ISSN 0376-5156
Geophytology 54(2): 201–212
November 2024

Morpho-anatomical diversity in roots of *Epipremnum aureum* (Linden & André) G.S. Bunting (*Araceae*)

Lal J. Singh[1*] and Dharm R. Misra[2]

[1*]Botanical Survey of India, Andaman & Nicobar Regional Centre, Port Blair–744102, India. E-mail: [1*]laljisingh1970@rediffmail.com
[2]Department of Botany, Allahabad University, Allahabad–211002, India.
*Corresponding Author

Manuscript received: 14 May 2024
Accepted for publication: 08 July 2024

ABSTRACT

Singh L.J. & Misra D.R. 2024. Morpho-anatomical diversity in roots of *Epipremnum aureum* (Linden & André) G.S. Bunting (*Araceae*). Geophytology 54(2): 201–212.

The paper describes, for the first time, comparative morphology and anatomy of dimorphic roots of *Epipremnum aureum* (Linden & André) G.S. Bunting (*Araceae*) with special reference to an adaptive strategy. The dimorphic roots show both aerial and terrestrial habits. Aerial and terrestrial roots are fundamentally alike in positively geotropic nature, presence of radially arranged polyarch vascular bundles with exarch xylem, endogenous lateral branch but exhibit a wide range of variations in morpho-anatomical features. Unlike terrestrial roots, aerial roots are rarely branched. Aerial roots become stiff and pointed at apical parts. It looks like a spine type. Sometime they become very hard and flattened. The aerial roots show large number of interesting morpho-anatomical features like epidermis with papillate root hairs and numerous lenticels, a wart like structure outside epidermis, large lysigenous cavities and chlorophyllous cells in the cortex, Hard and flattened aerial roots show 'V' or 'Y' shaped sclerenchymatous tissue around the phloem. Pith of both roots is composed of scattered vessels, usually more in number in aerial roots. These features appear as an adaptive strategy under stress ecosystem.

Keywords: *Epipremnum aureum*, *Araceae*, adaptation, anatomy, environmental stress, roots.

INTRODUCTION

Root is a fundamental unit of plant body and morpho-anatomically more diversified in vascular plants with adaptive strategies. The monocot roots are usually characterized by presence of fibrous root system. The mature roots of monocotyledons are developed from stems and hence these are technically called as adventitious roots. The stem borne adventitious roots, which are exposed to the air, known as aerial roots. Occurrence of aerial roots is considered as a characteristic feature of monocots (Gill & Tomlinson 1975, Misra et al. 1997, Misra & Singh 2000 a, b, Singh 2002). Unlike monocots, there are relatively scanty reports on occurrence of aerial roots in dicotyledonous plants like *Ficus benghalensis* (Kapil & Rustagi 1966), *F. benjamina* (Zimmermann et al. 1968), *Cissus* (Pfeiffer 1937) and *Tinospora* (as mentioned in Esau 1965, Fahn 1982, Mauseth 1988), *Vitis rotundifolia* (Turner 1934), *Acalypha hispida* Burm f. and *A. wilkesiana* Müll.Arg. (*Euphorbiaceae*), *Bignonia alliaceum* Lam., *Doxantha unguiscatii* Rehd., *Pyrostegia venusta* Baill. (*Bignoniaceae*), *Justicia gendarussa* Burm f., *Pseuderanthemum reticulatum* Radlk, *Sanchezia nobilis* Hook. f. (*Acanthaceae*), *Petrea volubilis* L. (*Verbenaceae*), *Plumeria rubra* forma *acutifolia* Woodson (*Apocynaceae*) and *Syzygium cumini* Skeel of *Myrtaceae*, etc. (Misra & Singh 2000b, 2002, 2004a, b, c, 2005, 2007a, b, 2008a, b, Singh 2002, Singh & Misra 2012, 2015, 2024) as well as in some gymnosperms and pteridophytes (Campbell 1911, Chamberlain 1935, Ogura 1972, Pant 1973, 2002, Pant & Das 1989, Taylor & Taylor 1993, Singh 2017, Singh & Misra 2017, 2020, Singh et al. 2021).

The development of aerial roots can be seen in monocotyledonous families like *Araceae*, *Arecaceae*, *Commelinaceae*, *Liliaceae*, *Orchidaceae*, *Pandanaceae*, *Poaceae*, etc. These families show numerous interesting morpho-anatomical features. The root morphology of *Araceae* has been worked out by Van Tieghem (1866), Van Tieghem & Douliot (1866), Schwarz (1878), Engler (1919), Sachs (1882), Bertrand (1884), Tschirch (1885), Lierau (1888), Went (1895), Schoute (1902), Gürtler (1905), Giovannozi (1911), Haberlandt (1914), Solereder (1919), Philipp (1923), Arber (1925), Bloch (1926, 1935, 1937, 1941, 1944, 1946), Solereder & Meyer (1928), Cheadle (1941, 1942, 1943a, b, 1944), Esau (1943 a, b, c) and Misra & Singh (2000b). Many details regarding morphology and anatomy of these roots are still unknown. Various morpho-anatoical accounts on roots reveal that the poor aeration in habitats induces the development of aerial root in plants with adaptive strategies and with much morpho-anatomical diversity (Singh 2002, Singh & Misra 2012, 2015, 2024). It has generated a lot of interest amongst the morphologists, anatomists and ecologists and with this view this study has been undertaken. In the present study attempt has been made to make the detailed study of aerial and terrestrial roots of *Epipremnum aureum* (Linden & André) G.S. Bunting (*Araceae*).

MATERIAL AND METHODS

Both aerial and terrestrial roots of *Epipremnum aureum*, belonging to family *Araceae*, have been collected from Roxburgh Botanical Garden of Botany Department of Allahabad University and also from some private gardens of the city which was grown in terrestrial habitats. Thereafter, the plants were identified by comparing with authentic herbarium sheets which are presently located in Duthie Herbarium of Botany Department, Allahabad University, Allahabad. During identification, help from other authentic literature was also taken (Duthie 1903–1929, Engler 1919, Hutchinson 1934, Bailey 1949, Willis 1973, Dahlgren & Clifford 1982, POWO 2024). The external morphology of these roots was studied by the technique followed by Misra & Singh (2000). Microscopic studies of both fresh and fixed materials were made by cutting free hand and microtome sections. The roots were further macerated by Schulze's technique and vascular elements were separated. The terminology used in the present text is usually the same as in previous chapters.

