Morphology and anatomy of aerial and terrestrial roots of *Petrea volubilis* L.

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The paper for the first time describes the morphology and anatomy of aerial and terrestrial roots of *Petrea volubilis* L. of family Verbenaceae. Both aerial and terrestrial roots are positively geotropic. Aerial roots are short lived and originate from the nodal parts of stem. The texture of the aerial roots is either delicate or woody. The terrestrial roots are woody in nature. The aerial roots are rarely branched while terrestrial roots are much branched. Both aerial and terrestrial roots show radially arranged polyarch vascular bundles of exarch nature with secondary growth. In aerial, roots the secondary growth is like that of other dicotyledonous roots, but terrestrial roots show eccentric secondary growth which is new for the genus.

Key-words—*Petrea volubilis*, Aerial roots, Terrestrial roots, Eccentric secondary growth.

INTRODUCTION

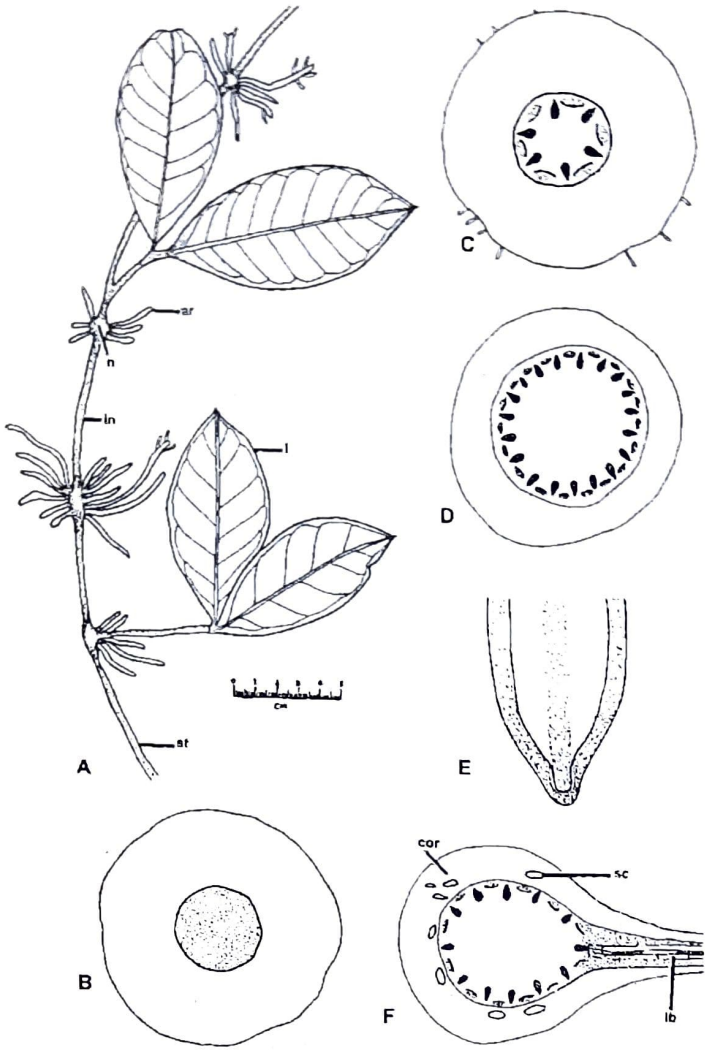
THE morphology and anatomy of roots of Verbenaceae have been described earlier by Solereder (1908), Holm (1910), Leibau (1913), Haberlandt (1914), Jeffrey (1917), Mullan (1931, 1933), Chapman (1944), Eames and MacDaniels (1947), Metacalfe & Chalk (1950), Mauseth (1988) and Fahn (1997). Except for a few notable genera like *Avicennia nitida, Clerodendron inerme, Phryma leptostachya,* the aerial and terrestrial roots in majority of the verbenaceous forms have not been studied in detail. In the present study, the dimorphic roots in *Petrea volubilis* have been described for the first time.

