FOLIAR VENATION PATTERNS AND THEIR TAXONOMIC IMPORTANCE IN INDIAN PORTULACACEAE

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ABSTRACT

Foliar venation patterns of the Portulacaceae occurring in India have been studied. The veins in the leaves are not expressed and, as such, do not fit into the patterns earlier described. In order to accommodate them, new terms have been introduced. Two new venation patterns have also been recorded. The venation patterns are of taxonomic use and accordingly an identification key for the species studied has been presented.

INTRODUCTION

Foliar venation as a taxonomic tool has been since long time in use, but recent comprehensive classification of venation patterns by HICKEY (1973) has positively stimulated a wider interest in its study. Indian Portulacaceae is a small family of eight species belonging to two genera, *Portulaca* (seven species) and *Talinum* (one species) which are widely distributed in the subcontinent. The family possesses mostly succulent leaves and, therefore, was considered appropriate for studying its foliar venation.

MATERIAL AND METHODS

Mature leaves were fixed in Carnoy's fixative (JOHANSEN, 1940), which also makes them transparent after some weeks. Hence, the material was as such used for preparing permanent whole mounts by following the usual procedure of dehydration and clearing. Slides of microtome sections (t.s. and l.s.) of leaves were prepared and stained with haematoxylin and basic fuchsin for studying the venation.

The terms used are mostly after HICKEY (1973) with slight modifications. But, as HICKEY's (1973) terms were inadequate to express certain additional venation patterns, the following terms have been introduced :

Hyphodromous : All veins concealed within a coriaceous or fleshy mesophyll.

Semi-hyphodromous : All but primary veins absent, rudimentary or concealed within a coriaceous or fleshy mesophyll.

Epidromous : Veins not concealed within the mesophyll, i.e., expressed as ribs or in the epidermis.

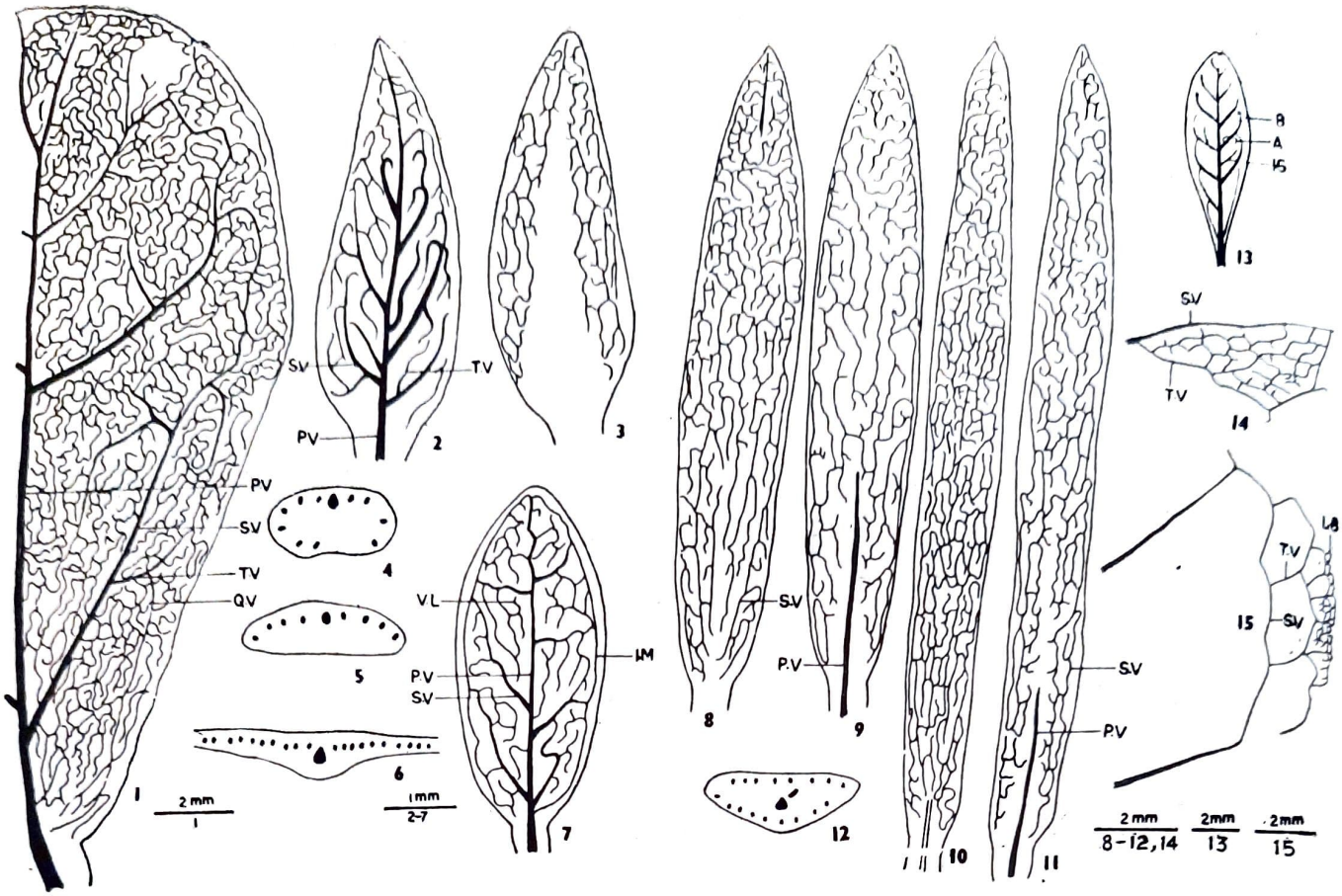
Pinnately planiusculus : Veins pinnate, distributed in one plane.

