Indian Journal of Plant Sciences ISSN: 2319–3824
An Open Access, Online International Journal Available at http://www.cibtech.org/jps.htm
2020 Vol. 9, pp.80-90/Sahney and Tripathi
Research Article

STEM AND ROOT ANATOMY OF *PORANA PANICULATA* ROXB. (CONVOLVULACEAE) WITH SPECIAL REFERENCE TO WOOD AND ITS ANATOMICAL AND ECOLOGICAL ADAPTATION

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ABSTRACT
This article describes the detailed anatomical study on the young stem and wood anatomy of *Porana paniculata.* Epidermis shows the presence of two types of hairs- unicellular with small stalk cells and a long terminal cell and multicellular hairs. Young stem has patches of intraxylary phloem present below the protoxylem. Presence of soft patches of axial parenchyma in between the lignified tissues may aid flexibility to the climbing axis. In root wood rays are mostly biseriate and occasionally uniseriate while in stem wood rays are mostly uniseriate and occasionally biseriate. Quantitatively, vessels are wider and higher density in stem wood as compared to those of root wood while fibers are longer and rays are wider in root wood. Vulnerability (v) and mesomorphy (m) values indicating the mesic condition of the plant.

Keywords: *Porana paniculata, Fibriform Vessels, Rays, Intraxylary Phloem, Wood Anatomy*

INTRODUCTION
Interesting anatomical features like presence of medullary bundles, inter and intraxylary phloem and formation of successive ring of cambia have been reported in various members of family Convolvulaceae (Solereder 1908; Metcalfe & Chalk, 1950; Pant & Bhatnagar, 1975; Carlquist & Hanson 1991; Rajput *et al.*, 2013, 2014). Although anatomy of stem and wood of various members of family Convolvulaceae have been documented by various workers. No detailed investigation exclusively on that of *Porana paniculata* Roxb. is available. Moreover, nothing is known about the root wood anatomy of *P. paniculata*.

P. paniculata is a perennial strong shrubby climber up to 6-9 meters in height with large dark green heart-shaped leaves and small fragrant flowers. It has been described as a creeper (Kumar *et al.*, 2014) and twining shrub (Tayade *et al.*, 2015).

It is well known that plants develop anatomical strategies and adaptations for the successful ascent of sap, depending on their form and environment. Climbing plants tend to develop anatomical characteristics that theoretically would allow higher conductivities (Haberlandt, 1909; Carlquist 1975, 1985; Zimmermann & Jeje 1981; Bamber, 1984; Ter Welle, 1985; Baas & Schweingruber, 1987).

Thus to understand the adaptation of climbing axis of *P. paniculata* an integrated anatomical study of young stem and root and stem wood is undertaken. This is the first integrated comprehensive report on the anatomy of *P. paniculata* exploring the correlation between the habit and ecology of the plant.

MATERIALS AND METHODS
Fresh materials of both stem and root were collected from Prayagraj, Lucknow and Mirjapur district of Uttar Pradesh. The stem and root woods were cut into small pieces and fixed in FAA (Berlyn and Miksche 1976). Transverse and longitudinal (both T.L.S and R.L.S) sections of 15-20 µm in thickness were cut, stained with safranin–fastgreen combination, and mounted in Canada balsam. Small pieces of stem and root woods were macerated using Jaffery's fluid (Johansen, 1940) and thirty random measurements of the macerated cells were taken, using an ocular micrometer scale, to obtain the mean measurements for each cell type. An Olympus binocular compound microscope (Model No.CH2i) and a Leica binocular compound microscope (Model: DM2500) were used for examining the anatomical

sections and for photography, respectively. F/V ratio is calculated by dividing mean libriform fibre length with mean vessel element length. Vulnerability (v) of wood was calculated by dividing mean vessel diameter with vessel frequency, while mesomorphy (m) was obtained by multiplying the vulnerability with mean vessel-element length, following Carlquist, (1977). The cell counts, measurements and anatomical description follow the rules of the IAWA Committee, 1989.

RESULTS

Young stem

Young stem of *Porana paniculata* is slightly wavy in outline as seen in a T.S. Epidermis is single layered, made up of compactly arranged radially elliptical cells and covered by thin layer of cuticle. Epidermal hairs of two types are present- unicellular with a small stalk cell and a long terminal cell (150-500µm) and multicellular hairs (130-350µm). Multicellular hairs have 2-5 stalk cells and a long terminal cell which may be single armed or two armed. Cortex is narrow, 3-4 cells wide, composed of compactly arranged parenchymatous cells. A layer of endodermis is present at the inner boundary of cortex distinguished by its large cells with starch grains. Pericycle is represented by isolated small groups of sclerenchymatous cells. Vascular bundles are arranged in a ring joined by interfacicular cambium. Vascular bundles collateral, conjoint and endarch and open. Patches of Intraxylary phloem are present below the protoxylem. As the stem matures intraxylary phloem derivatives increase in number and become prominently visible. Secretory cells appear above the vascular bundles. Pith is parenchymatous with a wavy outline due to presence of intraxylary phloem (Pl. 1A-E).

