

FOLIAR ARCHITECTURE PATTERN OF INDIAN *BOERHAVIA* L. (NYCTAGINACEAE)

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ABSTRACT

The genus *Boerhavia* L., a pantropical taxon, is medicinally important due to the drug plant ‘Punarnava’ (*B. diffusa* L.), mentioned in different ancient literatures and well known in Indian medicinal system since the time immemorial. Flowers and fruits characters are used mostly in identifying the taxonomic complexity lies in the genus. Different features of leaves including venation pattern are of systematic importance and can act as taxonomic marker in resolving species complex. The present article emphasizes significant role of leaf architecture pattern in identification of *Boerhavia* members in India.

Keywords: *Boerhavia*, Foliar Architecture, Pinnate-Brochidodromous

INTRODUCTION

The genus *Boerhavia* L., belongs to the family Nyctaginaceae, is widely distributed in tropical and subtropical regions of both the hemispheres (Fosberg, 1999; Spellenberg, 2003), is comprising of c. 50 species (Mabberley, 2008) of which only four (04) are reported from India, viz. *B. crispa* Heyne ex Hook. f., *B. diffusa* L., *B. erecta* L. and *B. rubicunda* Steud. Among these, *B. crispa* Heyne ex Hook. f. is of restricted distribution and reported only from Tamil Nadu and Karnataka while *B. rubicunda* Steud. is distributed in arid regions of Western India. *B. diffusa* L. is of cosmopolitan distribution, widely distributed in almost all the states of India. *B. erecta* L. is an exotic species, now widely found in many states of India. Economically the genus is well known due to the drug plant ‘Punarnava’ (*B. diffusa* L.), a herbaceous plant species, has been in use in Ayurveda, Unani, Siddha, Homeopathy and Tribal medicinal system since long. In taxonomic study, morphological characters of flower and fruit play a key role in identification of plants since long time.

Leaves are generally neglected in taxonomic and comparative studies due to lack of a detailed, standardized, unambiguous classification of different attributes. Because most of the dicotyledonous taxa possess consistent pattern of leaf architecture, this rigorous method of describing features of leaf (shape, size, marginal configuration, gland characters, venation etc) is of immediate useful in both extinct and extant taxa.

Application of leaf architecture can also be implemented in phylogenetic and ecological studies. In recent year, foliar architecture is gaining much importance in identification of living as well as fossil angiosperm species (Dilcher, 1974; Hicky, 1973, 1979; Melville, 1969, 1976; Annamani & Prabhakar, 1991).

A very few works have been done on genus *Boerhavia* L. in India. Nair & Nair (1961) worked on morphology of some members of Nyctaginaceae with special reference to nodal anatomical features of the genus *Boerhavia* L. Howard (1979) also stressed on importance of venation pattern and the characters of nodal and petiolar structures in solving taxonomic controversies.

The present study highlights foliar architectural features of four species of the genus *Boerhavia* L. and uses of these characters as an additional tool for identification.

MATERIALS AND METHODS

The present study is mainly based on herbarium specimens deposited in different National herbaria (CAL, MH, ASSAM, DD, BSD, PBL, LWG, TBGT, RHT) and on the basis of several live specimens collected from different states of India. The voucher specimens, deposited at Central National Herbarium, are listed in Table-1.

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Table 1: Details of Studied Specimens for Foliar-Anatomical Characters of the Members of *Boerhavia* L.

