Indian J. Applied & Pure Bio. Vol. 28(2), 121-132 (2013).

Leaf architectural studies in some Meliaceae

Sarala C. Tadavi and Vijay V. Bhadane*

*P. G. and Research Department of Botany,
Pratap College, Amalner-425401 (India)
E-mail: bhadanevv2009@rediffmail.com

ABSTRACT

The present study deals with the leaf architectural studies of eighteen species distributed over fifteen genera of the Meliaceae has been carried out to provide comprehensive account on the leaf architecture of Meliaceae and its taxonomic significance. The leaves are compound except for simple once in *Turraea villosa*. The leaf shape, apex, base, number of areoles and vein endings entering the areoles are species specific. The major venation pattern conforms to pinnate brochidodromous either with eucamptodromous or craspedodromous types. The highest degree of vein order is up to 6º. Quantitative parameters like the numbers of secondary veins, areoles and vein endings per unit area have using analyzed. The veinlets terminations are mostly conventional tracheids or occasionally dilated. The presence of bundle sheath is common around 1º to 5º veins. Leaf architectural characteristics such as presence of major venation categories, nature of marginal ultimate venation, areoles, presence or absence of bundle sheath and type of leaf margins are found to the helpful in delimiting the taxa study. Based on these characters a key is prepared for identification of species investigated.

Key words: Leaf architecture, taxonomy, Meliaceae

In the earlier communication the authors have discussed the taxonomic significance of the rachis, petiole and petiolule and foliar epidermal structures in Meliaceae[1,2]. This paper reports on the leaf architecture and it's bearing on the circumscription of the family.

Though the study of leaf architecture is more than a century old, due importance was not given to it in the systematic studies of the dicotyledons. However, the work of Hickey[4,5] gave a new impetus and precision to the subject. A perusal of the past literature revealed that studies on leaf architecture in Meliaceae are almost negligible[4,5,7,8]. Therefore, the present investigation has been carried out to provide a detailed account on the same besides its evaluation for taxonomic purpose.

Eighteen species of the Meliaceae obtained from Kolhapur, Belgaon, Hyderabad, Waghai, Calicut, Amlibari, Botanical garden of Dr. B.A. Marathwada University (Aurangabad) for the study. The leaves of the material fixed in acetic alcohol are cleared in a supersaturated solution of chloral hydrate for 2 or 3 days. However, the leaves of the herbarium material are first boiled in 5% sodium hydroxide for a few minutes and then kept in 10% potassium hydroxide at 30ºC for 2-3 days. Permanent Canada balsam mounts of the cleared leaves are prepared after dehydration in alcohol and staining them with alcoholic safranin. In those taxa with compound leaves, the middle leaflets of a mature leaf are selected and the leaflet is referred to as leaf. The terms described are adapted from Hickey[4] and Tucker[9].

Leaves uni- or bi- or tri-pinnately compound, tri-foliate or simple; leaflets unlobed, pari- or imparipinnate; leaflets ovate, lanceolate, elliptic or oblong; margin entire, serrate or wavy; apex acute, acuminate or obtuse; base acute, obtuse or oblique; texture herbaceous or coriaceous.

In all the taxa studied, the venation is unicostate, reticulate and may be differentiated in to a number of size and classes. The veins of first, second and third categories are considered under the major venation pattern and the veins of the subsequent categories -- the minor venation patterns that form the reticulum. The species wise qualitative leaf features are given in the Table 1a and Table-1b.

Major venation pattern:

The venation pattern is of pinnate camptodromous, either with eucamptodromous or brochidodromous conditions. Eucamptodromous type occurs in *Azadirachta*, *Cipadessa*, *Melia dubia*, *Naregamia*, *Turraea*, *Aglaia* and *Aphanamixis* (Plate I, Figs. 1, 2, 5-7), while brochidodromous in *Walsura*, *Chickrassia*, *Khaya*, *Soymida*, *Swietenia*, *Toona*, *Chloroxylon*, and *Dysoxylum* (Plate I, Figs. 8-15). In addition pinnate-mixed craspedodromous is observed in *Melia azedarach* and *Melia birmanica* (Plate I, Figs. 3-4).

Primary veins :

The primary vein (1º) is the thickest vein of the leaf/leaflets and its thickness decreases gradually towards the apex and it gives off other degree veins on either side. The primary vein is stout to moderate or weak. It runs straight or bends into a small curve in the lamina (Plate I, Figs. 1, 5, 10, 12, 13, 15). The primary veins are simple and remain unbranched.

