Foliar architecture of Asclepiadaceae in relation to taxonomy

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Foliar architecture including gross morphology and venation of 20 species of Asclepiadaceae is investigated. The venation patterns recorded are planiusculus, semihyphodromous, hyphodromous, pinnate-brochidodromous, reticulodromous and palmatous-brochidodromous. The variations in the characters of secondary, tertiary and other minor veins are found to be taxonomically useful and accordingly a key for identification is provided.

Key-Words—Asclepiadaceae, Taxonomy, Foliar architecture.

INTRODUCTION

THE gross features of angiospermous leaves, like shape, size, type of margin, apex, base, petiole and venation have been used in describing the leaves of extinct and extant taxa. These have successfully helped in identification of many fossil taxa (Ashby, 1948; Carlquist, 1958, 1961; Nicely, 1965; Hickey, 1973; Doyle & Hickey, 1976; Hickey & Doyle, 1977; Stace, 1984; Basinger *et al.*, 1985 & Dilcher & Steven, 1986). But rarely these characters have been made use of in identification of extant taxa (Morill, 1978; Singh *et al.* 1978; Gupta & Bhambie, 1979; Mouton, 1979; Mohan & Inamdar, 1982, 1985; Bhatt & Tuteja, 1986; Ghosh & Roy, 1986; Ferzana Jabeen *et al.*, 1991; Anna Mani & Prabhakar, 1991a, 1991b, 1993a, 1993b, 1994; Anna Mani *et al.*, 1993; Prabhakar & Anna Mani, 1996).

As far as Asclepiadaceous taxa are concerned, very little information is available (Chaudhury, 1961; Wahi & Chunekar, 1965; Gupta *et al.*, 1971; Mitra *et al.*, 1974; Mohan & Inamdar, 1984 and Gupta, 1985). Hence an indepth study on foliar architecture in 20 species (Table 1) has been carried out to impress upon its usefulness in identification of Asclepiadaceae. The observations are presented in Tables 1 to 5.

MATERIAL AND METHOD

Randomly 20 mature leaves of each species (Table 1), were collected from ten different plants growing in different localities of Andhra Pradesh to record if there is any variation in morphology and venation patterns. The leaves were fixed in Carnoy's fixative (Johansen, 1940) and various acids and alkalies (HCl, HNO_3, KOH, NaOH, Cr_2 O_4 or in combinations) were used for separating veins from the other tissues. These were thoroughly washed with water, dried and were preserved for photography, as well as macro and microscopic studies. The terms are used after Hickey (1973) and Prabhakar & Anna Mani (1996).

OBSERVATION AND DISCUSSION

As presented in Table 1, the texture of the leaves is observed to be the membranous in *Asclepias*, *Ceropegia candelabrum*, *Gymnema*, *Hemidesmus*, *Marsdenia*, *Oxystelma*, *Pergularia*, *Telosma;* coriaceous in *Calotropis*, *Cryptolepis*, *Cryptostegia*, *Leptadenia*, *Tylophora* and *Wattakaka;* sub-coriaceous in *Decalepis*, while they are fleshy in *Caralluma*, *Ceropegia bulbosa* and *C. juncea*. Further the leaves, are observed to be sessile in *Caralluma* and *Ceropegia juncea;* sub-sessile in *Calotropis*, while rest of the 16 taxa possess normal petiole. Phyllotaxy is observed to be decussate and whorled in *Asclepias* and *Hemidesmus*, but opposite decussate in *Calotropis*. In rest of the 16 taxa, the leaves are opposite superposed. Leaves are symmetri-

Table 1. Macromorphology of leaf in Asclepiadaceae

Sl. No.	Name of the species	Texture	Form	Base	Apex
1.	*Asclepias curassavica* L.	MB	LA-L	A	A
2.	*Calotropis gigantea* (L.) R.Br.	CO	OO-OL	AR	A
3.	*C. procera* (Ait.) R.Br.	CO	OO	C	A
4.	*Caralluma attenuata* W.	F	O	RO	A
5.	*Ceropegia bulbosa* Roxb.	F	E,OR	A	A
6.	*C. candelabrum* L.	MB	E,O,LA	C,RO	OM
7.	*C. Juncea* Roxb.	F	LA,L	T	A
8.	*Cryptolepis buchanani* Roem & Schult.	CO	E-OL	A	A
9.	*Cryptostegia grandiflora* R. Br.	CO	E-OL	A	A
10.	*Decalepis hamiltonii* W. & A.	SCO	E-OO, OR	A	RE
11.	*Gymnema sylvestre* (Retz.) R.Br. ex Schult.	MB	E,OO,C,O	C,RO	A-AC
12.	*Hemidesmus indicus* (L.) R.Br.	MB	E,L-LA,OO,OL	A,OB	OM
13.	*Leptadenia reticulata* (Retz.) W. & A.	CO	E,O-C	SC	A
14.	*Marsdenia tenacissima* (Roxb.) Moon.	MB	C	C	AC
15.	*Oxystelma esculentum* (L.f) R.Br. ex Schult.	MB	LA,L-LA,L	RO,OB	AC
16.	*Pergularia daemia* (Forsk.) Chiov.	MB	C	C	AC
17.	*Telosma minor* (Andrews.) Craib.	MB	C	C	AC
18.	*T. pallida* Craib.	MB	C	C	AC
19.	*Tylophora indica* (Burm.f.) Merr.	CO	E-OL,O	C,RO	A-AC
20.	*Wattakaka volubilis* (L.f.) Stapf.	CO	O,C,SOR	RO,T,C	AC

A-acute; AC-acuminate; AR-auriculate; C-cordate; CO-coriaceous; E-elliptic; F-fleshy; L-linear; LA-lanceolate; MB-membranous; O-ovate; OB-obtuse; OL-oblong; OM-obtusely mucronate; OO-obovate; OR-orbiculate; RE-retuse; RO-round; SA-semi-amplexicaul; SCO-sub-coriaceous; SCS-sub-cordate, sinuses shallow; SOR-sub-orbiculate; T-truncate.