OBSERVATIONS

External morphology: *Epipremnum aureum* (Linden & André) G.S. Bunting (Syns. *Pothos aureus* Linden & André, *Rhaphidophora aurea* (Linden & André) Birdsey, *Scindapsus aureus* (Linden & André) Engl.) belongs to the monocotyledonous family *Araceae*. It is an evergreen and fast growing climber commonly known as 'money plant'. Leaves are ovate, waxy and small at young stage and attaining large size at maturity. The leaves show wide range of colours from yellowish to green and finally green with white strips. Its stem is creeper as well as pendulous in nature. Stems show characteristic nodes and internodes. The roots of *Epipremnum aureum* are dimorphic in shape. It shows both aerial and terrestrial habits. Both kinds of roots arise from nodal and inter nodal regions of the stems. These roots are borne either singly or in tufts. The roots grow on walls or on stems of other plants and such roots are called clinging roots (Figure 1.B, D). These clinging roots help stems in climbing and enable plant to obtain more height. In addition, some aerial roots become stiff and pointed at apical parts. It looks like a spine type. Sometime they become very hard and flattened. (Figure 1.B). Both aerial and terrestrial roots are positively geotropic. The aerial roots are usually unbranched and dark brown in colour. While their terrestrial roots are much branched and dull white to light brown in colour. Both aerial as well as terrestrial roots show root caps, root hairs and lenticels and their apices are of blunt or obtuse. The lenticels are numerous in aerial roots than their terrestrial roots. The arrangement of the lenticels on the roots greatly varies. It appears like elongated longitudinal or horizontal narrow cavities. They have an irregularly scattered distribution over the entire surface. Externally mature lenticels are lenses shaped and they are convex both towards the exterior and the interior (Figure 1.C–D). The root hairs of terrestrial roots are longer and tubular and greater in number than their aerial roots. In some aerial roots of *Epipremnum aureum,* some wart like new structures are present (Figure 1.C) which are situated just behind the zone of root hairs and it is continued up to the region of stem or branches. These structures are narrow, elongated and dark brown in colour. Aerial roots show thick cuticle which come out easily by pressing the root mechanically.

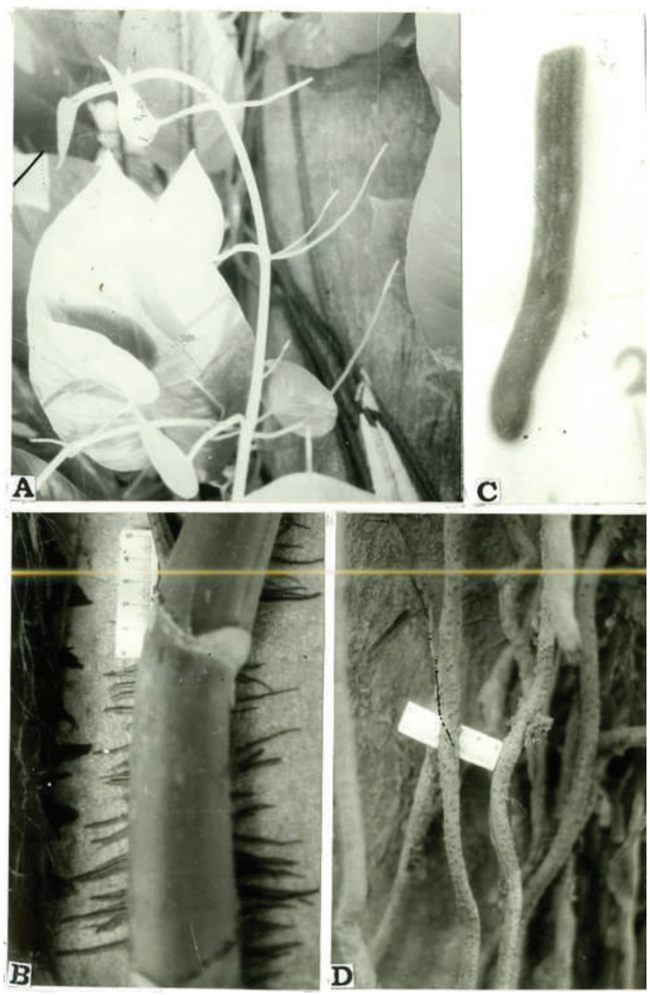

Figure 1. A–D. Aerial roots of *Epipremnum aureum* **A.** Aerial roots arising from stem. **B.** Clinging aerial roots sticking on stem of Palm. **C.** Single aerial root with wart like structure. **D.** Aerial roots approaching to the soil.

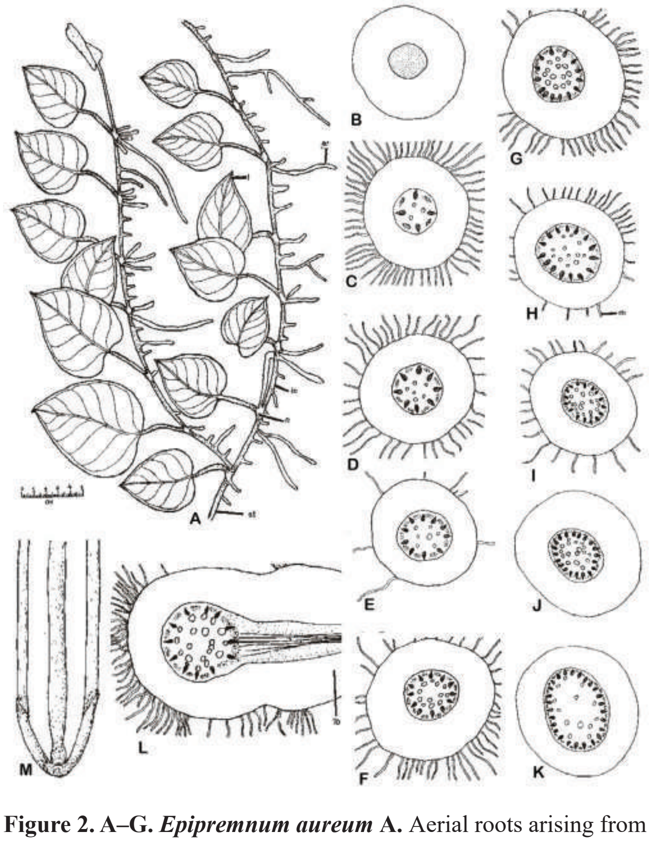

Figure 2. A–G. ***Epipremnum aureum*** **A.** Aerial roots arising from nodes as well as internodes of stem **B–H.** Topographic sketches of transverse sections of aerial roots at different selected leaves from apex to base ×30.I. L.S. of root tip of aerial root ×30. **J.** T.S. of aerial root showing endogenous lateral branching ×30. (ar: aerial root, in: internode, l: leaf, lb: lateral branching, n: node, rh: root hair, st: stem).

Anatomy: In transaction, the roots of *Epipremnum aureum* show a single layered epidermis covering a cortex and vascular region. (Figures 2.B–L, 3, 4.B–H, 5, 6.A-C). The uniseriate layer of an epidermis is composed of compactly arranged cells with cuticularized outer walls, but the cuticle is usually absent in the region of root hairs. Root hairs are papillate, long, tubular and unicellular (Figures 3, 5). The root hairs arise as a small protuberance from epidermal cells. In older roots the epidermis interrupted at many places with numerous lenticels (Figures 6.C, 7.B). The cells of lenticels are loosely arranged. These cells are meant for aeration. Epidermal cells of roots consist of simple pits on radial and anticlinal walls (Figures 7.C, 8.C, 9.A–B). Towards outside of the epidermis an interesting wart like structures are present (Figures 7.A, 8.A–B). These are composed of cavities and its upper part gives rise narrow elongated hairs like structures on the outer side. These cells look slightly larger than epidermal cells (Figures 7.A, 8.A–B). Next to an epidermis, there is cortex which is composed of unspecialized rounded or polygonal parenchymatous cells with conspicuous intercellular spaces. The cortical cells frequently contain chloroplasts where as these chlorophyllous cells are absent in terrestrial roots. The cortical region of aerial root consists of 18 to 28 cells in thickness, where as in terrestrial root cortex shows 12 to 21 cells in thickness. In aerial roots cortical cells are larger in size than the cortical cells of their terrestrial roots. Lysigenous cavities

