"Comparative Anatomical Studies of Root and Phylloclade in Selected Members of Family Cactaceae from Amravati District, Maharashtra, India"

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Abstract

The family Cactaceae represents one of the most specialized groups of xerophytic plants characterized by remarkable structural and physiological adaptations for survival under arid and semi-arid conditions. The present investigation was undertaken to study the anatomical characteristics of roots and phylloclades of selected members of family Cactaceae collected from Amravati district, Maharashtra, India. Ten species namely *Opuntia elatior*, *Opuntia oricola*, *Nopalea cochenillifera*, *Eriocereus bonplandii*, *Epiphyllum macropterum*, *Cereus peruvianus*, *Pereskia grandiflora*, *Echinocactus grusonii*, *Ferocactus peninsulae* and *Melocactus azureus* were analyzed using standard microtomy techniques. Transverse sections of roots and phylloclades were prepared, stained and observed under a light compound microscope. The study revealed several xeromorphic and succulent adaptations including thick cuticularized epidermis, multilayered hypodermis, broad succulent cortex, hydrenchyma, chlorenchyma, mucilage cavities, scattered collateral vascular bundles, extensive secondary xylem, medullary rays and water storage tissues. Variations in the arrangement of vascular tissues and development of storage tissues among species indicate their adaptive significance and taxonomic importance. The presence of mucilage cavities, hydrenchymatous tissues and lignified vascular regions reflects efficient water conservation and mechanical support in xeric habitats. The anatomical features documented in the present study contribute valuable information for taxonomic identification, pharmacognostic evaluation and understanding ecological adaptations in Cactaceae.

Keywords: Cactaceae, anatomy, microtomy.

1. Introduction

The family Cactaceae is one of the most distinctive and highly evolved families of angiosperms adapted to xeric and semi-arid environments. Members of this family are widely distributed in tropical and subtropical regions and exhibit extraordinary morphological and anatomical modifications that enable survival under conditions of water scarcity and high temperature. Succulence, reduction of leaves into spines, thick cuticle, specialized water storage tissues and extensive mucilage production are among the important adaptive features commonly observed in cacti.

Cactaceae consists of approximately 130 genera and more than 1800 species distributed primarily in the Americas. These plants possess modified stems known as phylloclades or cladodes that perform photosynthetic functions in place of leaves. Anatomical adaptations in cacti are directly associated with water conservation, storage and reduced transpiration. The development of hydrenchyma, chlorenchyma, mucilage cells, multilayered hypodermis and specialized vascular systems are considered important xerophytic adaptations.

Anatomical studies play a significant role in plant taxonomy, pharmacognosy and ecological interpretation. Internal structural characters such as epidermal modifications, arrangement of vascular tissues, development

of secondary xylem, mucilage cavities and storage tissues provide valuable diagnostic features for identification and classification. Comparative anatomical analysis also helps in understanding evolutionary relationships and adaptive mechanisms in desert plants.

Roots and phylloclades of cacti exhibit remarkable structural specialization. Root systems are generally characterized by extensive parenchymatous cortex, storage tissues, medullary rays, mucilage cavities and well-developed vascular tissues that facilitate absorption and storage of water. Similarly, phylloclades possess thick cuticle, chlorenchyma, hydrenchyma, scattered vascular bundles and mucilage canals that minimize water loss and maintain photosynthetic efficiency.

The present study focuses on comparative anatomical investigations of roots and phylloclades of selected members of family Cactaceae from Amravati district, Maharashtra. Detailed observations on tissue organization, vascular arrangement, mucilage distribution and storage tissues were undertaken to evaluate their adaptive and taxonomic significance.

2. Materials and Methods

2.1 Collection of Plant Material

Fresh and healthy specimens of ten selected members of family Cactaceae were collected from different localities of Amravati district, Maharashtra, India. The selected species included:

1. *Opuntia elatior*
2. *Opuntia oricola*
3. *Nopalea cochenillifera*
4. *Eriocereus bonplandii*
5. *Epiphyllum macropterum*
6. *Cereus peruvianus*
7. *Pereskia grandiflora*
8. *Echinocactus grusonii*
9. *Ferocactus peninsulae*
10. *Melocactus azureus*

The collected specimens were identified using standard floras and taxonomic literature.

2.2 Preparation of Anatomical Sections

Fresh root and phylloclade materials were washed thoroughly with distilled water to remove dust and debris. Small pieces of root and phylloclade tissues were fixed in FAA solution (Formalin-Acetic acid-Alcohol) for 24 hours.

Thin transverse sections were prepared using standard microtomy techniques. Sections were carefully obtained to ensure proper tissue differentiation.

2.3 Staining and Mounting

The prepared sections were stained with safranin stain for proper visualization of tissues. Excess stain was removed by washing gently with distilled water. The stained sections were mounted in glycerin/DPX on clean glass slides and covered with cover slips for microscopic observation.

2.4 Microscopic Observation

Permanent slides were observed under a light compound microscope. Anatomical characters such as epidermis, hypodermis, cortex, chlorenchyma, hydrenchyma, mucilage cavities, vascular bundles, medullary rays and secondary growth were recorded and photographed.

