FOLIAR VENATION AS AN AID TO THE SYSTEMATICS OF SCROPHULARIACEAE, 1. THE TRIBES DIGITALEAE, GERARDIEAE AND EUPHRASIEAE (SERIES RHINANTHEAE)

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ABSTRACT

On the basis of the number of strands entering the petiole or the base of the lamina, the eighteen investigated species of the Series Rhinantheae (family Scrophulariaceae) can be broadly classified into three categories —single, tri-, and pentastranded. Leaves with a single strand are more numerous, followed by the tri- and penta-stranded conditions. Differences have been noticed in the venation organization not only within the tribes but also in the various species of some genera such as *Veronica* and *Pedicularis*. It is invariably pinnate in all the representatives which can be further grouped into camptodromous types. Variations have also been recorded regarding the size and structure of the areoles and nature of vein-endings. A comparative analysis has been presented of these characters in the families Acanathaceae and Scrophulariaceae—especially the series Rhinanthae—to ascertain its value in the systematics of these families which have long been debated in the literature.

INTRODUCTION

Von Ettinghausen (1861), as a result of his pioneering work, ascribed important venation characters to be used in studying the taxonomy of fossil leaf forms. Later, Foster (1950a, b), in a series of papers dealing with foliar venation emphasized the use of diagnostic characters of venation of living taxa. Leaf venation has also been proposed as a tool for interpreting palaeoclimatic vegetation. Manze (1968) considered the abundance of fine veins in relation to numerous environmental variables such as sun *versus* shade, north *versus* south facing, height, and moisture. He correlated density of fine venation with relative humidity and found that leaves of a species may exhibit quite different densities of fine venation dependent upon certain environmental factors.

This report is a part of the studies on the leaf anatomy of some scrophulariaceous genera carried out at this laboratory. The family has been chosen because of the controversy that centers around the various sub-families included in the Scrophulariaceae as well as on the various taxa included in them. In an attempt to rationalize these ideas, Bremekamp (1953) transferred sub-family Nelsonioideae of the family Acanthaceae to sub-family Rhinanthoideae of Scrophulariaceae on the basis of the presence of a well-developed endosperm. According to him, in both *Elytraria* (Nelsonioideae) and Rhinantheae, the early segmentation of endosperm corresponded to the *Pedicularis* type. However, in its later growth both differ fundamentally. Johri and Singh (1959), Mohan Ram and Masand (1963), and Mohan Ram and Wadhi (1965) held that the morphology and embryology of *Elytraria* agree in general with the other members of Acanthaceae and therefore, the transfer of *Elytraria* to the Rhinantheae is not warranted. Contrarily, Raj (1961) and Chaubal (1966) supported the viewpoint of Bremekamp on the basis of palynological characters. Nafday (1964-65) also reached the same conclusion from anatomical investigations of the

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genus. PALIWAL (1966, 1967), investigated the ontogeny of stomata in *Elytraria* and several other members of the Acanthaceae and found a close resemblance among them. AHMAD (1972) indicated that all genera which belong to the Nelsonioideae are characterized by diacytic stomata, panduriform glandular hairs, and the absence of cystoliths. According to him these and other epidermal features are similar to those of the Acanthaceae in general and show an important difference from those of the Scrophulariaceae (Rhinantheae included). KUMAR AND PALIWAL (1975) also support this contention.

The present study deals with the foliar venation of 18 species of the family and has been undertaken to supplement our knowledge of the vasculature of the representatives of the Rhinantheae. For the descriptive terminology of leaf form and venation patterns, suggestions made by VARGHESE (1969) have been combined with the more recent, comprehensive and handy systems proposed by HICKEY (1973) and DILCHER (1974). Attempts have been made to see as to how far the foliar venation can help us in tracing the systematic position.

