STUDIES ON LEAF ARCHITECTURAL PATTERN AND CUTICULAR FEATURES OF SOME MEMBERS OF THE TRIBE EUCAESALPINIEAE, FABACEAE

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Abstract

Venation pattern and cuticular features of *Caesalpinia bonducella*, *C. pulcherrima*, *C. coriaria*, *Peltophorum ferrugenum*, *Delonix regia*, *Parkinsonia aculeata* and *Brownea coccinia* are described. It has been observed that taking all the parameters of leaf architectures and cuticular features it is possible to identify various genera and species of the tribe Eucaesalpinieae.

Introduction

The subfamily Caesalpinioideae is represented by 76 genera and 2,800 species (Bentham & Hooker, 1862-1883). No work has been done so far on the leaf architecture and cuticular features of Indian Eucaesalpinieae except the report of Leelavathi, Ramayya and Prabhakar (1980). Therefore, the present investigation on this aspect provides some understanding about their taxonomic value.

Material and methods

For the present study leaves of seven species belonging to five genera of the tribe Eucaesalpinieae were collected from twelve different locations within Burdwan District. For studying the leaf architectural patterns fresh or dried leaves were treated with 5 per cent NaOH solution for bleaching. The duration of treatment in NaOH solution varied from 24 to 36 hours depending on the texture of the leaf. After bleaching the leaves were transferred to chloral hydrate solution (Foster, 1952; Hickey, 1973) and then were stained in 1% aqueous safranin solution followed by gradual dehydration through ethanol grades. Leaves were then mounted in glycerine-jelly.

For cuticular preparation fresh or dried leaves were kept in 10 per cent nitric acid for 24 to 48 hours. Maceration time was varied depending on the thickness of the cuticle. After maceration leaves were washed thoroughly in water to make them acid free. These were then treated with 5 per cent KOH or NaOH solution for 2-5 minutes and 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. This operation was performed with a little water all round the leaf. Finally the cuticles (abaxial & adaxial surfaces) were separately mounted in glycerine jelly for microscopic observations.

Description

1. *Caesalpinia bonducella* Fleming.
Pl. 1, fig. 1; Text-figs. 1-6

Leaves compound, bi-pinnate; pinnules stalked, surface of the leaf-rachis hairy; pinnules asymmetrical in shape, oblong in form, base obtuse, margin entire, apex acute.

Pinnule-architecture unicostate with 8-14 pairs of secondaries; secondary veins brochidodromous; reticulation up to 6th order of veinlets; areole formation mostly by 4th and 5th order of veinlets or by 4th category of veins only; areole quadriangular, mostly with 1-2 free vein endings; free vein endings formed by 6th or 5th order of veinlets, traverse 3/4th of the areole, branched (twice to many), consisting of 2-3 rows of tracheids, ensheathed by more or less rectangular parenchymatous cells; tips mostly swollen;

marginal ultimate venation complete and looped towards apex.

Pinnules amphistomatic; lower surface showing mostly anomocytic type of stomata; stomatal apparatus containing 3-5 adjacent cells; guard cells not sunken but cutinised near the aperture only; stomata present all over except on midvein and primary lateral veins, irregularly arranged, variously oriented; stomatal index 15.34.

Ordinary epidermal cells irregular in shape, randomly arranged and sinuous walled. Trichomes nonglandular, 2-celled horn-like; thin-walled with thickened base. Glandular hairs with spherical bases also present.

Upper surface shows similar types of stomata and stomatal apparatus like the lower surface; stomata present only on the basal portion of the pinnule, irregularly arranged, variously oriented.

Epidermal cell wall undulate and irregular in shape. Glandular hairs absent on the upper surface of the pinnule, but nonglandular trichomes present like the lower surface.

2. *Caesalpinia pulcherrima* Sw.
Pl. 1, fig. 5; Text-figs. 7-11

Leaves compound, bi-pinnate, pinnules stalked; surface of the leaf-rachis smooth; pinnules mostly asymmetrical in shape, obovate in form, base acute, margin entire and apex retuse.

Pinnule-architecture unicostate reticulate with 8-10 pairs of secondaries. Secondary veins eucamptodromous; reticulation up to 6th order of veinlets, areole-formation mostly by 4th category of veins or by 4th and 5th order of veinlets, shape of the areole quadriangular, areoles with mostly one free vein ending; free vein endings formed by 5th or 6th order of veinlets, traverse 1/2—3/4th of the areole, mostly branched (twice to many) or unbranched, consisting of 2-3 rows of tracheids, ensheathed by parenchymatous cells of various sizes; the very tips mostly swollen and curved ; marginal ultimate venation nearly complete and looped.

Pinnules hypostomatic, lower surface showing mostly anomocytic and paracytic types of stomata; stomatal apparatus containing 3-5 adjacent cells; guard cells not sunken but cutinised near the aperture only ; stomata present all over, except on midvein, irregularly arranged, variously oriented ; stomatal index 17.56.

Ordinary epidermal cells polygonal in shape, randomly arranged and undulate walled. Trichomes mostly nonglandular, 2-celled. Spherical glandular, hairs also present. In the upper surface, epidermal cells sinuous walled but polygonal in shape and randomly arranged. Trichomes very rare and only nonglandular types present.

3. *Caesalpinia coriaria* Willd.
Text-figs. 12-16

Leaves compound, bi-pinnate; pinnules stalked; the surface of the leaf-rachis hairy; pinnules asymmetrical in shape, oblong or obovate in form, base lobate, margin entire, apex retuse or rounded.

Pinnule-architecture unicostate reticulate with 8-10 pairs of secondaries. Secondary veins eucamptodromous, reticulation up to 5th order of veinlets, areole formation mostly by 4th category of veins only, shape of the areole quadrangular, mostly with one free vein endings formed by 5th order of veinlets, traverse half the areole, consisting of 1-2 rows tracheids, ensheathed by parenchymatous cells; the very tips mostly swollen, branched or unbranched; marginal ultimate venation incomplete.

