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TAXONOMIC IMPLEMENTATION OF ROOT ANATOMY IN IDENTIFICATION OF SOME SELECTED LAMIACEAE TAXA

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Abstract

The present research work focuses the important root anatomical features of 15 medicinally important species of Lamiaceae with scanning electron microscopy (SEM) which are helpful in differentiation and identification of plant species. Various anatomical characteristics were measured in root including periderm, cortex, Endodermis, vascular cylinder, xylem elements, vessels and tracheieds, phloem strand, pith cells, pith rays and root hairs. Root anatomy in the Lamiaceae family exhibits distinctive features that set it apart from other plant families. *Mentha haplocalyx* L. had 1-2, *Coleus scutellaroides* (L.) Benth**.** Showed 2-3 and *Tectona grandis* L.f. showed 3-4 layered periderm. *Origanum vulgare* L. had the maximum 15-19 layers of periderm. The maximum length of peridermal cells were observed in *Stachys bazantina* K.Koch. Ranged from 29-38.5 µm and the minimum layers of peridermal cells were seen in *Galeopsis tetrahit* L. ranged from 5-11 µm. The maximum width of peridermal cells was observed in *Ocimum basilicum* L. ranged from 28-32.5µm and the minimum width of peridermal cells was observed in *Colebrookea opppositifolia* Sm. ranged from 6.5-10µm. *Thymus vulgaris* L. had maximum 30-32 cortex layers and *Coleus scutellaroides* (L.) Benth. Had minimum 3-6 cortex layers. The maximum thickening of the cortex was observed in *Mentha piperata* L. ranged from 39.5-42.5 µm and the minimum thickening of the cortex cells was observed in 7-10 µm. Mostly polygonal to rectangular shaped parenchyma cells were seen in *Ajuga reptans* L. Whereas circular and polygonal shaped mostly pentagonal shaped parenchyma cells were seen in *Colebrookea opppositifolia* Sm. and irregular to polygonal shaped parenchyma cells were seen in *Coleus scutellaroides* (L.) Benth. These anatomical revelations, encompassing vascular arrangement, tissue organization, and specialized cell types, serve as pivotal markers for taxonomy and phylogenetic relationships within the family.

Keywords: Lamiaceae; Parenchyma Cells; Vascular Cylinder Diameter; Phloem Strand; Pith Rays.

INTRODUCTION

Root anatomy in the Lamiaceae family exhibits distinctive features that set it apart from other plant families. The roots typically display adaptations that reflect the diverse habitats in which these plants thrive, ranging from arid regions to moist woodlands. Exploring the intricacies of Lamiaceae root anatomy provides valuable insights into their ecological resilience and the mechanisms they employ to adapt to varying environmental conditions. By examining the root anatomy of the Lamiaceae family, we gain a deeper appreciation

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for the remarkable strategies these plants have evolved to ensure their survival and thriving across diverse ecosystems (Baran and Özdemir 2019). The root anatomy of plants in the Lamiaceae family exhibits several characteristics and there can be variations among different species in different characteristics. Many Lamiaceae species develop a fibrous root system, consisting of numerous fine roots emerging from the base of the stem. This type of root system enhances the plant's ability to anchor itself in the soil and facilitates efficient nutrient and water absorption. Lamiaceae roots often bear root hairs, tiny, hair-like extensions that increase the root surface area. Root hairs play a crucial role in nutrient and water uptake from the soil, enhancing the plant's capacity to absorb essential elements for growth and development. (Harley *et al*., 2021). Some members of the Lamiaceae family exhibit secondary growth in their roots, leading to the development of woody roots. This adaptation is particularly notable in shrubby or tree-like Lamiaceae species. Woody roots provide structural support and allow for the efficient transport of water and nutrients.The root anatomy of Lamiaceae plants typically includes an endodermis and pericycle, two important tissue layers responsible for controlling the movement of water and nutrients into the vascular system. The endodermis, with its casparian strips, acts as a barrier regulating the passage of substances into the vascular tissues. (Hacke & Sperry. 2011).

Many Lamiaceae species form symbiotic relationships with mycologist fungi. These associations enhance nutrient uptake, especially phosphorus, from the soil. The presence of mycorrhizae in the root system contributes to the ecological success of Lamiaceae plants in various habitats.In species that inhabit wet or waterlogged environments, Lamiaceae roots may develop aerenchyma – a tissue with air spaces that facilitates oxygen transport to submerged parts of the root. This adaptation helps the plants thrive in conditions with low oxygen availability. (Akçin *et al*., 2011). Understanding the root anatomy of Lamiaceae plants provides valuable insights into their ecological strategies for survival and adaptation. The diverse features observed in their root systems highlight the versatility of this plant family across different habitats and environmental conditions. (Koyuncu *et al*., 2020). In the cross-section view of the root, the following major cells (periderm, cortex parenchyma cells, endodermis, xylary elements, xylem arches, vessels, tracheidss, phloem strands, pith rays and root hairs) were observed. Secondary growth was observed in the root as it is a dicotyledonous plant. The outer layer of root contained a periderm in the form of an epidermis. The periderm observed was thin or thick, and was crushed or broken up or in fragmented form.