cal in all the taxa presently studied. Further the shapes of the leaves are observed to be variable from taxon to taxon. Among the taxa studied *Ceropegia bulbosa, C.candelabrum, Decalepis, Gymnema, Hemidesmus, Leptadenia, Tylophora* and *Wattakaka* are polymorphous. The leaves in general are elliptic, lanceolate, linear, oblong, cordate, ovate, obovate or orbiculate (Table 1). The leaf base is observed to be auriculate in *Calotropis gigantea,* truncate in *Ceropegia juncea* and *Wattakaka,* while in rest of the 17 taxa it is either acute, obtuse, rounded or cordate. Further the leaf apex is observed to be retuse in *Decalepis;* obtusely mucronate in *Ceropegia candelabrum* and *Hemidesmus* and acute to acuminate in *Gymnema* and *Tylophora,* while in rest of the 15 taxa it is either acute or acuminate (Table 1). Leaf margin in all, is entire except *Cryptostegia* and *Decalepis,* where it is repand (Figs. 1-20; Table 1).

Presently veins are observed to be planiusculus, semi-hyphodromous in *Caralluma* and *Ceropegia juncea,* while epidromous in rest of the eighteen taxa. The general venation pattern in the family has been described to be festooned brochidodromous and actinodromous, but in *Pergularia* as actinodromous (Mohan & Inamdar, 1984). However, presently in *Marsdenia, Pergularia* and *Telosma,* it is recorded to be palmatous-brochidodromous (Figs. 14, 16-18) and in *Caralluma* and *Ceropegia juncea* it is pinnate - reticulodromous (Figs. 4, 7) and in rest of the fourteen taxa it is pinnate-brochidodromus (Figs. 1-3, 5-6, 8-13, 15, 19-20; Table 2).

The median primary vein in straight but feebly curved at apex in *Calotropis gigantea* (Fig. 2); straight to feebly sinuous in *Ceropegia juncea* and *Gymnema* (Figs. 7 & 11); but feebly sinuous in *Caralluma* (Fig. 4), while straight in rest of the sixteen taxa (Figs. 1, 3, 5-6, 8-10, 12-20; Table 2). The midvein is massive in *Asclepias, Caralluma, Ceropegia juncea* and *Oxystelma* (Figs. 1, 4, 7, 15); stout in nine other taxa (Figs. 2-3, 6, 9, 12, 14, 18-

Table 2. Venation patterns and characters of Primary and Secondary Veins of leaf lamina in Asclepiadeceae

Sl. No.	Name of the species	Venation type	Median primary		Secondary veins			
			Course	Size	Num. (P)	Position	Angle of divergence	Course
1.	*Asclepias curassavica*	PNB	S	MA	17	SO	M	U-A
2.	*Calotropis gigantea*	PNB	S-FCA	ST	7	SO	MR	U-A
3.	*C. procera*	PNB	S	ST	7	SO	M	U-A
4.	*Caralluma attenuata*	PNR	FS	MA	4	SO	OPW	C-SN
5.	*Ceropegia bulbosa*	PNB	S	WE	7	SO	N	U-A
6.	*C. candelabrum*	PNB	S	ST	7	AO	MWR	U-A
7.	*C. juncea*	PNB	S-FS	MA	6	SA	NMW	S-C-SN
8.	*Cryptolepis buchanani*	PNB	S	WE	19	SAO	RWBA	FS-A
9.	*Cryptostegia grandiflora*	PNB	S	ST	12	ASO	RWBA	FS-A
10.	*Decalepis hamiltonii*	PNB	S	WE	7	SA	WMNBA	U-A
11.	*Gymnema sylvestre*	PNB	S-FS	SO	5	MO	BWMAN	U-A
12.	*Hemidesmus indicus*	PNB	S	ST	6	SOA	BMAN	U-A
13.	*Leptadenia reticulata*	PNB	S	MO	6	SOA	BWAM	U-A
14.	*Marsdenia tenacissima*	PLB	S	ST	9	A	MW	U-A
15.	*Oxystelma esculentum*	PNB	S	MA	5	SOA	NM	S
16.	*Pergularia daemia*	PLB	S	WE	6	OS	M	U-A
17.	*Telosma minor*	PLB	S	MO	4	OS	NM	U-A
18.	*T. pallida*	PLB	S	ST	5	SOA	M	U-A
19.	*Tylophora indica*	PNB	S	ST	6	ASO	M	U-A
20.	*Wattakaka volubilis*	PNB	S	ST	5	ASO	M	U-A.

A-alternate; AO-alternate to opposite; ASO-alternate to sub-opposite to opposite; BMAN-basally acute moderate, but apically acute narrow; BWAM-basally acute wide, but apically acute moderate; BWAN-basally acute wide to acute moderate, but apically acute narrow; C-SN-curved to sinuous; FS-feebly sinuous; but abruptly curved at margin; M-acute moderate; MA-massive; MO-moderate; MR-acute moderate to right angle; MW-acute moderate to acute wide; MWR-acute moderate to acute wide to right angle; N-acute narrow; NM-acute narrow to acute moderate; NMW- acute narrow to moderate to wide; OPW- obtuse, perpendicular to acute wide; OS-opposite to sub-opposite; P-in pairs, PLB-palmatous-brochidodromous; PNB-pinnate-brocidodromous; PNR-pinnate-reticulodromous; RWBA-right angle to acute wide, frome base to apex; S-straight; SA-sub-opposite to alternate; SAO-sub-opposite to alternate to opposite; S-C-SN-straight to curved to sinuous; S-FCA-straight but feebly curved at apex; S-FS-straight to feebly sinuous; SN-sinuous; SO-sub-opposite to opposite; SOA-sub-opposite to opposite to alternate; ST-stout; U-A- uniformly curved but abruptly curved at margin; WE-weak; WMNBA-acute wide to acute moderate to acute narrow from base to apex.