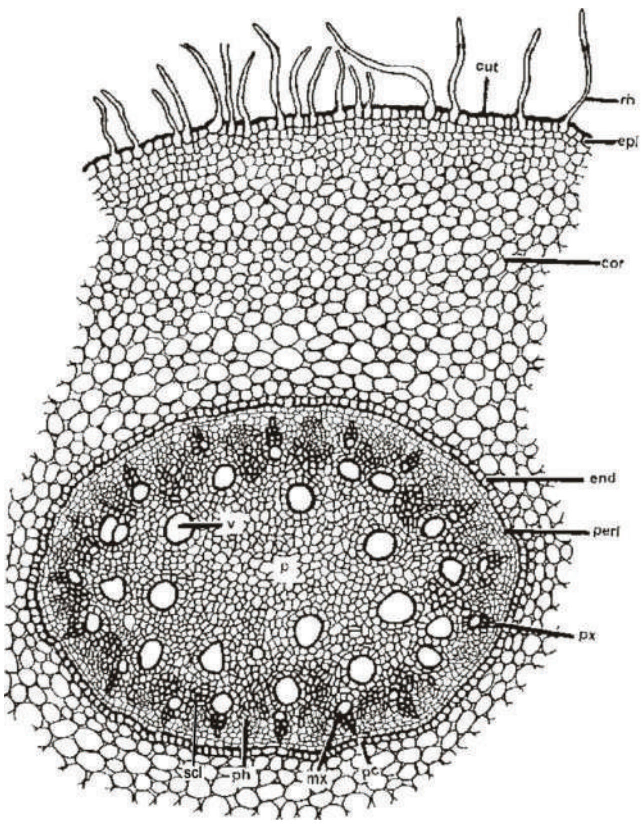

Figure 3. T.S. of aerial root of *Epipremnum aureum* showing cellular details ×90. (cor: cortex, cut: cuticle, end: endodermis, epi: epidermis, mx: metaxylem, p: pith, pc: passage cell, peri: pericycle, ph: phloem, px: protoxylem, rh: root hair, scl: sclerenchyma, v: vessel).

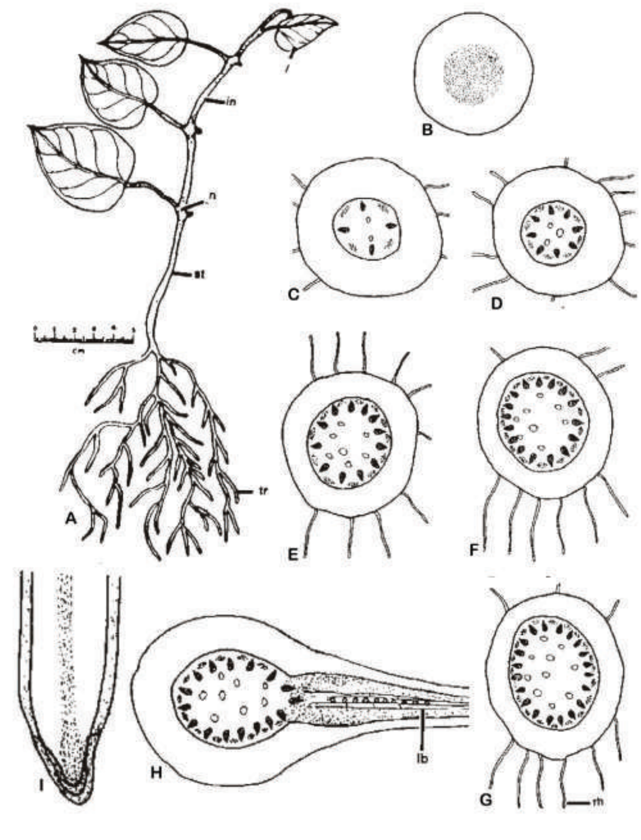

Figure 4. A–I. ***Epipremnum aureum*** **A.** External features of young plant with terrestrial roots. **B–G.** Topographic sketches of transverse sections of terrestrial roots at different selected levels from apex to base ×30. **H.** L.S. of root tip of terrestrial root ×30. **I.** T.S. of terrestrial root showing endogenous lateral branching ×30. (in: internode. Lb: lateral branching, n: node, rh: root hair, st: stem, tr: terrestrial root).

are present, which appear in the old aerial roots (Figure 6.E). However, these cavities are absent in terrestrial roots. In the older roots the periderm like tissue is present. Next to the cortex is an endodermis. It is made up of compactly arranged barrel shaped cells with suberized casparian thickenings as well as thin walled passage cells. The passage cells are situated opposite to the protoxylem strands. Next to an endodermis is a pericycle which is made up of thin walled parenchyma cells. Lateral roots usually arise from this meristematic region (Figures 2.L, 4.H). The central part of the root is made up of vascular bundles and pith. Vascular bundles are exarch and show polyarch condition. The vascular bundles range from 4 to 26 in aerial roots, whereas 4 to 20 in terrestrial roots (Figures 2.C–L, 3, 4.C–H, 5, 6.A–B). In transection of phloem of the flattened roots are characterized by presence of 'V' or 'Y' shaped sclerenchymatous tissue and it surrounds the vascular bundles. (Figures 3, 6.A, D). The pith is composed of polygonal, parenchymatous cells with mixed vessel elements (Figures 3, 6.A, D). The tracheary elements of aerial and terrestrial roots are composed of tracheids and vessels (Figure 10.A–N). The size and form of the tracheary elements vary greatly in these roots. The tracheids are simple, imperforated and tapered at both ends and their secondary walls show scalariform thickenings as well as with simple pits. Their size varies from 389–490 µm in length and 11–23 µm in width in terrestrial roots and 243–380 µm in length and 11–22 µm in width

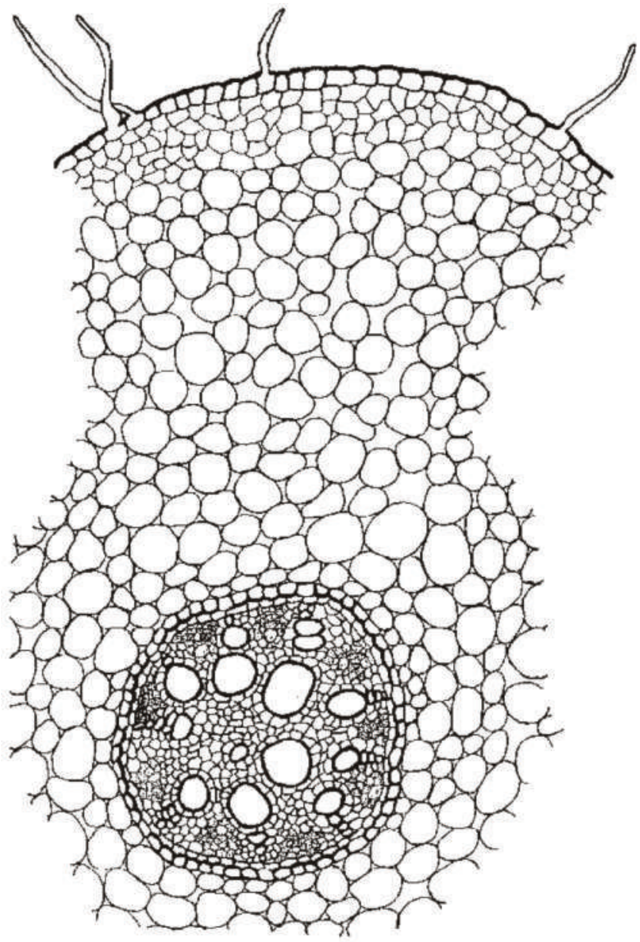

Figure 5. T.S. of terrestrial root *of Epipremnum aureum* showing cellular details ×90.