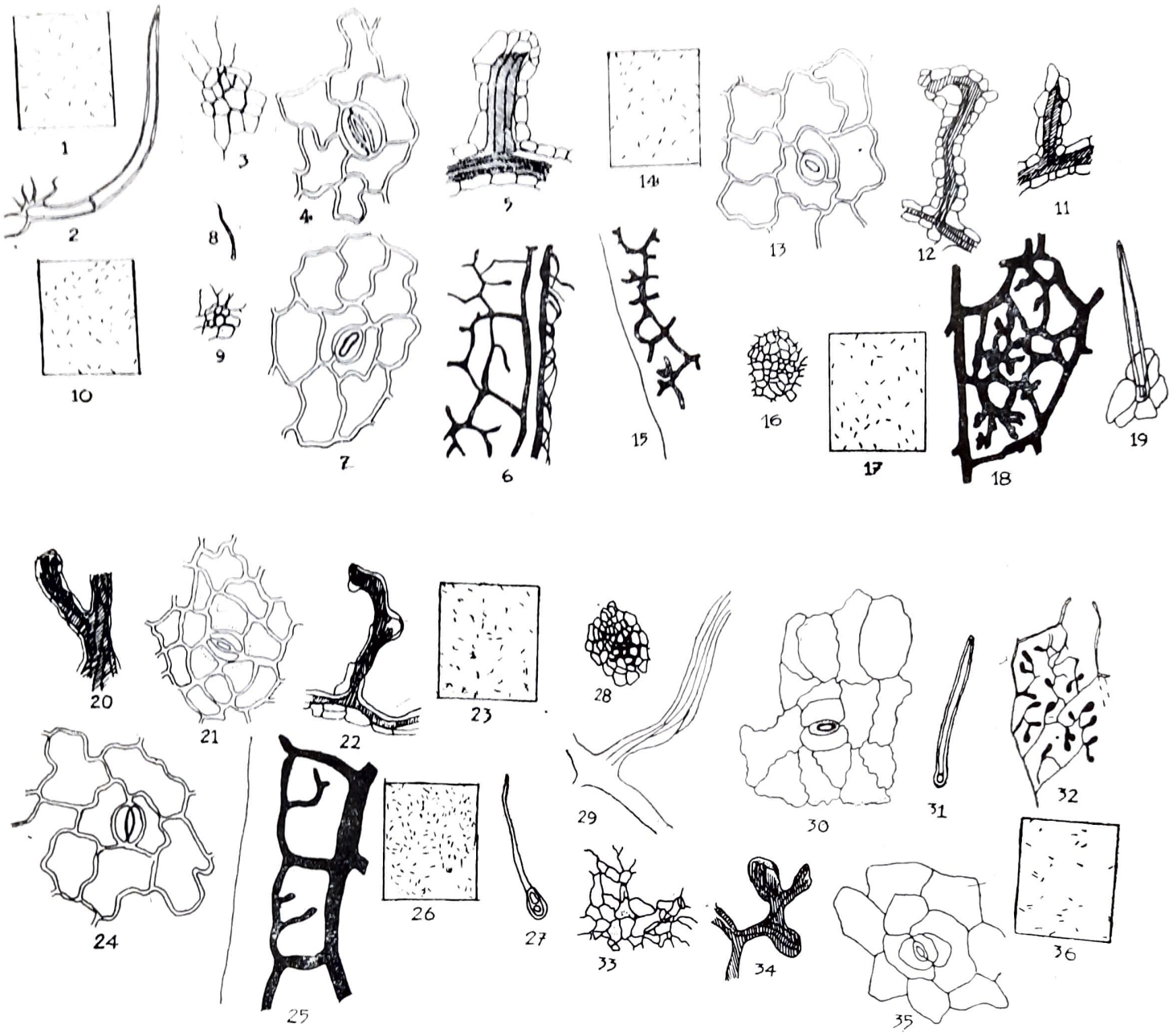
Pinnules hypostomatic, lower surface showing mostly hemiparacytic to paracytic type of stomata; stomatal apparatus containing 1-2 (unequal) subsidiary cells; guard cells not sunken but cutinised. Stomata present all over, except on midvein, irregularly arranged, variously oriented; stomatal index 32.96.

Ordinary epidermal cells irregular in shape, randomly arranged and sinuous-walled. Trichomes glandular and spherical. In the upper surface, nature of the epidermal cells similar to those on the lower surface. Trichomes absent on the upper surface.

4. *Peltophorum ferrugenum* Benth.
Pl. 1, figs. 2, 4; Text-figs. 22-25, 27

Leaves compound, bipinnate; pinnules with very short stalks, surface of the leaf-rachis hairy, pinnules asymmetrical (base only) in shape, oblong in form, base obtuse, margin entire, apex retuse.

Pinnule-architecture unicostate reticulate with 8-10 pairs of secondaries. Secondary veins brochidodromous, reticulation upto mostly 5th and rarely 6th order of



Text figure 1-6—*Caesalpinia bonducella* : 1. Lower cuticle showing distribution of stomata. X 50; 2. Nonglandular trichome, X 250; 3. Glandular trichome. X 250; 4. Stoma. X 500; 5. Vein ending showing the number of tracheids and the nature of sheath. X 250; 6. Areolar and marginal venation pattern. X 50;

Text-figure 7-11—*C. pulcherrima* : 7. Stoma, X 500; 8. Nonglandular trichome. X 50; 9. Glandular trichome. X 50; 10. Lower cuticle showing distribution of stomata. X 50; 11. Vein ending showing the number of tracheids and nature of sheath. X 250.

Text figure 12-16—*C. coriaria* : 12. Vein ending showing the number of tracheids and nature of sheath. X. 250; 13. Stoma. X 500; 14. Lower cuticle showing distribution of stomata. X 50; 15. Marginal venation pattern. X 50; 6. Glandular trichome. X 250.

Text Figure 17-21—*Parkinsonia aculeata* : 17. Lower cuticle showing distribution of stomata. X 50; 18. Areolar venation pattern. X 50 : 19. Nonglandular trichome. X 250; 20. Vein ending showing tracheids and nature of sheath. X 250; 21. Stoma. X 50.

Text Figure 22-25, 27—*Peltophorum ferrugenum* : 22. Vein ending showing the number of tracheids and nature of sheath. X 250; 23. Lower cuticle showing distribution of stomata. X 50; 24. Stoma X 500; 25. Marginal venation pattern. X 50; 27. Nonglandular trichome. X 250.

Text Figure 26, 28-30—*Brownea coccinia*; : 26. Lower cuticle showing distribution of stomata. X 50; 28. Glandular trichome. X 250; 29. Vein ending showing tracheids. X 250; 30. Stoma. X 500.

Text Figure 31-36—*Delonix regia* : 31. Nonglandular trichome. X 250; 32. Areolar venation pattern. X 50; 33. Glandular trichome. X 250; 34. Vein ending showing tracheids. X 250; 35. Stoma. X 500 36. Lower cuticle showing distribution of stomata. X 50.

veinlets; areole formation mostly by 3rd and 4th order of veinlets, shape of the areole rectangular to polygonal, with one free vein ending; free vein endings formed by 5th order of veinlets, traverse more than 3/4th of the areole, consisting of 1-2 rows of tracheids, mostly branched (twice to many), encheathed by selerenchymatous cells, crystals also present in each category of veins; the very tips mostly swollen and simply curved; marginal ultimate venation nearly complete and looped.

Pinnules hypostomatic, lower surface showing mostly paracytic type of stomata; stomatal apparatus containing 2-subsidiary cells; guard cells not sunken but cutinised near the aperture only. Stomata present all over, except on mid-vein, irregularly arranged, variously oriented; stomatal index 19.95.

Ordinary epidermal cells irregular in shape, randomly arranged and sinuous walled. Trichomes multicellular, nonglandular, uniseriate with thickened prominent base accmpanied by an elongated terminal cell. Epidermal cells in the upper surface also irregular in shape, randomly arranged but undulate-walled. Trichomes similar to those present in the lower surface.

5. *Delonix regia* (Boj. ex Hook.)
Pl. 1, fig. 6; Text-figs. 31-36.

Leaves compound, bipinnate, bipinnules without stalks; surface of the leaf-rachis hairy; pinnules asymmetrical (base only) in shape, oblong in form, base obtuse, margin entire, apex obtuse.

The pinnule-architecture unicostate reticulate with 6-8 pairs of secondaries. Secondary veins brochidodromous, reticulation up to 5th order of veinlets; areole fromation mostly by 3rd and 4th order of veinlets, shape of the areole irregular, mostly with 1-2 or more free vein endings; free vein endings formed by 4th and 5th order of veinlets, traverse 1/3-1/2 the areole, consisting of 1-2 rows of tracheids; vein-endings sheathed; tips mostly swollen, tracheids fused to form a ball-like structure; marginal ultimate venation nearly complete and looped.