Sr. No.	Name of Species	Localities	Field No.
1.	<i>Boerhavia crispa</i> Heyne ex Hook. f.	Tamil Nadu: Coimbatore, Mettupalayam, Tinnevely, Alankolum; Nilgiri dist., Thengumarada, 525 m, 04.08.1971.	<i>D. Pramanick</i> 38403; Barker 3335 (CAL); <i>Subba Rao</i> 41622 (MH)
2.	<i>Boerhavia diffusa</i> L.	West Bengal: Howrah, Mourigram Rly. Station; Kerala: Trivandrum	<i>D. Pramanick</i> 38410; <i>Mohanan</i> 52767(CAL)
3.	<i>Boerhavia erecta</i> L.	West Bengal: Howrah, Chengail; Tamil Nadu: Coimbatore, Sayibaba colony	<i>D. Pramanick</i> 38411; <i>Chandrabose</i> 29841(CAL)
4.	<i>Boerhavia rubicunda</i> Steud.	Rajasthan: Barmer, Sundra; Jaisalmer, BadaBag	<i>B.V. Shetty</i> 2313; <i>Tiwari</i> 802(CAL)

For the study of foliar-architectural pattern, either entire lamina or a portion of the lamina (2/3rd from the base and 1/3rd from apex) were selected and soaked in water for overnight (for dried specimens). The experimental materials were transferred to 2.5% NaOH soln. for bleaching purpose. Next, the cleared materials were transferred to chloral hydrate soln. following Arnott (1959) and finally stained in 1% aqueous safranin soln. Permanent slides were prepared through gradual dehydration and mounted in Canada balsam. For representation of the vein order up to 3^o, higher magnification (x10, x40, x100) of the microscope was used. Drawings were made using camera lucida.

The foliar vasculature pattern were described following Metcalfe & Chalk (1950), Hickey (1973), Dilcher (1974), Melville (1976) and Pole (1991).

RESULTS AND DISCUSSION

Observations

Leaf Morphology

The foliar morphological characters are more or less similar in respect to shape, size, surface features and the petiolar nature. A comparative descriptions of foliar architectural pattern were presented for the studied four species in Table 2.

Foliar Venation Pattern

Venation is pinnate-brochidodromous with one strong mid vein associated with 3-5 pairs of pinnate secondary, either opposite, sub-opposite or alternate, forming loops joining with the super adjacent secondaries. The angel of divergence is mostly acute. Outer secondaries are developed from basal pairs of secondaries.

Tertiaries are of both interangular and joining veins, and rare often with cascade of composite veins. In case of interangular and joining veins, the angles at admedial and exmedial sides are different with various combinations.

Venation is lax having networks to 5^o-6^o orders. The ultimate areoles are formed with the joining of 3^o, 4^o and 5^o orders of veins without any regular shape and sizes or orientation. Free vein endings, both unbranched and dichotomously branched, are usually present within the areoles, consisting of 1-3 spirally thickened tracheids, associated with parenchymatous sheath cells. Marginal veins are either incomplete or looped having areoles and free vein endings as of normal type.

The details of the venation characters of each species is provided in Table 3 in a comparative basis (Figure 1; Plate 1)

Table 2: Morphological Characters of Leaves of Studied Species of *Boerhavia* L.

Name of the Species	<i>Boerhavia crispa</i> Heyne ex Hook. f.	<i>Boerhavia diffusa</i> L.	<i>Boerhavia erecta</i> L.	<i>Boerhavia rubicunda</i> Steud.
Characters (Leaves)				
Lamina	Oblong to ovate-oblong or ovate, 2-4 x 1.2-2.9cm, obtuse at apex, base rounded, margin crisped, coriaceous; 5-6 pairs, prominent beneath; scabrid on both surfaces, densely puberulous.	Ovate-rounded or sub-orbicular, 3-5 x 0.5-4cm, rounded at apex, sometimes acuminate or acute, base subcordate or truncate, entire or slightly undulate, often red due to presence of marginal glands, leathery, tapering from the center, thick and subfleshy, secondary veins 3-5 pairs, glabrous or sparingly hairy above, minutely scaly beneath	Ovate to elliptic-ovate, 1-6 x 0.5-4.5cm, acute or apiculate at apex, rarely obtuse, truncate or cuneate at base, margin undulate, herbaceous; secondary veins 4-5 pairs, sulcate above, elevated beneath; glabrescent above, punctate beneath with red sunken glands.	Lanceolate to elliptic-lanceolate or oblong-lanceolate or linear-oblong, 1.5-5.2 x 0.4-0.9cm, obtuse, often apiculate or mucronate at apex, gradually narrowed and rounded at base, entire, fleshy, rugose and canescent beneath, secondary veins 3-4 pairs, glabrous, mottled with white.
Petiole	Stout, 0.5-1cm long, densely puberulous, sulcate above, convex beneath.	Slender, 1-3.5cm long, glabrous, deeply grooved.	Slender, 0.5-4cm long, glabrous, weakly grooved.	Slender, 1.0-1.5mm long, slightly grooved.

