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LEAF ARCHITECTURAL STUDIES IN SOME CUCURBITACEAE

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Architectural features of the leaf in 31 taxa of Cucurbitaceae have been studied of which 26 taxa are investigated for the first time. The leaves are palmately lobed and venation is exclusively actinodromous. The marginal ultimate venation is either looped or incomplete and the highest vein order resolved is 50 to 70. . Quantitative parameters like the number of secondary veins, areoles and vein-endings per unit area have been analyzed. Vein terminations are conventional or dilated. Isolated tracheids and extension cells are present in a few taxa. Presence of bundle sheath is found to be a common feature in Cucurbitaceae. Based on the leaf architectural characteristics, a key is presented for delimitation of the taxa studied.

Key words: Cucurbitaceae, Leaf architecture, Taxonomy.

In the recent years, considerable attention is paid to the foliar architectural studies in relation to taxonomy among several angiospermous taxa. Plant venation pattern is one of the prominent aspects of leaf form and is species specific, indicating that it is under strict genetic control. The leaf architecture is also a showcase of plant diversity ranging from grid like net-work in grasses, to a wide variety of dendritic system in angiosperms. It is an important plant performance with key implication for the distribution and productivity of ecosystem and application in palaeobotany, agriculture and technology (Hickey 1979, Ash *et al.* 1999, Ellis *et al*. 2009, Sack and Scoffini 2013).

Cucurbitaceae with 800 species under 130 genera is one among the economically most important plant families (Jeffrey, 2005) and Indian representation being 31 genera with 94 species (Renner and Pandey 2013, Shanmukha Rao and Srinivas Rao 2014). Investigations on leaf architecture in Cucurbitaceae are meagre (Melati and Scialabbe 1982, Meenakshi and Mhatre 2013). Therefore, presently 31 taxa belonging to 16 genera of Cucurbitaceae have been studied of which 26 taxa are investigated first time with reference to the foliar venation characteristics.

MATERIALS AND METHODS:

The taxa collected for the study are given in Table 1. Mature leaves are cleared following the procedure of Thakur (1988) which is slightly modified to suit the present investigation. The leaves are kept in 5% KOH solution at 25 °C for 6-8 hours. The material was then washed with water and transferred to acetic acid, H_2O_2 and lacto-phenol in 1:1:1 ratio for 1 to 2 hours. Leaves of some taxa are first cleared in 50% sodium hypochlorite solution for 6-8 hours and later transferred to supersaturated solution of chloral hydrate for 1-2 days. Then the material is washed in water. Later, the preparations were stained with alcoholic safranine and mounted in glycerine. The terms described are adapted from Hickey (1979), Ash *et al*. (1999) and Tucker (1964).

RESULTS AND DISCUSSION

Past literature reveals that the palmately lobed leaves possess actinodromous condition (Mohan and Inamdar 1984, Shanmukha Rao and Leela 1990). The leaves of cucurbits are palmately lobed, alternate, ovate, wide ovate, cordate, reniform, apex acute, obtuse mucronate, acuminate; base cordate, lobate; margin irregular dentate, denticulate, serrate, toothed, entire wavy; texture, herbaceous, chartaceous, membranous, coriaceous and possess actinodromous basal venation type. Their marginal ultimate venation is either incomplete (Fig. 1A) or looped (Fig. 1C) (Table1).

Venation Pattern (Fig. 1-3)