When secondary growth begins vessels of extremely smaller size are formed and later secondary xylem with large vessels is produced. Later formed vessels are large in diameter than those of primary xylem. A wavy ring of sclerenchymatous cells delimits the pith region. Calcium oxalate crystals in the form of druses are frequently found in the pith region (Pl. 1D-F).

A T.S of old stem shows large and small vessels embedded in irregular mass of lignified cells separated by thin walled patches of axial parenchyma and radially by broad medullary rays. In axial parenchyma islands of phloem (interxylary) are visible (Pl. 2G).

Stem wood

Vessels: occur mostly as solitary vessels; dimorphic; occasionally in group of two; individual vessel element oval to circular in cross section; 30-220µm in diameter; frequency of vessels-50-55/mm^2; Vessel elements showing variation in length (150-250µm), frequently tailed at one or both the ends with simple perforation plate. Fibriform vessels with sub-terminal perforation plate (diam. 8-10 µm) present. Intervascular pitting alternate; pits are oblong or elliptical in shape; mean size of intervascular pits 8 µm. Vessel wall thickness 2.5 µm. Tyloses present; starch grains are present in tyloses (Pls. 2G, I, K, L, N; 5A-F).

Vulnerability index (v)- 2.51, mesomorphy index (m)- 511.

Imperforated elements: libriform fibres septate as well as non-septate; extremely short to very short in length (300-491-680µm). Vasicentric tracheids present, 105-250µm in length (Pls. 2O, Q; 5G, H). F/V ratio- 2.41.

Parenchyma: axial parenchyma- scanty vasicentric paratracheal, as well as apotracheal axial parenchyma are present. Interxylary phloem is found present embedded in the axial parenchyma patches. Rays predominantly uniseriate; rarely biseriate; uniseriate rays are 2-10 cells in height; biseriate rays are 3-5 cells height, heterocellular with upright and square cells. Druses (10-17µm) present in parenchyma cell (Pl. 2 G, H, J, M, O, P).

Root wood

Vessels: occur mostly as solitary vessels; dimorphic; frequency of vessels- 40-45/mm^2; individual vessel element oval to circular in cross section; 50-150µm in diameter. Vessel elements showing variation in length (140-230µm), and frequently tailed at one or both the ends with simple perforation plate. Fibriform vessel elements (7-9 µm in diameter) present. Intervascular pitting alternate; pits oblong or elliptical in shape; mean size of intervascular pits 9.5µm. Vessel wall thickness 3.0 µm. Tyloses present in vessel

