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Morpho-anatomical Diversity of Roots in Some Euphorbiaceae- Acalyphoideae species: An Adaptive Strategy under Stress Ecosystem

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Abstract

The paper describes the comparative morphology and anatomy of dimorphic roots of *Acalypha hispida* Burm f. and *A. wilkesiana* Muell.-Arg. with special reference to an adaptive strategy. The roots are dimorphic in nature showing aerial as well terrestrial roots. The aerial roots differ from terrestrial roots by its ephemeral nature, reddish pink to brownish colour with plenty of lenticels, schizo-lysigenous cavities and polyarch condition. Origin and occurrence of aerial roots with plenty of lenticels, wider intercellular spaces in cortex indicate high adaptive strategy under stress ecosystem for survival and sustainable growth. An adaptive significance of morpho-anatomical features in dimorphic roots has been evaluated. This seems to be the first report from Andaman and Nicobar Islands.

Key words: *Adaptation; Environmental Stress; Euphorbiaceae, Morpho-anatomical Diversity; Roots.*

Introduction

Acalypha is a well recognized most species-rich genus in the in the subfamily Acalyphoideae of the family Euphorbiaceae. It was originally described by Linnaeus in 1753. Thereafter, the genus *Acalypha* L. has been studied by various workers (Alvarez Filho, 1977; Seberg, 1984; Levin *et al.,* 2005; Tokuoka 2007; Wurdack & Davis 2009; Sagun *et al.,* 2010; Montero-Munoz *et al.,* 2018, 2020; Turland *et al.,* 2018; Cardiel 1995, 2022; Geoffrey *et al.,* 2022). The genus *Acalypha* is distinct from other genera of the family by having combination of decorative unique foliage and floral characteristics especially attractive inflorescences and easily recognized in the field. It comprises ca 500 species worldwide in the tropics, subtropics, and temperate regions (Cardiel, 2022). Most of the species are grown for their decorative potential and also used in the various traditional system of medicine. In India two species of *Acalypha* viz. *Acalypha hispida* Burm f. and *Acalypha wilkesiana* Muell.-Arg. are cultivated as a ornamentals for their decorative foliage and alluring inflorescences (Singh and Ranjan, 2021). These species are best used as an accent plant as the very showy leaves make them stand out.

The studies on the genus *Acalypha* are mostly confined on the taxonomy, phytogeny, phytochemical and morphometric analysis but morpho-anatomical studies in family Euphorbiaceae have not drawn much attention. Although taxonomic significance of anatomical characters has also described in higher vascular plants by various authors (Jeffrey, 1917; Metchalfe and Chalk 1950; Metcalfe, 1960; Mauseth, 1988; Singh, 2002; Singh and Misra 2012, 2015). The morpho-anatomical traits also expressed in different organs at different levels is the reason for adaptation to stress condition and plays a significant role in coordination and function of plant body when considering ecological trends in the evolution (Singh, 2002; Brodribb. 2009; Singh and Misra, 2015). Every plant body organ is ideally designed to fulfill metabolic and physiological processes in specific environmental conditions and its survival depends upon the ability to harmonize structure and function to withstand desiccation without permanent damage (Maximov, 1931). Root is considered as a fundamental unit of plant body. It is morphologically, ontogenetically and physiologically different from stems and exist much variations among the vascular plants which is related to ecological conditions of habitat of plants (Jeffrey, 1917; Metchalfe and Chalk

1950; Metcalfe, 1960; Mauseth, 1988; Singh, 2002; Misra and Singh, 2004; Singh and Misra 2012, 2015).

The earlier reports about the description of morphology and anatomy of roots in family Euphorbiaceae belonging to the dicotyledons are mentioned by Holm (1911, 1924); Griebel (1922); Reiche (1923); Vischer (1923); Quisumbing (1927); Parija & Misra (1933); Metcalfe & Chalk (1950) and Singh (2002). Besides it a lot of work has also been done on the axes and leaves of the family Euphorbiaceae but no detailed accounts of the root are available about the family Euphorbiaceae except in *Bridelia pubescens*, *Euphorbia corollata*, *Euphorbia radians*, *Manihot utillissima* and *Stillingia sylvatica* (Metcalfe & Chalk, 1950). Therefore, in the present study, an attempt has been made to describe morpho-anatomical diversity of roots of species of *Acalypha* L. (Euphorbiaceae) viz.: *Acalypha hispida* Burm f. and *Acalypha wilkesiana* Muell Arg. as an adaptive strategy under stress ecosystem. A preliminary account of the morpho-anatomical diversity of *Acalypha* has already been reported by Misra & Singh (2004).

Material and Methods

The aerial and terrestrial roots of *Acalypha hispida* Burm f. and *Acalypha wilkesiana* Muell.-Arg. of Euphorbiaceae were collected from diverse localities of Allahabad district during the months of July to November from Roxburgh Botanical Garden of Botany Department, University of Allahabad, Allahabad and some private gardens of the city. Soon after the onset of the first monsoonic rains, the aerial roots are seen arising luxuriantly in these plants. These roots survive only for a limited span of time and therefore they could be rightly called as an ephemeral in nature. To verify the identity of species, critical analysis of morphological characters was carried out by comparing our collections with the herbarium specimens housed in Indian herbaria and consulted the relevant literature. i.e. Hooker (1872-1897); Heinig (1899); Duthie (1903-1929); Bailey (1949); Hutchinson (1959); Graf (1973); Willis (1973). The roots were thoroughly washed in running water and were fixed in F.A.A. The external morphology, of these roots was studied by a new technique devised by Misra and Singh (2000). Microscopic studies of both fresh and fixed materials were studied by cutting free hand as well as microtome sections and maceration was done of these roots to study their tracheary elements. The method of microtomy and dehydration was adopted after Johansen (1940) and maceration technique was done by Jeffrey (1917); Johansen (1940) and Jane (1956) methods. Presence of cut in the roots was tested with Sudan IV and other microchemical test like lignin and starch were made by phloroglucinol and Iodine solutions respectively. The terminology used in the present text is already mentioned in previous chapters.

Results

External Morphology

Acalypha hispida Burm. f. and *Acalypha wilkesiana* Muell. - Arg. belongs to the family Euphorbiaceae of dicotyledons. The stems of both species have nodes and internodes with leaves. The leaves of *A. hispida* are coarsely toothed, green or yellowish broadly ovate, long, acute or acuminate rounded at base. Unlike that of *Acalypha hispida*, leaves of *Acalypha wilkesiana* are dentate, bronzy green variously mottled with shades of red and purple colours. The plants show dimorphic roots, aerial as well as terrestrial roots. (Fig**.** 1A; 3A; 5A; 7A & 10A-D). Presences of dimorphic roots in both species have been reported for the first time in the present study. In both species external morphology of aerial as well as terrestrial roots are identical. In both species aerial roots originate during the rainy season from stem and these are forming bunches over them (Fig. 1A; 5A &10A-D). These roots survive only for a limited span of time from two to five months. Thereafter these ephemeral roots die. Both aerial and terrestrial roots are positively geotropic and show the presence of root caps, root hairs and lenticels. Aerial roots are delicate in texture, rarely branched, white or dull white in colour and size ranges 0.5 mm to 3.0 mm in diameter where as terrestrial roots of both species are woody in nature, usually branched and light brown to grey in colour. The branches of roots may be equal or unequal and can be seen in several orders in terrestrial roots. (Fig. 3A & 7A).