Secondary veins :

The secondary veins (2º) arise on either side of the primary vein in alternate fashion and sometimes opposite manner, which diverge uniformly at a moderately acute angle from the primary vein and extend towards the margin bending in a smooth or abrupt curve. The secondaries are present more on one side of the primary vein in leaves with oblique base (Plate I, Figs. 1, 6, 8, 11-16). The number of secondary veins acute wide, acute moderate or acute narrow and varies from species to species and even within the same species from base to apex. In *Azadirachta*, *Melia*, *Aglaia*, *Chickrassia*, *Khaya*, *Toona* and *Swietenia* (Plate I, Figs. 1, 3-5, 10-13), the basal secondary veins are acute wide. Some secondary veins

become more acute wide at the apical region of lamina in *Aphanamixis*, *Khaya*, and *Swietenia* (Plate I, Figs. 10, 11). The secondaries may or may not show branching into two towards tip. These are interconnected by super-adjacent secondaries.

The inter-secondaries are present running parallel or nearly so to the secondaries as in *Azadirachta*, *Cipadessa*, *Melia*, *Chickrassia*, *Khaya*, *Soymida*, *Toona*, *Chloroxylo*n, *Swietenia* and *Dysoxylum* (Plate I, Figs. 1-5, 8, 10-15).

Tertiary veins :

The next higher order veins are the tertiaries (3º) arising from the secondaries and are of RR, RO, RA types. They form either orthogonal reticulate pattern or random reticulate and occasionally percurrent, simple or branched.

Minor venation pattern:

The veins of the next originating from the tertiaries and those of the same size originating from secondaries and even primary constitute the quaternary (4º) veins and those originating from these and those of equal size from the lower orders are the quinternaries (5º). The highest order veins are identified up to 6º. In *Azadirachta, Melia, Soymida, Swietenia, Khaya, Dysoxylum* and *Walsura*, it is up to 6º and in the rest of the genera investigated it is up to 5º. The numerical data on the venation pattern are charted in Table 2.

The freely ending ultimate veins are called veinlets. The number of veinlets entering an areole also varies from species to species and within the same species.

The marginal venation :

The marginal ultimate venation is incomplete in *Azadirachta, Cipadessa, Melia, Naregamia, Turraea, Aglaia, Aphanamixis, Walsura, Chickrassia* and *Chloroxylon* (Plate II, Figs. 1-6, 8). It is Fimbriate in *Dysoxylum, Khaya, S. macrophylla* and *Toona* (Plate II, Figs. 7, 9, 10, 12) and looped in *S. mahogani* (Fig. 11, Plate II).

Areoles :

The areoles are the smallest areas of the leaf tissue, which are bounded by the thinnest branches of the veins, mostly either with quaternary or quinternaries. The areoles are generally imperfect. In *Cipadessa, Dysoxylum, Walsura* and *Toona* the areoles are well developed (Plate II, Figs. 2, 7, 8, 12). The size and shape of the areoles are variable. The shape is generally quadrangular, pentagonal and polygonal rarely circular, triangular or irregular (Plate II, Figs. 2, 7, 8). The size of the areoles also varies. The areoles generally contain terminal vein endings. In *Dysoxylum*, the areoles are empty (Plate II, Fig. 7), very few areoles contain vein endings (Plate III, Fig. 1). The vein endings end blindly in the mesophyll. In several cases, loop formation is observed (Plate II, Fig. 3; Plate III, Fig. 2) the vein endings may be simple or branched. The simple vein endings may be linear or curved. The branched ones divide dichotomously once, twice or three times. The branches may be symmetrical or asymmetrical.

Vein endings :

The vein terminations show variations

and include conventional and dilated tracheids (Plate II, Figs. 2-4, 6, 8). They are either linear, isodiametric; spindle shaped or T shaped (Plate III, Figs. 7-11), they are uniseriate, biseriate, multi-seriate, and juxtaposed in arrangement (Plate III, Figs. 4, 6-12). The tracheids in groups or clusters are observed as in *Cipadessa*, *Aphanamixis* (Plate III, Figs. 4, 6, 8, 12). The uniseriate superimposed tracheids occur in *Melia birmanica* (Plate III, Fig. 10).

Isolated vein endings – uniseriate, biseriate or multiseriate – are observed in some plants with terminal tracheids lying free. Isolated tracheids are also of common occurrence in few plants (Plate III, Fig. 5). Extension cells are parenchymatous, which adjoin a vein with an isolated tracheids are observed in *Soymida* (Plate III, Fig. 3).