MATERIAL AND METHODS

The leaves employed for the present study were obtained from Meerut College, Botany Department Herbarium, Delhi University Botany Department Herbarium, and Botanical Survey of India, Dehra Dun. Table 1 shows the various taxa studied and localities of collection :

Table 1

Tribe	Name of the species	Locality
Digitaleae	*Hemiphragma heterophyllum* Wall.	Kedarnath, Uttar Pradesh
	Scoparia dulcis L.	Pachmarhi, Madhya Pradesh
	Picrorhiza kurrooa Royle	Tunganath area
	Wulfenia amherstiana Benth.	Rawalpindi, Pakistan
	Veronica agrestis Linn.	Azadpur, Delhi
	V. anagallis Linn.	Lucknow, Uttar Pradesh
		Timarpur, Delhi
	V. serpyllifolia Linn.	Chhota Simla, Himachal Pradesh
Gerardieae	*Buchnera hispida* Ham.	Pachmarhi, Madhya Pradesh
	Striga lutea Lour.	Chakrata, Uttar Pradesh
		Pachmarhi, Madhya Pradesh
	S. euphrasioides Benth.	Hastinapur, Delhi
	Ramphicarpa longiflora (Benth.) Benth.	Purandhar, Maharashtra
	Centranthera hispida Br.	Ranikhet, Uttar Pradesh
	**Leptorhabdos benthamiana* Walp.	Ranikhet, Uttar Pradesh
	Leptorhabdos parviflora (Benth.) Benth.	Kashmir
	Sopubia delphinifolia (Linn.) G. Don	Purandhar, Maharashtra
Euphrasieae	*Euphrasia officinalis* Linn.	Badrinath, Uttar Pradesh
	Pedicularis carnosa Wall.	Mussoorie, Chakrata, Uttar Pradesh
	P. zeylanica Benth.	Bharatpur, Rajasthan

*According to some recent workers this species is synonymous to *L. parviflora*.

Dried leaves were soaked in hot water for about half an hour. These were transferred to a 2.5 per cent aqueous solution of NaOH at 37-40°C in an oven till all the pigments got bleached out. The leaves were then rinsed thoroughly with distilled water to remove alkali and brought in a mixture of saturated aqueous solution of chloral hydrate and hydrogen peroxide (1 : 1). When these became transparent, they were again brought to water through a graded series of chloral hydrate solution. They were washed thoroughly with distilled water and dehydrated in an usual manner by passing through alcoholic series. Staining was carried out in safranin dissolved in a mixture of absolute alcohol and xylene. The preparations were mounted in piccolyte.

OBSERVATIONS

Tribe—DIGITALAE

Considerable variation exists in the size of the leaves. They are all symmetrical and microphyllous* except that of *Veronica serpyllifolia* (Table 2). Their form is variable with acute or obtuse apex and a broad narrow base. The margin is toothed except in *V. serpyllifolia* with serrate, acute or obtuse type of dentations extended to the complete margin or upper half of the blade. The attachment wherever present is normal. The strands entering the petiole may be three or five except *V. anagallis* and *V. serpyllifolia* where a single-stranded condition has been recorded.

The venation is of pinnate camptodromous, brochidodromous, semicraspedodromous type. The primary or 1° vein is weak or moderate and follows a straight or markedly curved course (Table 3). Secondary or 2° veins have acute or moderate divergence except in *V. serpyllifolia*, being curved abruptly and these are usually fine or moderate in thickness. The inter-secondary vein if present is composite or simple. The tertiary or 3° vein shows a variable pattern. It may be in alternate, opposite or right angle type of relationship to the midrib, with a variable arrangement (Text-fig. 1 A-D).

The areoles are imperfect or well-developed, polygonal, usually large except in *Wulfenia amherstiana* (Text-fig. 3D) with a random or oriented arrangement. The veinlets are branched (once, twice or thrice) except in the leaves of *Veronica anagallis* (Table 4 ; Text-fig. 3 A-G). The ratio between the size of lamina and areole is variable (Table 4).

Tribe—GERARDIEAE

The leaves show considerable variation in their size and are symmetrical, nanophyllous or microphyllous except in *Leptorhabdos benthamiana* (Table 2). They also vary in form with acute or obtuse apex and cuneate base except those of *Ramphicarpa longiflora*. The margin is variable with serrate, acute dentation and an acute apex lobe which may be obtuse or extended to the upper half of the blade. The attachment—whenever existing—is normal.

Usually only one (Table 4) strand enters the petiole. In some cases, however, a smaller one also joins from below. The leaves show pinnate type of venation with variation in details (Table 3). The primary or 1° vein is moderate or stout and markedly curved. Secondary or 2° veins are moderate or diverged at right angle except in *Sopubia delphinifolia*, curved abruptly and fine or moderate in thickness. The intersecondary vein if present is simple or composite. Tertiary or 3° veins shows a variable pattern and relationship to the midrib with close or distant type of arrangement except in *Striga euphrasioides* (Text-fig. 2A-E).

*Terminology after DILCHER (1974).

