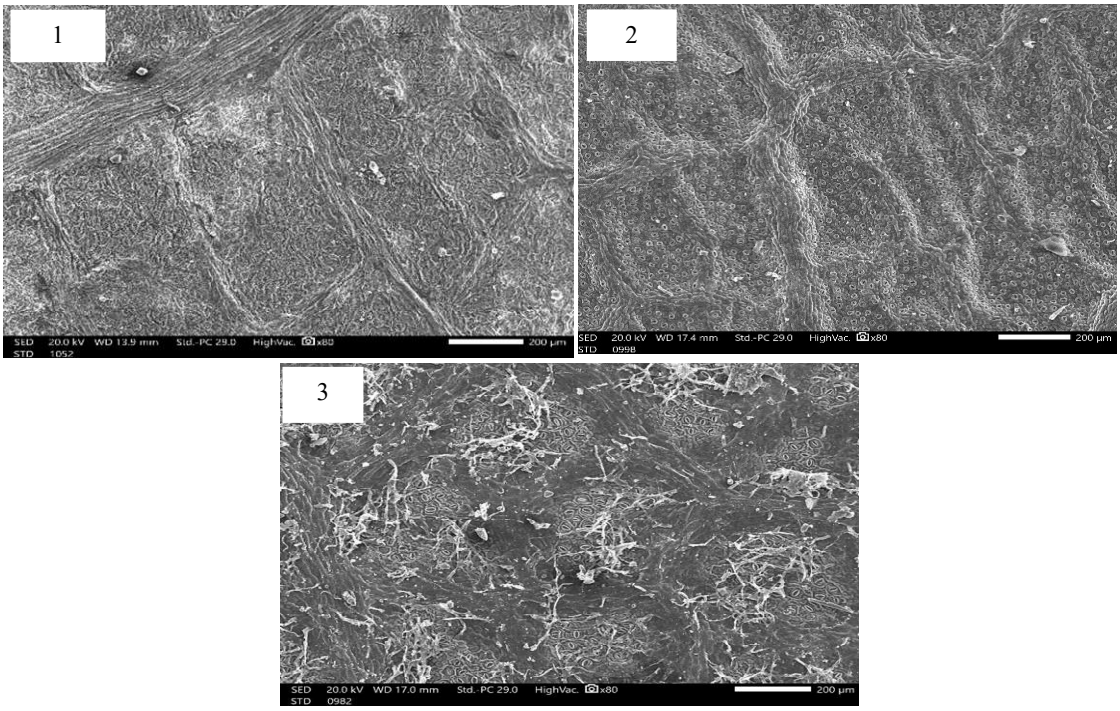


Fig. (1-12): (1) *F. carica*: (note the giant stoma); (2) *F. palmata*; (3) *F. hirta*; (4) *F. aspera*; (5) *F. sycomorus*; (6) *F. racemosa*; (7) *F. hispida*; (8) *F. pumila* var. *pumila*; (9) *F. nymphaeifolia*: (note a plate of wax); (10) *F. saussureana*, (note the peristomatal cuticular rim); (11) *F. drupacea* var. *pubescens*: (note the polygonal peristomatal cuticular thickening); (12) *F. macrophylla*.

Plate 5: SEM micrographs showing dense stomata and its presence in groups among *Ficus* taxa.



Figs. (1-3): (1) *F. nymphaeifolia*; (2) *F. saussureana*; (3) *F. macrophylla*.

Table (3): Stomata size among the studied taxa.

