

LEAF MORPHOLOGY, ARCHITECTURAL PATTERN AND CUTICULAR FEATURES IN SOME INDIAN MEMBERS OF BORAGINACEAE

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Abstract

The present paper deals with the leaf morphological characters, architectural pattern and epidermal features of six genera: *Cordia* Linn., *Heliotropium ovalifolium* Linn., *Ehretia* R. Br., *Coldenia* Linn., *Cynoglossum* Linn., *Trichodesma* R. Br.) and nine species (*Cordia myxa* Linn., *Cordia sebestena* Linn., *Heliotropium ovalifolium* Forsk., *Heliotropium strigosum* Willd., *Heliotropium indicum* Linn., *Ehretia laevis* Roxb., *Coldenia procumbens* Linn., *Cynoglossum lanceolatum* Forsk., *Trichodesma indicum* R.Br.) of Boraginaceae. It has been observed that taxa investigated here have simple leaves which are petiolate except in two species (*Cynoglossum lanceolatum* Forsk., *Trichodesma indicum* R. Br.).

Leaf architectural pattern shows uniformly unicostate reticulate nature in all taxa, but there are variations in number and nature of these secondaries. The cuticles show both hypostomatic and amphistomatic types and the stomata are all anomocytic type.

Introduction

The leaf anatomical work, specially of the architectural pattern and cuticular features has received little attention until now from the anatomists. Therefore, the present authors undertook investigations into these two aspects in order to evaluate the range of diversity in architectural pattern and epidermal features in nine commonly occurring members of Boraginaceae in Eastern region of India.

A review of literature on these two aspects shows that Ashby (1948 a), Baranova (1975), Cotthem (1970), Di Fulvio (1982), Duun, Sharma and Campbell (1965), Foster (1952), Gupta (1961), Gupta and Dutta (1979), Neischlova and Kaplan (1976) studied epidermal features, while Hickey (1973), Kundu (1974), Melville (1976), Wylie (1943) studied leaf architectural patterns, their classification and taxonomic values in dicots. Metcalfe and Chalk (1979) gave general range of these features in this family. Therefore, the detailed investigations in these two aspects on certain members of Boraginaceae provide additional informations regarding the taxonomic value of these two features for segregating species and genera.

The anatomical description of the species given here, are based on the terminologies followed previously by various workers and the taxa have been arranged on the basis of Bentham and Hooker's classification (1862-1883).

Material and Methods

For leaf architectural preparation fresh or dried leaves were treated with 5% NaOH solution for bleaching. After clearing in NaOH solution, the material was transferred to chloral hydrate solution following the method of Foster (1952) as modified by Hickey (1973). Finally it was stained in 1% aqueous safranin solution followed by gradual dehydration and permanent slide was prepared in Canada balsam.

For cuticular preparation, fresh or dried leaves were kept in concentrated 10% Nitric acid for 24 to 48 hours, depending on the thickness of cuticle. After maceration, leaves were washed thoroughly in water to make them acid free. These were then treated with 5% KOH or NaOH solutions for 2-5 minutes. Then washed thoroughly to make them alkali free. By incision on two sides of the leaf, the two cuticles were separated by means of fine needle and were separately mounted in glycerine jelly.

Observations

Cordia myxa Linn.

Pl. 1, fig. 1; Pl. 2, fig. 9; Text-figs. 1, 10, 21

Leaves simple, alternate, 7.5—12.5 cm. \times 6.3—11.4 cm.; broadly ovate, obtuse, margins more or less scabrous above, without white discs (Cystolith) on the upper surface, base obtuse, normal; petioles 2-4 cm. long.

Leaf architecture is unicostate reticulate with 5-7 pairs of secondary veins. Secondary veins are of eucamptodromous type; reticulation is upto 4th order of veinlets; areole formation is mostly by 4th and 5th order of veinlets or 5th order veinlet alone, shape of the areole is quadrandular to polygonal, areoles are with mostly one free vein ending; free vein ending are formed by 6th order of veinlets, traverse 1/2-3/4 the areole, mostly unbranched, few are branched once, consisting of 3-4 rows of tracheids; all categories of veins and veinlets are ensheathed with parenchymatous cells with various sizes; tips are mostly slightly curved. Marginal ultimate venation is fimbriate.

Leaf is amphistomatic; lower surface is showing mostly anomocytic type of stomata, stomatal apparatus is surrounded by 3-5 epidermal cells: guard cells are not sunken; inner wall of the guard cells are thickened. Stomata are present all over the surface, except on veins, irregularly arranged, variously oriented. Stomatal index is 16.2. Epidermal cells are irregular in shape, variously oriented and undulate walled. Trichomes are unicellular, nonglandular, thick base, apex blunt with tuberculate projections on the trichome base. Upper surface also shows anomocytic type of stomata. Stomatal apparatus, thickening, arrangement and orientation are similar to those present in the lower surface but only exception is that very few stomata are present on the upper surface. Epidermal cells are rectangular linear to pentangular in shape, randomly arranged and mostly sinuous, few undulate-walled. Trichomes are similar to those present in the lower surface.