The areoles are well organized except in *S. euphrasioides* (Table 4 ; Text-fig. 4A). These are polygonal or quadrangular, very large with oriented arrangement except in *S. euphrasioides*. The penultimate veinlet is linear and branched except in *R. longiflora* (Text-fig. 3H, I ; 4 A-E) or simply branched (not linear) once, twice, or even thrice. The size of the lamina and aeroles has been given in Table 5.

Tribe—EUPHRASIEAE

The leaves are symmetrical and microphyllous with a variable form and size, obtuse apex and acute to cuneate or obtuse base (Table 2). The margin is toothed or lobed with variable dentation extended to the entire margin. The attachment, wherever present, is normal. The number of strands entering the petiole is one (another joining it from below).

The venation is pinnate, semicraspedodromous (Table 3). The primary or 1° vein is moderate in size and curved. The secondary or 2° vein has wide divergence, curved abruptly or uniformly, moderate or fine in thickness. The intersecondary vein if present is simple. The tertiary or 3° vein shows considerable variation in pattern, relationship to the midrib and arrangement. Marked accumulation of tracheidal elements was noticed at the tips or the margin (Text-fig. 2F-H).

The areoles are well-developed, polygonal or quadrangular, very large with random or oriented arrangement (Table 4). The veinlets are linear and straight except in *Euphrasia officinalis* (Text-fig. 4 G-I) and branched once or twice. The ratio of size of lamina and areole is variable (Table 5).

DISCUSSION

On the basis of the number of strands entering the petiole, the 18 species of the Scrophulariaceae investigated in the present work can be broadly classified into three categories—single-, tri-, and penta-stranded. Leaves with a solitary strand are more numerous followed by tri- and penta-stranded conditions. Variation exists not only within the tribe but many a time also within the same genus as for instance in *Veronica* and *Pedicularis* species.

The venation in all cases is of the pinnate type. It can be grouped further into two types—camptodromous brochidodromous and semicraspedodromous, depending upon the differentiation of the secondaries in relation to the primary. Within the types variations have been recorded with regard to the size of the areoles, nature of vein-endings, and their tips per areole. The areole size differs even in the same genus, except in *Pedicularis* and *Veronica* but here also the ratio of areole and lamina size tends to be variable. In general no direct correlation could be established between the size of the areoles and number of vein-endings and their tips per areole (Tables 3-4).

A survey of the literature reveals that LEVIN (1929) attached great systematic importance to vein islet areas or size of areole based upon his study of the genera *Barosma*, *Cassia*, *Digitalis* and *Erythroxylon*. Later, HALL AND MELVILLE (1951, 1954) opined that the veinlet termination number, either alone or in conjunction with other histological characters is of taxonomic value particularly in genera having only a small number of species.

The present investigation which is based on a limited number of species tends to suggest that the size of areole and veinlet termination number vary among the genera within a limited range (may even be ascribed as specific for a species) except in *Veronica* and *Pedicularis* species. Thus, these features can be regarded to be of taxonomic significance more so in conjunction with other characters of leaf anatomy.