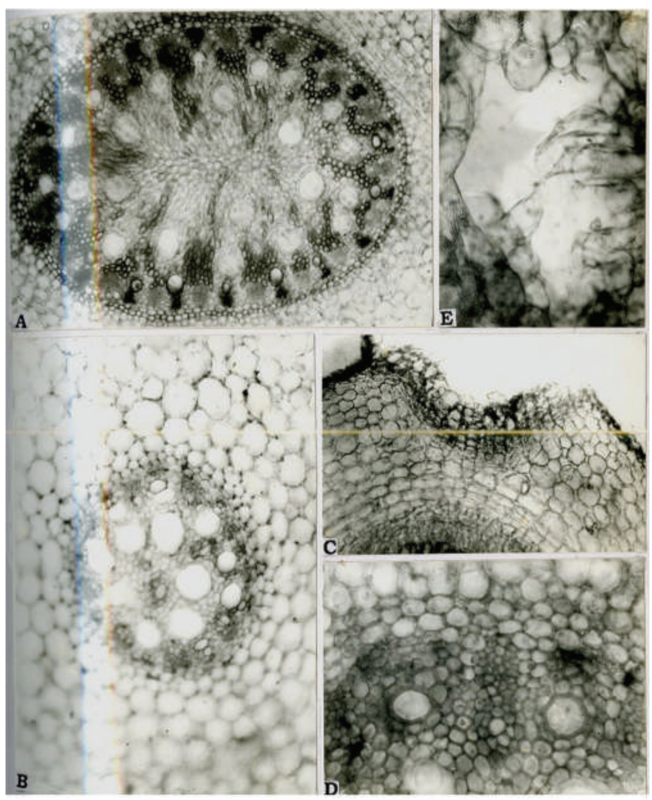

Figure 6. A–**E.** Roots of *Epipremnum aureum*. **A.** T.S. of central part of flattened aerial root showing cellular details ×150.**B.** T.S. of central part of terrestrial root showing cellular details ×200. **C.** Enlarged portion of outer region of aerial root ×150. **D.** Part of the aerial root in T.S. showing magnified view of endodermis, pericycle and radial vascular bundles ×150. **E.** Enlarged portion of middle region of cortex showing lysigenous cavity ×50.

in aerial roots. Aerial as well as terrestrial roots also show vessel elements. The vessels of aerial roots (250–380 × 11–22 µm) are relatively shorter than those of terrestrial roots (280–450 µm × 22–36 µm). The vessel elements are perforated having wider lumen than their tracheids. Perforations are either circular or elliptical in outline and their size ranges from 22–36 m in length and 11–36 µm in width in terrestrial roots and 11–23 µm in length and 11–22 µm in width in aerial roots. Perforations may be present at both ends or only at one end, either distal or proximal. The secondary walls of vessels show characteristic scalariform thickenings and simple pits. The pits are multiseriate and sub-opposite or alternate.

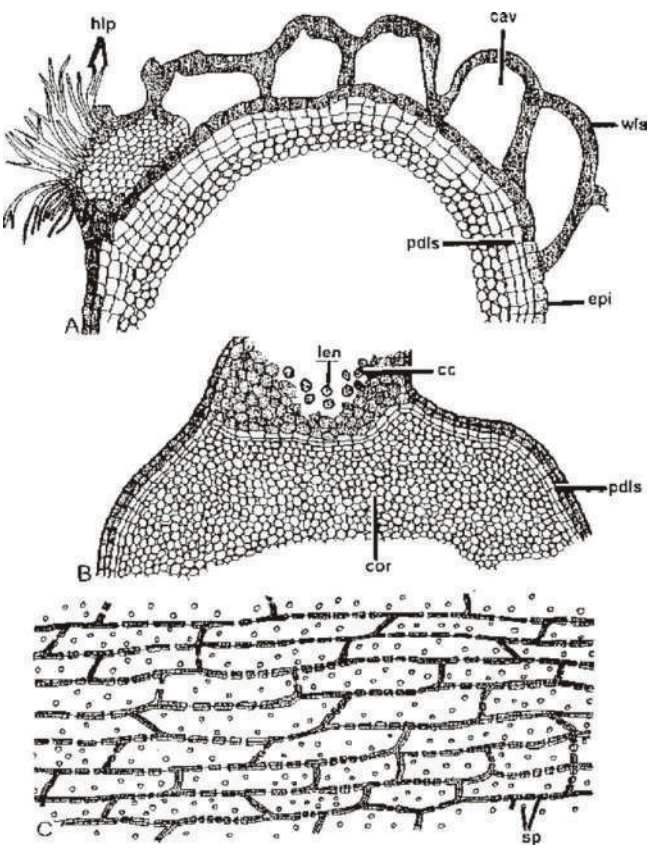

Figure 7. A–C. ***Epipremnum aureum*** **A.** Part of aerial root in T.S. showing magnified view of wart like structure outside epidermis ×150. **B.** Part of the aerial root in T.S. showing magnified view of outer region with lenticels ×150. **C.** Cells of the epidermis of aerial root showing characteristic pitting on the anticlinal and periclinal walls ×200. (cav: cavity, cc: complimentary cells, cor: cortex, epi: epidermis, hlp: hair like projections, len: lenticel, pdls: periderm like tissue, wls: wart like structure, sp: simple pit).

DISCUSSION AND COMPARISON

The morpho-anatomical structures play a significant role in physiology and ecology of plant body and also indicated evolutionary as well as taxonomic significance. In the present study, an attempt has been made to evaluate the morphological and anatomical features in roots of *Epipremnum aureum* and describes here in great detail for the first time.

The morpho-anatomical adaptations observed in *Epipremnum aureum* which include the development of ephemeral aerial roots with

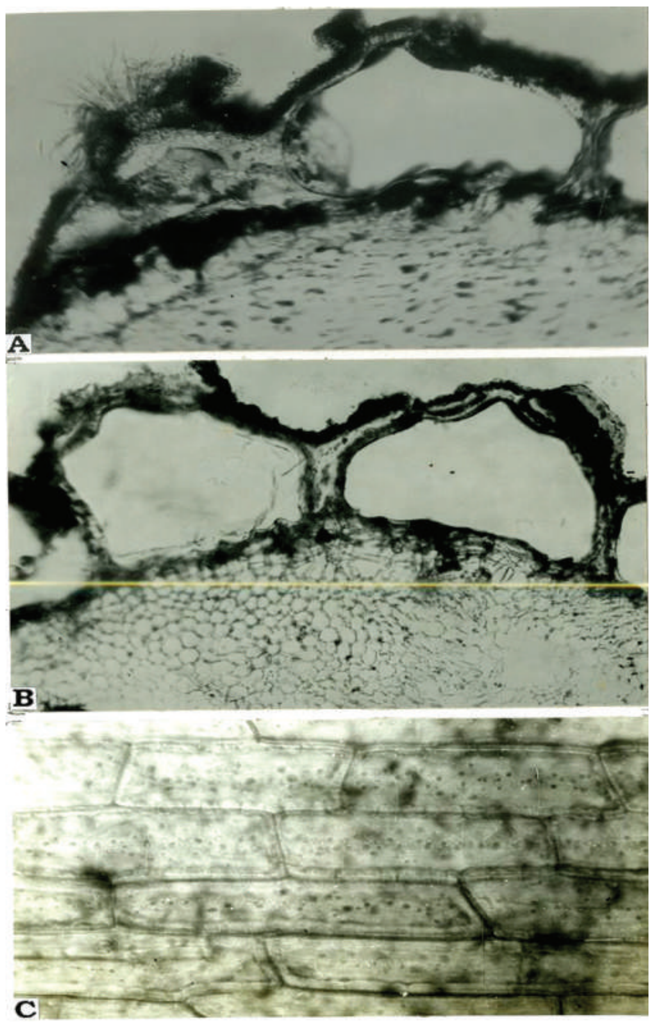

Figure 8. A–C. Aerial root of *Epipremnum aureum* **A–B.** Part of aerial root in T.S. showing magnified view of wart like structure outside epidermis ×250. **C.** Cells of the epidermis of aerial root showing characteristic pitting on the anticlinal and periclinal walls ×250.