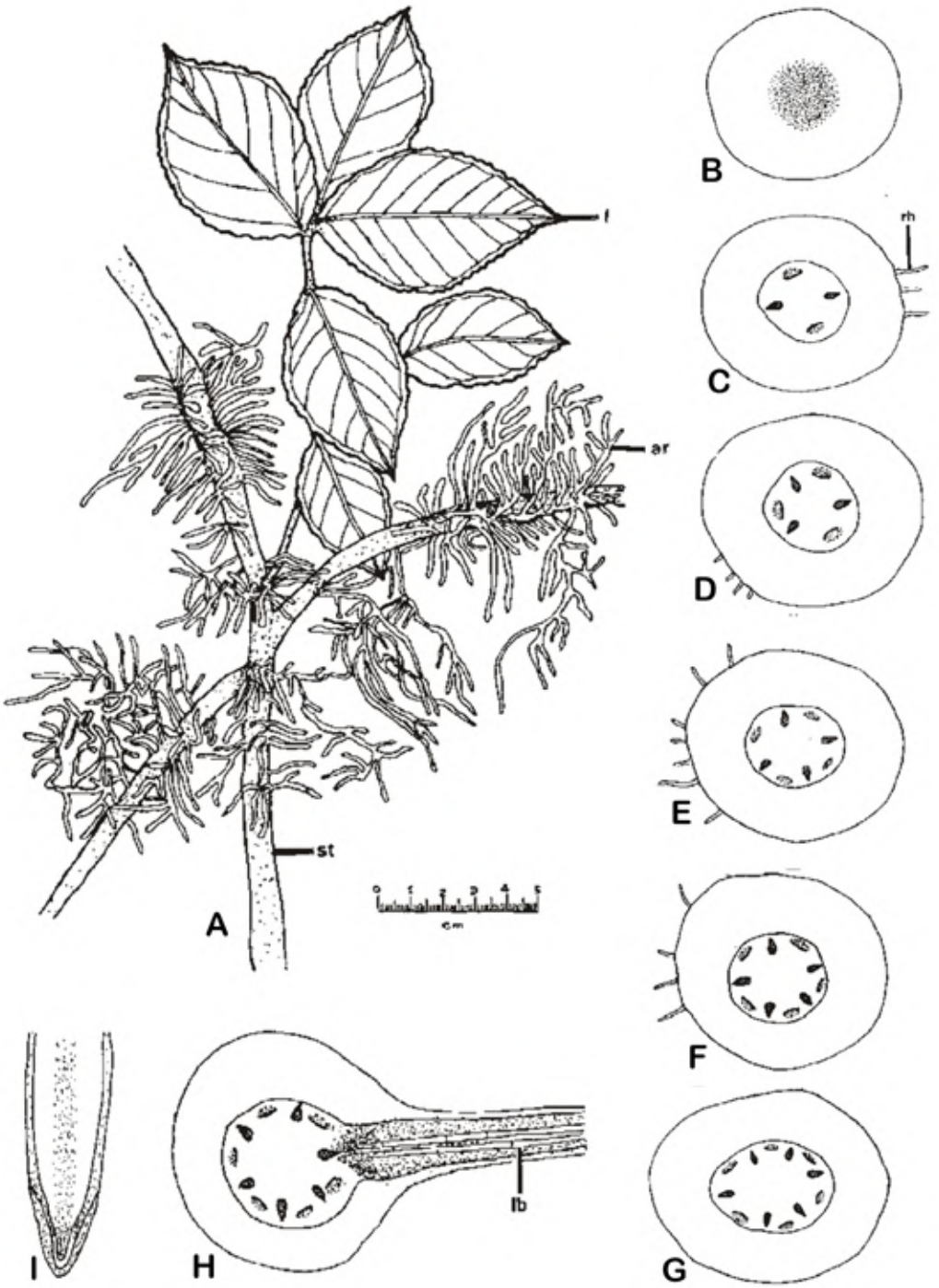

Fig.1. Acalypha hispida: A: A Twig with aerial roots; B-G: Topographic sketches of transverse sections of aerial root at different selected levels starting from apex to bases x 30; H: T.S. of old aerial roots showing lateral branching x 30; I: L.S. of root tip of aerial root x 30. (ar-aerial root, l-leaf, lb-lateral branching, rh- root hair, st-stem).

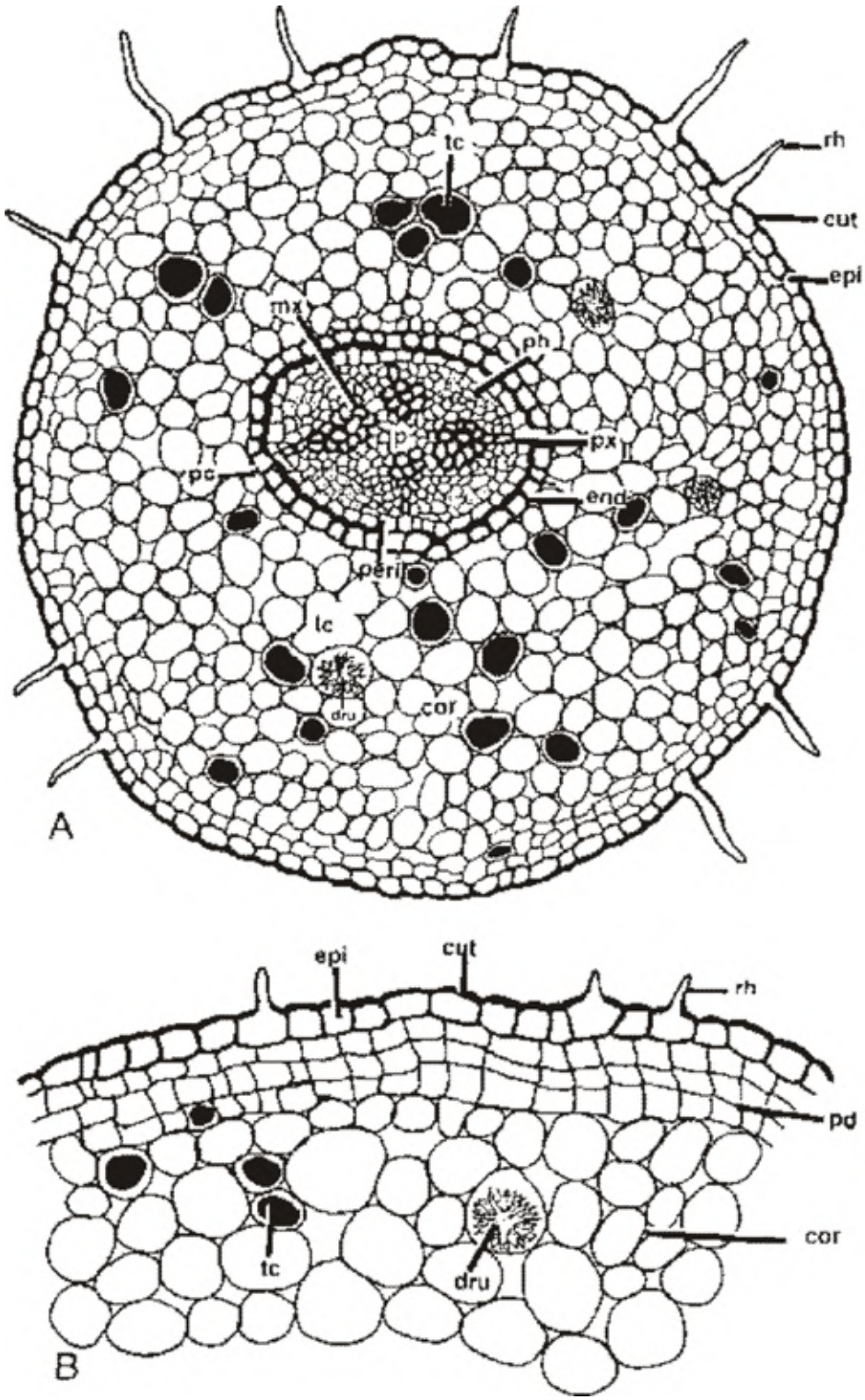

Fig.2. Acalypha hispida: A: T.S. of young aerial root showing cellular details x 90; B: Enlarged portion of outer region of aerial root x 100. (cor-cortex, cut-cuticle, dru-druses, end-endodermis, epi-epidermis, lc- lysigenous cavity, mx-metaxylem, p-pith, pc-passage cell, pd-periderm, peri-pericycle, ph-phloem, px- protoxylem, rh- root hair, tc- tannineferous cell).

Anatomy

In transaction the dimorphic roots of *Acalypha hispida* and *Acalypha wilkesiana* show the single layered epidermis covering a cortical and vascular region (Fig. 2A-B; 4A-B; 6A; 7A;10E; G-H & 11G). The uniseriate layer of epidermis is composed of tightly set cells with cuticularized outer walls, but the cuticle is usually absent in region of root hairs. Root hairs are papillate as well as long, tubular and unicellular in nature. **(**Fig.1C-F; 2A-B; 3C-D, F; 4B; 5D-E; 6A; 7C & 11G). The root hairs arise as a small protuberance from the epidermal cells. In older roots the epidermis is interrupted with numerous lenticels. (Fig.2A-B; 4B; 6A; 8B & 11F).