Table 2—Morphological characters of the leaf

Name of the species	Lamina length (cm)	Lamina area	Balance	Form	Apex	Base	Margin	Dentation	Extent of dentation	Attachment
Hemiphragma heterophyllum	1.1	microphyll	symmetrical	very wide, ovate	obtuse	cordate	toothed	serrate (obtuse)	on complete margin	absent
Scoparia dulcis	1.5	,,	,,	narrow, oblong	acute	acute (cuneate)	toothed	serrate (acute)	on upper ½ margin	normal
Picrorhiza kurrooa	2.5	,,	,,	oblanceolate	obtuse	acute (cuneate)	toothed	serrate (acute)	on upper ½ margin	absent
Wulfenia amherstiana	1.5	,,	,,	narrow, oblong	obtuse	acute (cuneate)	toothed	serrate (acute)	on entire margin	normal
Veronica agrestris	1.5	,,	,,	narrow, ovate	obtuse	truncate	toothed	serrate (obtuse)	on entire margin	normal
V. anagallis	1.5	,,	,,	narrow, ovate	acute	truncate	toothed	serrate (acute)	on entire margin	normal
V. serpyllifolia	1.3	nanophyll	,,	very wide, ovate	obtuse	rounded	entire	..	..	normal
Buchnera hispida	1.4	microphyll	,,	narrow, obovate	obtuse	acute (cuneate)	toothed	serrate (acute)	on upper ½ margin	normal
Striga lutea	1.5	nanophyll	,,	oblanceolate	acute	acute (cuneate)	entire	..	..	absent
S. euphrasioides	7.4	microphyll	,,	narrow, oblong	acute	acute (cuneate)	,,	..	..	..
Ramphicarpa longiflora	3.0	nanophyll	,,	pinnatisect	acute	normal	lobed	apex lobed, obtuse	..	absent
Centranthera hispida	2.5	microphyll	,,	oblanceolate	obtuse	acunte (cuneate)	dentated	apex lobed obtuse	..	normal
Leptorhabdos benthamiana	1.0	leptophyll	,,	special shape needle-like	acute	acute (cuneate)	entire	..	..	absent
L. parviflora	2.5	microph yll	,,	special shape	acute	acute (cuneate)	lobed apex	apex lobed acute	..	absent
Sopubia delphinifolia	2.0	microphyll	,,	,,	,,	,,	,,	serrate acute	..	absent
Euphrasia officinalis	1.0	microphyll	,,	very wide, ovate	obtuse	obtuse	toothed	,,	entire margin	absent
Pedicularis carnosa	1.5	,,	,,	narrow, oblong	obtuse	acute (cuneate)	lobed	serrate obtuse	,,	absent
P. zeylanica	1.0	,,	,,	obovate	obtuse	,,	lobed	apex lobed obtuse	..	normal

Table 3—Venation patterns

Name of the species	Type of venation	Primary 1°		Secondary 2°		Relative thickness	Inter-secondary	Tertiary 3°		
		Size	Course	Divergence	Course			Pattern	Relationship course to the midrib	Arrangement
Tribe Digitaleae										
Hemiphragma heterophyllum	pinnate camptodromous brochido-dromous	weak	straight	acute	curved abruptly	fine	..	percurrent, retereo-flexed	at right angle	alternate opposite
Scoparia dulcis	pinnate, semi-craspedo-dromous	moderate	,,	,,	,,	moderate	..	,,	alternate, opposite	approximately at right angle
Picrorhiza kurrooa	,,	,,	markedly curved	moderate	,,	,,	composite	percurrent, recurved	,,	,,
Wulfenia amherstiana	,,	,,	,,		,,	,,	..	percurrent, sinuous	,,	,,
Veronica agrestis	pinnate, semi-craspedo-dromous	weak	straight	,,	,,	fine	composite	,,	approximately at right angle	close
V. anagallis	,,	weak	,,	,,	,,	,,	..	percurrent, retereoflexed	,,	,,
V. serpyllifolia	pinnate, camptodromous, brochido-dromous	moderate	,,	wide	,,	,,	simple	percurrent, sinuous	,,	distant
Tribe Gerardieae										
Buchnera hispida	pinnate, campto-dromous, brochi-dodromous	,,	,,	moderate	,,	,,	,,	,,	,,	close
Striga lutea	pinnate moderate, camp-todromous, bro-chidodromous	stout	markedly curved	right angle	,,	moderate	composite	,,	longitudinally	distant

S. euphrasioides	pinnate camptodromous, brochidodromous	moderate	straight	,,	,,	,,	..	percurrent, straight	longitudinally parallel	alternate opposite in about equal proportion
Ramphicarpa longiflora	pinnate camptodromous, brochidodromous	stout	markedly curved	,,	,,	fine	..	percurrent, simple	,,	distant
Centranthera hispida	,,	moderate	,,	moderate	,,	,,	..	percurrent, sinuous	approximately at right angle	,,
Leptorhabdos benthamiana	,,	stout	,,	right angle	,,	,,	..	..	approximately parallel	,,
L. parviflora	pinnate, semicraspedodromous	,,	straight	moderate	,,	,,	..	percurrent, retereoflexed	approximately at right angles	
Sopubia delphinifolia	pinnate semicraspedodromous	,,	,,	wide	,,	moderate	..	percurrent, convex	,,	distant
Tribe Euphrasieae										
Euphrasia officinalis	pinnate, semicraspedodromous	moderate	curved	wide	,,	,,	simple	..	approximately at right angle	predominately alternate joining with an offset
Pedicularis car nosa	pinnate semicraspedodromous	,,	,,	,,	curved uniformly	fine	,,	random, reticulate	approximately oblique	close
P. zeylanica	,,	,,	,,	,,	curved abruptly	moderate	..	percurrent, retereoflexed	approximately parallel	distant