Pinnately saccal : Veins pinnate, distributed in the adaxial and abaxial tissues of the mesophyll, forming a sac-like structure throughout.

Pinnately semi-saccal : Veins pinnate, distributed in the adaxial and abaxial mesophyll tissues and partially forming a sac-like structure.

OBSERVATIONS

Portulaca oleracea—In the proximal half of the lamina only the primary vein and two or three secondary veins are partially expressed as ribs towards the leaf abaxial side.



Figs. 1, 6. *Portulaca oleracea*. 1. venation pattern of leaf, 6. T. S. of leaf showing distribution of veins ; Figs. 2-4. *Portulaca wightiana*. 2, 3. Venation patterns from leaf adaxial and abaxial respectively. 4. T. S. of leaf showing distribution of veins ; Figs. 5, 7. *Portulaca quadrifida*. 5. T. S. of leaf showing distribution of veins, 7. Venation pattern of leaf ; Figs. 8, 9, 12. *Portulaca pilosa*. 8, 9. Venation patterns of leaf adaxial and abaxial respectively, 12. T. S. of leaf showing distribution of veins ; Figs. 10, 11. *Portulaca tuberosa*. Venation pattern from leaf adaxial and abaxial respectively ; Figs. 13-15. *Talinum portulacifolium*. 13. Venation pattern of leaf showing major veins, 14, 15. Enlarged portions of A and B in Fig. 13 respectively. (I.M.=Intramarginal vein ; I.S.=Intersecondary vein ; L.B.=Loop-branches ; P.V.=Primary vein; Q.V.=Quarternary vein ; S.V.=Secondary vein ; T.V.=Tertiary vein ; V.L.=Veinlets.)

Internally these are distributed in the midzone of the mesophyll, nearly parallel to the surfaces (Fig. 6). The general venation pattern is pinnate, semi-hyphodromous, pinnately planiusculus, camptodromous, reticulodromous and closed (Fig. 1).

Primary vein straight, branched near the apex, moderate in size with limited number of secondary veins ; secondary veins opposite to sub-opposite, angle of divergence narrow, acute in the proximal branches, becoming wide towards the apex, curved to sinuate, giving loop-forming branches, loop-branches enclosed by higher grade of veins ; tertiary veins distinct only half-way or more, later merging into 4° grade veins, few marginal ultimate veins looped , areoles imperfect, with one or more veinlets, some without veinlets; veinlets generally simple, few branched, usually curved or sinuate, rarely straight (Fig. 1).

Portulaca quadrifida—All veins including the midvein are enclosed in the fleshy mesophyll. They are all distributed in one plane and are embedded in the upper part of the mesophyll (Fig. 5). The general pattern of venation is pinnate, hyphodromous, pinnately planiusculus, camptodromous, brochidodromous and closed (Fig. 7).

Primary vein straight to zig-zag, stout with limited number of secondary veins ; secondary veins alternate to sub-opposite, angle of divergence variable, narrow, acute in

the proximal branches, widening towards the apex, sinuate. Loop-branches forming intramarginal veins ; tertiary veins ramified, randomly reticulate or percurrent, simple or branched, sinuate, few curving inward from the point of origin to terminate on the midvein of the leaf ; areoles limited in number, imperfect, some without veinlets; veinlets simple or once branched, generally curved or sinuate, rarely straight (Fig. 7).