MATERIAL AND METHOD

The aerial and terrestrial roots of *Petrea volubilis* have been collected from Roxburgh Botanical Garden of Botany Department, Allahabad University, Allahabad and from private gardens of the city in the months of July to October, soon after the onset of first monsoonic rains, when aerial roots are seen arising luxuriantly in this plant. Thereafter, these roots start perishing. So in these plants aerial roots are supposed to be ephemerals, survive only for a short period. Identification of the plant of *Petrea volubilis* was made by previously identified authentic herbarium sheets, which are presently housed in Duthie Herbarium of Botany Department, Allahabad University, Allahabad. During identifications, help from various authentic literatures i.e. Hooker (1872-1897), Jackson (1895), Heinig (1899), Bailey (1949), Hutchinson (1959), Graf (1973), Willis (1973) and Bose and Chowdhury (1991) was taken. Both aerial and terrestrial roots were thoroughly washed in running tap water to remove the soil particles attached to its surface and subsequently the material was fixed in F.A.A. For the study of external morphology, the method was adopted after Misra and Singh (2000a). Microscopic study of both fresh and fixed materials was done by cutting free hand as well as microtome sections and their tracheary elements were studied by maceration techniques as mentioned in Jeffery (1917), Johanson (1940) and Jane (1956). Presence of cutin in the roots was tested with Sudan IV and other microchemical tests like lignin and starch were made by phloroglucinol and Iodine solutions respectively.

EXTERNAL MORPHOLOGY

Petrea volubilis L., a woody climber, belongs to the family Verbenaceae of dicotyledons. Its stems have opposite leaves, which are ovate and elliptical with leathery and rough textures. The plant shows dimorphic roots, aerial and terrestrial (Text-figs. 1A, 3A, Plate 1A-B). Both aerial and terrestrial roots are positively geotropic. Aerial roots originate from the nodal parts of the stem. Aerial roots in young stage are light



Text-fig. 1 A-F. Aerial roots of *Petrea volubilis*.

A. Aerial roots arising from nodes of stem. **B-D.** Topographic sketches of transverse sections of aerial root at different selected levels from apex to base x20. **E.** L.S. of root tip of aerial root x20. **F.** T.S. of aerial root showing endogenous lateral branching x20. (ar - aerial roots, n - node, in - inter node, l - leaf, st - stem, cor - cortex, sc - schizogenous cavity, lb - lateral branching)

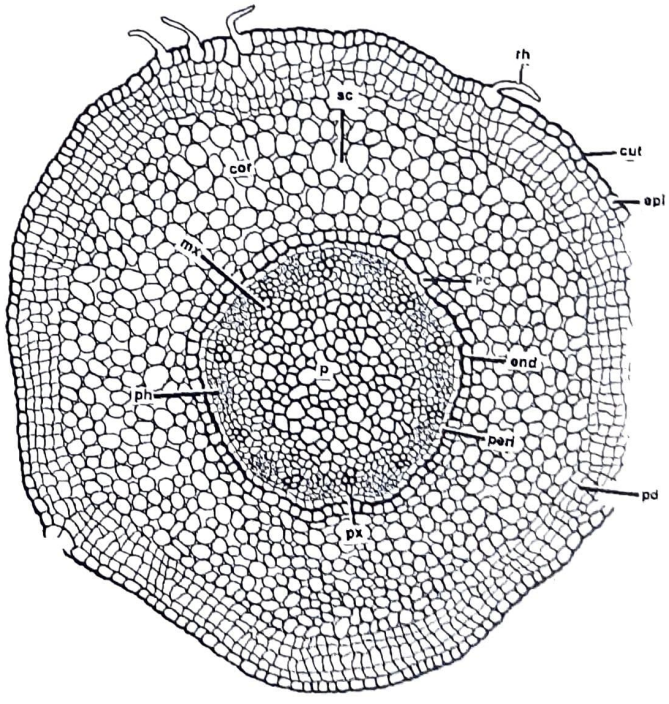
yellow in colour and at maturity tend to become brownish. The aerial roots are delicate as well as woody in nature. The terrestrial roots, on the other hand, are dirty white to light brown in colour and woody in nature. The aerial roots are short lived. The aerial roots are rarely branched. But terrestrial roots are always much branched. Both kinds of roots show root caps, root hairs and lenticels. The root hairs of terrestrial roots are longer and tubular. The size of aerial roots ranges from 1 mm to 7 mm in diameter. (Text-fig. 1A, Plate 1A-B).

ANATOMY

In transection, the roots of *Petrea volubilis* show basically three regions, dermal, ground and vascular region (Text-figs. 2, 4, Plate 1C-D). The first layer is epidermis. This is one layered and consists of rectangular, thin walled, cutinized cells. Root surface is thickened except in the region of root hairs. Root hairs are papillate as well as long, tubular and unicellular (Text-figs. 1C, 2, 3C, 4). In older roots, epidermis is interrupted with numerous lenticels. (Plate 1E-F).

