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Stem-Node-Leaf Continuum in *Indigofera linnaei* Ali

***RN Khorwal[1] and KC Sharma[2]**
[1]*G.D. Govt. College for Women, Alwar, Rajasthan 301002, India*
[2]*Department of Botany, University of Rajasthan, Jaipur 302055, India*
****Author for Correspondence:*** E-mail: khorwalrn@ymail.com

ABSTRACT
Vasculature was traced through internode, node, petiole and rachis in *Indigofera linnaei* Ali. A ring of conjoint, collateral and open bundles constituted the internodal vasculature. A trilacunar three-trace condition was observed at the nodal level. The subopposite stipules were vascularised by the lateral traces. The ridges bundles were organised successively after the first and second leaflets received their supply alternately. Remaining leaflets also received their vasculature alternately and the rachis terminated into a vacularised leaflet.

Key Words: Stem-node-leaf continuum, petiolar anatomy, imperipinnate, stipulate, leaf trace.

INTRODUCTION
Howard (1974), Sharma and Pillai (1982), Larson (1984), Sharma and Pillai (1985), Dubey *et al*., (1990) and others have emphasised the importance of study of vasculature through internode, node and leaf. Howard (1974) categorised the petiole types on the basis of vasculature which could be of use in systematic descriptions. Stem-node leaf continuum in paripinnate leaves have been studied in our laboratory which indicated significant clues towards petiolar vasculature (Sharma and Pillai, 1982, 1985; Pillai and Sharma, 1984; Dubey *et al*., 1990). Data on these aspects in *Indigofera linnaei* Ali with imparipinnate, stipulate leaves are presented here.

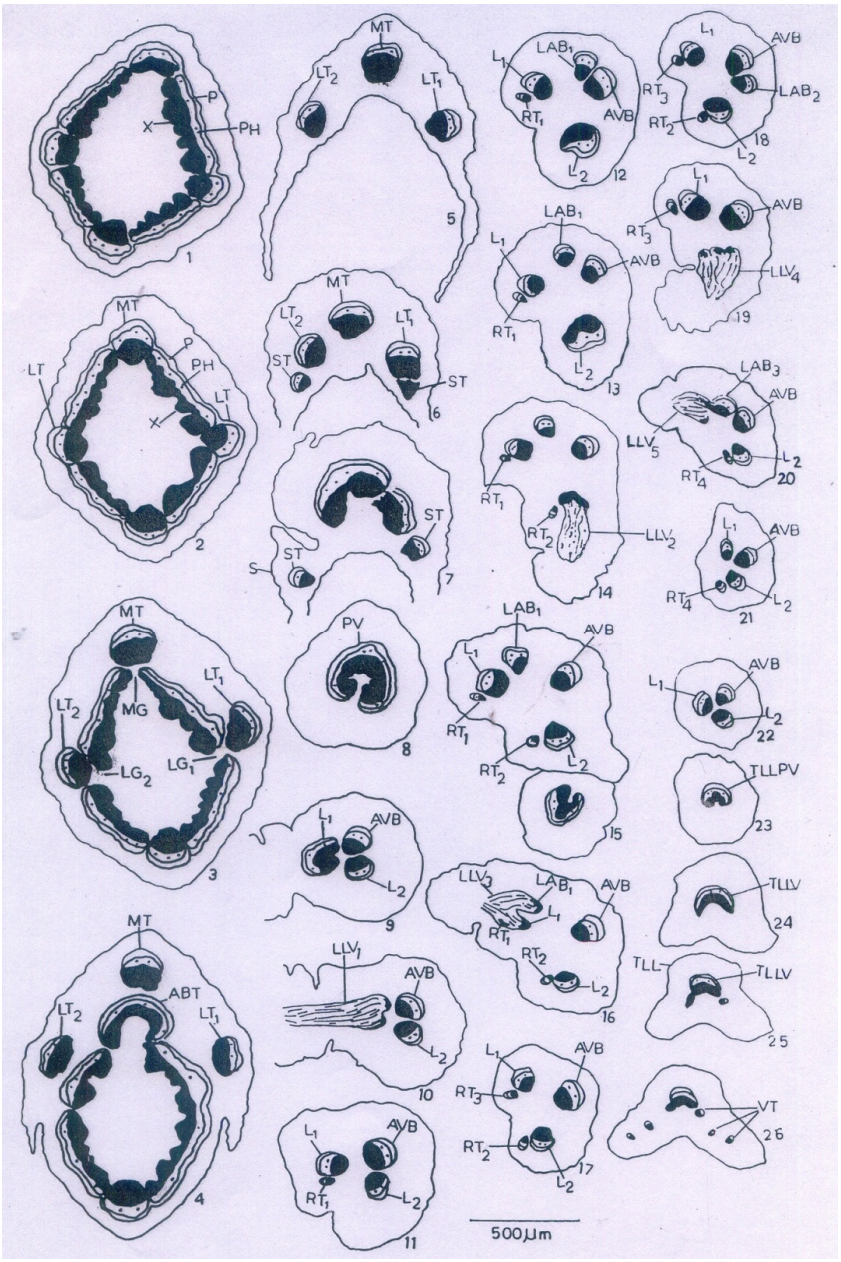
MATERIALS AND METHODS
The first five nodes involving the internodes and leaves were collected from well established plants of *Indigofera linnaei* Ali grown in Govt. Bangur college campus at Didwana. The materials were fixed in FAA, processed through TBA series and embedded in paraffin wax. Serial transverse sections cut at 6-8 µm were stained with safranin and light green combination. The course of vasculature was followed through the internode, node and petiole and the measurements are given in relation with the point where the three traces to the leaf have fused at the base of petiole.

