

## Pteridology Laboratory: Research & Development Activities

### PRESENT RESEARCH GROUP

<b>Scientists</b> <ol style="list-style-type: none"><li>1. Dr. P. B. Khare, Chief Scientist</li><li>2. Dr. Ajit Pratap Singh, Scientist</li></ol>	<b>Technical Assistants</b> <ol style="list-style-type: none"><li>1. Dr. S. K. Behera, Technical Officer</li><li>2. Mr. Manoj K. Srivastava, Tech. Assistant</li><li>3. Mr. Shyam Babu Sen, Lab Attendant</li></ol> <b>Research Scholars</b> <ol style="list-style-type: none"><li>1. Ms. Deepali Johari, Project Assistant-II</li><li>2. Ms. Akanksha Singh, Project Assistant-II</li><li>3. Ms. V. Jyotsna Singh, Project Assistant-II</li></ol>
<b>Name of Group Leader:</b> Dr. P. B. Khare, Chief Scientist <b>Phone:</b> 91-522-2297832-33 <b>Fax:</b> 91-522-2205836, 39 <b>Email:</b> kharepb@nbri.res.in; ajit.p.singh@nbri.res.in	

### ABOUT PTERIDOPHYTES

Pteridophytes are the vascular cryptogamic plants, which preferentially grow on soil, rock, peat and bark in moist, cool climatic conditions of the world. They are classified into ferns and fern allies, but usually comprise of six distantly related classes viz. Lycopodiopsida, Selaginellopsida, Isoetopsida, Equisetopsida, Psiloptopsida and Polypodiopsida. About 1100 species of ferns belonging to 144 genera 34 families; and 150 species of fern allies under 9 genera 6 families are known to occur in India. Ferns are distinct in having rhizomes, stripes, fronds and homosporous spores, whereas the fern allies exhibit scale like leaves and heterosporous (mega and micro) spores. In ferns, the spore matures into gametophyte that bears both male and female gametangia in a definite pattern. In fern allies, both the mega and microspore mature into female and male gametophytes that bear female and male gametangia respectively. Pteridophytes are unique in having two different phases—the gametophyte and sporophyte. There has been a wide range of variation in spatial distribution, habitat, growth pattern and morphology of pteridophytes. This has left behind many unknown new species, which are yet to be discovered. All above attributes of pteridophytes necessitated to identify, categorize and classify them into different taxonomic rank. In addition, knowledge on their population structure, status and reproductive behaviour was equally needed, which open another discipline to investigate cause of threat. Reproductive biology provides information on developmental pattern of gametophyte and sporophyte. It involves in-vitro studies which fortify possibility of plants culture, mass propagation and conservation. Variations in different accessions of a particular or different species also signify occurrence of polyploids. This tempts chromosome studies to ascertain cytotypes and polyploids. Pteridophytes exhibit antifungal and insecticidal compounds, which now became a thrust area of investigation. Survival to excessive water scarcity opened another opportunity to look upon their sustainable utilization for safety of food crops in drought condition. They are proficient pollutant scavenger, hence may be utilized as a resourceful organism to mitigate the pollutants impact. For reason to fill the gap of knowledge on their diversity and to address societal challenges, the pteridology group carry out research and development activities on taxonomic, floristic, monographic, reproductive biology, mass multiplication, conservation and prospection of pteridophytes.

### WORLD-CLASS CONTRIBUTION IN PTERIDOPHYTES

Since the inception of pteridology laboratory at CSIR-NBRI, the pteridology group is performing world-class unconquerable research and development activities on taxonomy, anatomy, developmental biology and conservation of pteridophytes. Taxonomic studies were initiated preparing monographs, revision of genera, families discovering many new species,

