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Editor-in-Chief
Indian Fern Journal

FRONT COVER PICTURE

***Asplenium khullarii* Reichst. & Rasbach ex Fraser-Jenk.**

Specimen In MUSEUM BOTANICUM UNIVERSITATIS, HELSINKI (FINLAND).

Picture of Herbarium Sheet (No. 1712951).

BACK COVER PICTURE

***Dicranopteris lanigera* (D. Don) Fraser-Jenk.**

Picture from a population found near Thal in Pithoragarh district (Kumaon, Himalaya).

Photo Credit : Prof. N. Punetha, (Pithoragarh).

Prof. Punetha is of the view that the correct name for this fern is *D. linearis*

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REPORT ON INTERNATIONAL CONFERENCE ON "NEXT GENERATION PTERIDOLOGY : THE INDIAN PERSPECTIVE" ON MAR 8-10, 2019

ORGANISED BY
DR. BHUPENDRANATH DUTTA SMRITI MAHAVIDYALAYA, HATGOBINDAPUR, PURBA BARDHAMAN, BURDWAN 713407, WEST BENGAL INDIA

IN COLLABORATION WITH
INDIAN FERN SOCIETY, CHANDIGARH

DR. NIRUPAMA BHATTACHARYYA GOSWAMI
Organizing Secretary and Convener
Email : nirupama1963@gmail.com

Dr. Bhupendranath Dutta Smriti Mahavidyalaya, Hatgobindapur, Purba Bardhamman (West Bengal) in collaboration with the Indian Fern Society, Chandigarh hosted an international conference spanning three days entitled "Next Generation Pteridology : The Indian Perspective" from 08-10 March, 2019 at the said college in Hatgobindapur, Purba Bardhamman, West Bengal. The college is situated in an rural location and is founded in the memory of the noted Indian revolutionary and sociologist Dr. Bhupendranath Dutta.

The sub-themes for the conference included :

- * Systematics and Evolution
- * Phytogeography, Distribution and Endemism
- * Ecology, Environmental and related edaphic factor studies
- * Cytology and Biotechnological inventions
- * Molecular Studies and Bioprospection

The seminar started by paying our deepest condolences to the late Prof. S. S. Bir who was a stalwart and very well-acclaimed professor in the field of Pteridology. Garlanding the photo of Prof. S. S. Bir, who was also the founder of the Indian Fern Society, was done by Prof. S. K. Roy (Retired Professor, the University of Burdwan) and all the participants of the conference observed a moment of silence. Following this event, the statues of Dr. Bhupendranath Dutta (after whom the college was named) and Swami Vivekananda (the brother of the aforesaid person) were also garlanded by Prof. S. P. Khullar (Secretary Treasurer, Indian Fern Society) and Prof. P. K. Rajagopal (President of Indian Fern Society) respectively. After this cermony all the participants moved to the main conference room and the lighting of the lamp was initiated.

The lighting of lamp, signaling the inauguration of the conference, was performed by Prof. Swapan Dutta (ex-Vice-Chancellor, Viswa-Bharati University), Prof. P.K. Rajagopal (President of Indian Fern Society), Prof. S. P. Khullar (Secretary Treasurer of Indian Fern Society), Prof. Harun Abdullah Chaudhuri (Prof. of Environmental Science, Khulna University, Bangladesh), Roshan Kumar Yadav, Tribhuvan University, Nepal, Dr. Samar Roychowdhury, Deputy Director NCCS, Pune, Mr. Nisith Kumar Malik, MLA,Purba Bardhaman and President of Governing Body of this college and Prof. Jagatpati Tah

(President, Organising Committee). Presentation of flower bouquet and mementos to the delegates was also done.

The opening song "Aguner Poroshmoni" was rendered by the Music Department of the college. This song, written by the Nobel Laureate Poet, Rabindranath Tagore, exemplifies the philosophy of moving forward even in the times of hardship. After the song, the Presidential address was delivered by Prof. P.K Rajagopal, President, IFS.

In his inaugural speech Prof. Swapan Dutta (ex. D. D. (Horticulture, ICAR, Ex. V. C. Viswa Bharati)), wished the conference a grand success. He also expressed his joy in seeing an international conference on a specific topic of a subject in a rural college and thanked the organisers for hosting such an event.

Prof. P. K. Rajagopal in his address discussed the ethnobotanical aspects of pteridophytes and its significance in the modern times. The biodiversity rich zones of Western Ghats and Eastern Himalaya, which harbors more than 320 species of ferns and lycophytes, were also discussed. Besides use in ethnobotany, the use of pteridophytes as food, fiber, fuel, shelter and ecosystem regulators were also highlighted.

Prof. S. P. Khullar, Secretary Treasurer IFS, addressed the audience next and expressed his immense pleasure to see the final fruition of the dreams of Dr. Nirupama Goswami, Principal of the College, Convener and Secretary General of the organizing committee. Dr. Goswami had a longtime dream of organizing a symposium on pteridophytes, and her constant endeavor and hard work made the conference possible. Dr. Goswami is a long term member of IFS and her dream was to be the host this time. She and her colleagues, Dr. Khullar expressed, deserved heartiest congratulations in this regard. Dr. Khullar also enlightened the audience with a short history of the Indian Fern Society.

Dr. J. Tah, President, Organizing Committee of the conference, expressed his pleasure to be a part of the conference and proceeded with the various ways pteridophytes can serve for human Besides maintaining ecosystems and biodiversity, Prof. Tah opined, pteridophytes can also harbour yet undiscovered compounds which can be of incalculable importance in the cure of various human diseases which are difficult to cure. Finally, he expressed his thanks to the participants who had come over from abroad and many far reaching places of India.

The conference proceedings were released during this time by the organisers. The Vote of thanks was by Dr. Debamitra Chakraborty, Asst. Professor, DBNDSM. After this, a short tea-break was observed. After the break, the invited talks session was started. Prof. H. K. Cheema spoke on Past, Present and Future of Plant Tissue Culture with Special reference to Ferns.

Prof. Abdullah Harun Chowdhury, Professor, Environmental Science, Khulna University, Bangladesh, blessed the occasion with his lecture on the impact of ecological and environmental changes on the biodiversity. In his lecture, the delegates got to know about the macro-issues that affect biodiversity in the biomes of the world. The top-down

The participants of the symposium : Top : Second day; Bottom : First day.

Top : The Poster session
Bottom : Prof Nirupama Goswami presenting the Gold Medal to Dr. Sachin Patil

approach helped the listeners to connect the dots on how various life forms, including us humans, are intimately connected as a system of systems. The impact of abiotic factors, which make up the climate, was also discussed. In the context of pteridology, it also raised questions on how to preserve and utilize the fern species in this complex cacophony of environmental stressors.

Prof. B. D. Sharma, retired professor in Botany, Jodhpur University, delivered his lecture on permineralized pteridophytes of the early cretaceous in the Rajmahal Hills of Jharkhand, India. In his lecture concerning prehistoric fossil records, which are an invaluable tool for evolutionists, the audience got to know about the treasures of cretaceous pteridophytes.

Prof. M. K. Seth, Dept. of Bio-science, Himachal Pradesh University, Shimla, delivered his lecture on the *Asplenium* species along the National Highway 22 from Parvanoo to Kaurik. He listed 11 species of the genus *Asplenium*. He highlighted his talk with detailed descriptions and habitat of these. The economic importance of some of these plants, as well as the keys for the identifications of these taxa were also described in his insightful lecture.

After these lectures there was the lunch break.

After the lunch break on the first day, two technical sessions started in different rooms. In room 1, Prof. Alka Kumari, Dept. of Botany, University of Lucknow, delivered her talk on "Diversity, threat status and ethnobotany of pteridophytes in Vikramshila Gangetic Dolphin Wildlife Sanctuary, Bihar, India". In her talk, the five year (2009-2014) study of the region in the title culminated in the collection of a total of sixty ferns and fern alleles from the region and their numerous uses, including the use as medicine, ornament, ceremonial etc were elucidated. Her talk further bolstered the importance of biodiversity management in the biodiversity rich zones.

Besides the invited talk of Prof. Kumari, 6 oral presentations were delivered in Room 1.

Simultaneously in Room 2, the invited talk was delivered by Prof. Rabindranath Bhattacharyya. Drug resistance, a alarming menace of this century, was put in the crossfire with the simultaneous use of the antimicrobial properties of silver nanoparticles and the some common weeds. The talk illustrated how these methods can provide a greener and safer way of fighting pathogens which are multi-drug resistant.

Besides the invited talk of Prof. Bhattacharyya, 6 oral presentations were delivered in Room 2.

After this lecture session, the tea break was observed in the afternoon. After the tea break, Prof. Kakali Sen delivered her lecture on spore and gametophyte of ferns as an experimental tool. Her talk focused on some of the recent contributions by scientists in this regard. The last lecture of the day was delivered by Prof. H.S. Kirn. In his insightful lecture, the audience got themselves acquainted with the phytogeography and diversity of pteridophytic flora of the Indian state of Jammu and Kashmir. The biodiversity hotspot of western Himalayas harbors, as we learnt, 361 species of ferns(Khullar 1994,2000) and over 184 species of fern-allies. In the present study, Prof. Kirn described their study on 180 species of pterdiophytes. The regional and origin-based information of these species were also described in detail.

All lectures surely inspired a lot of young delegates on the perseverance required for impactful researches.

The cultural program in the evening comprised of tribal dance as per the Santali tradition. This folk dance captured the enthusiasm of everybody, especially the youngsters, and reminded us about the cultural diversity of the country. This was followed by dinner on a continental theme.

The Principal of the college, who was also the Convener and the Secretary General of the conference. Prof. Nirupama Goswami, Professor of Botany, Life Member, Indian Fern Society and the Ex. Regional Director, Netaji Subhas Open University, welcomed the delegates on the second day of the conference. She reminisced about her early days with the Indian Fern Society since 1988, stressing on the constant evolution of the society over the years. She also thanked the various subcommittees, conveners and members, along with the teaching and the non-teaching staffs who toiled endlessly to make this conference a reality. In the absence of funding by most funding agencies, she noted, the monetary help provided by various business institutions and villagers were very much crucial for making the conference a success.

The second day of the technical session of the conference started with the Address of Prof. S. P. Khullar. He spoke on Ecological aspects of Pteridophytespointing out that ferns do act as Ecological Indicators. He also spoke about Colonization of New Habitats by ferns, Classification on Basis of Habitats, Distribution of Pteridophytes in India,Topography as an important factor in the distribution of Pteridophytes, and the Puzzling distribution of fern species.

After this, the invited talk session started. Prof. Ashwani Kumar showed the delegates a glimpse of the future with his talk on Next Generation Pteridology. This lecture encompassed the role of biotechnology in studies of ferns and the medicinal and therapeutic use of the same to provide new dimensions to Pteridology. Jaideep Mazumdar then enriched the audience with his lecture on the revised account of the fern *Lygodium*. After the invited lectures the Oral Presentation session started. A total of 14 lectures were delivered in two different rooms. The topics ranged from ecological, to taxonomic and biotechnological realms concerning the pteridophytes. Prof. B. L. Yadav spoke on ferns and fern allies of Rajasthan.

After the invited talk session lunch was taken. The delegates refreshed themselves for the upcoming sessions of Oral and Poster presentations. The Poster Session consisted of 12 posters by presenters. These were judged on the originality and impact and in a later session the 1st, 2nd and 3rd prizes were awarded for the same. A general body meeting of the life members of the Indian Fern Society, including the President and the Secretary Treasurer was held. The Secretary presented the future roadmap of the society, and guide lines for the awards of the Society were outlined and approved.

A tea-break was observed and then the final valedictory session began. The session was held at the auditorium of the DBNDS college. Prof. Anirban Ghosh, the Director of Vocational Studies, Netaji Subhas Open University, Kalyani was present as the chief guest for the occasion. Swami Ajneyananda, Secretary, Ramkrishna Mission Ashrama, Bajepratapur, was also present. Prof. Rajagopal kindly accepted to preside over this valedictory session. In the valedictory session, the prizes for Oral and Poster presentations were given in this session. Prof. Nirupama Bhattacharyya Goswami was conferred the Indian Fern Society Fellowship by the Indian Fern Society and the Birbal Sahni Paleobotany Award' by the Birbal Sahani Institute of Paleobotany, Lucknow. At the end all participants of the symposium praised and offered their thanks and expressed best wishes to the organizing committees of the conference.

The sessions ended with the cultural functions at the night. The function consisted of Raibesh dance and Baul songs, which are a tradition in West Bengal and have preserved their heritage for hundreds of years. After a long day, the delegates enjoyed being a part of these cultural events.

On the third and final day, an excursion to Santiniketan, Birbhum, W.B. an ecological hotspot and home of the Nobel Laureate poet, Rabindernath Tagore, was organized. Interested delegates got themselves acquainted with the ideas of the world-famous poet and visited the historical museums and educational institutions the town is famous for. Collection of ferns, especially of the genus *Lycopodium, Lygodium,* and *Pteris* was also done. Thus, with this short excursion, the three day gala came to a fitting closure.

The Symposium was a great success and all delegates were highly impressed by the standard of presentations during the symposium.

* * * * *

AWARDS OF THE INDIAN FERN SOCIETY 2019

1. LIFE TIME ACHIEVEMENT AWARD : (i) Prof. U. Sen
   (ii) Prof. Varaprasadam Irudayaraj
2. HONORARY FELLOW : Prof. Jagapati Tah
3. FELLOWS : (i) Dr. Nirupama Goswami
   (ii) Prof. Ashwani Kumar
   (iii) Prof. T. Sen
4. GOLD MEDAL : (i) Dr. Sachin Patil
   (ii) Dr. Devendra Tripathi
   (iii) Dr. Chandrika
5. CERTIFICATE OF MERIT : (i) Mr. Jesubalan
   (ii) Miss Priti

S. P. Khullar,
Secretary-Treasurer

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POTENTIALS AND PROSPECTS OF FERNS AND LYCOPHYTES OF WESTERN GHATS

(PRESIDENTIAL ADDRESS DELIVERED AT THE INTERNATIONAL CONFERENCE ON PTERIDOPHYTES, HELD AT DR. BHUPENDRA NATH DUTTA SMRITI MAHAVIDYALAYA, HATGOBINDAPUR, PURBA-BARDDHAMAN, WEST BENGAL ON 8-10 FEB. 2019)

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(Received April 26, 2019)

In the capacity of President of Indian Fern Society, let me, at the outset, express my immense pleasure in organizing this International conference here at Dr. Bhupendra Nath Dutta Smriti Mahavidyalaya, Hatgobindapur, Purba Bardhaman 713407, West Bengal, in collaboration with the Indian Fern Society. This college named after Dr. Bhupendra Nath Dutta, the younger brother of the most celebrated Swami Vivekananda, is situated at a very rural environment and is a renowned institution which has a high academic reputation. This explains how it is holding this conference entitled "New Generation Pteridology : The Indian Perspective". It is commendable that this time the conference of Indian Fern Society is being held in this serene rural setting. I sincerely express my deepest sense of gratitude to Prof. Jagathpati Tah, Dr. Nirupama Bhattacharyya Goswami and Prof. S. P. Khullar for their bold initiative and commendable task for making it possible here. I also thank all the donors and sponsors for funding this good cause. My heartiest congratulations to them. I sincerely hope the conference will bring into sharp focus the potential of ferns and allies, providing insights into their systematics, phytogeography, distribution, endemism, ecology, molecular biology, bioprospection and conservation.

A major boost to fern studies in India came with the establishment of Indian Fern Society (IFS) in 1983 by Prof. S. S. Bir. This organization has incessantly helped to bring together the Pteridologists of the country. Further with the publication of Indian Fern Journal, started by IFS in 1984, there opened up a platform for sharing various Pteridological research studies. Added to these IFS by organizing symposia/conferences almost every year establishes a channel for communication and academic interaction not only among Pteridologists of our country but also internationally.

The theme of the present conference being *'Next Generation Pteridology',* I decided to select a topic : POTENTIALS AND PROSPECTS OF FERNS AND LYCOPHYTES OF WESTERN GHATS for my present presidential address, as there is umpteen scope to explore the economic importance in the field of Pteridology for the of next generation of budding scientists. Even though I have mentioned in the topic the presentation is with reference to Western Ghats, actually the suggestions I am going to make here are applicable to any geographic region.

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The Western Ghats, in South India, are a 1600 km long hill range stretching north-south, parallel along west coast traversing six South Indian states- Gujarat, Maharashtra, Goa, Karnataka, Kerala and Tamil Nadu, starting from Tapti valley in Gujarat and stretching up to Kanyakumari in Tamil Nadu. Manickam & Irudayaraj (1992) have reported 239 species of Pteridophytes from Southern Western Ghats. From the Malabar region of Western Ghats, Nayar & Geevargese (1993) reported 174 species of ferns. Rajagopal & Bhat (1998, 2016a, 2016b) have reported ca. 180 species of Pteridophytes from central Western Ghats. As a whole there are ca. 400 species of Pteridophytes in Western Ghats, thus standing next to north-eastern Himalayas in its Pteridophytic diversity.

Although Pteridophytes are of minor economic importance when compared with Angiosperms, their contribution to the world's coal reserves cannot be ignored because in the past eras Pteridophytes dominated the world's vegetation. Since remote times, in addition for food, fuel, fibre, medicine and shelter, Pteridophytes are used in rituals of love, ceremonies and also as materials to make crafts and weapons. In the present days their role in pharmacology, toxicology, role in maintaining soil quality and as ornamentals makes their relationship with humans closer. The archeological literature offers much evidence of close relationship between humans and Pteridophytes. Several species of Pteridophytes possess medicinal properties (Singh 2003, Goswami *et al.* 2016). As early as 300 B.C. Greek Philosopher Theophrastus, and his Indian contemporaries Sushruta and Charaka had recorded medicinal Pteridophytes. Pteridophytes though lesser in number, compared with angiosperms, the ethnobotanical surveys conducted in the mountainous regions of various parts of the world among the tribal communities considerable information is available regarding the uses of ferns and lycophytes as sources of food, fuel, fiber, medicine and shelter.

H. A. Keller & G. T. Prancea (2015) presented the most important ways in which ferns have been important to humanity. 220 species of Pteridophytic plants are reported for their use to treat different ailments. Kritikar *et al.* (1935) have enumerated 27 species of ferns having different medicinal uses. Chopra *et al.* (1956) have reported 44 species of Pteridophytes having medicinal importance. Nadakarni (1954) has described 11 medicinal Pteridophytes. Nayar (1959) recorded 29 medicinal ferns. May (1978) published a detailed review of 105 medicinal ferns. Singh (1999) reported 160 species of useful Pteridophytes on the basis of phytochemical, pharmacological and ethnobotanical studies. Nevertheless, in India Pteridophytes have remained a much neglected subject so far as their exploitation for human use is concerned. The exploitation of Pteridophytes as ornamentals in South India is very meager. The ethno-botanical works on Pteridophytes of Western Ghats are also very limited in number. The knowledge of medicinal potentiality of Pteridophytes and their remedial activity against different diseases is rather incomplete. Hence, an exclusive study is essential for understanding them better and exploring the potentiality of their phytochemicals.

PTERIDOPHYTES OF WESTERN GHATS HAVING CLAIMS OF MEDICINAL VALUE

Manickam & Irudayaraj (1992) in their book Pteridophytic Flora of the Western Ghats have mentioned the medicinal uses of 35 Pteridophytes.

Benjamin and Manickam (2007) have identified 61 medicinal Pteridophytes species of the Western Ghats of India as useful in traditional methods of treatment of various diseases, poisonous bites, rheumatism, cough, asthma, fever, diabetes.

Patil *et al.*, (2013) did an intensive survey of traditional knowledge of utilisation of Pteridophytes by the people in the hilly regions of Western Ghats of Maharastra and found 38 Pteridophytes used in traditional medicine.

Ganeshan Sathiyaraj *et al.*, (2015) have studied the ethnobotanical importance of ferns traditionally used by the tribal people of Palani hills, South India and gave information about 50 species and the diseases in which they are used with the recipe of the medicine. Tripathi *et al.*,(2017) gathered information about 36 medicinal species of Pteridophytes from the tribal and non tribal people of Kudremukh National Park in Karnataka.

As a whole, Pteridophytes have claims such as: Anthelmintic, General tonic, for treating Bone fracture, Cancer, Cold, Cough, Asthma, bronchitis and other bronchial diseases, Cut injuries, Wounds, Diabetes, Digestive problems, Elephantiasis, Enteritis, Epilepsy, Eye diseases, Fever, Gynecological problems, Haemorrhage, Headache, Migraine, Herpes, Hypertension, Leprosy, Malaria, Piles, Rheumatism, Skin diseases—Eczema, Snakebite, Sore throat, Sprains, Swelling and inflammation, Throat pain, Tuberculosis, Typhoid, Urinary problems - ailments starting with cold till cancer.