Table 4—Variation in the organization of the areoles

Name of the species	Development	Arrangement	Shape	Size	Veinlet
Tribe Digitaleae					
Hemiphragma heterophyllum	imperfect	random	polygonal	very large	branched once
Scoparia dulcis	,,	,,	,,	large	,,
Picrorhiza kurrooa	well-developed	oriented	,,	very large	branched twice
Wulfenia amherstiana	imperfect	random	,,	medium	,,
Veronica agrestis	well-developed	oriented	,,	very large	branched thrice
V. anagallis	,,	,,	,,	,,	linear, curved
V. serpyllifolia	,,	,,	,,	,,	branched once
Tribe Gerardieae					
Buchnera hispida	,,	,,	,,	,,	linear, curved and branched once
Striga lutea	,,	,,	quadrangular	,,	linear and branched once
S. euphrasioides	imperfect	random	polygonal	,,	branched twice
Ramphicarpa longiflora	well developed	oriented	quadrangular	,,	linear
Centranthera hispida	,,	,,	polygonal	,,	linear, branched once or twice
Leptorhabdos benthamiana	,,	,,	,,	,,	,,
L. parviflora	,,	,,	,,	large	branched once, twice or thrice
Sopubia delphinifolia	,,	,,	quadrangular	very large	linear, branched once
Tribe Euphrasieae					
Euphrasia officinalis	,,	,,	polygonal	very large	,,
Pedicularia carnosa	,,	,,	quadrangular	,,	linear, straight branched once and twice
P. zeylanica	,,	random	polygonal	,,	linear, straight branched once and twice

Table 5—Details of foliar venation

Name of the species	Lamina size sq. mm.	Areole size sq. mm.	Ratio of areole lamina size	Vein ending per areole	No. of strands entering the petiole
Tribe Digitaleae					
Hemiphragma heterophyllum	90	0.8	0.009	0.9	Tri-stranded
Scoparia dulcis	60	0.3	0.005	0.8	Tri-stranded at the base of lamina
Picrorhiza kurrooa	211	0.5	0.002	0.9	5-stranded
Wulfenia amherstiana	150	0.2	0.001	0.7	Tri-stranded
Veronica agrestis	120	0.6	0.005	0.6	Penta-stranded
V. angallis	59	0.6	0.01	0.4	Single-stranded
V. serpyllifolia	24	0.3	0.01	0.4	Single-stranded
Tribe Gerardieae					
Buchnera hispida	69	0.7	0.01	0.8	Tri-stranded
Striga lutea	13	1.0	0.07	0.5	Single-stranded
S. euphrasioides	24	0.7	0.03	0.5	Single-stranded
Ramphicarpa longiflora	5	0.3	0.06	0.0	Tri-stranded
Centranthera hispida	62	0.5	0.008	0.4	Penta-stranded
Leptorhabdos benthamiana	45	0.1	0.2	1.3	Single-stranded, one joins from below
L. parviflora	25	0.3	0.01	0.6	Single-stranded, one joins from below
Sopubia delphinifolia	25	v. long			Single-stranded
Tribe Euphrasieae					
Euphrasia officinalis	67	1.0	0.01	0.9	Penta-stranded
Pedicularis carnosa	62	0.4	0.006	0.5	Tri-stranded
P. zeylanica	37	0.4	0.01	1.4	Single-stranded, one joins from below