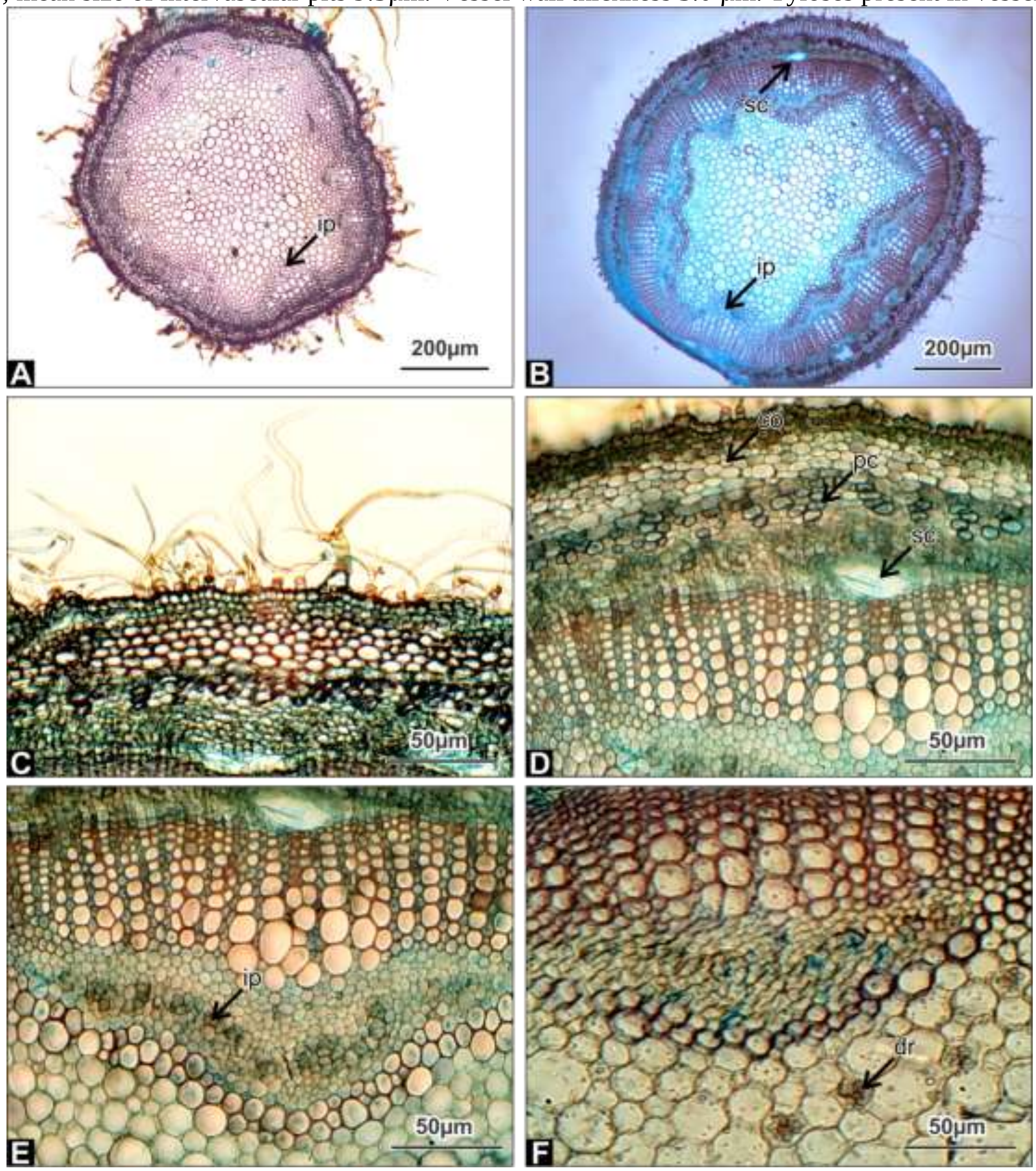

PLATE 1: Stem anatomy of *P. paniculata*
A. *T.S of the apical segment showing numerous vascular bundles with small isolated patches of intraxylary phloem*
B. *T.S showing vascular bundles, secretory cells and wavy ring of sclerenchymatous cells delimiting the pith*
C. *Magnified portion showing unicellular and multicellular hairs*
D. *Magnified portion showing cortex (parenchymatous), pericycle and secretory cell*
E. *Magnified portion showing intraxylary phloem*
F. *Magnified portion showing druses in pith region*
Abbreviations in Plate: *ip-intraxylary phloem, sc- secretory cell, co-cortex, pc- pericycle, dr- druses. Scale bars: A, B = 200 µm; C, D, E, F = 50 µm*