The number of primary veins range from 3 to 7,

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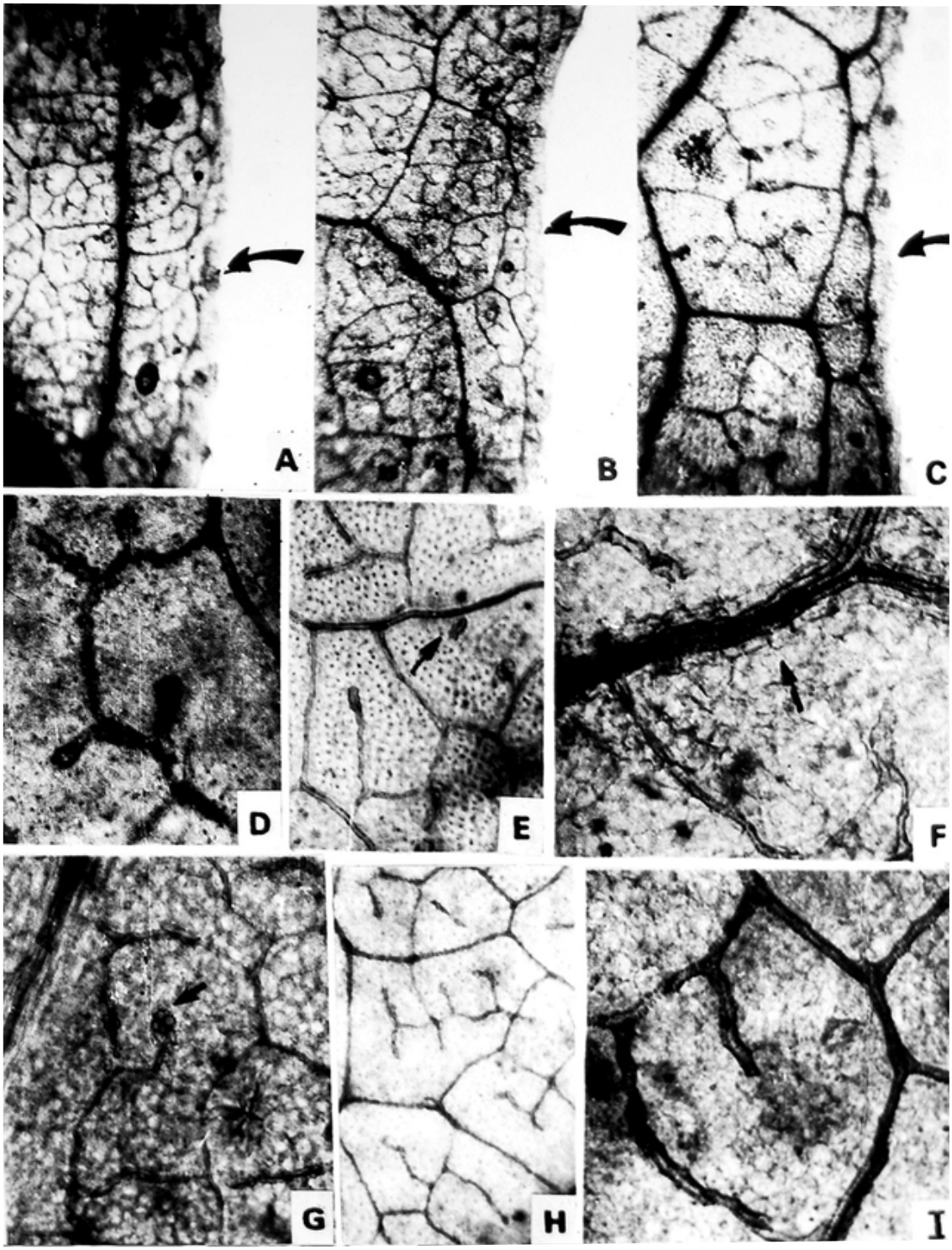

Figure 1 (A-I)

A. *Luffa tuberosa* – Marginal ultimate venation - Incomplete X 45 **B.** *Bryonopsis laciniosa* –orthrogonal reticulate X 37, **C.** *Cucumis prophetarum* – Marginal ultimate venation Looped X 44 **D.** *Lagenaria siceraria* – Dilated tracheids linear X 144 **E.** *Luffa cylindrica* – Isolated tracheid X 180 **F.** *Luffa cylindrica* – Bundle sheath X 150 **G.** *Coccinia grandis* – Tracheids in aggregates X 100 **H.** *Luffa tuberosa* – 'T' shaped tracheid X 90 **I.** *Benincasa hispida* – simple vein ending X 154.