Some of the ailments cited above treated with different Pteridophytes of Western Ghats are as follows :

ANTIBACTERIAL

Blechnum orientale L.
Botrychium lanuginosum Wall. ex Hook. & Grev.
Dicranopteris linearis (Burm. f.) Underw.
Dryopteris cochleata (D. Don) C. Chr.
Hypodematium crenatum (Forrsk.) Kuhn
Leucostegia truncata (D. Don) Fraser- Jenk.
Microsorum punctatum (L.) Copel.
Nephrolepis cordifolia (L.) C. Presl.
Ophioglossum gramineum Willd.
Parahemionitis cordata (Roxb. ex Hook. & Grev.) Fraser-Jenk.
Polystichum subinerme Fraser – Jenk.
Psilotum nudum (L.) P. Beauv.

Pteris vittata L.
Selaginella delicatula (Desv. ex Poir.) Alston
Selaginella radicata (Hook.& Grev.) Spring
Tectaria coadunata (Wall. ex Hook. & Grev.) C. Chr.

ANTHELMINTIC

Acrostichum aureum L.
Actiniopteris radiata (Sw.) Link
Athyrium falcatum Bedd.
Athyrium hohenackerianum (Kunze) T. Moore
Blechnum orientale L.
Doryopteris concolor (Langsd. & Fisch.) Kuhn
Drynaria quercifolia (L.) J. Sm.
Dryopteris cochleata (D. Don) C. Chr.
Dryopteris sparsa (D. Don) Kuntze
Oleandra musifolia (Blume) C. Presl
Parahemionitis cordata (Roxb. ex Hook. & Grev.) Fraser-Jenk.
Pityrogramma calomelanos (L.) Link
Pteridium revolutum (Blume) Nakai
Tectaria wightii (C. B. Clarke) Ching

RHEUMATISM

Athyrium hohenackerianum (Kunze) T. Moore
Dryopteris cochleata (D. Don) C. Chr.
Huperzia phlegmaria (L.) Rotham.
Lygodium flexuosum (L.) Sw.
Osmunda hilsenbergii Grev. & Hook.
Thelypteris parasitica (L.) Holttum
Vittaria elongata Sw.

DIABETES

Adiantum incisum Forssk.
Cyathea gigantea (Wall. ex Hook.) Holttum
Cyathea nilgirensis Holttum

CANCER

Asplenium phyllitidis D. Don
Athyrium falcatum Bedd.
Ophioglossum lusitanicum L.
Pyrrosia heterophylla (L.) M. G.Price

ANTIFUNGAL

Acrostichum aureum L.
Equisetum ramosissimum subsp. *debile* (Roxb. ex Vaucher) Hauke
Salvinia adnata Desv.
Selaginella delicatula (Desv. ex Poir.) Alston

DIARRHOEA AND DYSENTERY

Adiantum philippense L.
Angiopteris helferiana C. Presl
Botrychium lanuginosum Wall. ex Hook. & Grev.
Cheilanthes albomarginata C. B. Clarke
Cyathea gigantea (Wall. ex Hook.) Holttum
Dryopteris cochleata (D. Don) C. Chr.
Lygodium microphyllum (Cav.) R. Br.
Marsilea minuta L.
Ophioglossum gramineum Willd.
Psilotum nudum (L.) P. Beauv.
Pteridium revolutum (Blume) Nakai
Tectaria coadunata (Wall. ex Hook.

METHODS OF ETHNO-BOTANICAL STUDY

More extensive ethno-botanical survey should be conducted with the following things in mind :

- Field work in tribal areas.
- Interviews with Nati vaidyas of villages.
- Scrutiny of Herbarium specimens.
- Scrutiny of ancient literature.
- Scrutiny of ancient sculptures on temples, forts, and paintings.
- Analysis of different tribal folklore.
- Scrutiny of plants and plant parts from archaeological sites and excavations.
- Study of fossilized plant parts and remains.

Ethno-botanical field work

- Ethno-botanical field work is significant and different from routine plant collection.
- Additional data to be collected about areas like medicinal, food, musical instruments, religious belief etc.
- Identification of tribes and their jurisdiction.

- Developing familiarity about the tribes, their culture, dialect, vegetation.
- Locating knowledgeable and communicable informants. Many times they are hostile to outsiders.
- Sometimes one has to live for long durations among tribes; mix with them and acquire their confidence before gathering information.

Gathering ethno-botanical information

- Knowledgeable informants are taken to field and information about plants are recorded along with voucher specimens or collect the available plants and show one by one to the informant.
- Gather information- ask for uses of each. Gathering information from tribal's is not easy- many a time they are conservative, do not share information with outsiders even with incentives, the language may become a barrier between the two.
- Building confidence with informants is very important.
- Each tribe has its own name for a plant. Recording these names is also necessary. Local names help verification of uses with other tribes in other localities.
- Ethno-botanical information gathered should be pasted on the herbarium sheet before incorporating in the herbarium.

Challenges

It is a great challenge to find the feasibility and authenticity of the claims of informants.

- Problems in equating local names told by the informants. Scientific evaluation of ethnobotanical leads.
- Too many claims for a specific ailment within a tribe and among different tribes. Cross cultural studies among different ethnic groups is a must.
- Use of a particular species for the same ailment by different unrelated ethnic groups indicates the efficacy and potential of these plants.
- Development of a traditional knowledge Database.
- Ethnobotanists, botanists, pharmacologists should collectively work for the scientific scrutiny, chemical, pharmacological and clinical studies for the development of potential drugs.

Constraints

- Shortage of fern taxonomists, ethnobotanists.
- Field botanists are today critically endangered and need to develop a band of taxonomists by way of training programmes.

- Lack of financial support for ethnobotanical investgations.
- Lack of comprehensive ethnobotanical data.
- Lack of much needed co-operation between biotechnologists and ethnobotanists in bioprospection on ethnobotanical leads.

FERNS AND LYCOPHYTES AS ORNAMENTALS

Although devoid of flowers, Ferns and Lycophytes have full potentiality to be grown as ornamental plants because of their aesthetic value due to elegant foliage of varying heights, shapes and texture that grace them with delicate beauty. Pteridophytes grow in diverse habitats, majority of them are ground based, some are epiphytes, and others lithophytes. Majority of them can be exploited as ornamental plants since many of them can be grown well in shade and moist conditions. They can be grown as indoor plants or outdoors under various shade levels. The ornamental foliages of ferns vary from simple strap shaped fronds to the plumose froth of finely divided leaves. Due to their diverse habitats they can be grown well on the ground or on pots, as epiphytes, on tree trunks, or on hanging baskets, or on rocks as lithophytes. Here there is ample opportunity for the floriculture industry. Based on mature plant size, Pteridophytes suitable for ornamentation can be divided as follows :

Large Pteridophytes (more than 80 cm tall): Can be planted in parks, scenic areas, lawns, along water bodies, around buildings.

Medium Pteridophytes (30-80 cm tall): They are good indoor plants for foot traffic areas, such as theatres, shopping centres, etc.

Small Pteridophytes (Less than 30 cm tall): They can be used as potted plants for office, balcony and artificial rockeries. They are ideal for humid places.
All the above also fit into borders.

Climbing Pteridophytes: These can be used as hangings in designed baskets or allowed to spread on ground, walls or trees.

Ferns and Lycophytes provide many opportunities for floriculture sector due to -

- Year round supply is possible
- Low input and low labour demanding
- Far less prone to pests and diseases
- Easy multiplication

Some species of Ferns and Lycophytes growing wild in of Western Ghats are suggested as suitable candidates for domestication and use in floriculture industry:

Pteridophytes suitable for Pots

Actniopteris radiata (Sw.) Link
Adiantum philippense L.

Cheilanthes bicolor (Roxb.) Griff. ex Fraser-Jenk.
Diplazium esculentum (Retz.) Sw.
Lindsaea heterophylla Dryand.
Lycopodiella cernua (L.) Pic. Serm.
Nephrolepis sp.
Ophioglossum costatum R. Br.
Osmunda hilsenbergii Grev. & Hook.
Parahemionitis cordata (Roxb. ex Hook. & Grev.) Fraser-Jenk.
Pityrogramma calomelanos L. (Link) var. *aureoflava* (Hook.) Weath ex Bailey
Psilotum nudum (L.) P. Beauv.
Pteris argyraea T. Moore
Pteris vittata L.
Selaginella tenera (Hook. & Grev.) Spring

Suitable for hanging baskets

Huperzia phyllantha (Hook. & Arn.) Holub.
Huperzia squarrosa (G. Forst.) Trevis
Odontosoria chinensis (L.) J.Sm.

Suitable for rockeries

Actniopteris radiata (Sw.) Link
Cheilanthes swartzii Webb. & Berthel.
Doryopteris concolor (Langsd.& Fisch.) Kuhn
Parahemionitis cordata (Roxb.)ex Hook. & Grev.) Fraser-Jenk.

Suitable for arches

Dicranopteris linearis (Burm.f.) Underw.
Lygodium flexuosum (L.) Sw.
Stenochlaena palustris (Burm.f.) Bedd.

Suitable as epiphytes

Asplenium phyllitidis D. Don
Drynaria quercifolia (L.) J. Sm.
Huperzia phyllantha (Hook. &Arn.) Holub.
Huperzia squarrosa (G. Forst.) Trevis
Vittaria elongata Sw.

As outdoor plant in gardens

Angiopteris helferiana C. Presl

Cyathea gigantea (Wall.ex Hook.) Holttum
Cyathea nilgirensis Holttum

For shallow ponds, small tanks, shallow water containers

Azolla pinnata R.Br.
Marsilea minuta L.
Salvinia molesta Mitch.

CONCLUSION

Over the past decades herbal medicine has become a topic of global importance. Many taxa of Pteridophytes growing in Western Ghats have been attributed potentialities of great medicinal value. Intensive ethnobotanical surveys followed by pharmacological evaluation will certainly lead to the discovery of very effective life saving drugs from Pteridophytes. It is hoped that young Pteridologists will face the challenges and overcome constraints and develop potential drugs. We foresee the universities, the government funding agencies like CSIR and DST will support.

Western Ghats are blessed with a good level of diversity of Pteridophytic taxa with an enormous diversity of form, appearance and foliage patterns. They thrive in many habitats and are suitable to be used in floriculture industry. Several species are suggested as suitable candidates for domestication and use in floriculture industry. It is hoped that the medicinal and ornamental values of Ferns and Lycophytes will be taken up more seriously by the new generation of Pteridologists.

REFERENCES

BENJAMIN A & MANICKAM V S 2007 Medicinal Pteridophytes from the Western Ghats *Indian J of Traditional Knowledge* **6(4)** : pp 611-618

CHOPRA R N, NAYAR S L & CHOPRA I C 1956 *Glossary of Indian medicinal plants* Publication and information directorate New Delhi

GANESHAN S, MUTHUKUMAR T & RAVINDRAN K C 2015 Ethnobotanical importance of fern and fern allies traditionally used by tribal people of Palani hills (Kodaikanal), Western Ghats, SouthIndia *J Medicinal Herbs and Ethnomedicine* **1(1)** : 4-9

GOSWAMI H K, SEN K & MUKHOPADHYAY R 2016 Pteridophytes : evolutionary boon as medicinal plants *Plant Genetic Resources* **14(4) :** 328-355

KELLER H A & PRANCE G T 2015 The ethnobotany of ferns and lycophytes *Ferns Gazette* **20(1)** : 1-14

KIRTIKAR K R & BASU B O 1935 *Indian medicinal plants* 4 vols (2nd ed), Bishen Singh Mahendra Pal Singh, Dehra Dun

MANICKAM V S & IRUDAYARAJ V 1992 *Pteridophyte Flora of the Western Ghats of South India* B I Publications, New Delhi pp 1-653

MAY L W 1978 The economic uses and associated folklore of ferns and fern allies *Bot Rev* **44(4)** : 491-528

NADKARNI B K 1954 *Indian Materia Medica with Ayurvedic, Unani-Tibbi, Siddha, Allopathic, Homeopathic, Naturopathic and home remedies* Popular Book Depot Bombay

NAYAR B K 1959 Medicinal ferns of India *Bull Nat Bot Gard, Lucknow* **29** : 1-36

NAYAR & GEEVARGHESE 1993 *Fern Flora of Malabar* Indus Publishing Company, New Delhi Pp 1-424

PATIL S, MASAL V P & DONGARE M 2013 In search of ethno-medical Pteridophytes from the Western Ghats of Maharashtra (India) *Indian Fern J* **30 :** 69-77

RAJAGOPAL P K & BHAT K G 1998 Pteridophytic flora of Karnataka State, India *Indian Fern J* **15** : 1-28

RAJAGOPAL P K & BHAT K G 2016 *Pteridophytes of Karnataka State, India* Vinayaka Prakashana Udupi Pp 1-233

RAJAGOPAL P K & BHAT K G 2016b An updated account of Pteridophytes of Karnataka *Indian Fern J* **33** : 119-141

SINGH H B 1999 Potential medicinal Pteridophytes of India and their chemical constituents *J of Economic and Taxonomic Botany* **23(1)** : 63-78

SINGH H B 2003 'Economically Viable Pteridophytes of India' Chapter 29, In "*Pteridology in the New Millennium* eds S Chandra & M Srivastava; Kluwer Acads Publ Netherlands Pp 421-446

TRIPATHI D, BENNIAMIN A & JESUBALAN D 2017 An ethno-medicinal exploration of Pteridophytes of Kudremukh National Park, Central Western Ghats, Karnataka India Abstract : *National symposium on - genomic age challenges and opportunities in taxonomy and biology of Indian Pteridophytes* p 111

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A REVISED CHECKLIST OF INDIAN PTERIDOPHYTES-2

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ABSTRACT

The present list is the second part summarising the species and subspecies of ferns and fern-allies accepted by the author to be present in political India, Pakistan, Nepal and Bhutan, with hybrids listed at the end of each genus. It has been condensed from Fraser-Jenkins, Gandhi & Kholia's *Annotated Checklist of Indian Pteridophytes* vol. 2 (2018) and covers 2 large and complex families, Woodsiaceae (including Athyriaceae and Cystopteridaceae as synonyms) and Dryopteridaceae (including Tectariaceae, Didymochlaenaceae and Pteridryaceae as synonyms). Two smaller families with distant relations to Woodsiaceae are also treated, Onocleaceae and Blechnaceae. The present checklist covers 4 families, 30 genera and 323 species, with an additional 15 out of a total 27 subspecies. It also includes 48 spontaneous hybrids. Exotic adventive taxa that have become naturalised or established in the wild are included in these numbers and in the list and constitute a total of 5 species, marked with an asterisk. An Appendix of changes to part 1 of the list is also given. The third and last volume of the Annotated Checklist (Fraser-Jenkins, Gandhi & Kholia, in prep.), nearing completion, is to be published in 2019.

Key Words : Pteridophyte-list, India, species, subspecies, ferns.

INTRODUCTION

The present list continues the revised checklist of Indian pteridophyte names presented in Part-1 (Fraser-Jenkins, Indian Fern J. 33: 193-205. 2016), taking it up to the end of Dryopteridaceae, following Fraser-Jenkins, Gandhi & Kholia (2018). It is thus again based on specimens seen and verified by the present author as opposed to unverified literature records. It should be noted that as in Part 1 the families and genera do not always comply with and are not merely based on the recent purely molecular-cladonomic and preliminary scheme of PPG -1 (2016), but are based on wider, more holistic morpho-taxonomic considerations in addition to findings from molecular data.

Authority citations are in the internationally accepted standard format of Brummitt & Powell (1992) as utilised by Pichi Sermolli (1996) and in the International Plant Name Index, IPNI (www.ipni.org).

An Appendix of changes and corrections to Part 1 is given at the end.

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LIST OF ACCEPTED TAXA AND NAMES

Woodsiaceae

Acystopteris tenuisecta (Blume) Tagawa
Athyrium anisopterum Christ
Athyrium atkinsonii Bedd.
Athyrium atratum Bedd.
Athyrium attenuatum (C.B.Clarke) Tagawa
Athyrium clarkei Bedd.
Athyrium contingens Ching & S.K.Wu
Athyrium cumingianum (C.Presl) Ching
Athyrium cuspidatum (Bedd.) M.Kato
Athyrium davidii (Franch.) Christ
Athyrium decorum Ching
Athyrium delavayi Christ
Athyrium devolii Ching
Athyrium dissitifolium (Baker) C.Chr.
Athyrium distans (D.Don) T.Moore
Athyrium drepanopterum (Kunze) A.Braun ex Milde
Athyrium dubium Ching
Athyrium eburneum (J.Sm. ex Mett.) J.Sm.
Athyrium falcatum Bedd.
Athyrium fangii Ching
Athyrium fimbriatum T.Moore
Athyrium flabellulatum (C.B.Clarke) Tardieu
Athyrium foliolosum T.Moore ex R.Sim
Athyrium gymnogrammoides (Klotzsch ex Mett.) Bedd.
Athyrium himalaicum Ching ex Mehra & Bir
Athyrium hohenackerianum (Kunze) T.Moore
Athyrium kandelii Fraser-Jenk.
Athyrium khasimontanum Fraser-Jenk.
Athyrium mackinnoniorum (C.Hope) C.Chr.
Athyrium mehrae Bir
Athyrium mengtzeense Hieron.
Athyrium micropterum Fraser-Jenk.
Athyrium nakanoi Makino
Athyrium niponicum (Mett.) Hance
Athyrium otophorum (Miq.) Koidz.
Athyrium parasnathense (C.B.Clarke) Ching ex Mehra & Bir
Athyrium pectinatum (Wall. ex Mett.) C.Presl ex T.Moore
Athyrium praetermissum Sledge
Athyrium puncticaule (Blume) T.Moore
Athyrium repens (Ching) Fraser-Jenk.
Athyrium rupicola (Edgew. ex C.Hope) C.Chr.
Athyrium schimperi Moug. ex Fée subsp. *biserrulatum* (Christ) Fraser-Jenk.
Athyrium schizochlamys (Ching) K.Iwats.
Athyrium setiferum C.Chr.
Athyrium solenopteris (Kunze) T.Moore
Athyrium spinulosum (Maxim.) Milde
Athyrium strigillosum (T.Moore ex E.J.Lowe) Salom.
Athyrium triangulare Alderw.
Athyrium vermae Fraser-Jenk.
Athyrium wallichianum Ching
Athyrium xichouense Y.T.Hsieh & Z.R.Wang
Athyrium sp. indet. near *anisopterum*
Athyrium x *boreo-occidentale-indobharaticola-birianum* Fraser-Jenk.
Athyrium x *dixitii* Fraser-Jenk.
Athyrium x *drepanopteroides* Fraser-Jenk.
Athyrium x *gurungae* Fraser-Jenk.
Athyrium x *kathmanduense* Fraser-Jenk.
Athyrium x *langtangense* Fraser-Jenk.
Athyrium x *lobulosoimpolitum* Fraser-Jenk.
Athyrium x *manickamii* Fraser-Jenk.
Athyrium x *mantoniae* Fraser-Jenk.
Athyrium x *meghalaicum* Fraser-Jenk.
Athyrium x *nepalense* Fraser-Jenk.