20); moderate in *Gymnema, Leptadenia* and *Telosma minor* (Figs. 11, 13, 17), and weak in *Ceropegia bulbosa, Cryptolepis, Decalepis* and *Pergularia* (Figs. 5, 8, 10, 16; Table 2).

In palmately veined taxa viz., *Marsdenia, Pergularia, Telosma,* the lateral primaries are two pairs and their course is curved, but abruptly curved at margin forming loops with upper secondaries (Figs. 14, 16-18; Table 2). The angle of divergence of lateral primaries are at right angles to midvein (Figs. 14, 16-18).

The number of secondaries in a given taxon were found to be constant in leaves collected from different plants but vary from species to species. Mohan & Inamdar (1984) reported 2 to 8 pairs of secondaries. In the presently studied taxa, the secondaries vary from 4-19 pairs in pinnately veined leaves (Figs. 1-13, 15, 19, 20). In palmately veined leaves there are 3-5 pairs of secondaries on midvein, and 3 exmedial secondaries on lateral primaries (Figs. 14, 16-18, Table 2).

Branched secondary veins are observed only in *Marsdenia, Telosma* and *Wattakaka* (Figs. 14, 17, 18, 20). Position of secondary veins is alternate in *Marsdenia* (Fig. 14) but alternate to sub-opposite in *Cryptostegia, Tylophora* and *Wattakaka*

(Figs. 19-20), sub-opposite to opposite to alternate in alternate to opposite in *Cryptolepis,* (Fig 8). *Hemidesmus, Leptadenia, Oxystelma,* and *Telosma pallida,* alternate to opposite in *Ceropegia candelabrum* (Fig. 6), but sub-opposite to opposite in *Asclepias, Calotropis, Caralluma, Ceropegia bulbosa, Gymnema, Pergularia* and *Telosma minor* (Figs. 1-5, 11, 16-17; Table 2).

The angle of divergence of secondaries were reported to be acute narrow, acute moderate, acute wide or right angle (Mohan & Inamdar, 1984). Presently in pinnately veined taxa it is observed to be acute narrow throughout the leaf in *Ceropegia bulbosa* (Fig. 5); acute moderate in *Asclepias, Calotropis procera, Tylophora* and *Wattakaka* (Figs. 1, 3, 19-20), but vary from base to apex, being acute narrow to moderate in *Oxystelma* (Fig. 15); acute narrow to moderate to wide in *Ceropegia juncea* (Fig. 7); acute moderate to right angle in *Calotropis gigantea* (Fig. 2); acute moderate to acute wide to right angle in *Ceropegia candelabrum* (Fig. 6), and obtuse to perpendicular to acute wide in *Caralluma* (Fig. 4). In some of the pinnately veined leaves, the angle of origin of secondaries is observed to be variable from base to apex. It is found to be basally acute wide to moderate and apically acute narrow, as in *Gymnema* (Fig. 11); basally acute wide but apically acute moderate, as in *Leptadenia* (Fig. 13); basally acute moderate but apically acute narrow, as in *Hemidesmus* (Fig. 12); acute wide to moderate to narrow from base to apex of leaf, as in *Decalepis* (Fig. 10); right angle to acute wide, form base to apex, as in *Cryptolepis* and *Cryptostegia* (Figs. 8,9; Table 2). The exmedial secondaries of lateral primaries from base to apex are acute narrow to acute moderate (Figs. 14, 16-18), but on midvein they are acute moderate in *Pergularia* and *Telosma pallida* (Figs. 16, 18), and acute narrow to acute moderate in *Telosma minor* (Fig. 17), and acute moderate to acute wide in *Marsdenia* (Fig. 14; Table 2). Secondaries in *Oxystelma* are straight (Fig. 15); straight to curved to sinuous in *Ceropegia juncea* (Fig. 7); curved to sinuous in *Caralluma* (Fig. 4). They are feebly sinuous but abruptly curved at margins in *Cryptolepis* and *Cryptostegia* (Figs. 8-9) while they are uniformly curved but abruptly curved at margins in 15 other taxa (Figs. 1-3, 5-6 10-14, 16-20; Table 2).

The loop forming secondary branches in brochidodomous leaves join the superadjacent secondaries at acute angle in *Ceropegia bulbosa* (Fig. 5); at right angles in *Tylophora* (Fig. 19); at obtuse angle in *Cryptolepis* and *Oxystelma* (Figs. 9, 15); at acute to right angles in *Cerepegia candelabrum, Gymnema* and *Leptadenia* (Figs. 6, 11, 13); right angles to obtuse angle in *Asclepias, Calotropis gigantea, C. procera, Cryptostegia* and *Wattakaka* (Figs. 1-3, 9, 20) and obtuse to right to acute angle in *Decalepis* and *Hemidesmus* (Figs. 10, 12). In palmately veined leaves the loop forming branches of median secondaries join the superadjacent secondaries at acute to right angles in *Pergularia* and *Telosma* (Figs. 16-18); right to obtuse angles in *Marsdenia* (Fig. 14). Further, the loop forming branches of secondaries of lateral primaries in palmately veined taxa join the superadjacent secondaires at right angles (Figs. 14, 16-18; Table 3).

Composite intersecondaries were reported earlier in three taxa (Mohan & Inamdar, 1984). Presently, intersecondary veins are observed in fourteen taxa and vary from 1-36 in number, but are constant in a given taxon. They are observed to be of both simple and composite types (Figs. 1, 3, 5-6, 8-10, 12-16, 19-20; Table 3). Though the distances between two intersecondaries are found to vary within limits in a given taxon, the range of variation when compared among different taxa is found to be of taxonomic potential. The distances varied from 0.05-0.1 cm as in *Caralluma* and 1.5-6 cm as in *Marsdenia* (Table 3).