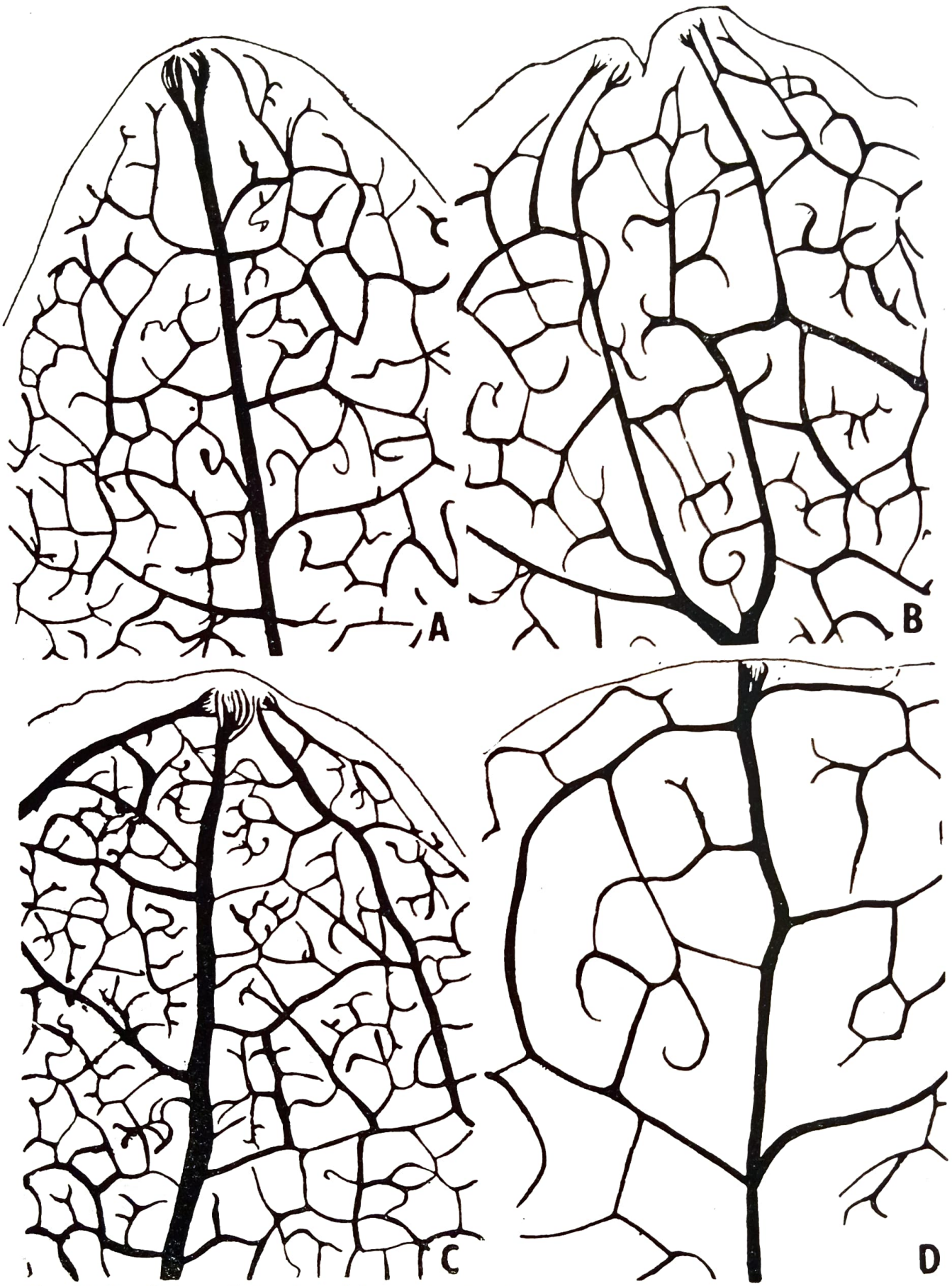

Fig. 1A-D. Apices of the cleared leaves showing simple organization of vascular elements. A. *Scoparia dulcis*, × 80. B. *Picrorhiza kurrooa*, × 60. C. *Wulfenia amherstiana*, × 60. D. *Veronica serpyllifolia*, × 60.