1. *Ajuga reptans* L.

Root Anatomy

Epidermis cells were in the form of a layer called periderm. The periderm is smooth with thick walls, composed of many layers, mostly 5-11 layered, and their length ranged from 7.5-12 µm and width observed was 11-25.5µm. The peridermal cells were mostly of rectangular to polygonal shaped. Under the periderm a multilayered cortex was seen having almost 18-22 cortex layers and the thickness of the cortex was observed as 35-39 µm. The cortex layers were composed of parenchymatous cells and were of different

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sizes and shapes. Mostly polygonal to rectangular shaped parenchyma cells were seen. The length of the parenchyma cells varied between 40-49 µm and their width ranged from 30-33µm. Endodermis observed was single layered and mostly of polygonal shaped cells. Endodermal cells varied in length and were ranged from 39-44 µm. The vascular cylinder diameter observed was almost 130-149 µm. The xylem was consisted of many well-developed xylem elements and their length ranged from 51-55 µm. Xylem contains vessels and tracheieds. Vessels observed were polygonal in shape. The diameter of tracheae observed was 6-17 µm. Xylem arches were also seen. Almost 9-11 xylem arches were seen. The maximum length of the phloem strand observed was 75 µm. The diameter of the pith cells observed was 15-40 µm. The pith rays were comprised of 1-2 rowed polygonal shaped cells. Root hairs were also seen.

2. *Coolebrookea opppositifolia* Sm.

Root Anatomy

The periderm seen was smooth with thick walls, composed of multilayers having almost 3-5 layers and their length ranged from 10-12.5 µm and width observed was 6.5-10µm. The peridermal cells were mostly irregular shaped. Under the periderm a cortex of many layers was seen having 4-10 cortex layers and the thickness of the cortex was observed as 10-15 µm. The size of the cortex layers was different and variation was also seen in shapes of cortex cells. Mostly circular and polygonal shaped parenchyma cells (pentagonal) were seen. The length of the parenchyma cells ranged between 32-36 µm and their width ranged from 15-20µm. A single layered endodermis was seen mostly having irregular shaped cells. Endodermal cells varied in length and were ranged from 29-34 µm. The vascular cylinder diameter observed was almost 110-129.5 µm. The xylem was consisted of many well xylary elements and their length ranged from 40-45 µm. Xylem contains vessels and tracheids. Vessels seen were polygonal in shape. The diameter of tracheae ranged from 9-15 µm. Xylem arches were also observed. Almost 7-9 xylem arches were observed. The phloem strand maximum length seen was 55.5 µm. The pith cells diameter observed was 13-20 µm. The pith rays were comprised of 1-2 rowed polygonal or irregular shaped cells. Root hairs were also seen.

3. *Coleus scutellaroides* (L.) Benth.

Root Anatomy

The periderm seen was smooth and thin walled and composed of 2-3 layers and their length ranged from 12-17.5 µm and width observed was 11-17µm. The peridermal cells were mostly polygonal to irregular shaped. Under the periderm a cortex of few layers was seen having 3-6 cortex layers and the thickness of the cortex was observed as 7-10 µm. The cortex layers size was although different but very less variation was seen in shapes of cortex cells. Mostly irregular to polygonal shaped parenchyma cells were seen. The length of the parenchyma cells ranged between 21-24 µm and their width ranged from 12-17µm. Endodermis with 2-3 layers was seen having polygonal shaped cells. Endodermal cells varied in length and were ranged from 19-23 µm. The vascular cylinder diameter was ranged between 90-98 µm. The xylem was consisted of some xylary

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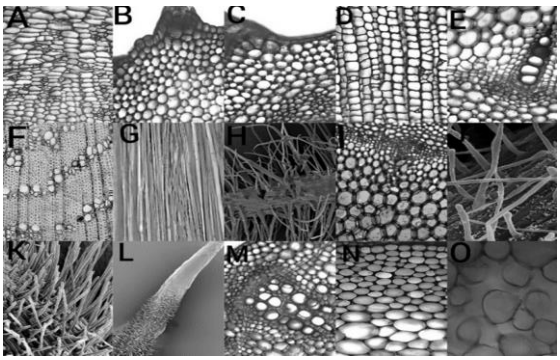
elements and their length ranged from 27-35.5 µm. Xylem consists of vessels and tracheieds. Vessels observed were irregular in shape. The diameter of tracheae ranged from 5-9 µm. Xylem arches were also observed. Almost 3-5 xylem arches were observed. The phloem strand maximum length seen was 39.5 µm. The pith cells diameter observed was 9-17µm. The pith rays were comprised of 1-2 rowed irregular shaped cells. Root hairs were also seen

4. *Galeopsis tetrahit* L.