Minor secondaries (Prabhakar & Anna Mani, 1996) are recorded in seven taxa. They are two in *Telosma* (Figs. 17-18), four in *Asclepias, Cryptostegia* and *Wattakaka* (Figs. 1, 9, 20), but six in *Pergularia* (Fig. 16), while as many as fourteen in *Cryptolepis* (Fig. 8; Table 3). Pseudo-intramarginal veins are observed in only *Cryptolepis* and *Oxystelma* (Figs. 8, 15).

Tertiaries were reported earlier to be percurrent and random or orthogonal reticulate (Mohan &

Table 3. Characters of secondary veins of leaf lamina in Asclepiadaceae

Sl. No.	Name of the species	Secondary veins	Intersecondary veins		
		Behavior of loop forming branches	No.	Type	Distance(cm)
1.	*Asclepias curassavica*	OR	19	S	0.3-1.2
2.	*Calotropis gigantea*	RO	-	-	0.6-3.2
3.	*C. procera*	RO	2	C	0.15-3.5
4.	*Caralluma attenuata*	-	-	-	0.05-0.1
5.	*Ceropegia bulbosa*	A	2	S	0.1-1.7
6.	*C. candelabrum*	AR	2	C	0.7-2.2
7.	*C. juncea*	-	-	-	0.03-0.3
8.	*Cryptolepis buchanani*	O	36	C	0.3-0.8
9.	*Cryptostegia grandiflora*	RO	18	C	0.5-0.8
10.	*Decalepis hamiltonii*	ORA	2	S	0.15-1.7
11.	*Gymnema sylvestre*	RA	-	-	0.2-2.1
12.	*Hemidesmus indicus*	RAO	2	S	0.5-1.3
13.	*Leptadenia reticulata*	AR	5	S	0.1-1.25
14.	*Marsdenia tenacissima*	ARO	1	S	1.35-6
15.	*Oxystelma esculentum*	O	6	S	0.4-1.6
16.	*Pergularia daemia*	AR	2	S	1.2-3
17.	*Telosma minor*	RA	-	-	0.8-3
18.	*T. pallida*	RA	-	-	1.6-3.9
19.	*Tylophora indica*	R	1	S	1.2.-3.2
20.	*Wattakaka volubilis*	RO	1	S	0.5-4

A-acute; Ar-acute to right angle; ARO-acute to right to obtuse angle; C-composite; O-obtuse angle; OR-obtuse to right angle; ORA-obtuse to right to acute angle; R-right angle; RA-right to acute angle; RAO-right to acute to obtuse angle; RO-right to obtuse angle; S-simple; - absent.

Inamdar, 1984), which is presently confirmed. They are observed to be orthogonal reticulate in *Cryptostegia* (Fig. 9), but random reticulate in *Caralluma, Ceropegia bulbosa, C. juncea* and *Cryptolepis* (Figs. 4-5, 7-8), while percurrent in other 15 taxa (Figs. 1-3, 6, 10-20). In *Gymnema, Hemidesmus, Leptadenia, Marsdenia, Oxystelma, Telosma minor, Tylophora* and *Wattakaka* the tertiaries are frequently forked (Figs. 11-15, 17, 19-20); but rarely branched in *Asclepias, Calotropis, Ceropegia candelabrum, Decalepis, Pergularia* and *Telosma pallida* (Figs. 1-3, 6, 10, 16-17).

The predominant angle of origin of tertiaries measured at admedial and exmedial side of secondaries may be similar throughout the leaf, or in a given taxon may vary within the leaf (Table 4). In *Marsdenia* and *Pergularia* the angle of origin of tertiaries are exmedially and admedially acute:acute (AA; Figs. 14, 16); in *Decalepis* it is actue: right angle (AR) (Fig. 10). Whereas the angle of origin varies in *Hemidesmus* and *Tylophora,* from acute:acute: to acute: right angle (AA to AR) (Figs. 12, 19); acute:acute to right:right angles (AA to RR) in *Telosma minor* and *Wattakaka* (Figs. 17, 20); right:acute angle to acute:acute angle (RA to AA) in *Ceropegia candelabrum* (Fig. 6); right:right angle to acute:acute angle (RR to AA) in *Asclepias* and *Calotropis gigantea* (Figs. 1-2); right:right angle to acute:right angle (RR to AR) in *Gymnema* (Fig. 11); acute:acute angle to acute:right angle to right:right angle (AA to AR to RR) in *Calotropis procera* (Fig. 3); acute:right angle to right:right angle to acute:acute angle (AR to RR to AA) in *Leptadenia* (Fig. 13); acute:obtuse to acute:right angle to right:right angle (AO to AR to RR) in *Oxystelma* (Fig. 15); and right:right angle to acute:acute to right:acute angle (RR to AA to RA) in *Telosma pallida* (Fig. 18).

The course of tertiaries are observed to be straight and recurved in *Asclepias* (Fig. 1); mostly straight, few curved and recurved in *Calotropis* (Figs. 2, 3); mostly curved and few recurved in *Ceropegia candelabrum, Tylophora* and *Wattakaka* (Figs. 6, 19, 20); mostly curved and few straight in *Gymnema, Hemidesmus, Leptadenia,* and *Telosma minor* (Figs. 11-13, 17); mostly curved and sinuate and few recurved in *Decalepis* and *Pergularia* (Figs. 10, 16); mostly straight and few curved and recurved in *Oxystelma* (Fig. 15); mostly recurved and curved and few straight in *Telosma pallida* (Fig. 18) and mostly recurved, curved and few retroflexed in *Marsdenia* (Fig. 14; Table 4). Relationship of tertiray veins to midvein is observed to be oblique constant in *Asclepias, Ceropegia candelabrum, Leptadenia, Oxystelma, Pergularia* and *Telosma minor* (Figs. 1, 6, 13, 15-17). In *Telosma pallida,* however, they are perpendicular and oblique but perpendicular constant upwards (Fig. 18) and in the other eight taxa it is oblique, but perpendicular upwards (Figs. 2-5, 7, 12, 14, 18-20; Table-4). Arrangement of tertiaries in eight of the presently studied taxa are alternate (Figs. 1, 3, 6, 11, 13, 17, 19, 20); but opposite in *Calotropis gigantea, Marsdenia, Pergularia* and *Telosma pallida* (Figs. 2, 14, 16, 18); and alternate to opposite in *Decalepis, Hemidesmus* and *Oxystelma* (Figs. 10, 12, 15; Table 4).