Athyrium pectinatum (Wall. ex Mett.) C.Presl ex T.Moore x *A. xichouense* Y.T.Hsieh & Z.R.Wang
Athyrium x *pichisermollianum* Fraser-Jenk.
Athyrium x *pokharense* Fraser-Jenk.
Athyrium x *sanjappae* Fraser-Jenk.
Athyrium x *simlense* Fraser-Jenk.
Athyrium x *sledgei* Fraser-Jenk.
Cornopteris badia Ching
Cornopteris banajaoensis (C.Chr.) K.Iwats. & M.G.Price
Cornopteris decurrentialata (Hook.) Nakai
Cornopteris opaca (D.Don) Tagawa
Cystopteris fragilis (L.) Bernh. subsp. *fragilis*
Cystopteris fragilis (L.) Bernh. subsp. *diaphana* (Bory) Litard.
Cystopteris fragilis (L.) Bernh. subsp. *dickieana* (R.Sim) Hook.f.
Cystopteris fragilis (L.) Bernh. subsp. *kansuana* (C.Chr.) Fraser-Jenk.
Cystopteris montana (Lam.) Bernh. ex Desv.
Cystopteris moupinensis Franch.
Cystopteris fragilis (L.) Bernh. nothosubsp. x *montserratii* (Prada & Salvo) Fraser-Jenk.
?*Cystopteris fragilis* (L.) Bernh. subsp. *dickieana* (R.Sim) Hook.f. x *C. fragilis* subsp. *diaphana* (Bory) Litard.
Cystopteris fragilis (L.) Bernh. agg. hybrids.
Deparia allantodioides (Bedd.) M.Kato
Deparia boryana (Willd.) M.Kato subsp. *boryana*
Deparia boryana (Willd.) M.Kato subsp. *austroindica* Fraser-Jenk.
Deparia heterophlebia (Mett. ex Baker) R.Sano
Deparia japonica (Thunb.) M.Kato subsp. *japonica*
Deparia japonica (Thunb.) M.Kato subsp. *indica* (Fraser-Jenk.) Fraser-Jenk.
Deparia japonica (Thunb.) M.Kato subsp. *petersenii* (Kunze) Fraser-Jenk.
Deparia japonica (Thunb.) M.Kato subsp. *sledgei* (Fraser-Jenk.) Fraser-Jenk.
Deparia lancea (Thunb.) Fraser-Jenk.
Deparia macdonellii (Bedd.) M.Kato
Deparia membranacea (Ching & Y.Z.Liu) Fraser-Jenk.
Deparia subsimilis (Christ) Fraser-Jenk.
?*Deparia allantodioides* (Bedd.) M.Kato x *D. subsimilis* (Christ) Fraser-Jenk.
Deparia japonica (Thunb.) M.Kato nothosubsp. x *birii* (Fraser-Jenk.) Fraser-Jenk.
Deparia x *nakaikeana* Fraser-Jenk.
Deparia japonica (Thunb.) M.Kato subsp. *petersenii* hybrid
Diplazium banglum Fraser-Jenk. & M.K.Pasha
Diplazium beddomei C.Chr.
Diplazium bellum (C.B.Clarke) Bir
Diplazium brachylobum (Sledge) Manickam & Irudayaraj
Diplazium burmanicum Ching ex W.M.Chu & Z.R.He
Diplazium chattagramicum (C.B.Clarke) Ching
Diplazium creniauritum Fraser-Jenk.
Diplazium crinitum (Baker) C.Chr.
Diplazium dameriae Pic.Serm.
Diplazium dilatatum Blume
Diplazium doederleinii (Luerss.) Makino
Diplazium donianum (Mett.) Tardieu
Diplazium esculentum (Retz.) Sw.
Diplazium fraxinifolium C.Presl
Diplazium griffithii T.Moore
Diplazium himalayense (Ching) Panigrahi

Diplazium integrifolium Blume
Diplazium javanicum (Blume) Makino
Diplazium kawakamii Hayata
Diplazium khullarii Fraser-Jenk.
Diplazium latifolium T.Moore
Diplazium laxifrons Rosenst.
Diplazium leptophyllum Christ
Diplazium lobatum (Tagawa) Tagawa
Diplazium longifolium T.Moore
Diplazium manickamii Fraser-Jenk. & Kholia
Diplazium maximum (D.Don) C.Chr.
Diplazium nagalandicum Fraser-Jenk., Odyuo & D.K.Roy
Diplazium okudairae Makino
Diplazium pinfaense Ching
Diplazium pinnatifidopinnatum (Hook.) T.Moore
Diplazium polypodioides Blume
Diplazium procumbens Holttum
Diplazium proliferum (Lam.) Thouars
Diplazium pseudosetigerum (Christ) Fraser-Jenk.
Diplazium sikkimense (C.B.Clarke) C.Chr.
Diplazium spectabile (Wall. ex Mett.) Ching
Diplazium squamigerum (Mett.) Matsum.
Diplazium stoliczkae Bedd.
Diplazium subspectabile Ching
Diplazium succulentum (C.B.Clarke) C.Chr.
Diplazium sylvaticum (Bory) Sw.
Diplazium tibeticum (Ching & S.K.Wu) Z.R.He
Diplazium travancoricum Bedd.
Diplazium virescens Kunze
Diplazium x *kashmirianum* Fraser-Jenk.
Diplazium x *neobirii* Fraser-Jenk.
Diplazium x *tertium-maximale* Fraser-Jenk.
Diplazium x *wallichianum* Fraser-Jenk.
Gymnocarpium fedtschenkoanum Pojark.
Gymnocarpium jessoense (Koidz.) Koidz.
Gymnocarpium oyamense (Baker) Ching
Woodsia alpina (Bolton) Gray
Woodsia andersonii (Bedd.) Christ
Woodsia cycloloba Hand.-Mazz.
Woodsia elongata Hook.
Woodsia glabella R.Br. ex Richardson
Woodsia hancockii Baker
Woodsia lanosa Hook.
Woodsia rosthorniana Diels

Onocleaceae

Onoclea intermedia (C.Chr.) M.Kato
Onoclea orientalis (Hook.) Hook.

Blechnaceae

**Blechnum appendiculatum* Willd.
Blechnum finlaysonianum Wall. ex Hook. & Grev.
Blechnum melanocaulon (Brack.) T.C.Chambers & P.A.Farrant subsp. *pallens* T.C.Chambera & P.A. Farrant
Blechnum melanopus Hook.
**Blechnum occidentale* L.
Blechnum orientale L.
Brainea insignis (Hook.) J.Sm.
**Doodia caudata* (Cav.) R.Br.
Doodia dives Kunze
Stenochlaena palustris (Burm.f.) Bedd.
Woodwardia unigemmata (Makino) Nakai

Dryopteridaceae

?*Acrorumohra* [gen. incert.] *diffracta* (Baker) H.Itô
Arachniodes amabilis (Blume) Tindale
Arachniodes assamica (Kuhn) Ohwi
Arachniodes carvifolia (Kunze) Ching
Arachniodes chinensis (Rosenst.) Ching
Arachniodes coniifolia (T.Moore) Ching
Arachniodes cornucervi (D.Don) Fraser-Jenk.

Arachniodes henryi (Christ) Ching
Arachniodes miqueliana (Maxim. ex Franch. & Sav.) Ohwi
Arachniodes palmipes (Kunze) Fraser-Jenk.
Arachniodes rhomboidea (Wall. ex C.Presl) Ching
Arachniodes simulans (Ching) Ching
Arachniodes sledgei Fraser-Jenk.
Arachniodes spectabilis (Ching) Ching
Arachniodes superba Fraser-Jenk.
Ctenitis mannii (C.Hope) Ching
Ctenitis subglandulosa (Hance) Ching
Cyrtomium anomophyllum (Zenker) Fraser-Jenk.
Cyrtomium caryotideum (Wall. ex Hook. & Grev.) C.Presl
Cyrtomium fortunei J.Sm.
Cyrtomium macrophyllum (Makino) Tagawa
Cyrtomium micropterum (Kunze) Ching
Didymochlanea truncatula (Sw.) J.Sm.
Dryopsis apiciflora (Wall. ex Mett.) Holttum & P.J.Edwards
Dryopsis arunachalensis Fraser-Jenk. & Benniamin
Dryopsis clarkei (Baker) Holttum & P.J.Edwards
Dryopsis ferruginea (Baker) Holttum & P.J.Edwards
Dryopsis heterolaena (C.Chr.) Holttum & P.J.Edwards
Dryopsis manipurensis (Bedd.) Holttum & P.J.Edwards
Dryopsis nidus (Baker) Holttum & P.J.Edwards
Dryopsis scabrosa (Kunze) Holttum & P.J.Edwards
Dryopsis transmorrisonensis (Hayata) Holttum & P.J.Edwards
Dryopteris acutodentata Ching
Dryopteris alpestris Tagawa
Dryopteris approximata Sledge
Dryopteris assamensis (C.Hope) C.Chr. & Ching
Dryopteris atrata (Kunze) Ching
Dryopteris austroindica Fraser-Jenk.
Dryopteris barbigera (T.Moore ex Hook.) Kuntze
Dryopteris basisora Christ
Dryopteris blanfordii (C.Hope) C.Chr. subsp. *blanfordii*
Dryopteris camusiae Fraser-Jenk.
Dryopteris carolihopei Fraser-Jenk.
Dryopteris chrysocoma (Christ) C.Chr.
Dryopteris cochleata (D.Don) C.Chr.
Dryopteris conjugata Ching
Dryopteris costalisora Tagawa
Dryopteris deparioides (T.Moore) Kuntze subsp. *deparioides*
Dryopteris dickinsii (Franch. & Sav.) C.Chr.
Dryopteris edwardsii Fraser-Jenk.
Dryopteris fangii Ching, Fraser-Jenk. & Z.R.Wang
Dryopteris filix-mas (L.) Schott subsp. *filix-mas*
Dryopteris flemingii Fraser-Jenk.
Dryopteris fructuosa (Christ) C.Chr.
Dryopteris gamblei (C.Hope) C.Chr.
Dryopteris hasseltii (Blume) C.Chr.
Dryopteris himachalensis Fraser-Jenk.
Dryopteris hirtipes (Blume) Kuntze
Dryopteris juxtaposita Christ
Dryopteris kashmiriana Fraser-Jenk. & Widén
Dryopteris khullarii Fraser-Jenk.
Dryopteris komarovii Kossinsky
Dryopteris lepidopoda Hayata
Dryopteris marginata (C.B.Clarke) Christ
Dryopteris meghalaica Fraser-Jenk. & Gibby

Dryopteris microlepis (Baker) C.Chr.
Dryopteris namegatae (Sa.Kurata) Sa. Kurata
Dryopteris nigropaleacea (Fraser-Jenk.) Fraser-Jenk.
Dryopteris nobilis Ching
Dryopteris odontoloma (T.Moore ex Bedd.) C.Chr.
Dryopteris panda (C.B.Clarke) Christ
Dryopteris pauliae Fraser-Jenk., Widén & Gibby
Dryopteris pseudosparsa Ching
Dryopteris pulvinulifera (Bedd.) Kuntze
Dryopteris ramosa (C.Hope) C.Chr.
Dryopteris redactopinnata S.K.Basu & Panigrahi
?*Dryopteris reflexosquamata* Hayata
Dryopteris rubrobrunnea W.M.Chu
Dryopteris scottii (Bedd.) Ching
Dryopteris serratodentata (Bedd.) Hayata
Dryopteris sikkimensis (Bedd.) Kuntze
Dryopteris sledgei Fraser-Jenk.
Dryopteris sparsa (D.Don) Kuntze subsp. *sparsa*
Dryopteris sparsa (D.Don) Kuntze subsp. *rectipinnula* Fraser-Jenk.
Dryopteris splendens (Hook.) Kuntze
Dryopteris stenolepis (Baker) C.Chr.
Dryopteris stewartii Fraser-Jenk.
Dryopteris subcochleata Fraser-Jenk. & Khatri Chhetri
Dryopteris subimpressa Loyal
Dryopteris sublacera Christ
Dryopteris subtriangularis (C.Hope) C.Chr.
Dryopteris tingiensis Ching & S.K.Wu ex Fraser-Jenk.
Dryopteris varia (L.) Kuntze
Dryopteris vidyae Fraser-Jenk.
Dryopteris wallichiana (Spreng.) Hyl. subsp. *wallichiana*
Dryopteris wallichiana (Spreng.) Hyl. subsp. *bhutanica* Fraser-Jenk.
Dryopteris wallichiana (Spreng.) Hyl. subsp. *himalaica* Fraser-Jenk.
Dryopteris wallichiana (Spreng.) Hyl. subsp. *madrasensis* (Fraser-Jenk.) Fraser-Jenk.
Dryopteris wallichiana (Spreng.) Hyl. subsp. *nepalensis* Fraser-Jenk.
Dryopteris wallichiana (Spreng.) Hyl. subsp. *pachyphylla* Fraser-Jenk. & R.Knapp
Dryopteris woodsiisora Hayata
Dryopteris xanthomelas (Christ) C.Chr.
Dryopteris yoroii Seriz.
Dryopteris zayuensis Ching & S.K.Wu
Dryopteris x *ghatakii* Fraser-Jenk.
Dryopteris x *liddarensis* Fraser-Jenk.
Dryopteris x *loyalii* Fraser-Jenk.
Dryopteris x *macdonellii* Fraser-Jenk.
Dryopteris sparsa (D.Don) Kuntze nothosubsp. x *lehalii* Fraser-Jenk.
Dryopteris x *wechteriana* Fraser-Jenk.
Dryopteris x *zygoparentalis* Fraser-Jenk.
Heterogonium pinnatum (Copel.) Holttum
Hypodematium crenatum (Forssk.) Kuhn subsp. *crenatum*
Hypodematium crenatum (Forssk.) Kuhn subsp. *loyalii* Fraser-Jenk. & Khullar
Hypodematium crenatum (Forssk.) Kuhn subsp. *mehrae* Fraser-Jenk.
Hypodematium crenatum (Forssk.) Kuhn nothosubsp. x *tiwanae* Fraser-Jenk.
Hypodematium crenatum (Forssk.) Kuhn subsp. *loyalii* Fraser-Jenk. & Khullar x subsp. *mehrae* Fraser-Jenk.
Lastreopsis tenera (R.Br.) Tindale
Nothoperanema hendersonii (Bedd.) Ching
Nothoperanema squamiseta (Hook.) Ching
Peranema aspidioides (Blume) Mett.

Peranema cyatheoides D.Don
Peranema paleolatum (Pic.Serm.) Fraser-Jenk.
Pleocnemia conjugata (Blume) C.Presl
Pleocnemia irregularis (C.Presl) Holttum
Pleocnemia submembranacea (Hayata) Tagawa & K.Iwats.
X *Polysticalpe mirabilis* Fraser-Jenk.
Polystichum acutidens Christ
Polystichum adungense Ching & Fraser-Jenk. ex H.S.Kung & L.B.Zhang
Polystichum annapurnicola Fraser-Jenk.
Polystichum anomalum (Hook. & Arn.) J.Sm. subsp. *travancoricum* (Bedd.) Fraser-Jenk.
Polystichum atkinsonii Bedd.
Polystichum attenutatum Tagawa & K.Iwats.
Polystichum austropaleaceum Fraser-Jenk.
Polystichum bakerianum (Atk. ex C.B.Clarke) Diels
Polystichum balansae Christ
Polystichum centronepalense Fraser-Jenk. & Tamang
Polystichum cyclolobum C.Chr.
Polystichum discretum (D.Don) J.Sm.
Polystichum duthiei (C.Hope) C.Chr.
Polystichum glaciale Christ
Polystichum grandifrons C.Chr.
Polystichum harpophyllum (Zenker ex Kunze) Sledge
Polystichum hecatopterum Diels
Polystichum hookerianum (C.Presl) C.Chr.
Polystichum jamunae Fraser-Jenk.
Polystichum lachenense (Hook.) Bedd.
Polystichum lentum (D.Don) T.Moore
Polystichum levingei C.Hope ex Christ
Polystichum lonchitis (L.) Roth
Polystichum longipaleatum Christ
Polystichum luctuosum (Kunze) T.Moore
Polystichum manickamianum Benniamin, Fraser-Jenk. & Irudayaraj
Polystichum manmeiense (Christ) Nakaike
Polystichum mehrae Fraser-Jenk. & Khullar
Polystichum mucronifolium (Blume) C.Presl
Polystichum neolobatum Nakai
Polystichum nepalense (Spreng.) C.Chr.
Polystichum obliquum (D.Don) T.Moore
Polystichum palniense Fraser-Jenk.
Polystichum piceopaleaceum Tagawa
Polystichum polyodon Ching
Polystichum prescottianum (Wall. ex Mett.) T.Moore
Polystichum pseudotsus-simense Ching
Polystichum punctiferum C.Chr.
Polystichum scariosum (Roxb.) C.V.Morton
Polystichum semifertile (C.B.Clarke) Ching
Polystichum shensiense Christ
Polystichum sinense (Christ) Christ
Polystichum squarrosum (D.Don) Fée
Polystichum stimulans (Kunze ex Mett.) Bedd.
Polystichum subinerme (Kunze) Fraser-Jenk.
Polystichum tangmeiense H.S.Kung & Tateishi
Polystichum thomsonii (Hook.f.) Bedd.
Polystichum wattii (Bedd.) C.Chr.
Polystichum woodsioides Christ
Polystichum yunnanense Christ
Polystichum zayuense W.M.Chu & Z.R.He
Polystichum x *flemingii* Fraser-Jenk.
Polystichum x *inayatii* Fraser-Jenk.
Polystichum x *mucrolentum* Fraser-Jenk.
Polystichum x *phulchowkiense* Fraser-Jenk.
Polystichum x *pseudobraunii* Fraser-Jenk.
Polystichum x *pseudolentum* Fraser-Jenk.
Polystichum x *pseudosemifertile* Nakaike & Gurung
Polystichum x *stewartii* Fraser-Jenk.

Polystichum x *tarebhirense* Nakaike & Gurung
Pteridrys cnemidaria (Christ) C.Chr.
Pteridrys syrmatica (Willd.) C.Chr. & Ching
Tectaria chattagramica (C.B.Clarke) Ching
Tectaria coadunata (J.Sm.) C.Chr.
Tectaria decurrens (C.Presl) Copel.
Tectaria fauriei Tagawa
Tectaria fuscipes (Wall. ex Bedd.) C.Chr.
**Tectaria gemmifera* (Fée) Alston
Tectaria griffithii (Baker) C.Chr.
Tectaria herpetocaulos Holttum
Tectaria heterocarpa (Bedd.) C.V.Morton
Tectaria impressa (Fée) Holttum
Tectaria ingens (Atk. ex C.B.Clarke) Holttum
Tectaria kehdingiana (Kuhn) M.G.Price
Tectaria melanocaulos (Blume) Copel.
Tectaria multicaudata (C.B.Clarke) Ching
Tectaria paradoxa (Fée) Sledge
Tectaria polymorpha (Wall. ex Hook.) Copel.
Tectaria pseudosiifolia Fraser-Jenk. & Wangdi
Tectaria puberula (Desv.) C.Chr.
Tectaria simonsii (Baker) Ching
Tectaria subconfluens (Bedd.) Ching
**Tectaria subtriphylla* (Hook. & Arn.) Copel.
Tectaria trimenii (Bedd.) C.Chr.
Tectaria vasta (Blume) Copel.
Tectaria wightii (C.B.Clarke) Ching
Tectaria zeilanica (Houtt.) Sledge
Tectaria x *pteropus-minor* (Bedd.) Fraser-Jenk.

APPENDIX

Corrections to list of Part 1

Revision to *The Annotated Checklist of Indian Pteridophytes* vol. 1. 2017 was made in the Appendix to vol. 2 (2018) and results in the addition or subtraction of various taxa, as follows :

Huperzia delavayi Ching - has been added to the Indo-Himalayan flora due to its occurrence in Nepal. It is not a synonym of *H. ceylanica*, as listed in vol. 1.

Huperzia lajouensis Ching - was listed in Vol. 1 as the revised identity of *H. cavei* Fraser-Jenk. & B.S.Kholia, but this has subsequently been questioned by Shalimov, Shrestha & Zhang (Indian Fern J. 34: 130-168. 2018 ("2017")) who maintained *H. cavei* as a separate species. It has not yet been possible for CRFJ to investigate further and recompare *H. lajouensis* with *H. cavei* to help decide this question and thus whether *H. cavei* should be accepted and *H. lajouensis* excluded from India. But it has to be said that Shalimov made a surprising number of glaring and obvious errors in that paper concerning several other species even though no reason to doubt this particular revision is suspected by CRFJ. Further study is required.

Huperzia serrata (Thunb.) Trevis - has been deleted from the Indian flora and replaced by *H. javanica*.

Huperzia shresthae Fraser-Jenk. - has been added to the Indian flora and the invalid *H. indica* S.R.Ghosh has been synonymised within it instead of within *H. javanica*.

Lycopodiella cernua (L.) Pic.Serm. - a second, as yet unidentified, but widely distributed S.E. Asian species within the aggregate has been reported in Vol. 2 from the Garo Hills, Meghalaya, and should be added to the Indian flora, though awaiting correct identification.

Selaginella indica R.M.Tryon - this name was by accident validated as a new species by Tryon, rather than as a new combination as he thought, and the authority must therefore be R.M.Tryon, not (Milde) R.M.Tryon. *S. emodi* Fraser-Jenk., named in replacement for what would have been an invalid combination, is therefore not necessary and is synonymised within *S. indica*.

Isoetes sahyadrii Mahab. ex L.N.Rao was carefully epitypified after detailed study by Fraser-Jenkins (Indian J. Forestry 38(3): 231-232. 2015) and in Vol. 1, following conclusive discussion on its identity with Prof. S.K. Srivastava, in order to create taxonomic clarity and nomenclatural stability concerning this well known first naming of a second Indian *Isoetes* species. The previous problem of Mahabale's having a mixed concept and thus his description involving two species, as often happens in earlier work on critical genera, was thus circumvented and Mahabale's main intention followed. Subsequently, however, Mazumdar et al. (Taxon 66(6): 1470. 2017) unfortunately attempted to reverse the stable situation brought about by Fraser-Jenkins. While admitting that he did not understand which species Mahabale was referring to, and evidently not realising the significance of the protologue description being mixed, he proposed rejection of the name itself spuriously claiming conflict with (part of) the protologue description, as can only be expected. But, as explained by Fraser-Jenkins, this is of course going to be the case whenever a mixed concept is involved, and his proposal was entirely unnecessary following the definitive and appropriate clarification of the species by Fraser-Jenkins. Perhaps deliberately, Mazumdar also did not show any understanding that many Indian *Isoetes* "species" merely represent minor infraspecific variation of various characters. Thus he failed to mention that the current Indian taxonomy, cytotaxonomy, cladonomy and nomenclature of the genus are preliminary, greatly unstable and require far-reaching revision, of which the epitypifiction of *I. sahyadrii* was an important first step. Committee decision on his proposal is awaited to see whether *I. sahyadrii* must now be known by one of its several later synonyms, *I. sampathkumaranii* L.N.Rao, as a result of this incomplete and misleading proposal.

