J. Indian bot. Soc. Vol. 91 (4) 2012 : 299-309

ANATOMY OF OCHREA AND STIPULE IN POLYGONACEAE*

D.K. AGRWAL AND N.P. SAXENA**

** The work was carried out in the Botany Department of D.N. College, Meerut.*

*** Present Address–IIMT Group of Colleges, 'O' Pocket, Ganga Nagar, Meerut.*

The present communication describes anatomy of ochrea and stipule in eighteen species of Polygonaceae. With the exception of *Antigonon leptopus* a tubular ochrea has been observed in all the seventeen species examined. On the basis of the present studies it is concluded that the ochrea consists of two parts; the lower portion is regarded as the sheathing base whereas the upper free tubular part as the stipule. Depending upon their vasculature, the stipules have been divided into seven categories. The stipular part usually receives many bundles but some times 4 or 3 or 2 and it is non-vascular in *Polygonum alatum, Rumex arifolius* and *R. dentatus.* There appears to be some correlation between the nodal vasculature and the number of vascular bundles present in the stipule. Nodes having only a few leaf traces generally possess either fewer bundles in the stipule or they are totally nonvascular.

Key Words: Ochrea, Stipule.

The family Polygonaceae is characterised by the presence of an ochrea. It has been variously interpreted by earlier workers like Asa Gray (1879), Goebel (1905), Jackson (1916), Willis (1931) etc. Sinnott and Bailey (1914) correlate multilacular node with sheathing leaf base. According to them the sheathing leaf base and ochrea are the fusion product of a row of adjacent stipules. Mitra (1945) studied the ochrea of *Polygonum orientale* and differentiates sheathing structure as ochrea and upper free portion as stipule. This has been supported by Mitra and Majumdar (1952) who do not support Sinnott and Bailey's contention on anatomical grounds. In an earlier communication Agrawal and Saxena (2012) described the nodal structure in the family. The present study is an endeavour to resolve the problem of ochrea and stipule of Polygonaceae on the basis of anatomy.

MATERIAL AND METHODS

In the present study, the following 18 species have been included:–

	Taxa	Place of Collection
1.	*Polygonum aviculare* Linn.	Switzerland
2.	*P. serrulatum* Lagasca	Meerut
3.	*P. alatum* Buch.-Ham. ex Spreng.	Shimla
4.	*P. pterocarpum* Wall. ex Meissn.	Manali
5.	*Persicaria bistorta* (L.) Sampai	Switzerland
6.	*P. maculata* (Ref.) Love & Love	Switzerland
7.	*P. polystachya* (Wall.) H. Gross	Manali
8.	*P. amplexicaulis* (D. Don.) Ronse Decraene	Mussoorie
9.	*Bilderdykia baldschuanica* D.A. Webb.	Switzerland
10.	*Fagopyrum cymosum* (Trev.) Meissn.	Shimla
11.	*Antigonon leptopus* Hook. & Arn.	Meerut
12.	*Rumex arifolius All.*	Switzerland
13.	*R. nepalensis Spreng.*	Mussoorie, Manali
14.	*R. scutatus Linn.*	Switzerland
15.	*R. hastatus* D.Don	Badrinath, Shimla
16.	*R. dentatus* Linn.	Meerut
17.	*R. acetosa* Linn.	Switzerland
18.	*Oxyria elatior* R.Br.	Switzerland

Received on September 21, 2011 Accepted on April 18, 2012

The Formal-Acetic Alcohol fixed nodes with petioles were processed following usual method of dehydration and clearing through ethanol-xylene series and then embedded in paraffin wax (Johnson 1940). This paraffin 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 good results.

OBSERVATIONS

The anatomy of ochrea and stipules of some 18 species belonging to seven genera viz. *Polygonum, Persicaria, Bilderdykia, Fagopyrum, Antigonon, Rumex* and *Oxyria* has been worked out. They have been described separately in the following account.

Polygonum Linn.

