FOLIAR MICROMORPHOLOGICAL SCREENING FOR IDENTIFICATION OF MORACEAE TAXA

Fazal Hadi[1], Urooj Jamal[1], Noreen Khan[1], Jawad Akbar[3], Abdur Rahman Khan[4], Atta Ur Rehman[2], Saqib Ullah[2*]

[1]Department of Botany, University of Peshawar, Peshawar, KP, Pakistan
[2]Department of Botany, Islamia College Peshawar, Peshawar, KP, Pakistan
[3]Qurtuba University of Science and Information Technology Peshawar, KP, Pakistan.
[4]Forest products Research Division, Pakistan Forest Institute, Peshawar, KP, Pakistan

***Abstract*;** The study was based on investigating the adaxial and abaxial surfaces of epidermis of nine species of family Moraceae. The study exhibited that most of the plants were hypostomatic i.e., there was absence of stomata on the adaxial surface of the leaf. Leaf epidermal anatomy was found taxonomically appropriate in the identification at the generic and species level. The shapes of epidermal cells were mostly irregular in shape but some with straight margins were also observed. Most of the characters especially trichomes were diagnostic and used for distinguishing the taxa. On the other hand, variation in shape and size of epidermal cells and other stomatal features were examined on both adaxial and abaxial surfaces in all selected species. Mostly all of the studied species having anomocytic type of stomata alone or with the combination of other types of stomata on adaxial and abaxial surfaces epidermal surfaces. Stomatal index is also an important tool used in classification of plants. Stomatal index of *Broussonetia papyrifera* 76.7% is the highest and *Ficus benjamina* 2.13% is the lowest among all species on adaxial surface. *Ficus religiosa* 61.8% is the highest and *Ficus virens* 3.06% is the lowest on abaxial surface. This research is important for the classification and identification of plants.

***Index-Term*:** Foliar anatomy, Moraceae, Light Microscopy, Scanning Electron Microscopy

I. INTRODUCTION

Plants are the very important and essential group of living things in the world. They are essential for many other groups of living organisms and spread nearly all around the world (Akkemik, 2011). The taxonomic problems that cannot be solved completely through the classification based only on classical morphology have been solved recently by the use of modern taxonomic parameters. Of these parameters, the anatomical and morphological characteristics are frequently used. The use of anatomical and morphological characters for certain group of plants is of importance to eliminate the uncertainties regarding the classification (İçeli, 2011). Foliar anatomical characters are very much important in the identification of plants species. Leaf epidermal anatomical features such as stomata, epidermal cell shapes, stomatal index and other characters are useful anatomical tools. According to WHO, the morphological (macroscopic) and anatomical (microscopic) descriptions of a medicinal plant is the first step towards establishing its identity and should be carried out. The Moraceae (mulberry family or fig family) comprising about 40 genera and over 1,000 species deciduous or evergreen trees and shrubs widespread in tropical and subtropical regions, less in temperate regions. The only character of Moraceae is presence of laticifers and milky sap in all parenchymatous tissues, but generally useful field characters include two carpels sometimes with one reduced, compound inconspicuous flowers and compound fruits. Family contains a milky latex and have alternate or opposite leaves and small, petalless male or female flowers. Stamens as many as sepals often less, antisepalous, filaments inflexed or erect in bud, free with dithecous, versatile, longitudinally dehiscent anthers; pistillode present or absent in male flowers. Ovary bicarpellate, one carpel frequently abortive, superior or inferior, unilocular, ovule solitary, anatropous or campylotropous, pendulus from the apex, rarely basal and upright; styles 2(-1), filiform, simple or forked. Fruit a simple drupe, nut or achen or sometimes sorosis or syconium. Seeds surrounded by endocarp, endospermous or exalbuminous; embryo mostly curved. A family of 1500 species and 53 genera, mostly distributed in tropical and sub-tropical regions. In Pakistan represented by 5 genera, and of which 16 are native. The term epidermis is the outer most layer of cells covering the leaf. It has various function like protecting the plants against water loss by transpiration, regulation of gaseous exchange, secretion of metabolic compounds and absorption of water. Most leaves show dorsiventral anatomy. The upper (adaxial) and lower (abaxial) surfaces have different characters and may serve different functions. It can also be used as taxonomic characters delimiting plants, some characters or features on the epidermis which are useful taxonomically include several

differentiated cell types: Epidermal cells, stomata, subsidiary cells, guard cells and epidermal hairs (trichomes). These features have been used previously to resolve some taxonomic problems or to contribute to ever increasing taxonomic data base in some genera and even families of plants. Glover (1999) reported that epidermis is multifunctional tissue have vital role in pollinator attraction, defense and water relation as well. Various different types of specialized cells which are differentiated from early undifferentiated epidermis show different degree of morphological specialization. Linsbaur (1930) and Avery (1933) described the most commonly found 3 types of epidermal complexes which are as follows:

1. Epidermis proper common type of tubular cells which are closely arranged with variable outlines depends upon plants. These cells have wavy outlines and also contain various depthed sinusitis.
2. Straight walled polyhedral shaped cells.
3. All integrates occurs in between these two types.

In monocots the cells of epidermis show variations in sizes and shapes. Some have straight walls while some have wavy walls. But in case of dicotyledons the upper epidermis has wavy deep outline and the lower epidermis are less wavy. The guard cells play a vital role in the life of a plant. Basically, there are two guard cells present on both sides of the stomata. In epidermal cells some different cells surrounding stomata are called subsidiary cells. Trichomes, epidermis proper and subsidiary cells are called epidermal emergencies due to their manner of growth and hair like structure (Foster, 1949). The minute pore guarded by the guard cells is called the stomata. The epidermis is the opening in the grand cells. A stoma is formed from two specialized cells in the epidermis (guard cells) which are morphologically different from general epidermal cells and are responsible for controlling stomatal aperture (Franks & Farquhar 2007). Paired guard cells, in some species together with epidermal subsidiary cells, form the stomatal complex. Subsidiary cells can play a role in stomatal movements either mechanically or as ion reserves (Reschke & Fellows 1971). In most of the plants stomata can be found on both the upper (adaxial) and lower (abaxial) leaf surfaces, such leaves being termed amphistomatous, with the majority of stomata found on the lower surface (Ticha, 1982). In som e species (specially trees) stomata are found only on the lower surface (i.e., the leaf is hypostomatous) while some aquatic plants (such as water lilies) have stomata only on the upper surface (i.e., the leaf is epistomatous) (Morison, 2003). Stomata are found generally on the leaf. Stomata also found on the petals, stamens and carpels of the flowers. The leaves may have stomata on both their surfaces or only on under surfaces. Their distribution is found to be different in different plants. Structurally these are different in the monocotyledons and dicotyledons. In the former these are somewhat kidney shaped and have unevenly thickened walls. The guard cells usually consist of chloroplasts. The chemical composition of the guard cells is same as of ordinary epidermal cells of the same plant. Due to unevenly thick walls, the guard cells are helpful in the opening and closing of stomata. The leaf cuticle is impermeable to H_2O and CO_2, the chief role of stomata is the regulation of gaseous exchange between the inside of the leaf and the external environment (Cowan & Troughton 1971; Jones, 1992). Through the role of stomata in controlling transpiration stomata also help in leaf cooling, metabolite fluxes and long distance signaling (Brownlee, 2001; Lake *et al*. 2001; Jia & Zhang 2008) as well as acting as a barrier to harmful pollutants such as ozone and pathogens (Meidner & Mansfield 1968; Mansfield & Majernik 1970). Plants require sufficient amount of CO_2 to enter the leaf for photosynthesis for conserving water to avoid dehydration and metabolic disruption. When fully open, stomatal pores only occupy between 0.5 and 5% of the leaf surface (Hetherington & Woodward 2003; Morison, 2003); however, almost all the water transpired as wells as CO_2 absorbed passes through these pores. For this reason, stomatal function has significant implications for global hydrological and carbon cycles. The quest to understand stomatal control of photosynthesis CO_2 fixation and plant water relations is becoming increasingly important with changing climatic conditions. Knowledge of stomatal function is critical to determine plant responses to environmental stresses, particularly reduced water availability, and is necessary to identify plants with decreased water use that are capable of high yields in more extreme environments (Morison *et al*. 2007). Regular opening and closing of stomata in light and darkness were described by (Stalfelt 1929 and 1963; Maskell, 1928; Sayre, 1923 and Knight, 1922). Stomata present in different distribution in plants leaves in reticulate venation and in parallel venation. Stomata are arranged in rows in leaves. The thickness of guard cell helps in opening and closing of stomata. Stomata occur on both

upper and lower surfaces of leaf, but they are present more on lower surface than the upper surface. In floating leaves, stomata are restrained only on the upper surface of the leaf. In stomata, the gaseous exchange takes place between the two identical guard cells.

II. MATERIALS AND METHODS

Floristic Studies

Plants were obtained from different locations during the blooming season. Identification of plants were carried out with the help of Flora of Pakistan and available literature (Ali & Nasir 1989-1992; Nasir & Ali 1980-1989; Ali & Qaiser 1995-2009). Fresh leaves were separated from these species for light microscopic studies.

Light Microscopy

Fresh leaves were obtained from plants and soaked in H_2O for 2 hours to avoid the leaves from wilting. The same leaves were boiled in concentrated acetic acid for 10-15 minutes. The epidermis then removed from both the surfaces by simple peeling method. Those leaves which have thick cuticular layer were dipped in Formalin ($C_3H_6O_3$), Indole acetic acid (IAA) and ethanol that have concentration of 1:1:3. The layers of epidermis were dipped in a glycerin and dyed by Safranin and were analyzed under light microscopic studies. The micromorphological characters *i.e.*, stomata and epidermis of both the adaxial and abaxial surfaces were studied at different magnifications (10X and 40X). The pictures captured by polarized camera. Metcalfe (1960) was followed for identification of cells of epidermis. Statistical analysis was obtained with the help of Mean, Standard Deviation, Variance, Co-Variance and Standard Error.

Stomatal Index

$$S.I = \frac{S}{S+E} \times 100$$

Where S. I = stomatal index and S = no. of stomata per unit, E = no. of epidermal cells per unit area

Calculation of Area

Area = πr^2

Whereas $\pi = 3.14$

r = D/2

D = μ (diameter of observed area)

Putting value of D in the formula the value of r will be obtained

r = 360 /2

= 180μ

After putting the values in above formula, we get area of the observed field are:

A = 3.14 x $(180/1000)^2$

= 3.14 x 32400/1000000

= 0.1017 mm^2

Conversion of Ocular Division to Micron

Formula: [(# divisions on Micrometer) (one division of stage micrometer in mm)/ (# Counted on Ocular Micrometer)] x 100

Stage Micrometer = 1 division to 80 divisions on ocular micrometer

Step 1 = [(1) (0.01)/80)] x 100

Step 2 = [0.1/80] x 1000

Step 3 = 1.25/ ocular division

Step 4 = Total length of specimen (x) = (Length of 1 division of ocular micrometer) (number of divisions counted as length of an individual specimen).

