



ANATOMY OF PETIOLE IN POLYGONACEAE

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The present communication describes petiolar vasculature of eighteen species of Polygonaceae. It is always supplied by the median bundle of the ochrea along with some laterals and/or their upper branches. On the basis of the pattern of vascularization, they are put under seven categories. However, on the basis of their vascular organization, they are put under 12 categories. The petiole may be triangular or semi-circular in outline but ribbed in *Rumex acetosa* and *R. nepalensis*. The hypodermis is usually collenchymatous. It is chlorenchymatous in *Rumex hastatus* and *Bilderdykia baldschuanica*; collenchymatous below the ridges and chlorenchymatous below the grooves in *Rumex acetosa* and absent in *Rumex arifolius* and *R. scutatus*. A sclerenchymatous sheath is present just outside the bundles in six species. In *Persicaria bistorta* numerous tanniferous cells are present in place of the bundle sheath. Druses have been observed in ground tissue in some 14 species and medullary bundles in three species. It has been observed that nodes with less number of lacunae and leaf traces have fewer vascular bundles in the petiole. Similarly, multilacunar nodes have larger number of vascular bundles in the petiole and in some cases the medullary bundles too. The herbs and climbers have fewer bundles in the petiole whereas the robust species have more bundles as also the medullary bundles.

Key words: Petiolar Vasculature, Abaxial Median Bundle, Adaxial Median Bundle

The petiolar anatomy has been used as a diagnostic tool in the systematics of numerous families and genera. Eversince the publication of the classical work by Metcalfe and Chalk, 1950, 1965, significant data has been added thereafter. The contributions of Dehgan, 1982 on Euphorbiaceae; Maksymowych *et al.* 1983 on herbaceous woody dicots; Olowokudyo, 1987 on Cruciferae; Kocsis *et al.* 2004 on Rubiaceae; Heneidak *et al.* 2007 on Papilionaceae; Eric *et al.* on Piperaceae; Oznur *et al.* 2011, Thakur and Patil, 2011; on Euphorbiaceae are some noteworthy contributions with reference to petiolar anatomy. These characteristics have been invariably used in making taxonomy. In an earlier communication the present authors described the anatomy of ochrea and stipule in the family (Agarwal and Saxena, 2012). The present study includes the vascular organization of petiole of eighteen species of Polygonaceae.

MATERIAL AND METHOD

The present study includes the result of observations made with undermentioned

eighteen species collected from places mentioned against them in Table 1:

The FAA fixed nodal regions alongwith petioles were processed following customary method of dehydration and clearing through ethanol-xylene series and then embedded in paraffin wax (Johnson, 1940). The embedded plant material was sectioned at 12-14 microns. The slides were stained with safranin-fast green and crystal violet-erythrosin combinations, both of which gave satisfactory results.

OBSERVATIONS

The anatomy of petiole of plants under investigation has been described at some length in the following account and their major characteristics have been compared in Table 2.

Polygonum aviculare: (Fig. II B) The petiole is almost triangular in outline with somewhat irregular abaxial surface. The epidermis is covered by irregular cuticle, followed by well developed collenchymatous hypodermis. It has a crescent of five collateral bundle on abaxial side, the central is called abaxial median bundle (AbM) and an inversely oriented adaxial

TABLE-1

S.No.	Taxa	Place of Collection
1.	<i>Polygonum aviculare</i> Linn.	Switzerland
2.	<i>P. serrulatum</i> Lagasca	Meerut
3.	<i>P. alatum</i> Buch.-Ham. ex Spreng.	Shimla
4.	<i>P. pterocarpum</i> Wall. ex Meissn.	Manali
5.	<i>Persicaria bistorta</i> (L.) Sampai	Switzerland
6.	<i>P. maculata</i> (Ref.) Love & Love	Switzerland
7.	<i>P. polystachya</i> (Wall.) II. Gross	Manali
8.	<i>P. amplexicaulis</i> (D. Don.) Ronse Decraene	Mussoorie
9.	<i>Bilderdykia baldschuanica</i> D.A. Webb.	Switzerland
10.	<i>Fagopyrum cymosum</i> (Trev.) Meissn.	Shimla
11.	<i>Antigonon leptopus</i> Hook. & Arn.	Meerut
12.	<i>Rumex arifolius</i> All.	Switzerland
13.	<i>R. nepulensis</i> Spreng.	Mussoorie, Manali
14.	<i>R. scutatus</i> Linn.	Switzerland
15.	<i>R. hastatus</i> D. Don	Badrinath, Shimla
16.	<i>R. dentatus</i> Linn.	Meerut
17.	<i>R. acetosa</i> Linn.	Switzerland
18.	<i>Oxyria elatior</i> R.Br.	Switzerland