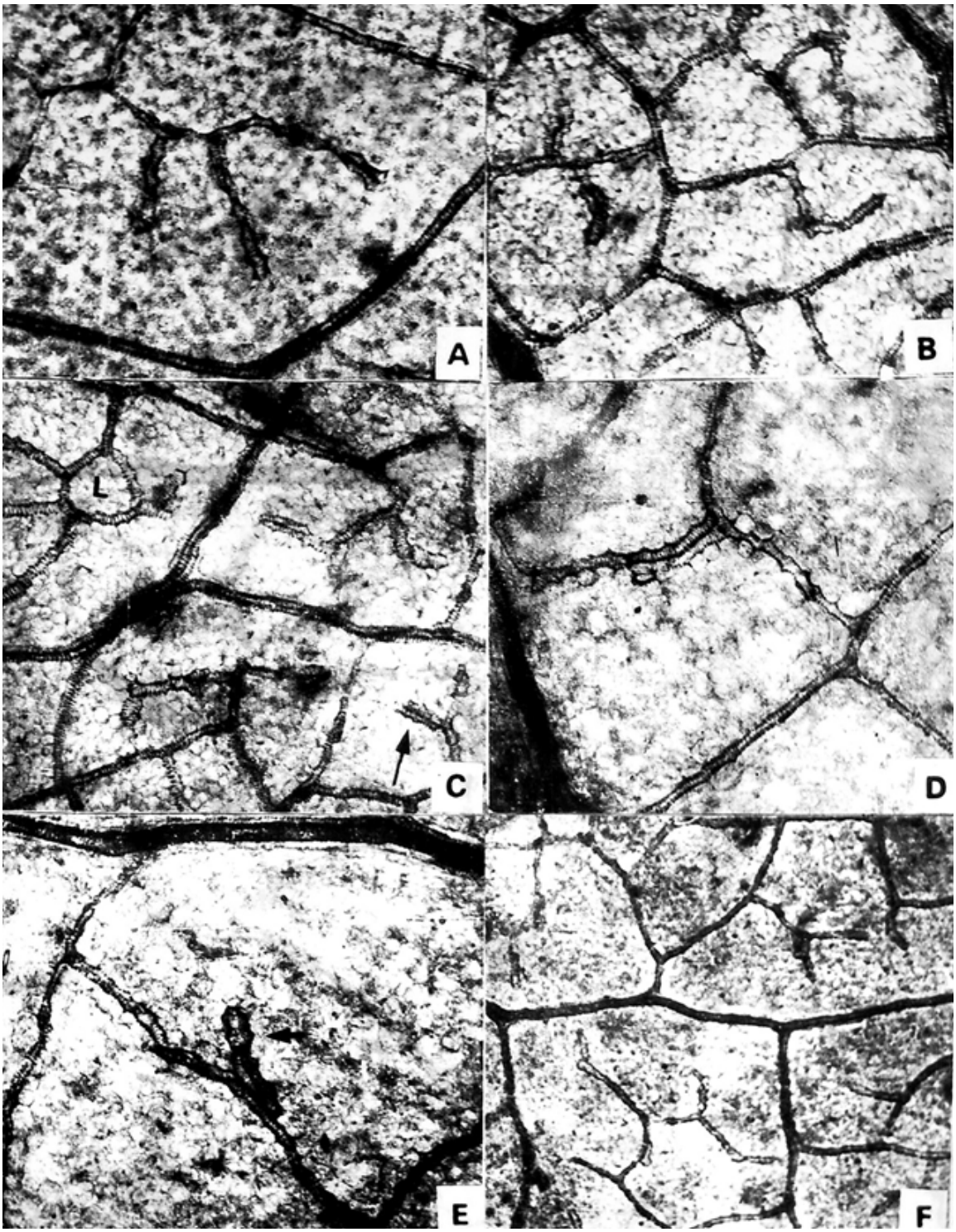

Figure 2(A-F)

A. *Bryonopsis laciniosa* – Branched vein ending X 107 **B.** *Citrullus colocynthis* - Simple curved vein ending X 103 **C.** *Coccinia grandis* – loop formation with vein ending **D.** *Trichosanthes cucumerina* var. anguina – Bundle sheath insignificant X 150 **E.** *Coccinia grandis* – Superposed tracheids and bundle sheath X 120 **F.** *Cucumis callosus* – 'Y' shaped vein ending X 156