Stomatal calculations for upper and lower epidermal cells and stomata

Mean

$$\mathbf{M = \sum(X)/N}$$

Where

$\sum X$ = Sum of observations

N = Number of observations

Standard Error

$$S.E = S/\sqrt{n}$$

S = Standard error

n = number of observations

SCANNING ELECTRON MICROSCOPY

Leaf samples of all selected species were taken for scanning electron microscopy. The leaves were soaked in xylene solution for 24 hours to remove the wax layer from both adaxial and abaxial surface. They were mounted in stubs with scotch tape and was double coated. Leaves were cut at the mid and were studied under Scanning Electron Microscope. One piece of the leaves was stucked on stub from the lower portion so that the adaxial surface of the leaf was exposed and other piece was stucked on the stub so that the abaxial surface of the leaf was exposed. Both of the pieces were sputter-coated with the gold palladium and then observed them under Scanning Electron Microscope installed in the Central Resource Library (CRL) Department of Physics University of Peshawar.

III. RESULTS

In the present research work foliar epidermal anatomy of 9 species of family Moraceae were studied and observed under light and scanning electron microscope. The following results were obtained.

4.1 Description of anatomical and microscopic studies of leaves on the basis of Light Microscopy

4.1.1. Ficus religiosa (L.)

Leaves are hypostomatic (Fig. 1.1.)

Adaxial surface

Epidermal cells are thick walled, rectangular with straight margins, length of epidermal cells is 12.13.5 µm = (12.78) $\pm$ 0.56, width of epidermal cells is 10-11.1 µm = (10.67) $\pm$ 0.67, there is absence of quantitative characters on upper epidermis, stomatal index is 62%.

Abaxial surface

The shape of epidermal cells are rectangular or polygonal thick walled with straight margins, length of epidermal cells is 24-27 µm = (25.9) $\pm$ 0.46, width of epidermal cells is 12-14 µm = (13.37) $\pm$ 0.24, stomata is anomocytic and staurocytic, length of stomatal complex is 9.5-11 µm = (10.23) $\pm$ 1.1, width of stomatal complex is 8-8.5 µm = (8.25) $\pm$ 0.12, length of subsidiary cells is 15-23 µm = (18.45) $\pm$ 2.45, width of subsidiary cells is 8-10.5 µm = (9.23) $\pm$ 1.2, length of stomata pore is 6-7 µm = (6.61) $\pm$ 0.56, width of stomatal pore is 2-3 µm = (2.45) $\pm$ 0.32, stomatal index is 61.8%.

4.1.2. Ficus religiosa (L.)

(A) Upper Epidermis

(a) Epidermis proper

The epidermis is thick comprises of epidermal cells while trichomes, subsidiary cells and stomata are absent. The epidermal cells are rectangular or polygonal in shape.

(b) Stomatal complex: Not observed.

(c) Stomata: Absent.

(d) Average size of stomata: Not observed.

(e) Stomatal index

Stomatal index of the upper epidermis is given below.

Field area = 0.1017mm^2

No. of stomata in field area = 0

No. of stomata in 1mm^2 = 0/0.1017mm^2 = 0

No. of epidermal cells in field area = 63.9

No. of epidermal cells in 1mm^2 = 63.9/0.1017mm^2 = 628.3µ

$$\text{Stomatal index} = \frac{0}{0 + 628.3} \times 100$$

Stomatal index = 62µ

(B) Lower epidermis

(a) Epidermis proper

The epidermis is thick, comprises of epidermal cells, trichomes, stomata and subsidiary cells. The epidermal cells are ambiguous.

(b) Stomatal complex

There are two types of stomata in *Ficus religiosa* one is anomocytic type of stomata and the other is staurocytic type of stomata. In anomocytic type of stomata there is no recognizable cells around stomata. (Fig. 1.11.)

(c) Stomata

The stomatal pore is guarded by a pair of foeniculum vulgare seed shaped guard cells.

(d) Average size of stomata

Average length of guard cells of stomata was 23µ, average width of guard cells was 6.9µ, average length of stomatal pore was 11.5µ, average width of stomatal pore was 5.75µ, average length of subsidiary cells was 23.2, average width of subsidiary cells was 36.5µ.

(e) Stomatal index

Stomatal index of the lower epidermis is given below.

Field area = 0.1017mm^2

No. of stomata in field area = 42

No. of stomata in 1mm^2 = 42/0.1017mm^2 = 412.9µ

No. of epidermal cells in field area = 68

No. of epidermal cells in 1mm^2 = 68/0.1017mm^2 = 668.6µ

$$\text{Stomatal index} = \frac{668.6}{668.6 + 412.9} \times 100$$

Stomatal index = 61.8µ

4.1.3. Ficus benghalensis (L.)

Leaves are amphistomatic (Fig. 1.2.)

Adaxial surface

The shape of epidermal cells is rectangular in shape, thick walled length of epidermal cells is 30-40.2 µm = (35.17) ± 2.84, width of epidermal cells is 19.9-22 µm = (20.87) ± 0.47, stomata is anomocytic, length of stomatal complex is 15.9-18.1 µm = (16.87) ± 0.46, width of stomatal complex is 7.9-10.1 µm = (8.87) ± 0.48, length of subsidiary cells is 43-47.5 µm = (44.67) ± 1.00, width of subsidiary cells is 18.5-22.5 µm = (20.0) ± 0.88, length of stomatal pore is 21-27 µm = (23.8) ± 1.24, width of stomatal pore is 7.5-9.5 µm = (8.22) ± 0.46, stomatal index is 22.7%.

Abaxial surface

The shape of epidermal cells is rectangular or sometimes irregular, thick walled length of epidermal cells is 17-22 µm = (19.5) ± 1.2, width of epidermal cells is 9-17 µm = (14) ± 2.5, stomata is anomocytic, length of stomatal complex is 9.8-11 µm = (10.23) ± 0.21, width of stomatal complex is 8-8.6 µm = (8.34) ± 0.23, length of subsidiary cells is 19-24 µm = (21) ± 1.1, width of subsidiary cells is 8-11 µm = (9.34) ± 1, length of stomatal pore is 7-13 µm = (10.9) ± 0.14 , width of stomatal pore is 1-5 µm = (2.30) ± 0.09, stomatal index is 13.7%.

4.1.4. Ficus benghalensis (L.)

(A) Upper epidermis

(a) Epidermis proper

The epidermis is thick, comprises of epidermis trichomes and stomata and subsidiary cells. The epidermal cells are rectangular.

(b) Stomatal complex

Stomata were observed on the upper epidermis. Anomocytic type of stomata is present. (Fig. 1.12.)

(c) Stomata

Stomata were guarded by two irregular shaped guard cells.

(d) Average size of stomata

Average length of guard cells of stomata was 27.6µ, average width of guard cells was 11.6µ, average length of stomatal pore was 16.1µ, average width of stomatal pore was 9.2µ, average length of subsidiary cells was 15.6, average width of subsidiary cells was 28.9µ.

(e) Stomatal index

Stomatal index of the upper epidermis is given below.

Field area = 0.1017mm^2

No. of stomata in field area = 59

No. of stomata in 1mm^2 = 59/0.1017mm^2 = 580.1µ

No. of epidermal cells in field area = 201

No. of epidermal cells in 1mm^2 = 201/0.1017mm^2 = 1976µ

$$\text{Stomatal index} = \frac{580.1}{580.1 + 1976} \times 100$$

Stomatal index = 22.7µ

(B) Lower epidermis

(a) Epidermis proper

The lower epidermis is thick comprises of epidermis, stomata and subsidiary cells. The epidermal cells are rectangular. Sometimes irregular in shape. Number of stomata were less than number of epidermal cells on upper epidermis.

(b) Stomatal complex

The type of stomata is anomocytic type in this type stomata have no recognizable epidermal cells are present around stomata. (Fig. 1.13.)

(c) Stomata

Stomata is guarded by irregular shaped guard cells.

(d) Average size of stomata

The average length of stomatal guard cells was 32.6µ, average width of stomatal guard cells was 10.5µ, average length of stomatal pore was 37.7µ, average width of stomatal pore was 11.1µ, average length of subsidiary cells was 65.4µ, average width of subsidiary cells was 14.5µ.

(e) Stomatal index

Stomatal index of the lower epidermis is given below.

Field area = 0.1017mm^2

No. of stomata in field area = 26.6

No. of stomata in 1mm^2 = 26.6/ 0.1017mm^2 = 261.5µ

No. of epidermal cells in field area = 166.8

No. of epidermal cells in 1mm^2 = 166.8/0.1017mm^2 = 1640µ

$$\text{Stomatal index} = \frac{261.5}{261.5 + 1640} \times 100$$

Stomatal index = 13.7µ

4.1.5. Ficus elastica (Roxb.)

Leaves are hypostomatic (Fig. 1.3.)

Adaxial surface

The shape of epidermal cells is polygonal or irregular, thick-walled length of epidermal cells is 22-24 µm = (23) $\pm$ 0.57, width of epidermal cells is 10.1-14 µm = (12.4) $\pm$ 0.87, there is absence of quantitative characters on upper epidermis, stomatal index is 33.19%.

Abaxial surface

The epidermal cells are thick walled irregular in shape, length of epidermal cells is 25-29 µm = (27.2) $\pm$ 0.84, width of epidermal cells is 16.5-20 µm = (18.5) $\pm$ 1.0, stomata is anomocytic and cyclocytic type, length of stomatal complex is 13-17 µm = (14.87) $\pm$ 0.82, width of stomatal complex is 4-6 µm = (5.12) $\pm$ 0.45, length of subsidiary cells is 53-55 µm = (54.2) $\pm$ 0.45, width of subsidiary cells is 22.9-24 µm = (23.65) $\pm$ 0.23, length of stomatal pore is 36-40.8 µm = (38.45) $\pm$ 1.16, width of stomatal pore is 10-11.9 µm = (11.15) $\pm$ 0.44, stomatal index is 21.8%.