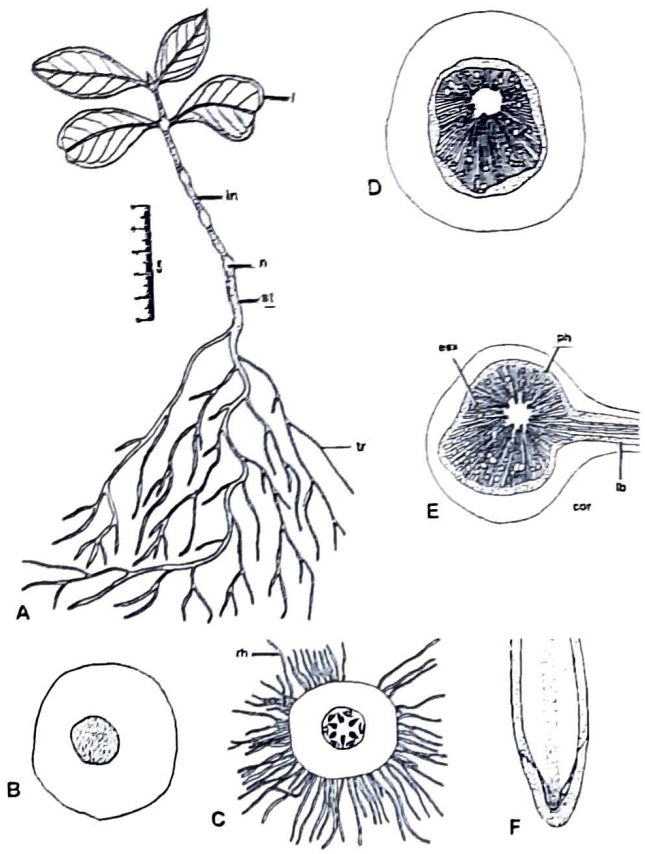
Next to the epidermis is cortex, which is usually composed of oval and rounded parenchymatous cells with intercellular spaces. It is wider in aerial roots than in terrestrial roots. (Text-figs 2, 4, 5, Plate 1 C-D). It is composed of 12 to 16 cells in thickness in aerial roots and 8 to 12 cells thickness in terrestrial root. Chloroplasts are present in outer region of cortex.

Below the cortex unilayered endodermis is present. It is characterized by the presence of suberized casparian strips in the radial and transverse walls.

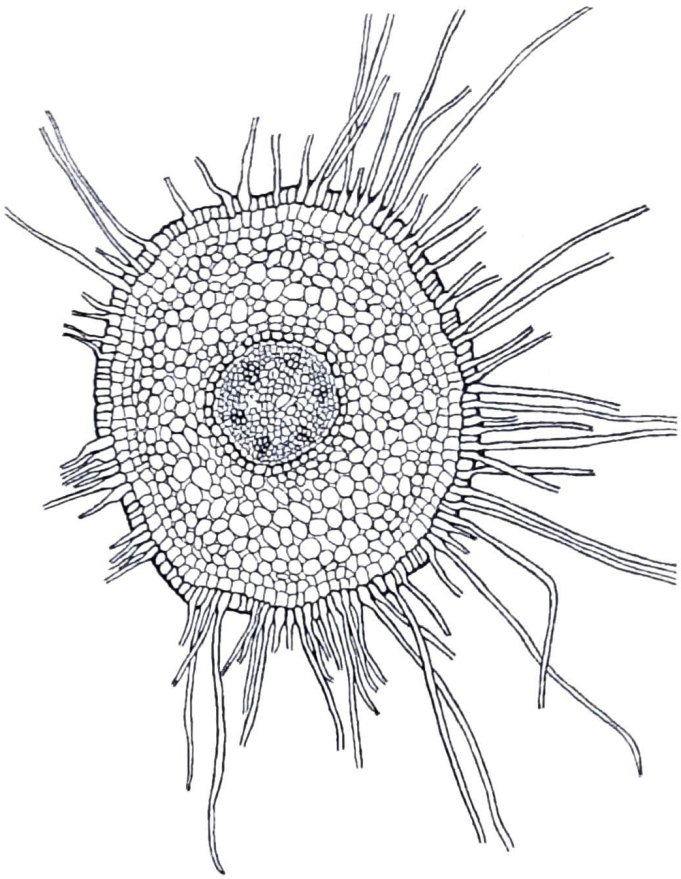


Text-fig. 2. T.S. of young aerial root of *Petrea volubilis* showing cellular details x60.