Ophioglossum lusitanicum L. - The exclusively South-Indian and Western Ghat plants long identified as *O. lusitanicum* appear to be rather different from the Portuguese (type-) populations, even after exclusion of misidentifications of other species, such as *O. gramineum*. In European plants the sterile lamina is shorter and more consistently narrowly elliptical and slightly oblanceolate, with a slightly blunt apex, while the fertile spike is shorter and slightly thicker. Whether or not this is just variation in the species is not clear, but a distribution from westernmost Atlantic Europe disjunctly to southern peninsular India is more than somewhat unusual, even though it is generally thought to be a cosmopolitan, albeit mostly temperate species. It seems possible that this just might be another residual case of outdated wide species-concepts harping back to the 19th Century, as with the Indian reports of *O. vulgatum*, and the Indian and European plants should be compared, including molecularly, and the identity of the Indian plants reassessed.

Cyathea brunoniana (Wall.) C.B.Clarke & Baker - Fraser-Jenkins, Kandel & Pariyar (2015) and in our vol. 1, agreed with Holttum's finding that Clarke (1880) applied the epithet in an independent and distinct sense, excluding the sense of Wallich and Hooker. Fraser-Jenkins & Kholia, Indian J. Forestry 41(4): 319-335. 2019 ["2018"], detailed our previous conclusion that that necessitated nomenclatural changes in *Cyathea* for two species. However Prof. J. McNeill (pers. comm. 2018) has now explained that nevertheless because Clarke (1879, 1880) and Clarke & Baker (1889) cited Wallich and later Hooker for the name-authority, it is obligatory under the ICN to take it that, even though unintentionally, they combined Wallich's name and sense of the validated epithet under *Hemitelia* and then *Cyathea*. Thus even though it was not what Clarke & Baker thought they were doing and attempted to bring about, the name must still be taken as applying to Wallich's and Hooker's species. Therefore in *Cyathea* the two species concerned are still to be called *Cyathea* (*Sphaeropteris*) *brunoniana* (syn.: *C. sollyana*), as above, and *Cyathea* (*Alsophila*) *chinensis* Copel. (syn.: *Gymnosphaera costularis*).

Microlepia tenera Christ - has been added to the Indian flora, from Nagaland.

Adiantum poiretii Wikstr. - has been re-interpreted as an adventive species in India (S. India).

Pteris semipinnata L. - due to the type being a specimen of *P. dispar*, *P. semipinnata* has now been conserved by the General Committee of the IBC with a new conserved type, and *P. alata* is now placed in its synonymy (see Appendix to Vol. 2: 424).

Pteris sylhetensis Fraser-Jenk. & SushilK.Singh - has been added to the Indian subcontinental flora, in N.E. Bangladesh.

Asplenium tripteropus Nakai - has been added to the Indian flora, from Nagaland (see Appendix to Vol. 2: 427).

Asplenium x *alternifolium* Wulfen nothosubsp. *heufleri* (Reichardt) Aizpuru, Catalán & Salvo - has been added to the Indian subcontinental flora, in N. Pakistan (see Appendix to Vol. 2: 428).

Thelypteris kingii C.F.Reed - has now been found in Yunnan, China, and is no longer to be considered endemic to India, as also anticipated in our Vol. 1.

Thelypteris leucolepis (C.Presl) Ching - has now been added to the Indian flora in the important Nagaland collections of Dr. N. Odyuo (see Appendix to Vol. 2: 430).

Thelypteris parasitica (L.) Tardieu - an epitype selected and illustrated by Mazumdar (see Appendix to Vol. 1: 430-432) with detailed photos seen and retained by CRFJ and by Dr. A.R. Smith was unequivocally typical *T. dentata*. In his unnecessary lectotypification and epitypification, Mazumdar evidently did not even know how to recognise the species concerned, thus illustrating the undesirability of many such bare lectotypification papers without taxonomic input, which seem to have become a fashionable way to increase the quantity, but not quality of publications as required in India. A proposal has therefore had to be published by Fraser-Jenkins et al. (Taxon 67(5): 1031-1032. 2018) to conserve the name *Polypodium parasiticum* L. with a correctly identified conserved type. Mazumdar's mistaken epitype, however, has now mysteriously disappeared from CAL herbarium where it was housed earlier in 2018, and though one may surmise by whose hand that happened, one can but guess its subsequent fate or labelling. A replacement would anyway not be possible to construct as the epitype had already been illustrated.

In the forthcoming appendix to our vol. 3, we add *Huperzia pinifolia* Trevis. to the Andaman & Nicobar Islands (Nevydeva, *B. Ghosh* 63516, CAL, det. CRFJ); synonymise *Selaginella trichophylla* H.S.Kung into *S. monospora* and *S. hookeri* Baker (lectotype here designated, Khasia, *Hooker* & *Thomson* s.n., K (H. 565/82 2) into *S. wallichii*; delete Uttarakhand from *Angiopteris helferiana*; make a new combination, ***Osmunda acuta*** (Burm.f.) Fraser-Jenk., ***comb. nov***., basionym: *Polypodium acutum* Burm.f., Fl. Indica 232. 1768, which replaces the synonym *Osmunda hilsenbergii* Grev. & Hook. (peninsular India) and does not belong to *O. regalis*, as misidentified by Mazumdar in Candollea 74: 98. 2019; make a new combination, ***Pteridium rostratum*** (Burm.f.) Fraser-Jenk., ***comb. nov***., basionym: *Polypodium rostratum* Burm.f., Fl. Indica 233. 1768, which replaces the synonym *P. revolutum* Blume and certainly does not belong to the European and African *P. aquilinum* in Mazumdar's erroneous taxonomy; *Pteris subiriana* Piu Das (Das, Padhye & Mazumdar, Phytotaxa 391(4): 247-252. 2019) is synonymised under *P. blumeana* J.Agardh, having been described with mistakenly supposed differences; *Christella kendhujarensis* S.K.Behera & K.Barik in Behera, Khare et al. (Phytotaxa 397(3): 246-252. 291) is synonymised into *Thelypteris dentata* (Forssk.) E.P.St.John as an obvious teratological abnormality, also showing some normal pinnae and having a thick, horizontal rhizome, not as described; Dr. S.Y. Dong (pers. comm. 2018) has shown convinclingly that *Tectaria dubia* is a further distinct species in India (Assam State) and China and is not a synonym of *T. griffithii*; the presence of *Tectaria fuscipes* in Karnataka, identified by CRFJ for S. Patil (J. Jap. Bot. 89: 186-188. 2014), was inadvertently forgotten and should be added.

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REFERENCES

BRUMMITT R K & POWELL C E 1992 Authors of plant names *Royal Botanic Gardens*, Kew

FRASER-JENKINS C R 2017 ("2016") A revised checklist of Indian pteridophytes-1, *Indian Fern J* **33(1&2)** : 193-205

FRASER-JENKINS C R, GANDHI, K N, KHOLIA B S & BENNIAMIN A 2016 ("2017") An Annotated Checklist of Indian Pteridophytes Part-1 (Lycopodiaceae to Thelypteridaceae) pp 562 Bishen Singh Mahendra Pal Singh, Dehra Dun

FRASER-JENKINS C R, GANDHI K N & KHOLIA B S 2018 An Annotated Checklist of Indian Pteridophytes Part-2 (Woodsiaceae to Dryopteridaceae) pp 573 Bishen Singh Mahendra Pal Singh, Dehra Dun

PICHI SERMOLLI R E G 1996 Authors of scientific names in Pteridophyta pp 78 *Royal Botanic Gardens*, Kew.

SHALIMOV A P, SHRESTHA N & ZHANG X-C 2018 ("2017") Taxonomic study of the genus *Huperzia* Bernh. (Lycopodiaceae) in the Pan-Himalayan region *Indian Fern J* **34** : 130-168

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STUDY OF BIOACTIVE COMPOUNDS IN RHIZOME EXTRACT OF *DRYOPTERIS COCHLEATA* (D. DON) C. CHR. BY USING GC-MS ANALYSIS

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ABSTRACT

Dryopteridaceae is a large, varied family belonging to Leptosporangiate fern group, has a worldwide distribution. Members of the family Dryopteridaceae are mostly terrestrial and medium-sized plants bearing creeping, ascending or erect rhizome, clothed with lanceolate scales. The rhizome of *Dryopteris* is reported to have medicinal value. In order to identify bioactive compounds in rhizome of *Dryopteris cochlearta*, ethanolic, methanolic and distilled water extracts were subjected to GC-MS analysis. Results revealed the presence of various bioactive compounds which may have high medicinal value to cure various diseases.

Key Words : Dryopteridaceae, Leptosporangiate, ethanolic, methanolic, GC-MS analysis

INTRODUCTION

Family Dryopteridaceae, commonly known as the male-fern family, is well-represented in India. Dixit (1984) reported 109 species under seven genera of family Dryopteridaceae from India. In the Western Ghats, Manickam & Irudayaraj (1992) reported 21 species and a variety under eight genera. From the Northern Western Ghats Patil *et al.* (2013) recorded seven species belonging to three genera. More recently, Fraser-Jenkins *et al*. (2018) in the *'Annotated Checklist of Indian Pteridophytes*-2' enlarged the concept of family Dryopteridaceae, recognising five sub-families within it, and a total of 16 genera, and the genus *Dryopteris* in India comprises about 72 species, two sub-species and 6 hybrids. The earliest use of the powder of rhizomes (with leaf bases) of the European Male-Fern, *Dryopteris filix-mas* (L.) Schott is as a vermifuge (anthelmintic), especially as a remedy for tapeworms (Llyod 1921), and its efficacy is attributed to the presence of an oleoresin, and phloroglucosides (raw filicin). *D. filix-mas* does not occur in India, hence there have been attempts to discover comparable Indian substitutes of the Male-Fern, in terms of the filicin content, identity of species and pharmacognosy (Mehra & Mittal 1960, 1961a,1961b, 1962, Mittal 1961, Mittal & Mehra 1960, Mittal & Bir 2006, 2007). Mehra & Mittal, 1961 studied the macroscopy and microscopy of the rhizome and leaf bases of *D. ramosa* and *D. chrysocoma*, and both the species compare very favourably in oleoresinous content and "crude filicin" with the official Male-Fern. *D. cochleata* is characterized by dimorphic fronds. The rhizome is reported to be antibacterial and anti-epileptic (Singh 2003), for treating diarrhea and eczema, and as an anthelmintic (Goswami *et al.* 2016). An anatomical and histochemical investigation was carried out on the rhizomes of *Dryopteris filix-mas* (L.)

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Schott, and of *Dryopteris affinis* (Lowe) Fr.-Jenk. These rhizomes show considerable differences which permit their identification even without the fronds. As regards the pharmacognos-tic elements the internal glandular hairs are particularly interesting. (Maria, 1988)

During the experimental work the rhizome part of *D. cochleata* showed the presence of various phytoconstituents, like flavonoids, tannins, protein, amino acid etc. (Das *et al.* 2014). However, reports on GC-MS analysis of species within the family Dryopteridaceae seems to be meager. Hence the present work is undertaken.

MATERIAL AND METHODS

A : Material - The material has been collected from Patan (Satara district), Maharashtra, during rainy season. Only the rhizome part was used for analysis.

B : Method - 1. Preparation of plant extract- The plant extract was prepared by Soxhlet extraction method. 5 g of powdered plant material was used for the extraction. Dried stored extracts were concentrated and used for analysis.

2. GC-MS analysis- Ethanol, methanol and distilled water extracts of rhizome were subjected to GC-MS for the determination of bioactive volatile compounds. Some of the important features are summarized below.

GC-MS analysis of the samples were carried out using Shimadzu make QP-2010 with non polar 60 M RTX 5MS column as previously described by Dubal *et al.* (2015).

3. Identification of phytocomponents- Interpretation of GC-MS mass spectrum and subsequent identificationof phytocomponents was carried out by using the database of NIST (>62,000 patterns).

RESULTS AND DISCUSSION

The analysis of *D. cochleata* rhizome extract in methanol by GC-MS clearly shows the presence of four bioactive compounds. Chromatogram with the four peaks of compounds detected, their retention time, concentration (% peak area), molecular weight and molecular formula are shown in Fig.1 and Table 1. The most prevalent compounds are Ethanol, Cyclohexasiloxane-Dodecamethyl, Diphenyl ether and Cycloheptasiloxane, tetradecamethyl.

The analysis of *D. cochleata* rhizome extract in ethanol showed the presence of 7 bioactive compounds. The GC-MS Chromatogram with seven peaks of compounds detected, their retention time, concentration (% peak area), molecular weight and molecular formula are shown in Fig.2 and Table 2.The most prevalent compounds are Dimethyl sulfoxide ($C2H6O5$) with retention time 6.911 and peak area of 17.84, neoisolongifolene, 8, 9-dehydro ($C15H22$) with retention time 18.260 and peak area of 2.18, Germacrene D ($C18H36$) with retention time 20.208 and peak area of 13.14. Dimethyl sulfoxide identified has been used against cancer. It has been used in pharmaceutical science as anti-inflammatory and antioxidant agent (Heena and Achaleshwar, 2010). Germacrene D has anti-inflammatory properties (Easa, 2003).

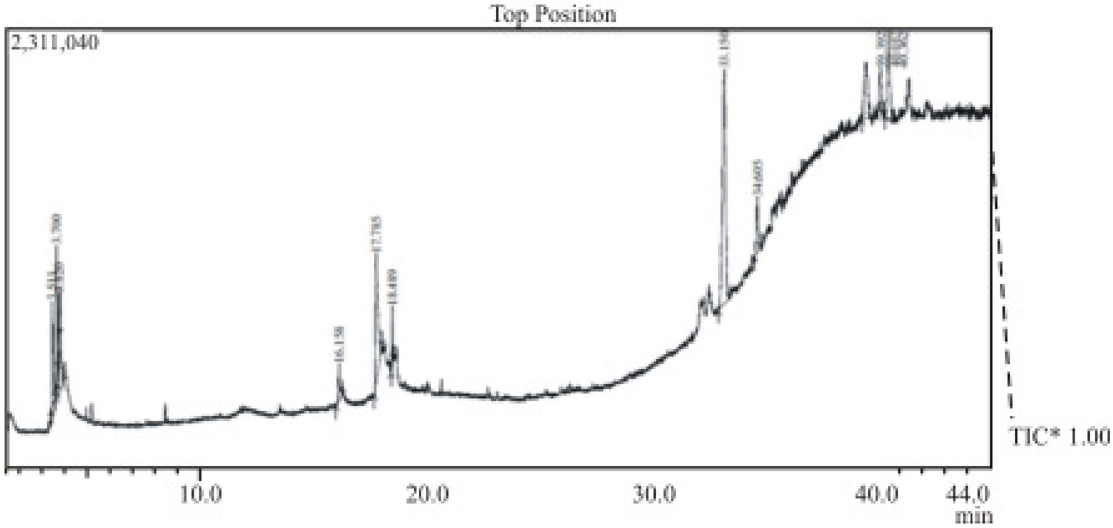

Fig. 1 : GC-MS chromatogram of *D. cochleata* rhizome extract in methanol.

TABLE 1 : Bioactive compounds of *D. cochleata* rhizome extract in methanol.

Sr. No.	Retention Time (Min.)	Peak Area (%)	Compound Name	Molecular Weight	Molecular Formula
1.	3.511	6.96	—	—	—
2.	3.700	4.86	Ethanol	46	C_2H_6O
3.	3.820	1.50	—	—	—
4.	16.158	2.75	Cyclohexasiloxane, dodecamethyl-	444	$C_{12}H_{36}O_6Si_6$
5.	17.785	14.63	Diphenyl ether	170	$C_{12}H_{10}O$
6.	18.489	1.72	Cycloheptasiloxane, tetradecamethyl-	518	$C_{14}H_{42}O_7Si_7$
7.	33.150	37.31	—	—	—
8.	34.605	5.09	—	—	—
9.	39.392	9.63	—	—	—
10.	40.017	3.90	—	—	—
11.	40.362	11.65	—	—	—

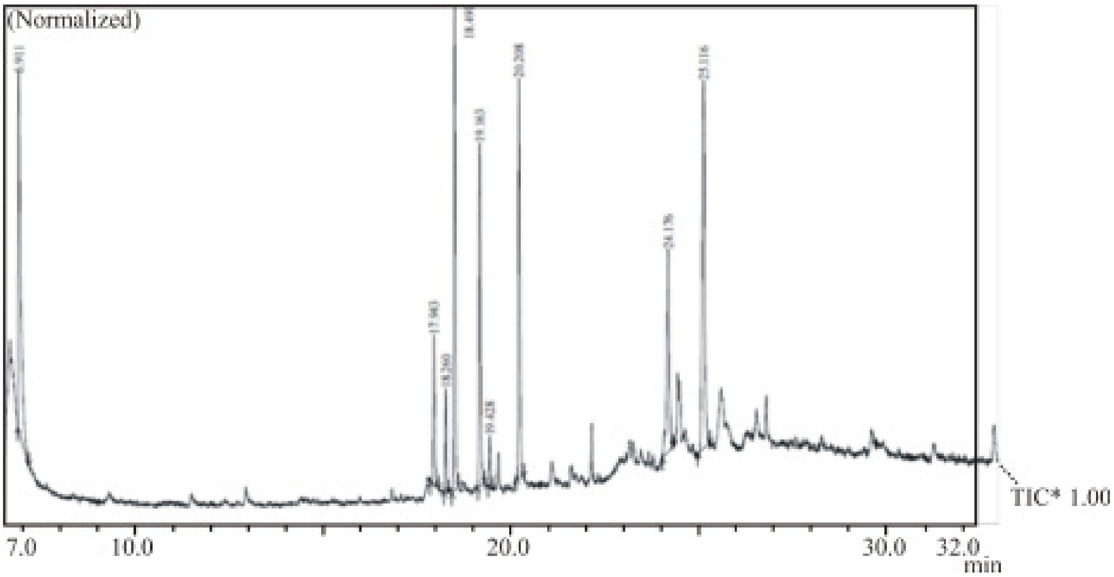

Fig. 2 : GC-MS Chromatogram of *D. cochleata* rhizome extract in ethanol.

TABLE 2 : Bioactive compounds of *D. cochleata* rhizome extract in ethanol.

Sr. No.	Retention Time (Min.)	Peak Area (%)	Compound Name	Molecular Weight	Molecular Formula
1.	6.911	17.84	Dimethyl Sulfoxide	78	$C_2H_6O_5$
2.	17.943	5.53	1,3-Cyclohexanedione, 2-methyl-2-(3-oxobutyl)	196	$C_{11}H_{16}O_3$
3.	18.260	2.18	Neoisolongifolene, 8,9-dehydro	202	$C_{15}H_{22}$
4.	18.492	15.27	Germacrene D	204	$C_{15}H_{24}$
5.	19.167	12.65	Cyclohexane, 1,1,3-trimethyl-2-(3-methylpentyl)	210	$C_{15}H_{30}$
6.	19.425	1.38	1,6,10-Dodecatrien-3-ol, 3,7,11-trimethyl	222	$C_{15}H_{26}O$
7.	20.208	13.44	Cyclopropane	252	$C_{18}H_{36}$

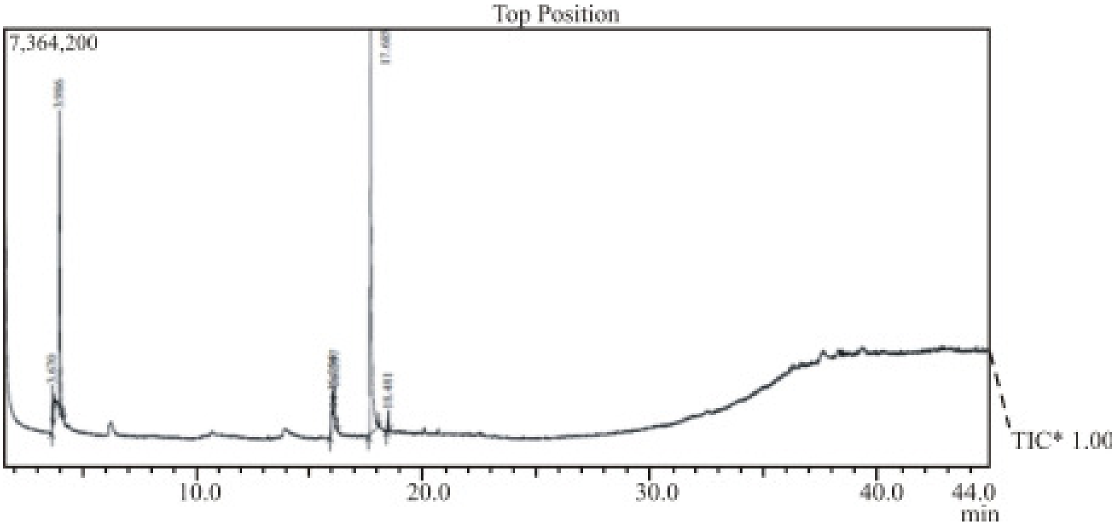

Fig. 3 : GC-MS Chromatogram of *D. cochleata* rhizome extract in distilled water.

TABLE 3 : Bioactive compounds of *D. cochleata* rhizome extract in distilled water.