4.1.6. Ficus elastica (Roxb.)

(A) Upper epidermis

(a) Epidermis proper

The epidermis is thick comprises of epidermis, trichomes while the stomata are absent. The epidermal cells are polygonal or irregular in shape.

(b) Stomatal complex: Not observed

(c) Stomata: Absent

(e) Stomatal index

Stomatal index of the upper epidermis is given below.

Field area = 0.1017mm^2

No. of stomata in field area = 0

No. of stomata in 1mm^2 = 0/0.1017mm^2 = 0

No. of epidermal cells in field area = 337.6

No. of epidermal cells in 1mm^2 = 337.6/0.1017mm^2 = 3319µ

$$\text{Stomatal index} = \frac{0}{0 + 3319} \times 100$$

Stomatal index = 33.19µ

(B) Lower epidermis

(a) Epidermis proper

The epidermis is thick comprises of epidermis, stomata, trichomes and subsidiary cells. The epidermal cells are irregular.

(b) Stomatal complex

Stomata were present on lower epidermis. There are two types of stomata in *Ficus elastica*. One type is anomocytic and the other is cyclocytic. In cyclocytic type of stomata the subsidiary cells forming one or two rings around the stomata. (Fig. 1.15)

(c) Stomata

The stomatal pore is guarded by two kidney shaped guard cells. The stomata are spherical in shape.

(d) Average size of stomata

Average length of guard cells was 36µ, average width of guard cells was 9.2µ, average length of stomatal pore 26µ, average width of stomatal pore was 12.5µ, average length of subsidiary cells was 60.2µ, average width of subsidiary cells was 12.1µ.

(e) Stomatal index

Stomatal index of the lower epidermis is given below.

Field area = 0.1017mm^2

No. of stomata in field area = 21

No. of stomata in 1mm^2= 21/0.1017mm^2 = 206.4µ

No. of epidermal cells in field area = 75

No. of epidermal cells in 1mm^2 = 75/0.1017mm^2 = 737.4µ

$$\text{Stomatal index} = \frac{206.4}{206 + 737.4} \times 100$$

Stomatal index = 21.8µ

4.1.7. Ficus virens (Aiton.)

Leaves are hypostomatic (Fig. 1.4.)

Adaxial surface

The epidermal cells are thick-walled irregular in shape, length of epidermal cells is 12-14 µm = (13.2) $\pm$ 1.2, width of epidermal cells is 11-16 µm = (14.56) $\pm$ 2.11, there is absence of quantitative characters on adaxial surface, stomatal index is 44.2%.

Abaxial surface

The epidermal cells are thick-walled irregular in shape, length of epidermal cells is 16.7-21.71 µm = (18.71) $\pm$ 0.15, width of epidermal cells is 9-14 µm = (12.12) $\pm$ 2.3, stomata is paracytic type, length of stomatal complex is 9-11 µm = (10.21) $\pm$ 1.5, width of stomatal complex is 7-8 µm= (7.46) $\pm$ 0.6, length of subsidiary cells is 10-15 µm = (12.98) $\pm$ 2.31, width of subsidiary cells is 9-12 µm = (10.75) $\pm$ 1.41, length of stomatal pore is 8-9.5 µm = (8.23) $\pm$ 1.2, width of stomatal pore is 1.1-2.5 µm = (1.9) $\pm$ 1.21, stomatal index is 3.06%.

4.1.8. Ficus virens (Aiton.)

(A) Upper epidermis

(a) Epidermis proper

The epidermis is thick comprises of epidermal cells and trichomes while the stomata and subsidiary cells are absent. The epidermal cells are rectangular in shape.

(b) Stomatal complex: Not observed.

(c) Stomata: Absent.

(d) Average size of stomata: Not observed.

(e) Stomatal index

Stomatal index of the upper epidermis is given below.

Field area = 0.1017mm^2

No. of stomata in field area = 0

No. of stomata in $1mm^2 = 0/0.1017mm^2 = 0$
No. of epidermal cells in field area = 45
No. of epidermal cells in $1mm^2 = 45/0.1017mm^2 = 442.4\mu$

$$\text{Stomatal index} = \frac{0}{0 + 442.4} \times 100$$

Stomatal index = 44.2 µ

(B) Lower epidermis

(a) Epidermis proper

The epidermis is thick comprises of epidermal cells, trichomes, stomata and subsidiary cells. The epidermal cells are rectangular in shape.

(b) Stomatal complex

There is one type of stomata in *Ficus virens*. The stomata are paracytic type. In paracytic type stomata consists of two subsidiary cells which are parallel to the long axis of the pore and guard cell. (Fig. 1.17.)

(c) Stomata

The stomata are *Feoniculum vulgare* seed shaped. The stomatal pore is guarded by two hemispherical kidney shaped guard cells.

(d) Average size of stomata

Average length of guard cells was 28µ, average width of guard cells was 4.6µ, average length of stomatal pore 16.1µ, average width of stomatal pore was 2.3µ, average length of subsidiary cells was 42.6µ, average width of subsidiary cells was 13.5µ. The stomatal pore is wide at their broad position and the guard cells with the stomatal pores are thicker than those away from the pores.

(e) Stomatal index

Stomatal index of the lower epidermis is given below.
Field area = $0.1017mm^2$
No. of stomata in field area = 3
No. of stomata in $1mm^2 = 3/0.1017mm^2 = 29.49\mu$
No. of epidermal cells in field area = 95
No. of epidermal cells in $1mm^2 = 95/0.1017mm^2 = 934.1\mu$

$$\text{Stomatal index} = \frac{29.49}{29.49 + 934.1} \times 100$$

Stomatal index = 3.06µ

4.1.9. Ficus benjamina (L.)

Leaves are amphistomatic (Fig. 1.5.)

Adaxial surface

The epidermal cells are thick-walled, rectangular in shape contain lines, length of epidermal cells is 9.5-12 µm = (10.75) $\pm$ 0.59, width of epidermal cells is 9-12 µm = (11) $\pm$ 2.11, stomata is anomocytic type, length of stomatal complex is 6-12.5 µm = (10.12) $\pm$ 1.47, width of stomatal complex is 3-8 µm = (5.75) $\pm$ 1.10, length of subsidiary cells is 14.6-16 µm = (15.5) $\pm$ 0.32, width of subsidiary cells is 15.9-17 µm = (16.42) $\pm$ 0.22, length of stomatal pore is 29-30.6 µm = (29.87) $\pm$ 0.33, width of stomatal pore is 3.9-5 µm = (4.42) $\pm$ 0.22, stomatal index is 2.13%.

Abaxial surface

The epidermal cells are thick-walled rectangular, pentagonal or polygonal with straight margins, length of epidermal cells is 11-13 µm = (12.7) $\pm$ 1.25, width of epidermal cells is 6-10 µm = (8.5) $\pm$ 2.23, stomata are anomocytic and cyclocytic type, length of stomatal complex is 12-13 µm = (12.6) $\pm$ 1.32, width of stomatal complex is 10-11.5 µm = (10.45) $\pm$ 1.1, length of subsidiary cells is 8-16 µm = (13.5) $\pm$ 2.13, width of subsidiary cells is 5-10 µm = (8.2) $\pm$ 3.25, length of stomatal pore is 7-8 µm = (7.6) $\pm$ 1.2, width of stomatal pore is 1-2 µm = (1.7) $\pm$ 1.12, stomatal index is 54.83%.

4.1.10. Ficus benjamina (L.)

(A) Upper epidermis

(a) Epidermis proper

The epidermis proper is thick comprises of epidermal cells, stomata, subsidiary cells and trichomes. Epidermal cells are rectangular and contain lines.

(b) Stomatal complex

Anomocytic type of stomata were present on upper surface. (Fig. 1.18.)

(c) Stomata

Stomata were guarded by two kidney shaped guard cells.

(d) Average size of stomata

Average length of guard cells was 43.5µ, average width of guard cells was 8.68µ, average length of stomatal pore was 34.5µ, average width of stomatal pore was 13.04µ, average length of subsidiary cells was 65.4µ, average length of subsidiary cells was 54µ.

(e) Stomatal index

Stomatal index of the upper epidermis is given below.

Field area = $0.1017mm^2$

No. of stomata in field area = 11.6

No. of stomata in $1mm^2$ = $11.6/0.1017mm^2$ = 114.06 µ

No. of epidermal cells in field area = 54

No. of epidermal cells in $1mm^2$ = $54/0.1017mm^2$ = 530.9µ

$$\text{Stomatal index} = \frac{11.6}{11.6 + 530.9} \times 100$$

Stomatal index = 2.13 µ

(B) Lower epidermis

(a) Epidermis proper

The epidermis is thick comprises of epidermal cells, stomata, subsidiary cells and trichomes. The epidermal cells are rectangular, pentagonal or polygonal with straight margins. Number of stomata were more than number of epidermal cells.

(b) Stomatal complex

The type of stomata present in *Ficus benjamina* is anomocytic and cyclocytic type. (Fig. 1.19.)

(c) Stomata

The stomatal pore is guarded by two guard cells which are much wider than the stomatal pore.

(d) Average size of stomata

Average length of guard cells was 43µ, average width of guard cells was 9.8µ, average length of stomatal pore was 13.4µ, average width of stomatal pore was 7.2µ, average length of subsidiary cells was 54.8µ, average width of subsidiary cells was 31.2µ.

(e) Stomatal index

Stomatal index of the lower epidermis is given below.

Field area = $0.1017mm^2$

No. of stomata in field area = 68

No. of stomata in $1mm^2$ = $68/0.1017mm^2$ = 668.6µ

No. of epidermal cells in field area = 56

No. of epidermal cells in $1mm^2$ = $56/0.1017mm^2$= 550.6µ

$$\text{Stomatal index} = \frac{668.6}{668.6 + 550.6} \times 100$$

Stomatal index = 54.83µ

4.1.11. Ficus hawaii (L.)

Leaves are hypostomatic (Fig. 1.6.)

Adaxial surface

Epidermal cells are thick irregular mostly polygonal with straight margins, length of epidermal cells is 14-22 µm = (17.6) $\pm$ 3.1, width of epidermal cells is 13-19 µm = (15.54) $\pm$ 1.5, the quantitative characters are absent on adaxial surface, stomatal index is 22%.