Portulaca wightiana—The venation pattern is more like an open type and all the veins including the midrib are enclosed in the periphery of the mesophyll (Fig. 4). Midrib traverses the upper zone of the mesophyll, whereas the lateral veins after branching out from the midvein and spreading along the upper periphery recurve at the leaf margin towards the leaf abaxial side, thereafter extend nearly up to the leaf middle, but remain without fusing with those of the opposite side excepting in the distal end (Fig. 3). The laterals after recurving appear as a reticulum towards the leaf abaxial (Fig. 3). In surface view the veinless middle zone of the abaxial side appear as '∧'-shaped from the base to apex (Fig. 3). Secondary veins increasingly recurve at margins from base towards the leaf apex. The general venation pattern is pinnate, hyphodromous, pinnately semisaccal, camptodromous, and closed (Figs. 2, 3).

Primary vein sinuate, stout to massive with limited number of secondary veins; secondary veins alternate, angle of divergence variable, narrow, acute to moderately acute, curved or recurved, showing no definite loop-branches; tertiary veins randomly reticulate towards the abaxial side, ramified, simple or branched, retroflexed or recurved towards the abaxial side; areoles adaxially rare, but abaxially more frequent, imperfect one or more veinlets, few without veinlets; veinlets simple, straight, curved to sinuate (Figs. 2, 3).

Portulaca tuberosa—The midvein traverses through the middle of the mesophyll, whereas the laterals branching off from the midvein, spread out into a network along the periphery of the leaf towards its adaxial side (Figs. 10, 11). The laterals recurve later at the margins, further extend along the abaxial side and fuse with those of the opposite side. However, in the proximal part of the leaf, these do not show fusion, but leave a small '∧'-shaped veinless area as in *P. wightiana* (Fig. 11). The veins are denser in the mesophyll of the adaxial side than towards the abaxial side of the leaf (Figs. 10, 11). The venation in general is pinnate, hyphodromous, pinnately saccal, camptodromous, reticulodromous and closed (Figs. 10, 11).

Primary vein concealed, straight, stout; secondary veins concealed, opposite or alternate, angle of divergence variable being acute to nearly right angle, distinct halfway or less; tertiary veins not distinct from the secondaries, areoles frequent, imperfect with usually one rarely two or more veinlets, some incompletely closed veinlets simple or branched, straight, curved or sinuous, rarely absent (Figs. 10, 11). *Portulaca gradiflora*, *P. pilosa* and *P. suffruticosa* : The venation pattern of these species is similar to that of *P. tuberosa* described earlier (Figs. 8, 9, 12).

Talinum portulacifolium—The midvein is strongly expressed as rib towards the abaxial side and as a groove on the adaxial side of the leaf, whereas the laterals are concealed within the mesophyll, parallel to the leaf surface. The general venation pattern is pinnate, semi-hyphodromous, pinnately planiusculus, camptodromous, brochidodromous and closed (Figs. 13-15).

Primary vein straight, stout to massive, secondary veins opposite to sub-opposite, angle of divergence generally narrow to moderately acute but the lowest pair more acute than others, abruptly curved, sinuous to zig-zag, unbranched, loop-forming

branches joining superadjacent secondary veins, at acute angles, enclosed by secondary arches of 3° and 4° arches; intersecondary veins composite; tertiary veins randomly reticulate, angle or divergence variable, acute to obtuse; those present outside the loop-branches of secondaries, looped, enclosing the secondaries; loop-forming tertiaries joining superadjacent tertiary vein at acute or right angles, enclosed by quaternary veins, Quaternary veins relatively randomly oriented; those present outside the loop-branches of tertiaries also looped, enclosing the tertiary veins, few forming marginal ultimate veins which are generally looped, very rarely incomplete; areoles imperfect, polygonal to irregular with one or more veinlets, few without them; veinlets simple or branched once or twice, usually curved, rarely straight or sinuate (Fig. 14).