Ficus taxa	Stomata size		
	Length (um)	Width (um)	L/W
1 *F. carica*	20.0-25.0-30.0	10.0-12.5-15.0	1.6-2.0-2.0
2 *F. palmata*	10.0-13.7-16.7	5.0-8.2-10.0	1.5-1.8-2.0
3 *F. hirta*	10.0-12.7-16.0	6.0-7.33-8.0	1.5-1.7-2.0
4 *F. aspera*	8.0-11.9-18.0	5.0-5.07-7.5	2.0-2.3-2.5
5 *F. sycomorus*	14.3-16.1-17.9	7.2-7.67-9.2	2.0-2.0-2.5
6 *F. racemosa*	11.1-13.9-16.7	5.6-6.47-8.3	2.00-2.14
7 *F. hispida*	14.3-16.1-17.9	7.2-7.67-8.9	2.0-2.1-2.3
8 *F. pumila* var. *pumila*	15.8-18.7-23.4	7.9-10.2-12.9	1.7-1.8-2.0
9 *F. nymphaeifolia*	25.0-28.9-33.3	20.0-24.0-27.8	1.0-1.2-1.2
10 *F. saussureana*	14.3-19.6-26.0	14.0-14.9-17.7	1.0-1.3-1.3
11 *F. drupacea* var. *pubescens*	30.0-33.9-40.0	20.0-26.2-30.0	1.0-1.3-1.3
12 *F. macrophylla*	20.0-25.0-30.0	11.0-13.1-17.5	2.0-1.9-2.4

Table 4: Data matrix and coding of 31 micromorphological epidermal leaf traits among 12 selected taxa of the genus *Ficus.*

Taxa **SEM Micromorphological Characters**	*F. carica*	*F. palmata*	*F. hirta*	*F. aspera*	*F. sycomorus*	*F. racemosa*	*F. hispida*	*F. pumila* var. *pumila*	*F. nymphaeifolia*	*F. saussureana*	*F. drupacea* var. *pubescens*	*F. macrophylla*
1- Shape of epidermal cells: regular polygonal=0; irregular polygonal=1; irregular polygonal, rectangular=2	0	1	1	2	1	1	1	0	1	1	1	0
2- Pattern of anticlinal walls in adaxial surface: straight-arched=0; straight-arched, undulate=1; undulate=2	1	0	0	0	0	0	0	1	1	1	1	2
3- Periclinal surface: flat=0; concave=1	1	1	0	1	1	0	1	1	1	1	1	1
4- Epicuticular wax (adaxially): granules & flakes=0; granules & platelets=1; granules, platelets & wax threads=2	0	1	0	1	0	0	0	0	2	1	1	2
5- abaxial surface with a plate of wax: absent=0; present=1	0	0	0	0	0	0	0	0	1	0	0	0
6- Hydathodes (adaxially): absent=0; present=1	0	0	0	0	1	0	1	1	1	1	1	0
7- Hydathodes (abaxially): absent=0; present=1	0	0	0	1	1	0	1	1	1	0	1	1
8- Hydathodes (adaxially): absent=0; pit-like=1; wart-like=2	0	0	0	0	1	0	1	1	2	2	1	0
9- Stomata-like hydathode abaxially: absent=0; present=1	0	0	0	1	1	0	1	1	1	0	1	1