TABLE-2 MAJOR CHARACTERISTICS OF THE PETIOLE IN DIFFERENT TAXA OF POLYGONACEAE

S. No.	TAXA	Shape	Adaxial face	Cuticle	hypodermis	Ground tissue	V.B. sheath	Druses	Number of V.B.		
									Ab	Ad	Med
1.	<i>Polygonum aviculare</i>	Tri	Concave	Ir	Col	Par	Scl	+	5	1	
2.	<i>P. serrulatum</i>	Tri	Concave	Sm	Col	Par	x	+	10	3	
3.	<i>P. alatum</i>	Semi	Concave	Sm	Col	Par	x	+	5	1	-
4.	<i>P. pterocarpum</i>	Semi	Flattened	IR	Col	Par	x	+	5	1	-
5.	<i>Persicaria bistorta</i>	Semi	Concave	Ir	Col	Par	Tan		6	2	
6.	<i>P. maculata</i>	Semi	Flattened	Sm	Col	Par	Scl	+	5	3	
7.	<i>P. polystachya</i>	Semi	Concave	Sm	Col	Par	Scl	+	1	7	-
8.	<i>P. amplexicaulis</i>	Semi	Concave	Ir	Col	Par	Scl	-	1	3	-
9.	<i>Bilderdykia baldschuanica</i>	Semi	Flattened	x	Chl	Par	x	+	5	1	
10.	<i>Fagopyrum cymosum</i>	Tri	Concave	Ir	Col	Par	x	+	8	3	1
11.	<i>Antigonon leptopus</i>	Cir	Flattened	Sm	Col	Par	Scl	-	14	2	-
12.	<i>Rumex arifolius</i>	Tri	Concave	x	x	Chl	x	+	3	-	-
13.	<i>R. nepulensis</i>	Tri	Ribbed	Ir	Col	Par	Scl	+	7	1	
14.	<i>R. scutatus</i>	Semi	Concave	x	x	Par	x	-	7	1	-
15.	<i>R. hastatus</i>	Tri	Flattened	x	Chl	Par	x	+	7	1	-
16.	<i>R. dentatus</i>	Tri	Concave	Sm	Col	Par	x	+	1	1	3
17.	<i>R. acetosa</i>	Tri	Ribbed	Sm	Col(R), Chl(G)	Par	x	+	7	1	1
18.	<i>Oxyria elatior</i>	Semi	Concave	Ind	Col	Par	x	+	5	1	

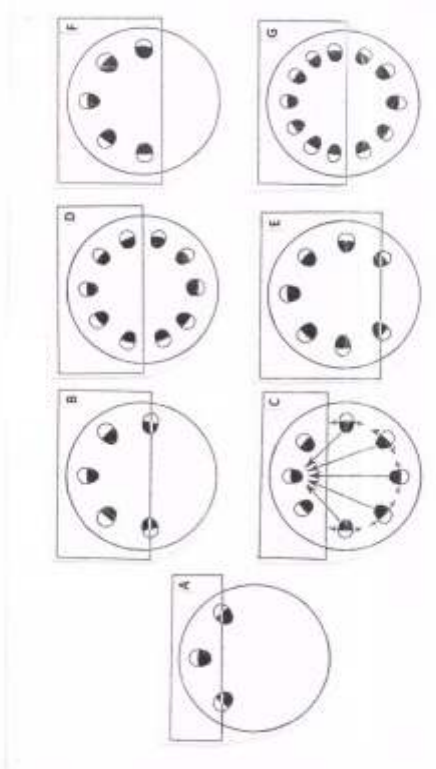


Figure I A-G. Diagrammatic representation of various patterns of vascular supply to the petiole in different taxa.