Next to epidermis the cortex occurs and it represents the extra-stellar ground tissue (Fig. 2A; 6A; 10E, G-H; 11E & G); it consists of unspecialized, round or polygonal parenchymatous cells with conspicuous intercellular spaces (Fig. 2A-B; 6A; 10E-F, H & 11A, D). The cells of cortex show large number of intercellular spaces and schizo-lysigenous cavities. These are present in both aerial as well as terrestrial roots. The cells of the cortex are often packed with crystals like druses. They are spherical or prismatic in shapes. (Fig. 2A-B; 4A; 6A; 8B; 10E-G &11E). It is composed of calcium oxalate. Some cortical cells are filled with tannin in the roots of both species (Fig.2A-B; 4A; 6A; 8B; 10E-G &11E). The cortical region of aerial roots is composed of 3 to 15 cells in thickness; where as in terrestrial roots cortex show 4 to 9 cells in thickness.

Next to the cortex is an endodermis. It consists of compactly arranged barrel shaped cells with suberized casparian thickenings (Fig.2A; 6A-B & 10E). Passage cells often occur opposite to the protoxylem strands these passage cells should be helping for absorption of water and other solutes from root hairs via cortical cells.

Next to an endodermis thin walled single layer of parenchymatous layer of the pericycle is present. This nonvascular tissue is the seat of origin of endogenous lateral roots (Fig. 1H; 3F; 5F; 7F &10H). The cells of pericycle region appears meristematic in nature (Fig. 2A; 6A-B & 10E).

The central region is clearly demarcated from the cortex due to presence of endodermis with that of central part of roots of both species and it is represented by vascular region and pith. The exarch, centripetal vascular bundles are radial, xylem and phloem occurs in separate patches arranged in alternate radii. (Fig.1C-H; 2A; 3C-F; 5C-F; 6A; 7C-F & 10E). The vascular bundles range from 4 to 6 in aerial roots of *Acalypha hispida* and 3 to 4 in *Acalypha wilkesiana* where as 2 to 4 in terrestrial roots of *Acalypha hispida* and *Acalypha wilkesiana*. The central parts of aerial roots of both species are occupied by small pith, and it is composed of parenchymatous cells, where as it is absent in terrestrial roots of both species.

The dimorphic roots of both species show secondary growth. The secondary growth is well developed in terrestrial roots than their aerial roots (Fig.3E; 4A-B; 7E-F; 8A; 10G & 11E). All cells of the cambium ring except in the region of protoxylem become actively meristematic and cut off more rapidly towards the inner side and slowly towards the outer side, with the result amount of secondary xylem formed towards the inner side is comparatively more than the secondary phloem on the outer side. The cambium cells situated above the protoxylem cut off thin walled parenchymatous cells extending up to the secondary phloem. These are known as medullary rays and these rays are uni-seriate in nature.

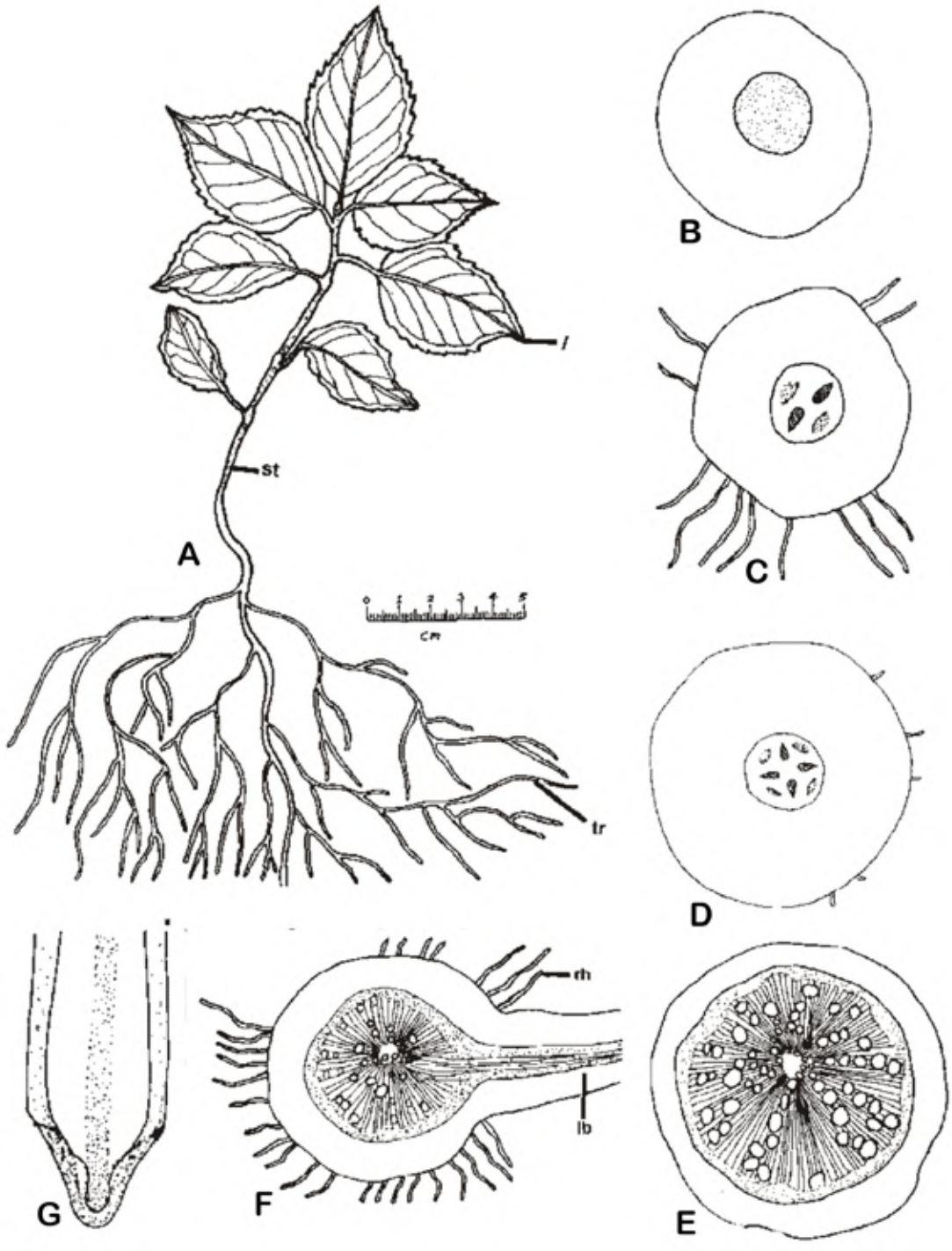

Fig.3. Acalypha hispida: A: External Features of plant with terrestrial roots; B-E: Topographic sketches of transverse sections of terrestrial roots at different selected levels from apex to base x 30; F: L.S. of root tip of terrestrial root x 30; G: T.S. of terrestrial root showing endogenous lateral branching x30. (ar-aerial root, l-leaf, lb-lateral branching, rh-root hair, st-stem, tr–terrestrial root).