monotypic genera, which culminates with the recent trends of in-vitro studies and their prospection. Studies in polypodiaceae (Nayar 1954, 1955, 1957, 1959), gymnogrammeoid and pleopeltoid ferns (Nayar 1955a), pteridaceae (Nayar 1956, 1960), *Bolbitis* (Nayar 1960a, Nayar and Chandra P. 1964), ferns of India (Nayar 1961, 1961a, 1961b, 1962, 1962a, 1962b, 1963, 1964, Nayar and Kaur 1963, 1963a, 1964, 1964a, 1964b), *Leptochilus* and *Paraleptochilus* (Nayar 1963a), *Cheilanthes* (Nayar 1963b), *Microsorium* (Nayar 1963c), *Pityrogramma* (Chandra P. 1963), ferns and fern allies in Tawang (Chandra P. 1989), spore morphology of Indian ferns (Devi 1973), concept of perispore (Devi 1980), stelar cylinder in *Bolbitis* and *Egenolfia* (Kaur 1964), *Pityrogramma* (Nayar 1964a), *Kaulinia* ((Nayar 1964b), Lomariopsidaceae (Nayar 1966, Kaur 1974), *Christiopteris* (Nayar 1967), phylogenetic classification of homosporous ferns (Nayar 1970), classification of homosporous ferns (Nayar 1974, 1976, 1980), *Arachniodes* (Nayar and Chandra P. 1968), *Pyrrosia* (Chandra P. 1964, Nayar and Chandra S. 1965, 1967), *Tectaria* (Nayar and Kaur 1964c, Kaur 1978, 1979), *Dennstaedtia* (Kaur 1972), companion to Beddome's Ferns of British India (Nayar and Kaur 1974), *Oleandra* (Nayar *et al.* 1968), *Onychium* (Nayar *et al.* 1972), *Pronephrum* (Chandra P. 1971), *Camptodium* (Chandra S. 1976), *Ananthocorus* (Chandra S. 1976a), *Marginariopsis* (Chandra S. 1978), drynarioid ferns (Chandra S. 1979, 1980), paleae in the polypodiaceae (Chandra P. 1962), epidermal studies in *Polystichum* and *Asplenium* (Chandra P. 1977, 1979), vascular organization in *Cibotium* (Chandra S. 1970) and *Gymnogrammitis* (Nayar and Bajpai 1976), rhizome of *Maxonia* (Chandra S. 1975), vascular organization of the rhizome in spleenworts (Chandra and Nayar 1975), gametophytes of homosporous ferns (Nayar and Kaur 1971) and chromosome in ferns (Khare 1980) were some of the pioneer and primary studies on various aspect of pteridophytes. A nomenclatural guide to R. H. Beddome's Ferns of South India and Ferns of British India (Chandra and Kaur 1987), the ferns of India-enumeration, synonyms and distribution (Chandra 2000) and pteridology in the new millennium (Chandra and Srivastava 2003) attempted to fill the gap of taxonomic lacuna in the ferns of India.

#### **PRESENT STATE OF RESEARCH AND DEVELOPMENT ACTIVITIES IN PTERIDOLOGY LABORATORY**

During last decade pteridology group is working on taxonomy, reproductive biology, in-vitro multiplication, conservation and prospection of pteridophytes. Study covering over 75 genera and 350 species of ferns was undertaken in North East Himalayas, North West Himalaya, Peninsular India, Eastern India, Central India and Gangetic plains. Assessment of diversity, discovery of new species, endemic taxa, chromosome analysis, experimental studies on foliar buds, spore morphology, germination, gametophyte development, reproductive behaviour, environmental studies, in-vitro propagation of RET taxa have been made. Prospection of pteridophytes for antifungal formulations, insecticidal, drought tolerant potentiality and environmental cleanup was made. Survey covering the entire Indian region is in progress and about 5000 specimens representing all the phytogeographical expanse of India are deposited in the herbarium (national facility). The herbarium now has been recognised as repository of pteridophytes by Ministry of Environment & Forests, Government of India. Living plants were introduced to fern house and in-vitro multiplication of RET taxa was made to conserve them into living repository of the Institute. Now the fern house came to have largest number of pteridophytes growing under one roof anywhere in the India. Discovery of new cytotypes and new records of pteridophytes (Singh *et al.* 2009) have been made. The biology and genetic diversity of *Pteris vittata* L., *Equisetum* sp. was made (Srivastava *et al.* 2008, Srivastava *et al.* 2009). Ethnobotanical studies on the Indian pteridophytes were made to bring their utility in to the public domain (Singh and Khare 2011). Reproductive biology of many species including threatened species viz. *Cyathea spinulosa*, *C. gigentia*, *Dipteris*

*wallichii* (Behera *et al.* 2011), *Anemia rotundifolia* (Singh *et al.* 2012), *Adiantum peruvianum* (Singh *et al.* 2013) were made.

## **MAJOR ACHIEVEMENTS DURING PAST DECADE**

### **Preparation of Flora and Biology of Pteridophytes**

1. The Ferns of India comprising 34 families, 144 genera, more than 1100 species from the Indian region was prepared (Chandra S. 2000).
2. About 235 endemic species of ferns in Indian regions were recorded (Chandra S. 2000).
3. Pteridology in the New Millennium comprising systematics, morphology, anatomy, cytology, ecology, floristic, phyto-remediation, economic utility, reproductive biology, tissue culture and palaeobotany is prepared (Chandra and Srivastava 2003).