abundant lenticels and cortex featuring wide intercellular spaces and cavities. These features serve as significant adaptive traits, facilitating oxygen transport to sustain root aeration in the plants. While such characteristics are typically associated with monocotyledonous plants found in aquatic and moist environments, *Epipremnum aureum* exhibits similar traits despite being a terrestrial habitat. Only few notable studies have highlighted similar morpho-anatomical adaptations in both monocotyledonous and dicotyledonous terrestrial plants under stressful conditions (Misra & Singh 2000a, b, 2002, 2004a, b, c, 2005, 2007 a, b, 2008a, b, Singh 2002, Singh & Misra 2012, 2015, 2024).

Sansevieria suffruticosa Brown, a member of the *Liliaceae* family, exhibits ephemeral aerial roots during the rainy season, particularly in dark and humid climatic conditions. This plant strictly grows in terrestrial habitats, showcasing various intriguing features. In addition to the typical ring of radial vascular bundles, its dimorphic roots (both aerial and terrestrial) possess numerous scattered vascular bundles of different types, including collateral and concentric patches of vascular strands such as xylem and phloem in the central part of the root. These vascular bundles are characterized by being collateral and concentric, with the patches of xylem and phloem surrounded by sclerenchyma cells. The outer region of the roots displays a multilayered epidermis, exodermis, and cortex (Misra & Singh 2000b, Singh 2002).

According to Singh and Misra (2015), morpho-anatomical diversity serves as an adaptive strategy in roots, especially in stress ecosystems. They

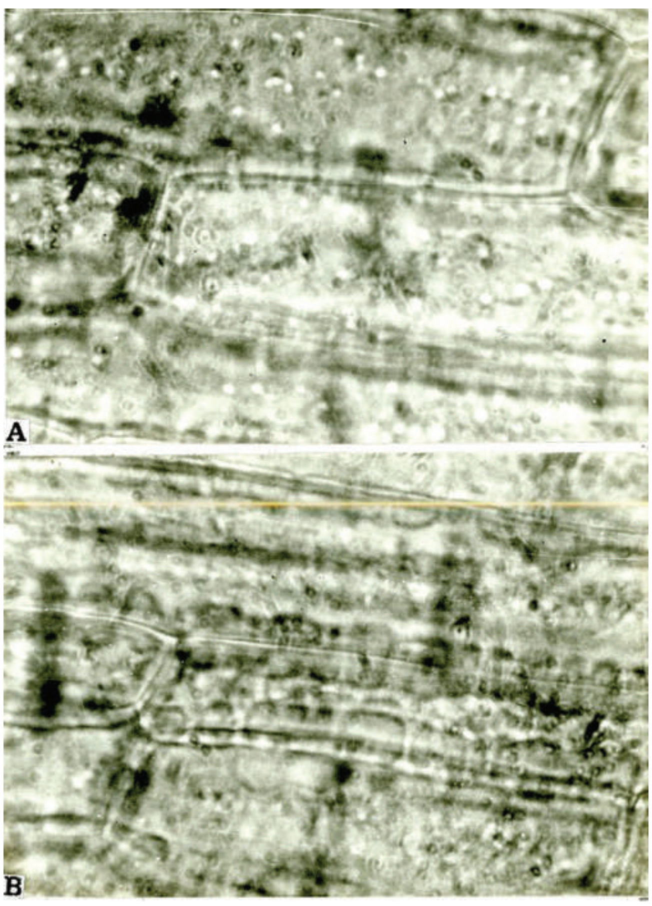

Figure 9. A–B. Magnified view of epidermal cells of aerial root of *Epipremnum aureum* showing characteristic pitting on the anticlinal and periclinal walls ×400.

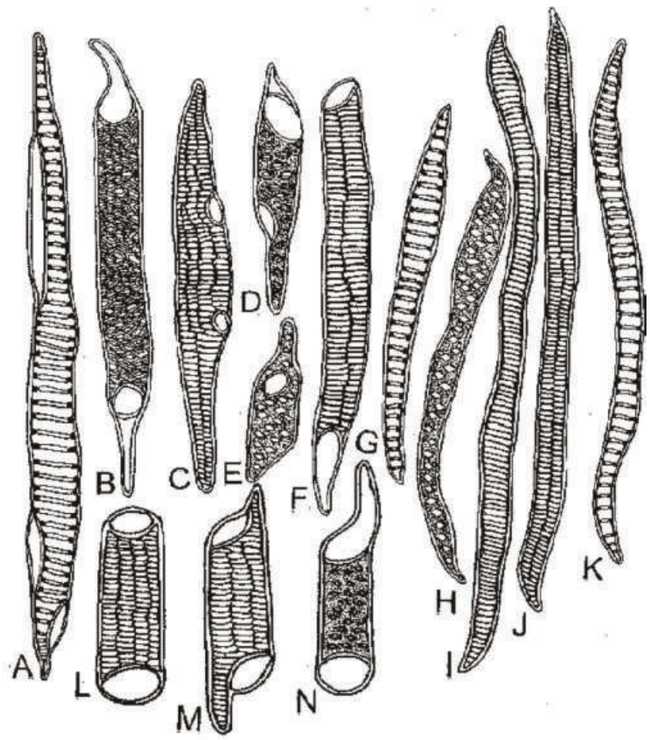

Figure 10. A–N. Tracheary elements of roots of *Epipremnum aureum*. **A-F.** Vessel elements of terrestrial roots showing thickenings and pits ×250. **G–I.** Tracheidial elements of terrestrial roots showing thickenings and pits ×250. **J–K.** Tracheidial elements of aerial roots showing thickenings and pits ×250. **L–N.** Vessel elements of aerial roots showing thickenings and pits ×250.

described how morpho-anatomical adaptations significantly contribute to the enhanced survival and sustainable growth of plant species, in *Syzygium cumini* Skeels (*Myrtaceae*), an evergreen tree. Morpho-anatomical structures as an adaptive strategy are also described in roots of terrestrial dicotyledonous plants of *Acalypha hispida* Burm f. and *A. wilkesiana* Müll.Arg. (*Euphorbiaceae*), *Bignonia alliaceum* Lam., *Doxantha unguiscatii* Rehd., *Pyrostegia venusta* Baill. (*Bignoniaceae*), *Justicia gendarussa* Burm f., *Pseuderanthemum reticulatum* Radlk, *Sanchezia nobilis* Hook. f. (*Acanthaceae*), *Petrea volubilis* L. (*Verbenaceae*), *Plumeria rubra* form *acutifolia* Woodson (*Apocynaceae*).