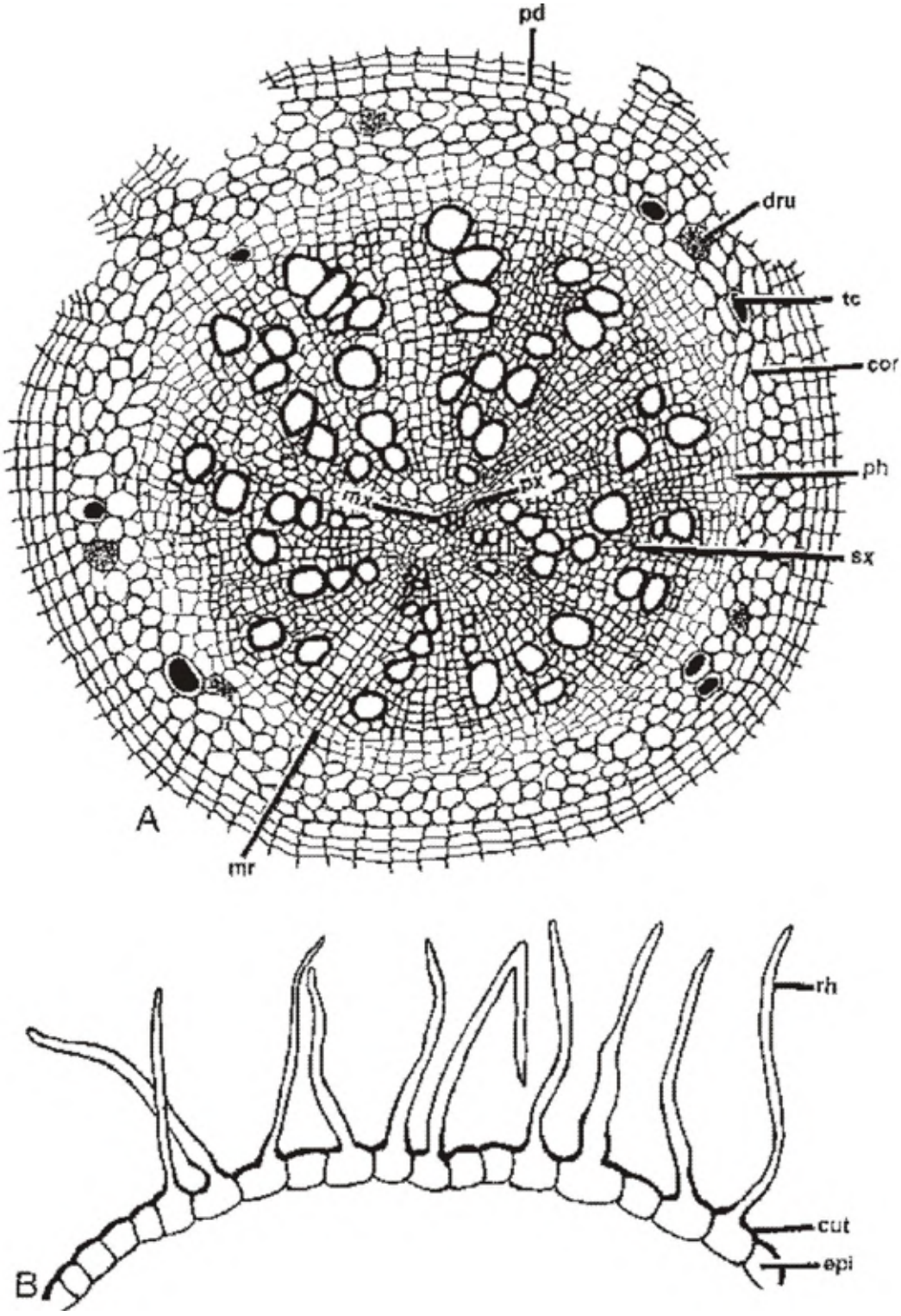

Fig.4. Acalypha hispida: A: T.S. of terrestrial root showing cellular details x 10; B: Part of the terrestrial root in T.S. showing magnified view of epidermis with root hairs x150. (cor- cortex, cut- cuticle, dru- druses, epi- epidermis, mr- medullary rays, mx- metaxylem, p-pith, pd- peridermph- phloem, px- protoxylem, rh- root hair, sx- secondary xylem, tc- tannineferous cell).

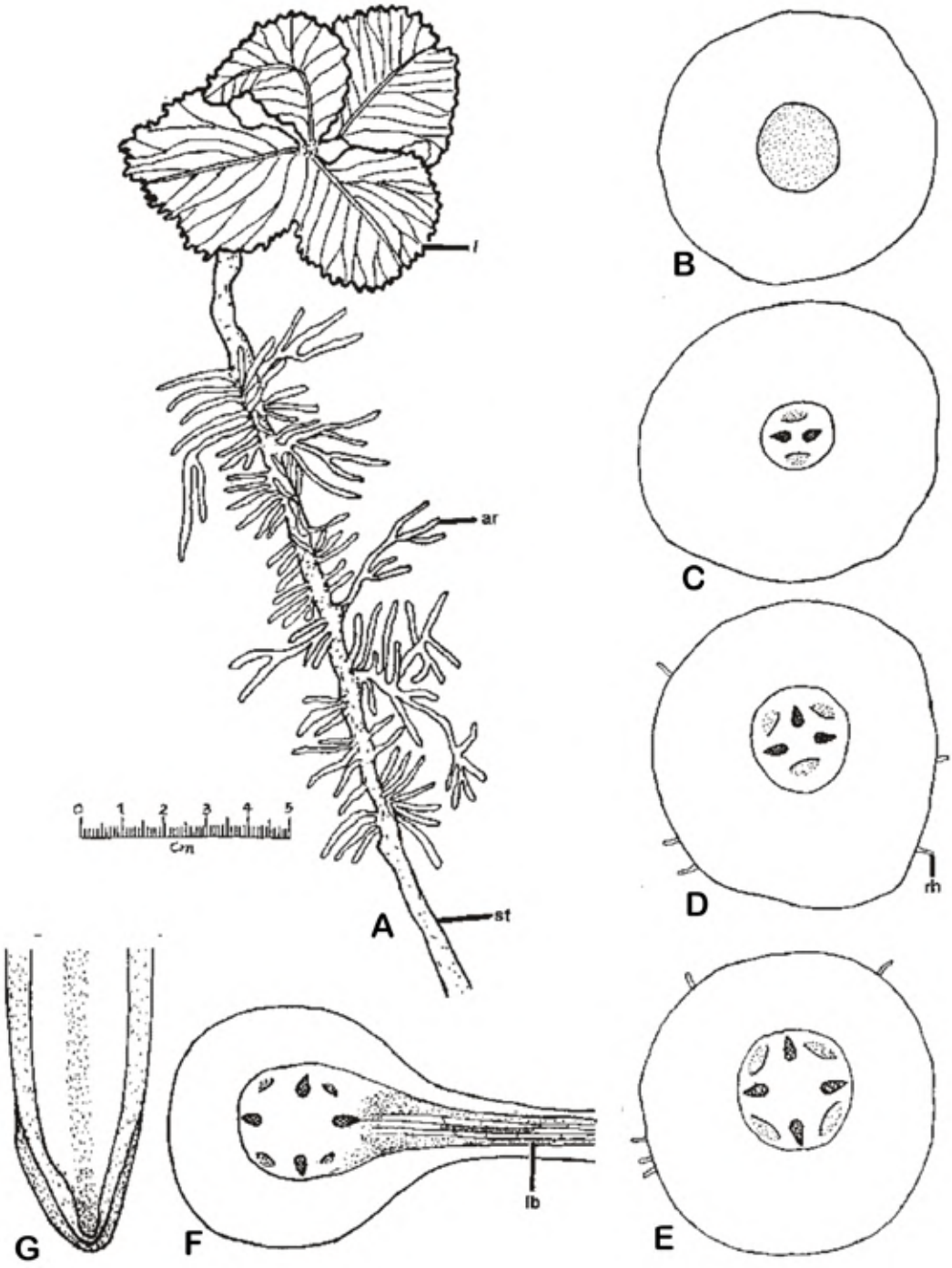

Fig.5. Acalypha wilkesiana: A: A Twig with aerial roots; B-E: Topographic sketches of transverse sections of aerial root at different selected levels from apex to base x 30; F: T.S. of aerial root showing endogenous lateral branching x 30; G: L.S. of root tip of aerial root x 30. (ar-aerial root, l-leaf, lb-lateral branching, rh- root hair, st-stem).

The tracheary elements of terrestrial and aerial roots of both species consist of tracheids and vessels. The size and form of the tracheary elements vary greatly in these dimorphic roots (Fig.9A-T). The tracheids are simple, imperforated, elongated and tapered at both ends and their secondary walls show scalariform thickenings as well as simple and with bordered pits. Their size vary from 550 µm - 1250 µm long x 11 µm - 33 µm in wide in terrestrial roots and 90 µm - 580 µm long x 11 µm - 27 µm in wide in aerial roots. Aerial as well as terrestrial roots show vessel elements. The vessels of aerial roots are relatively short than their terrestrial roots measuring 80 µm - 985 µm long x 22 µm - 60 µm wide in terrestrial roots and 80 µm - 325 µm long x 22 µm – 45 µm wide in aerial roots. The vessel elements are perforated having wide lumen than their tracheids. Perforations are either circular or elliptical in out line and their size rang from 22 µm - 75 µm in length and 22 µm - 55 µm in width in terrestrial roots and 11µm - 60 µm in length and 22 µm - 40 µm in width in aerial roots. Perforations may be present at both ends or only at distal or proximal ends. The secondary walls of vessels show characteristic scalarifrom thickenings and bordered pits. Simple pits are also present in few vessel members. The pits are multiseriate and sub-opposite or alternate.