DISCUSSION

Earlier workers recognised venation patterns mainly with reference to their external expression as ribs of the leaf lamina (VON ETTINGSHAWSEN, 1861, FOSTER, 1965; GOEBEL, 1905; KERNER VON MARILAUN, 1895; FOSTER, 1936, 1950, 1963; TROLL, 1938; PRAY, 1954; VARGHESE, 1963, 1966, 1969; LEMS, 1964; PALIWAL & KAKKAR, 1972; HICKEY, 1971a, 1971b, 1973; SEHGAL & PALIWAL, 1975). But the present investigation shows that in the majority of Portulacaceae species veins are not expressed as ribs due to their concealment in the mesophyll and thus they do not fit into the patterns described by earlier workers. However, it was also noted that though the veins are not expressed externally, they display consistent variation which is of taxonomic significance. The study of their patterns suggests that with due modifications they could be appropriately accommodated into HICKEY's (1973) classification which is followed here. Consequently, few new terms had to be introduced, viz., hyphodromous, semi-hyphodromous, epidromous, pinnately palaniusculus and pinnately saccal. The general venation pattern in *P. oleracea* is pinnate, semi-hyphodromous, pinnately planiusculus, camptodromous, reticulodromous and closed. In *T. portulacifolium* and *P. quadrifida* it is similar to that of *P. oleracea*, except that in the former it shows brochidodromous, while in the later, hyphodromous and brochidodromous conditions. In *P. wightiana* the pattern is pinnate, hyphodromous, pinnately semi-saccal, camptodromous and closed, while in the remaining four species, *P. pilosa*, *P. suffruticosa*, *P. tuberosa*, and *P. grandiflora*, it is pinnate, hyphodromous, pinnately saccal, camptodromous, reticulodromous and closed. The epidromous condition is, however, not observed in the present study.

The primary veins are straight in *P. oleracea*, *P. pilosa*, *P. suffruticosa*, *P. tuberosa*, *P. grandiflora* and *T. portulacifolium*, straight to zig-zag in *P. quadrifida*, sinuate in *P. wightiana*. They are stout to massive in *T. portulacifolium* and *P. wightiana*, stout in *P. quadrifida*, *P. pilosa*, *P. suffruticosa*, *P. tuberosa* and *P. grandiflora* and moderate in *P. oleracea*. The primary veins produce limited number of secondary veins in all the species.

Secondary veins are opposite in *P. oleracea*, sub-opposite to alternate in *P. quadrifida* and *T. portulacifolium*, alternate in *P. wightiana*, opposite to alternate in *P. pilosa*, *P. suffruticosa*, *P. tuberosa* and *P. grandiflora*. The angle of divergence is narrow to broadly acute in *P. oleracea* and *P. quadrifida*, narrow to moderately acute in *P. wightiana* and *T. portulacifolium*, while in *P. pilosa*, *P. suffruticosa*, *P. tuberosa* and *P. grandiflora* it is acute to nearly right angled.

The course of secondary veins is curved to sinuate in *P. oleracea*, sinuate to zig-zag in *P. quadrifida* and *T. portulacifolium* and curved or recurved in *P. wightiana*, *P. pilosa*, *P suffruticosa*, *P. tuberosa* and *P. grandiflora*. Loop-forming branches are present in *P. oler-*

acea, *P. quadrifida* and *T. portulacifolium*. They are enclosed by higher grade veins in *P. oleracea* and form intramarginal veins in *P. quadrifida*, whereas in *T. portulacifolium*, they are further enclosed by secondary arches of 3° and 4° veins. In *P. wightina*, *P. pilosa*, *P. suffruticosa*, *P. tuberosa* and *P. grandiflora* loop-forming veins are totally lacking.

Tertiary veins may be merely ramified or sometimes reticulate in *P. wightiana*, ramified, reticulate or percurrent in *P. quadrifida*, and reticulate in *T. portulacifolium*. They are simple or branched in *P. quadrifida*, whereas simple or branched, retroflexed or recurved in *P. wightiana*. In *T. portulacifolium* they are randomly reticulate, but those outside the loop-branches of the secondaries are again looped enclosing the secondaries, while they are absent in *P. oleracea*, *P. pilosa*, *P. suffruticosa*, *P. tuberosa* and *P. grandiflora*.

Areoles are imperfect in all the species investigated, except in *T. portulacifolium* where they are apparent and polygonal. They are either with one or more veinlets or without them.

Veinlets are generally simple, randomly branched, usually curved or sinuate, rarely straight in all the species of *Portulaca* except in *P. wightiana* where they are simple and usually curved to sinuate, whereas in *T. portulacifolium* they are simple, usually curved rarely straight or sinuate.