A. *Polygonum aviculare*, *P. pterocarpum*, *Bilderdykia bald-schuanica*. B. *Persicaria amplexicaulis*, *P. bistorta*, *Rumex nepalensis*, *R. scutatus*, *R. hastatus*, *Oxyria elatior*. C. *Fagopyrum cymosum*. D. *Polygonum serrulatum*. E. *Persicaria maculata*, *P. polystachya*. F. *Polygonum alatum*, *Rumex arifolius*, *R. dentatus*, *Antigonon leptopus*. G. *Rumex acetosa*.

median bundle (AbM) lying opposite to AbM bundle. The AbM bundle remains distinct throughout its course. Each bundle is covered by a poorly developed sclerenchymatous sheath. Several cells of ground parenchyma contain druses.

Polygonum serrulatum: (Fig. II F) The petiole is somewhat triangular in outline and concave abaxially. The epidermis is covered by poorly developed cuticle. It is followed by a single layered collenchymatous hypodermis. The vasculature comprises a crescent of ten

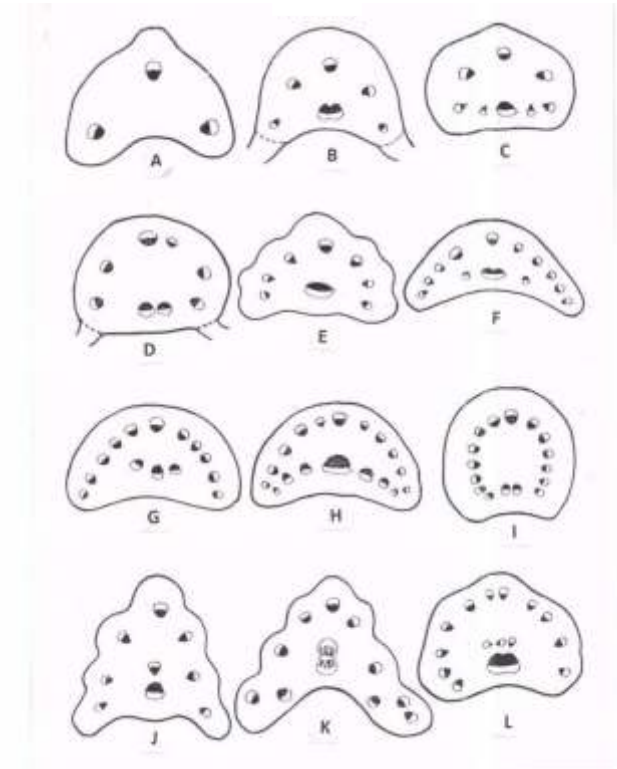


Figure II A-L. Semi-diagrammatic representation of the various types of petioles in different taxa.

A. *Rumex arifolius*. B. *Polygonum aviculare*, *P. alatum*, *P. pterocarpum*, *Bilderdykia baldschuanica*, *Oxyria elatior*. C. *Persicaria maculata*. D. *Persicaria bistorta*. E. *Rumex nepalensis*, *R. scutatus*, *R. hastatus*. Fig. F. *Polygonum serrulatum*. G. *Persicaria amplexicaulis*. H. *Persicaria polystachya*. Fig. I. *Antigonon leptopus*. J. *Rumex acetosa*. K. *Fagopyrum cymosum*. L. *Rumex dentatus*.

normally oriented collateral vascular bundles with a distinct abaxial median bundle (AbM) and an arc of three inversely oriented adaxial bundles. The adaxial median bundle (AdM) is formed by the fusion of two bundles. The vascular bundles lack sclerenchymatous sheath but druses are present in abundance in the ground tissue.

Polygonum alatum: (Fig. IIB) The petiole is adaxially concave and semi-circular in outline. The epidermis is covered by a very poorly developed and smooth cuticle followed by a

collenchymatous hypodermis. It is similar to *P. aviculare* in its vascular organization. There is, however, no sclerenchymatous bundle sheath but the cells of ground tissue possess several druses.

Polygonum pterocarpum: (Fig. II B) The petiole is adaxially flattened and semi-circular in outline. The epidermis, covered by a poorly developed irregular cuticle, is followed by a collenchymatous hypodermis. It also resembles *P. aviculare* in its vascular organization. There is no sclerenchymatous sheath above the bundles but the cells of the ground tissue possess a few druses.

Persicaria bistorta: (Fig. II D) The petiole is adaxially concave and semi-circular in outline. The epidermis, covered by irregular cuticle, is followed by a poorly developed collenchymatous hypodermis. The vascular bundles are surrounded by tenniferous cells and there are no druses. The petiolar vasculature comprises a crescent of six normally oriented collateral bundles with a distinct abaxial median bundle (AbM) and two inversely oriented adaxial median bundles (AdM), thus forming almost a ring of eight bundles.