Abaxial surface

Epidermal cells are thick-walled irregular or polygonal with straight margins, length of epidermal cells is 24-28 µm = (25.77) $\pm$ 0.84, width of epidermal cells is 13-19 µm = (15.75) $\pm$ 1.25, stomata are anomocytic type, length of stomatal complex is 28-31 µm = (29.5) $\pm$ 0.64, width of stomatal complex is 22.1-25 µm = (23.65) $\pm$ 0.66, length of subsidiary

cells is 18-21.1 µm = (19.65) ± 0.64, width of subsidiary cells is 35-43.6 µm = (39.02) ± 1.83, length of stomatal pore is 24-26 µm (25) ± 0.41, width of stomatal pore is 5.01-8.35 µm = (6.01) ± 0.07, stomatal index is 6.5%.

4.1.12. Ficus hawaii (L.)

(A) Upper epidermis

(a) Epidermis proper

The epidermis is thick comprises of epidermal cells and trichomes. The epidermal cells are mostly polygonal or irregular in shape.

(b) Stomatal complex: Stomata were absent on upper epidermis.

(c) Stomata: Absent.

(d) Average size of stomata: Absent.

(e) Stomatal index

Stomatal index of the upper epidermis is given below.

Field area = 0.1017mm^2

No. of stomata in field area = 0

No. of stomata in 1mm^2 = 0/0.1017mm^2 = 0

No. of epidermal cells in field area = 229.4

No. of epidermal cells in 1mm^2 = 229.4/0.1017mm^2 = 225µ

$$\text{Stomatal index} = \frac{0}{0 + 225} \times 100$$

Stomatal index = 22µ

(B) Lower epidermis

(a) Epidermis proper

The epidermis is thick comprises of epidermal cells, stomata complex and subsidiary cells. Epidermal cells are irregular or polygonal shaped with straight margins. Stomata were present on lower epidermis less in number.

(b) Stomatal complex

Anomocytic type of stomata were present on lower epidermis. (Fig. 1.21.)

(c) Stomata

Stomata were surrounded by two guard cells.

(d) Average size of stomata

Average length of guard cells was 34.12µ, average width of guard cells was 13.11µ, average length of stomatal pore was 43.22µ, average width of stomatal pore was 12.6µ average length of subsidiary cells was 44µ, average width of subsidiary cells was 28.85µ.

(e) Stomatal index

Stomatal index of the lower epidermis is given below.

Field area = 0.1017mm^2

No. of stomata in field area = 15

No. of stomata in 1mm^2 = 15/0.1017mm^2 = 147µ

No. of epidermal cells in field area = 213

No. of epidermal cells in 1mm^2 = 213/0.1017mm^2 = 2094µ

$$\text{Stomatal index} = \frac{147}{147 + 2094} \times 100$$

Stomatal index = 6.5µ

4.1.13. Morus alba (L.)

Leaves are amphistomatic (Fig. 1.7.)

A**daxial surface**

Epidermal cells are thin-walled irregular or polygonal in shape with straight anticlinal walls, length of epidermal cells is 24-28 µm = (25.77) ± 0.84. width of epidermal cells is 13-19 µm = (15.75) ± 1.25, stomata are anomocytic and anisocytic type, length of stomatal complex is 28-31 µm = (29.5) ± 0.64, width of stomatal complex is 22.1-25 µm = (23.65) ± 0.66, length of subsidiary cells is 18-21.1 µm = (19.65) ± 0.64, width of subsidiary cells is 35-43.6 µm = (39.02) ± 1.83, length of stomatal pore is 24-26 µm = (25) ± 0.41, width of stomatal pore is 72.9-74 µm = (73.4) ± 0.27, stomatal index is 39%.

Abaxial surface

Epidermal cells are thin-walled irregular in shape, length of epidermal cells is 10-14 µm = (12.15) ± 0.88, width of epidermal cells is 8-13 µm = (10.75) ± 1.10, stomata are anomocytic type, length of stomatal complex is 30-33 µm = (31.62) ± 0.62, width of stomatal complex is 20-24 µm = (22.5) ± 0.62, length of subsidiary cells is 50.9-52 µm = (51.5) ± 0.26, width of subsidiary cells is 19-22 µm = (20.75) ± 0.64, length of stomatal pore is 28-31.5 µm = (29.75) ± 0.72, width of stomatal pore is 9-12.1 µm = (10.65) ± 0.64, stomatal index is 28.3%.

4.1.14. Morus alba (L.)

(A) Upper epidermis

(a) Epidermis proper

The epidermis is thin comprises of epidermis, trichomes, stomatal complex and subsidiary cells. The epidermal cells are irregular or polygonal in shape. They have straight anticlinal walls.

(b) Stomatal complex

Anomocytic and anisocytic type of stomata were present. (Fig. 1.22.)

(c) Stomata

Stomata were surrounded by two kidney shaped guard cells.

(d) Average size of stomata

Average length of guard cells was 45.18µ, average width of guard cells was 13.12µ, average length of stomatal pore was 42.22µ, average length of subsidiary cells was 43µ, average width of subsidiary cells was 26.84µ.

(e) Stomatal index

Stomatal index of the upper epidermis is given below.

Field area = 0.1017mm^2

No. of stomata in field area = 43

No. of stomata in 1mm^2 = 43/0.1017mm^2 = 422µ

No. of epidermal cells in field area = 67

No. of epidermal cells in 1mm^2 = 67/0.1017mm^2 = 658µ

$$\text{Stomatal index} = \frac{422}{422 + 658} \times 100$$

Stomatal index = 39µ

(B) Lower epidermis

(a) Epidermis proper

The epidermis is thin comprises epidermis, stomatal complex and subsidiary cells. The epidermis cells are irregular in shape. Stomata were less in number.

(b) Stomatal complex

Anomocytic type of stomata were present. (Fig. 1.23.)

(c) Stomata

Stomata were surrounded by two bean shaped guard cells.

(d) Average size of stomata

Average length of guard cells was 18.4µ, average width of guard cells was 2.3µ, average length of stomatal pore was 7.3µ, average width of stomatal pore was 3.4µ, average length of subsidiary cells was 34.7µ, average width of subsidiary cells was 19.5µ.

(e) Stomatal index

Stomatal index of the lower epidermis is given below.

Field area = 0.1017mm^2

No. of stomata in field area = 34

No. of stomata in 1mm^2 = 34/0.1017mm^2 = 334µ

No. of epidermal cells in field area = 86

No. of epidermal cells in 1mm^2 = 86/0.1017mm^2 = 845µ

$$\text{Stomatal index} = \frac{334}{334 + 845} \times 100$$

Stomatal index = 28.3µ

4.1.15. Morus laevigata (L.)

Leaves are hypostomatic (Fig. 1.8.)

Adaxial surface

Epidermal cells are thin-walled, pentagonal or hexagonal, length of epidermal cells is 16-18 µm = (17.25) ± 1.31, width of epidermal cells is 10-14 µm (12) ± 1.58, quantitative characters are absent on adaxial surface, stomatal index is 50.7%.

Abaxial surface

Epidermal cells are thin-walled pentagonal or irregular, length of epidermal cells is 32-40 µm = (36) ± 1.68, width of epidermal cells is 17.9-20 µm = (18.75) ± 0.49, stomata are anomocytic and paracytic type, length of stomatal complex is 8-13 µm = (10.87) ± 0.49, width of stomatal complex is 9-11.9 µm = (10.47) ± 0.62, length of subsidiary cells is 55-61 µm = (58.2) ± 1.25, width of subsidiary cells is 25-32 µm = (29.76) ± 1.48, length of stomatal pore is 5.8-8 µm = (7) ± 1, width of stomatal pore is 2-2.5 µm = (2.3) ± 0.46, stomatal index is 12.36%.

4.1.16. Morus laevigata (L.)

(A)Upper epidermis

(a) Epidermis proper

The epidermis is thin comprises of epidermis and trichomes. Stomata and subsidiary cells are absent. The epidermal cells are pentagonal or irregular in shape.

(b) Stomatal complex: Stomata were absent on upper epidermis.

(c) Stomata: Absent.

(d) Average size of stomata: Absent.

(e) Stomatal index

Stomatal index of the upper epidermis is given below.

Field area = 0.1017mm^2

No. of stomata in field area = 0

No. of stomata in 1mm^2 = 0/0.1017mm^2 = 0

No. of epidermal cells in field area = 51.66

No. of epidermal cells in 1mm^2 = 51.66/0.1017mm^2 = 507.9µ

$$\text{Stomatal index} = \frac{0}{0 + 507} \times 100$$

Stomatal index = 50.7µ

(B) Lower epidermis

(a) Epidermis proper

The epidermis is thin comprises of epidermis, trichomes, stomata and subsidiary cells. Epidermal cells were varied in size and shape, may be pentagonal or irregular in shape. Number of stomata were less than number of epidermal cells on lower surface.

(b) Stomatal complex

Anomocytic and paracytic type of stomata were observed on lower epidermis. (Fig. 1.25.)

(c) Stomata

Stomata were guarded by guard cells.

(d) Average size of stomata

Average length of guard cells was 44.6µ, average width of guard cells was 12.4µ, average length of stomatal pore was 31.5µ, average length of stomatal pore was 9.3µ, average length of subsidiary cells was 56.8µ, average width of stomatal pore was 24.3µ.

(e) Stomatal index

Stomatal index of the lower epidermis is given below.

Field area = 0.1017mm^2

No. of stomata in field area = 18

No. of stomata in 1mm^2 =18/0.1017mm^2 = 176.9µ

No. of epidermal cells in field area = 127.6

No. of epidermal cells in 1mm^2 = 127.6/0.1017mm^2 = 1254µ

$$\text{Stomatal index} = \frac{176.9}{176.9 + 1254} \times 100$$

Stomatal index = 12.36µ

4.1.17. Broussonetia papyrifera (L.)

Leaves are amphistomatic (Fig. 1.9.)

Adaxial surface

Epidermal cells are thin-walled rectangular, polygonal or irregular in shape, length of epidermal cells is 42-47.5 µm = (44.7) ± 1.19, width of epidermal cells is 22.5-25 µm = (23.62) ± 0.55, stomata are paracytic type, length of stomatal complex is 22-27.7 µm = (24.9) ± 1.61, width of stomatal complex is 17-25 µm = (21) ± 1.68, length of subsidiary cells is 20-25 µm = (22.1) ± 1.03, width of subsidiary cells is 39.9-42 µm = (41.05) ± 0.52, length of stomatal pore is 26-28 µm = (27.5) ± 0.43, width of stomatal pore is 71-77 µm = (74.5) ± 1.32, stomatal index is 76.7%.