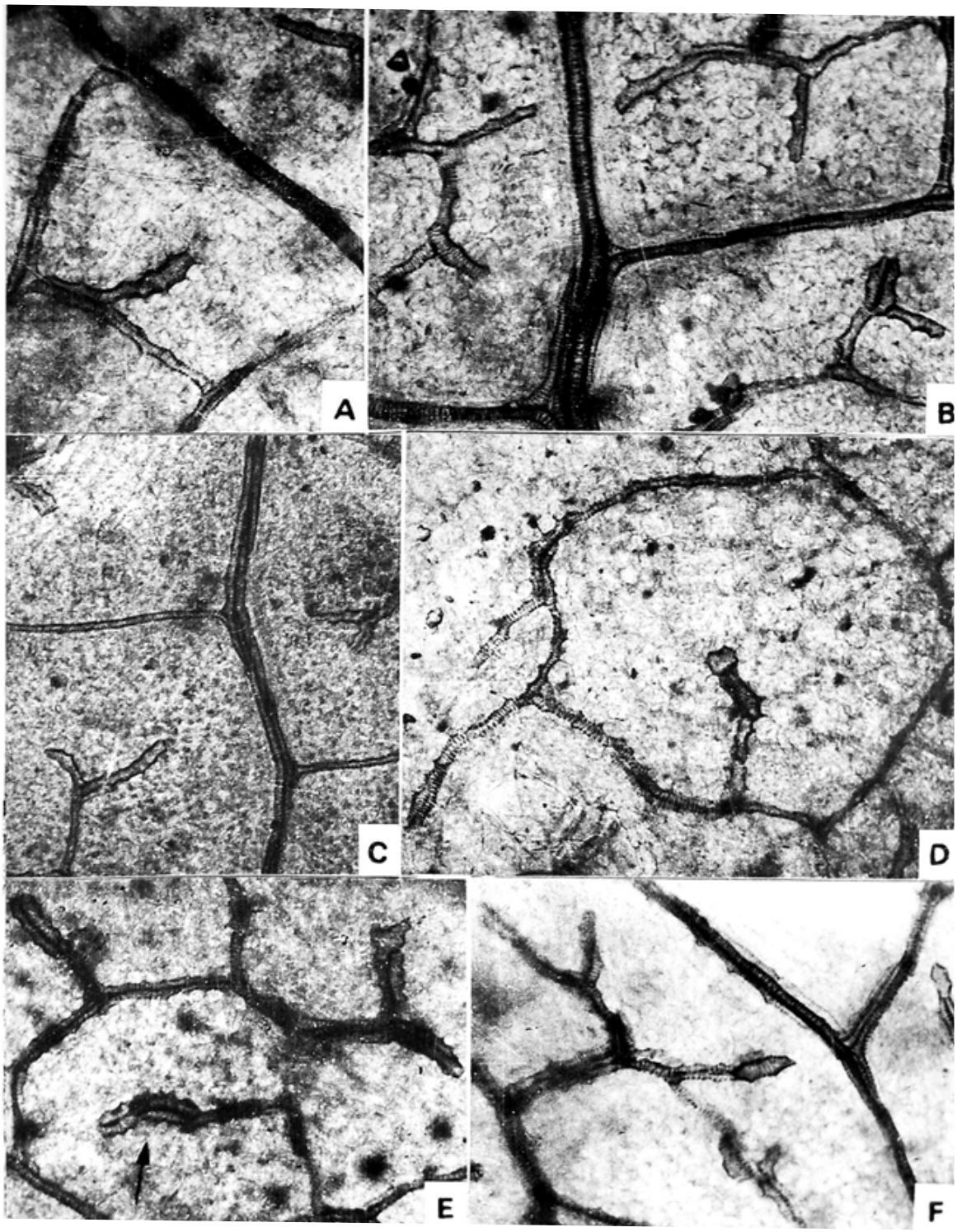

Figure 3 (A-F)