### **Exploration and Survey of Pteridophytes**

1. During first decade of 21<sup>st</sup> century about 1755 specimen of pteridophytes were collected from Almora, Pithoragarh, Nainital, Kilbury, Corbette Tiger Reserve, Mukteshwar, Joshimath, Chamoli, Tapovan, Chopta, Rishikesh, Haridwar, Dhanaulti, Govind Wildlife Sanctuary (Uttarakhand), Gangtok (Sikkim), Tirunelveli, Calicut Botanic Garden, Wayanad, Kodaikanal (Kerala), Annapara, Shakti Nagar, Sonebhadra, Mirzapur, Lucknow (U.P.), Pachmarhi Biosphere Reserve, Sahdol, Amarkantak (M.P.), Shimla, Kangra Valley, Mandi (H.P.), Itanagar (Arunachal Pradesh) and certain localities of Orissa and Tripura. Ecological data related to habit, habitat, longitude, latitude, altitude, associates, diversity, distribution and ethno-botanical information were also collected.

### **Enrichment of Herbarium (National Facility)**

1. During last ten years about 1755 specimens collected from different regions of country have been enriched in the pteridophyte's holdings. Herbarium holds more than 5000 holdings of pteridophytes collected from various regions of the country, including some valuable specimens from overseas countries. In addition, about 3901 specimens were revisited, renovated and looked for appropriate accession numbers preparing a list in total. Pteridophyte herbarium of CSIR-NBRI is recognized as repository by Ministry of Environment & Forests, Government of India.

### **Enrichment of Fern House**

1. The fern house (living repository) has been christened providing appropriate habitat and environmental conditions to conserve important pteridophyte species (Fig. 1-A). It exhibit more than 65 species of ferns and their allies collected from different part of the country. Amongst them, the *Psilotum nudum*, *Anemia rotundifolia* (Fig. 1-B), *Equisetum debile*, *Ophioglossum reticulatum*, *Adiantum peruvianum* (Fig. 1-C), *Doryopteris ludens* (Fig. 1-D), *Selaginella bryopteris* (Fig. 2-A), *Bolbitis heteroclita*, *Blechnum orientale*, *Anemia rotundifolia*, *Selaginella dicitii*, *Adiantum hispidulum*, *Microlepia striginosa*, *Colysis elliptica* is threatened in nature, conserved for future research and development activities. Extension of pre-existing fern house was made establishing an additional house (750 feet<sup>2</sup> area). This newly established house exhibit more than a dozen acclimatized fern species.

### **New Records of Pteridophytes**

1. Two new cytotype (triploid and pentaploid) of *Pteris vittata* were discovered. *Ophioglossum polyphyllum* was recorded first time from Pachmarhi Biosphere Reserve, and is new addition to the pteridophytic flora of central India (Singh *et al.* 2009).

### **In-vitro Culture and Mass Propagation**

1. In-vitro culture and mass multiplication (about 4500 replicates) of more than a dozen pteridophytes viz. *Asplenium nidus* (Fig. 2-B), *Bolbitis heteroclita*, *Blechnum orientale*, *Proneprium nudatum* (Fig. 2-C), *Adiantum peruvianum*, *Anemia rotundifolia* (Fig. 2-D), *Microlepia striginosa*, *Colysis elliptica*, *Cyclosorus cylindrothrix*, *Nephrolepis tuberosa*, *N. exaltata*, *N. cordifolia*, *Microsorium punctatum*, *M. alternifolium*,

*Selaginella bryopteris*, *Ophioglossum reticulatum* and *Asplenium nidus* have been made. In vitro multiplied taxa were acclimatized and conserved in the fern house.

#### **Reproductive Biology of RET Pteridophytes**

1. Reproductive biology of *Dipteris wallichii*, *Anemia rotundifolia*, *Adiantum peruvianum*, *Actiniopteris radiata*, *Adiantum hispidulum*, *Cyclosorus cylindrothrix*, *Cyathea gigantea*, *Cyathea spinulosa*, *Lygodium japonicum*, *Osmunda regalis* were carried out (Behera *et al.* 2011, Singh *et al.* 2012, Singh *et al.* 2013). Reproductive biology on *Cyathea spinulosa* (Khare *et al.* 2005, Shukla and Khare 2012), *C. nilgirensis* (Khare and Srivastava 2009), *C. gigantea*, *Lygodium japonicum*, *Osmunda regalis*, *Actiniopteris radiata*, *Adiantum hispidulum* and *Cyclosorus cylindrothrix* confirmed the real cause of reproductive barriers and threats.