The venation patterns studied in the family can be recognised into three categories, viz., 1. the normal type, pinnately planiusculus in *P. oleracea*, *P. quadrifida*, *T. portulacifolium*, 2. Pinnately semi-saccal in *P. wightiana* and 3. pinnately saccal in *P. pilosa*, *P. suffruticosa*, *P. tuberosa* and *P. grandiflora*. In the first three species the venation again differs in detail from one to another. *T. portulacifolium* is characterised by possession of quaternary veins and areoles which are polygonal, the former being absent in *P. quadrifida* and *P. oleracea*. *P. quadrifida* is peculiar in its veins distribution being the upper half of the mesophyll, whereas in *P. oleracea* they are about the middle of the mesophyll. Their venation characters are found to be partly helpful in the identification of the species studied and it is as follows :

Ia. Venation pinnately planiusculus
IIa. Veins distributed in the middle zone of the mesophyll
IIIa. Quaternary veins present..... *T. portulacifolium*
IIIb. Quaternary veins absent..... *P. oleracea*
IIb. Veins distributed in the adaxial zone of the mesophyll..... *P. quadrifida*
Ib. Venation pinnately semi-saccal..... *P. wightiana*
Ic. Venation pinnately saccal..... *P. grandiflora*
P. pilosa
P. suffruticosa
P. tuberosa

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REFERENCES

FOSTER, A. S. (1936). Leaf differentiation in angiosperms. *Bot. Rev.*, **2** : 349-372.

FOSTER, A. S. (1950). Morphology and leaf venation of the leaf *Quiina actangula* Ducke. *Am. J. Bot.*, **37** : 159-171.

FOSTER, A. S. (1952). Foliar venation in angiosperms from ontogenetic standpoint. *Am. J. Bot.*, **59** : 752-766.

FOSTER, A. S. (1963). The morphology and relationships of *Circaeaster*. *Jour. Arn. Arb.*, **55** : 299-327.
GOEBEL, K. (1905). *Organography of Plants*. Part II (Ed.) Balfour, I. B., Oxford.
HICKEY, L. J. (1971a). Leaf architectural classification of the angiosperms (Abstr.). *Am. J. Bot.*, **58** : 450.
HICKEY, L. J. (1971b). Evolutionary significance of leaf architectural features in the woody dicots (Abstr.). *Am. J. Bot.*, **58** : 469.
HICKEY, L. J. (1973). Classification of the architecture of dicotyledonous leaves. *Am. J. Bot.*, **60** : 17-33.
JOHANSEN, D. A. (1940). *Plant Microtechnique*. McGraw-Hill Book Co., New York.
KERNER VON MARILAUN, A. J. (1895). *The Natural History of Plants*. Vol. I (Ed.) Oliver, F. W., New York.
LEMS, K. (1964). Evolutionary studies in the Ericaceae. II. Leaf anatomy as phylogenetic index in the andromedeae. *Bot. Gaz.*, **124** : 179-186.
PALIWAL, G. S. & KAKKAR, LALITA. (1972). Studies on the leaf anatomy of *Euphorbia*. I. Foliar venation and laticifers in *Euphorbia thymifolia* Linn. p. 145-150 *in* Ghouse, A. K. M. & Mohd. Yunus (Editors) —In *Research Trends in Plant Anatomy*, K. A. *Chowdhury Comm. Vol.* Aligarh.
PRAY, T. R. (1954). Foliar venation of angiosperms 1. Mature venation of *Liriodendron*. *Am. J. Bot.*, **41** : 663-670.
SEHGAL, L. & PALIWAL, G. S. (1975). Studies on the leaf anatomy of *Euphorbia*. II. Venation patterns. *Jour. Linn. Soc. Bot.*, **68** : 173-208.
TROLL, W. (1938). *Vergleichende Morphologie der hohern Pflanzen*. **1**(2). Borntraeger, Berlin.
VARGHESE, T. M. (1963). Intramarginal tracheids in *Anticharis linesaris*. Hochst. *Curr. Sci.*, **32** : 423-424.
VARGHESE, T. M. (1966). Foliar venation of some Scrophulariaceae. *Curr. Sci.*, **35** : 315-317.
VARGHESE, T. M. (1969). A contribution on the foliar venation of Scrophulariaceae : pp. 253-266 *in* Chowdhury, K. A. (Editor)—*Recent Advances in the anatomy of tropical seed plants*. Hindustan Publ. Corp., Delhi.