10- Glandular trichomes: on one surface only=0; on both surfaces=1	0	1	1	1	1	1	1	1	1	1	1	1
11- Ellipsoid glandular trichomes: absent=0; on one surface=1; on both surfaces=2	0	0	2	0	2	1	1	0	1	1	0	1
12- Elongate glandular trichomes: absent=0; on one surface=1; on both surfaces=2	0	1	1	2	0	0	0	0	1	0	0	1
13- Lobed Papillae: absent=0; present=1	0	0	1	1	0	0	0	0	0	0	0	0
14- Papillae lithocysts: absent=0; abaxial=1; on both surfaces=2	1	2	2	1	1	1	1	1	0	0	1	0
15- Prickle: absent=0; abaxial=1; adaxial & abaxial=2	1	2	2	1	1	1	2	1	0	0	1	0
16-Trichomes: simple only=0; complex only=1; trichomes simple & complex =2	0	0	0	0	0	0	0	0	1	1	2	1
17- Tortuosus trichome: absent=0; present=1	0	0	0	0	0	0	0	0	0	0	1	0
18- Flagelliform trichome: absent=0; present=1	0	1	0	0	1	1	0	0	0	0	0	0
19- Cuticle Ornamentation on Leaf ± Smooth: absent=0; present=1	0	0	0	0	0	0	0	0	0	1	1	0
20- Lateral wings from ordinary stoma: absent=0; present=1	1	1	1	1	1	1	1	1	0	0	0	1
21- Concentric striae around ordinary stoma: absent=0; present=1	1	0	0	0	0	0	0	0	0	0	0	0
22- Radiating striae from primary stoma: absent=0; fine=1; thick=2	1	1	1	1	1	1	1	1	2	0	2	2
23- Peristomatal cuticular thickening: absent=0; poorly-developed=1; well-developed=2	0	0	0	0	0	0	0	0	2	2	2	1
24- Short irregular striae randomly oriented: absent=0; present=1	0	0	0	0	0	0	0	0	1	0	0	0
25- Densely aggregated thick striae: absent=0; present=1	0	0	0	0	0	0	0	0	0	0	0	1
26- Mean length of stomata: less than 16.5 um=0; more than 16.5 um=1	1	0	0	0	0	0	0	1	1	1	1	1
27- Mean width of stomata: 5.18-12.50 um=0;13.11-26.14 um=1	0	0	0	0	0	0	0	0	1	1	1	1
28- Stomata outline: narrowly elliptical=0; elliptical=1; Sub-orbicular or widely-elliptical=2	1	1	1	0	0	0	0	1	2	2	2	0
29-Stomata distribution: evenly=0; in groups=1	0	0	0	0	0	0	0	0	1	1	1	1
30- Stomata location: leveled=0; slightly raised=1; sunken=2	0	0	1	1	0	0	0	0	2	0	2	2
31- Stomatal rims: curved & flat=0; raised=1	1	1	0	0	1	1	1	1	0	1	1	1