Pinnules amphistomatic; lower surface showing mostly paracytic to amphiparacytic types of stomata; stomatal apparatus containing 2-4 subsidiary cells; guard cells not sunken but cutinised. Stomata present all over, except on midvein, irregularly arranged, variously oriented; stomatal index 7.03.

Ordinary epidermal cells polygonal in shape, randomly arranged and straight walled. Rod-like ornamentation present on the surface of the cell wall. Trichomes of two types: (i) unicellular, nonglandular with prominent base and pointed apex, (ii) glandular multicellular shaggy hair with a spherical base.

In the upper surface, stomata confined to midvein, irregularly arranged, variously oriented. Types of stomata mostly anisocytic and anomocytic; stomatal apparatus containing 3 subsidiary cells or 4 or more epidermal cells.

Nature of the epidermal cells and trichomes similar to those present in the lower surface.

6. *Parkinsonia aculeata* Linn.
Text-figs. 17-21.

Leaves compound, bipinnate pinnules with very short stalks; surface of the leaf-rachis hairy, pinnules asymmetrical in shape, oblong-narrow in form, base acute, margin entire, apex obtuse.

Pinnule-architecture unicostate, reticulate with 6-8 pairs of secondaries. Secondary veins brochidodromous, reticulation up to 5th order of veinlets; areole formation mostly by 3rd and 4th order of veinlets, shape of areole polygonal, mostly with one free vein ending, free vein endings formed by 4th or 5th order of veinlets, traverse 1/2-3/4th of the areole, consisting of 2-3 rows of tracheids, ensheathed by parenchymatous cells; tips mostly swollen; tracheids fused to from a ball-like structure; marginal ultimate venation nearly complete and looped.

Pinnules amphistomatic, lower surface showing mostly paracytic and anomocytic types of stomata; stomatal apparatus containing 2 subsidiary cells or a number of adjacent cells; guard-cells not sunken but cutinised. Stomata present all over, irregularly arranged, variously oriented; stomatal index 11.7.

Ordinary epidermal cells irregular in shape, randomly arranged and undulate walled. Trichomes two types: (i) unicellular, nonglandular with thickened base and pointed or blunt apex, and (ii) glandular, multicellular hairs also present rarely.

Upper surface shows similar types of stomata, stomatal apparatus; arrangement and orientation of stomata like the lower surface; stomatal index of the upper surface of

the pinnule 9.6. Nature of epidermal cells and trichomes similar to those present in the lower surface.

7. *Brownea coccinia* Jacq.
Pl. 1, fig. 7; Text-figs. 26, 28-30

Leaves compound, unipinnate; leaflets stalked; surface of the leaf-rachis smooth; leaflets asymmetrical in shape, ovate-lanceolate in form, base cordate, margin entire and the apex attenuate.

Leaflet-architecture unicostate reticulate with 8-12 pairs of secondaries; secondary veins brochidodromous; reticulation upto 5th order of veinlets; areole formation mostly by 3rd and 4th order of veinlets; shape of areole mostly quadriangular, with mostly one free vein ending; free-vein endings formed by 5th order of vein-lets, traverse 3/4th of the areole, mostly branched (twice to many) or unbranched, consisting of 2-3 or more rows of tracheids, vein endings not sheathed; the very tips not swollen but curved; marginal ultimate venation complete and thick fimbrial vein formed.

Leaflets hypostomatic; lower surface showing mostly hemiparacytic to paracytic types of stomata; stomatal apparatus containing 1-2 subsidiary cells; guard cells not sunken but cutinised near the aperture only. Stomata present all over except on midveins, irregularly arranged, variously oriented; stomatal index 33.2. Ordinary epidermal cells polygonal in shape, randomly arranged and sinuous walled. Trichomes spherical, glandular. In the upper surface epidermal cells polygonal or somewhat star-shaped, randomly arranged and sinuous-walled. Trichomes also glandular, spherical.

Antificial key for identification of some genera and species of Eucaesalpinieae on the basis of leaf characters

(i) Leaves compound	
(ia) Unipinnate	... *Brownea coccinia*
(ib) Bipinnate	... *Caesalpinia bounducella*, *C. pulcherrima*, *C. coriaria*, *Parkinsonia aculeata*, *Peltophorum ferrugenum*, *Delonix regia*
(ii) Unicostate	
(iii) Secondary veins brochidodromous	... *Delonix regia*, *Caesalpinia bonducella*, *Parkinsonia aculeata*, *Peltophorum ferrugenum*
(iv) Marginal vein complete and looped	... *Caesalpinia bonducella*
(v) Marginal vein nearly complete and looped	... *Parkinsonia aculeata*, *Peltophorum ferrugenum* and *Delonix regia*
(v) Hairs uniseriate, multicellular	... *Peltophorum ferrugenum*
(v) Hairs glandular and non-glandular	... *Delonix regia* and *Parkinsonia aculeata*
(vi) Stomata all over, except on midvein, irregularly arranged, variously oriented, in the lower surface of pinnule	... *Delonix regia*
(vi) Stomata all over, irregularly arranged, variously oriented	... *Parkinsonia aculeata*
(iii) Secondary veins eucamptodromous	... *Caesalpinia pulcherrima* and *C. coriaria*
(iv) Marginal vein incomplete	... *Caesalpinia coriaria*
(iv) Marginal vein nearly complete and looped	... *Caesalpinia pulcherrima*

Discussion

It has been observed that all the species investigated possess bipinnate leaves except *Brownea coccinia* and the pinnae are stalked except in *Delonix regia*. The surface of pinnae is hairy in *Caesalpinia bonducella*, *C. coriaria*, *Peltophorum ferrugenum*, *Delonix regia*, *Parkinsonia aculeata*, but it is smooth in *C. pulcherrima* and *Brownea coccinia*. There are variations in the shape of the pinnae (asymmetrical, narrow-oblong or obovate or lanceolate), base of the pinnae (obtuse, acute, lobate or cordate) and the apex which is acute in *C. bonducella*, retuse in *C. pulcherrima*, *C. coriaria* and *Peltophorum ferrugenum*, obtuse in *Delonix regia* and *Parkinsonia aculeata* and attenuate in *Brownea coccinia*.

While studying the range of leaf architectural pattern 9 different parameters, according to Dilcher (1974) and Hickey (1973), have been taken into consideration (Table 2). All the species studied here, have unicostate reticulate venation. There

Table 1—Showing the range of leaf morphological characters

Plant Name of species	Simple or compound	Petiolate or sessile	If compounds, pinnate or or digitate and number of pinnation	Shape and form	Surface lamina leaf-rachis	Base	Margin	Apex
Tribe : Eucaesalpinieae :								
Caesalpinia bonducella	Compound	Stalked	Bi-pinnate	Symmetrical, oblong	Hairy	Obtuse	Entire	Acute
C. pulcherrima	Compound	Stalked	Bi-pinnate	Mostly asymmetrical, obovate	Smooth	Acute	Entire	Retuse
C. coriaria	Compound	Stalked	Bi-pinnate	Asymmetrical or obvate	Hairy	Lobate	Entire	Retuse or rounded
Peltophorum ferrugenum	Compound	Stalked	Bi-pinnate	Asymmetrical (base only), oblong	Hairy	Obtuse	Entire	Retuse
Delonix regia	Compound	Without stalk	Bi-pinnate	Asymmetrical (base only) oblong	Hairy	Obtuse	Entire	Obtuse
Parkinsonia aculeata	Compound	Stalked	Bi-pinnate	Asymmetrical, oblong-narrow	Hairy	Acute	Entire	Obtuse
Brownea coccinia	Compound	Stalked	Simply evenpinnate	Asymmetrical, ovate-lanceolate	Smooth	Cordate	Entire	Attenuate

are variations in number of secondaries and their nature (8-10 pairs—brochidodromous, 6-8 pairs—brochidodoromous, 8-10 pairs—eucamptodromous), level of reticulation (up to 5th & 6th level), level of areole formation (3rd, 4th & 5th categories), shape of the areoles [mostly quadriangular except in *Parkinsonia aculeata* (polygonal)], number of rows of tracheids in the vein endings (1-3) and other features.