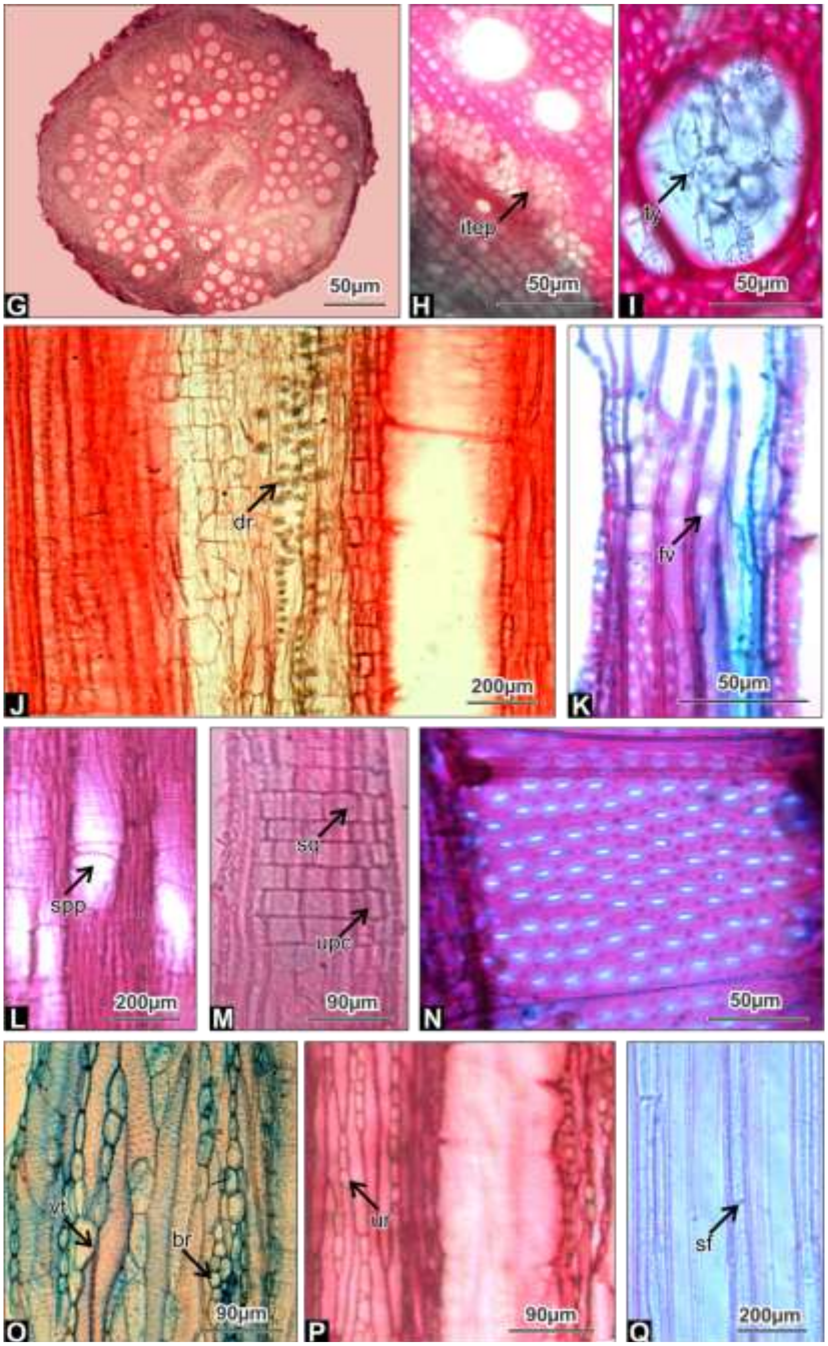

PLATE 2: Stem wood anatomy of *P. paniculata*

G. *T.S of the stem wood showing dimorphic vessels and axial parenchyma;* **H**. *Magnified portion showing interxylary phloem;* **I**. *T.S showing tyloses with starch grains;* **J**. *T.L.S showing druses in parenchyma cells;* **K**. *T.L.S showing fibriform vessel ;* **L**. *T.L.S showing simple perforation plate;* **M**. *R.L.S showing upright and square ray cells;* **N**. *T.L.S showing alternate intervascular pits;* **O**. *T.L.S showing biseriate rays and vasicentric tracheids;* **P**. *T.L.S showing uniseriate rays;* **Q**. *T.L.S showing libriform fibers and septate fibre*

Abbreviations in Plate: *itep- interxylary phloem, ty- tyloses, dr- druses, fv- fibriform vessel, spp- simple perforation plate, sq- square cell, upc- upright cell, vt- vasicentric tracheid, br- biseriate rays, ur- uniseriate rays, sf- septate fibre. Scale bars: G, H, I, K, N = 50 µm; J, L, Q = 200 µm; M, O, P = 90 µm.*