Cordia sebestena Linn.

Pl. 1, fig. 2; Pl. 2, fig. 12; Text-figs. 2, 11, 19

Leaves simple, alternate, 12.0—20.0 cm \times 8.0—12.0 cm, lamina slightly asymmetrical, ovate, obtuse to acute, margin entire, surface roughly hairy, base round; petioles 2-3 cm. long, petiole surface hairy. Leaf architecture is unicostate reticulate with 7-8 pairs of secondary veins. Secondary veins are of brochidodromous (apical few pairs are not true brochidodromous) type; reticulation is upto 5th order of veinlets; areole formation is mostly 4th and 5th order of veinlets, shape of the areole is rectangular to pentagonal with one free vein ending, free vein ending is formed by 6th order of veinlets, traverse 1/4-1/2 the areole, branched or unbranched, consisting of two rows of tracheids; vein endings are partially ensheathed with parenchymatous cells, tips are straight or slightly curved. Marginal ultimate vena-

tion is looped. Leaf is hypostomatic, lower surface showing mostly anomocytic stomata. Stomatal apparatus are surrounded by 4-5 epidermal cells; guard cells are not sunken, the inner wall of guard cells are thickened. Stomata are present all over, except on vein and veinlets, irregularly arranged, variously oriented, stomatal index is 14.88. Epidermal cells are irregular in shape, variously oriented and sinuous walled. Trichomes are unicellular, nonglandular, thick base, apex blunt, 8-10 epidermal cells surrounding the trichome base. Upper epidermal cells are polygonal to anisodiametric in shape, randomly arranged, sinuous walled. Trichomes are similar to those in the lower surface.

Heliotropium ovalifolium Forsk.

Pl. 1, fig. 3; Pl. 2, fig. 13; Text-figs. 3, 12, 24

Leaves simple, alternate, 1.0-2.2 cm x 0.4-0.9 cm, symmetrical, elliptic or ovate, mucronate, margin entire, both petiole surface and lamina surface are closely hairy with appressed long silky hairs, base is acute cuneate, petioles of lower leaves 0.9-1.3 cm long, those of upper leaves usually shorter.

Leaf architecture is unicostate reticulate with 3 pairs of secondary veins. Secondary veins are of reticulodromous type; reticulations is up to 3rd order of veinlets; areole formation is mostly by 4th and 5th order of veinlets; shape of the areole is quadrangular to polygonal, areoles are with mostly single free vein ending; free vein endings are formed by 6th order of veinlets, traverse 1/4-1/2 the areole, mostly unbranched, simple, consisting of two to three rows of tracheids; all categories of veins and veinlets are not sheathed; tips are mostly curved. Marginal ultimate venation is complete.

Leaf is amphistomatic, lower surface is showing mostly anomocytic type of stomata, stomatal apparatus is surrounded by 4-5 epidermal cells; guard cells are not sunken; wall of the guard cells is thick along the aperture only. Stomata are present all over the surface except on veinlets and trichome base, irregularly arranged, variously oriented. Stomatal index is 22.4.

Epidermal cells are irregular in shape, variously oriented and undulate walled. Trichomes are long unicellular, nonglandular, with thick base and acute apex. Upper surface also shows anomocytic type of stomata. Stomatal apparatus, thickening, arrangement and orientation are similar to those present in the lower surface. Stomatal index is 17.8. Epidermal cells are irregular in shape, randomly arranged and mostly sinuous walled. Trichomes are similar to those present in the lower surface.

