Ramseena A, 2026, 14:4
ISSN (Online): 2348-4098
ISSN (Print): 2395-4752

International Journal of Science, Engineering and Technology
An Open Access Journal

Spore Morphology of Selected Pteridophytes from the Southern Western Ghats, India: A Taxonomic Perspective

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Abstract- Pteridophytes constitute an important component of the flora of the Western Ghats, one of the world's biodiversity hotspots. Spore morphology has long been recognized as a valuable taxonomic character for species identification and phylogenetic interpretation. The present study investigated the spore morphology of selected pteridophytes collected from the Southern Western Ghats of Kerala, India. Twenty-one species representing 18 genera and 15 families were collected from diverse forest habitats. Spores were examined using light microscopy (LM) and scanning electron microscopy (SEM) following acetolysis preparation. Morphological characters including spore size, shape, aperture type, exospore thickness, and ornamentation were recorded. The study identified two major spore types, namely trilete and monolete spores, with considerable interspecific variation in ornamentation and dimensions. SEM analysis revealed diagnostic exospore patterns such as verrucate, reticulate, cristate, and granulose ornamentation that were not fully distinguishable under LM. The findings demonstrate that spore morphology provides reliable taxonomic evidence for distinguishing closely related taxa and contributes to the documentation and conservation of pteridophyte diversity in the Western Ghats.

Keywords— Pteridophytes, Spore morphology, Western Ghats, Taxonomy, Scanning Electron Microscopy, Ferns

I. INTRODUCTION

Pteridophytes are seedless vascular plants that represent one of the oldest lineages of terrestrial vegetation. Although their dominance declined after the Carboniferous period, they continue to play significant ecological roles in tropical and subtropical ecosystems. India harbors a rich diversity of pteridophytes, particularly within the Western Ghats, where favorable climatic and topographic conditions support numerous endemic and threatened species.

Spore morphology has emerged as an important taxonomic tool because spore characteristics remain relatively stable within species and often provide diagnostic features that complement vegetative morphology. Modern microscopic techniques, particularly scanning electron microscopy (SEM), have enhanced the understanding of spore wall ornamentation and its systematic significance.
Even though there is advancement in the material that provides official information of ferns and fern allies of Western Ghats, the information about the diversity of pteridophytes among habituations and in urbanized areas is lacking. One of the main reasons for this is the lack of sporulation. Spore morphology study provides the distributional patterns and level of spore production in sporangia. Study of spore morphology acts as a taxonomic aid to the identification of species and it has wide application in forensic studies. Pteridophyte diversity is facing extinction due to lack of sporulation and urbanization. Documentation of ferns and fern allies through this dimension can help the survival of ferns and conservation of pteridophytes in specific areas.
The present study aims to characterize the spores of selected pteridophytes from the Southern Western Ghats using both light and scanning electron microscopy and to evaluate their taxonomic significance.

II. REVIEW OF LITERATURE

Pteridophytic spores remain protected by an efficient envelope against environmental pressures.

Spores, the main agent of dispersal carrying the essential genetic material for sexual reproduction of ferns and persistence of the species, are single, air borne cells with complex walls. The spore system presents a unique basis as a test system for evolution, toxicity of pollutants, especially mutagens and carcinogens. The advancement in optical technology and in microtechniques, have served enormously in gaining an understanding of the spore wall structure, sculpture and its development, to the benefit of phylogenetic morphologists working in ferns (Devi , 1977).

Most advanced, sexual leptosporangiate ferns have 16 spore mother cells per sporangium. After meiosis each spore mother cell will yield 4 spores, and there by 64 spores are produced per sporangium. On the other hand, most apogamous species have only 8 spore mother cells, instead of 16, and yield 32 spores per sporangium through normal meiosis. A few apogamous ferns may produce 16 spore mother cells but will also yield 32 spores per sporangium due to a failure of meiosis (Manton, 1950; Braithwaite, 1964). Thus, having 32 spores per sporangium is presumptive evidence of apogamous ferns (Knobloch, 1966).