Similarly in studying epidermal features we have taken into consideration seven different parameters (Table 3). The variations in the distribution of stomata have been observed within different species of the same genus, e. g., *Caesalpinia bonducella* (amphistomatic), *C. pulcherrima* and *C. coriaria* (hypostomatic). The stomatal apparatus belongs to two different types—anomocytic and hemiparacytic. The shape of the epidermal cells, the distribution of stomata in lower and upper epidermis are often different within the same species. However, the trichomes are similar in both the surfaces in all the species except in *C. coriaria* and *Brownea coccinia*. Thus taking all the characters into consideration, i. e., the external morphology of the leaf, venation pattern and epidermal features, it is possible to identify different genera belonging to this tribe These features are helpful in segregating species within the same genus.

Table 2—Showing the range of leaf architectural pattern of 7 species of the family Leguminosae

Taxa	Unicostate or multicostate	No. of secondaries & nature	Reticulation upto	Areole formation by	Shape of the areole	Areole mostly with (No. of vein ending)	Free vein ending consisting of tracheids in rows	Tips of vein endings	Marginal ultimate venation
1	2	3	4	5	6	7	8	9	10
Caesalpinia bonducella	Unicostate	6-14 pairs Brochidodromous	6th	4th & 5th or category only	Quadrangular	1-2	2-3	Swollen, branched	Complete and looped
C. pulcherrima	Unicostate	8-10 pairs Eucamptodromous	6th	4th category or 5th & 4th	Quadrangular	One	2, rarely 3	Swollen, curved, unbranched or branched	Nearly complete and looped
C. coriaria	Unicostate	8-10 pairs Eucamptodromous	5th	4th category	Quadrangular	One	1-2	Swollen, branched or unbranched	Incomplete
Brownea coccinia	Unicostate	8-10 pairs or 12 pairs Bicchidodromous	5th	3rd & 4th	Quadrangular	One	2-3	Not swollen, curved, unbranched or branched	Complete, thick, fimbrial vein formed
Parkinsonia aculeata	Unicostate	6-8 pairs Brochidodromous	4th	3rd & 4th & 4th category	Polygonal	2 to many	One	Swollen, tracheids anastomosis to spherical structure	Nearly complete and looped
Peltophorum ferrugenum	Unicostate	8-10 pairs Brochidodromous	5th rarely 6th	3rd & 4th	Rectangular to polygonal	One	1-2	Swollen, unbranched, curved	Nearly complete and looped
Delonix regia	Unicostate	Brochidodromous	5th	3rd & 4th	Various types	1-2	1-2	Swollen, tracheids fused to form a ball like structure, branched or unbranched	Complete and looped

Table 3—Showing the range of cuticular features

Plant Name of species	Amphistomatic or hyposto-matic	Types of stomata and their distribution pattern ; arrangement, orientation and stomatal index (S. I.)		Shape and nature of cell-wall of the epidermal cells		Trichome and its nature	
		Lower surface	Upper surface	Lower surface	Upper surface	Lower surface	Upper surface
1	2	3	4	5	6	7	8
Caesalpinia bonducella	Amphisto-matic	Anomocytic ; stomata all over, except on midvein and primary lateral veins, irregularly arranged, variously oriented, S.I. 15.34	Anomocytic stomata present only on the basal portion of the midvein	Irregular, sinuous	Irregular, undulated	Non-glandular, 2-celled horn-like, and glandular, spherical based type	Only non-glandular type present
C. pulcherrima	Hyposto-matic	Anomocytic ; stomata all over, except on midvein, irregularly arranged, variously oriented, S.I. 16.56	Nil	Polygonal undulated	Polygonal, sinuous	Non-glandular, 2-celled, and spherical glandular type	Only non-glandular type persent
C. coriaria	Hyposto-matic	Hemiparacytic to paracytic ; stomata all over except on midvein, irregularly arranged, variously oriented, S.I. 32.96	Nil	Irregular, sinuous	Irregular	Glandular, spherical type	Absent
Peltophorum ferrugenum	Hyposto-matic	Paracytic; stomata all over, except on midvein, irregularly arranged, variously oriented, S.I. 19.5	Nil	Irregular, sinuous	Irregular, undulated	Non-glandular, uniseriate, with 2-basal cells accompanied by an elongated terminal cell	Similar
Delonix regia	Amphisto-matic	Paracytic to amphiparacytic; stomata all over except on midvein, irregularly arranged, variously oriented, S. I. 7.03	Anisocytic and anomocytic; stomata confined to midvien, irregularly, variously oriented	Polygonal, striaght and cutinised	Polygonal, straight and Polygonal,	Non-glandular, unicellular, non-glandular multicelluar shabby type	Similar Similar
Parkinsonia aculeata	Amphisto-matic	Paracytic and anomocytic; stomata all over, irregularly arranged, variously oriented, S. I. 11.7	Similar types and distribution pattern, S. I., 9.6	Irregular, undulated or slightly undulated	Irregular, straight or slightly undulated	Non-glandular, unicellular type	Similar

Table 3 (Contd.)

1	2	3	4	5	6	7	8
Brownea coccinia	Hypostomatic	Hemiparacytic to paracytic; stomata all over except on midvein, irregularly arranged, variously oriented, **S. I. 33.20**	Nil	Polygonal, sinuous	Polygonal, sinuous and ridged	Glandular spherical type	Similar

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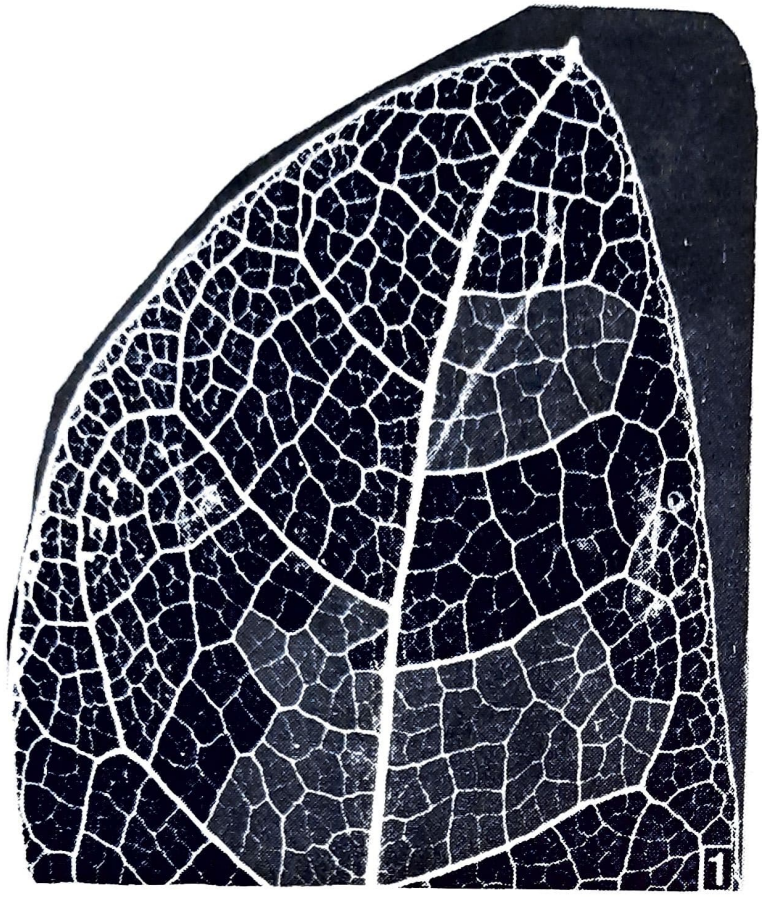
Explanation of Plate