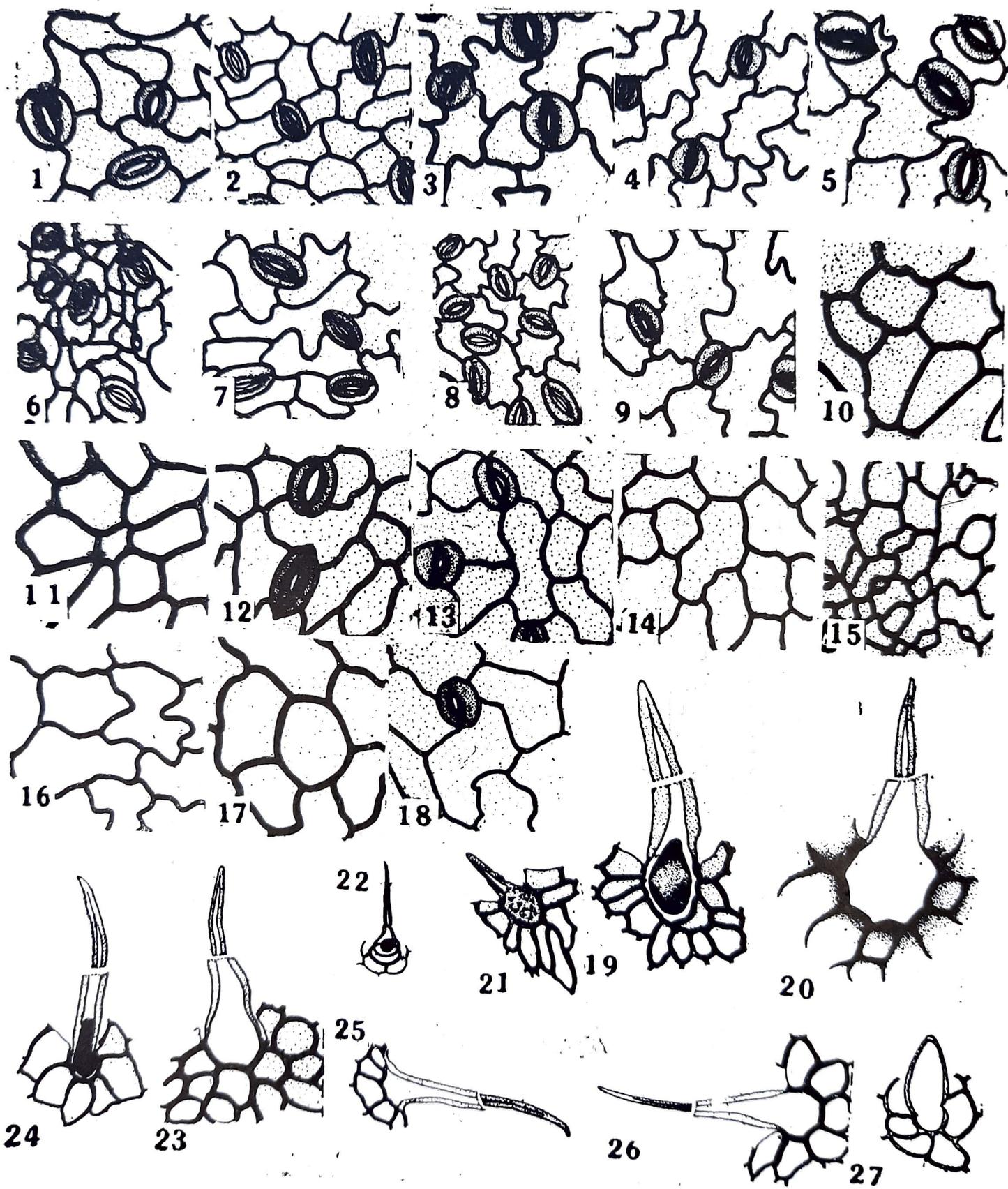
Heliotropium strigosum Willd.

Pl. 1, fig. 6; Text-figs. 4, 13, 20

Leaves simple, alternate, 1.0-2.5 cm x 0.2-0.4 cm, symmetrical, lanceolate, acute, margin entire, both surface hairy, base is obtuse normal, petiole very short.

Leaf architecture is unicostate reticulate with 4-5 pairs of secondary veins. Secondary veins are of cladodromous type; reticulation is upto 3rd order of veinlets; areole formation is mostly by 3rd and 4th order of veinlets, shape of the areole is triangular, polygonal or round, areoles are with single free vein ending, free vein ending are formed by 5th order of veinlets, traverse 1/4-1/2 the areole, mostly unbranched, consisting of one to four rows of tracheids; all categories of veins and veinlets are not sheathed; tips are slightly curved. Marginal ultimate ventation is incomplete.

Leaf is amphistomatic, lower surface showing anomocytic type of stomata. Stomatal



Text-figs. 1-27

apparatus is surrounded by 4-5 epidermal cells; guard cells are not sunken, wall of guard cells is thick along the aperture only. Stomata are present all over the surface, except on veinlets and trichome base, irregularly arranged and variously oriented. Stomatal index is 31.57. Epidermal cells are irregular in shape, variously oriented and undulate walled. Trichomes are unicellular, nonglandular with thick base and acute apex. Upper surface also shows anomocytic type of stomata. Stomatal apparatus, thickening, arrangement and orientation are similar to those present in the lower surface. Stomatal index is 15.61. Epidermal cells irregular in shape, randomly arranged and sinuous walled. Trichomes are similar to those present in lower surface.

Heliotropium indicum Linn.

Pl. 1, fig. 5; Pl. 2, fig. 14; Text-figs. 5, 14, 22

Leaves simple, alternate or often subopposite, 4.5-10.0 cm × 2.5-5.0 cm, symmetrical, ovate or ovate-oblong, obtuse or subacute, usually with a few scattered hair above, minutely pilose beneath, the margin much undulate or subserrate, base cordate or narrowed, often unequal sided and then suddenly contracted and decurrent into petiole, petiole 2.0-3.7 cm long, more or less winged.