Higher order veins are distinct up to 8° in *Marsdenia,* 7° in 12 species; 6° in *Asclepias, Cryptolepis* and *Tylophora* and up to quintenaries (5°) in *Ceropegia bulbosa* and *Oxystelma* (Table 4). These veins are randomly oriented in seventeen taxa (Figs. 1-3, 5, 6, 8, 10-20) while only in *Cryptostegia* they are orthogonal (Fig. 9). However, higher order veins are indistinct in reticulodromous taxa (*Caralluma* and *Ceropegia juncea* (Figs. 4, 7; Table 4).

Areoles were reported to be well developed or imperfect and oriented (Mohan & Inamdar, 1984). In

Table 4. Characters of the tertiary and higher order veins of leaf lamina in Asclepiadaceae.

Sl. No.	Name of the species	Tertiary veins		Relationship to midvein	Arrangement	Higher order veins
		Angle of origin	Course			
1.	*Asclepias curassavica*	RR,AA	S,RC	OC	AL	6
2.	*Calotropis gigantea*	RR,AA	S-C,RC	OPU	OP	7
3.	*C. procera*	AA,AR,RR	S-C,RC	OPU	AL	7
4.	*Caralluma attenuata*	-	-	-	-	-
5.	*Ceropegia bulbosa*	-	-	-	-	5
6.	*C. candelabrum*	RA,AA	C,RC	OC	AL	7
7.	*C. juncea*	-	-	-	-	-
8.	*Cryptolepis buchanani*	-	-	-	-	6
9.	*Cryptostegia grandiflora*	-	-	-	-	7
10.	*Decalepis hamiltonii*	AR	C-SN,RC	OPU	ALOP	7
11.	*Gymnema sylvestre*	RR,AR	C-S,RC	OPU	AL	7
12.	*Hemidesmus indicus*	AA,AR	C-S,RC	OPU	ALOP	7
13.	*Leptadenia reticulata*	AR,RR,AA	C-S,RC	OC	AL	7
14.	*Marsdenia tenacissima*	AA	RC,C,RT	OPU	OP	8
15.	*Oxystelma esculentum*	AO,AR,RR	RC,S,C	OC	ALOP	5
16.	*Pergularia daemia*	AA	C-SN,RC	OC	OP	7
17.	*Telosma minor*	AA,RR	C-S,RC	OC	AL	7
18.	*T. pallida*	RR,AA,RA	RC,C-S	POPU	OP	7
19.	*Tylophora indica*	AR,AR	C,RC	OPU	AL	6
20.	*Wattakaka volubilis*	AR,RR	C,RC	OPU	AL	7

AA-acute:acute angle; AL-alternate; ALOP-alternate to opposite; AR-acute:right angle; AO-acute:obtuse angle; C-curved; OC-oblique constant; OP-opposite; OPU-oblique, but perpendicular upwards; OGR-orthogonal reticulate; POPU-perpendicular to oblique but perpendicular upwards; RA-right:acute angle; RC-recurved; RR-right:right angle: RT-retroflxed; S-straight, SN-sinuous; absent.