Bundle sheath :

The bundle sheath is well developed and mostly with sclerenchymatous cells on all the grades of veins in *Aphanamixis*, *Walsura*, *Soymida*, *Toona* and *Dysoxylum* (Plate III, Fig. 1) It is observed on primary and secondary veins in *Melia azedarach*, *M. birmanica*, *M. dubia*, *Swietenia macrophylla*, *S. mahogani*, *Chloroxylon* and *Chickrassia*. In *Azadirachta* it is developed on primary veins. *Chloroxylon* and *Azadirachta* have parenchymatous bundle sheath.

Sclereids :

These elements are ramiform with short arms or processes and are scattered throughout the leaf on either side of veins in *Cipadessa* and *Dysoxylum*.

Crystals :

Calcium oxalate crystals lie on either side of primary veins in *Azadirachta*, *Melia azedarach* and *Melia dubia*.

The plants in this family are chiefly unicostate with reticulate venation. The earlier observations by Hickey[4] in venation pattern is of pinnate, camptodromous -- eucamptodromous type in seven taxa, camptodromous -- brochidodromous in nine species and pinnate-mixed craspedodromous in *Melia azedarach* and *M. birmanica*. While Melville[7] noted venation pattern curvipinnate simple in seven taxa, curvipinnate -- coarcuate other nine species and rectipinnate in *Melia azedarach* and *M. birmanica*.

According to Hickey and Wolfe[6], the venation in this family is pinnate-semicraspedodromous while Sarma *et al*.[8]describe it as pinnate -- eucamptodromous, pinnate -- brochidodromous and pinnate -- mixed craspedodromous.

The marginal ultimate venation exhibits great uniformity in that in majority of the plants; it is incomplete. *Dysoxylum*, *Toona*, *Khaya*, *Soymida*, and *Swietenia macrophylla* show fimbriate margins. Looped marginal venation occurs only in *Swietenia mahogani* and this character makes this taxon stand apart from the other species investigated.

The areole formation is mostly either with quaternary or quinternaries in all the taxa investigated. The areoles are variable in size and shape but imperfect in many species. They are well developed in certain taxa, *e.g. Cipadessa*, *Dysoxylum*, *Walsura* and *Toona*. The areoles may show veinlets and free vein