Leaf architecture is unicostate reticulate with 5-6 pairs of secondary veins. Secondary veins are of cladodromous type; reticulation is upto 3rd order of veinlets; areole formation is mostly by 4th and 5th order or 5th order of veinlet alone. Shape of the areole is quadrangular to polygonal, areoles are with one free vein ending; free vein endings are formed by 6th order of veinlets, traverse 1/4-1/2 the areole, mostly unbranched, few are branched (twice), consisting of two to three rows of tracheids; all categories of veins and veinlets are not sheathed, tips are mostly simple. Marginal ultimate venation is looped.

Leaf is amphistomatic; lower surface showing mostly anomocytic type of stomata, stomatal apparatus is surrounded by 3-4 epidermal cells; guard cells are thick along the aperture only. Stomata are present all over the surface except on veins and veinlets, irregularly arranged, variously oriented. Stomatal index is 38.29. Epidermal cells are irregular in shape, variously oriented and undulate walled. Trichomes are unicellular, nonglandular, with thick base and sharp pointed apex. Upper surface also shows anomo-

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- Text-figure 1. *Cordia myxa* Linn. :—1. Lower surface showing few stomata and epidermal cells, ×250; 10. Upper surface showing few epidermal cells, ×250; 21. Trichome, ×125.
- Cordia sebestena* Linn. : 2. Lower surface showing few stomata and epidermal cells, ×250; 11. Upper surface showing a few epidermal cells, ×250; 19. Trichome, ×125.
- Heliotropium ovalifolium* Forsk. : 3. Lower surface showing few stomata and epidermal cells, ×250; 1. Upper surface showing stomata and epidermal cells, ×250; 24. Trichome, ×125.
- Heliotropium strigosum* Willd. : 4. Lower surface showing few stomata and epidermal cells, ×250; 13. Upper surface showing few stomata and epidermal cells, ×250; 20. Trichome, ×125.
- Heliotropium indicum* Linn. : 5. Lower surface showing few stomata and epidermal cells ×250; 14. Upper surface showing few epidermal cells, ×250; 22. Trichome, ×125.
- Ehretia laevis* Roxb. : 6. Lower surface showing few stomata and epidermal cells, ×250; 15. Upper surface showing few epidermal cells, ×250; 27. Trichome, ×250.
- Coldenia procumbens* Linn. : 7. Lower surface showing few stomata and epidermal cells, ×250; 16. Upper surface showing few epidermal cells, ×250; 26. Trichome, ×125.
- Cynoglossum lanceolatum* Forsk. : 8. Lower surface showing few stomata and epidermal cells, ×250. 17. Upper surface showing few epidermal cells, ×250; 26. Trichome ×125.
- Trichodesma indicum* R.Br. : 9. Lower surface showing few stomata and epidermal cells, ×250; 18. Upper surface showing a stomata and epidermal cells, ×250; 23. Trichome, ×125.

cytic type of stomata. Stomatal apparatus, thickening, arrangement and orientation are similar to those present in the lower surface. Stomatal index is 21.59.

Epidermal cells are irregular in shape, randomly arranged and mostly undulate walled. Trichomes are similar to those present in the lower surface.

Ehretia laevis Roxb.

Pl. 2, fig. 11; Text-figs. 6, 15, 27

Leaves simple, alternate, 6.5-12.5 cm × 4.0-7.5 cm, symmetrical, very variable, elliptic-oblong or ovate, acute to obtuse, entire, glabrous or nearly so when mature, paler beneath, base usually unequally cuneate, but some times rounded or almost truncate at the base, petioles 1.0-1.5 cm long.

Leaf architecture is unicostate reticulate with 7-10 pairs of secondary veins. Secondary veins are of brochidodromous (basal two pairs are not true brochidodromous) type; reticulation is upto 5th order of veinlets; areole formation is mostly by 4th and 5th order of veinlets, shape of the areole is quadrangular to pentangular, areoles are mostly with one to two free vein endings, free vein endings are formed by 5th order of veinlets, traverse 3/4 the areole. simple or branched upto twice, consisting of one to three rows of tracheids; all categories of vein and veinlets are not sheathed; the tips are curved. Marginal ultimate venation is looped.

Leaf is hypostomatic; lower surface showing anomocytic type of stomata, stomatal apparatus is surrounded by 4-5 epidermal cells, guard cells are not sunken, the wall of the guard cells is thick only along the aperture. Stomata present all over the surface except on primary vein and secondary vein, irregularly arranged, variously oriented. Stomatal index is 13.5.