A. *Coccinia grandis* – Conventional tracheids X 150 **B.** *Benincasa hispida* – Juxtaposed tracheids X 165 **C.** *Luffa cylindrica* – Asymmetrical vein ending & biseriate tracheids X 135 **D.** *Coccinia grandis* – Ovate tracheid X 120 **E.** *Luffa cylindrica* – Juxtaposed contiguous biseriate tracheid X 129 **F.** *Lagenaria siceraria* – Dilated tracheids Spindle shaped - Tracheid located on the veins - Juxtaposed tracheid X 200

Table 1 : Foliar charactersitics in Cucurbitaceae

Name of the Taxon	Shape	Apex	Base	Margin	No. of primary veins	Nature of the primary vein	Predominant secondary vein origin angle	Highest degree of vein order	Marginal ultimate venation	No. of 2° veins (one side)	Range of angle between 1° & 2° veins	No. of areoles per mm²	No. of veinlets entering into areoles	Vein terminations	Venation pattern
Tribe : [illegible]															
Corallocarpus epigaeus (Rottl.) C.B.Cl. *	Cordate	Obtuse	Cordate	Irregular Crenate	5	Stout	RR, OA	6	Looped	3-4	Acute	[illegible]	[illegible]	10	Actinodromous Basal
Ctenolepis garcinii (Burm.f.) C.B.Cl. *	Wide Ovate	Obtuse Mucronate	Cordate	Denticulate	5	Stout	RR, AR	6	Looped	3-4	Acute	10	25	32	Actinodromous Basal
Cucumis callosus (Rottl.) Cogn. *	Wide Ovate	Acute	Cordate	Dentate	5	Stout	RR, AR	6	Looped	3-4	Acute	24	41	5	Actinodromous Basal
C. melo L. *	Cordate Ovate	Acute	Cordate	Dentate	5	Stout	RR, AR	6	Looped	3-4	Acute	20	5	18	Actinodromous Basal
C. prophetarum L. *	Cordate Ovate	Acute	Cordate	Dentate	5	Stout	OA, RR	5	Looped	3-4	Acute	15	5	11	Actinodromous Basal
C. sativus L.	Cordate Ovate	Acute	Cordate	Dentate	5	Stout	RR, AR	6	Looped	3-4	Acute	29	12	29	Actinodromous Basal
Melothria maderaspatana (L.) Cogn. *	Ovate	Acute	Cordate	Denticulate	5	Moderate	RR, OA	5	Looped	2-3	Acute	17	12	24	Actinodromous Basal
M. [illegible] Cogn. *	Wide Ovate	Acute	Cordate	Denticulate	5	Stout	RR, OA, AR	6	Looped	2-3	Acute	16	5	11	Actinodromous Basal
Solena amplexicaulis (Lam.) Gandhi *	Ovate, Cordate	Acuminate, Acute	Cordate	Dentate, Entire	5	Stout	RR, OA, AR	5	Looped	3-4	Acute	18	12	20	Actinodromous Basal
Zehneria maysorensis (W.& A.) Arn.	Cordate Ovate	Acuminate Acute	Cordate	Serrate	5	Stout	RR, OA	6	Looped	3-4	Acute	15	9	16	Actinodromous Basal
Tribe : [illegible]															
Momordica [illegible] Lour. [illegible] (Kurz) *	Ovate, Reniform	Acute, Mucronate	Cordate	Dentate	5	Moderate	AR, RR	6	Incomplete	3-4	Acute	15	53	17	Actinodromous Basal
M. [illegible] Lour. [illegible] (Willd.) [illegible] *	Ovate, Reniform	Acute	Cordate	Dentate	3	Moderate	RR, AR	6	Looped	3-4	Acute	12	8	29	Actinodromous Basal
M. dioica Roxb. Ex Willd. *	Ovate	Acute	Cordate	Dentate	3	Moderate	RR, AR	6	Incomplete	2-3	Acute	11	13	3[illegible]	Actinodromous Basal
M. subangulata Bl. *	Ovate	Acute	Cordate	Denticulate	3	Stout	AR, RR, OA	5	Looped	3-4	Acute	11	5	14	Actinodromous Basal
Tribe: Trichosantheae															
Trichosanthes cucumerina L. var. anguina (L.) Haines *	Cordate, Ovate	Acute	Cordate	Denticulate	3	Stout	RR, AR, OA	6	Looped	5-6	Acute	17	[illegible]	20	Actinodromous Basal
T. cucumerina L. * *var. cucumerina L.*	Cordate Ovate	Acute	Cordate	Denticulate	3	Stout	RR, AR	6	Looped	3-4	Acute	14	15	16	Actinodromous Basal
T. palmata Roxb. *	Ovate	Acute	Cordate	Denticulate	3	Stout	RR, OA, AR	5	Looped	3-4	Acute	18	8	17	Actinodromous Basal
Tribe : [illegible]															
*Benincasa hispida * (Thunb.) Cogn.*	Ovate, Cordate	Acute	Cordate	Irregular Crenate	3	Stout	RR, AR, OA	6	Looped	4-5	Acute	10	25	3	Actinodromous Basal
Citrullus colocynthis (L.) Schrad.	Wide Ovate	Acute	Cordate	Toothed	3	Moderate	RR, AR	6	Incomplete	3-4	Acute	32	45	50	Actinodromous Basal
C. lanatus (Thunb.) Matsum. & Nakai *	Wide Ovate	Acute	Cordate	Toothed	3	Moderate	RR, AR, OA	6	Looped	4-5	Acute	13	34	33	Actinodromous Basal