RESULTS
Indigofera linnaei Ali is a small prostrate and profusely branched perennial herb. Both ramal and cauline branches bear alternate, stipulate, imperipinnate leaves (Fig. 27). Each leaf bears 5-7 alternately arranged leaflets and the rachis terminates into a leaflet. The description here is given for a leaf bearing five leaflets.

The internode is roughly circular to ovate and shows a thick layer of cuticle outside the epidermis. Bicelled thick walled hairs are distributed all over the epidermis. Sunken stomata with parallel sided subsidiary cells are also present. Outer cortex is made of 3-4 layers of collenchyma followed by 3-4 layers of parenchymatous inner cortex, the innermost layer of which is made up of dome shaped cells which constitutes the endodermis. 3-4 layers of penta-or hexagonal thick walled cells without intercellular spaces are present out side the vascular bundles representing the pericycle. About 20-22 conjoint, collateral and open vascular bundles forming the internodal vasculature surround the pith which has large, ovate and thin walled parenchymatous cells. The medullary cells have large intercellular spaces and occasionally contain rod shaped raphides.

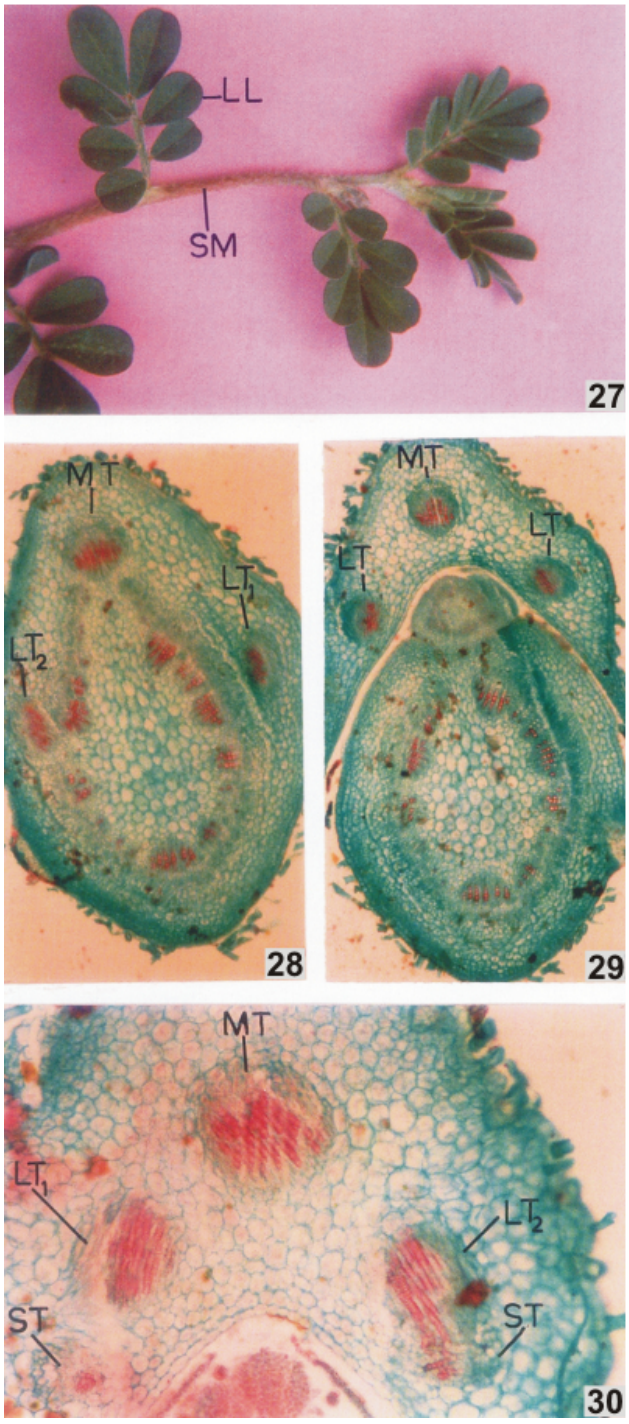
The node is trilacunar three-trace type (Figs. 3, 28, 29). The axis bundles which are destined to become the three traces to a leaf are comparatively larger (Fig. 1). The first lateral departs first followed by the second lateral and the median in that order (Figs. 2-4, 28). The two laterals traverse through the cortex and approach the median and the three traces fuse to form an arcuate vascular group at the base of the petiole (Figs. 4-8, 31). Prior to this, small branches, from the laterals separate out to supply the two stipules on either sides (Figs. 6, 7, 30).