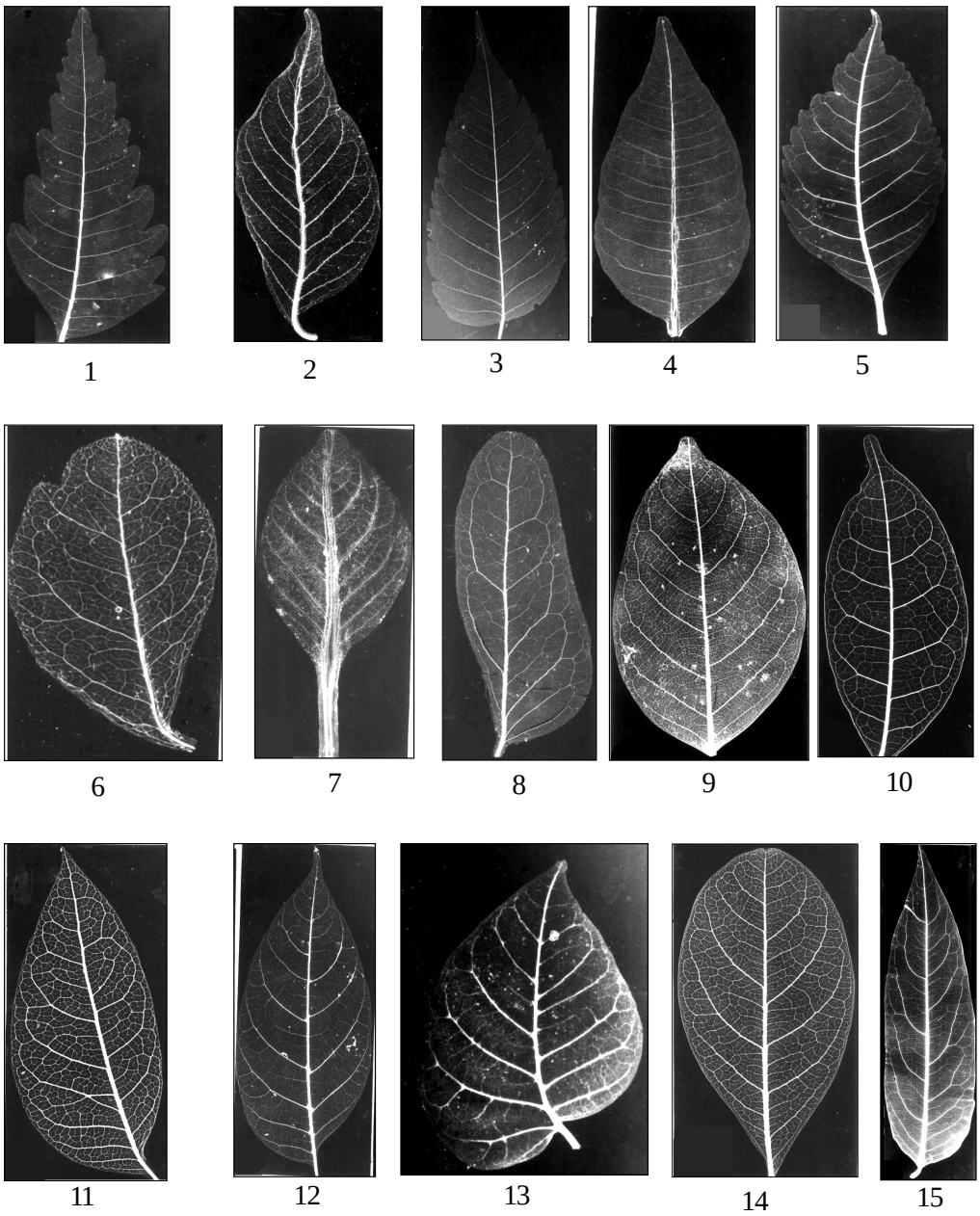

Photo Plate-I. Cleared leaves of

1. *Azadirachta indica*, 2. *Cipadessa fruticosa*, 3. *Melia azedarach*, 4.*Melia birmanica* 5. *Melia dubia*, 6.*Naregamia alata*, 7.*Turraea villosa*, 8.*Chloroxylon swietenia* 9.*Walsura trifolia*, 10. *Khaya senegalensis*, 11.*Swietenia mahogani*, 12. *Toona ciliata*, 13. *Chickrassia tabularis*, 14.*Soymida febrifuga*, 15. *Dysoxylum binectariferum*