The present study includes four species of *Polygonum* namely *P. aviculare, P. serrulatum, P. alatum* and *P. pterocarpum.* The number of vascular bundles entering ochrea may be three (*P. aviculare, P. pterocarpum*) or four (*P. alatum*) or ten (*P. serrulatum*). They are designated as abaxial median bundle (AbM) and paired or unpaired laterals (L_1 to L_5). The abaxial median bundle remains more prominent than others throughout its course. The number of laterals may be two ($2L_1$) in *P. aviculare* and *P. pterocarpum*, three ($2L_1$ & $1L_2$) in *P. alatum* or nine (2 each L_1L_2, L_3, L_4 and L_5) in *P. serrulatum* which are almost equally distributed on either side of abaxial median. Lateral branches are given off from the abaxial median and laterals which fuse, anastomose and reorganize into a crescent of varying number of vascular bundles and inversely oriented adaxial median bundle (AdM). In *P. serrulatum* and *P. alatum* the solitary adaxial median is formed by the fusion of two bundles. The crescent comprises five normally oriented, collateral bundles and a single inversely oriented adaxial median bundle in three species studied except *P. serrulatum* where the crescent is made up of ten normally oriented, collateral bundles and three inversely oriented adaxial bundles. Of these three the central bundle is designated as adaxial median bundle. At a higher level, the petiole separates from the U-shaped stipular part. The stipule continues for some distance after separation from the petiole. The vasculature for upper tubular part may arise from the bundles of ochrea differently in different species studied. It may arise from L_1 alone (*Polygonum aviculare*) or L_1 and AbM both (*P. pterocarpum*) or from L_3, L_4 and L_5 (*P. serrulatum*). No stipular vasculature was seen in *P. alatum.* The stipule may have stomata and/or glands in all the species studied except *P. alatum* which has none.

Persicaria Mill.

Four species of *Persicaria* namely *P. bistorta, P. maculata, P. polystachya* and *P. amplexicaulis* have been studied. The number of vascular bundles entering ochrea may be six (*P. amplexicaulis*) or seven (*P. maculata*) or eight (*P. bistorta, P. polystachya*). They are normally oriented, collateral and differentiated as abaxial median bundle (AbM) and paired or unpaired laterals (L_1 to L_4) . The number of laterals may be five ($2L_1$, $2L_2$, $1L_3$) in *P. amplexicaulis* or six (2 each L_1, L_2, L_3) in *P. maculata* or seven (2 each L_1, L_2, L_3 and $1L_4$) in *P. bistorta* and *P. polystachya*. The odd lateral in *P. amplexicaulis* is inversely oriented lying opposite to abaxial median. The laterals are otherwise almost equally distributed on either side of abaxial median. The lateral branches given off from the abaxial median and laterals fuse, anastomose and then reorganise into a crescent of variable number of normally oriented, collateral bundles and inversely oriented adaxial bundles. The number of bundles forming the crescent as also the adaxial median bundles varies in different species as under:–

i) The crescent comprises six bundles and there are two inversely oriented adaxial median bundle (AdM) in *P. bistorta.*

ii) The crescent comprises seven bundles and there are three inversely oriented adaxial bundles, the central adaxial median bundle being most prominent in *P. maculata.*

iii) The crescent comprises eleven bundles and there are seven inversely oriented adaxial bundles, the central adaxial median bundle being most prominent in *P. polystachya.*

iv) The crescent comprises eleven bundles and there are three inversely oriented adaxial bundles which become five higher up. Of these three, the central adaxial median bundle is most prominent in *P. amplexicaulis.*

The stipular supply is derived from L_2 and L_3 in *P. amplexicaulis*, from only L_3 in *P. maculata*, from L_3 and L_4 in *P. bistorta* and *P. polystachya.* The stipules may possess only stomata and no glands in *P. amplexicaulis;* only glands in *P. maculata* and none in *P. bistorta* and *P. polystachya*.

***Bilderdykia* Dum:**

Only one species, *B. baldschuanica* has been worked out. The three collateral vascular bundles entering the ochrea are designated as abaxial median (AbM) and a pair of laterals (L_1), one on either side of the median. The AbM remains undivided throughout its course. The laterals move upward and give out two branches, one on either side. The remaining vascular masses give two more traces, one on either side, for the stipular part and then fuse with each other and again organises into three bundles - two laterals and an adaxial median (AdM). The tubular stipule separates from the petiole at a higher level which is supplied by only two vascular bundles. The petiole has a crescent of five normally oriented, collateral bundles on the abaxial side and a very prominent AdM. The stipule has neither glands nor the stomata.