Abaxial surface

Epidermal cells are thin-walled polygonal in shape, length of epidermal cells is 4-14 µm = (7.75) ± 0.14, width of epidermal cells is 12-17 µm = (14.5) ± 1.7, stomata are anomocytic and laterocytic type, length of stomatal complex is 11.5-15 µm = (13.4) ± 1.2, width of stomatal complex is 9-11 µm = (10.3) ± 1.3, length of subsidiary cells is 10-15 µm = (13.5) ± 2.1, width of subsidiary cells is 4-6.1 µm = (3.5) ± 1, length of stomatal pore is 7-8 µm = (7.75) ± 0.34, width of stomatal pore is 2.5-3 µm = (2.75) ± 0.46, stomatal complex is 27.3%.

4.1.18. Broussonetia papyrifera (L.)

(A)Upper epidermis

(a) Epidermis proper

The epidermis is thin comprises of epidermis, trichomes, stomata and subsidiary cells. Epidermal cells were varied in size and shape, may be rectangular, polygonal or irregular in shape. Trichomes were in abundant and unicellular.

(b) Stomatal complex

Paracytic type of stomata were present on upper epidermis. (Fig. 1.26.)

(c) Stomata

Stomata were guarded by two bean shaped guard cells.

(d) Average size of stomata

Average length of guard cells was 34.5µ, average width of guard cells was 9.4µ, average length of stomatal pore was 32.5µ, average width of stomatal pore was 14.2µ, average length of subsidiary cells was 48.3µ, average width of stomatal pore was 22.8µ.

(e) Stomatal index

Stomatal index of the upper epidermis is given below.

Field area = 0.1017mm^2

No. of stomata in field area = 51

No. of stomata in 1mm^2 =51/0.1017mm^2 = 501.4µ

No. of epidermal cells in field area = 152.3

No. of epidermal cells in 1mm^2 = 152.3/0.1017mm^2 = 1497.5µ

$$\text{Stomatal index} = \frac{501.4}{501.4 + 152.3} \times 100$$

Stomatal index = 76.7µ

(B) Lower epidermis

(a) Epidermis proper

The epidermis is thin comprises of epidermis, stomata. Trichomes and subsidiary cells were absent. The epidermal cells were polygonal with straight margins.

(b) Stomatal complex

Anomocytic and laterocytic type of stomata were observed on lower epidermis. In laterocytic type one subsidiary cell cover half of the stomata. (Fig. 1.27.)

(c) Stomata

Stomata were surrounded by pair of kidney shaped guard cells.

(d) Average size of stomata

Average length of guard cells was 16.1µ, average width of guard cells was 8.6µ, average length of stomatal pore was 35.2µ, average width of guard cell was 3.6µ, average length of subsidiary cells was 20.4µ, average width of subsidiary cells was 26.72µ.

(e) Stomatal index

Stomatal index of the lower epidermis is given below.

Field area = 0.1017 mm^2

No. of stomata in field area = 45

No. of stomata in $1mm^2$ = $45/0.1017mm^2$ = 442.4µ

No. of epidermal cells in field area = 119.3

No. of epidermal cells in $1mm^2$ = $119.3/0.1017mm^2$ = 1173µ

$$\text{Stomatal index} = \frac{442.4}{442.4 + 1173} \times 100$$

Stomatal index = 27.3µ

Table 2. Quantitative leaf epidermal characters of family Moraceae based on light microscopy.

Taxa	L/W	Leaf epidermal Min-Max=Mean±SE		Stomata Min-Max=Mean±SE		Stomatal pore Min-Max=Mean±SE		Subsidiary cell Min-Max=Mean±SE		Stomatal index	
		Ad	Ab	Ad	Ab	Ad	Ab	Ad	Ab	Ad	Ab
F. religiosa	L	12-13.5=12.78±0.56	24-27=25.9±0.46	-	9.5-11=10.23±1.1	-	6-7=6.61±0.56	-	15-23=18.45±2.45	62	61.8
	W	10-11.1=10.67±0.67	12-14=13.37±0.24	-	8-8.5=8.25+0.12	-	2-3=2.45±0.32	-	8-10.5=9.23±1.2	-	-
F. benghalensis	L	30-40.2=35.17±2.84	17-22=19.5±1.2	15.9-18.1=16.87±0.46	9.8-11=10.23±0.21	21-27=23.8±1.24	7-13=10.9±0.14	43-47.5=44.67±1.00	19-24=21±0.21	22.7	13.7
	W	19.9-22=20.87±0.47	9-17=14±2.5	7.9-10.1=8.87±0.48	8-8.6=8.34±0.23	7.5-9.5=8.22±0.46	1-5=2.30 ±0.09	18.5-22.5=20.0±0.88	8-11=9.34±1	-	-
F. elastica	L	22-24=23±0.57	25-29=27.2±0.84	-	13-17=14.87±0.82	-	36-40.8=38.45±1.16	-	55-53=54.2±0.45	33.19	21.8
	W	10.1-14=12.4±0.87	16.5-20=18.5±1.0	-	4-6=5.12±0.45	-	10-11.9=11.15±0.44	-	22.9-24=23.65±0.23	-	-
F. virens	L	12-14=13.2±1.2	16.7-21.71=18.71±0.15	-	9-11=10.21±1.5	-	8-9.5=8.23±1.2	-	10-15=12.98±2.31	44.3	3.06
	W	11-16=14.56±2.11	9-14=12.12±2.3	-	7-8=7.46±0.6	-	1.1-2.5=1.9±1.21	-	9-12=10.75±1.41	-	-
F. benjamina	L	9.5-12=10.75±0.59	11-13=12.7±1.25	6-12.5=10.12±1.47	12-13=12.6±1.32	29-30.6=29.87±0.33	7-8=7.6±1.2	14.6-16=15.5±0.32	8-16=13.5±2.13	2.13	54.83
	W	9-12=11±2.11	6-10=8.5±2.23	3-8=5.75±1.10	10-11.5=10.45±1.1	3.9-5=4.42±0.22	1-2=1.7±1.12	15.9-17=16.42±0.22	5-10=8.2±3.25	-	-
F. hawaii	L	14-22=17.6±3.1	24-28=25.77±0.84	-	28-31=29.5±0.64	-	24-26=25±0.41	-	18-21.1=19.65±0.64	22	6.5
	W	13-19=15.54±1.5	16.7-25=19.96±0.16	-	22.1-25=23.65±0.66	-	5.01-8.35=6.01±0.07	-	35-43.6=39.02±1.83	-	-
M. alba	L	24-28=25.77±0.84	10-14=12.15±0.88	28-31=29.5±0.64	30-33=31.62±0.62	24-26=25±0.41	28-31.5=29.75±0.72	18-21.1=19.65±0.64	50.9-52=51.5±0.26	39	28.3
	W	13-19=15.75±1.25	8-13=10.75±1.10	22.1-25=23.65±0.66	20-24=22.5±0.62	72.9-74=73.4±0.27	9-12.1=10.65±0.64	35-43.6=39.02±1.83	19-22=20.75±0.64	-	-
M. laevigata	L	16-18=17.25±1.31	32-40=36±1.68	-	8-13=10.87±0.49	-	5.8-8=7±1	-	55-61=58.2±1.25	50.7	12.36
	W	10-14=12±1.31	17.9-20=18.75±0.49	-	9-11.9=10.47±0.62	-	2-2.5=2.3±0.46	-	25-32=29.76±1.48	-	-
B. papyrifera	L	42-47.5=44.7±1.19	4-14=7.75±0.14	22-27.7=24.9±1.61	11.5-15=13.4±1.2	26-28=27.5±0.43	7-8=7.75±0.34	20-25=22.1±1.03	10-15=13.5±2.1	76.7	27.3
	W	22.5-25=23.62±0.55	12-17=14.5±1.7	17-25=21±1.68	9-11=10.3±1.3	71-77=74.5±1.32	2.5-3=2.75±0.46	39.9-42=41.05±0.52	4-6.1=3.5±1	-	-

Table 3. Stomata sizes and percentage of open and close stomata on upper epidermis of investigated species of Moraceae.

S. No	Species	ALG	AWG	SPL	SPW
1	*F. religiosa*	-	-	-	-
2	*F. benghalensis*	27.6	11.6	16.1	9.2
3	*F. elastica*	-	-	-	-
4	*F. virens*	-	-	-	-
5	*F. benjamina*	43.5	8.68	34.5	13.04
6	*F. hawaii*	-	-	-	-
7	*M. alba*	45.18	13.12	42.22	54
8	*M. laevigata*	-	-	-	-
9	*B. papyrifera*	34.5	9.4	32.5	14.2

Key words: ALG: Average length of guard cells, AWG: Average width of guard cells, SPL: Stomatal pore length, SPW: Stomatal pore width, -: Absent.

Table 4. Stomata sizes and percentage of open and close stomata on lower epidermis of investigated species of Moraceae.

S.No	Species	ALG	AWG	SPL	SPW
1	*F. religiosa*	23	6.9	11.5	5.75
2	*F. benghalensis*	32.6	10.5	37.7	11.1
3	*F. elastica*	36	9.2	26	12.5
4	*F. virens*	28	4.6	16.1	2.3
5	*F. benjamina*	43	9.8	13.4	7.2
6	*F. hawaii*	34.12	13.11	43.22	12.6
7	*M. alba*	18.4	2.3	7.3	3.4
8	*M. laevigata*	44.6	12.4	31.5	9.3
9	*B. papyrifera*	16.1	8.6	35.2	3.6

Key words: ALG: Average length of guard cells, AWG: Average width of guard cells, SPL: Stomatal pore length, SPW: Stomatal pore width, -: Absent.

Table 5. Stomatal and subsidiary cells length and width on upper epidermis of investigated species of Moraceae.

S. No	Species	SL	SW	SCL	SCW
1	*F. religiosa*	-	-	-	-
2	*F. benghalensis*	16.87	8.87	15.6	28.9
3	*F. elastica*	-	-	-	-
4	*F. virens*	-	-	-	-
5	*F. benjamina*	10.12	5.75	65.4	54
6	*F. hawaii*	-	-	-	-
7	*M. alba*	29.5	23.65	43	26.84
8	*M. laevigata*	-	-	-	-
9	*B. papyrifera*	24.9	21	48.3	22.8

Key words: SL: Stomatal length, SW: Stomatal width, SCL: Subsidiary cells length, SCW: Subsidiary cells width, -: Absent.