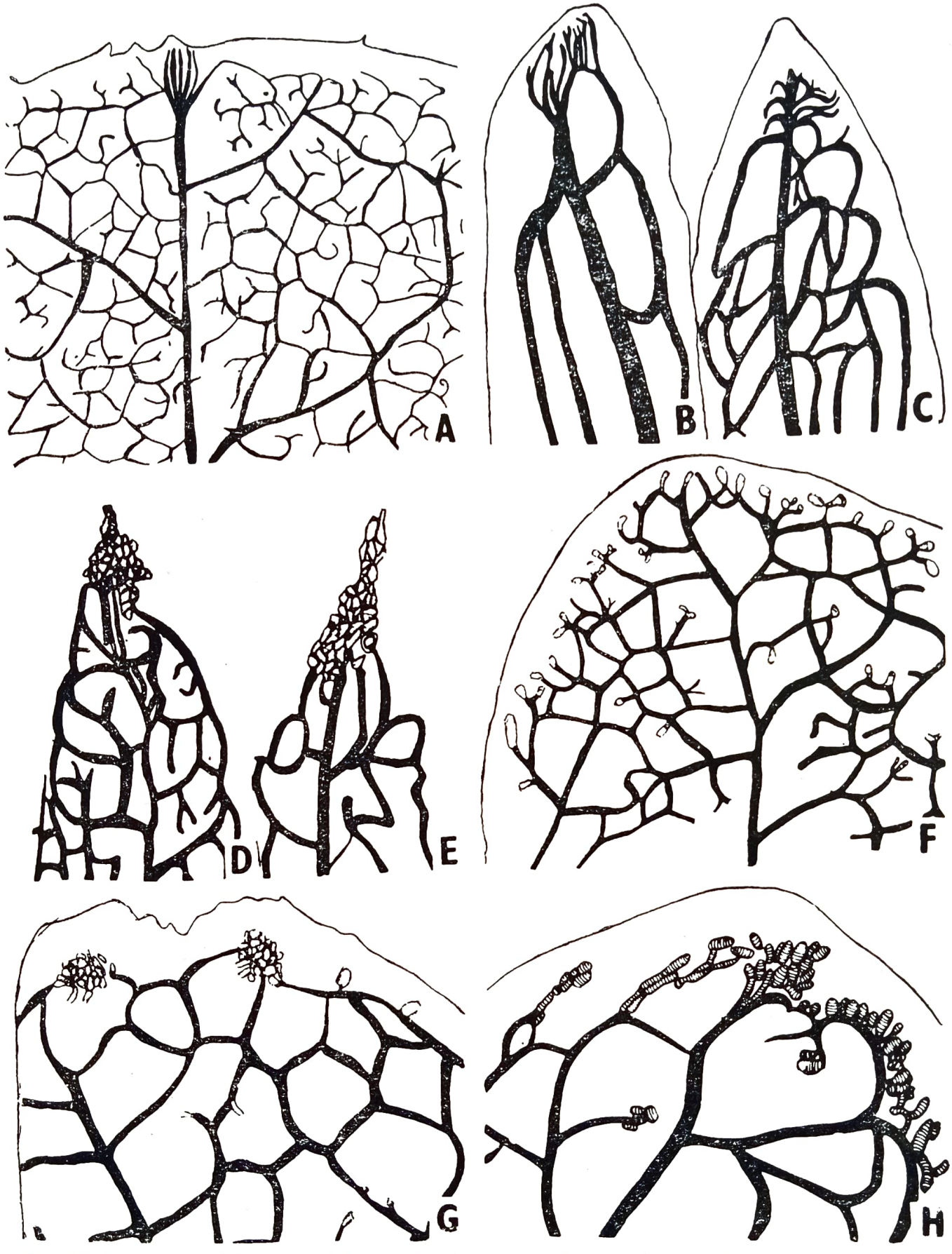

Fig. 2A-I. Apices of the cleared leaves showing accumulation of tracheidal elements. A. *Buchnera hispida*, × 80. B. *Ramphicarpa longiflora*, × 100. C. *Striga euphrasioides*, × 80. D. *Leptorhabdos benthamiana*, ×100. E. *L. parviflora*, ×100. F. *Euphrasia officinalis*, ×100. G. *Pedicularis carnosa*, ×100. H. *P. zeylanica*, × 100.

Fig. 3A-I. Venation patterns and types of areole organization in the series Rhinantheae. A. *Hemiphragma heterophyllum*, × 80. B. *Scoparia dulcis*, × 80. C. *Picrorhiza kurrooa*, × 80; D. *Wulfenia amherstiana*, × 80. E. *Veronica agrestis*, × 80. F. *V. serpyllifolia*, × 80. G. *V. anagallis*, × 80. H. *Buchnera hispida*, × 80. I. *Striga lutea*, × 80.

Fig. 4A-I. Venation pattern and the organization of areoles in the series Rhinantheae (Contd.). A. *Striga euphrasioides*, × 80. B. *Ramphicarpa longiflora*, × 80. C. *Centranthera hispida*, × 80. D. *Leptorhabdos benthamiana*, × 80. E. *L. parviflora*, × 80. F. *Sopubia delphinifolia;* × 80. G. *Euphrasia officinalis;* × 80. H. *Pedicularis carnosa*, × 80. I. *P. zeylanica*, × 100.

The accumulation of tracheids has been recorded in some members of the series Rhinantheae. In *Pedicularis carnosa, P. zeylanica* and *Leptorhabdos* sp. tracheidal accumulation has been noticed at the apical region of the lobes, while this is present in the marginal lobes in *E. officinalis*. Since *Pedicularis* and *Euphrasia* grow in physiologically xerophytic conditions due to high altitude, tracheidal accumulation may be considered an adaptation.