Sr. No.	Retention Time (Min.)	Peak Area (%)	Compound Name	Molecular Weight	Molecular Formula
1.	3.670	3.15	Carbon dioxide	44	CO2
2.	3.986	26.53	Ethanol	46	C2H6O
3.	16.016	3.22	Thymol	150	C10H14O
4.	16.097	0.57	Cyclohexasiloxane, dodecamethyl-	444	C12H36O6Si6
5.	17.685	65.05	Diphenyl ether	170	C12H10O
6.	18.481	1.47	Cycloheptasiloxane, tetradecamethyl-	518	C14H42O7Si7

The analysis of *D. cochleata* rhizome extract in distilled water shows by GC-MS clearly shows the presence of four bioactive compounds. Chromatogram with the four peaks of compounds detected, their retention time, concentration (% peak area), molecular weight and molecular formula are shown in Fig.3 and Table 3.The most prevalent compounds are carbon dioxide with retention time 3.670 and peak percentage 3.15, Thymol with retention time 16.016 and peak percentage 3.22 and Diphenyl ether with retention time 17.685 and peak percentage 65.05.

CONCLUSION

Results revealed the presence of various bioactive compounds which may have high medicinal value to cure various diseases. Dimethyl sulfoxide has been used against cancer. It has been used in pharmaceutical science as anti-inflammatory and antioxidant agent. Germacrene D has anti-inflammatory properties. Identification of above compounds can be valuable in pharmaceutical industries. It may be mentioned that the compounds identified in GC-MS analysis have no relevance to filicin.

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REFERENCES

DAS S, SHARMA S & LARIYA S 2014 Physico-chemicaland phytochemical study of rhizome of *Dryopteris cochleata International Journal ofPharmaceutical and Chemical Sciences* **3(2) :** 517-521

DIXIT R D 1984 A Census of the Indian Pteridophytes Flora of India Ser 4, *Botanical Survey of India* Howrah (Calcutta) India

DUBAL K, PATIL S, DONGARE M and KALE M 2015 Investigation of chemical composition from *Dryopteris cochleata Asian Journal of Pharmaceutical and Clinical Research* **8(4)** : 311-314

EASA P S 2003 Biodiversity Documentation for Kerala part 5 *Pteridophytes* Vol 17 Peechi Kerala : Forest Research Institute Kerala KRFRI pp 70

FRASER-JENKINS C R, GANDHI K N & KHOLIA B S 2018 *An Annotated Checklist of Indian Pteridophytes*, Part-2 (Woodsiaceae to Dryopteridaceae). Bishen Singh Mahendra Pal Singh Publishers Dehra Dun pp 573

GOSWAMI H K, SEN KAKALI & MUKHOPADHYAY R 2016 Pteridophytes : Evolutionary boon as medicinal plants *Plant Genetic Resources* **14(4)** : 328-355

HEENA P and ACHALESHWAR B 2010 In vitro antimicrobial activity of fronds (leaves) of some important pteridophytes *J Microbiol Antimicrob* **2(2)** : 19-22

LLOYD J U 1921 *Origin and History of all Pharmaceutical Vegetable Drugs* The Caxton Press Cincinnati Ohio USA

MANICKAM V S & IRUDAYARAJ V 1992 *Pteridophytic flora of South India* Today and Tomorrows Publications New Delhi pp 653

MARIA P A 1988 Differential Characters of Rhizomes of *Dryopteris filix-mas* and *Dryopteris affinis Pharmaceutical Biology - PHARM BIOL* **26** 145-153 10.3109/13880208809053909. An anatomical and histochemical investigation was carried out on the rhizomes of *Dryopteris filix-mas* (L) Schott

MEHRA P N & MITTAL T C 1960 Indian substitutes of Male Fern *Pharmacognosy Nature* **186** : 722-723

MEHRA P N & MITTAL T C 1961a *Pharmacognosy of Indian substitutes of Male Fern* Part I *Dryopteris ramosa* (Hope) C.Chr. and *D chrysocoma* (Christ) C.Chr. *J Pharmacy & Pharmacognosy* **13** : 300-308

MEHRA P N & MITTAL T C 1961b Significance of internal secretary glands in relation to filicin *Planta Medica* **9** : 189-199

MEHRA P N & MITTAL T C 1962 Pharmacognosy of Indian substitutes of Male Fern-II *Dryopteris barbigera* and *Dryopteris cochleata, J Pharmaceutical Sci* **51** : 367-371

MITTAL T C 1961 Pharmacognosy of Indian substitutes of Male Fern-III *Dryopteris splendens* (Hk) O Ktze *Indian J Pharmacy* **23** : 249-253

MITTAL T C & BIR S S 2006 The Indian substitutes of Male Fern (*Dryopteris filix-mas* (L) Schott)-I Taxonomy and drug macroscopy *Indian Fern J* **23** : 133-187

MITTAL T C & BIR S S 2007 The Indian substitutes of Male Fern (*Dryopteris filix-mas* (L) Schott)-II Drug microscopy *Indian Fern J* **24** : 1-53

MITTAL T C & MEHRA P N 1960 Preliminary chemical investigations on some Indian +substitutes of Male Fern *J Pharmacy & Pharmacognosy* **12** : 317-319

PATIL S M & DONGARE M 2013 New additions to the pteridophyte flora of Maharashtra *Phyto Taxo* **13 :** 89-91

SINGH H B 2003 Economically viable pteridophytes of India In "*Pteridology in the New Millennium*" (eds S Chandra & M Srivastava), Kluwer Academic Publishers, Netherlands pp 421-446

Indian Fern J. **36 :** 37-79 (2019) ISSN 0970-2741

BIOACTIVE PHYTOCONSTITUENTS OF PTERIDOPHYTES - A REVIEW

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ABSTRACT

Plants have been used since ancient time for curing human ailments and diseases. Although, the medicinal properties of pteridophytes are recognized worldwide, the survey of previous work indicates that the medicinal plants specially the angiosperms are given more importance and non-flowering plants particularly pteridophytes are mainly ignored. We have insufficient studies regarding the particular active constituent responsible for bioactivity in case of pteridophytes. The aim of this review was to explore the medicinal activities of pteridophytes, one of the ancient vascular plants. Phytochemical investigations on different species of fern and fern allies have revealed a range of secondary bioactive metabolites such as flavonoids, phenolic acids, terpenoids, etc. We have documented the curative properties of pteridophytes belonging to more than thirty different families.

Key Words : Pteridophytes, Antioxidant, Anti-Cancer, Antidiabetic, Antiviral, Antimicrobial, Bioactive compounds

INTRODUCTION

Fern and Fern-allies are one of the most ancient vascular plants. Linnaeus recognized 15 fern genera in *Species Plantarum* (1753) and *Genera Plantarum* (1754), which now substantially increased upto 319 fern genera in 51 families, 14 orders and 2 classes in PPGI, 2016 (Schuettpelz 2018). The second largest groups of vascular plants are used by local people around the world to treat various ailments (Rout *et al.* 2009). Theophrastus (ca 327-287 BC) and Dioscorides (ca. 50 AD) had referred to medicinal attributes of certain ferns. Sushruta and Charaka (ca. 100 AD) mentioned uses of *Marsilea minuta* L. and *Adiantum capillus-veneris* L. in their samhitas. Earlier work related to bioactive constituent's dates back to 1980's, potions formulated in different ways were taken orally for various remedies (Grepin & Grepin 1980, Petard 1986) followed by various workers namely Whistler (1992), Cambie & Ash (1994), Whistler (1996), Singh (1999, 2003), Mittal & Bir (2007), Goswami *et al.* (2016), and so on. Fronds, rhizomes, rachis, spores as well as whole plant parts are utilized in preparation of herbal juices, decoction, pastes and powder (Sureshkumar *et al.* 2018). Wide varieties of secondary metabolites belong to terpenoids, phenolics, alkaloids, flavonoids, and among them terpenoids are the most abundant in ferns (Ho *et al.* 2011). These active constituents are known to possess varied range of medicinal activity such as antimicrobial, anti-inflammatory, anti-viral, antioxidant, anti-tumour, anti-HIV, *etc.* and are generally considered as safe substances (Proestos *et al.* 2005). So, medicinal plants can be exploited on basis of their active constituents in discovery of new drugs and as an alternatve to synthetic drugs due to their

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lesser side effects.

We have listed the compiled data on bioactive phytoconstituents of medicinally important pteridophytes in Table 1, belonging to 99 species of ferns and fern-allies arranged in alphabetical order for each species with name, family, bioactive components, bioactivities reported and references. The major genera which got attention of scientific fraternity belong to families Pteridaceae, Dryopteridaceae, Polypodiaceae, Selaginellaceae, *etc*. This study is a part of our research work on cytomorphological investigations of medicinal ferns from North West India.

MATERIALS AND METHODS

A comprehensive search was conducted using offline databases and online databases such as NCBI, Pub Med, SciFinder, Science Direct, Google Scholar, whereisdoc, Web of Science and book database library genesis for searching all relevant materials about medicinal ferns. Literature on bioactive compounds from pteridophytes across the globe was collected from scientific journals, books, book chapters, magazines, conference proceedings. We tried to incorporate as much as information available till date about bioactive principles of ferns in this review. The terms used in the search were as follows: pteridophytes, bioactive compounds of ferns, ferns, fern-allies, medicinal uses of pteridophytes, bioactivity of ferns, phytochemicals in ferns, bioactive constituents of ferns. Information regarding botanical names was extracted from online databases such as the International plant names index (http://www.ipni.org), www.eFloras.org. and "The Plant List" (http://www.theplantlist.org/). We have used an accepted name irrespective of what is given in the original publication.

ACTIVE CONSTITUENTS AND PHARMACOLOGICAL EFFECTS

Plants are the global resource being used by human societies throughout world for various purposes like medicinal, ornamental, commercial purposes etc. Pteridophytes though found scattered all over world yet not much attention was given toward economics including medicinal uses. Fern and fern allies are being used by physicians practicing the Chinese system (Kimura & Noro 1965) and Unani system of medicine (Uddin *et al.* 1998).

Pteridophytes have a unique feature of not being infected by any microbial pathogen, a factor that enables them to survive more than 350 million years (Shinozaki *et al.*, 2008). Chemistry of medicinal plants has been developed as a major field of scientific research. A cursory survey of literature on medicinal plants revealed that curative properties of ferns are being more thoroughly studied in last few decades.

Terpenoids

Diterpenoids namely entkaurane-2β, 16α-diol, entkaur-16-ene-2β, 15α-diol, pterokaurane M1, pterokaurane M2, pterokaurane M3 (Zheng *et al.* 2008a,b) and sesquiterpenoids such as Multifidoside A; multifoside, B; multifidoside C; (2S, 3S) - pterosin

TABLE 1 : Bioactive compounds of Medicinal Pteridophytes wth different bioactivities

No.	Botanical name and Family	Bioactive compounds	Bioactivity	References
1.	*Acrostichum aureum* L (Pteridaceae)	Quercetin, quercetin-3-O-β-d-glucoside, quercetin-3-O-β-d-glucosyl-(6→1)-α-l-rhamnoside, quercetin-3-O-α-l-rhamnoside, quercetin-3-O-α-l-rhamnosyl-7-O-β-d-glucoside, kaempferol, catechin, 2-butanone, patriscabratine, tetracosane, campesterol, cycloarnatol, 24-Methylene cycloarnatol, ponasterone, pterosterone, γ-sitosterol, stigmasterol, (2S,3S)-Pterosin C, (2R)-Pterosin P, (2R,3S)-Sulphated pterosin C, (2S,3S)-Sulphated pterosin C, Di-(2-methylheptyl) phthalate, (2'S-Methylhexyl)(2"S-methyl-5'-acetylpentyl)phthalate, 2"-(Methoxycarbonyl)-5"-methylpentyl-2'-methylhexylphthalate	Anti-inflammatory/ antimicrobial/ antioxidant/ antiseptic / anthelminthic/ emollients/ tyrosinase inhibiting activity/ antitumour/ anti-parasitic/ analgesic/ cytotoxic/ anti-diarrhoeal/ anti-fertility	Cambie and Ash, 1994; Lai *et al,* 2009; Lai and Lim, 2011; Uddin, 2011; Uddin *et al,* 2012; Devi *et al,* 2015; Thomas *et al,* 2016; Kimura *et al,* 2017; Badhsheeba and Vadivel, 2018; Kerry *et al,* 2018
2.	*Actiniopteris radiata* (Sw) Link (Pteridaceae)	Quinones, terpenoids, steroids	Antidiabetic/ antitubercular/ anthelmentic/ antimicrobial/ hepatoprotective/ antifungal/ antioxidant/ anti-stress/ anti-allergic	Manjunath *et al,* 2008; Naik and Jadge, 2010; Parihar *et al,* 2010; Manjunath *et al,* 2011; Gracelin *et al,* 2012; Vadnere *et al,* 2013; Paulsamy *et al,* 2013; Chand Basha *et al,* 2013; Manubolu *et al,* 2013; Munna *et al,* 2014; Sreenivasulu *et al,* 2014; Shashikanth *et al,* 2014; Manubolu *et al,* 2014; Kalpana Devi *et al,* 2015; Rajesh *et al,* 2014; Mathad *et al,* 2015; Rupnath *et al,* 2016; Chandrakant *et al,* 2019
3.	*Adiantum capillus-veneris* L (Pteridaceae)	Adiantone, adiantoxide, astragalin, β-sitosterol, caffeicacids, caffeylgalactose, caffeylglucose, campesterol, carotenes, coumaric acids, coumaryl-glucoses, diplopterol, epoxyfilicane, fernadiene, fernene, filicanes, hopanone, hydroxy-adiantone,	Antiproliferative/ antidermatitis/ anticholesterolemic/ antioxidant/ DNA protecting effect/	Kumar and Kaushik, 1999; Mukhopadhyay and Gupta, 2005; Ibraheim *et al,* 2011; Pan *et al,* 2011; Jiang *et al,* 2011; Rajurkar and Gaikwad, 2012; Yuan *et al,* 2012; Ahmed *et al,* 2012; Haider *et al,*

		hydroxy-cinnamic acid, isoadiantone, isoquercetin, kaempferols, lutein, mutatoxanthin, naringin, neoxanthin, nicotiflorin, oleananes, populnin, procyanidin, prodelphinidin, quercetins, querciturone, quinic acid, rhodoxanthin, rutin, shikimic acid, violaxanthin, and zeaxanthin, more than 130 compounds belonging to triterpenoids, flavonoids, phenyl propanoids, phenolics, coumarins, phytosterols, fatty acids and others	anticancerous/ antiviral/ gastroprotective/ neuroprotective/ photoreceptor/ antimicrobial/ antiobesity/ antihyperglycaemic/ antiseptic/ anti-inflammatory/ antidiabetic/ antifungal/ antidysentric/ antiulcer/ anticancer/ antiviral	2013; Sharma *et al,* 2013; Yuan *et al,* 2013; Vijayalakshmi *et al,* 2013; Ansari *et al,* 2012;Jain *et al,* 2014; Ishaq *et al,* 2014; Ranjan *et al,* 2014; Santhosh *et al,* 2014; Al-Snafi, 2015; Kale, 2015b; Kapoor and Kanwar, 2015; Nath *et al,* 2016; Ranjan and Vats, 2016; Yousaf *et al,* 2016; Hussein *et al,* 2016; Johnson *et al,* 2017; Kasabri *et al,* 2017; Dehdari and Hajimehdipoor, 2018; Rastogi *et al,* 2018; Abdulqadir and Cakmak, 2018; Rautray *et al,* 2018; Nazim *et al,* 2018; Yumkham *et al,* 2018; Zhang *et al,* 2019; Chandran *et al,* 2019
4.	*Adiantum caudatum* L (Pteridaceae)	Gallic acid, rutin, 16-hentriacontanone and hentriacontane, 17b, 21b-Epoxyhopane, Neohop-13(18)-ene, 19a-Hydroxyadiantone, 29-Norhopan-22-ol	Antimicrobial/ antiseptic/ antidiabetic/ α-amylase/ α-glucosidase inhibitory activity	Burkill, 1996; Saha *et al,* 2011; Telagari and Hullatti, 2015; Ahmed *et al,* 2015; Rastogi *et al,* 2018
5.	*Adiantum chilense* var *sulphureum* (Kaulf) Kuntze ex Hicken (Pteridaceae)	Rutin, isoquercetin, quinic acid, astragalin	Expectorant/ antioxidant	Laware and Limaye, 2012
6.	*Adiantum edgeworthii* Hook (Pteridaceae)	Hop-22(29)-ene (= Diploptene), Hydroxyhopane (= Hopanol), 19a-Hydroxyadiantone, Fern-9(11)-en-25-oic acid, Fern-9(11)-ene(= Fernene, Davallene), Fern-7-ene= 7-fernene, Filic-3-ene (= 3-Filicene, Filicene)	Antimicrobial/ anxiolytic/ analgesic/ anti-inflammatory/ antinociceptive	Shiojima and Ageta, 1994; Pan *et al,* 2011; Halder and Chakraborty, 2018; Yumkham *et al,* 2018
7.	*Adiantum incisum* Forssk (Pteridaceae)	Rutin, isoquercetin, hentriacontane, 16-hentriacontanone, adiantone, isoadiantone, β-sitosterol, fernene	Antimicrobial/ hepatoprotective/ antioxidant/ antimicrobial activity/ α-amylase/ α-glucosidase inhibitory	Bhramchari *et al,*2003; Sharma *et al,* 2013; Sengottuvel *et al,* 2015; Ahmed *et al,* 2015; Latha, 2016; Johnson *et al,* 2017; Antonysamy *et al,* 2017; Yumkham *et al,* 2018; Adam *et al,* 2018

			activity/ analgesic, expectorant/ anti-inflammatory	
8.	*Adiantum latifolium* Lam (Pteridaceae)	Stigmast-4-en-3-one , stigmasta-4,22-dien-3-on, Stigmasterol, β-Sitosterol, 22-hydroxyhopane	Antimicrobial/ anxiolytic/ analgesic/ anti-inflammatory/ antinociceptive/ larvicidal	Nonato *et al,* 2011; Gracelin *et al,* 2013; Krishnakumar *et al,* 2015; Rosandy, 2017; Antonysamy *et al,* 2017; Kumar *et al,* 2019
9.	*Adiantum monochlamys* Eaton (Pteridaceae)	Adian-5-ene ozonide, Hop-22(29)-ene, Neohop-12-ene, Neohop-13(18)-ene, Neohopa-11,13(18)-diene, 21-Hydroxy-30-norhopan-22-one, Isoadiantone, Isoadiantol B, Ferna-7,9(11)-diene	Antimicrobial/ anti-inflammatory/ analgesic	Baskaran *et al,* 2018
10.	*Adiantum phillipense* L (Pteridaceae)	6a-Acetoxy-16b,22-dihydroxy-3-ketoisohopane, 3b-Acetoxy-6a-hydroxy-hop-15,17(21)-diene, 3b-Acetoxy-21aH-hop-22(29)-ene, Adiantone, 22,29x-Epoxy-30-norhopane-13b -ol, Fern-9(11)-en-28-ol, Fern-9(11)-en-25-oic acid, Fern-9(11)-en-6a-ol, Fern-9(11)-ene (= Fernene, Davallene, Filicenol B, astragalin, 3α, 4α-epoxyfilicane, isoquercetin, nicooiflorin, kaempferol-3-glucuronide, rutin, quercituroneketol-21-hydroxy-30-norhopan-22-one	Antimicrobial/ antidote/ anti-inflammatory/ antifungal/ antioxidant/ hypotensive/ nephroprotective	Mukhopadhyay and Gupta, 2005; Nair *et al,* 2005; Paul *et al,* 2012; Patil *et al,* 2013; Rajesh *et al,* 2014; Moorthy *et al,* 2014; Mengane, 2016; Nath *et al,* 2016; Vetter, 2018; Asif, 2018
11.	*Adiantum raddianum* C Presl (Pteridaceae)	Filicene, filicenal	Analgesic/ antioxidant	Bresciani *et al,* 2003; Lai and Lim, 2011; Sharma *et al,* 2013; Yumkham *et al,* 2018; Vetter, 2018
12.	*Adiantum venustum* D Don (Pteridaceae)	Saponin, tannins, fern -9(11)-en-25-oic acid, 30-normethyl lupine- 20 one, 30- normethyl olean-3-0ne- 30- betol, and lanost-20(22)- ene-30-ol, adiantulanostene ether	Antimicrobial/ tonic/ expectorant/ astringent/ emetic/ diuretic/ anti-diabetic/ antipyretic/ antioxidant/ anti-inflammatory/ anticancer/ antifungal	Mubashir and Shah, 2011; Tapwal *et al,* 2011; Vidyasagar, 2016; Hamid *et al,* 2017; Rastogi *et al,* 2018; Yumkham *et al,* 2018