Table 6. Stomatal and subsidiary cells length and width on lower epidermis of investigated species of Moraceae

S.No	Species	SL	SW	SCL	SCW
1	*F. religiosa*	33.8	24.7	23.2	36.5
2	*F. benghalensis*	30.3	42.1	65.4	14.5
3	*F. elastica*	26.9	23	60.2	12.1
4	*F. virens*	27.2	40.7	42.6	13.5
5	*F. benjamina*	28.39	37.6	54.8	31.2
6	*F. hawaii*	25.4	48.3	44	28.85
7	*M. alba*	38.6	21.7	34.7	19.5
8	*M. laevigata*	42.7	47.3	56.8	24.3
9	*B. papyrifera*	49	30.8	20.4	26.72

Key words: SL: Stomatal length, SW: Stomatal width, SCL: Subsidiary cells length, SCW: Subsidiary cells width, -: Absent

Table 7. Stomatal index on upper and lower epidermis of selected species of Moraceae

S.No	Species	Upper epidermis	Lower epidermis
1	*F. religiosa*	62%	31%
2	*F. benghalensis*	22%	13%
3	*F. elastica*	33%	21%
4	*F. virens*	44%	3%
5	*F. benjamina*	2%	54%
6	*F. hawaii*	22%	6%
7	*M. alba*	39%	28%
8	*M. laevigata*	50%	12%
9	*B. papyrifera*	76%	27%

Table 8. Presence and absence of stomata on upper and lower epidermis of selected species of Moraceae.

S.No	Species	Upper epidermis	Lower epidermis
1	*F. religiosa*	Absent	Present
2	*F. benghalensis*	Present	Present
3	*F. elastica*	Absent	Present
4	*F. virens*	Absent	Present
5	*F. benjamina*	Present	Present
6	*F. hawaii*	Absent	Present
7	*M. alba*	Present	Present
8	*M. laevigata*	Absent	Present
9	*B. papyrifera*	Present	Present

A. Light Microscopy (Study of leaf epidermis, stomata, guard cells and stomatal pore)

Fig. 1.1. *Ficus religiosa* (UE) 10X (Epidermis: thick, rectangular and straight margins. Stomata and trichomes: absent). **Fig. 1.2.** *Ficus religiosa* (LE) 40X (Epidermis: thick and polygonal margins. Stomata: anomocytic and staurocytic type. Trichomes: present). **Fig. 1.3.** *Ficus benghalensis* (UE) 10X (Epidermis: thick rectangular sometimes irregular. Stomata: anomocytic type. Trichomes: present).

Fig. 1.4. *Ficus benghalensis* (LE) 40X (Epidermis: thick-walled. Stomata: anomocytic type. Trichomes: present). **Fig. 1.5.** *Ficus elastica* (UE) 10X (Epidermis: thick, polygonal and irregular. Stomata and trichomes: absent). **Fig. 1.6.** *Ficus elastica* (LE) 40X (Epidermis: thick and irregular. Stomata: cyclocytic type. Trichomes: present).

Fig. 1.7. *Ficus virens* (UE) 10X (Epidermis: thick-walled. Stomata and trichomes: absent). **Fig. 1.8.** *Ficus virens* (LE) 40X (Epidermis: thick-walled. Stomata: paracytic type. Trichomes: present). **Fig. 1.9.** *Ficus benjamina* (UE) 10X (Epidermis: thick-walled. Stomata: anomocytic type. Trichomes: present).

Fig. 1.10. *Ficus benjamina* 40X (Epidermis: thick-walled, rectangular, pentagonal or polygonal. Stomata: anomocytic and cyclocytic type. Trichomes: present). **Fig. 1.11.** *Ficus hawaii* (UE) 10X (Epidermis: thick, polygonal or irregular. Stomata and trichomes: absent). **Fig. 1.12.** *Ficus hawaii* (LE) 40X (Epidermis: thick-walled. Stomata: anomocytic type. Trichomes: present).

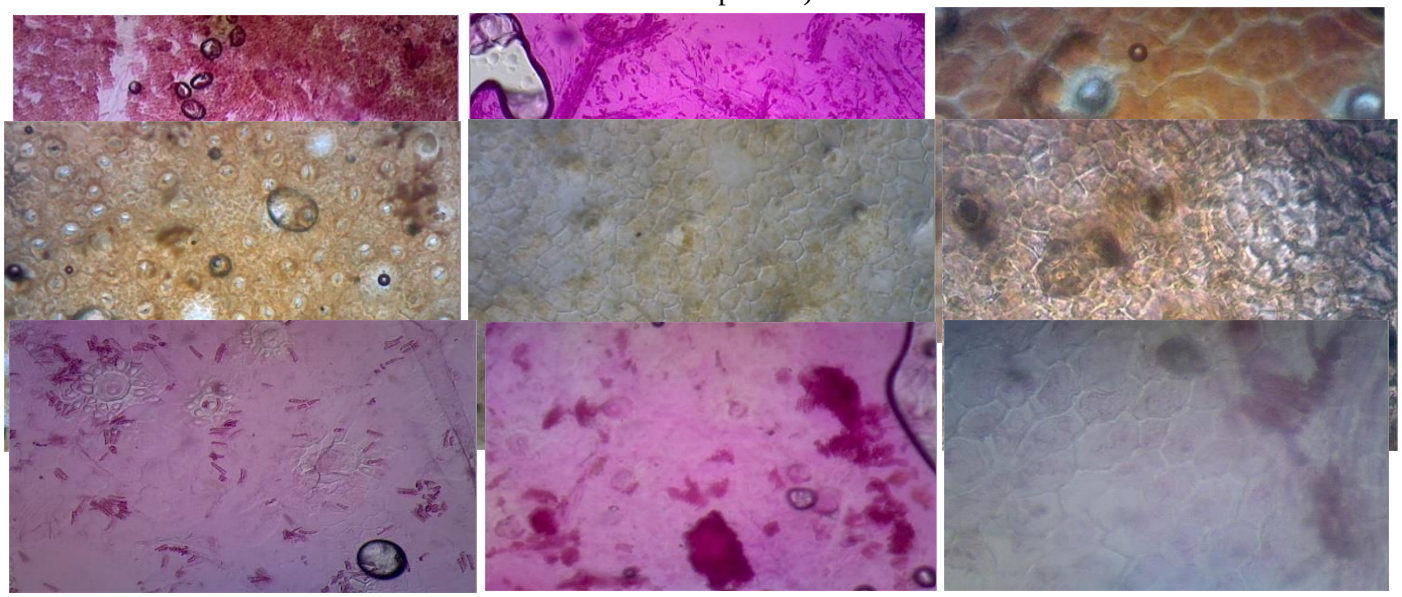

Fig. 1.13. *Morus alba* (UE) 10X (Epidermis: thin- walled, polygonal or irregular. Stomata: anomocytic and anisocytic type. Trichomes: present). **Fig. 1.14.** *Morus alba* (LE) 40X (Epdermis: thin-walled. Stomata: anomocytic type. Trichomes: present). **Fig. 1.15.** *Morus laevigata* (UE) 10X (Epidermis: thin- walled, pentagonal or irregular. Stomata and trichomes: absent).

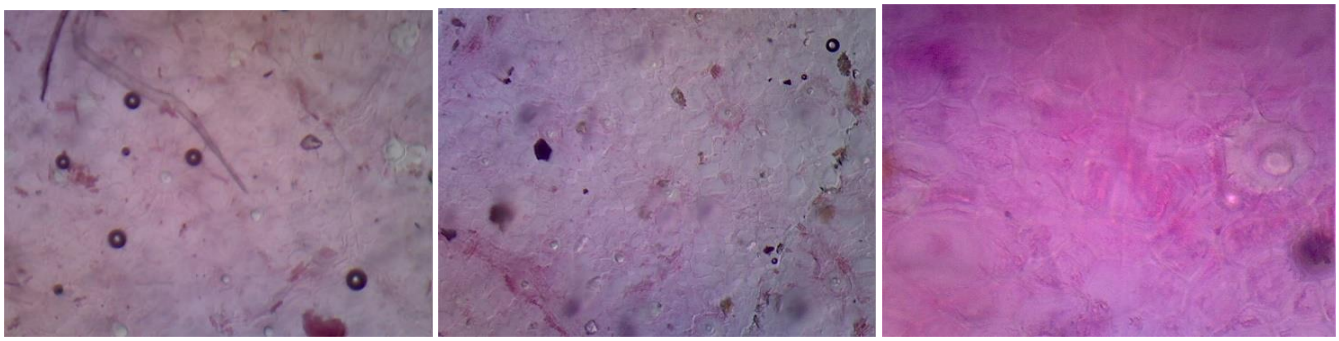

Fig. 1.25. *Morus laevigata* (LE) 40X Epidermis: thin, polygonal or irregular. Stomata: anomocytic and paracytic type. Trichomes: present). **Fig. 1.26.** *Broussonetia papyrifera* (UE) 10X (Epidermis: thin-walled, rectangular or polygonal. Stomata: paracytic type. Trichomes: present. **Fig. 1.27.** *Broussonetia papyrifera* (LE) 40X (Epdermis: thin-walled and polygonal. Stomata: anomocytic and laterocytic type. Trichomes: present).