Plate 1

1. *Caesalpinia bonducella*, venation pattern. X 5.
2. *Peltophorum ferrugenum*, venation pattern. X 5.
3. *Delonix regia*, venation pattern. X 5.
4. *Peltophorum ferrugenum*, venation pattern. X 5.
5. *Caesalpinia pulcherrima*, venation pattern. X 5.
6. *Delonix regia*, venation pattern. X 10.
7. *Brownea coccinia*, venation pattern. X 5.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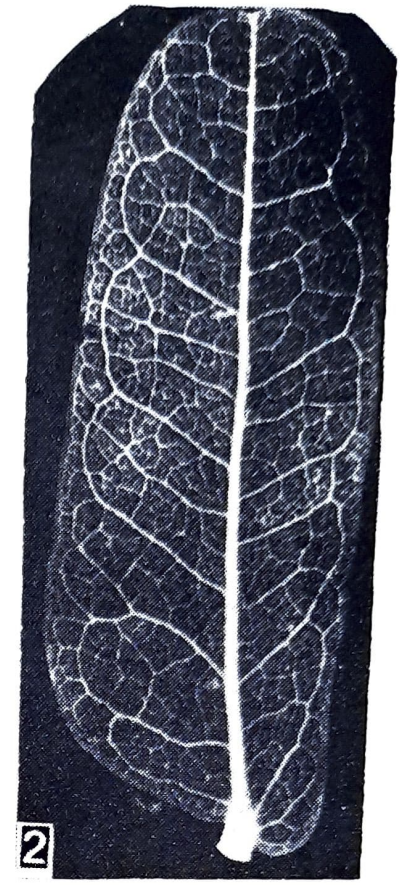
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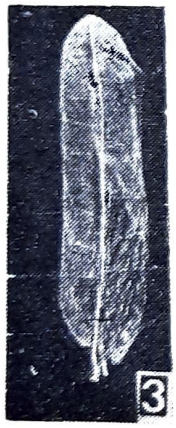
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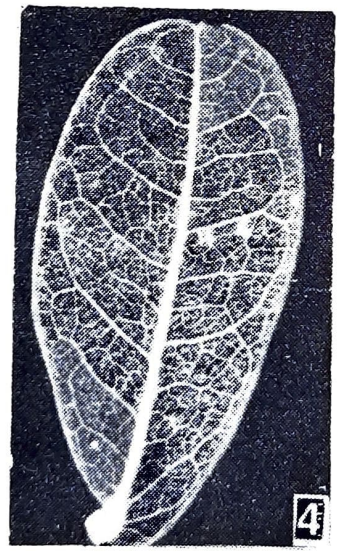
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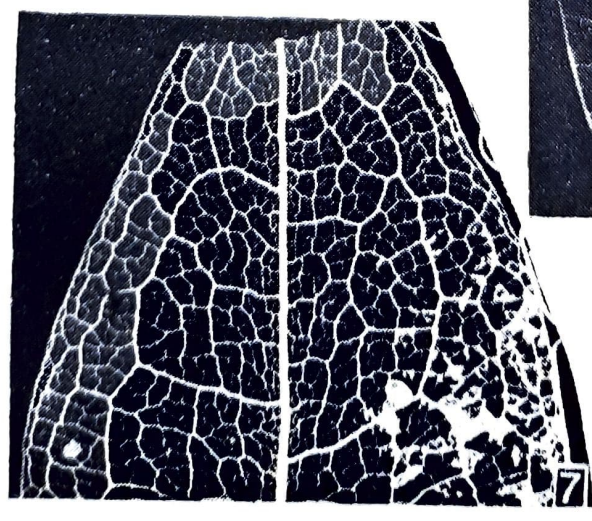
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Table 1—(*Contd.*)

1	2	3	4	5	6	7	8	9	10	11
O. emarginata Benth.	Pro.Sph.	Comp.oval	25-34×23-31 / 28.5×26	2	ret.	1-1.5	3-colpr.	tap.	lolong	Sex.=nex., colpus constricted at the equator. Eq. margin of the endoap. indistinct. Lumina larger at poles.
O. hoaensis Prain	Pro.	Fllip.oval	21.5-31×21-27 / 27×23	1.75-2	ret.	1	3-colpr.	slit.	lolong	Sex. thicker than nex. Ex. thicker at poles. Endoap. ornate type.
O. macrodisca Baker	Pro.-Sph.	Comp.oval	21-27×21-26 / 24×22.5	1.75	micro-ret.	0.5-0.75	3-colpr.	tap.	lalong	Sex.=nex., ret. finer towards aperture, endoap. rectangular.
O. microsperma Baker	Pro.Sph.	Comp.oval	23-32×23-30.5 / 29×28	2	f.ret.	0.75-1	3-colpr.	tap.	lalong	Sex.=nex. colpus constricted at the equator. Eq. margin of endoap. indistinct.
O. pinnata (Lour) Merr.	Pro.	Ellip.oval	26-33×24-31 / 29.5×25.5	2	ret.	1-1.5	3-colpr.	tap.	lalong	Sex.=nex., ret. heterobrochate, finer towards aperture. Colpus constricted at the equator. Col. distinct.
O. polita Prain	Pro.-Pro. sph.	Comp.oval	24.5-33×26-32 / 29.5×27.5	1.5-2	f. ret.	0.75-1	3-colpr.	tap.	lolong	Sex. thicker than nex., Ex. thin at mesocolpium, lumina larger at poles and finer towards aperture.
O. scandens Prain	Pro-sph.	Comp.oval	26.5-34×26-32.5 / 30.5×28	1.5	f. ret.	0.75	3-clopr.	slit.	lolong	Endoap. area granulated.
O. sumatrana(Miq.) Prain	Poo.	Ellip.oval	24.31×21.30 / 27+23.5	1.5	obs.	—	3-colpr.	slit.	lolong	Endoap. area indistinct.