Root Anatomy

The periderm is smooth with thin walls, composed of 1-3 layers and their length ranged from 5-11 µm and width observed was 10-14µm. The peridermal cells were mostly of polygonal shape. Beneath periderm a multilayered cortex was observed having 8-12 cortex layers and the thickness of the cortex observed was 24.5-29.5 µm. The cortex layers were composed of parenchymatous cells which were of different shapes, mostly square shaped cells and also of different sizes. The length of the parenchyma cells varied between 30-35 µm and their width ranged from 20-23.5µm. Endodermis observed was composed of one layer and mostly cells of endodermis were polygonal shaped. Endodermal cells varied in length and were ranged from 22-29.5 µm. The vascular cylinder diameter observed was almost 130-149 µm. The xylem was composed of xylem elements and their length ranged from 43-55.5µm. Xylem contains vessels and tracheieds. Vessels were polygonal in shape. The diameter of tracheae observed was 4-13.5 µm. Xylem arches were observed. Almost 10-12 xylem arches were seen. The maximum length of the phloem strand was 64 µm. The diameter of the pith cells observed was 20-23 µm. The pith rays were comprised of 1-2 rowed polygonal shaped cells. Root hairs were also seen.



(A). Ajuga reptans (SEM showing polygonal to rectangular shaped cortex parenchyma cells). B. Colebrookea opppositifolia (SEM showing root hairs) C. Coleus scutellaroides (SEM showing root hairs). D. Galeopsis tetrahit (SEM showing parenchyma cortex cells which are mostly square shaped). E. Mentha haplocalyx (SEM showing polygonal shaped vascular bundle cells). F. Mentha piperata (SEM showing vessels). G. Mentha suaveolens (SEM showing vessels). H. Origanum vulgare (SEM showing root hairs). I. Ocimum basilicum (SEM showing multi-layered peridermal cells and cortex parenchyma cells) J. Salvia officinalis (SEM showing root hairs). K. Salvia rosemarinus. (SEM showing root

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hairs). L. Salvia splendens (SEM showing root hairs). M. Stachys bazantina (SEM showing vessels). N. Tectona grandis (SEM showing parenchyma cortex cells). O. Thymus vulgaris (SEM showing cortex parenchyma cells).

5. *Mentha haplocalyx* L.

Root Anatomy

The periderm is smooth with thin walls, composed of 1-2 layers and their length ranged from 14.5-22.5 µm and width observed was 12.5-14µm. The peridermal cells were mostly of polygonal shape. Beneath periderm a multilayered cortex was observed having 14-18 cortex layers and the thickness of the cortex observed was 31.5-36 µm. The cortex layers were composed of parenchymatous cells having irregular or polygonal shaped cells and also of different sizes. The length of the parenchyma cells varied between 28.5-35.5 µm and their width ranged from 14-21µm. Endodermis observed was composed of one to two layers and mostly cells of endodermis were polygonal shaped. Endodermal cells varied in length and were ranged from 38-40 µm. The vascular cylinder diameter observed was almost 150-159 µm. The xylem was composed of xylem elements and their length ranged from 39-45.5µm. Xylem contains vessels and tracheids. Vessels were polygonal in shape. The diameter of tracheae observed was 10-15.5 µm. Xylem arches were also observed. Almost 8-10 xylem arches were seen. The maximum length of the phloem strand was 79.5 µm. The diameter of the pith cells observed was 18-21.5 µm. The pith rays were comprised of 4-6 rowed polygonal shaped cells. Root hairs were also seen

6. *Mentha piperata* L.

Root Anatomy

The periderm is smooth with thick walls, composed of many layers almost 10-12 layered and their length ranged from 27.5-30 µm and width observed was 12.5-17µm. The peridermal cells were mostly of square to rectangular shape. Beneath periderm a multilayered cortex was observed having 14-18 cortex layers and the thickness of the cortex observed was 39.5-42.5 µm. The cortex layers were composed of parenchymatous cells having polygonal mostly rectangular shaped cells and also of different sizes. The length of the parenchyma cells varied between 28.5-35.5 µm and their width ranged from 14-21µm. Endodermis observed was composed of one to two layers and mostly cells of endodermis were irregular shaped. Endodermal cells varied in length and were ranged from 38-40 µm. The vascular cylinder diameter observed was almost 150-159 µm. The xylem was composed of xylem elements and their length ranged from 39-45.5µm. Xylem contains vessels and tracheids. Vessels were rectangular to irregular in shape. The diameter of tracheae observed was 10-15.5 µm. Xylem arches were also observed. Almost 8-10 xylem arches were seen. The maximum length of the phloem strand was 57 µm. The diameter of the pith cells observed was 18-21.5 µm. The pith rays were comprised of 1-2 rowed polygonal shaped cells. Root hairs were also seen.