#### **Molecular systematic and cytology in Pteridophytes**

1. Molecular systematics and RAPD analysis in *Pteris vittata* complex and *Equisetum* sp. was made. Study revealed ploidy, evolutionary pattern in *P. vittata* and phylogeny status of *Equisetum* (Srivastava *et al.* 2008; Srivastava *et al.* 2009). Cytological study on *P. vittata* was made and two new cytotypes (triploid and pentaploid) were discovered.

#### **Digitized Herbarium of Pteridophytes**

1. Digitized databases (<http://www.nbri.res.in/padap>) on about 673 Indian pteridophytes altogether with their taxonomic character, cytology, ecology, distribution, economic importance and ethno-botanical uses with images on herbarium have been prepared.

#### **Ethnobotanical Studies on Pteridophytes**

1. Ethnobotanical studies on 114 pteridophytes used by tribes/common people in various localities of India have been comprehended with emphasis on their common name, parts used for cure of diseases and other utilization (Singh *et al.* 2010, Singh and Khare 2011).

#### **Prospection of Pteridophytes for Antimicrobial and Medicinal Properties**

1. Antibacterial and antifungal properties in *Psilotum nudum*, *Nephrolepis biserrata*, *N. cordifolia* (Rani *et al.* 2010), antimicrobial activity on *Adiantum* species (Singh *et al.* 2008a) *Pteris vittata* (Singh *et al.* 2008b), *Microsorium* species (Singh *et al.* 2007) were investigated.

#### **Prospection of Pteridophytes for Environmental Pollution Monitoring**

1. Two ferns *Adiantum capillus-veneris* and *Microsorium punctatum* for Cr accumulation potentiality and antioxidant responses (Sinam *et al.* 2012); metabolic adaptation of *Pteris vittata* gametophyte to arsenic induced oxidative stress (Raj *et al.*, 2011); arsenic accumulation pattern in 12 Indian ferns and assessing the potential of *Adiantum capillus-veneris*, in comparison to *Pteris vittata*, as arsenic hyper accumulator (Singh *et al.* 2010) has been studied.

#### **Prospection of Pteridophytes for Insecticidal Proteins**

1. About 45 species of pteridophytes and bryophytes have been substantially screened for insecticidal proteins. Discovery of six novel proteins with their encoding genes were made. Two patents (Singh *et al.*, 2011; 2012) were filed; however remaining are under process of filing.

#### **Prospection of Pteridophytes for Drought Tolerant Potentiality**

1. Desiccation tolerance in pteridophyte has been studied (Soni *et al.* 2012). *Selaginella bryopteris* was discovered potential species and displayed in CSIR-Technofest New Delhi during 2010. The species got more attention of masses with huge coverage by electronic/print media and placed in CSIR tableau during Republic Day parade.

#### **Research Project Completed**

1. Morphological and taxonomical studies of Ferns in India (CSIR-In-house).
2. Diversity of Pteridophytic flora of Corbett National Park (UPCST funded).

3. Diversity and conservation of Pteridophytic flora of Kumaon Himalayas with special reference to threatened taxa (DST funded).
4. Determination and analysis of genetic diversity of an economically important fern *Pteris vittata* L. complex (DBT funded).
5. Biodiversity and biosystematics study of heavy metal accumulating *Equisetum* (Horsetail) species in India (DBT funded).
6. Studies on genetic diversity and conservation of some threatened and economically important ferns (CSIR-In-house).
7. Pollution monitoring, mitigation systems and devices (CSIR Networking).
8. Remediation and eco-restoration & cleanup of contaminated ground and water resources (CSIR Networking)
9. Environmental contaminants-New screening technologies and effect on human health (CSIR Networking)
10. Biodiversity assessment, prospection and conservation of plant resources of India (CSIR-Supra Institutional)
11. System Biology for Drought Tolerance (CSIR-Supra Institutional)
12. Studies on Diversity and distribution pattern of Pteridophytes in Pachmarhi Biosphere Reserve, Madhya Pradesh (MoEF- funded).

#### **Ongoing Research Projects**

1. Taxonomic studies and digitization of plant diversity of India (CSIR-In house).
2. Digitization and organization of CSIR - NBRI Herbarium (CSIR-In house).
3. Bio-prospection of plant resources and other natural products -Biopros PR (CSIR-Networking).
4. Diversity, distribution and ethno-botany of Pteridophytes and Hepaticae (Bryophytes) in Dudhwa National Park in Uttar Pradesh and bordering regions (UPSBB-funded).