Name of the Taxon	Shape	Apex	Base	Margin	No. of primary veins	Nature of the primary vein	Predominant 2° vein origin angle	Highest degree of vein order	Marginal ultimate venation	No. of 2° veins (one side)	Range of angle between 1° & 2° veins	No. of areoles per mm²	No. of veinlets entering into areoles	Vein terminations	Venation pattern
Coccinia grandis (L.) Voigt	Ovate	Mucronate, Acute	Cordate	Entire, Wavy	5	stout	RR, AR	6	Looped	3-5	Acute	10	25	36	Actinodromous Basal
*Lagenaria siceraria (Mol.) Standl.**	Ovate, Cordate	Acute	Cordate	Irregular dentate	5	stout	RR, AR	6	Looped	4-5	Acute	38	35	60	Actinodromous Basal
*Luffa acutangula (L.) Roxb. var. acutangula C.B.**	Ovate, Cordate	Mucronate	Cordate	Dentate	5	stout	RR, AR	6	Looped	3-4	Acute	15	30	37	Actinodromous Basal
*L. acutangula (L.) Roxb. var. amara (Roxb.) C.B.Cl.**	Ovate, Cordate	Acute	Cordate	Dentate	5	weak	RR, AR	6	Looped	3-4	Acute	12	37	35	Actinodromous Basal
L. cylindrica (L.) Roem.	Wide Ovate	Acute	Cordate	Dentate	7	stout	RR, AR	6	Looped	3-4	Acute	14	37	37	Actinodromous Basal
*L. tuberosa Roxb.**	Ovate, Acuiform	Acute	Cordate	Entire	5	Moderate	RR, OA, AR	6	Incomplete	3-4	Acute	27	23	42	Actinodromous Basal
Tribe: Cucurbiteae															
*[illegible] (L.) Naud.**	Ovate	Mucronate	Cordate	Denticulate	3	stout	RR, AR	6	Looped	3-4	Acute	15	6	20	Actinodromous Basal
Cucurbita maxima Duchesne ex Lam.	Ovate, Cordate	Acute	Cordate	Serrate	5	stout	RR, AR, OA	7	Looped	4-5	Acute	11	33	33	Actinodromous Basal
*C. moschata (Duchesne ex Lam.) Duchesne ex Poir.**	Ovate, Cordate	Acuminate, Acute	Cordate	Serrate	5	stout	RR, AR	7	Looped	3-4	Acute	12	12	26	Actinodromous Basal
*C. pepo L.**	Ovate, Cordate	Acuminate, Acute	Cordate	Serrate	5	stout	RR, AR	7	Looped	3-4	Acute	10	4	22	Actinodromous Basal
Tribe: Sicyeae															
*Sechium edule (Jacq.) Swartz **	Ovate, Cordate	Acute	Cordate	Entire	5	stout	RR, OA	6	Looped	3-4	Acute	14	9	14	Actinodromous Basal

Treatment of Sub families and Tribes is after Jeffrey (2005).