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7. *Mentha suaveolens* L.

Root Anatomy

The periderm is smooth with thick walls, composed of many layers almost 6-13 layered and their length ranged from 21-27 µm and width observed was 19-23.5µm. The peridermal cells were mostly of polygonal shaped. Beneath periderm a multilayered cortex was observed having 19-24 cortex layers and the thickness of the cortex observed was 27.5-36.5 µm. The cortex layers were composed of parenchymatous cells having elongated shaped cells and also of different sizes. The length of the parenchyma cells varied between 45.5-50 µm and their width ranged from 24-38µm. Endodermis observed was composed of one to two layers and mostly cells of endodermis were rectangular shaped. Endodermal cells varied in length and were ranged from 22-30 µm. The vascular cylinder diameter observed was almost 195-199 µm. The xylem was composed of xylem elements and their length ranged from 29-33.5µm. Xylem contains vessels and tracheids. Vessels were rectangular and square in shape. The diameter of tracheae observed was 12-19 µm. Xylem arches were also observed. Almost 6-8 xylem arches were seen. The maximum length of the phloem strand was 67.5 µm. The diameter of the pith cells observed was 21.5-27.5 µm. The pith rays were comprised of rarely 1 rowed and oftenly 4-20 rectangular shaped cells. Root hairs were also seen.

8. *Origanum vulgare* L.

Root Anatomy

The periderm is smooth with thick walls, composed of many layers almost 15-19 layered and their length ranged from 28-32 µm and width observed was 22-26.5µm. The peridermal cells were mostly of polygonal shaped. Beneath periderm a multilayered cortex was observed having 20-28 cortex layers and the thickness of the cortex observed was 22-26.5 µm. The cortex layers were composed of parenchymatous cells having polygonal shaped cells and also of different sizes. The length of the parenchyma cells varied between 50-55.5 µm and their width ranged from 30-32.5µm. Endodermis observed was composed of mostly of two layers and mostly cells of endodermis were polygonal shaped. Endodermal cells varied in length and were ranged from 29-36 µm. The vascular cylinder diameter observed was almost 181-187.5 µm. The xylem was composed of xylem elements and their length ranged from 37-40µm. Xylem contains vessels and tracheids. Vessels were irregular in shape. The diameter of tracheae observed was 13-21.5 µm. Xylem arches were also observed. Almost 7-14 xylem arches were seen. The maximum length of the phloem strand was 64.5 µm. The diameter of the pith cells observed was 30.5-33.5 µm. The pith rays were comprised of 10-12 rowed irregular shaped cells. Root hairs were also seen.

9. *Ocimum basilicum* L.

Root Anatomy

The periderm is smooth with thick walls, composed of many layers almost 13-15 layered and their length ranged from 23.5-29 µm and width observed was 28-32.5µm. The

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peridermal cells were mostly of polygonal shaped. Beneath periderm a multilayered cortex was observed having 19-24 cortex layers and the thickness of the cortex observed was 19.5-24 µm. The cortex layers were composed of parenchymatous cells having polygonal shaped cells and also of different sizes. The length of the parenchyma cells varied between 56-60.5 µm and their width ranged from 29.5-40µm. Endodermis observed was composed of mostly of two layers and mostly cells of endodermis were polygonal shaped. Endodermal cells varied in length and were ranged from 17.5-23.5 µm. The vascular cylinder diameter observed was almost 141-157 µm. The xylem was composed of xylem elements and their length ranged from 22.5-31.5µm. Xylem contains vessels and tracheids. Vessels were irregular in shape. The diameter of tracheae observed was 17-25 µm. Xylem arches were also observed. Almost 9-18 xylem arches were seen. The maximum length of the phloem strand was 80 µm. The diameter of the pith cells observed was 35-39 µm. The pith rays were comprised of 1-2 rowed polygonal shaped cells. Root hairs were also seen.

10. *Salvia officinalis* L.

Root Anatomy

The periderm is smooth with thick walls, composed of many layers almost 10-11 layered and their length ranged from 28-33 µm and width observed was 14-20µm. The peridermal cells were mostly of polygonal shaped. Beneath periderm a multilayered cortex was observed having 18-20 cortex layers and the thickness of the cortex observed was 21-29 µm. The cortex layers were composed of parenchymatous cells having polygonal shaped cells and also of different sizes. The length of the parenchyma cells varied between 58-63.5 µm and their width ranged from 39-43.5µm. Endodermis observed was composed of mostly of two layers and mostly cells of endodermis were polygonal shaped. Endodermal cells varied in length and were ranged from 27.5-30 µm. The vascular cylinder diameter observed was almost 190-193 µm. The xylem was composed of xylem elements and their length ranged from 30-37.5.5µm. Xylem contains vessels and tracheids. Vessels were irregular in shape. The diameter of tracheae observed was 19-22.5 µm. Xylem arches were also observed. Almost 11-17 xylem arches were seen. The maximum length of the phloem strand was 93.5 µm. The diameter of the pith cells observed was 41-44.5 µm. The pith rays were comprised of 1-2 rowed polygonal shaped cells. Root hairs were also seen.