Table 3: Venation Pattern of Studied Species of *Boerhavia* L.

Species Name	<i>Boerhavia crispa</i> Heyne ex Hook. f.	<i>Boerhavia diffusa</i> L.	<i>Boerhavia erecta</i> L.	<i>Boerhavia rubicunda</i> Steud.
Char.				
Venation	Pinnate and brochidodromous	Pinnate and brochidodromous	Pinnate and brochidodromous	Pinnate and brochidodromous
Primary vein (1°)	1, moderately thick,	1, moderately thick,	1, moderately thick,	1, moderately thick,

	straight, unbranched	straight, unbranched	straight, unbranched	straight, unbranched
Secondary vein (2°)	Sub-opposite to alternate, rarely opposite; stout and moderately thick	Mostly alternate while the basal pair is opposite; moderately thick	Sub-opposite to alternate; moderately thick	Sub-opposite and opposite; moderately thick
No.	3-4 pairs	4-5pairs	4-5pairs	3-4pairs
Angle of divergence	Basal pair acute to right (60°-80°), other pairs more acute (35°-55°)	Basal pair acute (40°), upper pair less acute	Basal pair acute (40°), upper pair more acute (30°) than lower ones	Lower pair less acute (30°-40°) than other pair (40°-60°); variations occur
Angle of joining with super adjacent secondaries or branches of secondaries in the intramarginal part	Curved abruptly, oblique, joining with the superadjacent secondaries at right angle (90°) in basal pair and at acute angle (30°-40°) at the apical region	Curved abruptly, joining at acute angle at lowermost pair, at right angle at upper pairs in the intra-marginal regions	Curved abruptly, joining with the super-adjacent secondaries at right angles(90°) in the basal pairs and at acute angle (40°-60°) at the middle part in the intra-marginal region	Curved abruptly, joining with the super-adjacent secondaries at obtuse angel in the lower pair and right to obtuse angel at the upper pair in the intra-marginal region
Inter-secondary veins	Absent	Absent	Rarely present, composite	Absent
Tertiary veins(3°)	Inter-angular and joining veins, rarely of cascade pattern	Inter-angular, joining and cascade pattern	Inter-angular, joining and cascade pattern	Inter-angular and joining veins, sometimes cascade pattern
Inter-angular veins	1-5, curved, convex, with equal or unequal arms; angle of origin at admedial side is mostly acute(A), sometimes obtuse(O) and to the exmedial side is right(R), forming the combination of AR and OR respectively	2-3, curved, convex, with equal or unequal arms; angle of origin at admedial side is mostly right(R), sometimes obtuse(O) and acute(A) and to exmedial side is mostly obtuse(O) and right(R) forming different combinations of	2-3, curved, convex, with equal or unequal arms; angle of origin at admedial side is acute(A) and to the exmedial side is right(R) and obtuse(O) forming the combinations of AR and AO respectively	2-3, straight or slightly curved, forked, sometimes convex; angle of origin at admedial side is mostly obtuse (O), sometimes right (R) and to the exmedial side is obtuse (O) and right (R) forming the combinations of OO, OR, RR etc