Morpho-Anatomical Adaptations

Plant of *Acalypha hispida* and *A. wilkesiana* shows morpho-anatomical adaptation under stress condition. The aerial roots are usually produced during the rainy season which was grown under dark and excessive moisture habitat. This excessive moisture indicates oxygen deficit condition. Under this condition, the plant shows origin of aerial roots with plenty of lenticels, and wider intercellular spaces and aerenchyma formation in the cortex of dimorphic roots. In these roots the epidermis is often interrupted by a large number of lenticels and to establish a connection with the exterior environment which enhanced development of internal gaseous exchange and facilitates convey of oxygen from shoots to terrestrial roots. In addition, the plant also adapts anatomically with large number of schizo-lysigenous cavities and wider intercellular spaces in the cortical region under stress condition which improved delivery of oxygen to the plant. This helps to sustain and facilitate the metabolic process through lenticels of aerial roots. During field study it was observed that the aerial roots are dies out on offset of rainy season, it indicates an ephemeral in nature of aerial roots. All the above mentioned special traits s might that allow a plant to survive in a habitat under stress climatic conditions.

Discussion

Plant body develop a suite of morpho-anatomical and physiological responses in order to deal with unambiguous environmental conditions imposed by various factors as recently described in the account of Singh and Misra (2015). Every plant body organ has ideally designed morpho-anatomical structure to fulfill vital and physiological processes in specific environmental conditions which enhanced the ability to survive without any damage (Maximov, 1931). Plant of *Acalypha hispida* and *A. wilkesiana* belong to dicotyledon which show a number of interesting characters viz. development of ephemeral aerial roots with plenty of lenticels during rainy season under dark and humid climate condition and cortex with wide inter cellular spaces which indicates a suite of morphological, anatomical adaptive strategy to fulfill metabolic and physiological processes for survival under stress environmental conditions. These taxa representing the first repot of occurrence of aerial roots in the family Euphorbiaceae. However, occurrence of aerial roots is considered as a characteristic feature of monocots (Gill and Tomlinson, 1975; Singh, 2002; Singh and Misra, 2012, 2015). On the contrary, occurrence of aerial roots is scanty in dicotyledonous plants which includes *Bignonia alliaceum* Lam., *Doxantha unguis-cati* Rehd., *Justicia gendrrussa* Burm f., *Petrea volubilis* L., *Plumeria rubra* forma *acutifolia* Woodson, *Pseuderanthemum reticulatum* Radlk, *Pyrostegia venusta* Baill., *Sanchezia nobilis* Hook. f., *Syzygium cumini* Skeels which show morpho-anatomical adaptive strategy under stress environmental conditions where lysigenous cavities abundantly occur in the central region of the cortex (Misra *et al.,* 1997; Misra and Singh 2000 a, b, 2002, 2004 a, b, c, 2005; 2007a, b; 2008 a, b; Singh, 2002; Singh and Misra, 2012, 2015).

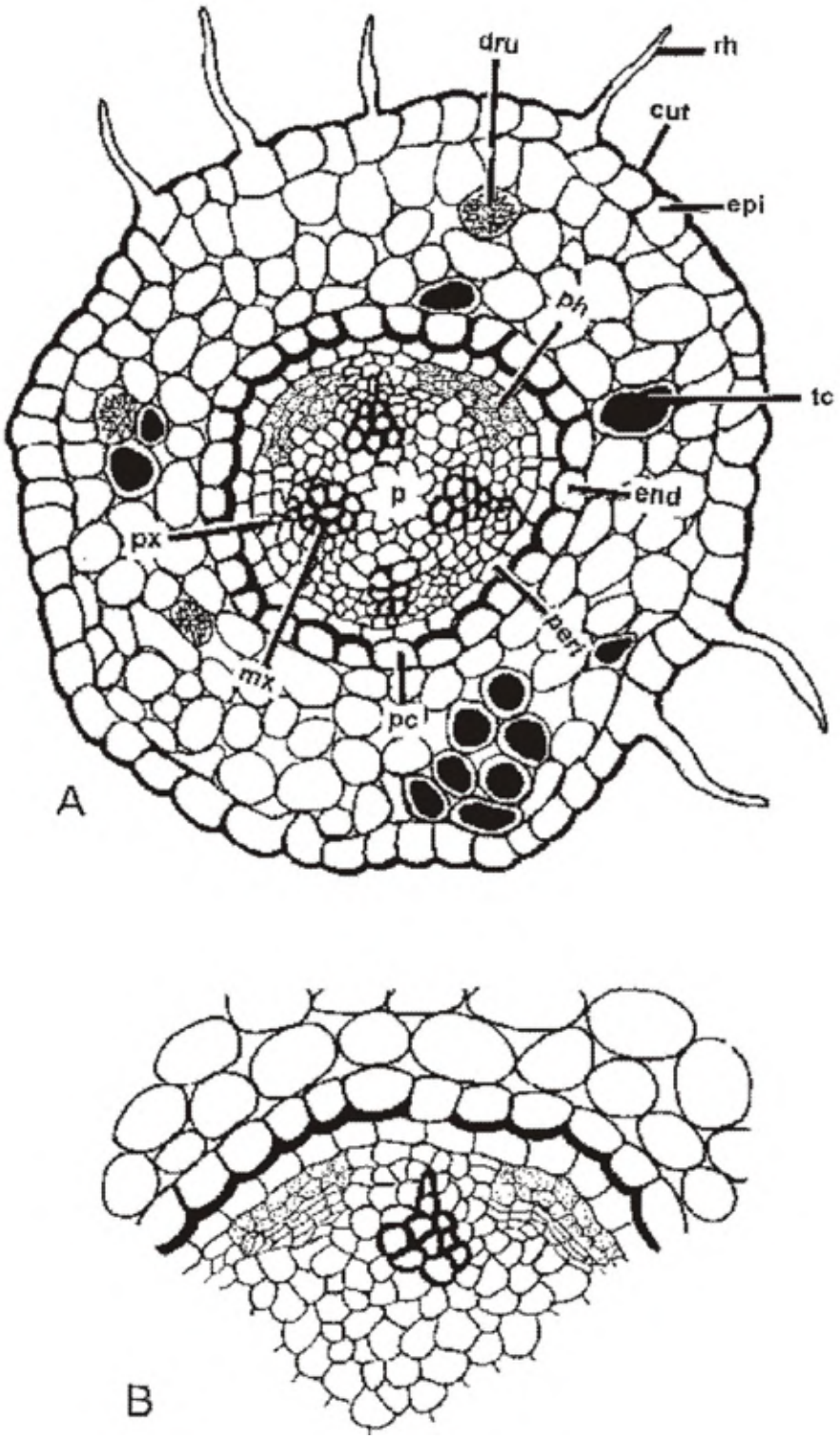

Fig.6. Acalypha wilkesiana: A: T.S. of young aerial root showing cellular details x 100; B: Part of the aerial root showing magnified view of inner cortex, endodermis, per-cycle and vascular bundles x 100. (cut-cuticle, dru-druses, end-endodermis, epi-epidermis, mx-metaxylem, peri- pericycle, p-pith, pc-passage cell, ph-phloem, px-protoxylem, rh-root hair, tc- tannineferous cell).