***Fagopyrum* Tournet Hall.:**

Only one species, *F. cymosum* has been worked out. The eight collateral vascular bundles entering the ochrea are differentiated into an abaxial median (AbM), three paired laterals (L_1, L_2, L_3), and an unpaired laterial (L_4) lying opposite to AbM. The AbM bundle gives out laterals, one on either side. The branch along with laterals organise into a vascular complex. It differentiates inside the petiole into a crescent of eight normally oriented collateral bundles on the abaxial side and a groups of three inversely oriented collateral bundles on the adaxial side. The adaxial median, a prominent bicollateral bundle is the fusion product of an inversely oriented adaxial median bundle (AdM) and a normally oriented medullary bundle. Higher up, the ochrea separates into an annular stipules and the petiole. The stipule is supplied by branches from L_2, L_3 and L_4 bundles and it lacks glands and stomata both.

***Antigonon* Endl.:**

Only one species, *A. leptopus* has been worked out. The five collateral bundles supplying the sheathing base are differentiated into an abaxial median (AbM) and two pairs of laterals (L_1, L_2). The laterals diverge during their upward course. Each L_1 bundle now splits and fuses with the L_2 on either side. The AbM gives out two laterals bundles, one on either side, which remain distinct throughout their upward course. The fusion products of L_1 and L_2 then re-organise into a crescent of fourteen normally oriented collateral bundles on the abaxial side and two inversely oriented adaxial median bundles. The sheathing base gradually narrows into the petiole.

***Rumex* Linn.**

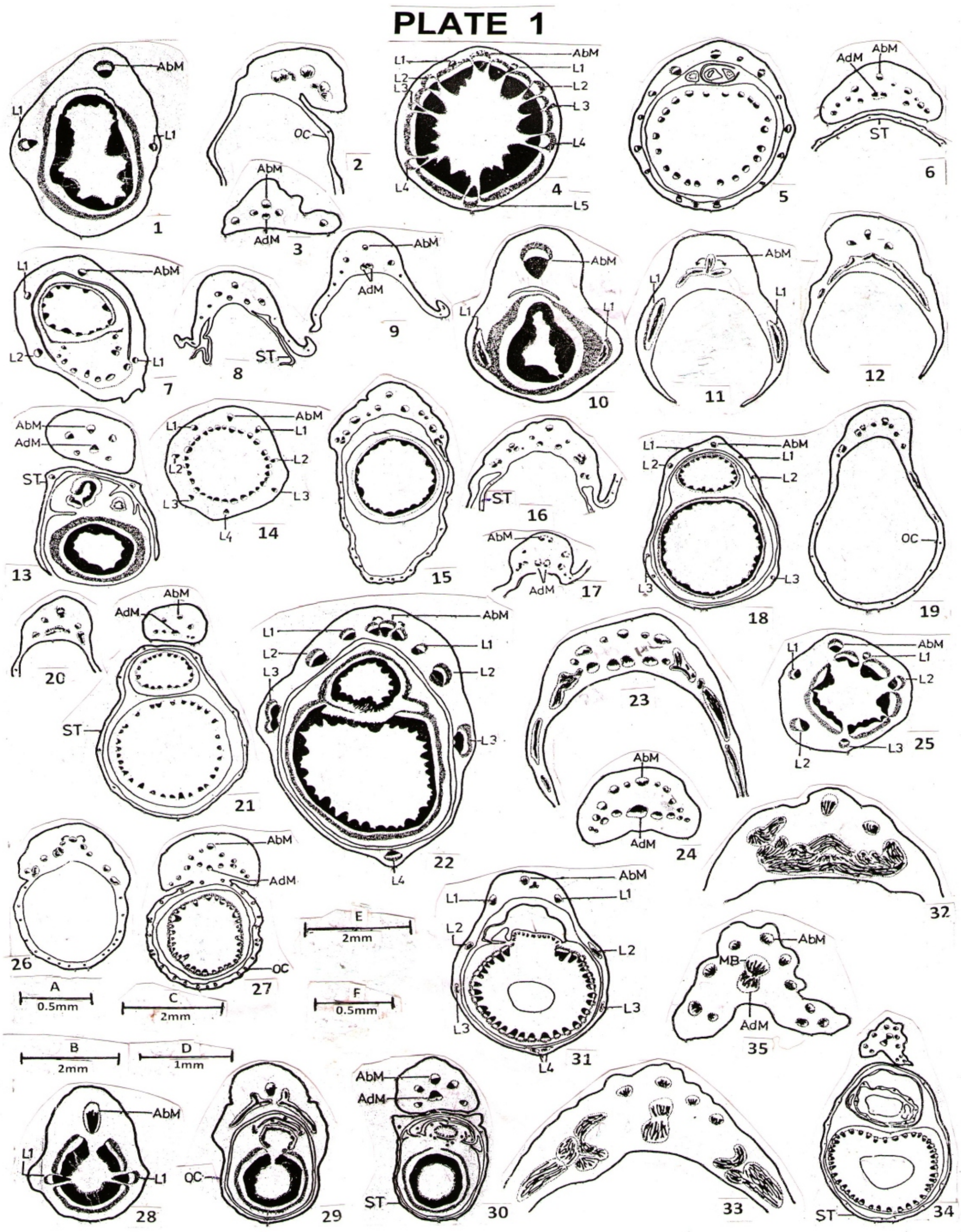