*These taxa have been studied for the first time.

and thickness is variable. The secondary veins originate from the primary veins on either side at a moderately acute angle and range from 2 to 6 in number whereas inter-secondaries are common and are of composite type. The tertiary veins arising from the secondaries and inter-secondaries are at right angle right (RR), acute right (AR), or obtuse-acute OA (Table 1). The present investigation shows that 23 taxa are orthogonal reticulate (i.e., tertiary veins amastomosing with other tertiary veins or with the secondary veins) (Fig. 1B) and remaining 8 are percurrent (i.e., tertiaries from the opposite secondaries joining) 40 veins are thin and form the areoles. In majority of taxa, 6° veins are the highest, usually 5° - 7° veins are form the imperfect areoles. The areoles are either polygonal, quadrangular, square or pentangular. The number of areoles per square millimeter is variable from species to species and ranges from 10 to 42. This is in general, agrees with the earlier observations made in several angiospermous taxa (Sehgal and Paliwal, 1974, Shanmukha Rao and Narmada, 1994). The ultimate veinlets entering the areoles are simple (Fig.1I) or branched (Fig. 1B). When simple they are linear (Fig. 1H) or curved (Fig. 2B) and branched twice or thrice (Fig. 2A) loop formation (Fig.2C).Tucker (1964) classified the veinlet termination into six types of which the cucurbits possess conventional (Fig. 3A) or dilated tracheids. The conventional ones are simple (Fig. 3A) whereas the dilated tracheids vary greatly in their shape. They are either linear (Fig. 1D), isodiametric, ovate (Fig. 3D) T-shaped (Fig. 1H) Y-shaped (Fig. 2F), spindle shaped (Fig. 3F) or contiguous (Fig. 3 E). Further, they are uniseriate, biseriate (Fig. 3C) or multi-seriate, juxtaposed (Fig. 3B) or superposed (Fig. 2E) in

arrangement. The dilated tracheids are probably meant for mechanical support, as also reported earlier by Mohan and Inamdar (1984).

Aggregate tracheids are reported by many workers in diverse taxa (Sehgal and Paliwal, 1974, Rao and Das, 1979, Saibaba and Shanmukha Rao, 1990). In the present studies, aggregate tracheids are observed in *Momordica charantia* var. *muricata*, *Benincasa hispida, Citrullus lanatus, Coccinia grandis* (Fig. 1G), *Lagenaria siceraria and Luffa cylindrica.* Probably their function is to provide mechanical support and also aid in retention of water for the leaf (Rao and Das 1979, Sperry *et al*. 2006).

Isolated tracheids are observed in *Momordica subangulata, Citrullus colocynthis. C. lanatus, Coccinia grandis, Lagenaria siceraria, Luff*a *cylindrica, Luffa tuberosa* and *Sechium edule*. They are uniseriate or biseriate (Fig. 1E). Similar structures are earlier reported in several angiospermous taxa (Inamdar and Murthy 1981, Shanumakha Rao and Leela 1990).

Extensions cells in association with vein terminations are observed in some taxa viz., *Cucumis callosus, Benincasa hispida, Citrullus colocynthis, , Coccinia grandis, Cucurbita maxima and Sechium edule*.

All grades of veins (1°-7°) are ensheathed by parenchymatous bundle sheath (Fig. 1F). The bundle sheath cells of 1°-3° veins are elongated, the subsequent grades of veins are isodiametric and insignificant (Fig. 2D). The bundle sheath is 3 to 5 layered around the primary veins while the number of layers gradually decreases in the other grades of veins. This is in conformity with earlier observations made in several angiospermous taxa (Sehgal and Paliwal 1974, Subba Rao and Shanmukha Rao 1992, Shanmukha Rao and Narmada 1994).