Table 1—(*Contd.*)

1	2	3	4	5	6	7	8	9	10	11
Placolobium gracilis (Prain) Yakovlev	Pro.sph.	Comp.oval	24.5-33.5 ×24-31 / 29.5×28	2	ret.	1	3-colpr.	slit	lalong	Sex.=nex., Eq. margin of the endoap. indistinct.
P. travancorica (Bedd.) Yakovlev	Pro.	Ellip.oval	30.5-38.5 ×28-36 / 35.5×33	2-2.25	ret.	1.5-2	3-colpr.	slit	lolong	Sex. thicker than nex., ex. thicker at poles. Endoap. area gradnulated, heterobrochate.
Ruddia fordiana (Oliv.) Yakovlev	Pro.	Ellip.oval	24-33 ×22-30.5 / 30×26.5	2-2.25	rug. ret.	1-1.5	3-colpr.	tap.	lalong	Sex. thicker than nex. ret. heterobrochate, finer towards aperture. Col. distinct.
Sophora ardexa Grah.	Pro.-Pro.sph.	Ellip.oval	19.5-29 ×19.5-27.5 / 24.5×23.5	1.5	rug. ret.	±0.5	3-colpr.	slit	lolong	Sex.=nex. colpus constricted at the eq., col. indistinct.
S. benthami V. Steen.	Pro.	Ellip.oval	22-30 ×19-24 / 25.5×22.5	1.5-2	ret.	±1	3-colpr.	tap.	lolong	Sex.=nex., Col. indistinct, Ex. thicker at poles, colpus constricted at the eq.
S. flavescens Ait. var. *flavescens*	Pro.	comp.oval	(24.5)-26--34× (18)-21-29 / (26)-30.5 ×(21.5)-27	±2	f. ret.	0.5-1	3-colpr.	tap.	lalong	Sex.thicker than nex. at poles, colpus constricted at eq., eq. margin of endoap. indistinct, lumina larger at poles. Mat. from Japan shows smaller size range and finer reticulation.
S. heptaphylla Linn.	Pro.	Ellip.oval	22-29 ×19.5-26.5 / 26.5×23	1.5	ret.	±1	3-colpr.	slit	lolong	Sex.=nex., Col. indistinct.
S. interrupta Bedd.	Pro.-Pro. Sph.	Comp.oval	24-31 ×21-26 / 29.5×24.5	1-1.75	f. ret	±1	3-colpr.	tap.	lolong	Colpus constricted at the eq. Endoap. gr., Sex. =nex.

Table 1—(*Contd.*)

1	2	3	4	5	6	7	8	9	10	11
S. japonica Linn. var. *japonica*	Pro.	Ellip.oval	23-30 × 21-25.5 / 26 × 23	1.5-2	ret.	1-1.25	3-colpr.	tap.	lolcmg	Sex.=nex., Ex. thicker at poles, col. indistinct.
S. littoralis Schrad	Pro.	Ellip.oval	24.5-31 × 21-29 / 26 × 23.5	1.5-2	ret.	±1	3-colpr.	tap.	lolong	Sex.=nex. col. indistinct at mesocolpium, colpus constricted at the equator.
S. mollis Grah. var *griffithii* (Stock) Tsoong	Pro.-pro. sph.	Ellip. oval	21-30.5 × 21-27 / 27.5 × 24	±2	ret.	1-1.25	3-colpr.	slit	lolong	Sex.=nex., Lumina larger at poles.
S. mollis Grah. var. *mollis*	Pro.-Pro sph.	Ellip.oval	25.5-32 × 23-29 / 30 × 27.5	±2	ret.	1-1.5	3-colpr.	slit	lolong	Sex.=nex., lumina larger at poles. Pollen grain size is the only difference with other var. studied.
S. moocroftiana Benth.	Pro.-Pro. sph.	Comp. oval	23-30.5 × 22-28.5 / 27 × 25.5	1.5	ret.	1-1-25	3-colpr.	slit	lolong	Sex.=nex., col. indistinct, lumina size larger at poles.
S. pachicarpa Schrenk ex C. A. Mayer	Pro.sph.	Comp.oval	(17-)24-32 × 22-30 / 30 × 28.5	2	ret.	1-1.75	3-colpr.	slit	lolong	Sex.=nex., Col. indistinct at mesocolpium, lumina larger at poles. Rarely ob. sph. grains observed.
S. prazeri Prain var. *prazeri*	Pro.sph.	Comp.oval	22-28 × 19-23 / 25.5 × 23	±2	f. ret.	±1	3-colpr.	tap.	lolong	Sex. thicker than nex., colpus constricted at the eq., eq. margin of the endocap. indistinct.
S. tomentosa Linn. var. *tomentosa*	Pro.	Comp.oval	26-35 × 18-29 / 31.5 × 26.5	1.5	f. ret.	0.5-0.75	3-colpr.	slit	lolong	Endoap. rectangular type, eq. margin indistinct, heterobrochate.

Table 1—*(Contd.)*

1	2	3	4	5	6	7	8	9	10	11
										In the aperture area nexine departed from the sexine and intruded inward forming vestibulum (Faegri and Iversen, 1964).
S. velutina Lin. var. *velutina*	Pro-Pro. Sph.	Comp. oval	21-26×18-24.5 / 24×22	1-1.5	rug.-ret.	(1-)1.5	3-colpr.	tap.	lolong	Colpus constricted at the eq., endoap. area gr., rarely gr. extends through colpus length, Sex.=nex. ret. finer towards aperture.
S. wightii Baker	Pro.	Ellip. oval	24-29.5(-36.5) ×19.5-23.5(-31) / 26×22	2	f. ret	±1	3-Colpr.	tap.	lolong	Sex.=nex., colpus constricted at the eq.
Trichocyamus pachycarpa (Camp. ex Benth.) Yakovlev	Pro.-Pro.sph.	Comp. oval	26.5-35×24-32 / 31×28	2.5	ret.	(0.75-) 1-1.5	3-colpr.	tap.	lalong	Colpus constricted at the eq., endoap. rectangular type, Sex. thicker than nex., heterobrochate, ret. finer towards aperture. Ap. membrane gr. Double layer of exine stratification is observed.
Vexibia alopecuroides (Spach. ex Jaub. et Spach.) Yakovlev	Pro.-Pro.sph.	Ellip.oval	(18-) 23-31 ×21-29.5 / 29.5×28	±2	ret.	1-1.5	3-colpr.	slit	lolong	Sex.=nex., Col. indistinct. Ex. thicker at poles. Some smaller grains also observed.

Abbreviations used: Ap.-Aperture; Col.-columella; comp. oval—compressed oval; colpr.—colporate; E.—Equatorial diameter; Ellip. oval—Elliptic oval; Ex.—Exine; Endoap.—Endoaperture; Ectoap.—Ectoaperture; eq.—equatorial; f. ret.—finely reticulate; gr.—granules granulated; lalong.—lalongate; lolong.—lolongate; Micro-ret.—Micro-reticulate; nex.—nexine; obs.—obscure; Ob. Sph-oblate spheroidal; P.—Polar axis length; Pat.—Pattern; Pro.—Prolate; Pro. Sph.—Prolate-spheroidal; Psi—Psilate; ret.—reticulate; Sex.—Sexime; Slit.—Slit like Sph..—Spheroidal; Tap.—Tapering; var.—variety.

J. M. Wood—6125. *C. sylvatica* E. Mey, Africa: Natal, R. Schlechter—6158.

Dalhousia africana S. Moore, Africa: Congo C. Evrad—5040, CAL—567580. *D. bracteata* Grah. ex Benth., India: Herb. Hort. Cal., J. C. Prazer—75, CAL—133783; Assam, Khasia, Jenkins—262. Bangladesh: Sylhet, NIL—7162, (24-5-1868), CAL—133181.

Fedorovia laxa (Prain) Yakovlev=*Ormosia laxa* Prain, Burma: Kachin Hills, Shaik Mokim, s. n. CAL—133679. *F. striata* (Dunn) Yakovlev=*Ormosia striata* Dunn., China: Yunan, Aug. Henry—41886.