Six species of *Rumex* namely *R. arifolius, R. nepalensis, R. sculatus, R. hastatus, R. dentatus* and *R. acetosa* have been worked out. The ochrea receives three (*R. arifolius*), five (*R. nepalensis*, *R*. sculatus, *R. hastatus*), eleven (*R. dentatus*) or twelve (*R. acetosa*) collateral vascular bundles. Of these, the central vascular bundle is identified as abaxial median (AbM) placed in between paired lateral (L_1 or L_1L_2 or $L_1L_2L_3L_4L_5$). The unpaired lateral of *R. acetosa* lies opposite to AbM. Higher up, branches diverge from the laterals on either side. These branches fuse with AbM or its branches to form a vascular complex that differentiates into a crescent and adaxial median bundle (AdM) which is inversely oriented lying opposite to AbM. In *R. scutatus*, however, two inversely oriented bundles are separated which fuse to form the adaxial median bundle. Sometimes, the complex reorganises into a peripheral crescent and a complex that differentiates into three collateral medullary bundles and two inversely oriented adaxial bundles which fuse to form AdM bundle in *R. dentatus.* The crescent comprises three normally oriented collateral bundles in *R. arifolius,* seven in *R. nepalensis, R. scutatus, R. hastatus* and *R. acetosa* and eleven in *R. dentatus*. The ochrea then separates into petiole and stipule. The stipule is vascularised in all species studied except *R. arifolius* and *R. dentatus.* While it is supplied by only two lateral bundles in *R. nepalensis* but by many bundles in *R. hastatus* which soon disappear. In *R. acetosa* it receives vasculature from L_4 and L_5. In all the species studied the stipules lack stomata as well as glands.