3. Observation and Results

Comparative Anatomical Characteristics of Root and Phylloclade of Selected Members of Family Cactaceae

Sr. No.	Plant Name	Root Anatomy - Major Features	Phylloclade Anatomy - Major Features
1	*Opuntia elatior*	Broad parenchymatous cortex, mucilage cavities, well developed secondary xylem, compact vascular cylinder, succulent water storage tissue	Thick cuticularized epidermis, multilayered hypodermis, scattered vascular bundles, broad succulent cortex, abundant mucilage cavities
2	*Opuntia oricola*	Broad succulent cortex with mucilage cavities, lignified secondary xylem, compact vascular region, vacuolated storage cells	Thick cuticle, multilayered sclerenchymatous hypodermis, scattered collateral vascular bundles, extensive water storage tissue
3	*Nopalea cochenillifera*	Extensive secondary xylem, radial vascular arrangement, medullary rays, succulent cortex with mucilage cells	Thick cuticular epidermis, chlorenchyma beneath epidermis, scattered vascular bundles, large succulent storage tissue
4	*Eriocereus bonplandii*	Distinct radial vascular wedges, broad succulent cortex, large lignified xylem vessels, mucilage cavities	Broad succulent cortex, chlorenchymatous outer cortex, scattered collateral bundles, mucilage cavities and storage cells
5	*Epiphyllum macropterum*	Extensive secondary growth, broad medullary rays, large lignified xylem vessels, succulent cortex	Peripheral vascular bundles, broad succulent cortex, large mucilage cavities, chlorenchymatous cortex
6	*Cereus peruvianus*	Numerous radial vascular wedges, large central vascular region, broad medullary rays, mucilage cells	Thick cuticle with sunken stomata, peripheral ring of vascular bundles, broad succulent cortex, chlorenchyma present
7	*Pereskia grandiflora*	Massive woody secondary xylem, broad parenchymatous cortex, mucilage cells, active cambium	Ring arranged vascular bundles, chlorenchymatous cortex, succulent

Sr. No.	Plant Name	Root Anatomy - Major Features	Phylloclade Anatomy - Major Features
			storage tissue, secondary vascular growth
8	*Echinocactus grusonii*	Star shaped radial xylem arrangement, hydrenchymatous cortex, extensive storage tissue	Thick cutinized epidermis, multilayered hypodermis, broad hydrenchyma, scattered vascular bundles
9	*Ferocactus peninsulae*	Thick periderm, massive secondary xylem wedges, broad medullary rays, succulent storage tissue	Thick cuticle, multilayered sclerenchymatous hypodermis, chlorenchyma, scattered vascular bundles in succulent cortex
10	*Melocactus azureus*	Broad succulent cortex, wedge shaped xylem arms, medullary rays, extensive storage tissue	Thick cuticularized epidermis, ring of collateral vascular bundles, hydrenchymatous cortex, sunken stomata

4. Discussion

The present anatomical investigation revealed significant xeromorphic and succulent adaptations among the studied members of family Cactaceae. These anatomical modifications are directly associated with survival under water-limited environmental conditions.

The roots of most species showed broad parenchymatous cortex and extensive succulent storage tissues which play an important role in water accumulation and retention. The presence of mucilage cavities and mucilage cells observed in several species is considered a characteristic feature of cacti. Mucilage helps in water retention, prevention of tissue dehydration and maintenance of cellular hydration during drought conditions.

Well-developed secondary xylem and radial vascular wedges observed in species such as *Nopalea cochenillifera*, *Cereus peruvianus*, *Ferocactus peninsulae* and *Pereskia grandiflora* provide mechanical strength and facilitate efficient conduction of water. The development of medullary rays in many species also supports radial transport and storage of nutrients.

The phylloclades of all studied species exhibited highly specialized xerophytic characters. Thick cuticularized epidermis and multilayered hypodermis help reduce transpiration losses. The presence of sclerenchymatous hypodermis in *Opuntia oricola* and *Ferocactus peninsulae* provides additional mechanical support and protection.

Hydrenchymatous tissues observed in *Echinocactus grusonii* and *Melocactus azureus* act as efficient water storage tissues. Similarly, chlorenchymatous cortex present in *Nopalea cochenillifera*, *Eriocereus bonplandii*, *Epiphyllum macropterum* and *Pereskia grandiflora* performs photosynthetic activity in the absence of true leaves.

Scattered vascular bundles and peripheral vascular arrangement observed in several species represent an important adaptive feature of succulent stems. Sunken stomata observed in *Cereus peruvianus* and *Melocactus azureus* reduce transpiration by minimizing exposure of stomatal pores to dry atmospheric conditions.

The anatomical variations observed among the studied taxa are taxonomically significant and may be used for species identification and classification. Similar anatomical findings have been reported in earlier studies on Cactaceae emphasizing the importance of mucilage cells, hydrenchyma, vascular arrangement and secondary growth in xerophytic adaptation.

5. Conclusion

The comparative anatomical study of roots and phylloclades of selected members of family Cactaceae revealed remarkable structural adaptations associated with xerophytic survival and succulence. Important anatomical features such as thick cuticle, multilayered hypodermis, chlorenchyma, hydrenchyma, mucilage cavities, scattered vascular bundles, extensive secondary xylem and succulent cortex were consistently observed among the studied species.

The presence of specialized storage tissues and mucilage cells demonstrates efficient water conservation mechanisms in Cactaceae. Variations in vascular arrangement, secondary growth and tissue organization provide valuable diagnostic and taxonomic characters. These anatomical characteristics are also important in pharmacognostic studies for authentication and identification of medicinally significant cactus species.

The present study contributes to the anatomical database of Cactaceae from Amravati district and provides a scientific basis for further taxonomic, ecological and pharmacognostic investigations.

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