#### **Areas open for collaboration**

1. Prospection of pteridophytes for active bio-molecules (antifungal, antimicrobial, antifeedant).
2. System biology of pteridophytes for drought, cold and low light tolerance potentiality.
3. Developmental biology, reproductive biology and reproductive barriers in threatened pteridophytes.
4. Database preparation on pteridophytes.
5. Monographic and floristic studies on Indian pteridophytes.

#### **Publications**

Research papers published – More than 425

Ph. D. degree awarded – 07

Books published – 06

Popular articles in Hindi – 17

Review articles – 10

#### **References**

1. Behera S.K., Rawat V. K., Singh Ajit Pratap and Khare P. B. 2011. Studies on the spore germination, developmental pattern and sexuality of gametophytes in *Dipteris wallichii* (R. Br. ex Hook. et Grev.) T. Moore. *Indian Fern J.*, 28: 172-178.
2. Chandra P. 1962. Ontogeny of peltate paleae in the Polypodiaceae. *Curr. Sci.*, 31: 477-79.
3. Chandra P. 1963. The genus *Pityogramma* Link in India. *J. biol. Sci.*, 6: 1-4.
4. Chandra P. 1964. A new species of *Pyrrhosia* from India. *Am. Fern J.*, 54: 62-67.

5. Chandra P. 1971. Genus *Pronephrium* Presl. in India. *Bull. bot. Surv. India*, 13: 274-81.
6. Chandra P. 1977. Epidermal studies in some species of *Polystichum* Roth. *New Botanist*, 4: 101-07.
7. Chandra P. 1979. Leaf epidermis in some species of *Asplenium* L. *Proc. Indian Acad. Sci.*, 88 B: 269-75.
8. Chandra P. 1989. Botanical exploration in Tawang- Ferns and fern allies. *Nova Hedwigia*, 32: 399-414.
9. Chandra S. 1970. Vascular organization in the rhizome of *Cibotium barometz*. *Am. Fern J.*, 60: 68-72.
10. Chandra S. 1975. Some morphological aspects of the rhizome of *Maxonia C. Chr.* (Dennstaedtiaceae). *Brenesia*, 6: 1-7.
11. Chandra S. 1976. Studies on the morphology of the monotypic fern genus *Camptodium* (Aspidiaceae). *Brenesia*, 9: 15-23.
12. Chandra S. 1976a. Morphology of the sporophyte of the vittarioid fern *Ananthacorus*. *Fern Gaz.*, 11: 247-53.
13. Chandra S. 1978. Studies on the monotypic fern genus *Marginariopsis* (Polypodiaceae). *Brenesia*, 14-15: 337-38.
14. Chandra S. 1979. Taxonomic use of foliar epidermis and hypodermis in drynarioid ferns. *Kalikasan, Philipp. J. Biol.*, 8: 211-26.
15. Chandra S. 1980. Sporangial morphology of drynarioid ferns. *Kalikasan, Philipp. J. Biol.*, 9: 31-42.
16. Chandra S. 2000. The Ferns of India (Enumeration, Synonyms and Distribution), International Book Distributors, Dehradun, (i-xi) 1-459.
17. Chandra S. and Kaur S. 1987. A Nomenclatural Guide to R. H. Beddome's Ferns of South India and Ferns of British India. Today and Tomorrow's Printers and Publishers, New Delhi, 1-139.
18. Chandra S. and Nayar B.K. 1975. Vascular organization of the rhizome of spleenworts. *J. Indian bot. Soc.*, 54: 188-89.
19. Chandra S. and Srivastava M. K. 2003. Pteridology in the New Millennium. Kluwer Academic Publishers, Netherlands, (i-xxxii) 1-520.
20. Devi S. 1973. Spore morphology of Indian ferns. *J. Palynol.*, 9:192-201.
21. Devi S. 1980. The concept of perispore – an assessment. *Grana*, 19: 159-72.
22. Kaur S. 1964. Development of the stelar cylinder in the rhizome of *Bolbitis* and *Egenolfia*. *Am. Fern J.*, 54: 57-62.
23. Kaur S. 1972. Contribution to the morphology of *Dennstaedita* *Proc. Indian Acad. Sci.*, 75B: 32-39.
24. Kaur S. 1974. The family Lomariopsidaceae (Filicopsida) and its probable ancestors. *Bot. J. Linn. Soc.*, 68: 153-62.
25. Kaur S. 1978. Contribution to the morphology of *Tectaria*. Venation pattern of sterile and fertile leaves. *Phytomorphology*, 28: 14-19.
26. Kaur S. 1979. Contribution to the morphology of *Tectaria*. Morphology of the sporophyte. *Phytomorphology*, 29: 87-92.