11. *Salvia rosemarinus* Spenn.

Root Anatomy

The periderm is smooth with thick walls, composed of 4-5 layers and their length ranged from 18-23 µm and width observed was 11-19.5µm. The peridermal cells were mostly of polygonal shaped. Beneath periderm a multilayered cortex was observed having 10-13 cortex layers and the thickness of the cortex observed was 32-35 µm. The cortex layers were composed of parenchymatous cells having polygonal shaped cells and also of different sizes. The length of the parenchyma cells varied between 45.5-52 µm and their width ranged from 20.5-24.5µm. Endodermis observed was composed of mostly of 1-2

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layers and mostly cells of endodermis were polygonal shaped. Endodermal cells varied in length and were ranged from 19.5-21.5 µm. The vascular cylinder diameter observed was almost 129-140 µm. The xylem was composed of xylem elements and their length ranged from 27.5-31.5.5µm. Xylem contains vessels and tracheids. Vessels were irregular in shape. The diameter of tracheae observed was 24.5-29 µm. Xylem arches were also observed. Almost 16-19 xylem arches were seen. The maximum length of the phloem strand was 105 µm. The diameter of the pith cells observed was 34.5-37 µm. The pith rays were comprised of 2-5 rowed polygonal shaped cells. Root hairs were also seen

12. *Salvia splendens* Sellow ex J.A. Schultes

Root Anatomy

The periderm is smooth with thick walls, composed of 3-4 layers and their length ranged from 13-17.5 µm and width observed was 10.5-13µm. The peridermal cells were mostly of polygonal shaped. Beneath periderm a multilayered cortex was observed having 9-15 cortex layers and the thickness of the cortex observed was 20-22 µm. The cortex layers were composed of parenchymatous cells having polygonal shaped cells and also of different sizes. The length of the parenchyma cells varied between 25.5-27.5µm and their width ranged from 9-12µm. Endodermis observed was composed of mostly of 3-4 layers and mostly cells of endodermis were polygonal shaped. Endodermal cells varied in length and were ranged from 26-30.5 µm. The vascular cylinder diameter observed was almost 99-120.5 µm. The xylem was composed of xylem elements and their length ranged from 19.5-23.5µm. Xylem contains vessels and tracheids. Vessels were irregular, circular or oval in shape. The diameter of tracheae observed was 14-19.5 µm. Xylem arches were also observed. Almost 21-24 xylem arches were seen. The maximum length of the phloem strand was 121 µm. The diameter of the pith cells observed was 30-39.5 µm. The pith rays were comprised of 7-11 rowed polygonal shaped cells. Root hairs were also seen.

13. *Stachys byzantina* K.Koch.

Root Anatomy

The periderm is smooth with thick walls, composed of 4-5 layers and their length ranged from 29-38.5 µm and width observed was 24-27µm. The peridermal cells were mostly of irregular shaped or some are circular to rectangular. Beneath periderm a multilayered cortex was observed having 17-23 cortex layers and the thickness of the cortex observed was 27.5-32 µm. The cortex layers were composed of parenchymatous cells having polygonal shaped cells and also of different sizes. The length of the parenchyma cells varied between 30.5-37.5µm and their width ranged from 15.5-17.5µm. Endodermis observed was composed of mostly of 2-4 layers and mostly cells of endodermis were polygonal shaped. Endodermal cells varied in length and were ranged from 30-38.5 µm. The vascular cylinder diameter observed was almost 130-140.5 µm. The xylem was composed of xylem elements and their length ranged from 22-29 µm. Xylem contains vessels and tracheids. Vessels were irregular in shape. The diameter of tracheae observed was 13-20.5 µm. Xylem arches were also observed. Almost 18-20 xylem arches

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were seen. The maximum length of the phloem strand was 141.5 μm. The diameter of the pith cells observed was 43.5-49 μm. The pith rays were comprised of 6-8 rowed polygonal shaped cells. Root hairs were also seen.

14. *Tectona grandis* L.f.