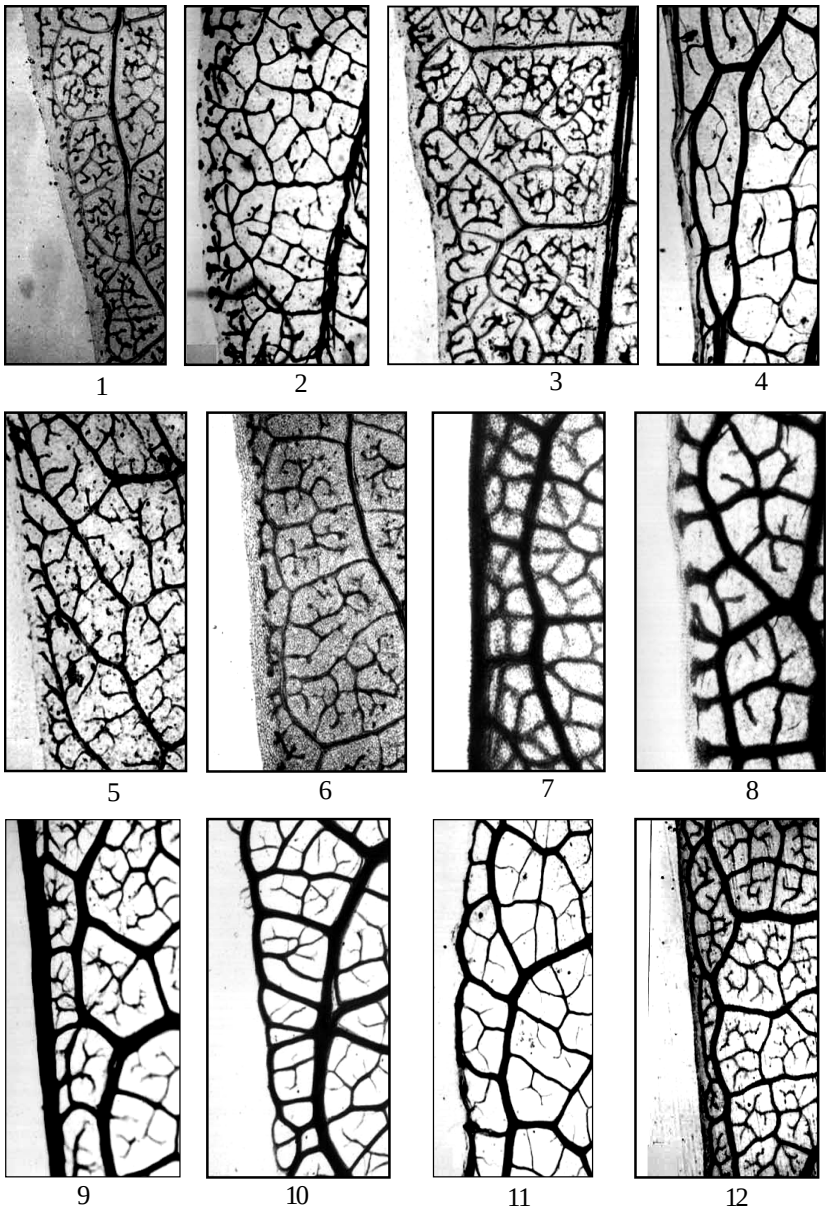

Photo Plate:II Laminar margins

1. *Azadirachta indica* 2. *Cipadessa fruticosa* 3.*Melia birmanica* 4.*Naregamia alata* 5.*Turraea villosa* 6.*Aglaia odoratissima* 7.*Dysoxylum binectariferum* 8.*Walsura trifolia* 9. *Khaya senegalensis* 10. *Swietenia macrophylla* 11. *Swietenia mahogany* 12. *Toona ciliata*