Based on a number of diagnostics foliar venation characteristics, a key presented below for the delimitation of Cucurbitaceae studied.

1. Marginal ultimate venation incomplete
2. Number of primary veins five
3. Isolated tracheids present

   …… *Luffa tuberosa*
3. Isolated tracheids absent

   … *Momordica charantia* var. *charantia*
2. Number of primary veins three
4. Tertiary vein percurrent; isolated tracheids and extension cells absent

   …… *Momordica dioica*
4. Tertiary vein reticulate; isolated tracheids and extension cells present
5. Tracheids in aggregate present

   ……, *Coccinia grandis*
5. Tracheids in aggregate absent

   .....*Citrullus colocynthis*
1. Marginal ultimate venation looped
6. Tertiary veins percurrent
7. Number of primary veins three
8. Highest degree of vein order

   … *Trichosanthes cucumerina* var. cucumerina
8. Highest degree of vein order 5
9. Isolated tracheids present

   …… *Momordica subangulata*
9. Isolated tracheids absent

   .....*Trichosanthes palmata*
7. Number of primary veins five
10. Extension cells and isolated tracheids present

    ……*Sechium edule*
10. Extension cells and isolated tracheids absent
11. Vein terminations per square mm more than 20

    …*Cucumis sativus*
11. Vein terminations per square mm less than 20
12. Secondary veins along one side of the midrib 2 to3 and veinlets per square mm 6

    ..... *Melothria mucronata*
12. Secondary veins along one side of the midrib 3 to 4 and veinlets per square mm 9

. . . . .*Zehneria maysorensis*

6. Tertiary veins reticulate

13. Number of primary veins seven

. . . . *Luffa cylindrica*

13. Number of primary veins less than seven

14. Number of primary veins three

15. Highest degree of vein order 7

16. Vein terminations per square mm more than 30

. . . . . *Cucurbita maxima*

16. Vein terminations per square mm less than 30

17. 'T' and 'Y' shaped tracheids present

. . . . . *Cucurbita pepo*

17. 'T' and 'Y' shaped tracheids absent

. . . . . *Cucurbita moschata*

15. Highest degree of vein order 6

18. Extension cells present

.. . . . *Benincasa hispida*

18. Extension cells absent

19. Isolated tracheids present

20. Vein termination per square mm more than 80

. . . . . *Lagenaria siceraria*

20. Vein termination per square mm less than 80

. . .. *Citullus lanatus*

19. Isolated tracheids absent

21. Tracheids in aggregates present

. . . . . .*Momordica charantia* var. *muricata*

21. Tracheids in aggregates absent

22. Multiseriate tracheids present

. . . . . *Trichosanthes cucumerina* var. *anguina*

22. Multiseriate tracheids absent

23. Vein terminations per square mm more than 40

. . . . *Corallocarpus epigaeus*

23. Vein terminations per square mm less than 40

24. Spindle shaped tracheids present

. . . . .*Bryonopsis laciniosa*

24. Spindle shaped tracheids absent

. . . . . *Ctenolepis garcinii*

14. Number of primary veins five

25. Highest degree of vein order 6

26. Extension cells present

. . . . . *Cucumis callosus*

26. Extension cells absent

27. Veins terminations per square mm more than 30

28. Number of areoles per square mm – 42

. . . . .*Luffa acutangula* var. *amara*

28. Number of areoles per square mm – 15

. . . . . *Luffa acutangula* var. *acutangula*

27. Vein terminations per square mm less than 30

. . . . . *Cucumis melo*

25. Highest degree of vein order 5

29. Vein terminations per square mm more than 20

30. Secondary veins along one side of the midrib 2 to 3; 'T' shaped tracheids absent

. . . . .*Melothria maderaspatana*

30. Secondary veins along one side of the midrib 3 to 4; 'T' shaped tracheids present

. . . . .*Solena amplexicaulis*

31. Veins termination per square mm less than 20

. . . . . *Cucumis prophetarum*

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