(cut - cuticle, epi-epidermis, rh-root hairs, pd-periderm, cor-cortex, sc - schizogenous cavity, end-endodermis, peri-pericycle, pc-passage cell, px-proto xylem, mx-metaxylem, ph-phloem, p-pith)



Text-fig. 3 A-F. Terrestrial roots of *Petrea volubilis*. **A.** External features of young plant with terrestrial roots. **B-D.** Topographic sketches of transverse sections of terrestrial root at different selected levels from apex to base x20. E. T.S. of terrestrial root showing endogenous lateral branching x20. F. L.S. of root tip of terrestrial root x20. (1 - leaf, in - inter node, n - node, st - stem, tr - terrestrial roots, rh - root hairs, esx - eccentric secondary xylem, ph - phloem, lb - lateral branching, cor - cortex)



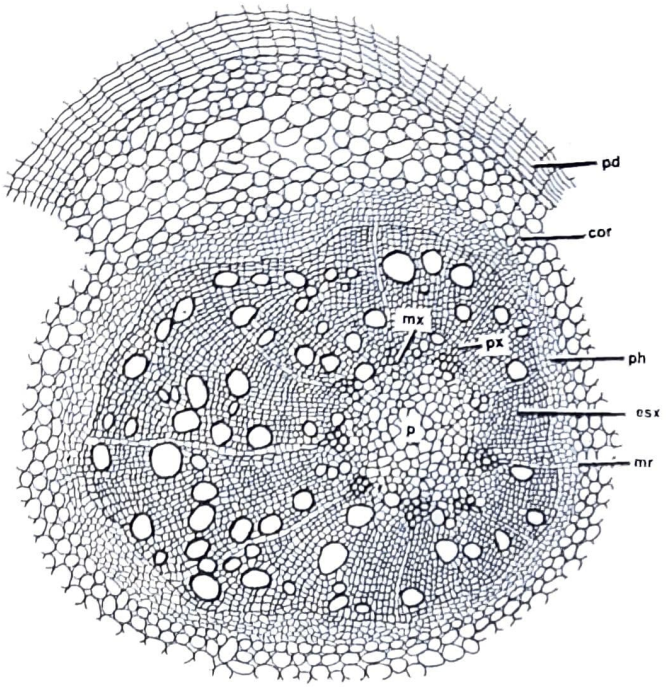
Text-fig 4. T.S. of young terrestrial root of *Petrea volubilis* showing cellular details x60.

Passage cells are usually present opposite to protoxylem points and these are thin walled. (Text-figs. 2,4).

Next to the endodermis there is a single layered, thin walled pericycle. Lateral roots usually arise from this region as in other roots. The central part of aerial roots is represented by larger vascular region and pith than the same in terrestrial roots. The vascular bundles show radial arrangement of alternating strands of xylem and phloem. Both aerial and terrestrial roots are polyarch and exarch in nature. The vascular bundles range from 4 to 19 in aerial roots and 4 to 12 in terrestrial roots (Text-figs 2, 4). The centrally situated pith is composed of sclerenchymatous cells. It is wide in aerial roots than their terrestrial roots (Text-figs 2, 4).