		RO, RR, OO, OR, AR and AO		
Joining veins	3-4 or a few, present at different part of secondary loop, at basal or middle or distal part, distantly placed, simple, branched or unbranched, convex or concave, angle of origin at the admedial side is mostly obtuse (O) and to the exmedial side is mostly right (R), sometimes obtuse(O) forming the combinations of OR and OO respectively	Very few, 1-2 towards lower part, sparse, unbranched, convex; angle of origin at the admedial side is acute(A) and at the exmedial side is acute(A) forming the combination of AA	Few or 2-4, present at different parts of secondary loops, at basal or middle or distal part, simple, distantly placed, unbranched, mostly convex, a few concave; angle of origin at admedial side is acute (A) and obtuse (O) and to the exmedial side is right (R), acute (A) and obtuse (O) forming the major combination of AR, AA and OO respectively	2-6, oblique or slightly curved, sometimes forked, mostly opposite, placed at moderate distance; angle of origin at admedial side is mostly right ®, sometimes acute(A) and to the exmedial side is mostly obtuse (O), sometimes right (R) forming the combination of RO, RR, AO and AR respectively
Cascade veins	Rarely present, within the loops of secondaries but does not follow any constant features of occurrence, present either within basal loops or apical loops	Cascade pattern is in maximum region within the loops of secondaries and forming network, both lax and closely interconnecting	Composite type, common, forked, without regular orientation	Composite type, forked or branched, few in number present in any loops of secondaries
Higher order venation	Network of venation is lax and upto 6° order; quaternary (4°) and quinternary (5°) veins both are moderately thick, randomly oriented, gradually after 5°order	Venation is upto 5°order, rare to 6°order; both quaternary(4°) and quinternary (5°) veins are thin, laxly randomly oriented	Network of venation is lax and upto 6°order; quaternary (4°) and quinternary (5°) veins both are thin, randomly oriented	Network of venation is lax and upto 6°order, rarely 7°order; quaternary(4°) and quinternary (5°) veins are gradually thinner, randomly oriented

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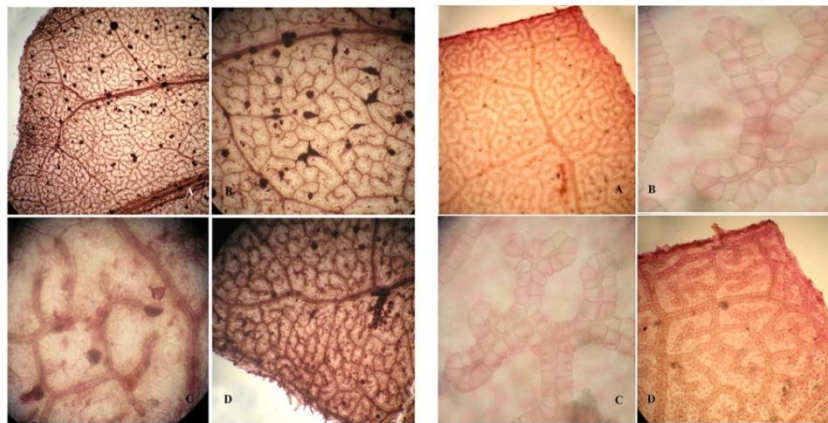
Areoles	Imperfect, irregular in shape and size, randomly oriented, having free vein ending in some cases	Imperfect, irregular in shape and size, with free vein endings within most of the areoles	Imperfect, mostly irregular in shape, sometimes penta-hexa- or poly-gonal in shape, medium sized, having free vein endings	Imperfect, irregular in shape and size, randomly oriented, with free vein endings within most of the areoles
Free vein endings	Mostly 1-2, often absent; both branched and unbranched; branching mostly dichotomous, straight or curved, with 1-4 spirally thickened elongated tracheids, traverse mostly 50% of the areolar space, long to medium in size, free vein endings are associated with regularly arranged oblong, thin walled, compact parenchymatous sheath cells, free-vein tip uniform	1-3, unbranched or dichotomously branched; with 1-3 spirally thickened, elongated tracheids, extending middle or more than middle of the space of areoles, long to medium in size, totally ensheathed with thinwalled, more or less loosely arranged bulbous parenchymatous sheath cells; free vein tips mostly dichotomously branched, some smaller loops devoid of any free vein endings	Mostly 1, very rarely 2, sometimes absent; branched or unbranched, branching dichotomous, straight or curved, with 1-2 spirally thickened, elongated tracheids, extending mostly 50% of the areolar space, long to medium in size; free vein endings are always associated with oblong, thin-walled, more or less loosely arranged parenchymatous sheath cells; ultimate ends of the very tips of the veinlets rarely associated with smaller and broader tracheids	Mostly 1, sometimes more; both branched or unbranched, branching dichotomous, straight or curved, with 1-3 spirally thickened elongated tracheids, extending most of the spaces of the areole; long to medium in size free vein endings are associated with parenchymatous vascular sheath cells; ultimate ends of veinlets are uniform
Marginal venation	Incomplete, associated with some loops, usually not associated with free vein-endings; free vein endings are branched or simple, curved, centric; areole irregular in shape and size	Incomplete, often associated with free vein-endings within loops. The free vein endings are simple, curved or straight with branching pattern as centric. Areoles irregular in shape and size	Looped; loops are with vein endings or the smaller loops are devoid of free-vein endings. The free vein endings are branched or simple, curved, branching pattern is centric. Areoles irregular in shape and size	Looped; loops are associated with free vein-endings, simple, curved, dichotomously branched, centric. Areoles irregular in shape and size