The arcuate petiolar vasculature (Fig. 8) splits at slightly higher levels into three bundles (AVB, L_1 and L_2) at about 0.08 mm from base of the petiole (Fig. 9). The L_1 bundle supplies vascular branches to the first leaflet at about 0.135 mm level (Fig. 10). Meanwhile a ridge bundle (RT_1) also separates out from the L_1. The rachis vasculature at this stage is represented by four bundles (Figs. 11, 32). A small bundle (LAB_1) separateds from the AVB on L_1 side at about 0.30 mm level and comes closer to it (Figs. 13, 14). At this stage the L_2 supplies supplies the second leaflet (at about 0.39 mm) (Fig. 14) and forms a small ridge bundle (RT_2) (at about 0.41 mm) on the other side. This results in formation of six bundles (AVB, LAB, L_1, L_2, RT_1 and RT_2) in the stele of the rachis.

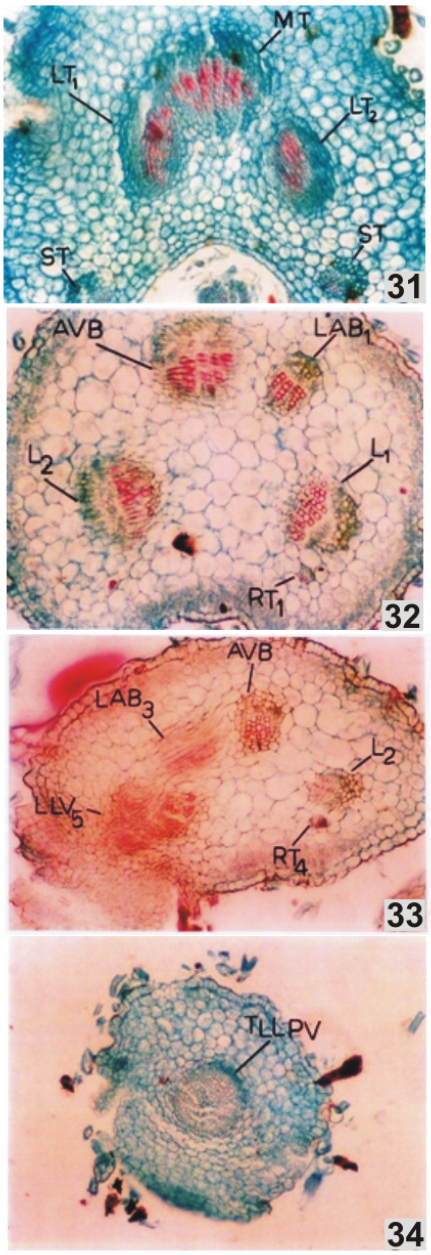


Figs. 1-26: Camera Lucida diagrams of transverse sections of *Indigofera* at stem, node and leaf regions. (1-2) Showing transverse sections of internode vasculature. (3-4) departure of leaf traces at nodal region. (6, 5) showing three traces at the base of petiole. (6) Stipular traces separating from the laterals. (7) Fusion of the first lateral trace with the median trace. (8) Petiole vasculature in semi-lunar form. (9) Petiole vasculature splitted into separate bundles. (10) Supply to the first leaflet. (11) Four vascular bundles after first leaflet supply. (12-13) Splitting of the abaxial vascular bundle and formation of lateral abaxial bundles. (13-15) Supply to the second leaflet. (16) Supply to the third leaflet. (17-18) Formation of RT_2 and LAB_2, AVB are fused to from an arcuate bundle. (25-26) Supply to the leaflet lamina.

(***Abbrv.*** ABT = Axillary bud trace; AVB = Abaxial vascular bundle; L_1 & L_2 = First & Second Lateral vascular bundle; LAB_1, LAB_2 & LAB_3 = First, Second & Third Lateral adaxial bundles; LG_1 & LG_2 = First & Second Lateral gaps; LLV_1, LLV_2, LLV_3, LLV_4 = First, Second, Third, Fourth & Fifth Leaflet vasculature supply, LT_1 & LT_2 = First & Second leaf traces; MG = Median gap; MT = Median traces; P = Pericycle, PH = Phloem; PV = Petiolar Vasculature; RT_1, RT_2, RT_3 & RT_4 = First, Second, Third & Fourth Ridges traces; ST = Stipular trace; TLLPV = Terminal leaflet petiolule Vasculature; VT = Vein trace).