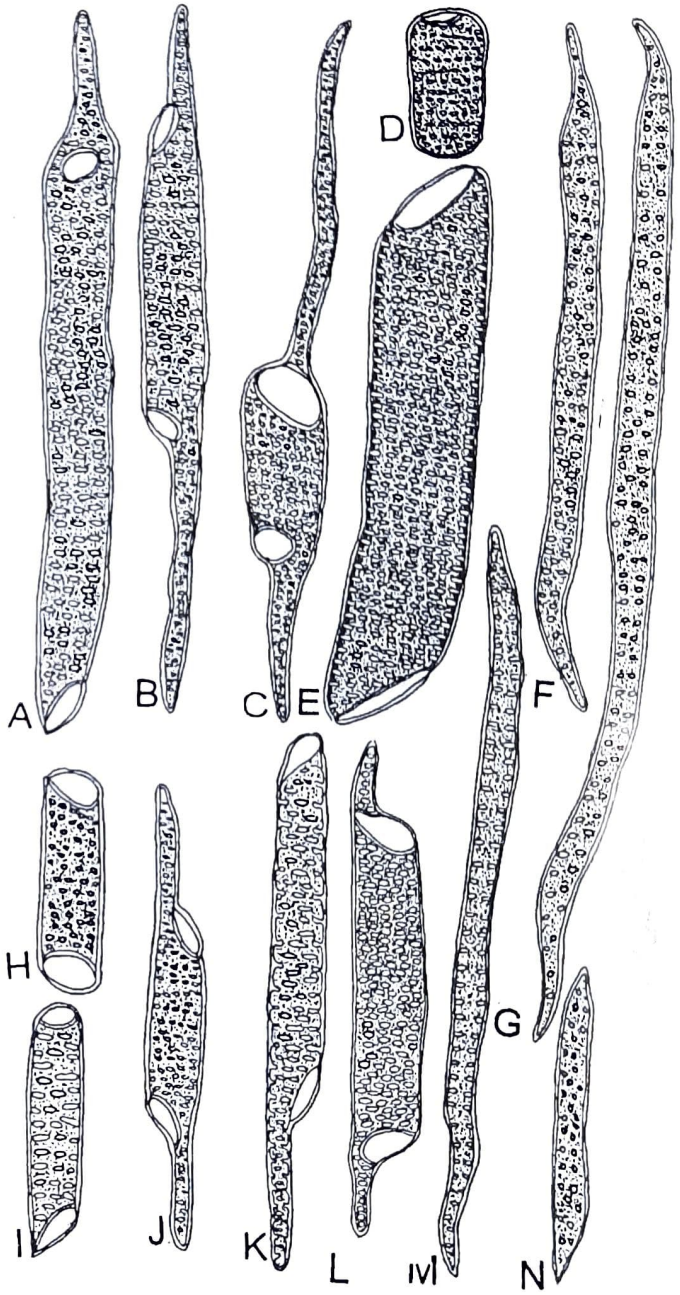
Both aerial as well as terrestrial roots show secondary growth. In aerial root, secondary growth is developed in normal condition as in other dicot roots (Misra & Singh, 2000a), whereas in terrestrial roots it is eccentric in nature. In the eccentric roots the activity of cambium appears to be abnormal type resulting the formation of more secondary xylem on one side and less on the other (Text-fig. 5). The primary xylem strands remain in their original position below the secondary tissue. The periderm is present in both kinds of mature roots and is usually produced by cork cambium. (Text-figs 2, 5, Plate 1E-F).

The aerial and terrestrial roots in maceration yield tracheary elements which are heterogeneous in composition (Text-fig. 6 A-N). The tracheary elements consist of tracheids and vessels. The tracheids are imperforated, elongated, narrow and tapered at both ends and their secondary walls show scalariform thickenings. The size and form of tracheary elements vary greatly in aerial and terrestrial roots. The size of tracheids vary from 622 μm to 1233 μm in length and



Text-fig. 5. T.S. of terrestrial root of *Petrea volubilis* showing cellular details with eccentrically formed secondary xylem x50. (pd - periderm, cor - cortex, px - protoxylem, mx - meta xylem, ph - phloem, esx - eccentric secondary xylem, mr - medulary rays, p - pith)

11 µm to 23 µm in width in terrestrial roots and 275 µm to 890 µm in length and 11 µm to 23 µm in width in aerial roots. On the contrary, vessels are relatively short with wide lumen measuring 67 µm to 1054 µm in length and 33 µm to 60 µm in width in terrestrial roots and 48 µm to 321 µm in length and 11 µm to 35 µm in width in aerial roots. The end walls of vessels are oblique or transverse showing simple perforation plates. The perforations are either circular or elliptical in outline and their size ranges from 11 µm to 45 µm in length and 11 µm to 88 µm in width in terrestrial roots and 11 µm to 22 µm in length and 6 µm to 11 µm in width in aerial roots. The secondary walls of vessel elements show scalariform thickenings.



Text-fig. 6 A-N. Tracheary elements of terrestrial and aerial roots of *Petrea volubilis*. A-E. Vessel elements of terrestrial root showing thickenings and pits x 100. F-G. Tracheidial elements of terrestrial root showing thickenings and pits x 100. H-L. Vessel elements of aerial root showing thickenings and pits x 100. M-N. Tracheidial elements of aerial root showing thickenings and pits x100.