Clustering analysis

The obtained clustering dendrogram (Fig. I) separated the taxa into two main groups. The first group was divided into A & B at similarity index 29.3. Group A: includes *F. carica* and *F.pumila* var. *pumila.* Group B: comprises 3 subgroups: The first subgroup with *F. palmata* and *F. hirta*. The second subgroup with *F. sycomorus*, *F. hispida* and *F. racemosa*. The third subgroup with only *F. aspera.* The second group was divided at similarity index 15.71 into C & D. Group C: with *F. nymphaeifolia*, *F. drupacea* var. *pubescens* and *F. saussureana.* Group D: includes only *F. macrophylla.*

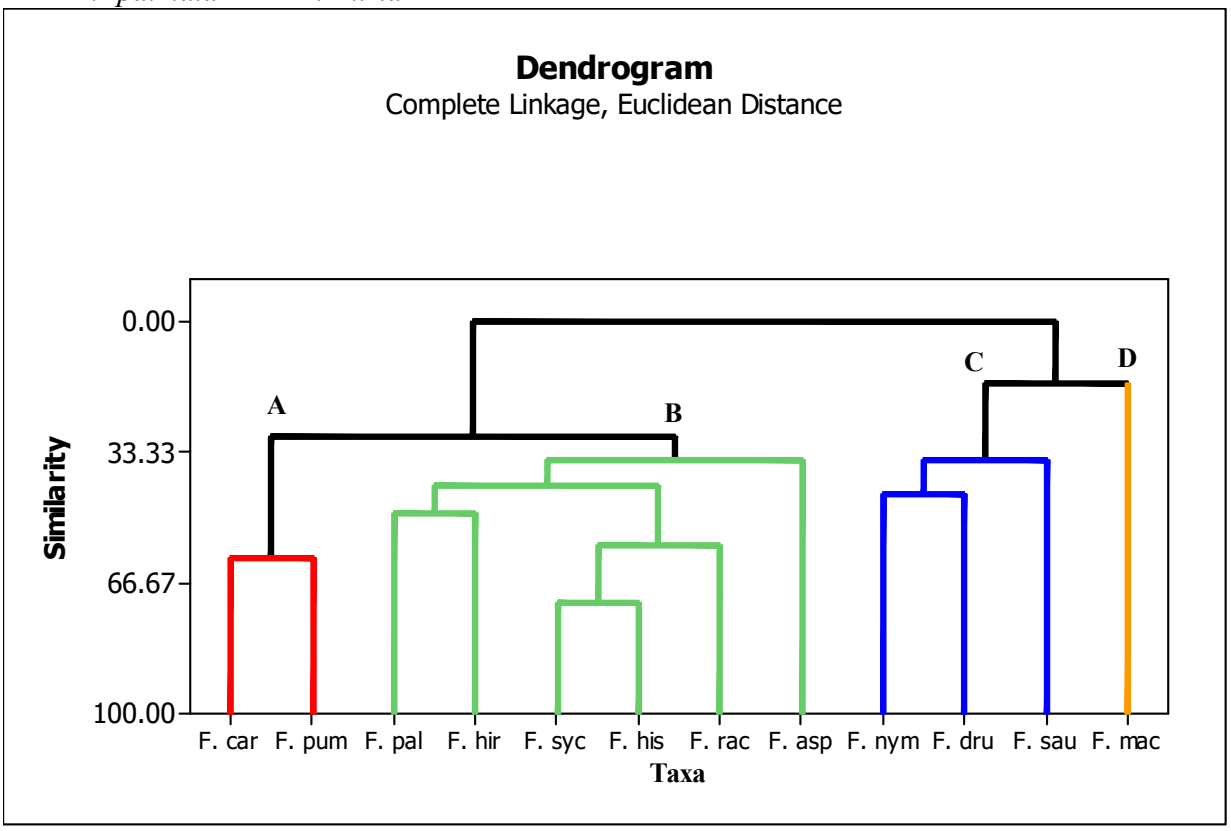


Fig. I: Clustering analysis of the studied taxa according to micromorphological characters. Abbreviations: *F. car= F. carica*; *F.pum= F.pumila* var. *pumila*; *F. pal= F. palmata*; *F. hir= F. hirta*; *F. syc= F. sycomorus*; *F. his= F. hispida*; *F. rac= F. racemosa*; *F. asp = F. aspera*; *F. nym=F. nymphaeifolia*; *F. dru =F. drupacea* var. *pubescens*; *F. sau= F. saussureana*; *F. mac= F. macrophylla.*

Identification key of the studied *Ficus* taxa.