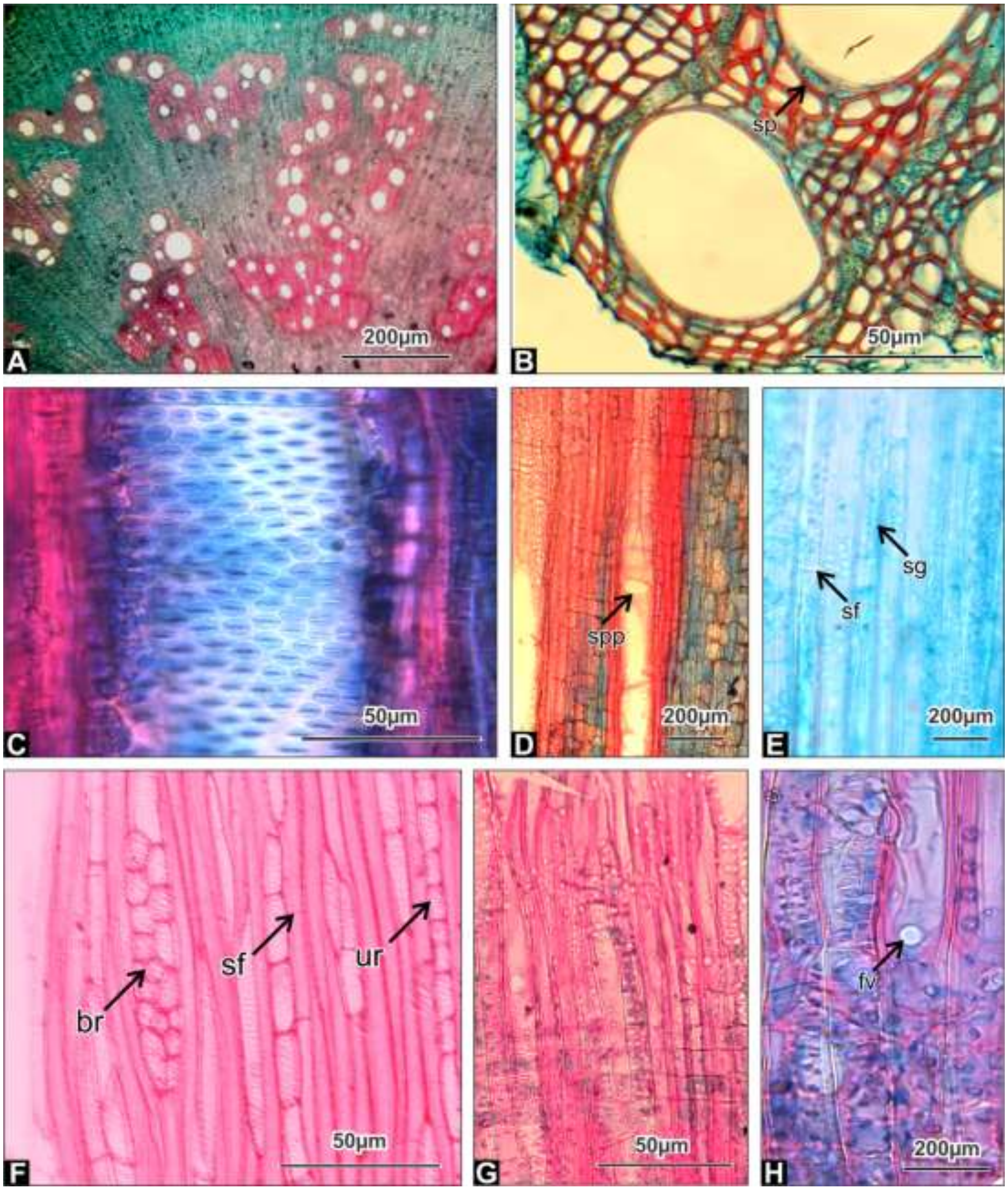

PLATE 3: Root wood anatomy of *P. paniculata*

A. T.S of the root wood showing dimorphic vessels and axial parenchyma
B. T.L.S showing scanty vasicentric paratracheal parenchyma
C. T.L.S showing alternate intervascular pits
D. T.L.S showing simple perforation plate
E. T.L.S showing septate fibers and starch grains
F. T.L.S showing uniseriate, biseriate rays and septate fibres
G. R.L.S showing fibriform vessels
H. Magnified portion showing fibriform vessel

***Abbreviations in Plate:** sp- scanty parenchyma, spp- simple perforation plate, sf- septate fibre, sg- starch grain, br- biseriate rays, ur- uniseriate rays, fv- fibriform vessel. Scale bars: A, D, E, H = 200 µm; B, C, F, G = 50 µm*