Persicaria maculata: (Fig. IIC) The petiole is adaxially flattened and semi-circular in outline. The epidermis, covered by a thin and smooth cuticle, is followed by a collenchymatous hypodermis. It has a crescent of five normally oriented collateral bundles on abaxial side of which the central is called abaxial median bundle (AbM), and an arc of three inversely oriented adaxial bundles of which the central one is designated as adaxial median bundle (AdM) which is most prominent. There is a poorly developed sclerenchymatous sheath on the outer side of each petiolar bundle. The cells of ground possess druses.

Persicaria polystachya: (Fig. II H) The petiole is semi-circular in outline but distinctly grooved adaxially. The epidermis, covered by a poor and smooth cuticle, is followed by a well developed collenchymatous hypodermis. It has

a crescent of eleven normally oriented collateral bundles on abaxial side with a distinct abaxial median bundle (AbM) and an arc of seven inversely oriented bundles. The adaxial median bundle (AdM) is centrally placed and is formed by the fusion of two bundles. There is a poorly developed sclerenchymatous sheath outside each petiolar bundle. The cells of the ground tissue possess druses abundantly.

Persicaria amplexicaulis: (Fig. II G) The petiole is somewhat concave adaxially and semi-circular in outline. The epidermis, covered by irregular cuticle, is followed by a collenchymatous hypodermis which is better developed on lateral sides, even embedding some of the vascular bundles. The petiolar vasculature comprises a crescent of eleven normally oriented collateral bundles, with a distinct abaxial median bundle (AbM) and an arc of three inversely oriented adaxial bundle of which the median is designated as adaxial median bundle (AdM). There is a sheath of sclerenchyma outside the vascular bundles. The cells of the ground tissue conspicuously lack the druses.

Bilderdykia baldschuanica: (Fig. II B) The petiole is semi-circular in outline but adaxially flattened. The epidermis is not covered by cuticle and is followed by chlorenchymatous hypodermis. It has a crescent of the collateral bundles on abaxial side, the central being termed as abaxial median bundle (AbM) and an inversely oriented adaxial median bundle (AdM) lying opposite to AbM. The abaxial median bundle remains distinct throughout its course. There is no sclerenchymatous sheath outside the bundles, but several cells of the ground tissue possess druses.

Fagopyrum cymosum: (Fig. II K) The petiole is somewhat triangular in outline with an adaxial depression. It has distinct ridges and grooves on the abaxial side. The epidermis, covered by irregular cuticle, is followed by collenchymatous hypodermis. Its vasculature comprises a crescent of eight normally oriented collateral bundles on abaxial side with an abaxial median bundle (AbM) in the centre and

a group of three collateral inversely oriented bundles in the adaxial side. The adaxial median bundle (AdM) which is prominent and bicollateral is the fusion product of an inversely oriented adaxial median bundle and a normally oriented medullary bundle. The vascular bundles are devoid of sclerenchymatous sheath but druses are present in abundance in the ground tissue.

Antigonon leptopus: (Fig. II I) The petiole is somewhat circular in outline but adaxially flattened. The epidermis, covered by smooth cuticle, is followed by collenchymatous hypodermis. The petiolar vasculature comprises a crescent of fourteen normally oriented collateral bundles on abaxial side and two inversely oriented adaxial median bundles (AdM) on the adaxial side. The bundles are provided with a sclerenchymatous sheath on the outer face and the ground tissue lacks druses.

Rumex arifolius: (Fig. II A) The petiole is almost triangular, with a prominent concavity on the adaxial side. There is no distinct cuticle and the epidermis is followed by chlorenchymatous ground tissue. The petiole has a crescent of three normally oriented collateral vascular bundles on abaxial side, the median being termed as abaxial median bundle (AbM). The bundles lack any sclerenchymatous sheath but a few druses are present in the ground tissue.

Rumex nepalensis: (Fig. II E) The petiole is somewhat ribbed and triangular in outline. The epidermis, covered by an irregular cuticle, is followed by collenchymatous hypodermis which is the thicker below ridges. The vasculature comprises a crescent of seven normally oriented collateral bundles on abaxial side with somewhat distinct abaxial median (AbM) and an inversely oriented adaxial median bundle (AdM) lying opposite to AbM bundle. Each vascular bundle is surrounded by sclerenchymatous sheath and several cells of the ground tissue contain druses.