Root Anatomy The periderm is smooth with thin walls, composed of 3-4 layers and their length ranged from 18-24 μm and width observed was 14.5-17μm. The peridermal cells were mostly of polygonal shaped. Beneath periderm a multilayered cortex was observed having 22-29 cortex layers and the thickness of the cortex observed was 19.5-24.5 μm. The cortex layers were composed of parenchymatous cells having polygonal shaped cells and also of different sizes. The length of the parenchyma cells varied between 41.5-47μm and their width ranged from 25.5-30.5μm. Endodermis observed was composed of mostly of 3-4 layers and mostly cells of endodermis were polygonal shaped. Endodermal cells varied in length and were ranged from 27.5-33.5 μm. The vascular cylinder diameter observed was almost 90-104.5 μm. The xylem was composed of xylem elements and their length ranged from 20-24.5 μm. Xylem contains vessels and tracheids. Vessels were irregular in shape. The diameter of tracheae observed was 21-25 μm. Xylem arches were also observed. Almost 14-18 xylem arches were seen. The maximum length of the phloem strand was 124.5 μm. The diameter of the pith cells observed was 31-37.5 μm. The pith rays were comprised of 4-7 rowed polygonal shaped cells. Root hairs were also seen.

15. *Thymus vulgaris* L.

Root Anatomy

The periderm is smooth with thin walls, composed of 6-9 layers and their length ranged from 20.5-27.5 μm and width observed was 15-21.5μm. The peridermal cells were mostly of polygonal shaped. Beneath periderm a multilayered cortex was observed having 30-32 cortex layers and the thickness of the cortex observed was 22.5-26.5 μm. The cortex layers were composed of parenchymatous cells having polygonal shaped cells and also of different sizes. The length of the parenchyma cells varied between 39.5-43μm and their width ranged from 26-29.5μm. Endodermis observed was composed of mostly of 4-5 layers and mostly cells of endodermis were polygonal shaped. Endodermal cells varied in length and were ranged from 20-23.5 μm. The vascular cylinder diameter observed was almost 101-110 μm. The xylem was composed of xylem elements and their length ranged from 22.5-30.5 μm. Xylem contains vessels and tracheids. Vessels were irregular in shape. The diameter of tracheae observed was 27-30.5 μm. Xylem arches were also observed. Almost 12-16 xylem arches were seen. The maximum length of the phloem strand was 114 μm. The diameter of the pith cells observed was 26-31 μm. The pith rays were comprised of 3-6 rowed polygonal shaped cells. Root hairs were also seen.

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Table 1: Quantitative analysis of root anatomical characteristics

No of plants	Name of plants	Length of periderm	Width of periderm	Thickness of cortex	Length of parenchyma cells	Width of parenchyma cells	Length of endodermal cells	Diameter of vascular cylinder	Length of xylem	Diameter of trachea	Length of phloem starnds	Diameter of pith cells
1	***A. reptans***	7.5-12 µm	11-25.5µm.	35-39 µm	40-49 µm	30-33µm	39-44µm	130-149µm	51-55µm	6-17 µm	75 µm	15-40 µm.
2	***C.opppositifolia***	10-12.5 µm	6.5-10µm	10-15 µm	32-36 µm	15-20µm	29-34µm	110-129.5 µm	40-45 µm.	9-15 µm	55.5 µm	13-20 µm
3	***C. scutellaroides***	12-17.5 µm	11-17 µm	7-10 µm	21-24 µm	12-17µm	19-23 µm	90-98 µm	27-35.5 µm	5-9 µm	39.5 µm	9-17 µm
4	***G. tetrahit***	5-11 µm	10-14 µm	24.5-29.5 µm	30-35 µm	20-23.5 µm	22-29.5 µm	130-149 µm	43-55.5 µm	4-13.5 µm	64 µm	20-23 µm
5	***M. haplocalyx***	14.5-22.5 µm	12.5-14 µm	31.5-36 µm	28.5-35.5 µm	14-21 µm	38-40 µm	150-159 µm	39-45.5 µm	10-15.5 µm	79.5 µm	18-21.5 µm
6	***M. piperata.***	27.5-30 µm	12.5-17 µm	39.5-42.5 µm	28.5-35.5 µm	14-21 µm	38-40µm	150-159 µm	39-45.5 µm	10-15.5 µm	57 µm	18-21.5 µm
7	***M. suaveolens***	21-27 µm	19-23.5 µm	27.5-36.5 µm	45.5-50 µm	24-38 µm	22-30 µm	195-199 µm	29-35.5 µm	12-19 µm	67.5 µm	21.5-27.5 µm
8	***O. vulgare***	28-32 µm	22-26.5 µm	22-26.5 µm	50-55.5 µm	30-32.5 µm	29-36 µm	181-187.5 µm	37-40 µm	13-21.5 µm	64.5 µm	30.5-33.5 µm
9	***O. basilicum***	23.5-29 µm	28-32.5 µm	19.5-24 µm	56-60.5 µm	29.5-40 µm	17.5-23.5 µm	141-157 µm	22.5-31.5 µm	17-25 µm	80 µm	35-39 µm
10	***S. officinalis***	28-33 µm	14-20 µm	21-29 µm	58-63.5 µm	39-43.5 µm	27.5-30 µm	190-193 µm	30-37.5 µm	19-22.5 µm	93.5 µm	41-44.5 µm
11	***S. rosemarinus***	18-23 µm	11-19.5 µm	32-35 µm	45.5-52 µm	20.5-24.5 µm	19.5-21.5 µm	129-140 µm	27.5-31.5 µm	24.5-29 µm	105 µm	34.5-37 µm
12	***S. splendens***	13-17.5 µm	10.5-13 µm	20-22 µm	25.5-27.5 µm	9-12 µm	26-30.5 µm	99-120.5 µm	19.5-23.5 µm	14-19.5 µm	121 µm	30-39.5 µm
13	***S. bazantina***	29-38.5 µm	24-27 µm	27.5-32 µm	30.5-37.5 µm	15.5-17.5 µm	30-38.5 µm	130-140.5 µm	22-29 µm	13-20.5 µm	141.5 µm	43.5-49 µm
14	***T. grandis***	18-24 µm	14.5-17 µm	19.5-24.5 µm	41.5-47 µm	25.5-30.5 µm	27.5-33.5 µm	90-104.5 µm	20-24.5 µm	21-25 µm	124.5 µm	31-37.5 µm
15	***T. vulgaris***	20.5-27.5 µm	15-21.5 µm	22.5-26.5 µm	39.5-43 µm	26-29.5 µm	20-23.5 µm	101-110 µm	22.5-30.5 µm	27-30.5 µm	114 µm	26-31 µm