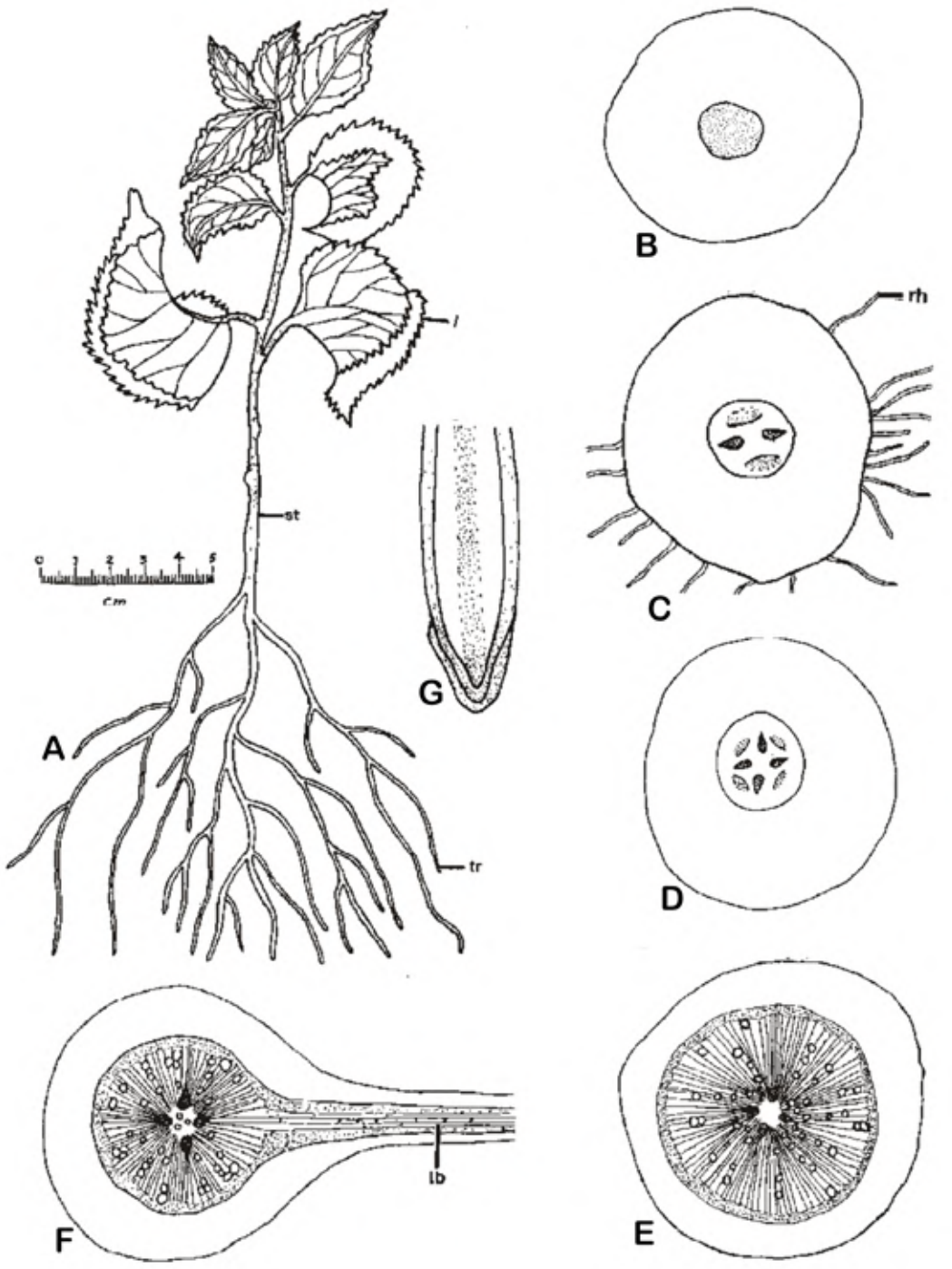

Fig.7. Acalypha wilkesiana: A: External feature of young plant with terrestrial roots; B-E: Topographic sketches of transverse sections of terrestrial root at different selected levels from apex to base x 30; F: T.S. of terrestrial root showing endogenous lateral branching x 30; G: L.S. of root tip of terrestrial root x 30. (ar-aerial root, l-leaf, lb-lateral branching, rh-root hair, st-stem, tr–terrestrial root).

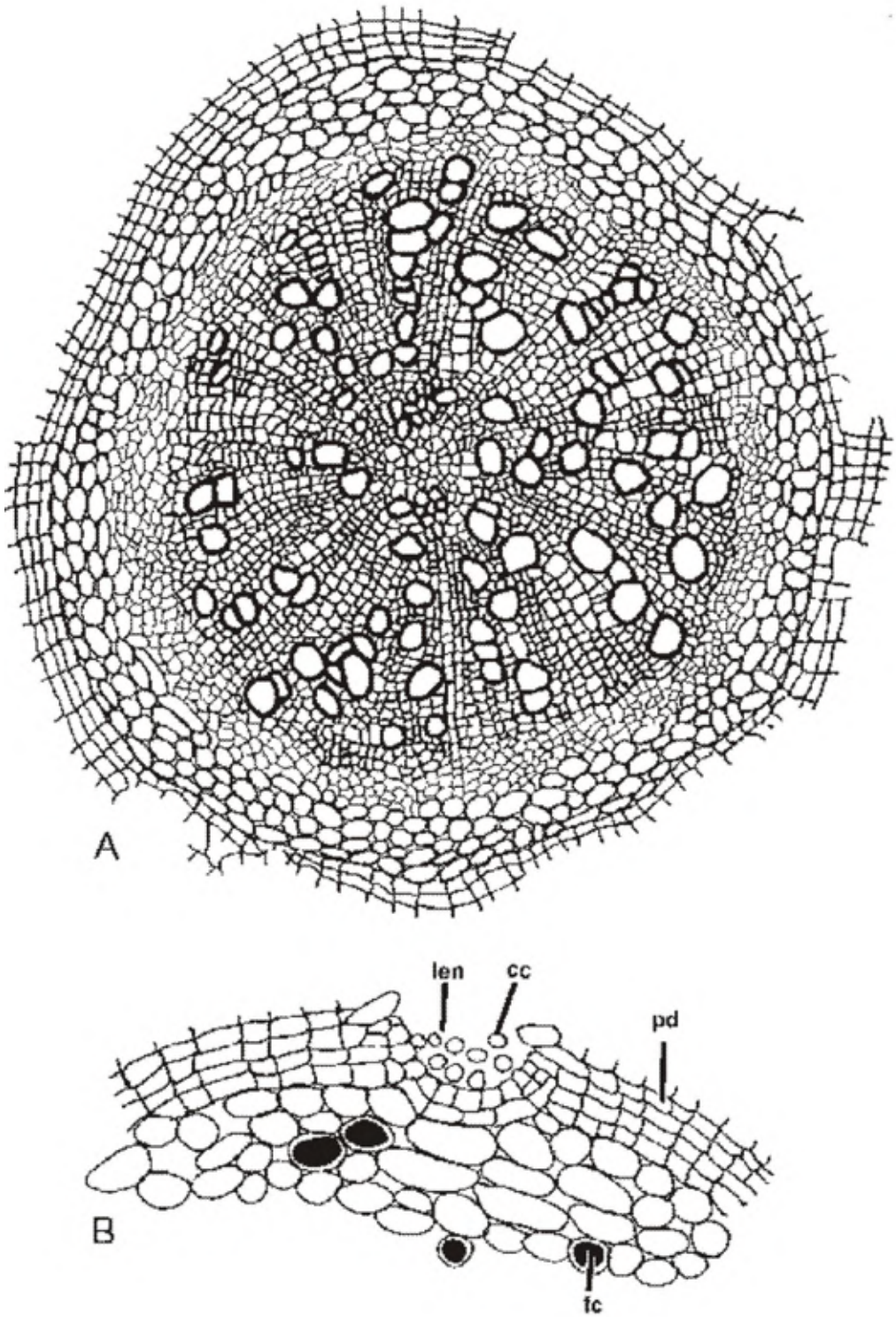

Fig.8. Acalypha wilkesiana: A: T.S. of old terrestrial root showing cellular details x 100; B: Outer part of terrestrial root in T.S. showing magnified view of periderm, lenticels and outer cortex x 150. (len-lenticel, cc- complimentary cells, pd-periderm, tc- tannineferous cell)

Although, occurrence of abundant aerenchyma is a common in plants of aquatic and moist habitats (Weaver, 1920; Maximov, 1931; Hasman & İnanç, 1957; Katayama, 1961; Drew, 1983; Laan *et al.,* 1989; Boris, 1997; Vartapetian and Jackson, 1997; Brodribb, 2009; Ejiri *et al.* 2020; Hayden & Hayden, 2000) but these plant species are strictly terrestrial in nature. Morpho-anatomical account by Singh & Misra (2015) revealed that the morpho-anatomical adaptive strategy (eg. especially development of aerial roots with plenty of lenticels and schizo-lysigenous cavities in cortex) is induced by poor aeration in plants which enhanced development of internal gaseous exchange and facilitates convey of oxygen from shoots to terrestrial roots.

Here we describes for the first time the comparative morphology and anatomy of aerial and terrestrial roots of *Acalypha hispida* and *A. wilkesiana* in great detail with special reference to an adaptive strategy. Roots often show consistent features than their divergent shoots. This is perhaps due to their different, environments where the two structures grow differently. However, anatomically roots show much variability. (De Bary 1884; Solereder, 1908; Stevens, 1916; Jeffrey, 1917; Arber, 1925, 1950; Weaver, 1926; Stromberg, 1937; Eames and Mac Daniels, 1947; Stover 1951; Bailey 1954; Metcalfe 1960; Esau 1965a, b; Troll, 1967; Guttenberg, 1968; Foster and Gifford, 1973; Gill and Tomlinson, 1975; Fahn, 1982, and 1997; Mauseth, 1988; Misra and Singh, 2000 a, b). This variability in many cases may be related to the adaptation and function of these roots. Aerial roots of *Acalypha hispida* and *Acalypha wilkesiana* are soft, thread like and almost uniform in thickness and the terrestrial roots are woody and normal in shape. The texture and shape of roots vary considerably in various genera of Euphorbiaceae. The roots of *Stillingia sylvatica* are fusiform in shape (Holm 1911) and the roots of *Euphorbia radians* and *Manihot utillissima* are fleshy in texture.