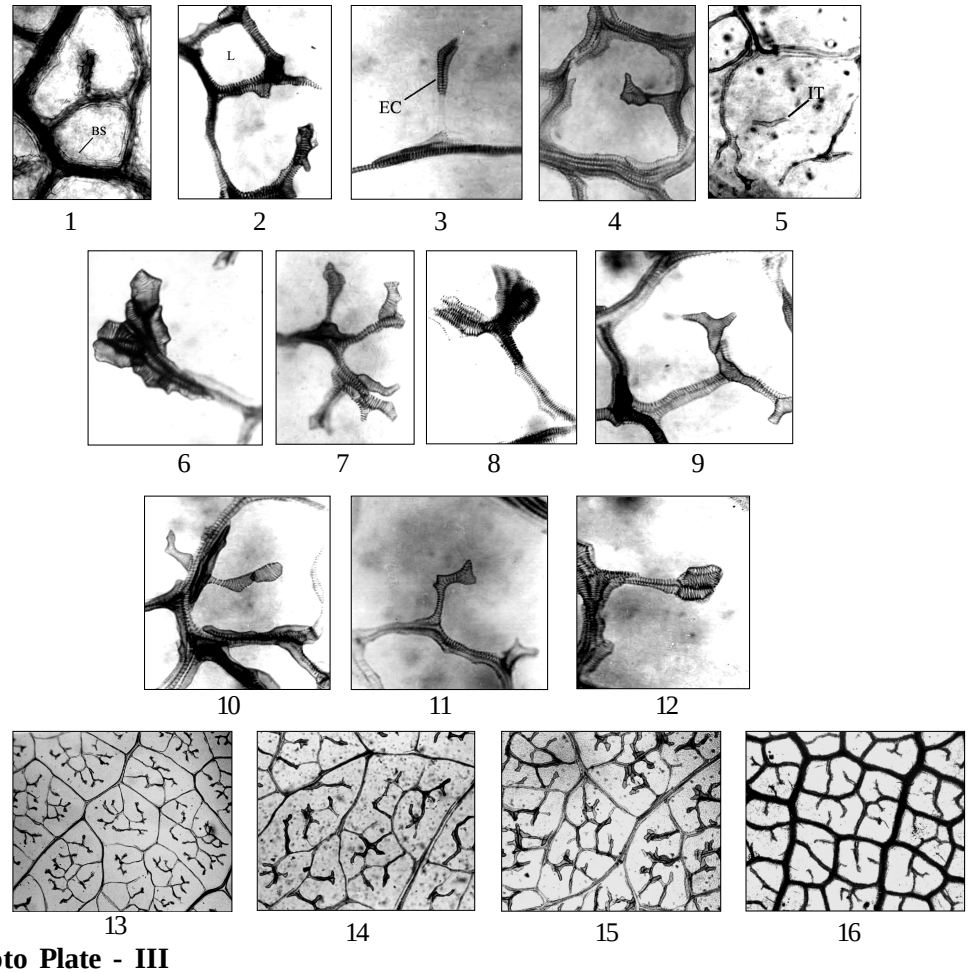

Photo Plate - III

1. *Dysoxylum binectariferum* - showing rare occurrence of simple veinlet and bundle sheath; 2. *Chickrassia tabularis* - showing loop formation; 3. *Soymida febrifuga* -showing parenchymatous extension cell and biseriate terminal tracheids; 4, 8 &12- *Aphanamixis polystachya* - showing juxtaposed and clustered tracheids; 5. *Aphanamixis polystachya* - showing isolated tracheid; 6. *Cipadessa fruticosa* - showing cluster of tracheids at the tip of veinlet; 7. *Chickrassia tabularis* - showing spindle shaped uniseriate and multiseriate tracheids; 9. *Melia dubia* - showing 'T' shaped tracheid; 10. *Melia birmanica* - showing superimposed tracheids; 11. *Chloroxylon swietenia* - showing uniseriate, 'T' shaped tracheid; 13. *Aphanamixis polystachya*- showing imperfect areole developments and loop formation; 14. *Melia azedarach* - showing imperfect areole developments, veinlets simple and branched loop formation; 15. *Melia birmanica* - showing mostly simple veinlets and loop formation; 16. *Walsura trifolia*- showing areoles with simple veinlets.

Table-1a. Showing species-wise leaf features

Sr. No.	Name of plant	Leaf	Leaf/leaflet shape	Base	Apex	Margin	Texture	Petiole/ petiole	Lamina balance
1	*Azadirachta indica*	Pinnately compound	Obliquely lanceolate or ovate/falcate	Inequilateral acute	Acute or acuminate	Serrate	Herbaceous	Terete	Asymmetrical base
2	*Cipadessa fruticosa*	-do-	Elliptic lanceolate	Acute	Acute	Coarsely serrate	Herbaceous	-do-	-do-
3	*Melia azedarach*	Bi-or sometimes tri-pinnate	Ovate or lanceolate	Slightly inequilateral	Acuminate	Obtusely serrate or sometimes lobed	Herbaceous	-do-	-do-
4	*Melia birmanica*	Bi-pinnate	Ovate or lanceolate	Obtuse or acute	Acute or acuminate	Entire	Coriaceous	-do-	-do-
5	*Melia dubia*	Bi-or sometimes tri-pinnate	Ovate or lanceolate to ovate-round	Acute or rounded, more or less oblique	Acute or acuminate	Entire or crenulate	Herbaceous	-do-	-do-
6	*Naregamia alata*	Tri-foliate	Cunate-ovate	Inequilateral acute	Mucronate	Entire or obtusely lobed	Herbaceous	-do-	-do-
7	*Turraea villosa*	Simple	Elliptic or ovate	Acute or rounded	Acuminate	Entire	Herbaceous	-do-	Symmetrical-asymmetrical
8	*Aglaia odoratissima*	Pinnately compound	Elliptic oblong or obovate	Cuneate-oblique	Shortly-acuminate	Quite entire	Thinly coriaceous	-do-	Asymmetrical
9	*Aphanamixis polystachya*	-do-	Elliptic oblong or oblong lanceolate	Very inequilateral obtuse or acute	Acuminate	Entire	Coriaceous	-do-	-do-
10	*Dysoxylum binectariferum*	-do-	Oblong elliptic	Acute	Acuminate	Entire	Coriaceous	-do-	-do-
11	*Walsura trifolia*	Tri-foliate	Oblong elliptic	Sub-acute	Obtuse	Entire	Coriaceous	Terete	Asymmetrical
12	*Chickrassia tabularis*	Pinnately compound	Ovate or ovate-oblong	Inequilateral	Acute or acuminate	Entire	Herbaceous	-do-	Asymmetrical
13	*Khaya senegalensis*	-do-	Elliptic-oblong	Acute	Acute or acuminate	Entire or slightly curved	Coriaceous	-do-	Symmetrical-asymmetrical
14	*Soymida febrifuga*	-do-	Elliptic-oblong	Rounded inequilateral	Obtuse	Entire	Coriaceous	-do-	Asymmetrical
15	*Swietenia macrophylla*	-do-	Ovate to lanceolate	Oblique inequilateral	Acute or acuminate	Entire	Coriaceous	-do-	-do-
16	*Swietenia mahogani*	-do-	Elliptic	Oblique inequilateral	Acuminate	Entire	Coriaceous	-do-	-do-
17	*Toona ciliata*	-do-	Lanceolate or ovate-lanceolate	Oblique inequilateral	Acuminate	Entire or obliquely undulate	Herbaceous	-do-	-do-
18	*Chloroxylon swietenia*	-do-	Oblong	Inequilateral acute or rounded-acute	Obtuse	Entire	Herbaceous	-do-	-do-