Went (1895) reported the dimorphic roots in *Araceae* and it makes as characteristic features. Dimorphic roots have also been reported in many other families like *Arecaceae*, *Commelinaceae*, *Liliaceae*, *Orchidaceae*, *Pandanaceae*, *Poaceae* (Purnell 1960, Jeffery 1967, Gill & Tomlinson 1969, 1971, 1977, Lamont 1972a, b, Jenik 1978, Boke 1979, Dell et al. 1980, Ellmore 1981, Misra & Singh 2000b, Singh 2002).

The other interesting features of these adventitious roots of monocots are the presence of uniseriate epidermis, wide cortex, uniseriate pericycle, polyarch radial vascular bundles, wide pith, lack of secondary growth, endogenous origin of lateral roots, however exception do occur in some epiphytic tropical genera of *Araceae* and *Orchidaceae* and few members of terrestrial monocot families *e.g. Amaryllidaceae*, *Commelinaceae*, *Dioscoreaceae*, *Iridaceae*, *Liliaceae*, *Traccaeae* show the velamen like tissue.

Exodermis is also present in roots of *Citrus, Iris, Orchid, Phoenix, Sansevieria suffruticossa* and *Smilax*. Multiseriate pericycle is also seen in members of *Poaceae* and *Aracaceae*. Scattered vascular elements are present in central region such as *Cordyline* Comm. ex R. Br., *Dracaena* Vand. ex L., *Musa* L., *Pandanus* Parkin. and *Sansevieria suffruticosa* N.E.Br. (now *Dracaena suffruticosa* (N.E. Br.) Byng & Christenh in Global Fl. 4: 67. 2018) (Zimmermann & Tomlinson 1969, 1970, Mauseth 1988, Misra & Singh 2000b). In some monocots like *Iris* Tourn. ex L., *Latania* Comm. ex Juss. *Monestra deliciosa* Liebm., *Phoenix dactylifera* L., *Raphia hookeri* G. Mann & H. Wendl., *Triticum* L., *Zea mays* L. etc. vessel elements are present in the central region of pith. In some monocotyledons like *Cordyline, Dracaena, Musa* members of *Pandanaceae* and *Sansevieria suffruticosa* N.E.Br. in addition to the vascular bundles the phloem strands are also present. Fahn (1982) stated that in majority of vascular seed plants the lenticels are present. The function of the lenticels is associated with gaseous exchange. (Eames & Mac Daniels 1947, Troll 1948, Stover 1951, Boureau 1954, Singh 2002, Singh & Misra 2012, 2015, 2024).

In *Epipremnum aureum*, numerous lenticels are present on the surface of both aerial as well as terrestrial roots. Aerial roots of *Epipremnum aureum* present interesting features like presence of wart like structure outside epidermis, cortex with lysigenous cavities 'V' or 'Y' shaped sclerenchymatous tissue around the phloem and scattered vessels in their pith region.

The development of numerous lenticels, wart like structures on epidermal surface and aerenchyma formation in the cortex, higher number of mixed vessels in pith of aerial roots of *Epipremnum aureum* seems as adaptive morpho-anatomical characters which improve delivery of oxygen to the plant. These structures help to facilitate the metabolic process and sustain against the adverse ecological condition particularly oxygen deficient condition. Many adaptive characters have also been described in aerial roots of number of dicotyledonous plants, *Acalypha hispida* Burm f. and *A. wilkesiana* Müll. Arg. (*Euphorbiaceae*), *Bignonia alliaceum* Lam., *Doxantha unguiscatii* Rehd., *Pyrostegia venusta*

Table 1. Showing comparison of Aerial and Terrestrial roots of *Epipremnum aureum* (Linden & André) G.S. Bunting

Sl. No.	Characters	Aerial Root	Terrestrial Root
1.	Nature	Soft in texture but wart like structures develop on its surface at some places	Soft in texture, warts like structure are absent.
2.	Shape	Tubular, Spinous and flattened	Tubular
3.	Colour	Dark brown	Dull white to light brown
4.	Cuticle	Thick, comes out easily by pressing the root mechanically	Thin
5.	Branching	Usually unbranched, rarely branched	Usually branched
6.	Lenticels	More in number	Less in number
7.	Root hairs	Papillate	Tubular
8.	Chlorophyllous cells	Present	Absent
9.	Air cavities	Small and lysigenous	Absent
10.	Vascular bundles	Polyarch, exarch and protoxylem ranges from 4 to 26.	Polyarch, exarch and protoxylem ranges from 4 to 20.
11.	Sclerenchymatous cells	'V' or 'Y' shaped sclerenchymatous tissue present around the phloem	Absent
12.	Vessel elements in pith	More in number	Less in number

Baill. (*Bignoniaceae*), *Justicia gendarussa* Burm f., *Pseuderanthemum reticulatum* Radlk, *Sanchezia nobilis* Hook.f. (*Acanthaceae*), *Petrea volubilis* L. (*Verbenaceae*), *Plumeria rubra* forma *acutifolia* Woodson (*Apocynaceae*) and *Syzygium cumini* Skeel of *Myrtaceae* (Misra et al. 1997, Misra & Singh 2000 a, b, 2002, 2004 a, b, c, 2005, 2007a, b, 2008a, b, Singh 2002, Singh & Misra 2012, 2015, 2024). These dicotyledonous plants show presence of dimorphic (aerial and terrestrial) roots. However, there are relatively few publications which give an account on the occurrence of aerial roots in dicotyledonous plants.

Aerial roots in plants of *Epipremnum aureum* attach to tree trunks for support and climb higher up to obtain more light by absorbing moisture and nutrients from the environment. The dimorphic roots of *Epipremnum aureum* resembles to the roots of *Monestra deliciosa* Liebm. (Bloch 1944). Although the aerial and terrestrial roots of *Epipremnum aureum* are fundamentally alike and show a large number of interesting morphological and anatomical features, they differ in many characters, as shown in Table 1.

ACKNOWLEDGEMENTS

The authors express their deep sense of gratitude to Late Professor D.D. Pant and Late Professor D.D. Nautiyal, Department of Botany, Allahabad University, Allahabad for constructive suggestions and encouragement during the early phases of study. Authors are thankful to Professor D.K. Chauhan and Late Professor S.P. Tewari of the same Department for their help in various ways. One of the authors (LJS) is grateful to the Director, Botanical Survey of India for constant supports. The authors are also thankful to Dr. R.K. Saxena, Chief Editor, Geophytology and anonymous reviewers for critical comments and suggestions that helped to improve the manuscript. The authors are thankful to scientists and staff of Botanical Survey of India, Andaman and Nicobar Regional Centre, who have always shown readiness for help.

REFERENCES

Arber A.1925. Monocotyledons: A Morphological study, Cambridge

Bailey L.H. 1949. Manual of Cultivated Plants; New York.

Bertrand H. 1884. Loi des surfaces libres. Comptes Rendus de l'Académie des Sciences, Paris 98: 48–51.

Bloch R. 1926. Umdifferenzierungen an Wurzelgenweben nach Verwundung. Berichte der Deutschen Botanischen Gesellschaft 44: 308–316.

Bloch R. 1935. Wound healing in *Tradescania fluminensis* Veli. Annals of Botany 49: 651–670.