13.	*Angiopteris evecta* (G Forst) Hoffm (Marattiaceae)	Angiopterioside, violanthin, isoviolaxanthin	Anti-cancer/ anti HIV/ antibacterial/ anti-oxidant/ antituberculosis/ anti-hairfall	Hseu, 1981; Cambie and Ash, 1994; Taveepanich *et al,* 2005; Khan and Omoloso, 2008; Mohamad *et al,* 2011; Nilanthi *et al,* 2012; Panda, 2014; Mismawati *et al,* 2015; Mustarichie *et al,* 2017
14.	*Anisocampium niponicum* (Mett) YCLiu, WL Chiou & M Kato (Athyriaceae)	Protoflavonoids	Antioxidant/ anti-HIV activity/ antitumour	Mizushina *et al,* 1998; Delong *et al,* 2011, Salehi *et al,* 2018
15.	*Araiostegia divaricata* var formosana (Hayata) M Kato (Davalliaceae)	Davallic acid, flavan-3-ol, proanthocyanidin allosides, (—)-epicatechin-3-O-β-D-allopyranoside	Antioxidant/ anti-diabetic	Lin *et al,* 2017
16.	*Asplenium adiantum-nigrum* L (Aspleniaceae)	Protocatechuic acid, gentisic acid, mangiferin, p-hydroxybenzoic acid, aesculin, chlorogenic acid, caffeic acid, p-coumaric acid, rosmarinic acid, gallocatechin, epigallocatechin, gallate, catechin, epicatechin, rutin, epigallocatechin, mangiferin glucoside, xanthone 2,4-di-c-glycosides	Contraceptive/ diuretic/ emmenagogue/ expectorant/ laxative/ ophthalmic/ pectoral/ antibacterial/ anti-oxidant	Imperato, 1991; Mir *et al,* 2013; Valizadeh *et al,* 2015; Bahadori *et al,* 2015; Zivkovic *et al,* 2017; Farr's *et al,* 2019
17.	*Asplenium dalhousiae* Hook (Aspleniaceae)	Total phenols, flavonoids, steroids, tannins, glycosides, proanthrocyanidines	Antidote/ anthelmintic/ vermifuge	Kumar *et al,* 2013; Berk *et al,* 2011
18.	*Asplenium scolopendrium* L (Aspleniaceae)	Triterpenoids, polyphenols	Wound healing activity/ antibacterial	Oniga *et al,* 2004; Bahadori *et al,* 2015
19.	*Asplenium trichomanes* L (Aspleniaceae)	4-vinyl-phenol-1-o-[a-L-rhamno(1-6)-b-d-glucopranosyde, kaempferol-3-o-a-[2 acetyl0-arabinofuranosyl-7-O-a-L-rhanopyranoside, phlligenin, arctigenin	Antimicrobial/ laxative/ expectorant/ emmenagogue/ estrogenic	Dall' Acqua *et al,* 2009
20.	*Blechnum brasiliense* Desv (Blechnaceae)	Chlorogenic acid, rosmarinic acids	Antioxidant/ neuroprotector potential	Andrade, 2016

21.	*Blechnum orientale* L (Blechnaceae)	Proanthocyanidin	Anti-inflammatory/ anticancer/ antimicrobial/ anthelmintic/ antioxidant/ contraceptive/ anti-diabetic	Lai *et al,* 2010; Nonato *et al,* 2009; Lai *et al,* 2017
22.	*Campyloneurum angustifolium* (Sw) Fée (Polypodiaceae)	Anthraquinone	Synthesis of corticoid hormones	Pareja, 1988
23.	*Ceterach officinarum* Willd (Pteridaceae)	p-coumaric, ferulic acid	Astringent/ diuretic/ emollient	Tackholm *et al,* 1973; Durdevic *et al,* 2007
24.	*Cheilanthes albomarginata* C B Clarke (Pteridaceae)	Quercetin-3-methyl ether 5-O-glucoside, kaempferol-3-methyl ether-5-O-β-(6'-malonyl) glycoside	Antifungal	Parihar *et al,* 2004
25.	*Cheilanthes anceps* Blanf (Pteridaceae)	Mono and 3,7-di-O-glycosides of kaempferol, quercetin	Antioxidant	Chowdhary *et al,* 2010; Goswami *et al,* 2016
26.	*Cheilanthes dalhousie* (Hook) (Pteridaceae)	Quercetin-3-methyl ether 5-O-glucoside, kaempferol-3-methyl ether-5-O-β-(6´-malonyl) glycoside	Antifungal	Mishra and Verma, 2010
27.	*Cheilanthes farinosa* (Forssk) Kaulf (Pteridaceae)	3, 7, 11, 15 tetramethyl-2-hexdecane-1-ol, n-hexadecanoic acid Hexadecanoic acid, ethyl ester 9-octdecanoic acid, 1, 2 –Benzene carboxylic acid, discotyl ester, n-tetracontane, diploptene, rutin, cinnamic acid, caffeic acid, quinic acid derivatives, chlorogenic acid	Anti-inflammatory/ antinociceptive	Yonathan *et al,* 2006; Ghorpade *et al,* 2015
28.	*Cheilanthes grisea* Blanf (Pteridaceae)	Quercetin-3-OCH3-5-O-β-d-glucoside, kaempferol-3-OCH3-5-O-β-d-glucoside, Quercetin-3, 4'-dimethyl ether- 5-O-β-d-glucoside	Antifungal	Mishra and Verma, 2013
29.	*Cheilanthes tenuifolia* (Burmf) Trevis (Pteridaceae)	Rutin, quercetin	Antioxidant/ antimicrobial/ anticancer	Jarial *et al,* 2018
30.	*Christella parasitica* H L (Thelypteridaceae)	Astragarin, kaempferol glucoside, kaempferol rutinoside	Anti-inflammatory/ antibacterial	Gogoi, 2002; Paul *et al,* 2011

31.	*Cibotium barometz* (L) J Sm (Cibotiaceae)	(24R)-stigmast-4-ene-3- one, 24-methylenecycloartanol, β-sitosterol, (3R)-des-O-methyl lasiodiplodin, protocatechuic aldehyde, onitin, alternariol, daucosterol	Antioxidant/ anti-inflammatory/ anodyne/ anti-osteoporosis	Cheng *et al,* 2003; Zhong-Yuan *et al,* 2004; Qi *et al,* 2007; Wu and Yang, 2009; Zhao *et al,* 2011; Xu *et al,* 2011; Xu *et al,* 2014
32.	*Cyathea gigantea* (Wall ex Hook) Holttum (Cyatheaceae)	β-sitosterol	Hepatoprotective	Woyengo, 2009; Kiran *et al,* 2012: Kale, 2015a
33.	*Cyathea phalerata* Mart (Cyatheaceae)	Kaempferol-3-neohesperidoside, 4-O-β-D-glucopyranMicrosorumosyl caffeic acid, 4-O-β-D-glucopyranosyl p-coumaric acid, 3,4-spyroglucopyranosyl protocatechuic acid, sitosterol β-D-glucoside, ?-sitosterol, vitexin, kaempferol	Antioxidant/ hepatoprotective/ hypoglycaemic activity	Pizzolatti *et al,* 2007; Hort *et al,* 2008
34.	*Cyrtomium caryotideum* (Wall ex Hook & Grev) C Presl (Dryopteridaceae)	Flavonoids, phlobatannins, alkaloids, saponins, tannins, phenols, terpenoids, cardiac glycosides	Antipyretic/ antifungal	Ullah *et al,* 2018
35.	*Cyrtomium fortunei* J Sm (Dryopteridaceae)	Protocate chaldehyde, woodwardinsaure methylester, physcion, pimpinellin, ursolic acid, sitost-4-en-3-one, betulin, 3',4',5-trihydroxy-3,7-dimethoxyflavone, woodwardinic acid, sutchuenoside A, kaempferol-3, 7-O-α-L-dirhamnoside, (—)-epicatechin, (+)catechin hydrate kaempferol, crassirhizomoside A, kaempferol-3-O-(3-O-acetyl-α-L) rhamnopyranoside	Antiviral/ antipyretic/ anti-inflammatory/ diuretic	Nguyen *et al,* 2004; Guo *et al,* 2006; Yang *et al,* 2013
36.	*Davallia mariesii* T Moore ex Baker (Davalliaceae)	Procyanidin-B5, epicatechin(4β-8)-epicatechin-(4β-6)-epicatechin, davallialactone, caffeic acid	Inhibition of protein kinase C	Cui *et al,* 1990, Cui *et al,* 1992
37.	*Davallia solida* (G Forst) Sw (Davalliaceae)	3•-O-p-hydroxybenzoylmangiferin, 4•-O-p-hydroxybenzoylmangiferin, 6•-O-p-hydroxybenzoylmangiferin, 3-O-p-hydroxybenzoylmangiferin, mangiferin, 2-C-β-d-xylopyranosyl-1,3,6,7-tetrahydroxyxanthone, 4β-carboxymethyl-(—)-epicatechin, 4β-carboxymethyl-(—)-epicatechin methyl ester, eriodictyol, eriodictyol-8-C-β-d-glucopyranoside, icariside E_5, icariside E_3	Antioxidant/ reversal of ciguatoxin-1B effects on myelinated axons	Whistler, 1992; Benoit *et al,* 2000; Chen *et al,* 2008

38.	*Dicranopteris linearis* (Burm f) Underw (Gleicheniaceae)	Afzelin, quercitrin, isoquercitrin, astragarin, rutin, kaempferol 3-O-(4-O-p-coumaroyl-3-O-α-lrhamnopyranosyl)-α-L-rhamnopyranosyl-(1→6)-β-Dglucopyranoside, (6S,13S)-6-[6-O-acetyl-β-Dglucopyranosyl-(1→4)-α-L-rhamnopyranosyloxy]-13-[α-lrhamnopyranosyl-(1→4)-β-D fucopyranosyloxy] cleroda-3,14-diene, Phenol, 2,6-bis(1,1-dimethylethyl), 2-Hexadecen-1-ol, 3, 7,11, 15-tetramethyl-, (R-[R*,] Methyl palmitate, Methyl 3-(3,5-di-tert-butyl-4-hydroxyphenyl) propionate, Gibberellin A3, N-Methyl-1-adamantaneacetamide, shikimic acid	Anti-inflammatory activity/ antibacterial/ antisterility	Raja *et al,* 1995; Zakaria *et al,* 2008, 2017
39.	*Diplazium esculentum* (Retz) Sw (Athyriaceae)	Total phenols and flavonoids	Antimicrobial/ antioxidant/ antiseptic	Gupta *et al,* 2014; Akhter *et al,* 2014; Junejo *et al,* 2015
40.	*Doryopteris concolor* (Langsd & Fisch) Kuhn (Pteridaceae)	7-O-Glycosides of apigenin, aglycone, 7-O-glycosides of luteolin, 7-O-glycosides of chrysoeriol, 3-O-glycosides of kaempferol, 3-O-glycosides of kaempferol, and 3-O-glycosides of quercetin, apigenin, kaempferol, luteolin	Antioxidant/ anti-inflammatory	Salatino and Prado, 1998
41.	*Drynaria quercifolia* (L) J Sm (Polypodiaceae)	Friedelin, epifriedelinol, β-amyrin, β-sitosterol, β-sitosterol 3-β-d-glucopyranoside, naringin	Antibacterial/ antipyretic/ anti-inflammatory/ analgesic/ antidermatophytic	Dixit and Vohra, 1984; Ramesh *et al,* 2001; Nejad and Deokule, 2009; Anuja *et al,* 2010; Chaity *et al,* 2016
42.	*Drynaria roosii* Nakaike (Polypodiaceae)	Kushennol F and sophoraflavanone G	Anti-osteoporotic	Wang *et al,* 2010
43.	*Dryopteris barbigera* (T Moore ex Hook) Kuntze (Dryopteridaceae)	Filicin	Anthelmintic	Mehra and Mittal, 1962
44.	*Dryopteris chrysocoma* (Christ) C Chr (Dryopteridaceae)	Filicin	Anthelmintic	Mehra and Mittal, 1961a, b

45.	*Dryopteris cochleata* (D Don) C Chr (Dryopteridaceae)	2-Propenoic acid, methyl ester, furfural, 2-Furanmethanol, 2-Hydroxy-2-cyclopenten-1-one, 4-Octanone, Piperazine, 2-fluoro-2-methyl, 2,4 (1H, 3H)-Pyrimidinedione, 5-methyl-3-Furancarboxylic acid, 2-Propanamine, 4H-Pyran-4-one, 2-Undecyltetrahydropyran, 3,4,5-trihydroxy benzoic acid (Gallic acid), 1-(Methylthio)-3-pentanone, cis-4-Nonene, Ferulic acid, β-D-Glucopyranose, 5,5,9 –trimethyl-3-methylene-2,3,5,6,7,8,9,9a-octahydro-1H-benzo[7]annulene, Bicyclo[720]undec-4-ene, 4,11,11-trimethyl-8-methylene,[1R- (1R*,4E,9S*)], filicin	Anti-inflammatory/ Anti-inflammatory/ antidote/ antioxidant/ antibacterial/ antifungal	Mehra and Mittal, 1962; Singh, 1999; Kathirvel *et al,* 2014
46.	*Dryopteris crassirizoma* Nakai (Dryopteridaceae)	Flaspidic acid PB, flavaspidic acid AB, sutchuenoside A, kaempferitrin	Anticancer/ analgesic/ anti-bacterial/ anti-inflammatory/ antiviral/ astringent/ febrifuge/ haemostatic/ vermifuge/ vulnerary/ anti-influenza/ anti-tumor/ anti-oxidant/ anti-reverse transcriptase/ fatty acid synthase inhibitory activity	Konoshima *et al,* 1996; Lee *et al,* 2003; Lee *et al,* 2009; Na *et al,* 2006; Wang *et al,* 2017
47.	*Dryopteris filix-mas* (L) Schott (Dryopteridaceae)	Filicin	Anthelmintic	Mittal and Bir, 2006; 2007
48.	*Dryopteris fragrans* (L) Schott (Dryopteridaceae)	Dryofracoumarin A, dryofragin, dryofraterpene A, fragranoside B, dihydroconiferyl alcohol, 1, 3-dihydroxyl-5-propylbenzene, 4-hydroxyacetophenone, 3,4-dihydroxybenzaldehyde, 2-ethyl-6-hydroxybenzoic acid, 3, 4-dihydroxyacetophenone, caffeic acid	Anticancer/ anti-oxidant/ insect repellant/ antimicrobial/ anti-inflammatory	Liu *et al,* 2018; Zhao *et al,* 2014; Zhang *et al,* 2014; Su *et al,* 2016; Zhong *et al,* 2017
49.	*Dryopteris ramosa* (C Hope) C Chr (Dryopteridaceae)	Filicin	Anthelmintic	Mehra and Mittal, 1961a, b

50.	*Dryopteris splendens* Kuntze (Dryopteridaceae)	Filicin	Anthelmintic	Mittal and Mehra, 1960; Mehra and Mittal, 1960; Mittal, 1961
51.	*Equisetum arvense* L (Equisetaceae)	Isoquercetin, quercetin 3-O-glucoside, quercetin 3-O-(6''-O-malonylglucoside), 5-O-caffeoyl mesotartaric acid, monocaffeoyl meso-tartaris acid, monocaffeoyl meso-tartaris acid, di-E-caffeoyl-meso-tartaric acid, hexahydrofarnesyl acetone, cis-geranyl scetone, thymol, trans-phytol	Anti-inflammatory/ antimicrobial/ antioxidant	Monte, 2004; Radulovic *et al,* 2006; Milovanovic *et al,* 2007; Mimica *et al,* 2008
52.	*Equisetum myriochaetum* Schltdl & Cham (Equisetaceae)	Kaempferol glucosides, caffeoyl glucoside	Anti-inflammatory	Cetto *et al,* 2000
53.	*Glaphyropteridopsis erubescens* (Wall ex Hook) Ching (Thelypteridaceae)	Flavan-4-ol, glycosides, abacopterins, eruberin B, eruberin C, (2S,4R)-4,5,7-trihydroxy-4•-methoxy-6, 8-dimethylflavan-5-O-β-D-6-acetylglucopyranoside-7-O-β-D-glucopyranoside, (2S,4R)-5,7-dihydroxy-4,4•-dimethoxy-6,8-dimethylflavan-5-O-β-D-6-acetylglucopyranoside-7-O-?-D-glucopyranoside, (2 S)-5, 2•, 5•-trihydroxy-7-methoxyflavanone	Antioxidant/ hypolipidemic/ anti-inflammatory/ neuroprotective/ anti-tumour/ multitargeted protective effect	Zhao *et al,* 2007; Zhao *et al,* 2010; Chen *et al,* 2011; Lei *et al,* 2011; Wei *et al,* 2012; Wei *et al,* 2013; Yang *et al,* 2014
54.	*Helminthostachys zeylanica* (L) Hook (Ophioglossaceae)	Ugonin M, 5,4•-dihydroxy-4••,4•-dimethyl-5••-methyl-5••H dihydrofurano[2••,3••:6,7] flavanone, and quercetin, ugonstilbene A, ugonstilbene B, and ugonstilbene C , and one known compound 3-hydroxyacetophenone, 4•-O-β-d-glucopyranosyl-quercetin-3-O-β-d-glucopyranosyl-(1•4)-β-d-glucopyranoside, 4•-O-β-d-glucopyranosyl-(1•2)-β-d-glucopyranosyl-quercetin-3-O-β-d-glucopyranosyl-(1•4)-β-d-glucopyranoside, 6-hydroxy-8-pentadecyloxocane-2,7-dione, 4••a,5••,6••,7••,8••, 8••a-hexahydro-5,3•,4•-trihydroxy-5••,5••,8••a-trimethyl-4H-chromeno[2••,3••:7,6]flavones, 4••?a, 5••,6••,7••,8••,8••a-hexahydro-5,3•,4•-trihydroxy-5••,	Anti-oxidant/ anti-inflammatory/ antipyretic/ hepatoprotective	Chen, 2003; Huang *et al,* 2003; Suja *et al,* 2004; Huang *et al,* 2009, Yamuchi *et al,* 2013; Huang *et al,* 2010; Wu *et al,* 2017

		5••,8••a-trimethyl-4H-chromeno[2••,3••:7,8]flavones, 2-(3,4-dihydroxyphenyl)-6-((2,2-dimethyl-6-methylenecyclohexyl)methyl)-5,7-dihydroxy-chroman-4-one, 2-(3,4-dihydroxy-2-[(2,6,6-trimethylcyclohex-2-enyl)methyl]phenyl)-3,5,7-trihydroxy-4H-chromen-4-one		
55.	*Hemionitis arifolia* (Burm f) T Moore (Pteridaceae)	Presence of phenols, flavonoids, tannins, steroids, glycosides	Antibacterial	Bindu *et al,* 2012; Rakkimuthu *et al,* 2018
56.	*Huperzia selago* (L) Bernh ex Schrank & Mart (Lycopodiaceae)	Huperzine A, selagoline, serratidine, lycopodine, 6-hydroxylycopodine (alkaloid L20), lycodoline (alkaloid L8, L30), isolycodoline (pseudoselagine, alkaloid L23), acrifoline	Acetyl cholinesterase inhibitor/ anti-AD drug	Zhu *et al,* 1999; Staerk *et al,* 2004
57.	*Huperzia serrata* (Thunb) Trevis (Lycopodiaceae)	Huperzine A and B, R, 8-β phlegmariurine B	Antioxidant/ neuroprotective/ anti-AD drug	Liu *et al,* 1986; Zangara, 2003
58.	*Huperzia sieboldii* (Miq) Holub (Lycopodiaceae)	Sieboldine A	Acetylcholinesterase inhibitor	Hirasawa *et al,* 2003
59.	*Lycopodiella cernua* (L) Pic Serm (Lycopodiaceae)	Cernuine, lycocernuine, lycopodine, dihydroxycernuine	Analgesic/ antifungal/ inhibition of candidiasis	Cambie and Ash, 1994; Zhang *et al,* 2002
60.	*Lycopodium casuarinoides* Spring (Lycopodiaceae)	Huperzine B, N-demethylhuperzinine	Anticholinesterase	Shen and Chen, 1994
61.	*Lycopodium clavatum* L (Lycopodiaceae)	Apigenin	Anti-inflammatory/ DNA protective	Das *et al,* 2013
62.	*Lycopodium japonicum* Thunb (Lycopodiaceae)	6-hydroxyl-6,7-dehydrolycoflexine, 6-hydroxyl-6,7-dehydro-8-deoxy-13 dehydroserratinine, 4α-hydroxyanhydrolycodoline, 4α,6α-	Anti-inflammatory/ antimicrobial/ cholinesterase inhibitor	Yan *et al,* 2005; Li *et al,* 2006; Sun *et al,* 2008; He *et al,* 2014; He *et al,* 2013; Wang *et al,* 2012a,b; Li *et al,* 2012;

		dihydroxyanhydrolycodoline, 6-epi-8β-acetoxylycoclavine, lycoposerramine G nitrate, Lycojapodine A, Lycojaponicumins A–E, (3β,8β, 14α, 21α)–26,27–dinoronocerane–3,8,14,21-tetrol, (3β,8β,14α,21αα)–26, 27-dinoronocerane-3,8,14, 21-tetrol, lycopodiin A, lycoclavanol, lycoclaninol, α-onocerin, 3-epilycoclavanol, japonicumins A-D, miyoshianine C, α-obscurine, lycodoline, miyoshianine A, lucidioline, 6α,8β-Dihydroxylycopodine, 4α,8β Dihydroxylycopodine, 8β-Hydroxylycodoline, 4α,8β,12β-Trihydroxylycopodine, 8β-Hydroxy-11α-acetoxylycopodine, 11β-Hydroxy-12-epilycodoline, 8β-Hydroxylycoposerramine K, 8β-Hydroxyhuperzine E, 11α-Hydroxyacetylfawcettine		Wang *et al,* 2013
63.	*Lygodium flexosum* (L) Sw (Lygodiaceae)	O-p-coumaryl dryocrassol, drycrassol, tectoquinone, kaempferol, kaempferol-3-β-D-glucoside, β-sitosterol, stigmasterol, antheridiogens	Expectorant/ anti-inflammatory/ hepatoprotective/ antiogenic/ antibacterial/ antifertility/ antiploriferative	Achari *et al,* 1986; Achari *et al,* 1990; Dhiman, 1998; Yamauchi *et al,* 1996; Wills and Asha, 2006; Wills *et al,* 2006; Wills and Asha, 2007; Wills and Asha, 2009; Nayak *et al,* 2013
64.	*Lygodium japonicum* (Thunb) Sw (Lygodiaceae)	Palmitic, oleic, linoleic, linolenic, arachidonic acids	Antiviral activity against herpes simplex virus/ sindbis virus and polio virus/ anti-androgenic and hair growth promoting	Taylor *et al,*1996; Matsuda *et al,* 2002
65.	*Marsilea minuta* L (Marsileaceae)	Alkaloids, flavonoids, saponins, Marceline, marsileagenin-A	Hypocholesterolemic/ anxiolytic/ anti-depressant/ anti-aggressive/ antifertility/ antiamnestic/ antistress/ expectorant/ antitussive/ antimicrobial/ anti-inflammatory	De Britto *et al,* 2013; Chakraborty *et al,* 2013