A point that deserves special mention with regard to the venation of members of Rhinantheae is that the number of the strands entering the petiole shows a great variation, i.e. starting from single- (8 species) to tri- (6 species) to penta-stranded (4 species) conditions.Members of the Nelsonioideae, on the other hand, are single-stranded uniformly—a characteristic feature of the other taxa of the family Acanthaceae as well, investigated by us (unpublished data). Several taxa, such as *Hemiphragma heterophyllum, Striga lutea,* and *R. longiflora* show similarity to *Elytraria acaulis* and *Nelsonia campestris* of the tribe Nelsonioideae (family Acanthaceae) in their gross or major venation. Furthermore, the accumulation of tracheidal elements recorded here for members of the tribe Rhinantheae has rarely, if at all, been noticed in acanthaceous taxa.

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REFERENCES

Ahmad, K. J. (1972). Cuticular studies in some Acanthaceae and Solanaceae. *Ph. D. Thesis, Lucknow University.*

Bremekamp, C. E. B. (1953). The delimitation of Acanthaceae. *Pro. K. Ned. Akad. Wet.* (ser. C) **56:** 533-546.

Bremekamp, C. E. B. (1965). Delimitation and subdivision of the Acanthaceae. *Bull. bot. Surv. India* **7 :** 21-30.

Chaubal, P. D. (1966). Palynological studies on the family Acanthaceae. *Ph. D. Thesis, Poona University.*

Dilcher, D. L. (1974). Approaches to the identification of angiosperm leaf remains. *Bot. Rev.* **40 :** 1-157.

Foster,A.S. (1950a). Morphology and venation of the leaf in *Quiina acutangula* Ducke. *Amer. J. Bot.* **37:** 159-171.

Foster, A. S. (1950b). Venation and histology of leaflets in *Touroulia guianensis* Aubl. and *Foresia tricarpa* Pires. *Amer. J. Bot.* **39 :** 848-862.

Hall, J. P. & Melville, C. (1951). Veinlet termination number : some further observations. *Jour. Pharm. & Pharmacol.* **3 :** 934-941.

Hickey, L. J. (1973). Classification of the architecture of dicotyledonous leaves. *Amer. J. Bot.* **60 :** 17-33.

Johri, B. M. & Singh, H. (1959). The morphology, embryology, and systematic position of *Elytraria acaulis* (Linn. f.) Lindau. *Bot. Not.* **112 :** 227-251.

Kumar, S. & Paliwal, G. S. (1975). Foliar anatomy of the family Acanthaceae. II. The tribes Thunbergieae and Nelsonieae. *Acta Bot. India* **3 :** 121-131.

Manze, U. (1968). Die Nervaturdichte der Blätter als Hilfsmmittel der paläoklimatologie scondervaeroffentl. *Inst. Univ. Koln.* **14 :** 1-103.

Mohan Ram, H. Y. & Masand, P. (1963). The embryology of *Nelsonia campestris* R. Br. *Phytomorphology* **13 :** 82-91.

Mohan Ram, H. Y. & Wadhi, M. (1965). Embryology and the delimitation of the Acanthaceae. *Phytomorphology* **15 :** 201-205.

Nafday, U. R. (1964-65). Anatomy of *Elytraria acaulis* Lindau. *Proc.* 51-52*nd Indian Sci. Congress,* **III,** Abstract, Sect. 5. Bot. 395.

Paliwal, G.S. (1966). Structure and ontogeny of stomata in some Acanthaceae. *Phytomorphology* **16 :** 527-532.

Paliwal, G. S. (1967). Stomatal ontogeny in the family Acanthaceae and systematic position of the genus *Elytraria. Proc.* 54*th Indian Sci. Congress,* (Abstract) **4 :** 306.

Varghese, T.M. (1969). A contribution on the foliar venation of Scrophulariaceae: pp. 253-266. *In:* Chowdhury, K. A. (ed.) *Recent Advances in the Anatomy of Tropical Plants.* Hindustan Publ. Corpn., Delhi.

Von Ettinghausen, C. (1854). Über die Nervation der Blätter der Papilionaceen. *Sitz. Ber. Kaiserl. Akad. Wiss., Math. Nature,* **12 :** 600-663.