Epidermal cells are irregular in shape, randomly arranged and sinuous walled. Trichomes are unicellular, nonglandular with thick base and blunt apex. Upper epidermal cells are also irregular, randomly arranged and sinuous-walled. Trichomes are similar to those present in the lower surface.

Coldenia procumbens Linn.

Pl. 2, fig. 7, 10; Text-figs. 7, 16, 25

Leaves simple, alternate, crisped, 1.2-3.8 cm × 0.7-1.8 cm, asymmetrical shape, ovate-oblong in form; rounded at the apex, coarsely serrate, very hairy on both the surfaces, base is acute decurrent in one side and in another side obtuse decurrent, petioles short, 0.3-0.9 cm long, shaggy.

Leaf architecture is unicostate reticulate with 3-4 pairs of secondary veins. Secondary veins are of cladodromous type; reticulation is up to 3rd order of veinlets; areole formation is mostly 3rd and 4th order of veinlets or 4th order of veinlets alone, shape of the areole is triangular to quadrangular, areoles are with mostly two free vein endings; free vein endings are formed by 6th order of veinlets, traverse 3/4 the areole, mostly branched (once), few are unbranched, consisting of two to three rows of tracheids; all categories of veins and veinlets are not sheathed; tips are mostly irregularly curved. Marginal ultimate venation is incomplete.

Leaf is amphistomatic, lower surface is showing anomocytic stomata, stomatal apparatus is surrounded by 3-4 epidermal cells, guard cells are not sunken, wall of the guard cells is thick along the aperture only. Stomata is present all over except on vein and veinlets and trichome base, irregularly arranged and variously oriented. Stomatal index is

26.22. Epidermal cells are irregular in shape, randomly arranged and undulate walled. Trichomes are long unicellular nonglandular with thick base and acute apex. Upper surface also shows anomocytic type of stomata. Stomatal apparatus, thickening, arrangement and orientation are similar to those present in the lower surface. Stomatal index is 17.04. Epidermal cells are irregular in shape, randomly arranged and mostly with undulate walled. Trichomes are similar to those present in the lower surface.

Cynoglossum lanceolatum Forsk.

Pl. 1, fig. 4; Text-figs. 8, 17, 26

Leaves simple, alternate, sessile, 5.0-7.5 cm × 1.6-2.5 cm, symmetrical in shape, broadly lanceolate, acute, margin entire, lamina densely hairy, base obtuse and decurrent.

Leaf architecture is unicostate reticulate with 3-4 pairs of secondary veins. Secondary veins are of brochidodromous type, reticulation is upto 3rd order of veinlets; areole formation is mostly by 4th and 5th order of veinlets. Shape of the areole is quadrangular to pentangular areoles are with single free vein ending; free vein ending is formed by 6th order of veinlets traverse 1/4-1/2 the areole unbranched consisting of one to three rows of tracheids; all categories of vein and veinlets are not sheathed, tips are mostly straight. Marginal ultimate venation is fimbriate.

Leaf is amphistomatic lower surface is showing anomocytic type of stomata, stomatal apparatus is surrounded by 4-5 epidermal cells; guard cells are not sunken, wall of the guard cells is thick along the aperture only, stomata are present all over the surface except on veins and veinlets and trichome base, irregularly arranged and variously oriented. Stomatal index is 40.5. Epidermal cells are irregular in shape, variously oriented and undulate walled. Trichomes are unicellular, nonglandular with thick base and acute apex. Upper surface also shows anomocytic type of stomata. Stomatal apparatus, thickening arrangement and orientation are similar to those present in the lower surface. Stomatal index is 22.4. Epidermal cells are irregular in shape, randomly arranged and sinuous walled. Trichomes are similar to those present in the lower surface.

Trichodesma indicum R. Br.

Pl. 2, fig. 8; Text-figs. 9, 18, 23

Leaves simple, opposite, sessile, 3.8-10.2 × 0.6-5.0 cm, variable, symmetrical in shape, ovate to oblong or lanceolate-oblong, entire, obtuse to subacute, clothed with stiff hair, base is cordate.

Leaf architecture is unicostate reticulate with 3-4 pairs of secondary veins. Secondary veins are of eucamptodromous type; reticulation is upto 4th order of veinlets; areole formation is mostly by 4th and 5th order of veinlets, shape of the areole is quadrangular to polygonal areoles are with 2-4 free vein endings; free vein endings are formed by 6th order of veinlets, traverse 1/4-3/4 the areoles, unbranched, consisting of one to three rows of tracheids, rarely with four rows of tracheids; all categories veins and veinlets are not sheathed, tips slightly curved. Marginal ultimate venation is fimbriate.