1	a.	Complex branched trichomes (+); stomatain groups and surrounded by peristomatal cuticular thickening, mean stomatal width 13.11-26.14 um……	2.
	b.	Complex branched trichomes (-); stomataevenly distributed and without peristomatal cuticular thickening, mean stomatal width 5.18-12.5 um……	5.
2	a.	Stomata narrowly elliptical; lateral wings from ordinary stomata (+); hydathodes (-) adaxially; T-shaped trichomes (-)……	*F. macrophylla*
	b.	Stomata sub orbicular to widely-elliptical; lateral wings from ordinary stomata (-); hydathodes (+) adaxially; T-shaped trichomes (+)……...	3.
3	a.	Abaxially stomata hydathode (-); stomata leveled, mean width 14.96 um; mean length 19.6 um; radiating striae from primary stomata (-); cladose-dendroid trichomes (+) adaxially.....	*F. saussureana*
	b.	Abaxially stomata hydathode (+); stomata sunken, mean width 24-26.14 um, mean length 28.89-33.92 um; radiating striae from primary stomata (+); cladose-dendroid trichomes (-) adaxially.……	4.
4	a.	Prickle unicellular trichomes(-), tortuosus trichome (-), T-shaped (+) abaxially, forked-dendroid (+) abaxially, elliptic and elongate glandular ones (+) abaxiallly; lithocysts (-) from both surfaces; wart-like hydathode (+) adaxially; wax formed of granules, platelets & wax threads; mean stomatal size 28.89X24 um ……	*F. nymphaeifolia*
	b.	Prickle unicellular trichomes (+), tortuosus trichomes (+), T-shaped (+) adaxially, forked-dendroid (+) adaxially, elliptic and elongate glandular ones (-); lithocysts(+) abaxially; pit-like hydathode (+) adaxially; wax formed of granules & platelets; mean stomatal size 33.92X26.14um……	*F. drupacea* var. *pubescens*
5	a.	Mean stomatal length >18um, mean stomatal width >10 um.……	6.
	b.	Mean stomatal length <18um, mean stomatal width <10 um ……..	7.
6	a.	Glandular trichomes (+) abaxially; hydathodes (-) from both surfaces; concentric striae around ordinary stomata present……	*F. carica*
	b.	Glandular trichomes (except peltate) absent from both surfaces; hydathodes (+) on both surfaces; concentric striae around ordinary stomata absent ……	*F.pumila*var. *pumila*
7	a.	Stomata elliptic; elongate glandular trichomes with unicellular head (+) abaxially…	8.
	b.	Stomata narrowly elliptic; elongate glandular trichomes (-) from both surfaces or with multicellular head if present……..…	9.
8	a.	Abaxial epidermal cells not papillose; wax of granules and platelets; periclinal surface of adaxial epidermal cells concave; stomatal rims raised; elliptic glandular trichomes(-) abaxially	*F. palmata*
	b.	Abaxial epidermal cells papillose; wax of granules and flakes; periclinal surface of adaxial epidermal cells flat; stomatal rims curved and flat; elliptic glandular trichomes (+) abaxially…	*F. hirta*
9	a.	Elongate glandular trichomes with multicellular head (+) on both surfaces; abaxial epidermal cells papillose; adaxial epidermal cells irregular polygonal or rectangular; wax of granules and platelets; stomatal rims curved and flat……	*F. aspera*
	b.	Elongate glandular trichomes with multicellular head (-) from both surfaces; abaxial epidermal cells not papillose; adaxial epidermal cells only irregular polygonal; wax of granules and flakes; stomatal rims raised……	10.
10	a.	Hydathodes (-) from both surfaces; periclinal surface of adaxial epidermal cells flat; mean stomata length <16 um …….	*F. racemosa*
	b.	Hydathodes (+) on both surfaces; periclinal surface of adaxial epidermal cells concave; mean stomata length >16 um……..	11.
11	a.	Prickle unicellular trichomes (+) abaxially, flagelliform ones (+) abaxially, elliptic glandular trichomes (+) on both surfaces; prickle lithocyst (+) only abaxially……	*F. sycomorus*
	b.	Prickle unicellular trichomes (-), flagelliform ones (-) abaxially, elliptic glandular trichomes only (+) only abaxially; prickle lithocyst (+) on both surfaces ……	*F. hispida*

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تباين التركيب الميكرومورفولوجي لخلايا البشرة فى أوراق بعض أنواع الزينة من جنس *Ficus* L. عائلة Moraceae في مصر

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تم إجراء دراسة ميكرومورفولوجية لتتبع التباين التركيبي لخلايا البشرة فى الأوراق لـ 12 نوعًا مزروعًا من جنس *Ficus* عائلة Moraceae وذلك بالإستعانة بالمجهر الإلكترونى الماسح نظراً لأهميته هذا التباين من السمات فى المغزى التصنيفى.

وقد أثبتت الدراسة عن وجود اختلافات مثيرة للاهتمام على مستوى تحت الجنس و ذات قيمة في التمييز بين الأنواع المندرجة لوحدات مختلفة وهذه السمات و مدى انتشارها على الأسطح المختلفة للأنواع هى: طبيعة الشعيرات وتكوينها -الهيداثودات-الأكياس الحجرية- الثغور (الشكل ، الحجم ، التوزيع ، الأنواع وخاصة مع وجود قرص جلدي سميك حول الثغور الغارقة)- شكل خلايا البشرةللسطح العلوي - طبقه الشمع علي السطح العلوي.

كما تم إجراء تحليل احصائي لهذه الصفات لتقييم اهميتها فى الفصل بين الأنواع و الوحدات المختلفة و إيجاد العلاقات الفينولوجية المتبادلة بينهم .