DISCUSSION

In order to understand the morphology of ochrea it is necessary to have a critical evaluation of a leaf in general and leaf base in particular. According to American School of thought (Asa Gray, 1879; Swingle, 1934; Sinnott, 1935; Hill and Popp, 1936; Lawrence, 1951 etc.) a leaf is distinguishable into lamina, petiole and a part of stipules or appendages at the base of the petiole i.e., a complete leaf is without a base. On the other hand, the European School (Bower, 1884; Vines, 1910; Strasburger, 1930; Lawson and Sahni, 1947; Willis 1931 etc.) considers a leaf being made up of lamina, petiole and the leaf base.

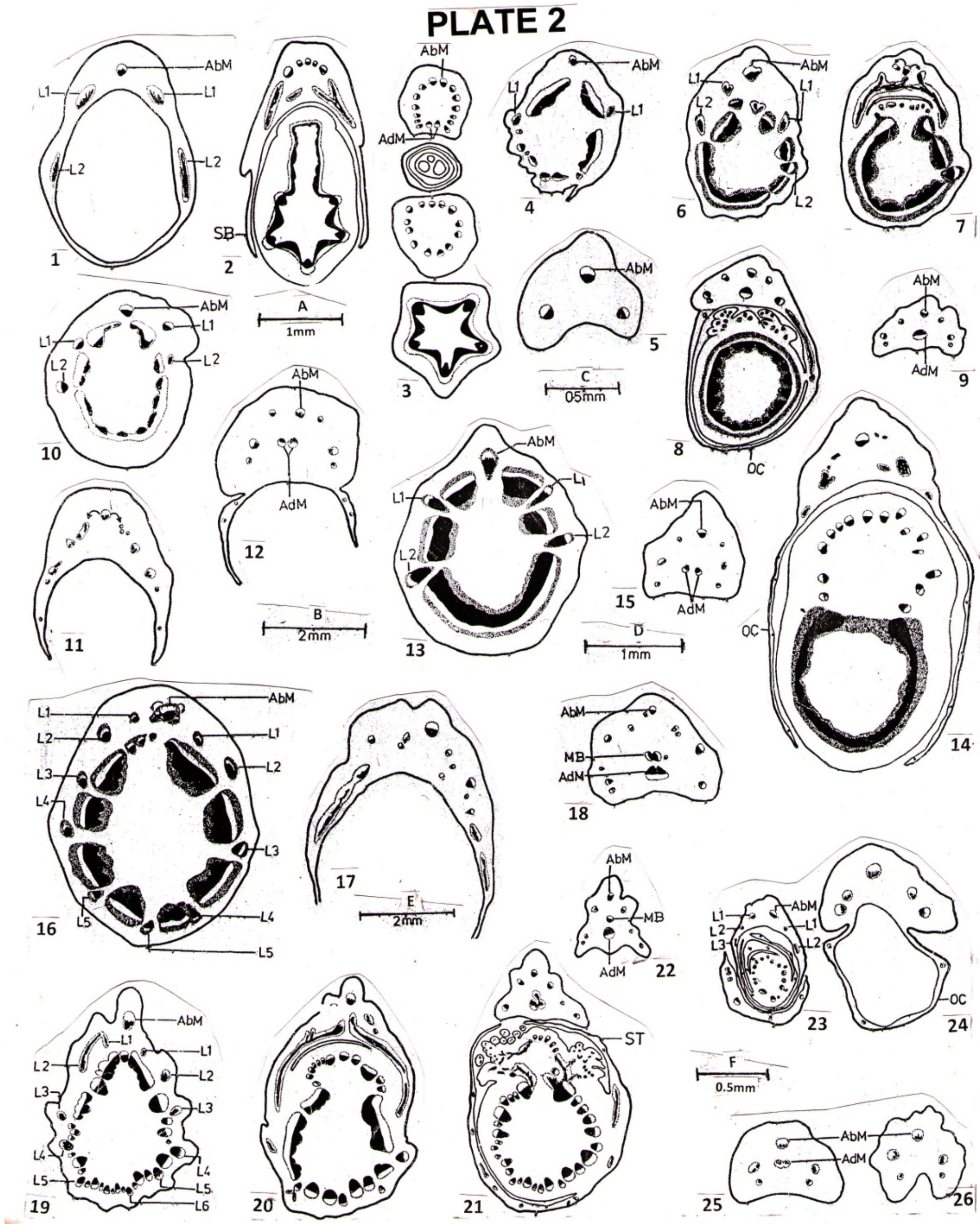
Gregoire (1935) and Louis (1935) distinguished "Soubassement foliare" which is formed prior to free limbs of the leaf. Foster (1935) termed it as "Foliar buttress" whereas Sharman (1942), Majumdar (1949, 55), Mitra and Majumdar (1952) as "Foliar Foundation". They consider it as the real base of the leaf. When the foliar foundation is wholly included in the axis, Majumdar (1955) named it as "Axial Component" or when a part free from the axis, then he describes it as "Sheathing Component". According to Mitra and Majumdar (1952) the base of dicot leaves comprises two regions – an adaxial component (the portion of the leaf base that grows with the axis during internodal development) and the free base (the portion of the leaf or leaf blade of a sessile leaf). It is from this free base that the stipules develop.

Asa Gray (1879) defines stipule as an appendage at the junction of a leaf, one on each side of the insertion. Dormer (1944), Willis (1931), McLean and Cook (1951) and Mitra and Majumdar (1952) consider stipules as outgrowth of the leaf base. The organization and development of different types of stipules has been investigated by Cross (1937), Engard



Figures. 1-2, 4-23, 25-34. Transections of node showing departure of vasculature to ochrea and petiole, Figures. 1-2. *Polygonum aviculare,* Figures. 4-6. *P. serrulatum,* Figures. 7-9. *P. alatum,* Figures. 10-13, *P. pterocarpum,* Figures. 14-17. *Persicaria bistorta,* Figures. 18-21. *P. maculata,* Figures. 22-23. *P. polystachya,* Figures. 25-27. *P. amplexicaulis,* Figures. 28-30. *Bilderdykia baldschuanica,* Figures. 31-34. *Fagopyrum cymosum,* Figures. 3, 24, 35. T.S. of petioles. Figures. 3 *Polygonum aviculare,* Figures. 24. *Persicaria polystachya*, Figures. 35. *Fagopyrum cymosum.*