Spore size is commonly used to distinguish different ploidy levels within allied species (Stebbins, 1950; Huang et al., 2006). Pteridophyte spores are usually larger in apogamous, polyploid taxa than in their sexual, diploid counterparts (Moran, 1982; Huang et al., 2006). In ferns, spore sizes are often positively correlated with ploidy levels within a genus (Kanamori, 1975; Huang et al., 2006).

III. MATERIALS AND METHODS

1. Study Area

Field investigations were conducted in selected forest ecosystems of the Southern Western Ghats, Kerala, India. Sampling sites included Attappadi, Meenvallam, Dhoni, Nelliyampathy, Chittur, Munnar, and surrounding forest regions, representing diverse ecological habitats favorable for pteridophyte diversity.

2. Methodology adopted

The present study focuses on micro-morphological and micrometric analysis of spores of selected Pteridophytes. The sporophylls of source plants were procured from field exploration. The taxonomic identity of the collections was established with standard descriptions like Fern flora of Malabar (Nair,Geevarghese,1993) and herbaria at University of Calicut (CALI) and Botanical Survey of India (MH). The materials were fixed and preserved in 70% ethanol (Nair, 1970) and the voucher specimens were preserved in the form of herbarium. The study involved both light microscopic (LM) and scanning electron microscopic (SEM) approaches for spore characterization.

3. Plant Materials

A total of 21 pteridophyte species representing 18 genera and 15 families were collected during field surveys. Specimens were identified using standard floras and authenticated through comparison with herbarium collections maintained at the University of Calicut (CALI) and the Botanical Survey of India (MH). Voucher specimens were prepared and preserved as herbarium collections for future reference.

4. Spore Preparation

Fertile sporophylls were collected and preserved in 70% ethanol. Spores were isolated from mature sporangia and processed using the acetolysis technique following Erdtman (1952) with modifications by Nair (1960). Acetolysis removed cellular debris while preserving the exospore, enabling detailed morphological examination. Permanent slides were prepared using glycerine jelly and sealed with paraffin wax.

5. Light Microscopy and Scanning Electron Microscopy

Morphological observations were performed using a Radical pathological microscope equipped with a digital camera. Fine surface ornamentation was examined using a JEOL Scanning Electron Microscope (SEM) at the National Institute for Interdisciplinary Science and Technology (NIIST), Thiruvananthapuram. SEM imaging facilitated detailed observation of exospore sculpture and

aperture characteristics that were not clearly visible under light microscopy.

6. Morphometric Analysis

For each species, ten mature spores were randomly selected for measurement. Polar diameter, equatorial diameter, exospore thickness, shape, aperture type, and ornamentation were recorded using standardized ocular micrometry techniques. Mean values were calculated to compare interspecific variation.

IV. RESULTS

1. General Characteristics of Pteridophyte Spores

Morphological analysis demonstrated considerable variation in spore size, shape, aperture type, and ornamentation among the investigated taxa. Two principal spore categories were recognized:

- Trilete spores, exhibiting radial symmetry with a triradiate aperture.
- Monolete spores, exhibiting bilateral symmetry with a single elongated aperture.

Among the 21 investigated species, 15 species possessed trilete spores, whereas 6 species exhibited monolete spores. Spore colour ranged from pale yellow to dark brown, while shape varied from triangular and tetrahedral to ellipsoidal and reniform.

2. Exospore Ornamentation

SEM analysis revealed considerable diversity in exospore sculpture. Ornamentation patterns included:

- Reticulate
- Verrucate
- Cristate
- Granulose
- Psilate
- Papillate
- Tuberculate

These characteristics provided valuable diagnostic features for species identification and taxonomic discrimination. SEM observations consistently revealed finer structural details than light microscopy alone.

3. Species-Level Variation

Distinct morphological differences were observed among genera.

Species of Pteris exhibited comparatively larger spores with reticulate ornamentation, whereas Selaginella delicatula possessed dimorphic microspores and megaspores. Species belonging to Angiopteris displayed remarkable variation in sporangial arrangement and exospore ornamentation, suggesting considerable morphological diversity within the genus.