Leaf is amphistomatic, lower surface is showing anomocytic type of stomata, stomatal apparatus is surrounded by 3-5 epidermal cells; guard cells are not sunken, wall of the guard cells is thick along the aperture only. Stomata are present all over the surface except on veins, veinlets and trichome base, irregularly arranged, variously oriented. Stomatal index is 25.00. Epidermal cells are irregular in shape, variously oriented and undulate walled. Trichomes are unicellular, nonglandular, with thick base and acute

apex. Upper surface also shows anomocytic type of stomata. Stomatal apparatus, thickening, arrangement and orientation are similar to those present in the lower surface. Stomatal index is 16.41. Epidermal cells are irregular in shape; randomly arranged and sinuous walled. Trichomes are similar to those present in the lower surface.

Discussion

The present investigation on leaf morphology, architectural pattern and cuticular features, has been done in order to evaluate their taxonomic significance, i.e., how far these characters can be used to segregate genera and species from each other.

While studying the external morphology of leaf, 7 different parameters have been taken into consideration. It has been observed that leaves are uniformly simple, but they may be either petiolate (*Cordia myxa* Linn., *Cordia sebestena* Linn., *Heliotropium ovalifolium* Forsk., *Heliotropium strigosum* Willd., *Heliotropium indicum* Linn., *Ehretia laevis* Roxb., *Coldenia procumbens* Linn.) or sessile (*Cynoglossum lanceolatum* Forsk., *Trichodesma indicum* R. Br.). The shape and form of lamina are mainly symmetrical in 8 taxa except in *Coldenia procumbens* Linn. The surface of lamina is either hairy or occasionally glabrous. Similarly base margin and apex of leaves have variable combinations of characters, which could be used with advantage in segregate taxa.

The leaf architectural pattern has been studied on the basis of 9 different parameters. It has been observed that leaf is uniformly unicostate reticulate, yet the nature of secondary veins are greatly variable, i.e., eucamptodromous, brochidodromous, reticulodromous, cladodromous and also the number of secondaries in a leaf varies from 3 pairs in some species 7-10 pairs in others. The level of reticulation, areole formation, shape of areole, number of vein endings etc varies from species to species. Therefore, a combination of these variable features may be helpful in distinguishing one species from the other.

The cuticular features studied in taxa have been done on the basis of 7 different parameters. Both amphistomatic and hypostomatic types occur here, but stomatal apparatus is uniformly anomocytic. The shape and nature of epidermal cells varies from species to species, but trichomes are uniformly unicellular and nonglandular types and therefore, the last feature is of little value in separating various taxa.