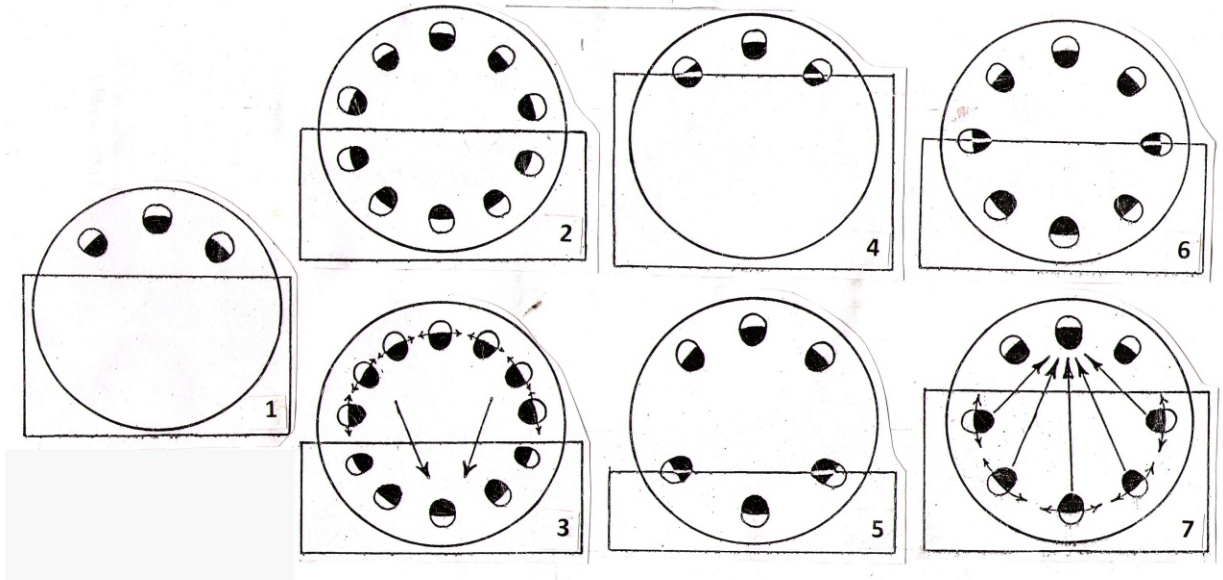
SCALES: A. for Figures. 1-3; B. for Figures. 4-6, 14-21, C. for Figures. 7-9, 22-27, D. for Figures. 10-13, E. for Figures. 28-30. F. for Figures. 31-35.



Figures. 1-4, 6-8, 10-14, 16-17, 19-20, 23-24. Transections of node showing departure of vasculature to ochrea and petiole. Figures. 1-3, *Antigonon leptopus,* Figures. 4. *Rumex arifolius,* Figures. 6-8. *R. nepalensis,* Figures. 10-12. *R. scutatus,* Figures. 13-14. *R. hastatus,* Figures. 16-17. *R. dentatus,* Figures. 19-21. *R. acetosa,* Figures. 23-24. *Oxyria elatior,* Figures. 5, 9, 15, 18, 22, 25, 26. T.S. petiole. Figures. 5. *Rumex arifolius,* Figures. 9. *R. nepalensis,* Figures. 15. *R. hastatus,* Figures. 18. *R. dentatus,* Figures. 22. *R. acetosa,* Figures. 25-26. *Oxyria elatior.*

SCALES: A. for Figures. 1-3; B. for Figures. 4, 6-12; C. for Figures. 5, D. for Figures. 13-15, E. for Figures. 16-22, F. for Figures. 23-26. AbM-Abaxial median bundle; AdM-Adaxial median bundle; L_1, L_2, L_3, L_4, L_5 – Lateral bundles; MB-Medullary bundle OC-Ochrea; SB–Sheathing base; ST-Stipule.

PLATE 3



Figures. 1-7. Diagrammatic representation of various patterns of vascular supply to stipule in different taxa of Polygonaceae. 1. *Polygonum alatum, Rumex arifolius, R. dentatus*. 2. *Polygonum serrulatum.* 3. *Rumex acetosa.* 4. *Polygonum aviculare, P. pterocarpum, Persicaria maculata, Bilderdykia baldschuanica, Rumex nepalensis, R. scutatus, R. hastatus.* 5. *Persicaria polystachya, P. amplexicaulis, Oxyria elatior.* 6. *Persicaria bistorta.* 7. *Fagopyrum cymosum.*

(1944), Mitra (1945, 48, 49a, b, 50a, b, c), Majumdar and Mitra (1948), Mitra and Majumdar (1952), Sensarma (1957), Majumdar and Pal (1958a, b), Gupta (1963) etc.