27. Khare P. B. and Srivastava R. 2009. Studies of the gametophyte development and reproductive biology of an endemic tree fern, *Cyathea nilgirensis* Holtt. *The Journal of Plant Reproductive Biology*, 1(1): 59-62.
28. Khare P. B., Behera S. K., Srivastava R. and Shukla S. P. 2005. Studies on reproductive biology of a threatened tree fern, *Cyathea spinulosa* Wall ex hook. *Current Science*, 89(1): 173-177.
29. Khare P. B. 1980. A note on the chromosome number of the fern flora of Amarkantak hills, Central India. *Sci. Cult.* 46: 138-39.
30. Nayar B. K. 1980. Classification of Ferns: Its present status and problems. In Aspects of Plant Sciences, S.S. Bir (ed.), Today and Tomorrow's Printers and Publishers, New Delhi, 3: 1-38.
31. Nayar B. K. and Kaur S. 1963. Fern of India-VIII: *Microlepia*. *Bulletin of Nat. Bot. Garden.* 79: 1-25.
32. Nayar B. K. and Kaur S. 1964. Fern of India-XI: *Bolbitis*. *Bulletin of Nat. Bot. Garden.* 88: 1-75.
33. Nayar B. K. and Kaur S. 1974. Companion to Beddome's Handbook to the Ferns of British India, Ceylon and Malaya Peninsula. Cronica Botanica, New Delhi.
34. Nayar B. K. 1954. Studies in Polypodiaceae – II. Contribution to the morphology of *Pseudodrynaria coronans* (Wall.) C. Chr. *Phytomorphology*, 4: 379-90.
35. Nayar B. K. 1955. Studies in Polypodiaceae - III: *Loxogramme* (Bl.) Presl. *J. Indian bot. Soc.*, 34: 395-407.
36. Nayar B. K. 1955a. The gymnogrammeoid and the pleopeltoid ferns – a summary. *J. Univ. Gauhati*, 6: 47-62.
37. Nayar B.K. 1956. Studies in Pteridaceae - II: *Hemionitis* Linn. *J. Indian bot. Soc.*, 35: 333-43.
38. Nayar B. K. 1957. Studies in Polypodiaceae – IV. *Drymoglossum* Presl. *J. Indian bot. Soc.*, 36: 169-79.
39. Nayar B. K. 1959. Studies in Polypodiaceae – VI. Further observations on the morphology of *Drynaria Bory*. *J. Univ. Gauhati*, 9: 95-103.
40. Nayar B.K. 1960. Studies in Pteridaceae – III. Morphology of spores, prothalli and juvenile sporophytes of *Doryopteris* J. Sm. *Curr. Sci.*, 29: 380-82.
41. Nayar B.K. 1960a. Morphology of two Indian species of *Bolbitis*. *J. Indian Bot. Soc.*, 39: 259-77.
42. Nayar B. K. 1961. Ferns of India- I. *Adiantum* Bull. natn. bot. Gdn., 52: 1-43.
43. Nayar B. K. 1961a. Ferns of India- II. *Drynaria* and *Pseudodrynaria*. Bull. natn. bot. Gdn., 56: 1-30.
44. Nayar B. K. 1961b. Ferns of India – III. *Microsorium* Link emend. Copel. Bull. natn. bot. Gdn., 58: 1-38.
45. Nayar B. K. 1962. Ferns of India – I. *Adiantum* Bull. natn. bot. Gdn., 52: 1-43.
46. Nayar B. K. 1962a. Ferns of India – V. *Hemionitis*. Bull. natn. bot. Gdn., 67: 1-14.
47. Nayar B. K. 1962b. Ferns of India – VI. *Cheilanthes*. Bull. natn. bot. Gdn., 68 : 1-36.
48. Nayar B. K. 1963. Ferns of India – VII. *Actiniopteris*. Bull. natn. bot. Gdn., 75: 1-14.
49. Nayar B. K. 1963a. Contribution to the morphology of *Leptochilus* and *Paraleptochilus*. *Am. J. Bot.*, 50: 301-08.
50. Nayar B. K. 1963b. The morphology of some species of *Cheilanthes*. *J. Linn. Soc. Bot.*, 58: 449-60.