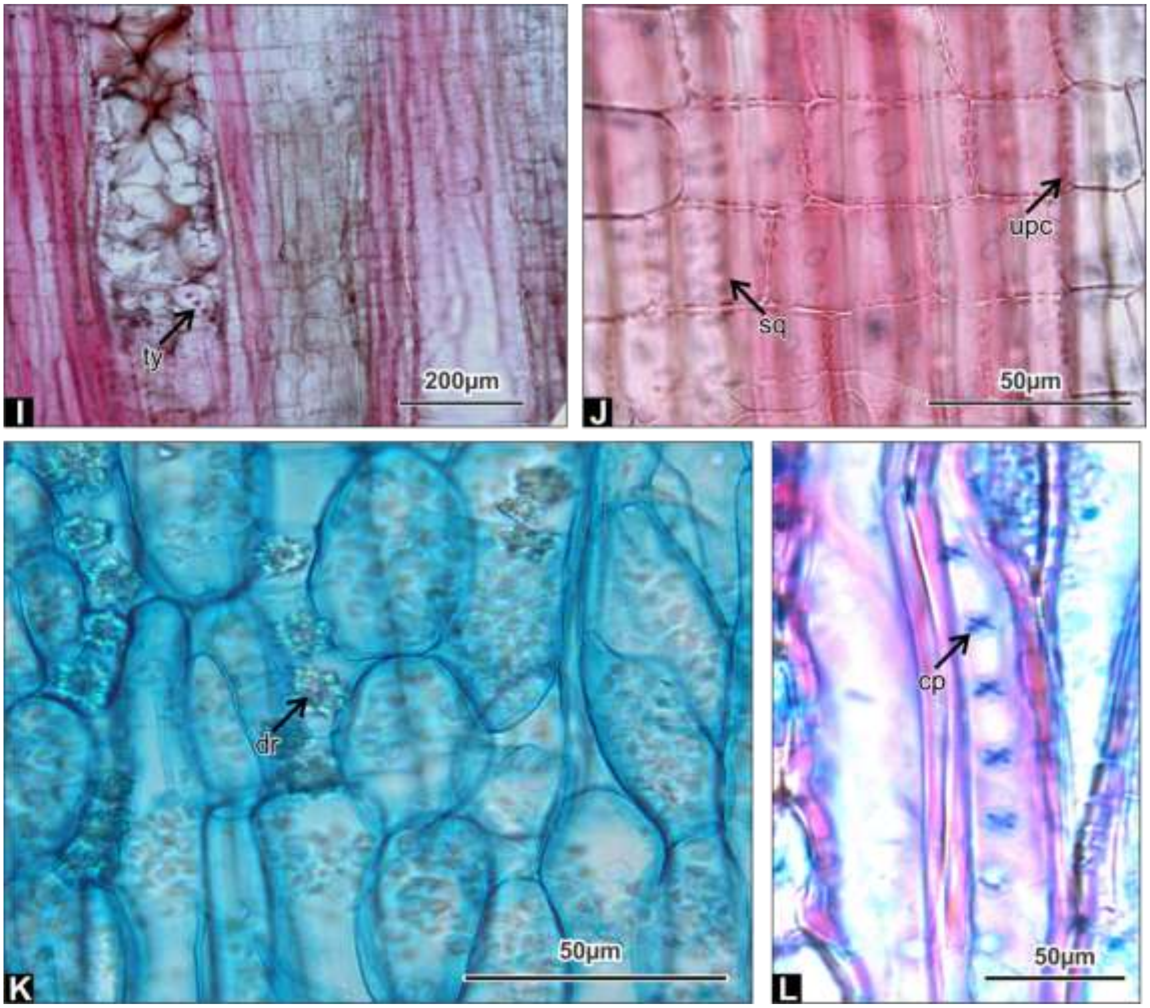

PLATE 4: Root wood anatomy of *P. paniculata*

I. T.L.S showing tyloses in vessel

J. R.L.S showing upright and square ray cells

K. T.L.S showing druses in axial parenchyma cells

L. T.L.S showing crossed pit-pore

Abbreviations in Plate: *ty- tyloses, sq-square cell, upc- upright cell, dr- druses, cp- cross-pit pore. Scale bars: I = 200 µm; J, K, L = 50 µm*

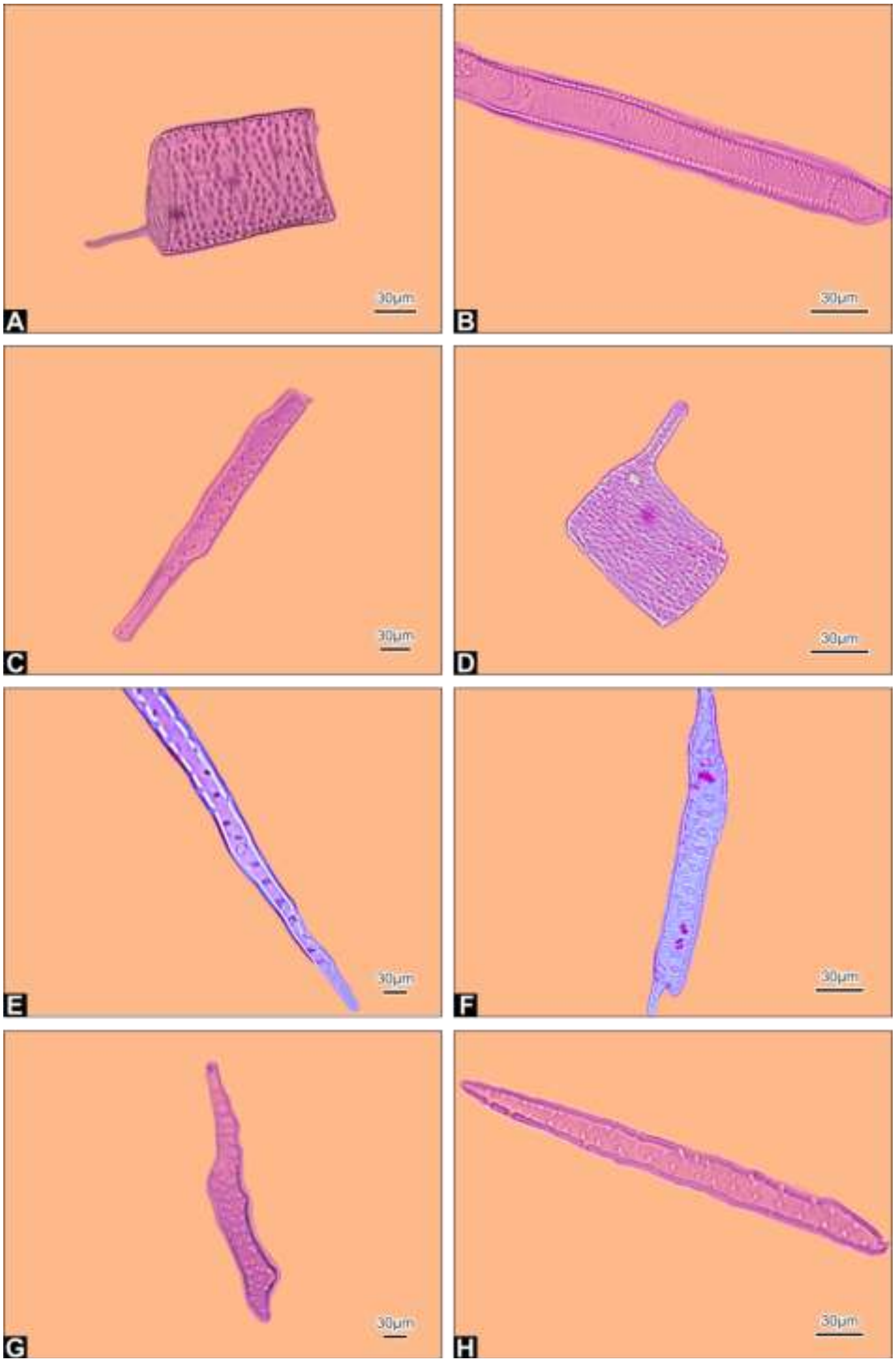

PLATE 5: Stem wood elements of *P. paniculata*
A -D. Different types of vessel elements
E.-F. Fibriform vessel elements
G.-H. Vasicentric tracheids
Scale bars: A-H = 30 µm