Mitra (1949a) describes the development and morphology of the so-called adnate stipules in *Rosa* and *Rubus*. They derive their vascular supply from the lateral bundles. On the basis of anatomy he regards the sub-petiolar region of the adult leaf of *Rosa* as the sheathing base. According to him these stipules should not be described as adnate. Mitra (1948, 50b) also describes the vascular anatomy of interpetiolar and intrapetiolar stipules. He interprets that the two stipules of the same leaf have fused to form "the intrapetiolar stipules" thus rejecting Goebel's (1932) interpretation of "axillary stipule". In the case of interpetiolar stipules the laterals of different leaves furnish stipular traces. The anatomy thus, disproves the interpretation of Sinnott and Bailey (1914) that these stipules develop as independent structures and their fusion is ontogenetic. The composite nature of inter-and intrapetiolar stipules has been supported by Gupta (1963) on anatomical grounds.

The family Polygonaceae is characterised by the presence of an ochrea. The structure of ochrea in *Rumex, Rheum, Polygonum* and *Fagopyrum* has been earlier described by Grevillus (1888) and Schultz (1888). It has been interpreted as a pair of stipules (Asa Gray, 1879) or as axillary stipules (Goebel, 1905) or as a row of stipules fused together (Sinnott and Bailey 1914) or as combinded pairs of opposite stipules (Jackson 1916). Mitra (1945) while studying the ochrea of *Polygonum orientale*, distinguishes it into a sheathing base and a terminal free portion which is axillary to the petiole. He interprets this upper free portion of ochrea as a stipule. This is further supported by Mitra and Majumdar (1952). Willis (1931), on the other hand, regards it as a sheathing stipule.

While Colomb (1886) considers the sheathing stipules of *Ficus* and Marigold as transitional stages between ochrea and stipule proper, Tyler (1897) regards them as axillary ligule. Lubbock (1899) calls the entire tubular sheath of *Polygonum lapathifolium* as ochrea. Parkin (1948), on the other hand, is of the opinion that the "free lateral cauline stipule may fuse with the edges to embrace the stem" and this structure he called ochrea.

Mitra and Majumdar (1952) on the basis of anatomy do not support the contention of Sinnott and Bailey (1914). They consider that in ochrea only the upper portion supplied by the branches of the laterals is to be regarded as the stipule and the lower portion in which the laterals run separate, following almost a parallel course, as the sheath (leaf base). According to McLean and Cook (1951) the ochrea is a membranous sheath arising from the leaf base and surrounding the axillary bud and the stem for a short distance above the node. They further interpret it as being derived from the axillary fusion of two stipules but developing as a single sheath organ. They regarded it as a tubular upgrowth of the leaf base and not of stipular nature.

During the course of present study the term ochrea is applied to the tubular or almost tubular portion which separates into a petiole and the upper membranous free portion encircling the internode. With the exception of *Antigonon leptopus* all the species investigated possess the characteristic ochrea. In *Antigonon leptopus* the five leaf traces supply the sheathing leaf base encircling the internode. The sheathing leaf base gradually recedes and all the five bundles form the petiolar vasculature. A similar type of petiolar formation has been reported by Mitra and Majumdar (1952) in *Centella* where they consider the expanded basal portion as a sheath devoid of any stipule. If the interpretation of leaf base and ochrea given by them is correct then the leaf of *Antigonon leptopus* is exstipulate.

While in most of the species the ochrea separates as a complete ring, in *Rumex scutatus* it separates as an incomplete ring. Sinnott and Bailey (1914) have reported sheathing leaf base in this family and tried to bring about correlatioin between multilacunar node and the presence of sheathing leaf base. They interpret the sheathing leaf base as well as the ochrea as the fusion product of a row of adjacent stipules, corresponding with the number of leaf traces. In *Rumex,* however, they have found the trilacunar node associated with two distinct stipules but there is no ochrea. The present investigation support Sinnott and Bailey's (1914) correlation that a multilacunar node is always associated with a sheathing leaf base which completely encircles the node. However, there are some exceptions, for instance in *Polygonum pterocarpum* and *Rumex arifolius* the node is pentalacunar, the sheathing leaf base does not encircle the internode completely.