51. Nayar B. K. 1963c. Contribution to the morphology of some species of *Microsorium*. *Ann. Bot.* (n.s.), 27: 89—100.
52. Nayar B. K. 1964. Ferns of India – XIV: *Lemmaphyllum*. *Bull. natn. bot. Gdn.*, 106: 1-15.
53. Nayar B. K. 1964a. Some aspects of morphology of *Pityrogramma calomelanos* and *P. chrysophylla*. *J. Indian bot. Soc.* 43: 203-13.
54. Nayar B. K. 1964b. *Kaulinia*, a new genus of polypodiaceous ferns. *Taxon*, 13: 67-69.
55. Nayar B. K. 1966. Morphology of fertile leaves of Lomariopsidaceae, with special reference to venation. *New phytol.*, 65 : 221-39.
56. Nayar B. K. 1967. Morphology of the spores and prothallus of *Christiopteris tricuspis*. *Am. Fern. J.*, 57: 15-127.
57. Nayar B. K. 1970. A phylogenetic classification of the homosporous ferns. *Taxon*, 19: 229-36.
58. Nayar B. K. 1974. A Classification of homosporous ferns. in “Companion to R.H. Beddome’s Hand book to ferns of British India” by B.K. Nayar and S.Kaur, *The Chronica Botanica*, New Delhi : 111-201.
59. Nayar B. K. 1976. The classification of ferns. in “Recent Advances in Botany”. P. Kachroo (ed.), *Bishen Singh Mahendra Pal Singh*, Dehra Dun: 145-205.
60. Nayar B. K. and Bajpai N. 1976. Vascular organization and some aspects of the morphology of the rhizome of *Gymnogrammitis dareiformis*. *Ann. Bot.*, 40: 515-19.
61. Nayar B. K. and Chandra P. 1964. A new species and variety of *Bolbitis* from India. *Am. Fern J.*, 54: 9-19.
62. Nayar B. K. and Chandra P. 1968. The fern genus *Arachniodes* Bl. in India. *Bull. bot. Surv. India*, 10: 234-36.
63. Nayar B. K. and Chandra S. 1965. Ferns of India- XV. : *Pyrrosia* Mirbel. *Bull. natn. bot. Gdn.* , 117 : 1-98.
64. Nayar B. K. and Chandra S. 1967. Morphological series within the genus *Pyrrosia* and their phylogenetic interpretation. *Can. J. Bot.*, 45: 615-34.
65. Nayar B. K. and Kaur S. 1963. Ferns of India – VIII. *Microlepidia*. *Bull. natn. bot. Gdn.*, 79.1-25.
66. Nayar B. K. and Kaur S. 1963a. Ferns of India – IX. *Peranema* and *Acrophorus*. *Bull. natn. bot. Gdn.* 81: 1-40.
67. Nayar B. K. and Kaur S. 1964a. Ferns of India – XII. Some new taxa. *Bull. natn. bot. Gdn.* 94: 1-15.
68. Nayar B. K. and Kaur S. 1964b. Ferns of India – XIII. *Egenolfia*. *Bull. natn. bot. Gdn.* 100: 1-38.
69. Nayar B. K. and Kaur S. 1964c. Contribution to the morphology of *Tectaria*: The spores, prothalli and juvenile sporophytes. *Bull. Torrey bot. Club*, 91: 95-105.
70. Nayar B. K. and Kaur S. 1971. Gametophytes of homosporous ferns. *Bot. Rev.*, 37: 295-396.
71. Nayar B. K., Bajpai N. and Chandra S. 1968. Contribution to the morphology of the fern genus *Oleandra*. *J. Linn. Soc. Bot.*, 60: 265-82.
72. Nayar B. K., Bajpai N. and Chandra S. 1972. Morphology of the genus *Onychium* in India. *J. Indian bot. Soc.*, 5: 63-72.