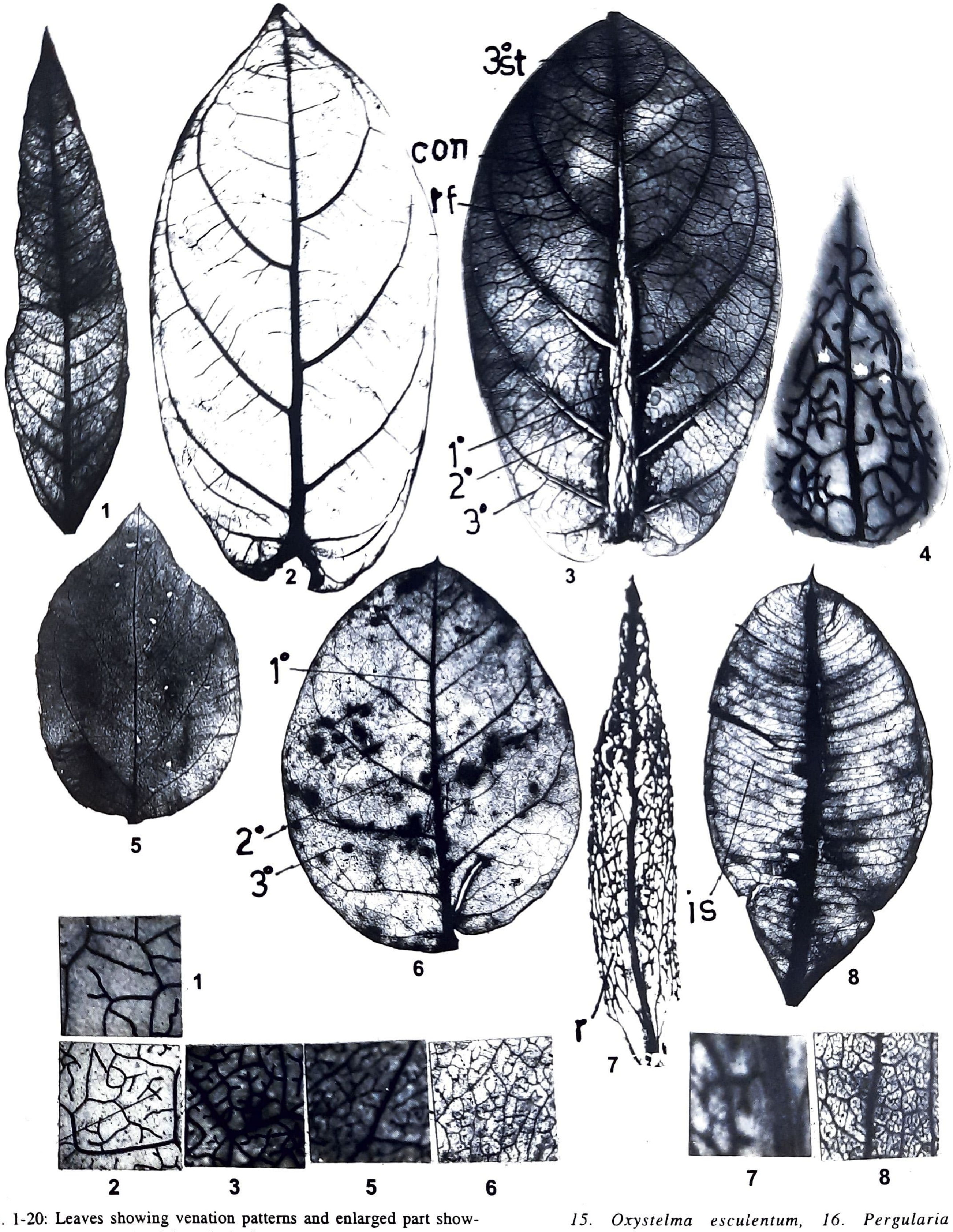
the presently studied taxa the areoles are imperfect in all (Figs. 1-7, 9-20) except in *Cryptostegia* where they are well developed and oriented (Fig. 8). The shape of the areoles were reported to be quadrangular, pentagonal, polygonal and irregular, without reference to any taxon (Mohan & Inamdar, 1984). Presently they are observed to be polygonal in fifteen taxa (Fig. 2-3, 5-6; 10-20); polygonal to quadrangular in *Asclepias, Cryptolepis* and *Cryptostegia* (Figs. 1, 8-9); polygonal, pentagonal and trapezial in *Caralluma* (Fig. 4) and trapezial, rhomboidal and polygonal in *Ceropegia juncea* (Fig. 7; Table 5). The size of the areoles has been observed to be very large to small (Table 5). The areoles, in the presently studied taxa, varied from 400 to 4700/ cm^2, as recorded in *Ceropegia bulbosa* and *Oxystelma* respectively (Table 5).

The veinlets are observed to be unbranched (simple) in *Marsdenia* (Fig. 14); simple to once branched in eighteen taxa (Figs. 1-7, 4, 9-13, 15-20) and simple to once or twice branched in *Cryptolepis* (Fig. 8). The veinlets are observed to be straight in *Calotropis procera, Ceropegia juncea, Marsdenia, Oxystelma* and *Pergularia* (Figs. 3,7,14-16); straight and curved in *Asclepias, Calotropis gigantea, Caralluma, Ceropegia bulbosa, C. candelabrum, Cryptolepis, Cryptostegia, Telosma pallida* and *Tylophora* (Figs. 1-2, 4-6, 8-9, 18-19) and curved in *Decalepis, Gymnema, Hemidesmus, Leptadenia, Telosma minor* and *Wattakaka* (Figs. 10-13; 17-20; Table 5). The number of veinlets per areole varied form 0-2 in *Calotropis procera, Caralluma, Ceropegia juncea, Marsdenia* and *Pergularia* (Figs. 3-4, 7, 14, 16); 0-4 in *Decalepis, Leptadenia, Oxystelma* and *Telosma pallida* (Figs. 10,13,15,18); 1-3 in *Gymnema* (Fig. 11); 1-4 in ten other taxa (Figs.1-2, 5-6, 8-9, 12, 17, 19, 20; Table 5). The frequency of veinlets varied form 900-2500/cm^2. Minimum number

Table 5. Characters of areoles, veinlets and marginal ultimate venation of leaf lamina in Asclepiadaceae