PLATE 1

A-F. Roots of *Petrea volubilis*.

A. Aerial roots arising from nodes of stem.

B. Part of stem showing magnified view of aerial roots.

C. T.S. of aerial root showing cellular details x200.

D. T.S. of old aerial root showing cellular details and scanty secondary growth x200.

E. Enlarged portion of outer region of terrestrial root in T.S. showing lenticels x400.

F. Enlarged portion of outer region of aerial roots in T.S. showing lenticels x400.

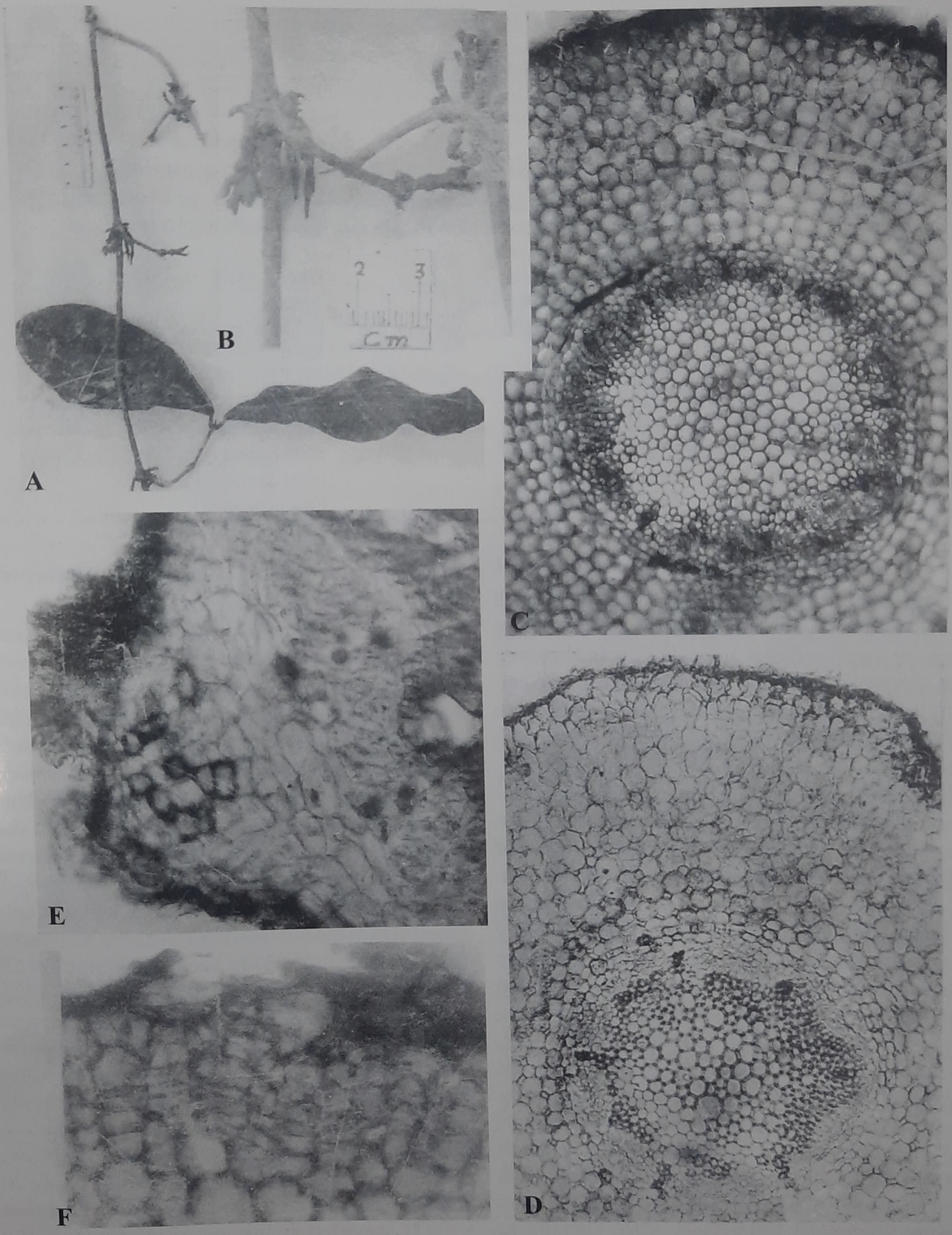


PLATE 1

Table 1. Comparison of aerial and terrestrial roots of *Petrea volubilis*

	Character	Aerial Roots	Terrestrial Roots
1.	Duration and timing	Throughout year, but more during rainy season	Perennial, throughout year
2.	Nature	Soft in texture	Woody in texture
3.	Colour	Light yellowish to brown	Dirty white to light brown
4.	Root hairs	Papillate, tubular and less in number	Long, tubular and more in number
5.	Cortex	Wider, aerenchymatic, 12 to 16 cells in thickness	8 to 12 cells in thickness
6.	Air cavities	Small, schizogenous	Present, in the inner region of cortex
7.	Chlorophyllous cells	Present in the outer cortex	Absent
8.	Vascular bundles	Polyarch, protoxylem ranges from 4 to 19 and exarch	Polyarch, protoxylem ranges from 4 to 12 and exarch
9.	Pith	Wide and well developed and sclerenchymatous	Absent
10.	Secondary growth	Very little in amount, usual	More in amount, unusual, i.e. eccentric
11.	Rays	Less developed	More developed
12.	Periderm	Less developed	More developed
13.	Lenticels	More in number	Less in number

DISCUSSION AND COMPARISON

The root constitutes the lower portion of the plant axis and generally grows below the soil surface. Though there are some roots that grow above soil. However, root, morphologically, ontogenetically and physiologically, is different from stems and basic differences in the development and arrangement of the primary tissues in these two organs are distinguishable. The uniformity in the root structure is due to the uniform environment and their underground nature in contrast to the aerial habit of stems. This is thought to be one of the factors causally connected with the relative simplicity of the root. However, much variations exist in the shape and size of the roots. This variability in many cases, is related to the function of roots, i.e. storage root, contractile root, buttress root, sucking root, prop root, stilt root, climbing root, clinging root, root thorn, mycorrhizal root, nodulated root, coralloid root, pneumatophores and aerial roots. However, in large number of vascular plants, e.g. pteridophytes, gymnosperms, dicotyledons, aerial as well as terrestrial roots have not drawn much attention. (Misra & Singh 2000a, b). There are relatively few-publications which give an account of the root structure in specific plant species. (Solereder 1908; Troll, 1967; Guttenberg 1968; Foster & Gifford 1974; Gill and Tomlinson 1975; Misra & Singh 2000a, b).