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DISCUSSION

The root anatomy of selected Lamiaceae taxa through LM and SEM is done first time in Pakistan.

In the present research work the general anatomical features observed in studied Lamiaceae taxa were in agreement with those discussed by Tarimcilar *et al*., 2013. The present research work focuses the important root anatomical features which are helpful in differentiation and identification of plant species.

The outermost root surface of Lamiaceae taxa is covered by a thick or thin periderm which might be broken up or crushed. While studying root anatomical features through transverse sectioning of Lamiaceae taxa it was observed that periderm showed a lot of variation and was consisted of one to several layers. *Mentha haplocalyx* L. had 1-2 layers of periderm whereas *Coleus scutellaroides* (L.) Benth**.** Showed 2-3 layered periderm and *Tectona grandis* L.f. showed 3-4 layered periderm. The maximum number of periderm layers were observed in *Origanum vulgare* L. having 15-19 layers of periderm. The maximum length of peridermal cells were observed in *Stachys bazantina* K.Koch. Ranged from 29-38.5 µm and the minimum layers of peridermal cells were seen in *Galeopsis tetrahit* L. ranged from 5-11 µm. The maximum width of peridermal cells was observed in *Oscimum basiculum* L. ranged from 28-32.5µm and the minimum width of peridermal cells was observed in *Colebrookea oppposititifolia* Sm. ranged from 6.5-10µm. These results were in agreement with the findings of Dinc *et al*., 2019 who reported multilayers of periderm with multiple variation in length and width of peridermal cells in Lamiaceae taxa. The specific presence and extent of periderm or secondary growth in the roots of Lamiaceae taxa can vary among different species within the family. Some might exhibit limited secondary growth or periderm development in their roots, while others might primarily maintain a primary growth pattern typical of herbaceous plants. (Seyedi and Salmaki, 2015).

Beneath the periderm multi layered cortex is present which is composed of many large parenchymatous cells. These parenchymatous cells are heterogeneous in shape and size. In the present studies cortex also showed variation and was consisted of one-to-many layers. The thickness of the cortex also varied in studied species. The maximum number of cortex layers were observed in *Thymus vulgaris* L. having almost 30-32 cortex layers. The minimum cortex layers were observed in *Coleus scutellaroides* (L.) Benth. Having 3-6 cortex layers. The maximum thickening of the cortex was observed in *Mentha piperata* L. ranged from 39.5-42.5 µm and the minimum thickening of the cortex cells was observed in 7-10 µm. This research findings in studied Lamiaceae taxa are in accordance with few other investigated members of Lamiaceae. Dinc¸ *et al*., 2019; Dinc¸ and Dogu, 2012; Celep *et al.*, 2011; Güvenc¸ and Duman, 2010 and Baran and Özdemir 2009).