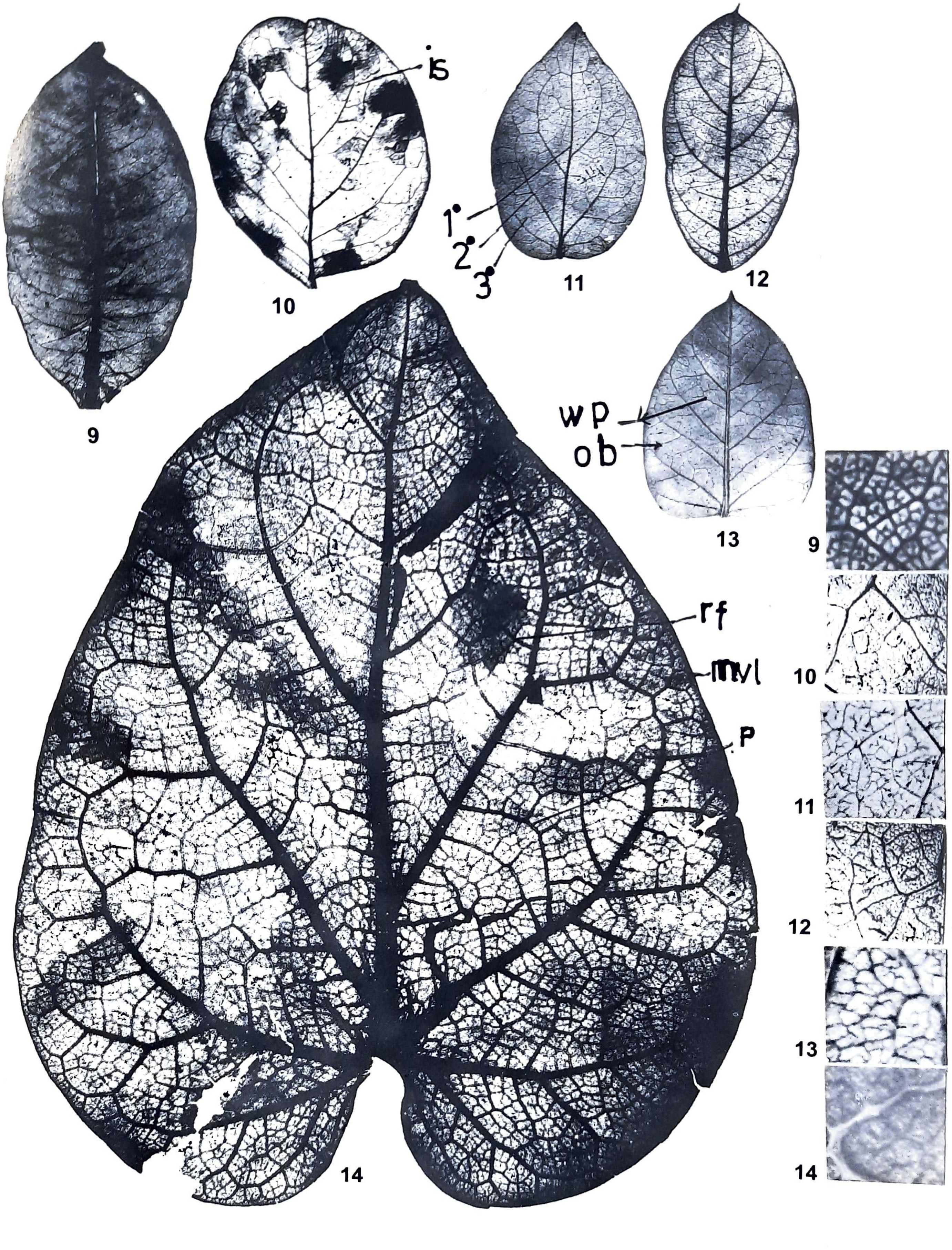
Sl. No.	Name of the species	Areoles			Veinlets		
		Shape	Size	Frequency/ cm^2	Course	Number/ areole	Frequency/ cm^2
1.	*Asclepias curassavica*	P-Q	L	900	ST-C	1-4	1500
2.	*Calotropis gigantea*	P	L	1500	ST-C	1-4	1800
3.	*C. procera*	P	SM	4000	ST	0-2	2100
4.	*Caralluma attenuata*	P,PN	L	1200	ST-C	0-2	1900
5.	*Ceropegia bulbosa*	P	VL	400	ST-C	1-4	900
6.	*C. candelabrum*	P	VL	500	ST-C	1-4	900
7.	*C. juncea*	T,R,P	L	1100	ST	0-2	1400
8.	*Cryptolepis buchanani*	P-Q	L	1000	ST-C	1-4	2000
9.	*Cryptostegia grandiflora*	P-Q	L	1200	ST-C	1-4	1000
10.	*Decalepis hamiltonii*	P	SM	3600	C	0-4	2500
11.	*Gymnema sylvestre*	P	M	1900	C	1-3	2000
12.	*Hemidesmus indicus*	P	L	1400	C	1-4	2200
13.	*Leptadenia reticulata*	P	L	1200	C	0-4	1400
14.	*Marsdenia tenacissima*	P	SM	3500	ST	0-2	2500
15.	*Oxystelma esculentum*	P	SM	4700	ST	0-4	2000
16.	*Pergularia daemia*	P	L	1400	ST	0-2	1000
17.	*Telosma minor*	P	M	1600	C	1-4	2000
18.	*T. pallida*	P	M	1900	ST-C	0-4	1800
19.	*Tylophora indica*	P	L	1000	ST-C	1-4	1900
20.	*Wattakaka volubilis*	P	L	1500	C	1-4	2000

C-curved; L-large; M-medium; P-polygonal; PN-pentagonal; Q-quadrangular; R-rhomboidal; SM-small; ST-straight; T-trapezial; VL-very large.



Figs. 1-20: Leaves showing venation patterns and enlarged part showing areoles and veinlets. *1. Asclepias curassavica*, *2. Calotropis gigantea*, *3. C. procera*, *4. Caralluma attenuata*, *5. Ceropegia bulbosa*, *6. C. candelabrum*, *7. C. juncea*, *8. Cryptolepis buchanani*, *9. Cryptostegia grandiflora*, *10. Decalepis hamiltonii*, *11. Gymnema sylvestre*, *12. Hemidesmus indicus*, *13. Leptadenia reticulata*, *14. Marsdenia tenacissima*, *15. Oxystelma esculentum*, *16. Pergularia daemia*, *17. Telosma minor*, *18. T. pallida*, *19. Tylophora indica*, *20. Wattakaka volubilis* (con-tertiary convex; is-inter-secondary vein; lp-lateral primary, mp-median primary; mvl-marginal vein looped; ob-tertiary oblique; p-tertiary percurrent; rf-tertiary reticulate; rf-tertiary retroflexed; sa-secondary alternate; st-tertiary straight; wp-tertiary weakly percurrent)