Bloch R. 1937. Wound healing and necrosis in air roots of *Phoenix reclinata* and leaves of *Araucaria imbricata*. American Journal of Botany 24: 279–287.

Bloch R. 1941. Wound healing in higher plants. Botanical Review 7: 110–146.

Bloch R. 1944. Developmental potency, differentiation and pattern in meristems of *Monstera deliciosa.* American Journal of Botany 31: 71–77

Bloch R. 1946. Differentiation and pattern in *Monstera deliciosa*. The idioblastic development of the trichoclereids in the air root. American Journal of Botany 33: 544–551.

Boke N.H. 1979. Root glochids and root spurs of *Opuntia arenaria* (*Cactaceae*). American Journal of Botany 66: 1085–1092.

Boureau E. 1954. *Anatomie vegetale,* Vol. 1. Paris.

Byng J.W. & Christenhusz J.M.M. 2018. *Asparagaceae*. In: Christenhusz, J.M.M., F.M. Fay & J.W. Byng (Eds.) The Global Flora. A practical flora to vascular plant species of the world. Special Edition. GLOVAP Nomenclature 1(4). Gateway Ltd., Bradford, pp. 64–67.

Campbell D.H. 1911. The Eusporangiatae. Carnegie Institute Publication No. 140.

Chamberlain C.J. 1935. Gymnosperms Structure and Evolution. The University of Chicago Press, Chicago.

Cheadle V.I. 1941. Investigation of the vascular system in the Monocotyledoneae. *American Philosophical Society* Year Book: 149–152.

Cheadle V.I. 1942. The occurrence and types of vessels in the various organs of the plant in the Monocotyledoneae. American Journal of Botany 29: 441–450.

Cheadle V.I. 1943a. The origin and certain trends of specialization of the vessel in the Monocotyledoneae. American Journal of Botany 30: 11–17.

Cheadle V.I. 1943b. The specialization of vessels in the late metaxylem of the various organs in the Monocotyledoneae. American Journal of Botany 31: 484–490.

Cheadle V.I. 1944. Specialization of vessels within the xylem of each organ in the Monocotyledonae. American Journal of Botany 31: 81–92.

Dahlgren R.M.T. & Clifford H.T. 1982. The Monocotyledons*:* A Comparative Study. New York.

Dell B. Kuo J. & Thomson G.J.1980. Development of proteoid roots in *Hakea obliqua* R. Br. (*Proteaceae*) grown in water culture. Australian Journal of Botany 28: 27–37.

Duthie J.E. 1903–1929. Flora of the Upper Gangetic plain and of the Siwalik and Sub-Himalayan Tracks (Complied by Parker R.N. & Turrill W.B.) 3 Volumes, Calcutta.

Eames A.J. & Mac Daniels L.H. 1947. An Introduction of Plant Anatomy 2nd ed.; New York

Ellmore G.S.1981. Root dimorphism in *Ludwigia peploides* (*Onagraceae*): development of two root types from similar primordia. Botanical Gazette 142: 525–533.

Engler A. 1919. *Araceae* in Das Pflanzenreich Vol. 4: 23A.

Esau K. 1943a. Vascular differentiation in the pear root. Hilgardia 15: 299–324.

Esau K. 1943b. Ontogeny of the vascular bundle in *Zea mays*. Hilgardia 15: 327–368.

Esau K. 1943c. Origin and development of primary vascular tissues in seed plants. Botanical Review 9: 125–206.

Esau K. 1965. Vascular Differentiation in Plants. New York: Holt, Rinehart & Winston

Fahn H. 1982. Plant Anatomy, 4th ed., Oxford.

Gill A.M. & Tomlinson P.B. 1969. Studies on the growth of red mangrove (*Rizophora mangle* L.). 1. Habit and general morphology. Biotropica 1: 1–9.

Gill A.M. & Tomlinson P.B. 1971. Studies on the growth of red mangrove (*Rhizophora mangle* L.) 2. Growth and differentiation of aerial roots. Biotropica 3: 63–77.

Gill A.M. & Tomlinson P.B. 1975. Aerial roots an array of forms and function. In the development and function of roots (ed. JG Torrey and DT Clarkson). London: 237–260.

Gill A.M. & Tomlinson P.B. 1977. Studies on the growth of red mangrove (*Rhizophora mangle* L.) 4. The adult root system. *Biotropica* 9: 145–155.

Giovannozzi U. 1911. Intorno al sughero delle monocotiledoni. *Nuovo Giornale* Botanico *Italiano*. (*Nuova* serie) 18: 5–79.

Gürtler F. 1905. Uber interzellulare Haarbildungen, insbesondere über die sogenannten inneren Haare der *Nymphaeaceen* und *Menyanthoideen*. *Inaug*. Diss. Berlin. 92 pages.

Haberlandt G. 1914. "Physiological Plant Anatomy" (translation of 4th German edition by M. Drmmond). London.

Hutchinson J. 1934. The families of flowering plants. II. Monocotyledons. London.

Jeffrey D.W. 1967. Phosphate nutrition of Australian heath plants. I. The importance of proteoid roots in *Banksia* (*Proteaceae*). Australian Journal of Botany 15: 403–411.

Jenik J. 1978. Roots and root systems in tropical trees: Morphologic and ecologic aspects. In: Tropical Trees as Living System, (eds. P.B. Tomlinson and M.H. Zimmermann) New York.

Kapil R.N. & Rustagi P.N. 1966. Anatomy of the aerial and terrestrial roots of *Ficus benghalensis* L., Phytomorphology 16:

382–386.

Lamont B. 1972a. The effect of soil nutrients on the production of proteoid roots by *Hakea* species. Australian Journal of Botany 20: 27–40.

Lamont B. 1972b. The morphology and anatomy of proteoid roots in the genus *Hakea* Australian Journal of Botany 20: 155–174.

Lierau M. 1888. Ueber die Wurzeln der Araceen. Bot. Jahrb. 9: 1–38

Mauseth J.D. 1988. Plant Anatomy; California.

Misra D.R. & Singh L.J. 2000a. The morphology and anatomy of aerial and terrestrial roots of *Justicia gendarussa.* Recent Trend In. Bot. Res. (Prof. D.D. Nautiyal Commemoration Volume, edited by D.K. Chauhan) 189–202.

Misra D.R. & Singh L.J. 2000b. Anatomical diversity of *Sansevieria suffruticossa*. Bionature 20: 23–45.

Misra D.R. & Singh L.J. 2002. On the morpho-anatomical diversity of roots of *Petrea volubilis* L. National Conference on Biodiversity: Past and Present. The Palaeobotanical Society Lucknow, U.P., India, 47.

Misra D.R. & Singh L.J. 2004a. The morphology and anatomy of aerial and terrestrial roots of *Petrea volubilis* L. Geophytology, 32(1&2): 107–113.

Misra D.R. & Singh L.J. 2004b. The morphology and anatomy of aerial and terrestrial roots of *Pseuderanthemum reticulatum* Radlk. and *Sanchezia nobilis* Hook. f. In: Srivastava, P.C. (ed.) Vistas in Palaeobotany and Plant Morphology, Evolutionary and Environmental Perspective: Professor D.D. Pant Memorial Volume U.P. Offset, Lucknow, pp. 395–407.