73. Raj A., Pandey A. K., Sharma Y. K., Khare P. B., Srivastava P. K., Singh N. 2011. Metabolic adaptation of *Pteris vittata* L. gametophyte to arsenic induced oxidative stress. *Bioresources Technology*, 102: 9827-9832.
74. Rani D., Khare P. B. and Dantu P. K. 2010. In Vitro Antibacterial and Antifungal Properties of Aqueous and Non-Aqueous Frond Extracts of *Psilotum nudum*, *Nephrolepis biserrata* and *Nephrolepis cordifolia*. *Indian J Pharm Sci.* 72(6): 818–822.
75. Shukla S. P. and Khare P. B. 2012. In vitro mass multiplication of a threatened tree fern *Cyathea spinulosa* Wall ex Hook. *International Journal of Genetic Engineering and Biotechnology*, 3(1): 15-23.
76. Sinam G., Behera S. K., Mishra R. K., Sinha S., Mallick S. and Khare P.B. 2012. Comparison of two ferns (*Adiantum capillus-veneris* Linn. and *Microsorium punctatum* (Linn.) Copel., for their Cr accumulation potential and antioxidant responses. *International J Phytoremediation*, 14:629-642.
77. Singh Ajit Pratap and Khare P. B. 2011. Status of Ethno-Pteridology in India-A Review Article. *Applied Botany Abstract*, 31(4): 332-361.
78. Singh Ajit Pratap, Johari D., Singh A. and Khare P.B. 2013. Reproductive biology of a rare fern species—*Adiantum peruvianum* (Adiantaceae: Pteridophyta). *Phytomorphology*, 63 (1&2): 105-114.
79. Singh Ajit Pratap, Johari D., Singh A., Behera S. K. and Khare P.B. 2012. Studies on regeneration of gametophytes and mass multiplication of *Anemia rotundifolia* Schrad. (Pteridophyte). *International Journal of Current Research*, 4 (12): 235-240.
80. Singh Ajit Pratap, Mishra S., Gupta S., Behera S. K. and Khare P. B. 2009. Studies on the Genus *Ophioglossum* L. in Pachmarhi Biosphere Reserve, Madhya Pradesh-India. *Tawania*, 5(4):353-364.
81. Singh Ajit Pratap, Rawat V.K., Behera S. K. and Khare P.B. 2010. Perspectives of Pteridophytes Biodiversity: A Source of Economy Elevation. In *Proceedings of National Conference on Biodiversity, Development and Poverty Alleviation*, Pp 46-49.
82. Singh M., Govindrajan R., Rawat A. K. S. and Khare P. B. 2008b. Antimicrobial flavonoid Rutin from *Pteris vittata* L. against pathogenic gastrointestinal Micro flora. *American Fern J.*, 98: 98-103.
83. Singh M., Rawat A. K. S. and Khare P. B. 2007. Antimicrobial activity of two *Microsorium* species, *Indian Fern J.*, 24: 167-171.
84. Singh M., Singh N., Khare P. B. and Rawat A.K.S. 2008a. Antimicrobial activity of some important *Adiantum* species used traditionally in indigenous systems of medicine. *J. of Ethnopharmacology*, 115:327-329.
85. Singh N., Raj A., Khare P.B., Tripathi R.D. and Jamil S. 2010. Arsenic accumulation pattern in 12 Indian ferns and assessing the potential of *Adiantum capillus-veneris*, in comparison to *Pteris vittata*, as arsenic hyper accumulator. *Bioresource Technology*, 101: 8960-8968.
86. Singh P.K., Upadhyay S.K., Chandrashekhar K., Saurabh S., Singh R., Rai P., Singh Harpal, Mishra M., Singh Ajit Pratap, Verma P.C., Nair K.N. and Tuli R. 2011. A process for preparation of a novel insecticidal chitinase toxic against whiteflies, its encoding nucleotides and application thereof.
87. Singh P.K., Upadhyay S.K., Chandrashekhar K., Saurabh S., Singh R., Rai P., Singh Harpal, Mishra M., Singh Ajit Pratap, Verma P.C., Nair K.N. and Tuli R. 2012. A process for preparation of a novel insecticidal chitinase toxic against whiteflies, its encoding nucleotides and application thereof.
88. Soni D. K., Ranjan S., Singh R., Khare P. B., Pathre U. V. and Shirke P.A. 2012. Photosynthetic characteristics and the response of stomata to environmental

determinants and ABA in *Selaginella bryopteris*, a resurrection spike moss species" *Plant Science*, 191-192: 43-52.

89. Srivastava J., Ranade S. A., and Khare P. B. 2008 RAPD profile diversity amongst two polyploidy accessions of *Pteris vittata* L. In: S.C. Verma, S.P. Khullar and H.K. Cheema (Eds.), *Perspectives in Pteridophytes*, pp. 433-443. Bishen Singh Mahendra Pal Singh, Dehradun, India
90. Srivastava J., Ranade S. A., and Khare P. B. 2009 SPAR profiling can provide support for the infra-generic taxonomy of the genus *Equisetum* L. *Plant and Fungal Biodiversity and Bio-prospecting*. 87-98.