66.	*Matteuccia struthiopteris* (L) Tod (Onocleaceae)	Matteflavoside A, Matteflavoside B, kaempferol-3-O-[β-d-galactopyranosyl-(1?2)-4-O-acetyl-α-l-rhamnopyranosyl]-7-O-α-l-rhamnopyranoside, kaempferol-3-O-[β-d-glucopyranosyl-(1•2)-4-O-acetyl-α-l-rhamnopyranosyl]-7-O-α-l-rhamnopyranoside, kaempferol-3-O-[(2,3-dihydroxy-3-methoxycarbonyl-5-methyltetrahydrofuran-2-yl)-(2→2)-α-l-rhamnopyranosyl]-7-O-α-l-rhamnopyranoside, kaempferol-3-O-{methyl 2,3-dihydroxy-3-[(1-methoxy-1-oxopropan-2-yl)oxy] propanoate-(3→2)-α-l-rhamnopyranosyl}-7-O-β-l-rhamnopyranoside, (2S)-6,8-dimethyl-4•-methoxy-5,3•,5•-trihydroxyflavanone-7-O-β-d-glucopyranoside, kaempferol-3-O-β-d-glucopyranoside, kaempferol-3-O-β-d-glucopyranosyl-7-O-β-l-rhamnopyranoside, kaempferol-3,7-di-O-α-l-rhamnopyranoside, kaempferol-3-O-(α-l-3-O-acetylrhamnopyranosyl)-7-O-α-l-rhamnopyranoside, kaempferol-3-O-(α-l-2-O-acetylrhamnopyranosyl)-7-O-α-l-rhamnopyranoside, kaempferol-3-O-(?-l-4-O-acetylrhamnopyranosyl)-7-O-α-l-rhamnopyranoside, kaempferol-3-O-[α-d-glucopyranosyl-(1→2)-α-l-rhamnopyranosyl]-7-O-α-l-rhamnopyranoside, kaempferol-3-O-[1,2,4-trihdroxy-3-oxo-5-methyltetrahydropyran-(1→2)-α-l-rhamnopyranosyl]-7-O-α-l-rhamnopyranoside, protoapigenone, ophiofolius, apigenin-4•-O-β-d-glucopyranoside, matteuorien	Anti-influenza virus (H1N1)	Li *et al,* 2015
67.	*Microsorum grossum* S B Andrews (Polypodiaceae)	20-hydroxyecdysone	Antimicrobial/ antiviral/ antisterility/ UV-protective effect	Whistler, 1992; Teai, 2015
68.	*Neocheiropteris palmatopedata* (Baker) Christ (Polypodiaceae)	Multiflorins A, B, afzelin, palmatosides A, B, 2, 4, 6-trihydroxybenzoic acid 4-O-β-D-allopyranoside, ecdysterone, β-sitosterol	Anti-inflammatory/ anti-rheumatism	Yang *et al,* 2010; Chen *et al,* 2010

69.	*Nephrolepis hirsutala* (G Frost) C Presl	Presence of alkaloids, phenols, tannins, flavonoids, polyuronides, saponins, terpenoids	Expectorant	Shah and Singh, 1990; Sajeev *et al,* 2015
70.	*Phymatosorus membranifolum* (R Br) S G Lu (Polypodiaceae)	Ecdysone, 20-hydroxyecdysone, 2-deoxy-20-hydroxyecdysone and 2-deoxyecdysone , E-2-deoxy-20-hydroxyecdysone 3-[4-(1-b-D-glucopyranosyl)]-caffeate, E-2-deoxy-20-hydroxyecdysone 3-[4-(1-b-D-glucopyranosyl)]-ferulate, E-2-deoxyecdysone 3-[4-(1-b-D-glucopyranosyl)]-ferulate	Antimicrobial/ antiviral/ antisterility	Cambie and Ash, 1994; Ho *et al,* 2008
71.	*Phymatosorus scolopendria* (Burm f) Pic Serm (Polypodiaceae)	Ecdysone, Amarasterone A, 20-Hydroxyecdysone, Amarasterone A, 25-Deoxyecdysone 22-glucoside, Inokosterone , Diepi-cyasterone, Makisterone A, Makisterone C, 20-Deoxymakisterone A, poststerone, coumarin	Purgative/ antibacterial/ antiviral/ diuretic/ antipyretic/ anti-inflammatory/ antioxidant/ bronchodilator activity	Bloomfield, 2002; Ramanitrahasimbola *et al,* 2004; Snogan *et al,* 2007; Ho *et al,* 2018
72.	*Pityrogramma calomelanos* (L) Link (Pteridaceae)	2'6'-dihydroxy-4,4'-dimethoxydihydrochalcone, kaempferol 7-methyl ether, apigenin 7-methyl ether	Antioxidant/ antidiabetic/ diuretic/ astringent/ analgesic/ anti-hemorrhagic/ anti-hypertensive/ anti-pyretic/ anthelmintic	Star and Mabry, 1971; Vasudeva, 1999; Lans, 2006; Sajeev *et al,* 2015
73.	*Pityrogramma ebenea* (L) Proctor (Pteridaceae)	2'6'-dihydroxy-4,4'-dimethoxydihydrochalcone, kaempferol 7-methyl ether, apigenin 7 methyl ether	Antioxidant/ antidiabetic/ diuretic	Star and Mabry, 1971
74.	*Polypodiodes niponica* (Mett) Ching (Polypodiaceae)	Triterpenoid hydrocarbons	Antioxidant/ antitumor	Konoshima *et al,* 1996; Lee and Shin, 2011
75.	*Polypodium decumanum* (Willd) J Sm (Polypodiaceae)	Fer-9(11)-ene, 29-acetoxy-hopane	Antimalarial/ antibacterial	Bustillos *et al,* 2002
76.	*Polypodium fauriei* (Copel) Makino & Nemoto (Polypodiaceae)	Triterpenoid hydrocarbons	Antitumor activity	Konoshima *et al,* 1996

77.	*Polypodium formosanum* (Baker) Ching (Polypodiaceae)	Triterpenoid hydrocarbons	Antitumor activity	Konoshima *et al,* 1996
78.	*Polypodium leucotomos* Poir (Polypodiaceae)	4-Hydroxycinnamic acid (p-coumaric), 3 methoxy-4-hydroxycinnamic acid (ferulic), 3,4-dihydroxycinnamic acid (caffeic), 3-methoxy-4-hydroxybenzoic acid, and 3-caffeoilquinic acid (chlorogenic), ecdysone, ecdysterone	Antioxidant activity/ photoprotectant/ anti-inflammatory/ immunomodulator/ anti-psoriasis	Brieva *et al,* 2001; Garcia *et al,* 2006; Das and Einstein, 2007; Parrado *et al,* 2016
79.	*Polypodium vulgare* L (Polypodiaceae)	Ecdysone-20E, abutasterone, polypodine B, inokosterone, 24-hydroxyecdysone, 5-hydroxyabutasterone, pterosterone, catechin, saponin, osladin, polypodin	Antiviral/ antioxidant/ diuretic/ hypocholesteremic/ antibacterial/ antibiofilm	Husson *et al,* 1986; Yamada *et al,* 1992; Coll *et al,* 1994; Konoshima *et al,* 1996; Farris *et al,* 2019; Glensk *et al,* 2019
80.	*Polystichum squarrosum* (D Don) Fée (Dryopteridaceae)	Phenols, flavonoids, tannins, terpenoids, saponins	Antioxidant/ antibacterial/ antifungal/ thrombolytic	Singh, 1999; Tapwal *et al,* 2011; Kapoor and Kanwar, 2015; Halder and Chakraborty, 2018
81.	*Psilotum nudum* (L) P Beauv (Psilotaceae)	Quercetin, kaempferol, amentoflavone, hinokiflavone, vicenin-2 psilotin, 3'-hydroxypsilotin, aglycone, psilotin	Antibacterial/ antifungal/ antioxidant/ antiviral	Cambie and Ash, 1994; Rani *et al,* 2010
82.	*Pteridium aquilinum* (L) Kuhn (Dennstaedtiaceae)	p-coumaric acid, p-hydroxybenzoic acid, caffeic acid, ferulic acid, vanillic acid, protocatechuic acid, kaempferol, quercetin, and apigenin, pterosins A and B, astragalin	Antimicrobial/ anticancer/ anthelmintic/ antiemetic/ antiseptic/ diuretic	Francisco and cooper-driver, 1984; Kovganko, 2004; Nwiloh *et al,* 2014
83.	*Pteris biaurita* L (Pteridaceae)	Eicosenes, heptadecanes	Anti-inflammatory/ anibacterial	Dalli *et al,* 2007; de Britto 2012; Gracelin *et al,* 2013
84.	*Pteris cretica* L (Pteridaceae)	(2R,3S)-pteroside C, pterosin C 14-O-β-d-glucoside, (2R,3S)-pterosin C, (2S,3S)-pterosin C, 2-hydroxypterosin C, pterosin T, pterosin S, terosin T, (2S,3S)-pterosin U, jamesonin, pterosin L, pterosin D, 2β,15α-dihydroxy-ent-kaur-16-ene, 2β,6β,15α-trihydroxy-ent-kaur-16-ene, creticoside A, creticoside B, 2β,6β,16α-trihydroxxy-ent-kaurane,	Antibacterial/ anti-diabetic/ antihyperlipidemic	Luo *et al,* 2016

		substanz D, 2β,6β,13α,16α-tetrahydroxy-ent-kaurane, (2R,3S)-5-hydroxymethylpterosin C, (2R,3S)-7-hydroxymethylpterosin C, 15-hydroxymethylpterosin C, pterosone A, (3R)-pteroside D		
85.	*Pteris ensiformis* Burm f (Pteridaceae)	2•-hydroxy-4•-methoxychalcone, quercetin, 2•, 4•dihydroxychalcone, 5,7,3•,4• tetrahydroxyflavone, 7,3•,4• trihydroxyflavone, multikaurane B, henrin A, ent-11α-hydroxy-15-oxokaur-16-en-19-oic acid, (+)-(βR)-3•,4-dihydroy-3,4•-dimethoxy-dihydrochalcone, (—)-(βS)-3•,4-dihydroy-3,4•-dimethoxy-dihydrochalcone, kaempferol 3-O-β-l-rhamnopyranoside-7-O-[α-d-apiofuranosyl-(1-2)-β-d-glucopyranoside], 7-O-caffeoylhydroxymaltol 3-O-β-d-glucopyranoside, hispidin 4-O-β-d-glucopyranoside	Antioxidant/ anti-inflammatory/ menstrual regulator/ bone healer	Wu *et al,* 2005; Chen *et al,* 2007; Shi *et al,* 2017; Jasmin, 2017
86.	*Pteris henryi* Christ (Pteridaceae)	Henrin A	Anticancer/ antibacterial/ anti-HIV	Li *et al,* 2015
87.	*Pteris multifida* Poir (Pteridaceae)	Luteolin-7-O-glucoside,16-hydroxy-kaurane-2-β-D-glucoside, luteolin, palmitic acid, rutin, apigenin4-O-α-L-rhamnoside, pterosin quercetin, hyperin, isoquercitrin, kaempferol, apigenin-7-O-β-D-glucoside, 12 ent-kaurane diterpenoids, pterokaurane M1 2-O-β-d-glucopyranoside, 2β,16α-dihydroxy-ent-kaurane 2,16-di-O-β-d-glucopyranoside, 2β,16α, 17-trihydroxy-ent-kaurane 2, 16-di-O-β-d-glucopyranoside, 2β,15α-dihydroxy-ent-kaur-16-ene, creticoside A, pterokaurane M_1, 2β,15α,19-trihydroxy-ent-kaur-16-ene 2-O-β-d-gluco-pyranoside, 2β,6β,15α-trihydroxy-ent-kaur-16-ene, pterokaurane P_1, pterokaurane P_1 2-O-β-d-glucopyranoside, 2β,16α-dihydroxy-ent-kaurane, pterokaurane R	Antipyretic/ detoxification/ antibiotic/ anti-inflammatory/ antimicrobial/ antimutagenic/ antioxidant, anti-tumor/ anti-hyperlipidemic/ anti-neuroinflammatory	Murakami and Machashi,1985; Lu *et al,* 1999; Qin *et al,* 2006; Wang and Zhang, 2008; Zheng *et al,* 2008a,b; Ouyang *et al,* 2008; Ouyang *et al,* 2009; Shu *et al,* 2012; Hoang and Tran, 2014

88.	*Pteris quadriaurita* Retz (Pteridaceae)	Alkaloids, flavonoids, phlobatannins, saponins, phenols, terpenoids, tannins, cardiac glycosides	Antimicrobial/ antihelminthic/ analgesic/ anti-inflammatory/ antipyretic/ antifungal	Thomas, 2011
89.	*Pteris tripartita* Sw (Pteridaceae)	α-caryophyllene, octadecanoic acid	Anti-cancer/ anti-inflammatory/ cytotoxic/ plant growth-regulatory/ antimicrobial	Baskaran and Jeyachandran, 2010
90.	*Pteris vittata* L (Pteridaceae)	Rutin, kaempferol monoglycoside, kaempferol diglycoside, quercetin monoglycoside, quercetin, diglycoside	Antimicrobial/ antioxidant/ antiproliferative	Salatino and Prado, 1998; Singh *et al,* 2008 b; Lai and Lim, 2011; Kaur *et al,* 2014
91.	*Salvinia natans* (L) All (Salviniaceae)	Methylbenzoate 3,4-dihydroxy methylbenzoate, natansnin, hypogallic acid, caffeic acid, paeoniflorin, pikuroside	Antioxidant/ anti-inflammatory/ antibacterial/ anti-cancer	Choudhary *et al,* 2008; Maliki *et al,* 2017; Li *et al,* 2017
92.	*Selaginella bryopteris* (L) Baker (Selaginellaceae)	Amentoflavone, hinokiflavone	Antiplasmodial/ leishmanicidal/ growth-promoting activity/ anti-stress/ antioxidant/ anti-carcinogenic	Dhiman, 1998; Sah *et al,* 2005; Kunert, 2008; Antony and Thomas, 2011; Mishra *et al,* 2011; da Silva *et al,* 2013; Paswan *et al,* 2017; Chandran *et al,* 2019
93.	*Selaginella delicatula* (Desv ex Poir) Alston (Selaginellaceae)	Robustaflavone 4'-methyl ether, robustaflavone 7, 4'-dimethyl ether, 2 '', 3 ''-dihydrorobustaflavone 7, 4'-dimethyl ether, 2'', 3'' dihydrorobustaflavone 7, 4', 7''-trimethyl ether, robustaflavone, amentoflavone, caffeoylquinic acids, 3, 5-di-O-caffeoylquinic acid, 3, 4-di-O-caffeoylquinic acid, 4, 5-di-O-caffeoylquinic acid, chamaecyparin, 2, 3-dihydroisocryptomerin, delicaflavone, delicatulines A, B, alkaloid	Anti-tumour	Lin *et al,* 2000; Yao *et al,* 2018
94.	*Selaginella deoderleinii* Hieronymus (Selaginellaceae)	Hordenine-O-α-L-rhamnopyranoside, N-methyltyramine-O-α-L-rhamnopyranoside, hordenine-O-[(6''-O-trans-cinnamoyl)-4-O-β-D-glucopyrnosyl-α-L-rhamnopyranoside, apigenin, hordenine, 2,2,3,3-	Antimutagenic against picrolonic acid-induced mutation/ anticancer/ hypertensive activity/	Chao *et al,* 1987; Lin *et al,* 1991; Lin *et al,* 1994; Lee *et al,* 2008; Cao *et al,* 2010; Li *et al,* 2010; Liu *et al,* 2011; Li *et al,* 2014; Wang *et al,* 2015; Sui *et al,* 2016

95.	*Selaginella moellendorffii* Hieron (Selaginellaceae)	Moellenoside B, selaginellic acid, 7–O–(β–glucopyranosyl(1•2)–[β–glucopyranosyl (1•6)]–β–glucopyranosyl)flavone–3•,4•,5,7–tetraol, 7–O–(β–glucopyranosyl(1•2)–[β–glucopyranosyl (1•6)]–β–glucopyranosyl)flavone–4•,5,7–triol, 2,3–dihydroflavone–5,7,4•–triol–(3••8•)– flavone–5•,6 , 7•,4•••–tetraol, 6–methylflavone–5,7,4•–triol–(3••O• 4•••)–6•–methylflavone–5•,7•–diol, (7•E)–3,5,3•,5•–tetramethoxy–8•:• 4•–oxyneolign–7•–ene–4,9,9•–triol, 3,3•–dimethoxylign–8•–ene–4,4•,9–triol, N-(2E)-3-(3,4 dihydrophenyl) prop-N$_1$•-(4-aminobutyl)-3-pyrrole formaldehyde, Ginkgetin, myo-inositol 1-caffeate, myo-inositol 6-caffeate, myo-inositol 5-caffeate, paucine 3'-b-d-glucopyranoside, paucine (¼(2E)-N-(4-aminobutyl)-3-(3,4-dihydroxy-phenyl)prop-2-enamide13), N1-cis-p-coumaroylagmatine (¼(2Z)-N-{4-[(aminoiminomethyl)amino]butyl}-3-(4-hydroxyphenyl)prop-2-enamide, N-(2E)-3-(3, 4-dihydrophenyl) prop-N 1•-(4-aminobutyl)-3-pyrrole formaldehyde, 5-carboxymethyl-3•, 4•, 7-trihydroxyflavone, (2S)- 5-carboxymethyl-3•, 4•, 7-trihydroxyflavonone, (2R)-5-carboxymethyl-3•, 4•, 7-trihydroxyflavonone, (2S)-5-carboxymethyl-4•, 7-dihydroxyflavonone, 5-carbomethoxymethyl-4•, 7-dihydroxyflavone, and a new chromone named 5-carboxymethyl-7-hydroxychromone, 5-carboxymethyl-4•-hydroxyflavone-7-O-β-d-glucopyranoside, 5-carboxymethyl-4•, 7-dihydroxyflavone	Protective effect against HUVECs/ idiopathic thrombocytopenic purpura (ITP)/ anti-inflammatory/ antibacterial	Sun *et al,* 1997; Wang *et al,* 2009; Cao *et al,* 2010; Wang *et al,* 2010; Wu and Wang, 2011; Zou *et al,* 2013; Zeng *et al,* 2017
96.	*Selaginella tamariscina* (P. Beauv.) Spring (Selaginellaceae) *tamariscina* (P Beauv)	Caffeic acid, ferulic acid, vanillic acid, syringic acid, adenosine, umbelliferone, amentoflavone, selaginellin A, B, Isocryptomerin, Involvenflavones A-F	Anti-inflammatory activity/ anti-cancer/ vasorelaxation/ anti-diabetic/ antifungal/ antihyperlipidemic/	Lee *et al,* 1996; Kang *et al,* 2004; Zheng *et al,* 2004; Woo *et al,* 2005; Yang *et al,* 2007; Cheng *et al,* 2008; Lee *et al,* 2009; Zheng *et al,* 2011;

			antioxidant	Yang *et al,* 2012; Zheng *et al,* 2013; Kim *et al,* 2015; Long *et al,* 2015
97.	*Selaginella uncinata* (Desv ex Poir) Spring (Selaginellaceae)	5-hydroxy-2,6,8-trimethylchromone 7-O-b -D-glucopyranoside, 5-acetoxyl-2,6,8-trimethylchromone 7-O-b-D-glucopyranoside, 2", 3"-dihydroamentoflavone-4'-methyl ether, 2,3,2",3"-tetrahydroamentoflavone-4'-methyl ether, tetrahydroamentoflavone, 2,3-dihydro- amentoflavone, amentoflavone, isoschaftoside, 6,8-di-C-β-L-arabinopyranoside-apigenin, 6-C-α-Larabinopyranosyl-8-C-β-L arabinopyranosylapigenin, 6-C-β-L-arabinopyranosyl-8-C-α-L-arabinopyranosyl-apigenin, (5-Carboxyl-2-methoxyphenyl)-apigenin, (3β, 7β, 12β, 25R)-spirost-5-ene-3, 7, 12-triol-3-O-α-L-rhamnopyranosyl-(1 →2)-O-[α-L-rhamnopyranosyl-(1 →4)]-O-β-d-glucopyranoside, (2α, 3β, 12β, 25R)-spirost-5-ene-2, 3, 12-triol-3-O-β-L-rhamnopyranosyl-(1 →2)-O-[α-L-rhamnopyranosyl-(1 →4)]-O-β-d-glucopyranoside, (3β, 12β, 25R)-spirost-5-ene-3,12-diol-3-O-α-L-rhamnopyranosyl-(1 →2)-O-[α-L-rhamnopyranosyl-(1 →4)]-O-β-d-glucopyranoside, (1α, 3β, 25R)-spirost-5-ene-2-diol-3-O-α-L-rhamnopyranosyl-(1 →2)-O-[α-L-rhamnopyranosyl(1 →4)]-O-β-d-glucopyranoside, uncinataflavones A and B, viburnolide A, viburnolide B, isololiolide, dehydrololiolide, cis, trans-abscisic acid, trans, trans-abscisic acid, 5, 7, 4", 5"-tetrahydroxy-7"-metroxy-[3-O-4'"]	Antiviral against respiratory syncytial virus/ anti-anoxic	Ma *et al,* 2003; Zheng *et al,* 2008; Lei *et al,* 2010; Zheng *et al,* 2011; Zheng *et al,* 2013; Zheng *et al,* 2014; Zou *et al,* 2013; Zou *et al,* 2014; Zou *et al,* 2016
98.	*Tmesipteris tannensis* (Spreng) Bernh (Psilotaceae)	Psilotin [6-(4'-β-D-glucopyranosyloxyphenyl)-5,6-dihydro-2-oxo-2H-pyran], phenolic glycoside	Insect feeding deterrent	Arnason *et al,* 1986
99.	*Woodwardia orientalis* Sw (Blechnaceae)	Woodorien	Antiviral	Xu *et al,* 1993