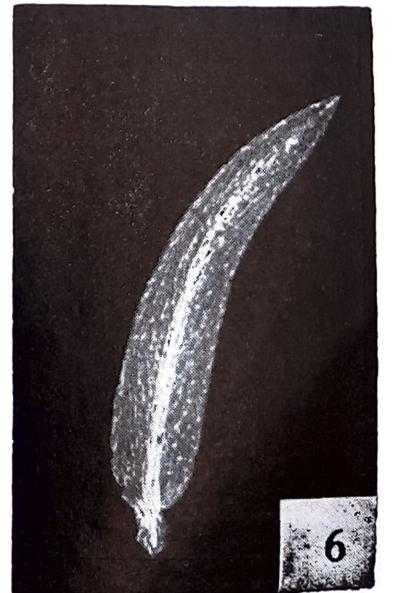
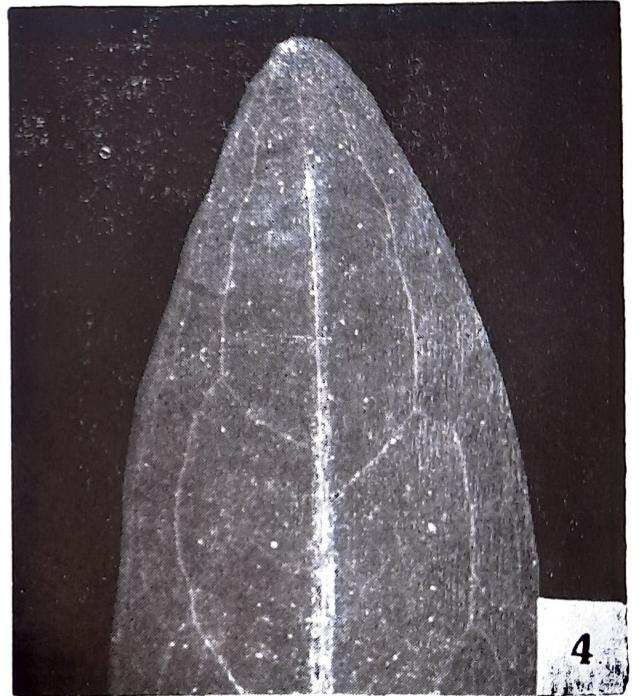
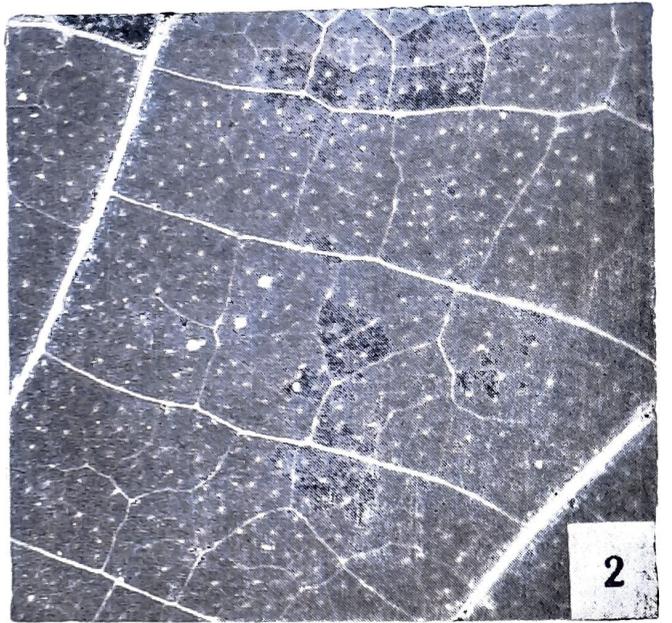
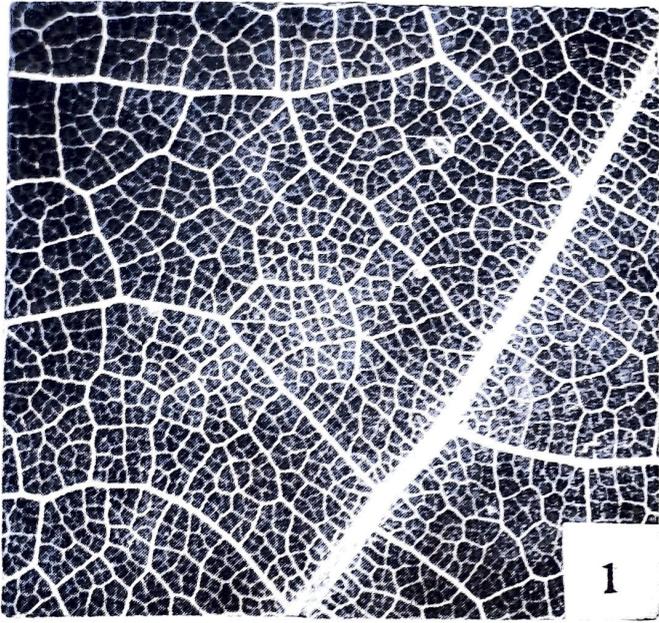
The Boraginaceae is a large family with about 2,000 species belonging to 100 genera. It is therefore essential that further investigation on these aspects are carried out in order to determine the range of variations within these characters and also their value for taxonomical purposes. However, it appears that external morphology of leaf, the architectural pattern and the epidermal features can be used with advantage in separating various genera and species. These characters are of little value in segregating taxa above family level.