Table-1b. Showing species-wise venation pattern

Sr. No.	Name of plant	Nature of the mid-vein on adaxial side	Primary vein size	Secondary veins, angle of divergence	Predominant tertiary vein origin angle	Marginal ultimate venation	Sub-type venation
1	*Azadirachta indica*	Slightly elevated	Weak	Acute wide	RR, RO, RA	Incomplete	Eucampto-dromous
2	*Cipadessa fruticosa*	-do-	Moderate, stout and curved	Acute moderate	AR, RR, RA	Incomplete	Eucampto-dromous
3	*Melia azedarach*	Elevated	Weak	Acute wide	AR, RR, OR	Incomplete	Craspedo-dromous
4	*Melia birmanica*	-do-	Moderate, stout, straight	-do-	RR, RA	Incomplete	Eucampto-dromous
5	*Melia dubia*	-do-	Moderate, stout and curved	Acute moderate	OA, RR, RA, AR	Incomplete	Craspedo-dromous
6	*Naregamia alata*	Slightly elevated	Moderate, stout, straight	-do-	RR, RA, OA	Incomplete	Eucampto-dromous
7	*Turraea villosa*	-do-	-do-	-do-	AA, AR, RR, RA	Incomplete	Eucampto-dromous
8	*Aglaia odoratissima*	Elevated	Moderate, stout, straight and curved	Acute moderate wide	RR, RA	Incomplete	Eucampto-dromous
9	*Aphanamixis polystachya*	Grooved	Stout and curved	Acute wide	RR, RA	Incomplete	Eucampto-dromous
10	*Dysoxylum binectariferum*	Slightly elevated	Stout and straight	Acute wide	RR, AR, RA, AO, RO	Fimbriate	Brochido-dromous
11	*Walsura trifolia*	-do-	Moderate, stout and straight	Acute moderate	AA, RA, RR, OA	Incomplete	Brochido-dromous
12	*Chickrassia tabularis*	Grooved	Moderate, stout and curved	Acute wide	RR, AR, RA	Incomplete	Brochido-dromous
13	*Khaya senegalensis*	Slightly elevated	-do-	Acute moderate	OR, OA, RA, RO	Fimbriate	Brochido-dromous

14	*Soymida febrifuga*	Grooved	Moderate, stout, straight and curved	-do-	RR, RA	Fimbriate	Brochido-dromous
15	*Swietenia macrophylla*	Elevated	Moderate, stout and curved	-do-	OR, RR, RA	Fimbriate	Brochido-dromous
16	*Swietenia mahogani*	-do-	-do-	Acute moderate	RR, AR, OR	Looped	Brochido-dromous
17	*Toona ciliata*	-do-	-do-	-do-	OR, RR	Fimbriate	Brochido-dromous
18	*Chloroxylon swietenia*	Slightly elevated	Weak	-do-	RR, RA, RO, AA, AO	Incomplete	Brochido-dromous

AA - Acute acute, AO - Acute obtuse, AR - Acute right, OA - Obtuse acute,
OR - Obtuse right, RA - Right acute,RO - Right obtuse, RR - Right right

Table-2. Numerical data on the venation pattern:

Sr. No.	Name of plant	Leaf area in mm^2	No. of 2^o Veins along one side of mid-rib	Angle between 1^o+2^o veins	No. of areoles per mm^2	Vein ending termi-nation	Highest vein order(^{o})
1	*Azadirachta indica*	1000	11	60º - 80º	7	4	6º
2	*Cipadessa fruticosa*	300	10	40º - 50º	9	4	5º - 6º
3	*Melia azedarach*	700	10	60º - 65º	9	3	5º
4	*Melia birmanica*	480	12	70º - 80º	10	9	5º - 6º
5	*Melia dubia*	833	9	50º - 70º	6	7	6º
6	*Naregamia alata*	325	7	50º - 60º	3	4	6º
7	*Turraea villosa*	200	9	40º - 50º	3	6	5º - 6º
8	*Aglaia odoratissima*	2733	9	60º - 70º	5	7	6º
9	*Aphanamixis polystachya*	6100	12	50º- 60º	3	6	5º
10	*Dysoxylum binectariferum*	4300	10	40º - 55º	6	2	5º - 6º
11	*Walsura trifolia*	800	7	45º - 60º	3	3	5º- 6º
12	*Chickrassia tabularis*	4066	9	50º - 65º	4	6	5º - 6º
13	*Khaya senegalensis*	2750	6	60º - 70º	5	8	6º
14	*Soymida febrifuga*	1400	7	55º - 70º	3	5	5º - 6º
15	*Swietenia macrophylla*	4600	9	60º - 70º	4	6	5º - 6º
16	*Swietenia mahogani*	1175	8	60º- 70º	4	6	5º -6º
17	*Toona ciliata*	4500	9	50º - 60º	4	6	5º - 6º
18	*Chloroxylon* swietenia	350	6	40º - 50º	9	4	5º - 6º

endings. Sometimes areoles are devoid of veinlets as in *Dysoxylum* wherein most of the areoles are empty. The free vein endings end blindly in the mesophyll. In most of the plants, these have terminal tracheids, which may be uniseriate, biseriate or in groups. The free vein endings, isolated tracheids and extension cells are observed in a few plants. Foster[3] used the term tracheary idioblasts for dilated enlarged terminal tracheids at the vein endings, while the tracheoidal idioblasts are those that lie free and distinct the areoles.