Misra D.R. & Singh L.J. 2004c. On the morphology and anatomy of aerial and terrestrial roots of *Acalypha hispida* Burm f. and *Acalypha wilkesiana* Müll.Arg. National Conference on Plants, Microbes and Environment Issue and Challenges, Burdwan, West Bengal, India 82.

Misra D.R. & Singh L.J. 2005. On the morphology and anatomy of aerial and terrestrial roots of *Scindapsus aureus* Engler National Symposium on Biodiversity, Conservation and Sustainable Utilization of Bioresources Allahabad, U.P., India. 74.

Misra D.R. & Singh L.J. 2007a. On the morpho-anatomical diversity of roots of *Syzygium cumini* Skeel. National Seminar on Emerging Trends in Plant Science, Biodiversity, Biotechnology and Environmental Conservation 30th Botanical Conference (I.B.S.) Gwalior, M.P., India. 73.

Misra D.R. & Singh L.J. 2007b. On The morpho-anatomical diversity of roots of *Plumeria rubra* form *acutifolia* Woodson. National Symposium on Biodiversity, Assessment, Conservation and Ecoplanning Allahabad, U.P., India. 89.

Misra D.R. & Singh L.J. 2008a. Aerial roots in some vascular plants: An overview XXXI All India Botanical Conference and International Symposium on Plant Biology and Environment Changing Senario. Allahabad, U.P., India. 263.

Misra D.R. & Singh L.J. 2008b. Studies of aerial roots in dicotyledonous plants Third J & K State Science Congress Jammu, 127.

Misra D.R., Singh L.J. & Nautiyal D.D.1997. On the anatomical diversity of roots of *Sansevieria suffruticosa* Brown. National Symposium on Biodiversity, Conservation and Evolution of Plants, Allahabad, U.P., India. 58.

Ogura Y. 1972. Comparative anatomy of vegetative organs of the pteridophytes. Gebriider Borntraeger, Berlin, Stuttgart.

Pant D.D. 1973. *Cycas* and the *Cycadales*. Central Book Depot., Allahabad.

Pant D.D. 2002. An introduction to gymnosperms, Cycas and Cycadales. Monograph no. 4. Birbal Sahni Institute of Palaeobotany, India.

Pant D.D. & Das K. 1989. Occurrence of noncoralloid aerial roots in *Cycas*. Memoirs of the New York Botanical Garden 57: 56–62.

Pfeiffer N.E. 1937. Anatomical Study of production on application of indolebutyric acid to *Cissue* aerial roots, Contr. Boyee Thomson Inst. Pl. Res. 8: 493–506.

Philipp M. 1923. Über die verkorkten Abschlussgewebe der Monolotylen. *Bibliotheca Bot.* 92: 1–28.

POWO 2024. Plants of the World Online. Facilitated by the Royal Botanic Gardens, Kew. Published on the Internet; http://www.plantsoftheworldonline.org

Purnell H.M. 1960. Studies of the family *Proteaceae*. I. Anatomy and morphology of the roots of some Victorian species. Australian Journal of Botany 8: 38–50.

Sachs J. 1882. Textbook of Botany. (2nd ed.) Oxford.

Schoute I.C. 1902. Zellteilungsvorgiinge. In Kambium Verhandel. Kon. Akd. Wetenschap. Amsterdam. Sect. 2, Deel 9: N. 4.

Schwarz F. 1878. Uber die Entstehung der Löcher und Einbuchtungen an dem Blatte von *Philodendron pertusum* Schott. Sitzungsbor. Akad. Wiss. Wein. (Math.-Nat. KI.) I. Abt.: 367–374.

Singh L.J. 2002. Studies in plant morphology: aerial and terrestrial roots in some vascular plants. D. Phil. Thesis, University of Allahabad, Allahabad, India.

Singh L.J. 2017. *Cycas dharmrajii* sp. nov. (*Cycadaceae*), a new species from the Andaman Islands, India. Nordic Journal of Botany 35(1): 69–76. https://doi.org/10.1111/njb. 01284

Singh L.J. & Misra D.R. 2012. On the morphology and anatomy of aerial and terrestrial roots in some Bignoniaceous genera. Phytomorphology, 62(3 & 4): 145–153.

Singh L.J. & Misra D.R. 2015. Morpho-anatomical diversity of roots of *Syzygium cumini* Skeels (*Myrtaceae*): An adaptive strategy under stress ecosystem. Phytomorphology, 65(1&2): 42–55

Singh L.J. & Misra D.R. 2017. Identity and status of recently described *Cycas pschannae* (*Cycadaceae*) in the Andaman and Nicobar Islands, India. Bionature 37(1): 38–55. https://doi.org/10.1111/njb.01284.

Singh L.J. & Misra D.R. 2020. Reappraisal of the genus *Cycas* L. (Cycadaceae) in Andaman and Nicobar Islands, India. Indian

Journal of Forestry 43(1): 46-57.

Singh L.J. & Misra D.R. 2024 Morpho-anatomical diversity of roots in some *Euphorbiaceae* - *Acalyphoideae* species: An adaptive strategy under stress ecosystem. Journal of Andaman Science Association 29(1): 53–72.

Singh L.J., Ekka G.A., Vivek C.P. & Misra D.R. 2021. Gymnosperms of the Andaman and Nicobar Islands: An Overview (In: eds. L.J. Singh and V. Ranjan – New Vistas in Indian Flora, Bishen Singh Mahendra Pal Singh, Dehra Dun, India 1: 265–278.

Solereder, H. 1919. Beiträge zur Anatomie der Araceen. Beih. Bot. Centralblatt 36(1): 60–77.

Solereder H. & Meyer, F.J. 1928. Systematische Anatomie der Monokotyledonen. Heft 3.

Stover E.L. 1951. An Introduction of the Anatomy of Seed plant; D.C. Heath Boston.

Taylor T.N. & Taylor E.L. 1993. The Biology and Evolution of Fossil Plants; Prentice Hall Englewood Cliffs, New Jersy.

Troll W. 1948. Allgemein Botanik, f. Enke, Stuttgart.

Tschirch A. 1885. Beitriige zur Kenntnis des mechanischen Gewebesystems der Pflanzen.

Turner L.M. 1934. Anatomy of aerial roots of *Vitis rotundifolia,* Bot. Gaz. 96: 367–371.

Van Tieghem P.H. 1866. Surla structure des Aroidees. Ann. Sci. Nat. 5 ser. Bot. 6: 72–210.

Van Tieghem P. & Douliot H. 1886. Sur la polystelie. Annls. Sci. nat. Bot. 3: 275–322.

Went F.A.F.C. 1895. Uber Haft-und Nahrwurzel bei Kletterpflanzen und Epiphyten Ann. Jard. Bot. Buitenz. 12: p. 1 et seq.

Willis J.C. 1973. A Dictionary of the Flowering Plants & Ferns 8th ed. (revised by H.K. Airy Shaw) Press London.

Zimmermann M.H. & Tomlinson P.B. 1969. The vascular system of the axis of *Dracaena fragrans* (*Agavaceae*). Distribution and development of primary strands. J. Arnold Arbor. 50: 370–383.

Zimmermann M.H. & Tormlinson P.B. 1970. The vascular system of the axis of *Dracaena fragrans* (*Agavaceae*). Distribution and development of secondary strands. J. Amold Arbor, 51: 478–481.

Zimmerman M.H., Wardrop A.B. & Tomlinson P.B. 1968. Tension wood in aerial roots of *Ficus bengamina* L., Wood Sci. Technol. 2: 95–104.