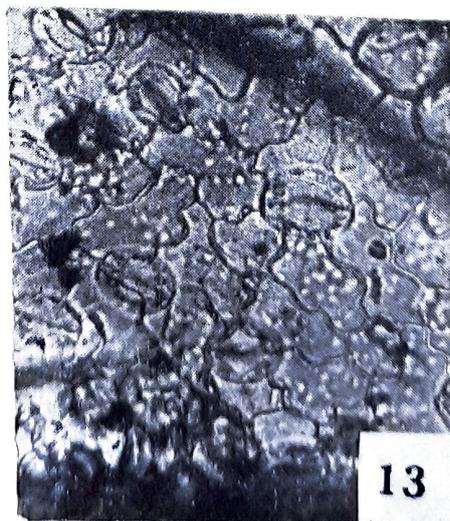
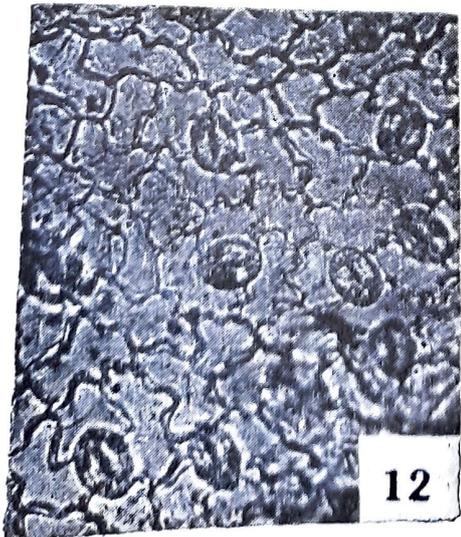
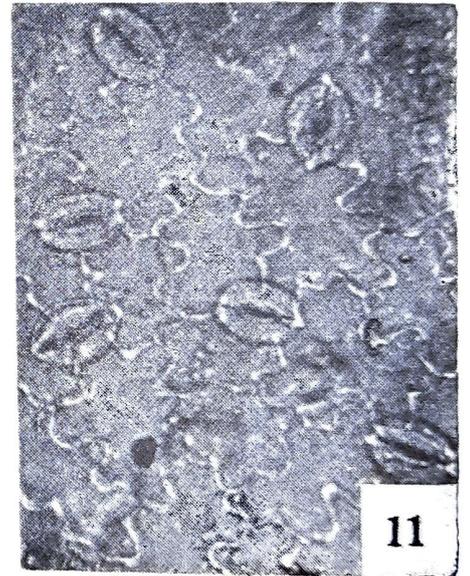
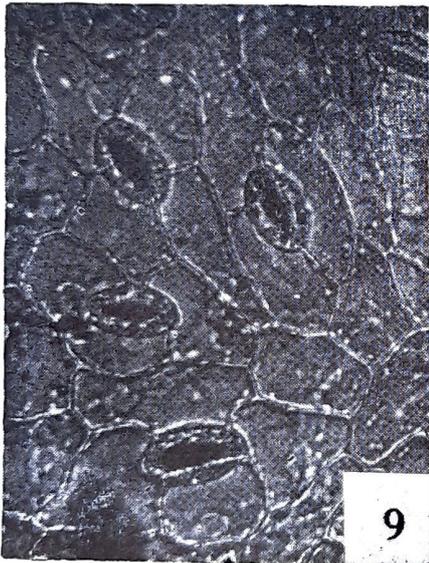
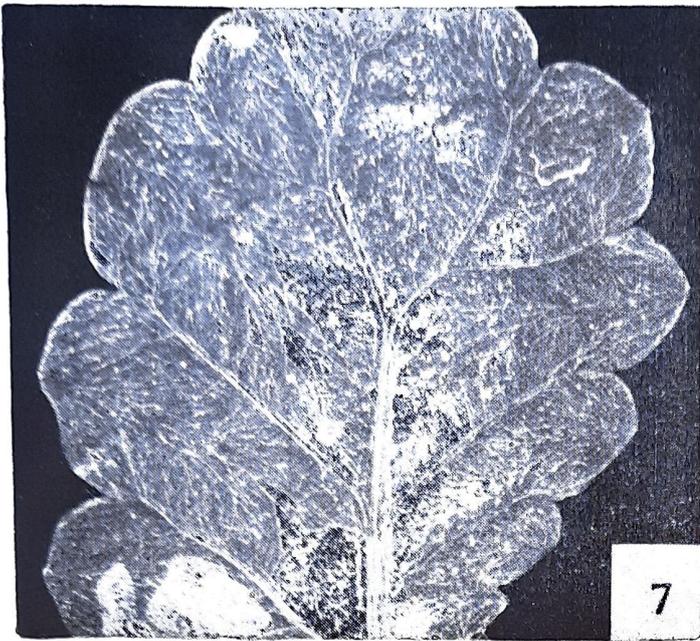
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Explanation of Plates

Plate 1

1. *Cordia myxa* Linn., Venation pattern. Slide no. 14-L2, ×4.
2. *Cordia sebestena* Linn., Venation pattern. Slide no. 8-L8, ×4.
3. *Heliotropium ovalifolium* Forsk., Venation pattern. Slide no. 19-L2, ×4.
4. *Cynoglossum lanceolatum* Forsk., Venation pattern. Slide no. 5-L4, ×4.
5. *Heliotropium indicum* Linn., Venation pattern. Slide no. 35-L1, ×4.
6. *Heliotropium strigosum* Willd., Venation pattern. Slide no. 43-L2, ×4.

Plate 2

7. *Coldenia procumbens* Linn., Venation pattern. Slide. no. 27-L1, ×4.
8. *Trichodesma indicum* R. Br., Venation pattern. Slide no. 21-L2, ×4.
9. *Cordia myxa* Linn., Lower epidermis showing stomata and epidermal cells. Slide no. 14-C1, ×300.
10. *Coldenia procumbens* Linn., Lower epidermis showing stomata and epidermal cells. Slide no. 27-C1, ×300.
11. *Ehretia laevis* Roxb., Lower epidermis showing stomata and epidermal cells. Slide no. 40-C1, ×300.
12. *Cordia sebestena* Linn., Lower epidermis showing stomata and epidermal cells. Slide no. 8-C1, ×300.
13. *Heliotropium ovalifolium* Forsk, Lower epidermis showing stomata and epidermal cells. slide. no. 9-C1, ×300.
14. *Heliotropium indicum* Linn., Lower epidermis showing stomata and epidermal cells. Slide no. 35-C1, ×300.