Presence of bundle sheath is an important feature in the presently investigated taxa. In *Walsura*, *Dysoxylum*, *Aphanamixis*, *Toona*, *Khaya* and *Soymida*, bundle sheath is present on all the grades of veins, whereas it is seen only on primary and secondary veins in *Melia*, *Chickrassia*, *Swietenia* and *Chloroxylon*. *Azadirachta* has it only on primary veins. Sarma *et al*.[8] also record the bundle sheath in *Toona*, *Azadirachta* and *Swietenia mahogani* earlier.

Occurrence of sclereids around the veins in *Cipadessa* and *Dysoxylum* are of common occurrence. Crystals are present on the sides of primary veins in *Azadirachta* and *Melia*.

The characters such as types of venation, marginal ultimate venation, bundle sheath, nature of areoles, tracheids etc. can be employed for the taxonomic delineations of the plants. Based on a number of diagnostic foliar venation characteristics, a key for delimiting the eighteen species of Meliaceae presently studied is in the following.

Key for the identification of Meliaceae investigated:

1.Venation pattern pinnate craspedodromous (Mixed)
2. Primary vein weak and straight……*Melia azedarach*
2. Primary vein moderate stout and curved……..*Melia dubia*
1.Venation pattern pinnate camptodromous
3. Brochidodromous condition is present
4. Marginal venation in leaf fimbriate or looped
5. Marginal venation looped……...*Swietenia mahogani*
5. Marginal venation fimbriate
6. Areoles well developed
7. Areoles mostly empty……*Dysoxylum binectariferum*
7. Areoles not empty……*Toona ciliata*
6. Areoles imperfect
8. Nature of mid vein on adaxial side elevated
9. Leaf shape elliptical oblong……..*Khaya senegalensis*
9. Leaf shape ovate to lanceolate……..*Swietenia macrophylla*
8. Nature of mid vein on adaxial side grooved ……. *Soymida febrifuga*
4. Marginal venation in leaf incomplete
10. Bundle sheath well developed
11. Bundle sheath occur on all grades of veins……*Walsura trifolia*
11. Bundle sheath occur on primary and secondary veins
12. Bundle sheath parenchymatous …….. *Chloroxylon swietenia*
12. Bundle sheath sclerenchymatous……..*Chickrassia tabularis*
3. Eucamptodromous condition is present
13. Leaf margin serrate or coarsely serrate
14. Presence of sclereids around veins. ……. ….…...*Cipadessa fruticosa*
14. Sclereids absent……..… *Azadirachta indica*
13. Leaf margin entire
15. Texture coriaceous
16. Primary vein stout and straight…….
17. Crystals present on sides of primary veins……..*Melia birmanica*
17. Crystals absent……*Aglaia odoratissima*
16. Primary vein stout and curved..…….. *Aphanamixis polystachya*
15. Texture herbaceous
18. Leaf simple..……..……..…… *Turraea villosa*
18. Leaf trifoliate.……..…… *Naregamia alata*

The authors wish to thank Principal, Pratap College, Amalner for encouragement and providing laboratory facilities during the course of investigation.

References:

1. Bhadane, V.V. (2006). *BIOINFOLET*, *3* (4): 2006, 234-239.
2. Bhadane, V.V. and Patil, Garima G. (2007). *BIOINFOLET*, *4*(3): 172-180.
3. Foster, A.S. (1956). *Protoplasma*, *46*: 184-193.
4. Hickey, L. J. (1973). *Amer. J. Bot*., *60*: 17-33.
5. Hickey, L. J. (1979). A revised classification of the architecture of dicotyledonous leaves. In: *Anatomy of the Dicotyledons* / ed. By C. R. Metcalfe; L. Chalk. Oxford.
6. Hickey, L.J. and J.A.Wolfe, (1975). *Ann. Missouri Bot. Gard*, *62*: 538-589.
7. Melville, R., (1976). *Taxon 25*: 549-561.
8. Sarma, V., S.R. Shanmukha Rao and C.H. Beena, (1992). *Feddes Repert*, *103*: 535-542.
9. Tucker, S.C. (1964). *Amer. J. Bot. 51*: 1051-1062.