Rumex sculatus: (Fig. II E) The petiole is semi-

circular in outline with a concavity on the adaxial side. No distinct cuticle and hypodermis have been observed. Its vascular organization is similar to *R. nepalensis*. The vascular bundles lack bundle sheath and there are no druses in the cells of ground parenchyma.

Rumex hastatus: (Fig. II E) The petiole is somewhat triangular in outline but almost flattened adaxially. The epidermis is followed by a chlorenchymatous hypodermis. It resembles *R. nepalensis* in its vascular organization. There is no bundle sheath but a few druses are present in the cells of ground tissue.

Rumex dentatus: (Fig. II L) The petiole is somewhat triangular in outline with an adaxial depression. The cuticle is distinct and the epidermis is followed by collenchymatous hypodermis. The petiole has a crescent of eleven normally oriented collateral bundle with a distinct abaxial median bundle (AbM), an inversely oriented adaxial median bundle (AdM) and three medullary bundles. The bundle sheath is absent and druses are present in the cells of ground tissue.

Rumex acetosa: (Fig. II J) The petiole is triangular structure with distinct ridges and grooves. The epidermis, covered by cuticle, is followed by collenchyma below the ridges and chlorenchyma below the grooves. The petiole has a crescent of seven normally oriented collateral bundles with a distinct abaxial median bundle (AbM), an inversely oriented adaxial median bundle (AdM) and a medullary bundle. The bundle sheath is absent but the druses are present in the cells of ground tissue.

Oxyria elatior: (Fig. II B) The petiole is semi-circular in outline with a distinct adaxial groove. The cuticle is poorly organised and the epidermis is followed by collenchymatous hypodermis. The petiole has a crescent of five normally oriented collateral bundles on abaxial side, the central being termed as abaxial median bundle (AbM) and an inversely oriented adaxial median bundle (AdM) lying opposite to AbM. The AbM bundle remains distinct

throughout its course. The vascular bundles are devoid of any sclerenchymatous sheath but druses are present in abundance in the cells of ground tissue.

DISCUSSION

During the course of present study the structure of the petiole and the vasculature received by it from ochrea has been studied in 18 species belonging to six genera of the family. In all the species studied the median bundle of ochrea is always present in the vasculature of the petiole. The lateral bundles also contribute to the petiolar vasculature, however, they show much variation in different species, on the basis of which the following patterns have been recognized (Fig. IA-G).

- (A) The upper branches of the first pair of laterals (L1) supply the petiole in *Polygonum aviculare*, *P. pterocarpum* and *Bilderdykia baldschuanica* (Fig. IA).
- (B) First pair of laterals (L1) and upper branches of second pair of laterals (L2) supply of petiole in *Persicaria amplexicaulis* and *P. bistorta*, *Rumex nepalensis*, *R. scutatus*, *R. hastatus* and *Oxyria elatior* (Fig. IB).
- (C) First pair of laterals (L1) and branches from second and third pairs of laterals (L2, L3) and fourth unpaired lateral (L4) supply the petiole in *Fagopyrum cymosum* (Fig. IC).
- (D) Only first and second pairs of laterals (L1, L2) supply the petiole in *Polygonum serrulatum* (Fig. ID).
- (E) First and second pair of laterals (L1, L2) as also the upper branches of the third pair of laterals (L3) supply the petiole in *Persicaria maculata* and *P. polystachya* (Fig. IE).
- (F) All the laterals supply the petiole in *Rumex arifolius*, *R. dentatus*, *Polygonum alatum* and *Antigonon leptopus* (Fig. IF).
- (G) Only first, second and third pairs of

laterals (L1, L2, L3) supply the petiole in *Rumex acetosa* (Fig. IG).

The major characteristics of the petiole in the species studied are listed in Table-2. Besides the entire ground tissue is uniformly chlorenchymatous or parenchymatous with no distinction of hypodermis in *Rumex arifolius* and *R. scutatus* respectively.