V. DISCUSSION

The present investigation demonstrates that spore morphology is a valuable taxonomic character for distinguishing pteridophyte species occurring in the Southern Western Ghats. Examination of spores using both light microscopy (LM) and scanning electron microscopy (SEM) revealed substantial variation in aperture type, size, shape, and exospore ornamentation among the investigated taxa. These findings support earlier reports that spore morphology provides reliable diagnostic characters for species delimitation and phylogenetic interpretation in ferns and lycophytes.

The occurrence of two major spore types, trilete and monolete, agrees with previous classifications of pteridophytes. Trilete spores were predominant among the investigated taxa, whereas monolete spores characterized a smaller group of species. Differences in exospore ornamentation—including reticulate, verrucate, cristate, granulose, papillate, and psilate patterns—proved particularly useful for distinguishing closely related taxa.

Species of Pteris exhibited considerable variation in spore ornamentation despite similarities in vegetative morphology. Likewise, Angiopteris showed notable differences in both sporangial arrangement and exospore sculpture, suggesting that these characters may have systematic significance. Such observations indicate that microscopic spore characters can complement conventional morphological traits in resolving taxonomic ambiguities.

Scanning electron microscopy was especially valuable because it revealed fine exospore structures that were difficult or impossible to detect under light microscopy. The combination of LM and SEM therefore provides a comprehensive approach for pteridophyte taxonomy and biodiversity assessment. The Western Ghats is internationally recognized as one of the world's biodiversity hotspots, yet many fern species remain poorly documented. The present study contributes baseline morphological information that can support floristic surveys, taxonomic revisions, conservation planning, and future phylogenetic investigations.

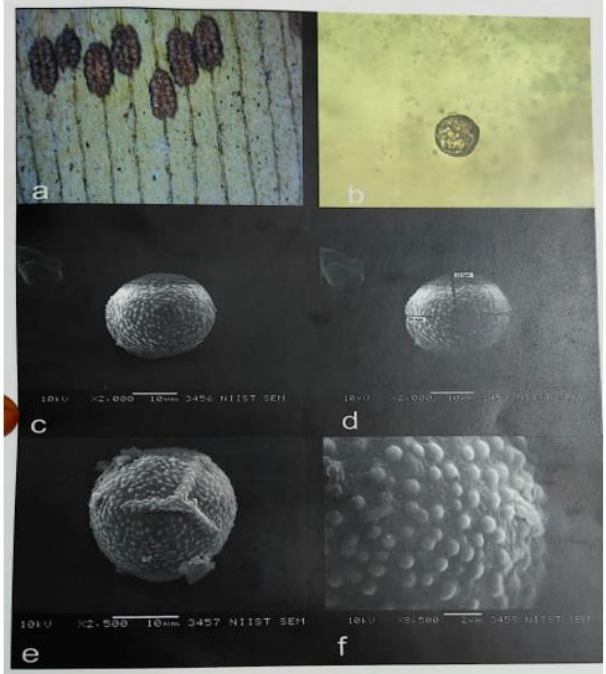

Plate 12. Angiopteris sp (RA009). Fig:a: Sori Fig b: Acetolysed spore, Fig (c - f) SEM photographs; c: Complete spore. d: Spore showing Equatorial and polar diameters. e: Spore with triradiate mark. f: Portion of spore showing verrucate densly granuate ornamentation

VI. CONCLUSION

This study provides a comprehensive analysis of spore morphology in selected pteridophytes from the Southern Western Ghats using light and scanning electron microscopy. Distinct variations in spore size, shape, aperture type, and exospore ornamentation were observed among the investigated species.

The findings confirm that spore morphology is an effective taxonomic tool for distinguishing closely related species and genera. SEM examination significantly enhanced the identification of diagnostic characters by revealing detailed exospore ornamentation that was not discernible through conventional microscopy.

The study also contributes valuable baseline information for the documentation and conservation of pteridophyte diversity in the Western Ghats. Future investigations integrating molecular markers with spore morphology may further improve the understanding of evolutionary relationships and species boundaries within Indian pteridophytes.

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