B. Scanning Electron Microscopy (Study of stomata, epidermis and trichomes)

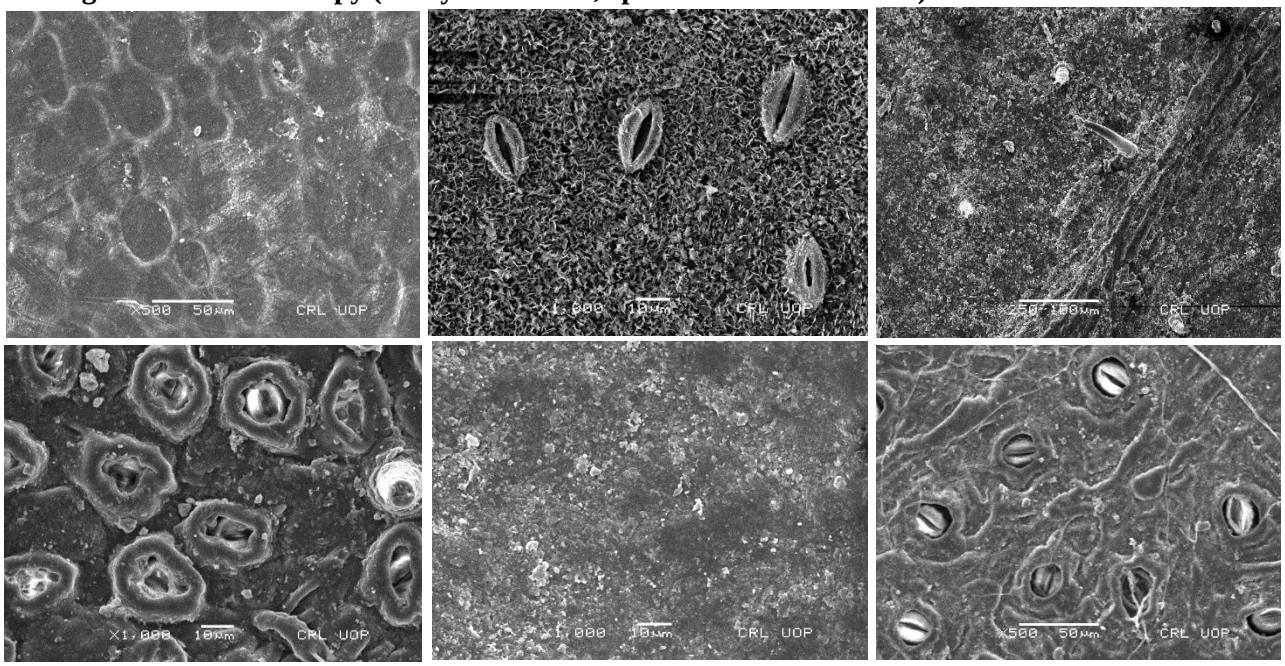

Fig. 2.1. *Ficus religiosa* (UE) 500X Epidermal cells. **Fig. 2.2.** *Ficus religiosa* (LE) 1000X Epidermal cells and stomatal cells. **Fig. 2.3.** *Ficus benghalensis* (UE) 250X Trichomes. **Fig. 2.4.** *Ficus benghalensis* (LE) 1000X Stomatal cells. **Fig. 2.5.** *Ficus elastica* (UE) 1000X Epidermal cells. **Fig. 2.6.** *Ficus elastica* (LE) 500X Stomatal cells.

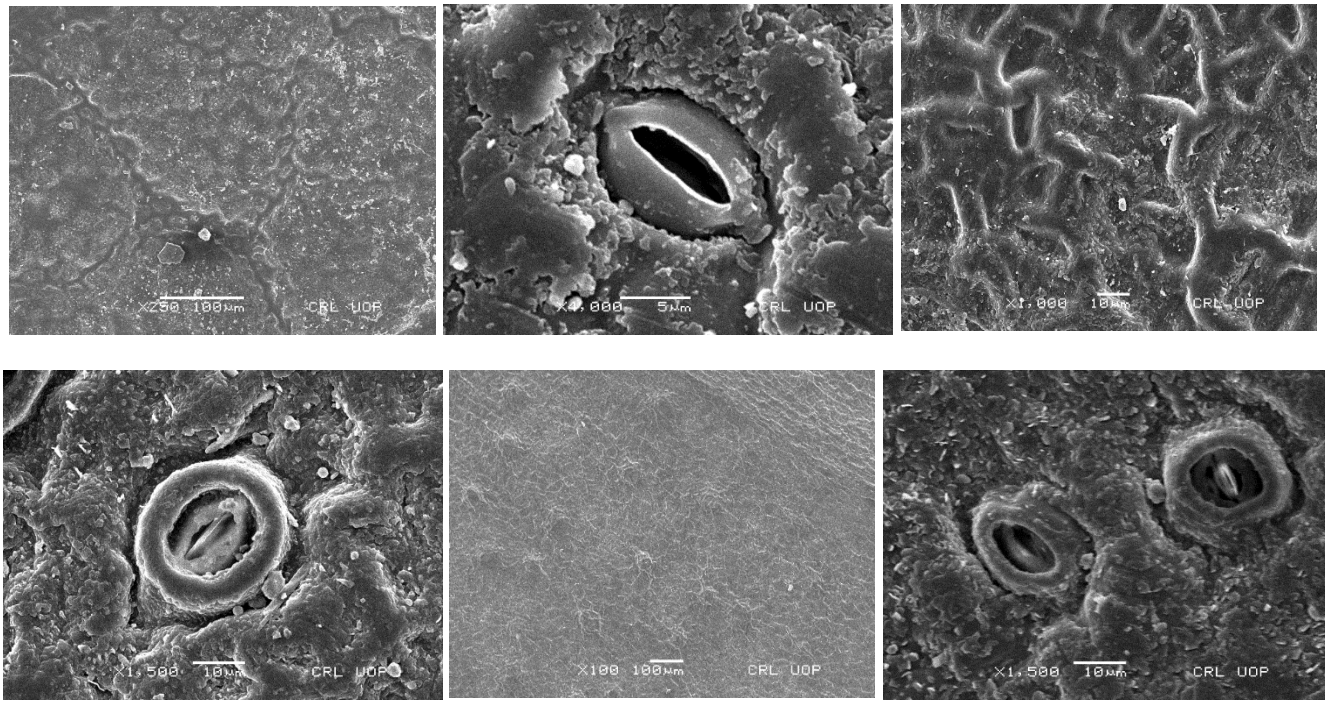

Fig. 2.7. *Ficus virens* (UE) 250X Epidermal cells. **Fig. 2.8.** *Ficus virens* (LE) 1000X Stomata. **Fig. 2.9.** *Ficus benjamina* (UE) 1000X Epidermal cells. **Fig.2.10.** *Ficus benjamina* (LE) 1500X Stomata. **Fig. 2.11.** *Ficus hawaii* (UE) 100X Epidermal cells and Stomata. **Fig. 2.12.** *Ficus hawaii* (LE) 1500X Stomatal cells.

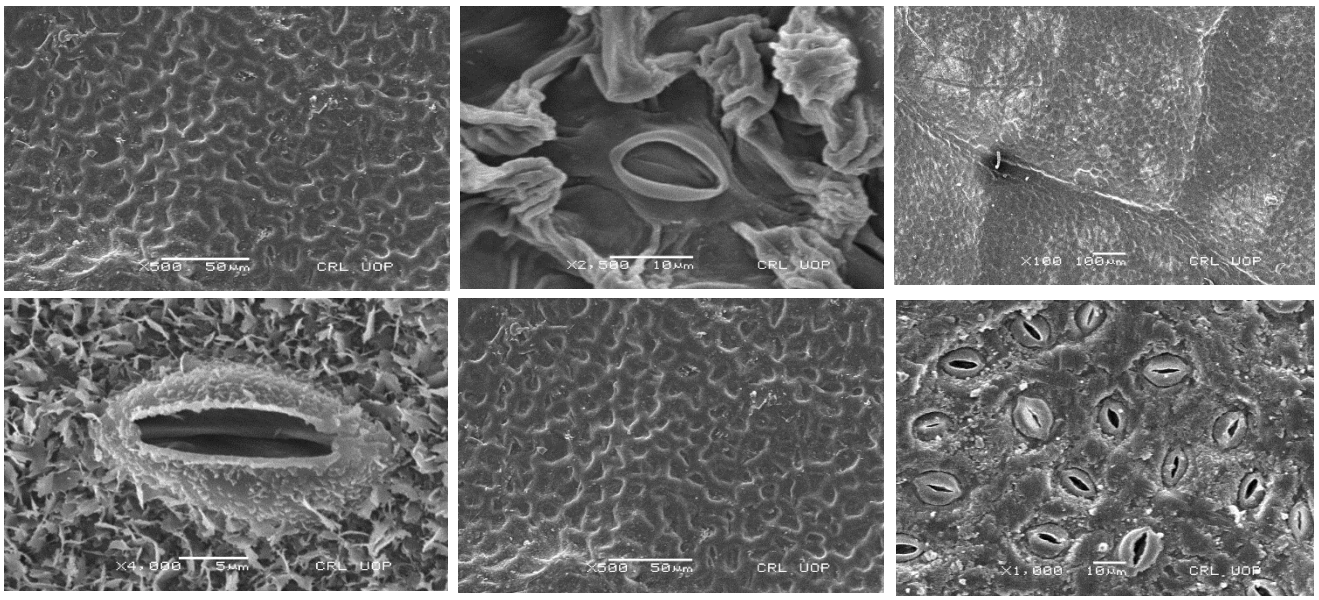

Fig. 2.13. *Morus alba* (UE) 500X Epidermal cells. **Fig. 2.14.** *Morus alba* (LE) 2500X Stomata. **Fig. 2.15.** *Morus laevigata* (UE) 100X Epidermal cells. **Fig. 2.16.** *Morus laevigata* (LE) 4000X Stomata. **Fig. 2.17.** *Broussonetia papyrifera* (LE) 500X Epidermal cells. **Fig. 2.18.** *Broussonetia papyrifera* (LE) 1000X Stomatal cells