On the basis of abaxial, adaxial and medullary bundles the petiolar vasculature can be categorised as under (Fig. IIA-L)

1. Adaxial as well as medullary bundles absent:
 - (A) Abaxial crescent composed of three bundles only e.g., *Rumex arifolius*.
2. Adaxial bundles present but medullary bundles absent:
 - (B) Abaxial crescent consists of five bundles; a single adaxial median bundle is present e.g., *Polygonum aviculare*, *P. alatum*, *P. pterocarpum*, *Bilderdykia baldschuanica* and *Oxyria elatior*.
 - (C) Abaxial crescent consists of five bundles; an adaxial arch of three bundles is present e.g., *Persicaria maculata*.
 - (D) Abaxial crescent consists of six bundles; an adaxial arch of two bundles is present e.g., *Persicaria bistorta*.
 - (E) Abaxial crescent consists of seven bundles; a single adaxial median bundle is present e.g., *Rumex nepalensis*, *R. scutatus* and *R. hastatus*.
 - (F) Abaxial crescent formed by ten bundles; the adaxial arch consists of three bundles e.g., *Polygonum serrulatum*.
 - (G) Abaxial crescent formed by eleven bundles; the adaxial arch consists of three bundles e.g., *Persicaria amplexicaulis*.
 - (H) Abaxial crescent formed by eleven bundles; the adaxial arch consists of seven bundles e.g., *Persicaria polystachya*.

- (I) Abaxial crescent formed by fourteen bundles; two adaxial bundles are present e.g., *Antigonon leptopus*.
3. Adaxial as well as medullary bundles present:
- (J) Abaxial crescent formed by seven bundles; an adaxial median bundle and a medullary bundle present e.g., *Rumex acetosa*.
- (K) Abaxial crescent formed by eight bundles; three adaxial and a medullary bundle present e.g., *Fagopyrum cymosum*.
- (L) Abaxial crescent formed by eleven bundles; an adaxial median bundle and three medullary bundles present e.g., *Rumex dentatus*.

When the nodes are trilacunar 3-trace, there are three (*Rumex arifolius*) or six vascular bundles (*Polygonum aviculare*, *P. pterocarpum* and *Bilderdykia baldschuanica*) in the petiole. A tetralacunar 4-trace (*Polygonum alatum*) or pentalacunar 6-trace node has six bundles in the petiole. A tetralacunar 5-trace (*Rumex nepalensis*), pentalacunar 5-trace (*Rumex scutatus* and *R. hastatus*) and six lacunar 7-trace (*Persicaria maculata*) node has eight bundle in petiole. While in *Antigonon leptopus* the node is pentalacunar 5-trace, the petiole has 16 bundles and in *Persicaria amplexicaulis* the node is six lacunar 6-trace and the petiole has 14 bundles in all. In *Fagopyrum cymosum*, *Persicaria bistorta* and *P. polystachya* the node is eight lacunar 8-trace but the petiole has 12, 9 or 18 bundles respectively. In *Polygonum serrulatum* and *Rumex dentatus*, the node is ten lacunar and in *R. acetosa* twelve lacunar with 10, 11 and 12 traces respectively and the petioles have 13, 15 and 9 bundles respectively.

On the basis of vascular anatomy Metcalfe and Chalk (1950) differentiated five types of petioles in the Polygonaceae. They also suggested that further investigations of the vascular structures of the petiole may yield patterns of diagnostic values in certain families and genera. Tumanyan (1965) differentiated

four species of *Polygonum* on the bases of petiolar anatomy. Haraldson (1978) used petiolar anatomy as an aid to taxonomy at generic and tribal level. Taxonomic significance has been attached to petiolar vasculature by many workers such as Ghosh and Banerji (1986) in *Ilex* and Lillyamma and Shah (1987) in some Verbenaceae. Osterova (1986) studied the anatomy of the petiole in some species of *Polygonum* section *Persicaria*. He pointed out that it shows combination of both xero- and hydromorphic features i.e., occurrence of well developed mechanical and conducting tissue along with well developed aerenchyma.

Thus in the present study a correlation has been observed in the number of lacunae, leaf traces and vascular bundles in the petiole. In those species where the nodes have a few lacunae and leaf traces there are only a few vascular bundles in the petiole. Similarly, multilacunar nodes with many leaf traces have larger number of vascular bundles in the petiole. In the latter case, medullary vascular bundle/s may also occur in the petioles of some plants.

There is some correlation between the number of bundles in the petiole and the habit of the plant too. The herbaceous and climbing species have a few vascular bundles whereas the number of bundles is more in robust species. Further the occurrence of the medullary bundles in the petiole is also associated with robustness of the plant. Lillyamma and Shah (1987) also concluded that medullary bundles occur in the petioles of woody and shrubby species in Verbenaceae.

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