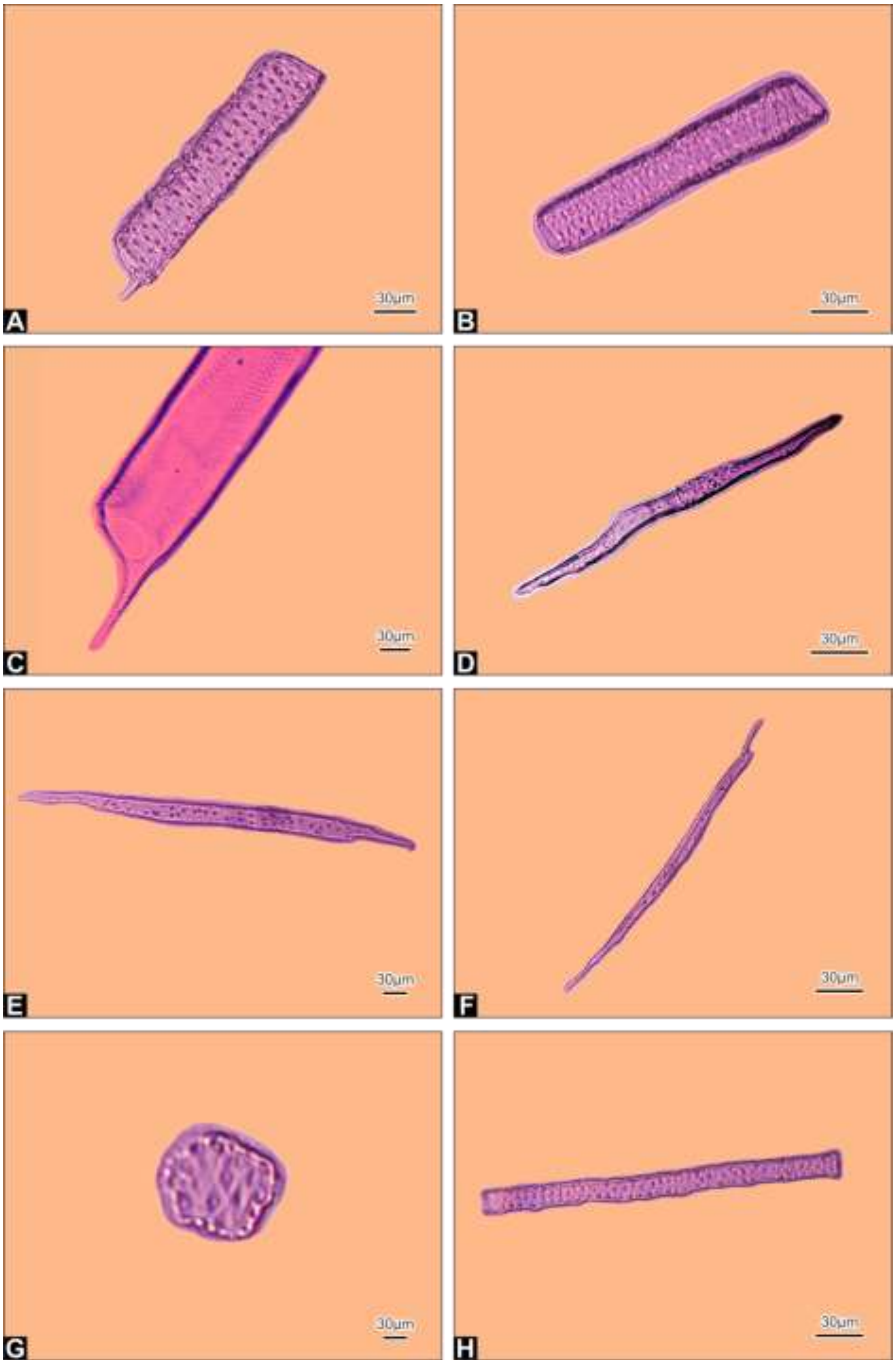

PLATE 6: Root wood elements of *P. paniculata*
A- C. Different types of vessel elements
D.-E. Vasicentric tracheids
F. A libriform fibre
G.-H. Parenchyma cells
Scale bars: A-H = 30 µm

element (Pls. 3A, C, D, G, H; 4I; 6A-C).
Vulnerability index (v)- 2.02 ,mesomorphy index (m)- 410.

Imperforated elements: libriform fibres septate as well as non-septate; extremely short to very short in length (450-1000µm). Starch grains present in septate fibres. Vasicentric tracheids present, 100-230µm in length. Tracheids with crossed pit-pores are present (Pls. 3E, 4L; 6D-F). F/V ratio- 2.67.