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Discussion and Conclusion

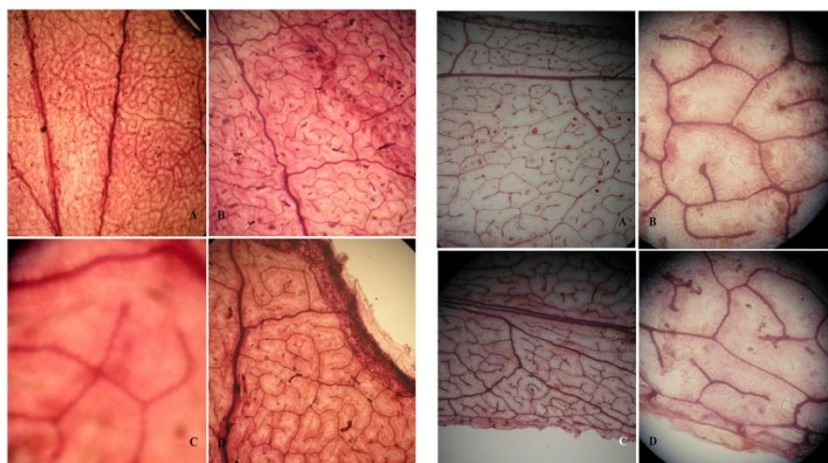
The genus *Boerhavia* L. is taxonomically quite significant as controversies lies regarding identification as well as inclusion and exclusion of number of species since decades. As most of the members of the genus are extremely polymorphic thus, morphological differentiation at species level is often painstaking. However, the identity of the studied species, has already been established on the basis of morpho-taxonomic features, is always not so much convincing. The present study is an additional support towards establishment of their identity along with interspecific relationship.

The present study reveals that foliar-venation pattern of four Indian members of *Boerhavia* L. is quite distinct. Presence of differential number of secondary veins (3-4), rare occurrence of cascade type of tertiary veins (3°), much lesser number of free vein ending within the areoles of *Boerhavia crispa* make the species quite different from other three species of *Boerhavia* L. Inter-secondary veins are absent in all the species except *B. erecta* where it is of composite type. Correlation of morpho-taxonomic and foliar-anatomical features establish identity of each species and suggesting closeness of the species *B. diffusa* and *B. rubicunda* while *B. crispa* and *B. erecta* are quite distantly related.