Fig. cont. on next page



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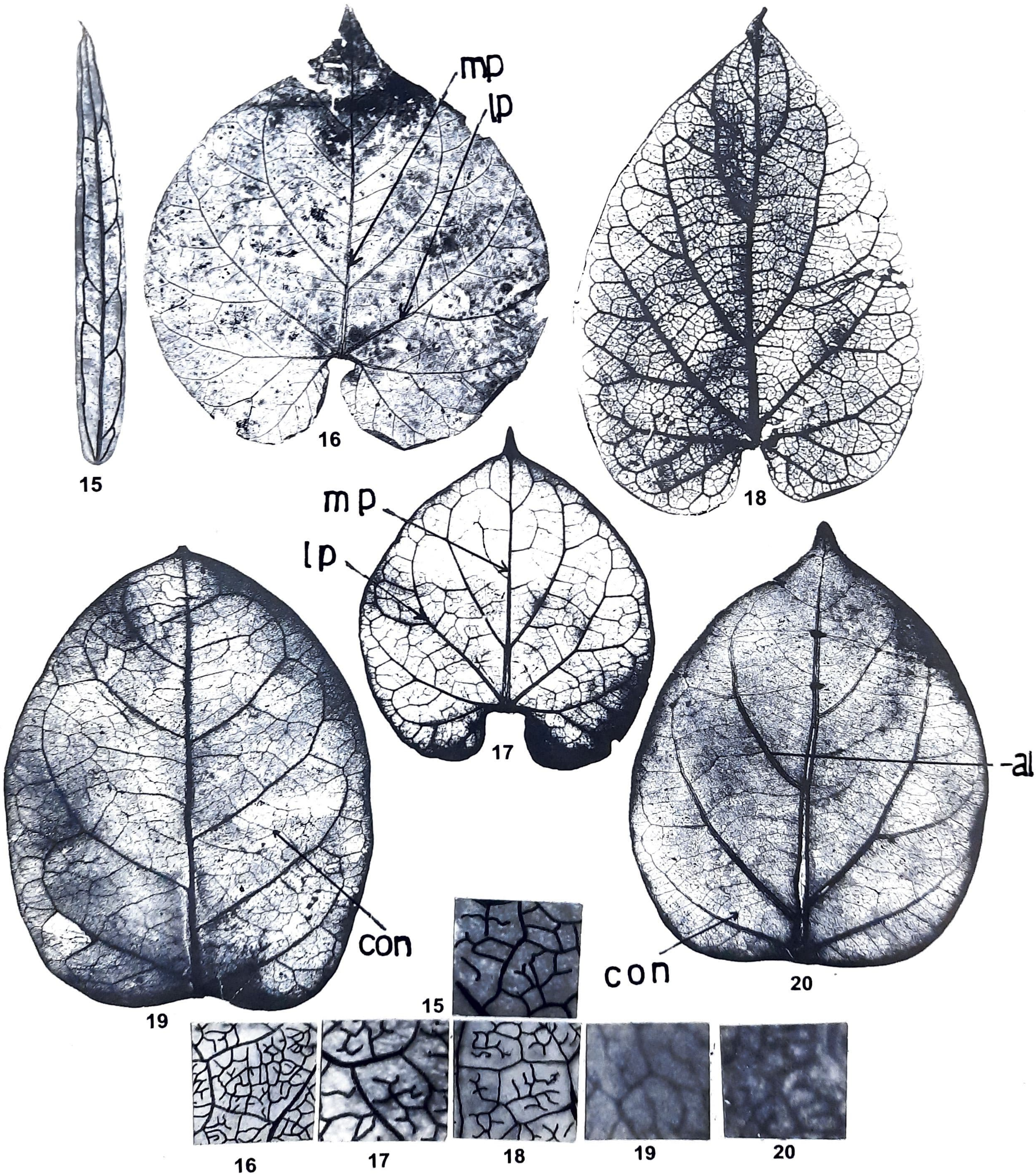
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of veinlets are observed in *Ceropegia bulbosa* and *C. candelabrum* and maximum number in *Decalepis* and *Marsdenia* (Table. 5).

The marginal ultimate venation are looped in all taxa studied, except in *Caralluma* and *Ceropegia juncea,* where it is incomplete.

The characters of leaf architecture, discussed above, exhibit great variation from species to species. Based on these characters, a key is presented below, for the identification of the taxa studied:

Key for the identification of Asclepiadaceous taxa based on leaf architecture

1. Venation palmate
2. Intersecondaries present
3. Midvein stout, secondaries alternate ....*Marsdenia tenacissima*
3. Midvein weak, secondaries opposite to alterante .... *Pergularia daemia*
2. Intersecondaries absent
4. Midvein moderate, tertiaries alternate and oblique constant ....*Telosma minor*
4. Midvein, stout, tertiaries opposite and oblique but perpendicular upwards ...*T. pallida*
1. Venation pinnate
5. Venation reticulodromous
6. Midvein feebly sinuous, secondaries alternate to opposite; obtuse to acute wide angled ... *Caralluma attenuata*
6. Midvein straight to feebly sinuous, secondaries alternate; acute narrow to wide angled ....*Ceropegia juncea*
5. Venation brochidodromous
7. Tertiaries reticulate
8. Secondaires less than 8 pairs ......*Ceropegia bulbosa*
8. Secondaries more than 11 pairs
9. Pseudo intramarginal vein present.......*Cryptolepis buchanani*
9. Pseudo-intramarginal vein absent ....*Cryptostegia grandiflora*
7. Tertiaries percurrent
10. Secondaries 17 pairs ....*Asclepias curassavica*
10. Secondaires less than 7 pairs
11. Minor secondaries present, secondaries branched ....*Wattakaka volubilis*
11. Minor secondaries absent, secondaries not branched
12. Intersecondaries absent
13. Midvein stout, secondaries acute moderate to right angled, tertiaries opposite ....*Calotropis gigantea*
13. Midvein moderate, secondaries basally acute wide to moderate, but apically acute narrow angled, tertiaries alternate ....*Gymnema sylvestre*
12. Intersecondaries present
14. Pseudo-intermarginal vein present ....*Oxystelma esculentum*
14. Pseudo-intramarginal vein absent
15. Number of intersecondaries five ....*Leptadenia reticulata*
15. Number of intersecondaries 1-2
16. Areoles small, 3000 to 4000/cm^2
17. Intersecondary distance 0.15-3.5 cm, intersecondaries composite, tertiaries alternate to opposite ....*Calotropis procera*
16. Areoles large, 400-1400/cm^2
18. Areoles up to 1400/cm^2 ....*Hemidesmus indicus*
18. Areoles up to 1000/cm^2
19. Areoles up to 500/cm^2 ....*Ceropegia candelabrum*
19. Areoles up to 1000/cm^2 ......*Tylophora indica*

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