Ormosia assamica Yakovlev=*O. robusta* Baker, Assam: Badal Khan—10; NIL, CAL—133806. *O. bancana* (Miq.) Merr.= *O. parviflora* Baker. Malaya Peninsula: NIL, s. n., Det.—Yakovlev (1967). *O. dulse* Prain, Burma: Shaik Mokim—s. n. Det.—Yakovlev (1967). *O. emerginata* Benth. Hongkong: B. Garden, NIL, s. n. CAL—133675. *O. hoaensis* Prain, Cochin—China: L. Pierre, s. n., CAL—133680. *O. macrodisca* Baker, Singapore: HNR—2103. *O. microsperma* Baker, Malacca: R. Derry—1090. *O. pinnata* (Lour.) Merr.=*O. hainanensis* Gagnep. China: Hainan, F. C. How—72995. *O. polita* Prain=*O. nitida* Prain, Burma: Shaik Mokim, s. n. Det. Yakovlev (1967). *O. scandens* Prain, Malay peninsula: Dr. King's Col.—3560. *O. sumatrana* (Miq.) Prain, China: Yunnan, Aug. Henry—12885, Det.—Yakovlev (1967).

Placolobium gracilis (Prain) Yakovlev= *Ormosia gracilis* Prain, Malay peninsula: Perak, King's Col.—4234. *P. travancorica* (Bedd.) Yokovlev=*Ormosia travancorica* Bedd. Tamil Nadu: Tinnevelly, C. A. Barber—3127, Det.—G. S. Gamble.

Ruddia fordiana (Oliv.) Yakovlev—*Ormosia fordiana* Oliv. China: Hainan, F. C. How —72898.

Sophora ardexa Grah. America: Ex. Horto. bot. Petropolitani, s. n. CAL—133547. *S. benthami* V. Steen.=*S. acuminata* Benth. ex Baker, Meghalaya: *G. gallatly*—258. Sikkim: H. F. Green—835. *S. flavescens* Ait. var. *flavescens*=*S. flavescens* Ait; *S. angustifolia* S. & Z. : *S. flavescens* var. *Stenophylla* Hayata; *S. angustifolia* S. & Z. var. *senophylla* Mak. et Nemoto. Japan: Yakohama, Ex. Herb. Bot. Petropolitani, CAL—133475; Tibet: Tali vally, George Forest—4233; China: Zimmermann—201—*S. heptaphylla* Linn. Srilanka: C. P. Thawaites—570; Herb. Sulp. Kurz—s. n. CAL—133333. *S. interrupta* Bedd. Madras: Beddome, s. n. CAL—133458, Det. J. G. Gamble (1917). *S. japonica* Linn. var. *japonica*=*S. japonica* L. Tamil Nadu: Yarkand, J. Scully—s. n. CAL—133490. China: Yunnan, Fr. Ducloux—7617. *S. littoralis* Schrad, Australia: Communicatum ereliquns Martianis (1875), Aquisitions —Journal Nr. 229, CAL—133580. *S. mollis* Grah. var. *griffithii* (Stock) Tsoong—*S. griffithii* Stocks, *S. mollis* subsp. *griffithii* (Stock) Ali, *Keyserlingia griffithii* (Stock) Bunge ex Boiss. Baluchistan: J. F. Duthie —8642. *S. mollis* Grah. var. *mollis*, N. W. Himalaya—H. B. Royle, s. n. CAL —133427; Afghanistan: H. A. Deane, s. n. Herb. Hort. Bot. Calcuttensis. *S. moocroftiana* Benth. Tibet: King's Col.—1, CAL —133280. *S. pachicarpa* Schrenk ex C. A. Mayer, Afghanistan: J. E. T. Aitchinson —435. *S. prazeri* Prain var. *prazeri*, Burma: Gilbert Rogers—1043; Abdul Khalil—s n. (1896), CAL—133467, *S. tomentosa* Linn. var. *tomentosa*=*S. tomentosa* Linn. Australia: Ferd Mueller, s. n. CAL—133564. *S. velutina* Lindl. var. *velutina*= *S. glauca* Lesch. Madras: Coimbatore, C. E. C. Fischer—1056, Det.—G. P. Yakovlev (1967). *S. wightii* Baker—*S. heptaphylla* Auct. non Linn. Wight, Maharashtra: Herb. Hort. Bot. Calcuttensis, NIL, 273B (1879).

Trichocyamus pachycarpa (Camp. ex Benth.) Yakovlev=*Ormosia panchycarpa* camp. ex Benth China: NIL, CAL—133684.

Vexibia alopecuroides (Spach. ex Jaub. et Spach) Yakovlev—*Sophora alopecuroides* Linn. Baluchistan: Stocks—1001, CAL 133390.

Observation and discussion

Pollen morphology of Sophoreae reveals that it is a stenopalynous tribe. Pollen isopolar, 3-zonocolporate, medium sized (exceptionally small), prolate or prolate spheroidal (very rarely oblate spheroidal) in equatorial view, polar axis length ranging from 18 to 38.5 μm and equatorial axis diameter ranging from 18-36 μm, either compressed oval or elliptic oval in meridional forms, circular in polar view. Colpi distinct, either narrow slit like or tapering When tapering sometimes with a median constriction at the equator. Colpus membrane generally smooth, sometimes granulated in the endoaperture area and rarely granules extend through the colpus length. OS generally distinct, either lolon-

gate or lalogate type. When lalongate sometimes it is rectangular. Sometimes equatorial margin of the endoapertures are indistinct. Endoaperture area sometimes provided with randomly distributed granules. In *Ormosia hoaensis* endoaperture is ornate type. Exine ornamentation in the tribe is generally reticulate type—either microrecticulate or coarsely recticulate (Praglowski *et al.*, 1973); rarely psilate, obscure or ruguloreticulate. Lumina homobrochate or heterobrochate, when heterobrochate, finer towards aperture and/or coarser at apocolpium region. Exine layers differentiated into tectum, columella and endexine (Erdtman, 1969) (=sexine and nexine—Faegri & Iversen 1964)). In most of the species foot layer is not distinguishable. Exine thickness varies from 1 to 2.5 μm in the tribe. Generally exine is of uniform thickness, sometimes thicker at apocolpium than the mesocolpium region. Columella in most of the species of *Sophora* are indistinct, but distinct with distinct columella heads in the species of *Ormosia Calpurnia* and *Dalhousia*. In most of the taxa sexine is as thick as nexine, but sometimes sexine is thicker than nexine. Exine stratification in the tribe is important because of the fact that in some species of *Ormosia* (s.l.) double layer of columellae are evident. This observation reminds the similar observation of Ferguson and Skvarla (1981) in *Castanospermum* (Leguminosae). A detail SEM observation on the exine stratification of the Tribe, preferably from the ontogenetic point of view, is necessary for the knowledge of such anomalous double layer exine stratification. In *Sophora tomentosa* Linn. var. *tomentosa*, nexine splitted from the sexine in the endoaperture area and bend inward forming a vestibulum (Faegri & Iversen, 1964) which is a specialized pollen character rarely observed in leguminoceous taxa. Detailed pollen morphological characters of individual species studied are given in the Table 1.

Palynological trends in the tribe Sophoreae

Shape (oblate spheroidal)—Prolate spheroidal—Prolate (rare)

Size (Small) (rare)—Medium - Large

Aperture—Ecto: Slit like—Tapering—Tapering, constricted at the equator.

Endo: (Circular)—Lolongate—Lalongate.