I. *Boerhavia crispa* Heyne ex Hok.f.

II. *Boerhavia diffusa* L.



III. *Boerhavia erecta* L.

IV. *Boerhavia rubicunda* Steud.

Plate 1. Foliar venation pattern of studied species of *Boerhavia* L. : A. Venation pattern; B. Venation pattern (magnified); C. Free vein ending; D. Marginal venation

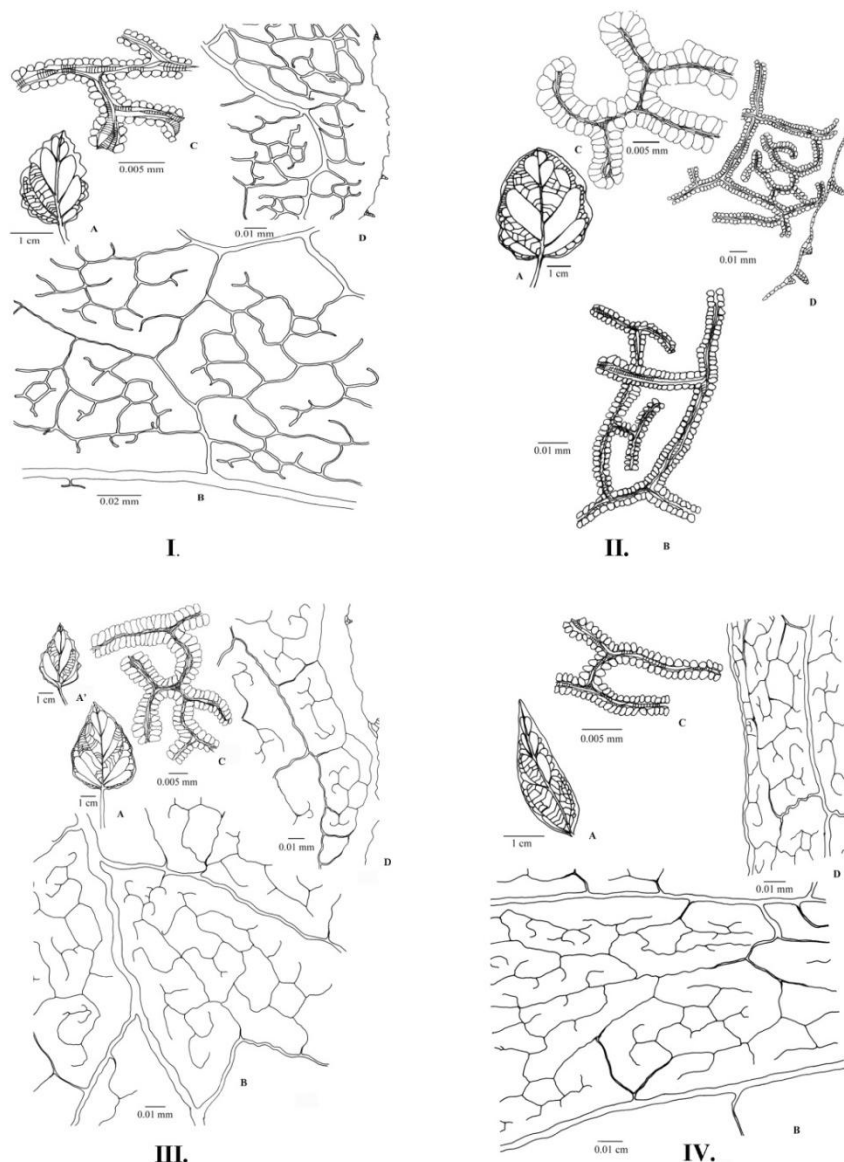


Fig 1 Foliar venation pattern of the studied species of *Boerhavia* L.: I. *B. crispa* Heyne ex Hook.f.; II. *B. diffusa* L.; III. *B. erecta* L.; IV. *B. rubicunda* Steud. (A & A': Major venation; B: Venation pattern; C: Free vein ending; D: Marginal venation)

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