The detailed morphology and anatomy have been worked out for the first time in the roots of *Petrea volubilis* L. of family Verbenaceae. Attempts have also been made to correlate the anatomical changes at different levels of the root length. This has been done with a view to find out the constancy of anatomical characters with special reference to the vascular bundles from the base of root to its apical ends and also to compare these features in aerial and terrestrial roots. A large number of variations in the root anatomy of both aerial and terrestrial roots are reported. The only other roots of the family whose anatomy is known is that of *Avicennia nitida* Jacq. by Holm (1913) Liebau, (1913); Emould (1921); Mullan (1931, 1933); Trochain & Dulau (1942) and Chapman (1944). *Avicennia nitida* is a mangroove plant growing in swampy areas. It has pneumatophores, which are negatively geotropic. It shows polymorphic nature e.g. primary adventitious roots, pneumatopho-res, horizontal roots, anchoring roots and absorbing roots, whereas the plants of *Petrea volubilis* have only dimorphic roots, aerial and terrestrial roots. Chapman (1944) stated that the aerial portions of the

pneumatophores are supplied with lenticels, cortex with air cavities and Mullan (1933) has described the roots of *Clerodendron inerme* and its lacunate cortex. These characters are also present in the roots of *Petrea volubilis*. The terrestrial roots of *Petrea volubilis* are notable in showing eccentric secondary growth. Although it is present in many stems of woody climbers. Anomalous type of eccentric growth may be more common in dicot stems of *Acacia radiana*, *Quercus* (Fahn, 1997). Another interesting feature observed in the presently investigated roots of *Petrea volubilis* is the occurrence of a polyarch stele, which is a feature of monocots, rarely reported in dicots. In the present study eccentric growth is being reported in the root of *Petrea volubilis* for the first time.

The dimorphic roots of *Petrea volubilis* show a large number of interesting morphological and anatomical features viz., abundance of root hairs, aerenchymatous cortex, polyarch condition and eccentric secondary growth (Table 1).

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