Membrane: Smooth—Granulated—random—Ornate.

Exine ornamentation—Psilate/Obscure—Reticulate

a) finely recticulate/microreticulate (lumina upto 1 μm)

b) Coarsely recticulate/(Lumina greater than 1 μm)

c) ruguloreticulate

Columella layer—Single layer—double layer (most anomalous). Indistinct distinct, with distinct head

Palynotaxonomic consideration and affinities

Review of taxonomic literature (Yakovlev, 1972, 1973a, b, 1978; Tsoong, 1980; Tsoong & Machi, 1981) reveals that the nomenclature and identity of a number of taxa of the tribe have been changed from time to time by the taxonomists. As a result 4 genera and 40 species (*sensu lato*) studied palynologically are now validated as 9 genera and 40 species (sensu genera and species nova). Three species of *Ormosia* have been given the gernic status by Yakovlev), viz., *Trichcyamus*, *Placolobium* and *Ruddia* but palynology has nothing to do in support of the creation of new taxa except for *Trichocyamus pachycarpa* (camp. ex Benth.) Yakovlev (=*O. pachycarpa*) which is distinct for its double layer of columellae in the exine. But similar important as well as anomalous feature is also observed in *O. assamica* Yakovlev (=*O. robusta*), *Placolobium travancorica* (Bedd.) Yakovlev (—*O. travancorica*), *P. gracilis* (Prain) Yakovlev (=*O. gracilis*). *Fedorovia laxa* (Prain) Yakovlev (=*O. laxa*), *F. striata* (Dunn) Yakovlev (=*O striata*) and *Ruddia fordiana* (Oliv.) Yakovlev (=*O. fordiana*) all these taxa have been given new rank in taxonomy but they do not show any distinct palynological character in support of their new taxonomic status. There are a number of overlapping characters with other species of *Ormosia*. Similarly *Vexibia alopecuroides* (Spach. ex Jaub. et Spach.) Yakovlev (=*Sophora jaubertii*) shows no additional palynological supporting character in favour of its new status except a few exceptionally smaller pollen grain size, which I belive is more phytogeographical criterion rather than a stable and important specific character. Some exceptionally small pollen grains (20.5 × 18 μm) were also observed in

Sophora flavescens Ait. var. *flavescens* while exceptionally large (36.5×31 μm) in *Sophora wightii* Baker. A few oblate-spheroidal pollen grains have been observed in contrary to the prolate-spheroidal normal ones in *Sophora pachicarpa* Schrenk ex C. A. Mayer. Some new species and variety of *Sophora* created by different authors from time to time have overlapping palynological characters with other species of the genus (Mitra *et al.*, 1979; Mitra & Mondal, 1982) published a detail pollen morphology of the tribe Hedysareae and *Desmodium*. Pollen morphologically *Sophora Ormosia* (some spp.) and *Calpurnia* show similarity with those of the tribe Dalbergieae and genera *Dalhousia* and *Ormosia* (some spp.) with the tribe Hedysareae and Desmodieae (sensu Polhill, 1981). Pollen grains of the tribe Amherstieae and Detarieae of the subfamily Caesalpinioideae (Okolo & Gill, 1987) show some similarity in shape, aperture and exine character. Bentham and Hooker's placement of the tribe Sophoreae as last tribe of Papilionioideae and just before Caesalpinioideae is justified in this regard. Similarity of pollen morphological features of the tribes of Leguminosae (Vishnu—Mittre & Sharma, 1962; Mitra *et al.*, 1969; Mitra & Mondal, 1982; Okolo & Gill, 1989) with Connaraceae (Dickison, 1979; Mondal, 1983, 1986) strengthen their possible common ancestry (Takhtajan, 1966, 1969, 1973).

Conclusion

Sophoreae is a stenopalynous tribe and supports natural grouping in Bentham and Hooker's (1852-1883) system of classification.

The taxa show a gradual trend from unspecialised to derived types of pollen morphoforms.

Creation of new genera is not supported palynologically.

Present study supports the recent phylogenetic scheme proposed by Polhill (1981), though through some bidirectional way. Palynologically Sophoreae links with Dalbergieae on one hand and Hedysareae (s.l.) on the other.

A detail SEM study is needed on the ontogeny of the pollen wall stratification of *Ormosia* for its unique development of double layer of columellae.

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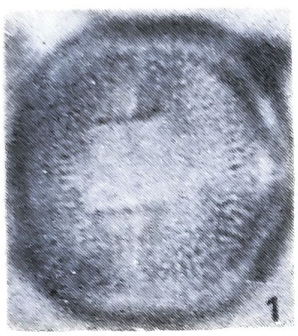
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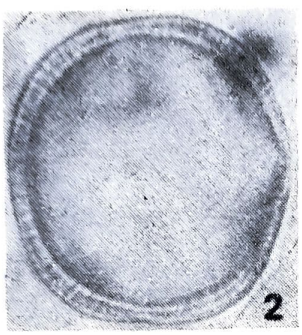
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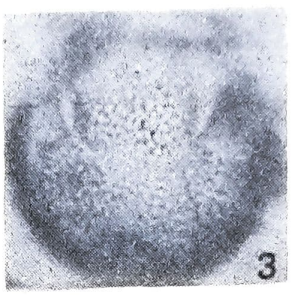
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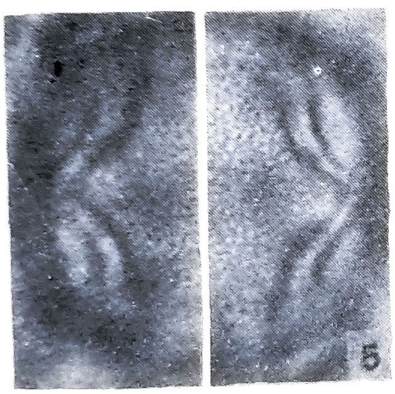
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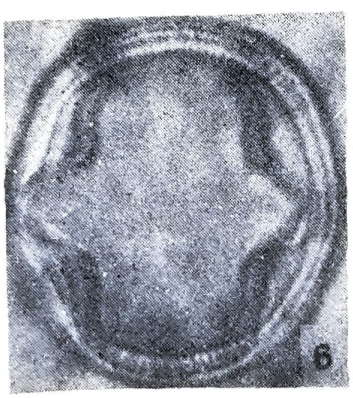
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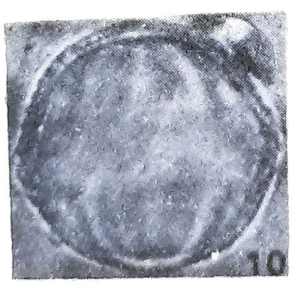
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Explanation of Plate

Plate 1

(All figures × 1000)

1—4. *Trichocyamus pachycarpa* (Camp. ex Benth.) Yakovlev. 1. Aperture rnd details of exine; 2. Optical section meridional showing double layer of columellae; 3. Polar view showing exine in apocolpium; 4. Optical section equatorial.

5—6. *Ormosia assamica* Yakovlev—5. Exine in Ist and 2nd focus; 6. Optical section meridional showing double layer of columellae.

7—8. *Sophora velutina* Lindl. var. *velutina*. 7. Details of exine; 8. Optical section meridional and aperture profile.

9—10. *Calpurnia auria* Baker. 9. Aperture and details of exine; 10. Optical section meridional.

11—12. *Dalhousia africana* S. moore. 11. Details of exine; 12. Optical section meridional and aperture profile.