Figs. 27-30: ***Indigofera*** **and its nodal vasculature.** (27) A twig. (28) Departure of the three traces. (29-30) The three traces at the base of petiole. Stipular traces are separating from the laterals traces. (***Abbrv.*** LL = Leaflets ; LT = Leaf traces, LT_1 & LT_2 = First & Second Leaf trace; MT = Medium leaf trace ; SM = Stem ; ST = Stipular trace.)



Figs. 31-34: **Petiole and Rachis vasculature in** ***Indigofera.*** (31) The three traces approaching each other. (32) Rachis vasculature after supplying the first leaflet. (33) The rachis vasculature supplying the fifth leaflet. (34) The vasculature to the terminating leaflet.

(***Abbrv.*** AVB = Abaxial vascular bundle; L_1 & L_2 = First & Second Lateral vascular bundle ; LAB1 & LAB3 = First & Third Lateral abaxial bundles ; LLV_5 = Fifth Leaflet vascular supply ; LT_1 & LT_2 = First & Second leaf traces ; MT = Median leaf trace ; RT_1 & RT_4 = First & Fourth Ridge trace ; ST = Stipular trace).

The LAB_1, L_1 and RT_1 bundles get fused at about 0.45 mm and supply the third leaflet and the remaining vasculature is organised into L_1 and RT_3 bundles (Fig. 17). At about 0.72 mm level a small bundle LAB_2 separates towards the L_2 bundle (Fig. 18). Branches from LAB_2, L_2 and RT_2 supply the fourth leaflet at about 0.78 mm (Fig. 19).

A lateral branch (LAB_3) coming from AVB and the L_1 and RT_3 bundles supply the fifth leaflet at about 0.84 mm (Figs. 20, 23). The complete RT_3 bundle enters into the fifth leaflet. So, after supplying the fifth leaflet the rachis vasculature at about 0.89 mm shows AVB, L_1, L_2 and RT_4 bundles (Fig. 21).

At slightly higher level the RT_4 moves towards the L_2 bundle and get fused with it (Fig. 22). At further higher levels (1.00 mm) the AVB, L_1 and L_2 bundles fuse and form an acrcuate bundle (Figs. 23, 24). These bundles enter into the petiolule of the rachis terminating leaflet and sends traces to the veins (Figs. 25, 26, 34).

DISCUSSION

Jeffrey (1917) described the primary vascular tissues of stems of seed plants as uniform morphological patterns which are of little use in systematic correlations. But several other celebrated Botanists have used the vascular patterns in different taxonomic consideration. Dormer (1945) studying the primary vascular systems divided the vasculature into two types such as "closed" or "open". The axis vasculature in *Indigofera* shows almost definite number of vascular bundles. The bundles becoming leaf traces are larger and depart one by one, fuse at base of petiole and redivide in the rachis. The data supports Philipson and Balfour (1963) and Benzing's (1967) suggestion that the primary vascular tissues or bundles either at maturity or during development offer the possibility of considerable pattern diversity and hence could be a source of data useful in systematics.

The three traces to a leaf arise from three gaps in the axis vasculature and the node is three-trace trilacunar type. This type of nodal anatomy seems to be common in legumes (Elias, 1972; Sharma and Pillai, 1982, 1985; Pillai and Sharma, 1984; Dubey *et al.*, 1990; Pathak, 2001; Negi, 2002). Majority of these studies document the trilacunar three-type to be primitive.

The terminal leaflet is vascularised as also the spinule at the apex of rachis in paripinnate leaves (Sharma and Pillai, 1985). This lends support to the Howard's (1974) contention that the vascularised spinules may indicate derivation from an original imparipinnate condition of a leaf.

The leaflets of a leaf are supplied alternately by the rachis vasculature. The ridges bundles are left out from the vascular sector supplying the leaflet. This is in contrast to the paripinnate leaves where ridges bundles are separated before supplying the leaflets and is taxonomically significant. Dormer (1945) described that in a closed system essentially a reticulum or network of bundles branch or anastomose depending on the direction to or from the leaves and in an open system the bundles branch (traces), but only exceptionally rejoin. In *Indigofera* the traces anastomose at the base of petiole and redivide to form a ring of bundles in the rachis. Howard (1963) categorised the petiolar structure into different types depending upon the number of leaf traces, their role in the formation of petiolar stele and the type of petiolar stele which could be helpful in systematic discussions and the present report support this.

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