Parenchyma: axial parenchyma scanty vasicentric paratracheal. Rays predominantly biseriate 3-6 cells in height; sometime uniseriate, 2-6 cells in height**;** heterocellular with upright and square cells; starch grains present in ray cells, rhomboidal crystal present in parenchyma cell (Pls. 3B, F; 4J, K).

DISCUSSION

The present study provides an integrated anatomical description of young stem and wood (stem and root) of *Porana paniculata*. Previously reported features of Convolvulaceae including some features of *Porana*, like unicellular and multicellular hairs with one to two short-stalked cells, secretory cells, sclerenchymatous patches of pericycle, endodermis layer with starch grains and intraxylary phloem of the young stem and presence of solitary vessels, simple perforation plate, vessel dimorphism, alternate intervascular pits, scanty paratracheal parenchyma, narrow heterocellular rays tyloses, calcium oxalate crystals in stem wood have also been observed in the present work (Metcalfe & Chalk, 1950 ; Solreder, 1908). Occurrence of fibriform vessels reported by Carlquist & Hanson (1991) has also been observed in *P. paniculata.* In Convolvulaceae cortex is usually collenchymatous (Solereder 1908; Metcalfe & Chalk 1950). My observations on presence of parenchymatous cortex in *P. paniculata* corroborate earlier report of Rajput *et al.,* (2014) in *Ipomea obscura*.

Porana paniculata is a shrubby climber. At the apical region, young stem shows abundance of unicellular as well as multicellular hairs which may help the young stem to cling the substrate/ host while climbing. Convolvulaceae are well known for possessing intraxylary phloem. In many lianoid species cambial development occurs between the inner margin of xylem and intraxylary phloem (Fukuda, 1967; Carlquist & Hanson, 1991; Rajput *et al.*, 2008). In *Porana paniculata* it was observed that more intraxylary phloem is added by adjacent parenchyma derivatives which differ morphologically from pith cells. Similar observations have been made by Rajput (2016) in *Rivea hypocriteriformis*. In *P. paniculata* metaxylem vessels form in typical radial sequence, but the subsequently formed secondary xylem is free of obvious vessels (fibriform vessel elements may be present) and then, suddenly, secondary xylem containing large vessels is produced. This type of vessel restriction pattern has been reported in some Convolvulaceae (Carlquist & Hanson, 1991).

Porana paniculata belonging to family Convolvulaceae is a shrubby climber with variant secondary growth. Convolvulaceae is known for presence of large patches of axial parenchyma and successive cambia (Carlquist & Hanson, 1991). In *P. paniculata* large patches of axial parenchyma are present in secondary xylem. Abundance of soft patches of axial parenchyma in between the lignified tissues may aid flexibility to the climbing axis. Axial parenchyma also functions as water storage in liana stem. A new feature observed in the present study is the occurrence of small islands of interxylary phloem in the patches of axial parenchyma. Similar observation has been made by Carlquist and Hanson (1991) in *Turbina stenosiphon*.

In *P. paniculata* presence of vessel dimorphism (wide and narrow vessel elements) along with fibriform vessels is found which has been reported in several species of Convolvulaceae. Fibriform vessel element are probably nearly as effective as tracheids in resisting formation of air embolisms in vessels, because air embolisms form far less commonly in narrow vessels than in wide ones (Ellmore & Ewers 1985). Moreover, fibriform vessels have greater potential conductivity because of presence of perforation plate.

Qualitative features like wide and narrow vessels, fibriform vessels, simple perforation plate, vasicentric tracheids, libriform fibres, scanty vasicentric axial parenchyma are of common occurrence in stem and root wood. In root wood rays are mostly biseriate and occasionally uniseriate while in stem wood rays are mostly uniseriate occasionally biseriate.

Quantitatively the vessels are wider and in higher density in stem wood as compared to those of root wood. While in root wood fibres are longer and rays are wider.

Woody climbers are known to have stems with wider vessels as compared to their roots (Ewers *et al.*, 1997; Fishers & Ewers, 1995). Wider vessels of liana stem compensate for the narrow stems by enhancing conducting efficiency per stem xylem cross-sectional area (Gartner, 1991; Ewers & Fisher, 1991; Ewers *et al.,* 1991; Chiu & Ewers 1992). However, wide vessels are in danger of being damaged when twisting of liana stem occurs. In such condition, small vessels along with the fibriform vessels may help in conduction. The occurrence of fibriform vessels along with the wider vessels are said to be associated with the climbing habit of the species. Presence of true or vasicentric tracheids offers ideal subsidiary conductive systems in case of embolism of the vessels in woody dicotyledons (Carlquist, 1985). In *P. paniculata* vulnerability index for stem wood is more than 1 (2.51), and the mesomorphy index is 511 indicating the mesic condition of the plant. Further, F/V ratio of 2.41 indicates optimal mechanical strength of the plant axis.

ACKNOWLEDGEMENTS
We are thankful to Professor D.K. Chauhan, Department of Botany, University of Allahabad, for his help in identification and collection of the materials.

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