In Euphorbiaceae, the anatomical character exhibit a wide range of variations in correlation with the diversity of habit and no important character occurs through out the numerous tribes in to which family is divided. (Solereder, 1908; Metcalfe and Chalk, 1950) Modified aerial roots with determinate growth may become prominent spines or thorns in number of genera of Euphorbiaceae family like *Bridelia pubescens* (Parija and Misra, 1933) where as aerial roots of *A hispida* & A. *wilkesiana* are not modified in the root thorns. Root thorns are also present in number of other dicotyledonous families like Burseraceae, Irvingiaceae, Guttiferae, Loganiaceae, Stercullariaceae. (Scott and Wager, 1897; Jenik and Harris, 1969; Mc Arther and Steeves, 1969; Uhl and Moore, 1973; Gill and Tomlinson, 1975) Roots Thorns grow best in a humid atmosphere and stimulated by the absence of light, their maximum development being attained if they are covered in soil. Modified aerial roots of *Bridelia pubescens* are polyarch in nature where as presently investigated aerial roots are tetrarch to hexarch in nature Laticiferous canals are present in the secondary cortex of roots of *Euphorbia corollata* and *Stillingia sylvatica* (Holm, 1911, 1924) According to Quisumbing (1927) the laticiferous vessels also occur in the pith, leaves and roots even in seedling plants, where as it is absent in roots of *A. hispida* & A. w*ilkesiana.* Pith is absent in terrestrial roots of *A. hispida* and *A. wilkesiana* where scanty pith is present in the aerial roots of both presently investigated species. Pith is also absent in the members of Euphorbiaceae family like *Stillingia sylvatica*. (Holm, 1911).

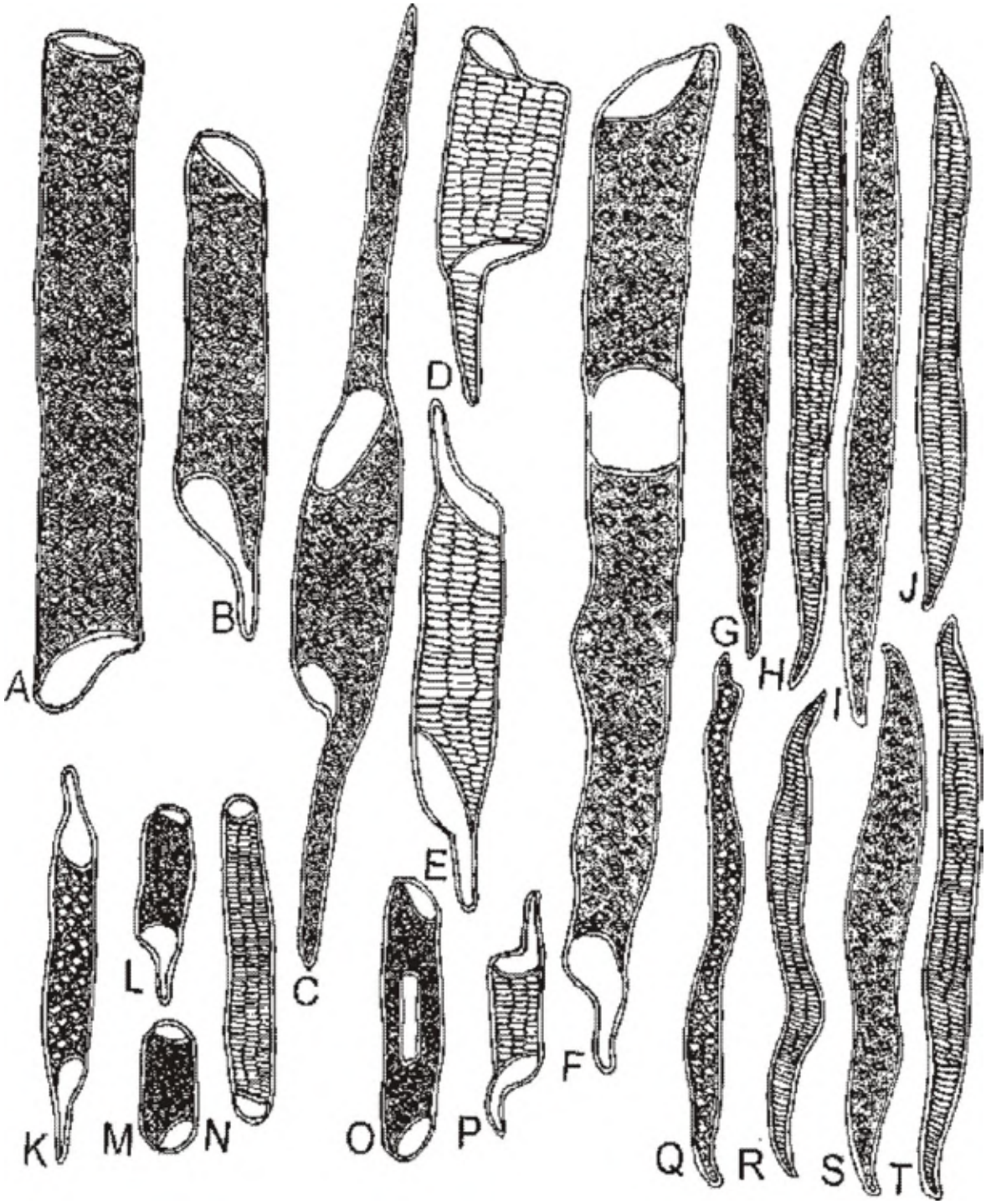

Fig.9. Tracheary elements: A-C: Vessel elements of terrestrial roots of *A. hispida* showing thickenings and pits.x100; D-F: Vessel elements of terrestrial roots of *A. wilkesiana* showing thickenings and pits x100; G-H: Tracheidial elements of terrestrial roots of *A hispida* showing thickenings and pits x 100; I-J: Tracheidial elements of terrestrial roots of *A. wilkesiana* showing thickenings and pits x100; K-M: Vessel elements of aerial roots of *A. hispida* showing thickenings and pits x 100; N-P: Vessel elements of aerial roots of *A. wilkesiana* showing thickenings and pits x100; Q-T: Tracheidial elements of aerial roots of *A. hispida* showing thickenings of pits x100.