Usually the upper free tubular portion of ochrea is supplied by a varying number of bundles but in *Polygonum alatum, Rumex arifolius* and *R. dentatus* it is non-vascular and a very thin structure which disappears after separation. In *Polygonum alatum* the node is tetralacunar, 4-trace, in *Rumex arifolius* it is trilacunar, 3-trace and in *R. dentatus* ten lacunar, 11-trace. In these taxa the medians divide and the laterals follow an upward course and enter the petiole leaving no vasculature for the upper free portion of the ochrea. In other species the node may be trilacunar, 3-trace (*Polygonum aviculare, P. pterocarpum* and *Bilderdykia baldschuanica*), four lacunar, 5-trace (*Rumex nepalensis*), five lacunar, 5-trace (*R. scutatus* and *R. hastatus*), five lacunar, 6-trace (*Oxyria elatior*), six lacunar, 6-trace (*Persicaria amplexicaulis*), eight lacunar, 8-trace (*Persicaria bistorta, P. polystachya* and *Fagopyrum cymosum*), ten lacunar, 10-trace (*Polygonum serrulatum*) or twelve lacunar, 12-trace (*Rumex acetosa*).

The vascular supply for the upper tubular portion arises from the bundles of ochrea in the following manners (Plate-3; Figs. 1-7).

(A) All bundles of ochrea entering the petiole leaving no vasculature for the upper tubular part e.g., *Polygonum alatum, Rumex arifolius* and *R. dentatus* (Fig. 3/1).

(B) Ohrea vasculature furnishing as many independent bundies for petiole and upper tubular part e.g., *Polygonum serrulatum* (Fig. 3/2)

(C) Ochrea furnishing independent and conjoint bundles to petiole and upper tubular part, however, independent bundles for upper part are missing in some case.

i) Upper tubular part receiving fewer numbers of bundles than the petiole and a few branches from upper laterals e.g. *Rumex acetosa* (Fig. 3/3).

ii) Lower branches of lower most pair of lateral leaf traces supplying the upper tubular part of ochrea whereas the upper branches supplying the petiole e.g., *Polygonum aviculare, P. pterocarpum, Persicaria maculata, Bilderdykia baldschuanica, Rumex nepalensis, R. scutatus* and *R. hastatus* (Fig. 3/4).

iii) Lower unpaired lateral and lower branches of lowermost pair of laterals supplying the upper tubular part of ochrea whereas the upper branches of the paired lateral supplying the petiole e.g., *Persicaria polystachya* and *Oxyria elatior*. In *Persicaria amplexicaulis* two additional traces from the petiolar vasculature also furnishes the supply to the upper part (Fig. 3/5).

iv) Median pair of laterals conjointly furnishing branches to upper tubular part of ochrea as well as petiole e.g., *Persicaria bistorta* (Fig. 3/6).

v) Petiole supplied by a few independent bundles and branches from all the remaining bundles which also supply the upper tubular part of ochrea e.g., *Fagopyrum cymosum* (Fig. 3/7).

On the basis of present study it is concluded that the ochrea consists of two distinct parts. The lower portion is interpreted as the sheathing base, whereas the upper tubular part which is an outgrowth from the sheathing base is regarded as stipule. The present observations, therefore, render support to the views of Mitra (1945) and Mitra and Majumdar (1952).

An adnate or interpetiolar or intrapetiolar stipule may receive one or more vascular bundles (Mitra 1948, 49a, 50b; Gupta 1963). In the interpretation of a stipule these workers have stressed upon the number of sources from where the stipular vasculature is derived as more significant than the number of traces received by an individual appendage. According to Mitra (1950b) the behaviour of the laterals during their course through the base towards the petiole determines the extent as also the nature of leaf base. The present investigation, however, provides no evidence to show that the ochrea consists of two opposite stipules or it is a fusion product of a rwo of adjacent stipules as thought by earlier workers.

The stipular part of ochrea usually receives many bundles, sometimes four or three or two and rarely none. There seems to be some correlation between the nodal vasculature and the number of vascular bundles received by the stipular part of the ochrea. Nodes with a few leaf traces have generally a few bundles or no vascular supply in the stipular part. Stipular portion of ochrea is non-vascular in *Rumex dentatus, R. arifolius* and *Polygonum alatum.* Non-vascular stipular appendages have also been reported by earlier workers in some cases such as *Dentella repens* (Majumdar and Pal, 1958) and *Mitchella repens* (Gupta, 1963).

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