IV. DISCUSSION

Leaf is an important organ of the plant which helps in making of food for the plant through the process of photosynthesis also it helps in the process of respiration in plants. It is composed of leaf base, lamina, and petiole (Garb & Srivastava 2005). The characteristics of epidermis has been examined in many families of Angiosperms and also a valued information has been assembled. The anatomical features of leaf are widely used in the classification of species and also to find out the relationship between morphological of same species (Edeoga and Eboka 2000; Edeoga and Ikem 2002; Essiet, 2004 and Okeke *et al*. 2009). Study of leaf epidermis is having significance in findings of phylogeny and taxonomy of closely related species. Leaf epidermal characters is given importance by the taxonomists to resolve the taxonomic conflicts (Taia, 2005). Morphological characters of leaf epidermal cells, i.e., shape of anticlinal walls and the distribution, density and type of stomata and trichomes are of potential taxonomic significance and have been widely used for the classification of taxa in various plant families (Stace, 1984; Baranova, 1992; Ahmad *et al*. 2010; Nurit-Silva & De Fatima Agra 2011). Anatomical characters are very important for the identification of problematic taxa at species level in some cases (Kowsalya *et al*. 2017; Stace, 1980). In literature numbers of families were identified using foliar epidermal characters (Baranova, 1972; Downton and Tregunna 1968). Since a long time, the anatomical characters are used in identification of species, genera and families (Li *et al*. 2016; Bo *et al*. 2010). Foliar epidermal anatomical characters such as trichomes and stomata are useful taxonomical tools for identification of many plant species (Diane *et al.* 2003; Kadiri *et al.* 2009; Syedi and Salmaki, 2015; Xiang *et al.* 2010). Scotland *et al.* (2003) opinioned that careful and decisive anatomical studied of fewer morphological characters, in framework of molecular phylogenies is productive to integrating the powers of morphological data with those of sequence information. Since the leaf epidermal studies are considered important in phylogeny and taxonomy (Taia, 2005), attention of plant taxonomists has been attracted towards the leaf epidermal anatomical studies to resolve the taxonomic problems (Hardin, 1979; Ming & Wen, 1993). In the current study, the foliar epidermal anatomical characteristics in nine species of Moraceae were studied using light microscopy (LM) and scanning electron microscopy (SEM). But the pin point purposes of the present study were to: (a) identify and compare the variation of different stomatal types in different species of the genus, (b) observe the quantitative and qualitative characters of leaf epidermal cells. Different epidermal characteristics were studied in nine species of family Moraceae. The recorded characters were analyzed using different quantitative measures i.e., stomatal length, number of epidermal cells, epidermal cell size (L x W), stomata size (L x W), subsidiary cell size (L x W), stomatal pore size (L x W) and stomatal index. The number of stomata per unit leaf area and the number of epidermal cells per unit area was based on the observation of 3 samples, and the area for counting the stomata and epidermal cells of each sample was ($0.1017mm^2$). Quantitative features are represented by minimum – maximum = mean $\pm$ standard error (for example 10-14 = 13.8 $\pm$ 3.24). For each character three findings were noted for both adaxial and abaxial surface then the noted quantitative data was processed by using EXCEL to determine the minimum maximum, mean and the standard error. The data obtained was very helpful in the identification of species and the nature of epidermal characters. Foliar epidermal micromorphological characters and the results of the qualitative and quantitative analysis of the 9 species of the family Moraceae under scanning electron microscope (Electron Micrographs EM-1 – EM-9) and light microscope (LM) Plate, I-IX. All these characters belong to distinct epidermal structures, i.e., epidermis and stomata. Stomatal index of *Broussonetia papyrifera* 76.7% is the highest and *Ficus benjamina* 2.13% is the lowest among all species on adaxial surface. *Ficus religiosa* 61.8% is the highest and *Ficus virens* 3.06% is the lowest on abaxial surface. The leaves of *Ficus religiosa* L., *Ficus elastica* (Roxb.), *Ficus virens* (Aiton.), *Ficus hawaii* and *Morus laevigata* L. were recorded as hypostomatic having stomata present only on abaxial surface. The leaves of *Ficus benghalensis*, *Ficus benjamina, Broussonetia papyrifera* and *Morus alba* L. were amphistomatic having stomata present on both adaxial and abaxial surfaces. On the basis distribution of stomata, the leaf may be amphistomatic i.e., (stomata present on both adaxial and abaxial surfaces) or epistomatic i.e., (stomata present only on adaxial surface) or hypostomatic i.e., (stomata present only on the abaxial surface) (Perveen *et al*., 2007). *B. papyrifera* L. having epidermal cells, stomatal complex and subsidiary cells present on adaxial surface. Epidermal cells were thin walled, rectangular, polygonal or irregular cells consisting of trichomes. The margins of these epidermis cells do not show any waviness. Stomata were more on adaxial surface as compared to abaxial surface. Paracytic type of stomata were observed on adaxial surface. The abaxial surface consists of epidermal cells, trichomes, stomatal complex and subsidiary cells. The stomata were surrounded by small subsidiary cells, whereas the guard cells were comparatively small in size and each stoma were surrounded by two subsidiary cells.

Epidermal cells were polygonal with straight margins. Anomocytic and laterocytic type of stomata were present on abaxial surface. *M. alba* L. having epidermal cells, trichomes, stomatal complex and subsidiary cells present on adaxial surface. Epidermal cells were thin walled, polygonal or irregular having straight anticlinal walls. Stomata were more on adaxial surface as compared to abaxial surface. Anomocytic and anisocytic type of stomata were observed on adaxial surface. The abaxial surface consists of epidermis, stomatal complex and subsidiary cells. Epidermal cells were thin, smooth and irregular in shape. Anomocytic type of stomata were observed. *M. laevigata* L. having epidermal cells, trichomes. Stomatal complex and subsidiary cells were absent on adaxial surface. Epidermal cells were thin walled, pentagonal or hexagonal in shape. Stomata were absent on adaxial surface. The abaxial surface consists of epidermis, trichomes, stomatal complex and subsidiary cells. Epidermal cells were varied in size and shape may be pentagonal or irregular in shape. Anomocytic and paracytic type of stomata were observed on abaxial surface. *F. benghalensis* L. having epidermal cells, trichomes and stomata. Epidermal cells were thick walled, rectangular in shape. Anomocytic type of stomata were present on adaxial surface. The abaxial surface consists of epidermal cells, stomata and subsidiary cells. Epidermal cells were rectangular in shape sometimes irregular in shape. Anomocytic type of stomata were present on adaxial surface. *F. benjamina* L. having epidermal cells, stomata and trichomes. Epidermal cells were thick walled and contain lines. Anomocytic type of stomata were present on adaxial surface. Anomocytic type of stomata were present on adaxial surface. The abaxial surface consists of epidermal cells, stomata, subsidiary cells and trichomes. Epidermal cells were rectangular, pentagonal or polygonal in shape with straight margins. Anomocytic and cyclocytic type of stomata were present on abaxial surface. *F. elastica* Roxb. having epidermal cells and trichomes while stomata were absent on adaxial surface. Epidermal cells were thick walled, polygonal or irregular in shape. The abaxial surface consists of epidermal cells, trichomes, stomata and subsidiary cells. Epidermal cells were irregular in shape. Anomocytic and cyclocytic type of stomata were present on abaxial surface. (Fig. 1.14., 1.15). *F. hawaii* L. having epidermal cells and trichomes while stomata were absent on adaxial surface. Epidermal cells were thick walled, polygonal or irregular in shape. The abaxial surface consists of epidermal cells, trichomes, stomata and subsidiary cells. Epidermal cells were irregular or polygonal shaped with straight margins. Anomocytic type of stomata were present on abaxial surface. *F. religiosa* L. having epidermal cells, while trichomes, stomata and subsidiary cells were absent. Epidermal cells were thick walled, irregular or polygonal in shape. The abaxial surface consists of epidermal cells, trichomes, stomata and subsidiary cells. Anomocytic and staurocytic type of stomata were present on abaxial surface. *F. virens* Aiton. having epidermal cells and trichomes while stomata and subsidiary cells were absent. Epidermal cells were rectangular in shape. The abaxial surface consists of epidermal cells, trichomes, stomata and subsidiary cells. paracytic type of stomata were present on abaxial surface. (Fig. 1.16., 1.17). The epidermal wall whether thick or thin is also helpful to some extent for identification. The epidermal morphology and stomatal ontogeny are distinguishing characters between primitive and advance types and are helpful in morphological and ontogenetical classification (Rasmussen, 1981). The different types of trichomes found are of unicellular trichomes, glandular peltate trichomes, pear head shaped trichomes and multicellular trichomes. On adaxial surface maximum length of epidermal cells was 42-47.5 µm = (44.7) $\pm$ 1.19, minimum length of epidermal cells was 9.5-12 µm = (10.75) $\pm$ 0.59, maximum width of epidermal cells was 22.5-25 µm = (23.62) $\pm$ 0.55, minimum width of epidermal cells was 9-12 µm = (11) $\pm$ 2.11, maximum length of stomatal complex was 28-31 µm = (29.5) $\pm$ 0.64, minimum length of stomatal complex was 6-12.5 µm = (10.12) $\pm$ 1.47, maximum width of stomatal complex was 22.1-25 µm = (23.65) $\pm$ 0.66, minimum width of stomatal complex was 3-8 µm = (5.75) $\pm$ 1.10, maximum length of subsidiary cells was 43-47.5 µm = (44.67) $\pm$ 1.00, minimum length of subsidiary cells was 14.6-16 µm = (15.5) $\pm$ 0.32, maximum width of subsidiary cells was 39.9-42 µm = (41.05) $\pm$ 0.52, minimum width of subsidiary cells was 15.9-17 µm = (16.42) $\pm$ 0.22, maximum length of stomatal pore was 29-30.6 µm = (29.87) $\pm$ 0.33, minimum length of stomatal pore was 21-27 µm = (23.8) $\pm$ 1.24, maximum width of stomatal pore was 72.9-74 µm = (73.4) $\pm$ 0.27, minimum width of stomatal pore was 3.9-5 µm = (4.42) $\pm$ 0.22, maximum stomatal index was 76.7%, minimum stomatal index was 2.13% on the same surface. On abaxial surface maximum length of epidermal cells was 32-40 µm = (36) $\pm$ 1.68, minimum length of epidermal cells was 4-14 µm = (7.75) $\pm$ 0.14, maximum width of epidermal cells was 17.9-20 µm = (18.75) $\pm$ 0.49, minimum width of epidermal cells was 6-10 µm = (8.5) $\pm$ 2.23, maximum length of stomatal complex was 30-33 µm = (31.62) $\pm$ 0.62, minimum length of stomatal complex was 8-13 µm = (10.87) $\pm$ 0.49, maximum width of stomatal complex was 22.1-25 µm = (23.65) $\pm$ 0.66, minimum width of stomatal complex was 4-6 µm = (5.12) $\pm$ 0.45, maximum length of subsidiary cells

was 55-61 µm = (58.2) ± 1.25, minimum length of subsidiary cells was 8-16 µm = (13.5) ± 2.13, maximum width of subsidiary cells was 35-43.6 µm = (39.02) ± 1.83, minimum width of subsidiary cells was 4-6.1 µm = (3.5) ± 1, maximum length of stomatal pore was 36-40.8 µm = (38.45) ± 1.16, minimum length of stomatal pore was 5.8-8 µm = (7) ± 1, maximum width of stomatal pore was 10-11.9 µm = (911.15) ± 0.44, minimum width of stomatal pore was 1-2 µm = (1.7) ± 1.12, maximum stomatal index was 61.8%, minimum stomatal index was 3.06% on the same surface.

CONCLUSION

The light microscopy and scanning electron microscopy investigation describes the foliar epidermal anatomy of nine selected species of family Moraceae. Anatomical studies of the leaves of some selected species were carried out through light microscope. The present study showed that foliar epidermal features through light microscope (LM) and scanning electron microscope (SEM) have a significant and important taxonomic value. These features are of systematic significance for the precise and discrimination of species of Moraceae. Qualitative and quantitative data are of significant value and importance for the taxonomists of plant in the identification of selected species of plants. It shows significant results and conclusions about the selected species of Moraceae. Some of the conclusions are given below. Stomatal type and stomatal index are a useful tool in the classification and identification of species. Scanning electron microscopy and light microscopy play an important and significant role and are useful tool in taxonomy. Stomatal types and stomatal index on the basis of keys are helpful in identification of selected species. Statistical analysis was also very useful to show the variations between the numbers of stomata and epidermal cells. Micromorphological study will be helpful in chemotaxonomy, in molecular studies and in genetical based taxonomy.

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