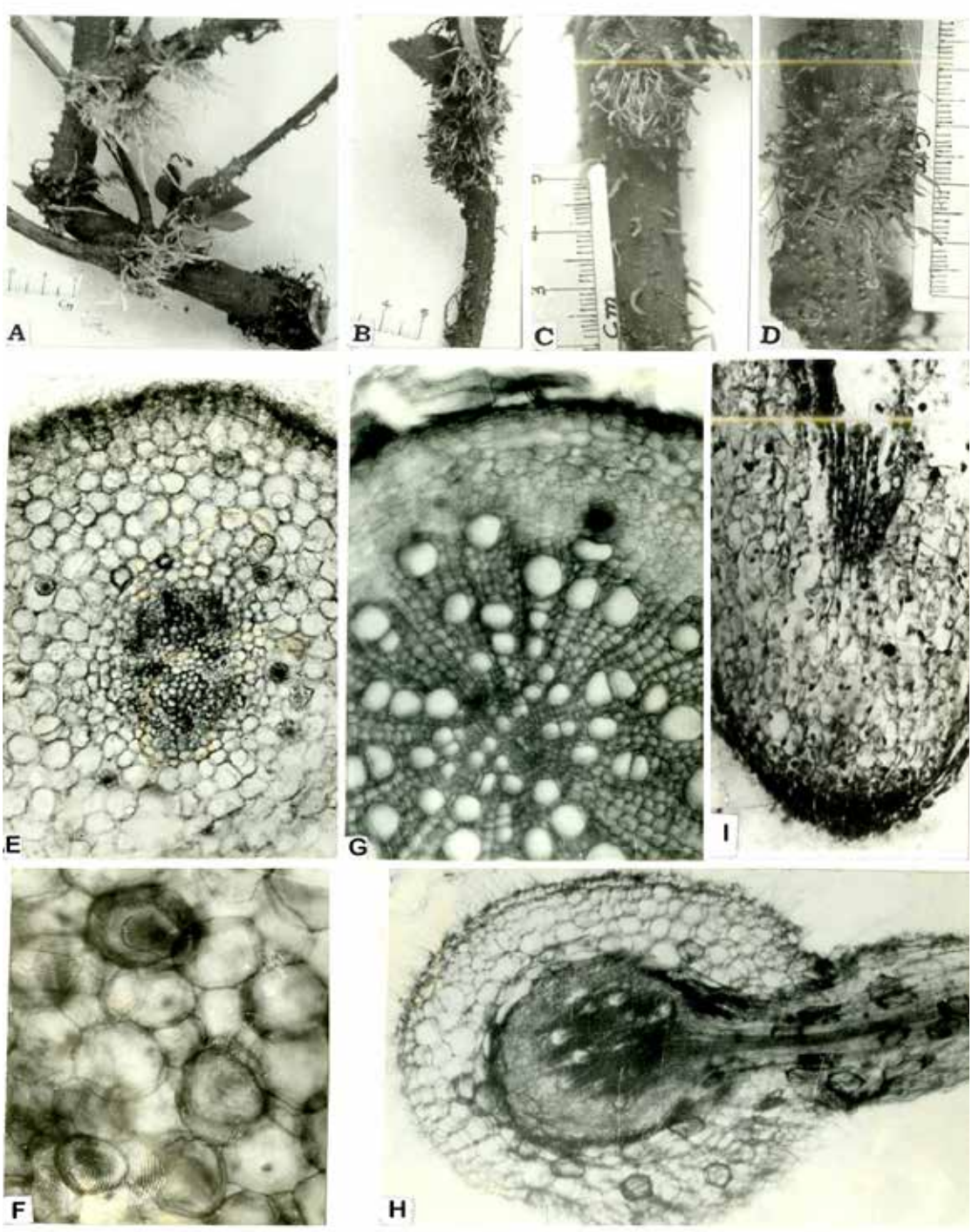

Fig.10. A,C, E-I: **Acalypha hispida**: B,D: **A. wilkesiana:** A: A Plant with aerial roots; B: A Plant with aerial roots; C: External feature, showing magnified view of aerial root; D: External feature, showing magnified view of aerial root; E: T.S. of Aerial root showing cellular details x 200; F: Part of the aerial root showing magnified view of cortical cells with tannin in T.S. x 250; G: T.S. of Terrestrial root showing cellular details x 200; H: T.S. of Aerial root showing endogenous lateral branching x 200; I: L.S. of aerial root tip x 250.

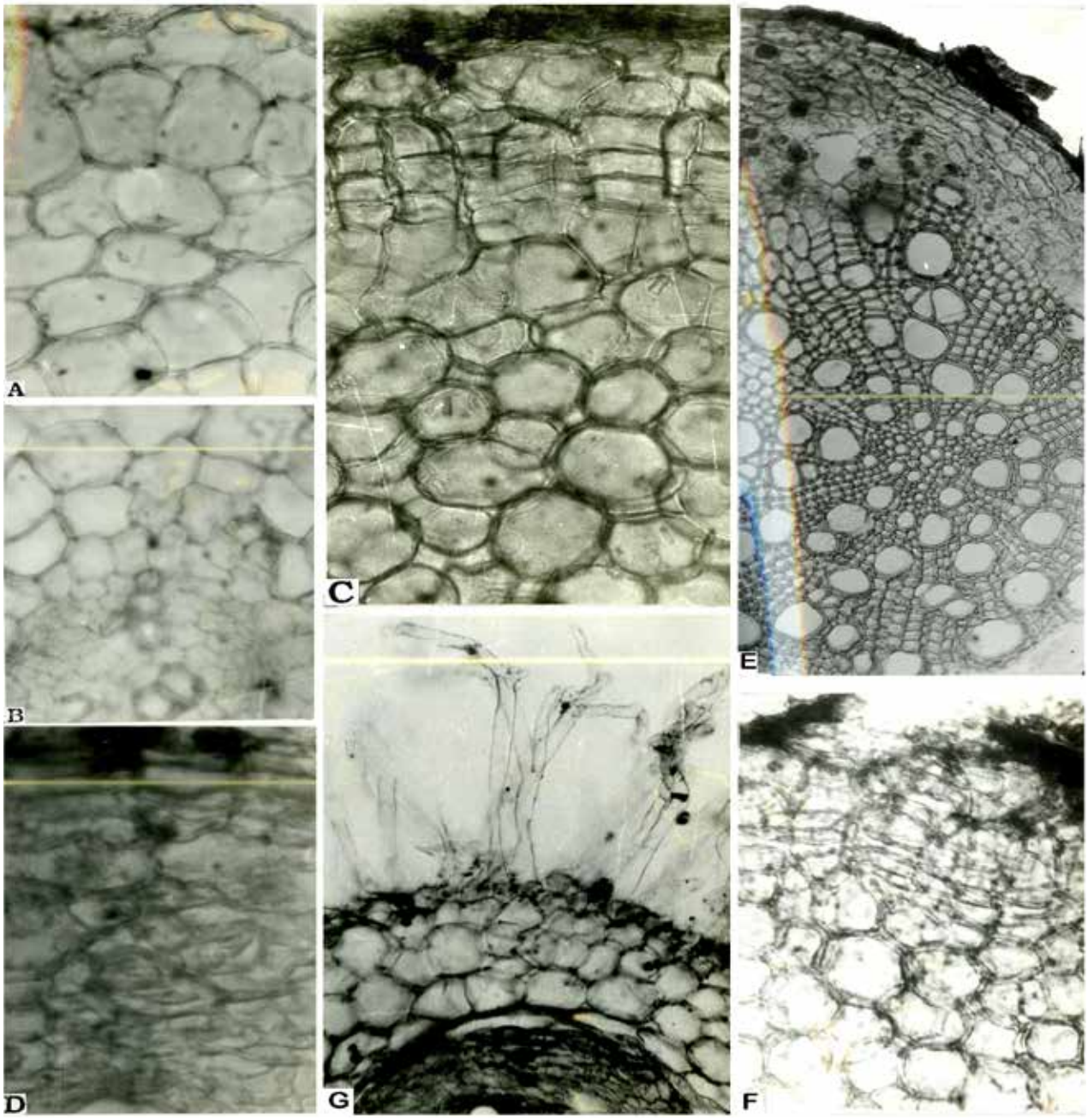

Fig.11.A-C, E-G:**Acalypha wilkesiana,** D: **A. hispida**; A: Outer part of the young aerial root showing magnified view of epidermis and outer cortex in T.S. x 400; B: Part of aerial root showing magnified view of inner cortex, endodermis and radial vascular bundles in T.S. x 400; C: Part of old aerial root showing magnified view of epidermis, periderm and outer cortex. in T.S. x 200; D: Part of aerial root showing magnified view of outer region in T.S. x 200; E: Old terrestrial root showing cellular details x 400; F: Outer region of aerial root showing magnified view of lenticels and outer cortex.x400; G: Enlarged portion of outer region of aerial root showing root hairs x 400.

The dimorphic roots (aerial and terrestrial) of *A. hispida* and *A. wilkesiana* show large number of interesting morphological and anatomical features and resemble fundamentally to the other dicotyledonous roots but they differ in combination of morpho-anatomical characters as mentioned in Table 1.

Table 1: Showing comparison of dimorphic roots of *A. hispida* and *A. wilkesiana*

	Characters	Aerial Roots	Terrestrial Roots
1.	Duration & Timing	Ephemeral, during rainy season	Perennial, throughout the year.
2.	Nature	Delicate in texture	Woody in texture
3.	Colour	White or dull white	Light brown to grey
4.	Branching	Rarely branched	Usually branched.
5.	Root hair	Papillate, less in number	Long, tubular and more in number
6.	Cortex	Wider, 3 to 15 cells in thickness	4 to 9 cells in thickness
7.	Vascular bundle	Exarch, protoxylem ranges from 4 to 6 in *A. hispida* and 3 to 4 in *A. wilkesiana*	Exarch, diarch to tetrarch in both species.
8.	Pith	Reduced and less developed	Absent
9.	Secondary growth	Scanty developed	Well developed
10.	Rays	Less conspicuous	More prominent
11.	Periderm	Poorly developed	Well developed
12.	Lenticels	More in number	Less in Number

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