The parenchymatous cells varied in shape, length and width in the studied Lamiaceae taxa root. A lot of variation was seen in the shapes of parenchyma cells in the studied taxa. Irregular, circular, rectangular, polygonal and oval shaped parenchyma cells were seen. Mostly polygonal to rectangular shaped parenchyma cells were seen in *Ajuga*

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reptans L. Whereas circular and polygonal shaped mostly pentagonal shaped parenchyma cells were seen in *Colebrookea oppositifolia* Sm. And irregular to polygonal shaped parenchyma cells were seen in *Coleus scutellaroides* (L.) Benth. Some square shaped parenchyma cells were also seen in *Galeopsis tetrahit* L. Some elongated shaped parenchyma cells were present in *Mentha suaveolens* L. The maximum length of parenchyma cells was seen in *Salvia officinalis* L. ranged from 58-63.5 µm. The minimum length of parenchyma cells was seen in *Coleus scutellaroides* (L.) Benth. Ranged from 21-24 µm. The maximum width of parenchyma cells was seen in *Salvia officinalis* L. ranged from 39.5-43 µm and the minimum width of parenchyma cells was seen in *Salvia splendens* Sellow ex J.A. Schultes ranged from 9-12 µm. These distinctions in parenchyma cells shape were also observed in the findings of Scantena *et al*., 2015 in which they mentioned muti-layered parenchyma cells with variations in shapes.

The endodermis of root is cylindrical boundary which segregates inner vascular tissue from the outer cortex and functions as apoplasmic barrier for the selective uptake of nutrients. The endodermis in Lamiaceae root also showed variation. The endodermis was composed of 1-many layers in studied taxa. Single layered endodermis was seen in *Ajuga reptans* L., *Colebrookea oppositifolia* Sm. and *Galeopsis tetrahit* L. Many taxa had two layered endodermis such as *Origanum vulgare* L. and *Oscimum basiculum* L. In some taxa endodermis observed was composed of mostly of 4-5 layers such as *Thymus vulgaris* L. Newer research in developmental and cell biology has begun uncovering the ways in which this solitary layer of cells functions as a crucial regulatory component in the growth of roots, the organization of tissues, and the movement of nutrients. (Atasagun *et al*., 2015).

Metcalfe and Chalk (1972) provided helpful information about Lamiaceae root anatomy. In the present studies it was observed that phloem strands are well developed and established. Next to the root cortex well developed phloem and xylem elements were seen which formed central cylinder. According to the present investigation the pith rays were comprised of 2-12 rows of cells in the roots of studied Lamiaceae taxa. The maximum vascular cylinder diameter observed was almost 195-199 µm in *Mentha suaveolens* L and the minimum vascular cylinder diameter observed was almost in 90-98 µm in *Coleus scutellaroides* (L.) Benth. In the present studies it was seen that xylem was composed of xylary elements and it also contained vessels and tracheids. The vessels were mostly irregular in many species except in some cases. Such as in *Mentha haplocalyx* L., *Galeopsis tetrahit* L., *Colebrookea oppositifolia* Sm. and *Ajuga reptans* L. polygonal shaped vessels were seen whereas in *Mentha piperata* L. rectangular shaped to irregular shaped vessels were seen. The maximum number of xylem arches were 21-24 which were seen in *Salvia splendens* Sellow ex J.A. Schultes whereas the minimum number of xylem arches was 3-5 seen in *Coleus scutellaroides* (L.) Benth. The maximum length of phloem strand was 141.5 µm observed *Stachys bazantina* K.Koch. Whereas the minimum length of phloem strand was 39.5 µm in *Coleus scutellaroides* (L.) Benth. Variation was also observed in pith diameter and pith rays. The pith rays were comprised of 3-6 rowed polygonal shaped cells in *Thymus vulgaris* L. whereas of 4-7 rowed pith rays were seen in *Tectona grandis* L.f., There were 6-8 pith rows in` *Stachys bazantina*

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K.Koch. And 7-11 pith rows were seen in *Salvia splendens* Sellow ex J.A. Schultes. The same findings were seen in the work of Özkan, 2007 in which he described variations in pith rows of Lamiaceae. The comprehensive exploration of root anatomy within the Lamiaceae family sheds light on the intricate structural characteristics and provides a foundation for taxonomic and ecological understanding. Through detailed examinations of various genera and species, this study unveils both commonalities and distinctive features in root structures. These anatomical revelations, encompassing vascular arrangement, tissue organization, and specialized cell types, serve as pivotal markers for taxonomy and phylogenetic relationships within the family. Moreover, the correlations between root anatomy and ecological adaptations offer valuable insights into the adaptive strategies of Lamiaceae plants in diverse habitats. This holistic comprehension of root anatomy within the Lamiaceae family not only enriches botanical knowledge but also holds significance in diverse fields, including ecology, conservation, and pharmaceutical research.

CONCLUSION

On the basis of scanning electron microscopy (SEM) we have provided anatomical tools for some medicinally valuable taxa of the Lamiaceae family Qualitative and quantitative measurements for the anatomical characters periderm, cortex, Endodermis, vascular cylinder, xylem elements, vessels and tracheieds, phloem strand, pith cells, pith rays and root hairs. Significant anatomical variations had been observed among the studied species. This result could provide further insight into the diversity and phylogeny of the family lamiaceae, as well as aid in identifying any species.

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