C, (2R, 3S)- pterosin C, (2S, 3S)- pterosin C has antitimour and anti-inflammatory properties (Ouyang *et al.* 2008). Triterpenoids are important secondary metabolites with wide range of pharmacological activities such as anti-inflammatory, antioxidant, antibacterial, antiviral, hepatoprotective, gastroprotective, cardiprotective, hypolipidemic, anti-antherosclerotic, immunoregulatory, anticancer (Rascon-Valenzuela *et al.* 2017). Triterpenoids such as filicene, filicenal, adiantone, 4-Hydroxyfilican-3-one, fern-9 (11)-en-12β-ol, olean-18-en-3-one, olean-12-en-3-one, Fern-9(11)-ene, fern-9 (11)-en-25-oic acid, fern-9 (11)-en-28-ol, 22,29-diepoxy-30-norhopane-13β-ol filicenol B, Polyporusterone I, β-sitosterol, β-rosasterol, scaphopetalone has antitumour, antibacterial and analgesic properties (Ho *et al.* 2011). Antifertility activity exhibited by *Lygodium flexuosum* (L.) Sw. is due to terpenes such as O-p-coumaryl dryocrassol, tectoquinone, kaempferol, kaempferol-3-/3-D-glucoside, 3-sitosterol, stigmasterol and dryocrassol. Pterosin sesquiterpenes from *Pteris multifida* and 2, 5, 7-Trimethyl-indan-1-one, pterosin Z, acetyl-β-dehydropterosin B, ptaquiloside from *Pteridium aquilinium* are cytotoxic bioactive compounds (Baskaran & Jeyachandran 2010).

Phenolic Compounds

The common phenolics in case of ferns are catechin, rutin, cinnamic acids, caffeic acids quinic acid derivatives and chlorogenic acids etc. 4-0-β-Glucopyranosyl-2, 6, 4β-trihydroxybenzophenone from *Davallia solida* (G. Forst.) Sw. is responsible for inhibition of spontaneous action potentials (Benoit *et al.* 2000). Atherosclerosis prevention by phenol compounds such as 7-O-caffeoylhydroxymaltol3-O-β-D-glucopyranoside; hispidin 4-O-b-D-glucopyranoside-[6-(3,4-dihydroxystyryl)-4-O-β-D-glucopyranoside-2-pyrone] in *Pteris ensiformis* was studied by Wei *et al.* (2007). Phenolic compounds such as benzoic acid, epicatechin, syringic acid and catechin are responsible for anti-oxidant activities in *Adiantum capillus-veneris* L. (Abdulqadir *et al.* 2018). *Pteris ensiformis* Burm. f. extracts have compounds such as kaempferol 3-O-α-l-rhamnopyranoside-7-O-[α-d-apiofuranosyl-(1-2)-β-d-glucopyranoside],7-O-caffeoyl hydroxymaltol 3-O-β-d-glucopyranoside, hispidin 4-O-β-d-glucopyranoside responsible for its antioxidant properties (Chen *et al.* 2007).

Flavonoids

Dihydrochalcone from *Pityrogramma calomelanos* has anticancer potential (Martin *et al.*, 2006). Another chalcone compound Licoagrochalcone D in *Pteris multifida* contribute to overall activity of this species (Hu & Zheng 2005). Estrogenic active components such as 4-vinylphenol4-Vinyl-phenol, 4-vinyl- phenol-1-O-[β–L-rhamnopyranosyl-(1—> 6) β–D-glucopyranose], phylligenin, arctigenin are responsible for emmenagogue and abortifacient activity of *Asplenium trichomanes* L. (Dall Acqua *et al.* 2009). Phytoecdysteroids such as Ecdysone; 20-hydroxyecdysone; 2dE, 2d20E, 2d20E 3-[4-(1β-D-glucopyranosyl)]- ferulate, 2dE 3-[4-(1β-D- glucopyranosyl)]-ferulate and 2dE25-α-L-rhamnopyranoside (6-deoxy-α-L-mannopyranoside), makisterones A and C; inokosterone, amarasterone; posterone, 24,28-diepi-cyasterone; 20-deoxymakisterone A, 25-deoxyecdysone-22-glucoside from *Microsorum* species possess antioxidant activity and these were tested for heart, liver and kidney diseases in humans (Lafont and Dinan 2003). Flavones named 5-carboxymethyl-4', 7-dihydroxyflavone, its ethyl ester and butyl ester from the herb *Selaginella moellendorffii* Hieron. displayed inhibitory activity *in vitro* on hepatitis B virus (HBV) (Cao *et al.* 2010).

Alkaloids

Alkaloids such as Huperzine A, B and R from *Huperzia serrata* are neuroprotective (Zangara 2003). Cerniune, lycocernuine, lycopodine, dihydroxycerniune of *Lycopodiella cernua* has potential against hay fever, fungal diseases (Zhang *et al.* 2002). Alkaloids naturally present in *Lycopodium* sp. and Huperzia sp. such as α-Onecerin and lycoperine A show acetylcholinesterase inhibition activity (Zhang *et al.* 2002).Alkaloid glycosides namely hordenine-O-α-L-rhamnopyranoside, N-methyltyramine-O-α-L-rhamnopyranoside, hordenine-O-[(6"-*O-trans*-cinnamoyl)-4-O-β-D-glucopyrnosyl-α-L-rhamnopyranoside from *Selaginella deoderleinii* Hieronymus possess anti-cancer properties. Pyrrolidinoindoline alkaloids from *Selaginella moellendorfii* exhibit antibacterial and acetylcholinesterase inhibitory activities.

The detailed information for each beneficial species is given in Table 1. Besides these compounds, pteridophytes are known to produce tannins, sterides, pyrones, violaxanthin, zeaxanthin, rhodoxanthin and aromatic compounds. In general, pteridophytes possess numerous bioactive constituents which can be used for treatment of almost all the diseases.

CONCLUSION

Pteridophytes are used throughout the world by herbal healers to cure diseases. Their potential roles in treatment of different kind of diseases such as diabetes, cancer, inflammation, fever, skin diseases etc. were evaluated to trace the active constituents. But, these studies were carried on less number of species as compared to known medicinally important ones. Our vast ethnobotanical knowledge of pteridophytes (283 species) should be directed towards phytochemical investigations to develop new drugs as large numbers of species are yet to be explored for their active constituents. The literature regarding bioactive compounds in medicinal ferns is scarce. Everday increase in demand of medicines and their high prices has become unaffordable for poor people. The phytochemical analysis of ferns can lead to discovery of novel compounds easing pressure of medicinal angiosperms. So, instead of publicising their carcinogenic and toxic effects we should focus on their positive side. Proficient drug discovery mechanism can be achieved step by step for upliftment of economy of world. Firstly, literature regarding ethnomedicinal importance can be consulted for the selection of "not so toxic" ferns. Secondly, it is crucial to disseminate the knowledge among local people across the world. This will help us to conserve the declining medicinal plants due to habitat destruction or voluntary uprooting by humans. Lastly, with the advancement of the new techniques such as HPLC, HPLTC, LC-MS/MS etc. traditional knowledge can be validated in scientific terms.

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REFERENCES

ABDULQADIR A, CAKMAK Y S & ZENGIN G 2018 Phenolic compounds, antioxidant properties and enzyme inhibition ability of *Adiantum capillus-veneris* L. linked to Alzheimer's disease, Diabetes Mellitus and Skin Disorders *Current Organic Chemistry* **22(17) :** 1697-1703.

ACHARI B, BASU K, SAHA, C R & PAKRASHI, S. C. 1986 A new triterpene ester, an anthraquinone and other constituents of the fern *Lygodium flexuosum*, *Planta Medica* **52(04)** : 329-330.

ACHARI B, CHAUDHURI C, SAHA C R, PAKRASHI S C, MCPHAIL D R & MCPHAIL A T 1990 X-ray crystal structure of lygodinolide : a novel spiro furopyran-perhydrophenanthrene derivative from *Lygodium flexuosum, The Journal of Organic Chemistry* **55(16) :** 4977-4978

ADAM M, ELHASSAN G O, YAGI S, SENOL F S, ORHAN I E, AHMED A A & EFFERTH T 2018 *In vitro* antioxidant and cytotoxic activities of 18 plants from the Erkowit Region, *Eastern Sudan Natural Products and Bioprospecting* **8(2) :** 97-105

AHMED A, JAHAN N, WADUD A, IMAM H, HAJERA S & BILAL A 2012 Physicochemical and Biological Properties of *Adiantum capillus-veneris* Linn: An Important Drug of Unani System of Medicine *International Journal of Current Research and Review* **4(21) :** 70-75

AHMED D, KHAN M & SAEED R 2015 Comparative analysis of phenolics, flavonoids and antioxidant and antibacterial potential of methanolic, hexanic and aqueous extracts from *Adiantum caudatum* leaves *Antioxidants* **4(2)** : 394-409

AKHTER S, HOSSAIN M M, ARA I & AKHTAR P 2014 Investigation of *in vitro* antioxidant, antimicrobial and cytotoxic activity of *Diplazium esculentum* (Retz) Sw *International Journal of Advances in Pharmacy, Biology and Chemistry* **3** : 723-733

ALI M S, AMIN M R, KAMAL C M I & HOSSAIN M A 2013 *In vitro* antioxidant, cytotoxic, thrombolytic activities and phytochemical evaluation of methanol extract of the *A philippense* L leaves Asian Pacific *Journal of Tropical Biomedicine* **3(6) :** 464-469

AL-SNAFI A E 2015 The chemical constituents and pharmacological effects of *Adiantum capillus-veneris* - A review *Asian Journal of Pharmaceutical Science and Technology* **5(2) :** 106-111

ANSARI R & EKHLASI-KAZAJ K 2012 *Adiantum capillus-veneris* L: Phytochemical constituents, traditional uses and pharmacological properties : a review *Journal of Advanced Scientific Research* **3(4):** 15-20

ANTONY R & THOMAS R 2011 A mini review on medicinal properties of the resurrecting plant *Selaginella bryopteris* (Sanjeevani) *International Journal of Pharmacy and Life Sciences* **2(7) :** 933-939

ANTONYSAMY J M A, RAMAKRISHNAN P, PERUMAL S & SHIBILA T 2017 Anti inflammatory activity of selected pteridophytes from Western Ghats *International Journal of Complementary* *and Alternative Medicine* **9(4) :** 00307

ANUJA G I, LATHA P G, SUJA S R, SHYAMAL S, SHINE V J, SINI S, PRADEEP S, SHIKHA P & RAJASEKHARAN S 2010 Anti-inflammatory and analgesic properties of *Drynaria quercifolia* (L) J Smith *Journal of Ethnopharmacology* **132(2) :** 456-460

ARNASON J T, PHILOGENE B J R, DONSKOV N, MUIR A & TOWERS G H N 1986 Psilotin, an insect feeding deterrent and growth reducer from *Psilotum nudum Biochemical Systematics and Ecology* **14 :** 287-289

ASIF M 2018 A review on various medicinal plants with for nephroprotective activity *International Journal on Recent Advancement in Biotechnology and Nanotechnology* **1(1) :** 1-28

BADHSHEEBA, R A & VADIVEL, V 2018 Evaluation of *in vitro* antioxidant activity of *Acrostichum aureum* Linn rachis *Journal of Pharmacognosy and Phytochemistry* **7(6) :** 1146-1151

BAHADORI M B, MAHMOODI KORDI F, ALI AHMADI A, BAHADORI S & VALIZADEH H 2015 Antibacterial evaluation and preliminary phytochemical screening of selected ferns from Iran *Research Journal of Pharmacognosy* **2(2) :** 53-59

BASKARAN X & JEYACHANDRAN R 2010 Evaluation of antioxidant and phytochemical analysis of *Pteris tripartita* Sw a critically endangered fern from South India *Journal of Fairy Lake Botanical Garden* **9(3)** : 28-34

BASKARAN X R, VIGILA A V G, ZHANG S Z, FENG S X & LIAO W B 2018 A review of the use of pteridophytes for treating human ailments Journal of Zhejiang University - *SCIENCE B* **19(2)** : 1-35

BENOIT E, LAURENT D, MATTEI C, LEGRAND A M & MOLGÓ J 2000 Reversal of Pacific ciguatoxin-1B effects on myelinated axons by agents used in ciguatera treatment Cybium : Revue *Internationale d'Ichtyologie* **24(3) :** 33-40

BERK S, TEPE B, ARSLAN S & SARIKURKCU C 2011 Screening of the antioxidant, antimicrobial and DNA damage protection potentials of the aqueous extract of *Asplenium ceterach* DC *African Journal of Biotechnology* **10(44) :** 8902-8908

BI Y F, ZHENG X K, FENG W S & SHI S P 2004 Isolation and structural identification of chemical constituents from *Selaginella tamariscina* (Beauv) Spring Yao xue xue bao= *Acta pharmaceutica Sinica* **39(1)** : 41-45

BLOOMFIELD S F 2002 Illness and cure in Tonga Tonga : Vavu'u Press

BRAHMACHARI G, MONDAL S, CHATTERJEE D & BRAHMACHARI A K 2003 Phytochemicals and biological activities of *Adiantum* species *Journal of Scientific and Industrial Research* **62** : 1119-1130

BRESCIANI L F, PRIEBE J P, YUNES R A, DAL MAGRO J, DELLE MONACHE F, DE CAMPOS F, DE SOUZA M M & CECHINEL-FILHO V 2003 Pharmacological and phytochemical evaluation of *Adiantum cuneatum* growing in Brazil Zeitschrift für Naturforschung C **58(3-4)** : 191-194

BRIEVA A, GUERRERO A & PIVEL J P 2001 Immunomodulatory properties of a hydrophilic extract of *Polypodium leucotomos Inflammopharmacology* **9(4)** : 361-371

BURKILL I H 1996 A dictionary of the economic products of the Malay Peninsula Government of Malaysia and Singapore

BUSTILLOS F, YOUNG F & ALMANZA G 2002 Triterpenoids from *Polypodium decumanum*, *Revista Boliviana de Quimica* **19** : 34-38

CAMBIE R C & ASH J 1994 Fijian medicinal plants CSIRO PUBLISHING

CAO Y, TAN N H, CHEN J J, ZENG G Z, MA Y B, WU Y P, YAN H, YANG J, LU L F & WANG Q 2010 Bioactive flavones and biflavones from *Selaginella moellendorffii*, *Hieron*

Fitoterapia **81(4)** : 253-258

CETTO A A, WIEDENFELD H, REVILLA M C & SERGIO I A 2000 Hypoglycemic effect of *Equisetum myriochaetum* aerial parts on streptozotocin diabetic rats *Journal of Ethnopharmacology* **72(1-2) :** 129-133

CHAITY F R, KHATUN M & RAHMAN M S 2016 *In vitro* membrane stabilizing thrombolytic and antioxidant potentials of *Drynaria quercifolia* L, a remedial plant of the Garo tribal people of Bangladesh *BMC Complementary and Alternative Medicine* **16(1) :** 184

CHAKRABORTY R, BIPLAB DE N D & SEN S 2013 Antitussive, expectorant activity of *Marsilea minuta* L, an Indian vegetable *Journal of Advanced Pharmaceutical Technology and Research* **4(1) :** 61

CHAND BASHA S, SREENIVASULU V & PRAMOD N 2013 Anti-diabetic activity of *Actinopteris radiata* (Linn) *Asian Journal of Research in Chemistry and Pharmaceutical Sciences* **1(1)** : 1-6

CHANDRAKANT J, SHETTY A N, METY S, ALI M L & MATHAD P 2019 *In vivo* assessment of antifertility potential of pteridophytic plants: *Selaginella bryopteris* (SW) L and *Actiniopteris radiata* (L) Baker in swiss albino mice *Asian Journal of Pharmacy and Pharmacology* **5(1)** : 152-158

CHANDRAN G, GRACE S S & CHAUHAN J B 2019 Fern to Pharma : Potential Neuroameliorative Properties of Pteridophytes In "*Plant and Human Health*" Eds Ozturk M, Hakeem K Publishers: Springer, Cham pp 195-208

CHAO L R, SEGUIN E, TILLEQUIN F & KOCH M 1987 New alkaloid glycosides from *Selaginella doederleinii, Journal of Natural Products* **50(3) :** 422-426

CHEN C C, HUANG Y L, YEH P Y & OU J C 2003 Cyclized geranyl stilbenes from the rhizomes of *Helminthostachys zeylanica Planta Medica* **69(10)** : 964-967

CHEN J, CHEN X, LEI Y, WEI H, XIONG C, LIU Y, FU W & RUAN J 2011 Vascular protective potential of the total flavanol glycosides from Abacopteris penangiana via modulating nuclear transcription factor-?B signaling pathway and oxidative stress *Journal of Ethnopharmacology* **136(1)** : 217-223

CHEN Y G, YANG J H, ZHANG Y & LIU Y 2010 A new alloside from *Neocheiropteris palmatopedata Chemistry of Natural Compounds* **46(2) :** 173-175

CHEN Y H, CHANG F R, LIN Y J, HSIEH P W, WU M J & WU Y C 2008 Identification of antioxidants from rhizome of *Davallia solida Food Chemistry* **107(2) :** 684-691

CHEN Y H, CHANG F R, LIN Y J, WANG L, CHEN J F, WU Y C & WU M J 2007 Identification of phenolic antioxidants from Sword Brake fern (*Pteris ensiformis* Burm) *Food Chemistry* **105 :** 48-56

CHENG Q H, YANG Z L & HU Y M 2003 Studies on the chemical constituents of *Cibotium barometz, Progress in Pharmaceutical Sciences* **5** : 2003-05

CHENG X L, MA S C, YU J D, YANG S Y, XIAO X Y, HU J Y, LU Y, SHAW P C, BUT P P H & LIN R C 2008 Selaginellin A and B, two novel natural pigments isolated from *Selaginella tamariscina*, *Chemical and Pharmaceutical Bulletin* **56(7)** : 982-984

CHOWDHARY S, VERMA D L, PANDE R & Kumar H 2010 Antioxidative properties of flavonoids from *Cheilanthes anceps* Swartz *The Journal of American Science* **6(5)** : 203-207

COLL J, REIXACH N, SANCHEZ-BAEZA F, CASAS J & CAMPS F 1994 New ecdysteroids from *Polypodium vulgare, Tetrahedron* **50(24) :** 7247-7252

CUI C B, TEZUKA Y, KIKUCHI T, NAKANO H, TAMAOKE T & PARK J H 1992 Davallin a new tetrameric proanthocyanidin from the rhizomes of *Davallia mariesii. Chemical and Pharmaceutical Bulletin* **39 :** 2179-2181

CUI C B, TEZUKA Y, KIKUCHI T, NAKANO H, TAMAOKI T & PARK J H 1990 Constituents of a fern, *Davallia mariesii Moore* I Isolation and structures of davallialactone and a new flavanone glucuronide *Chemical and Pharmaceutical Bulletin* **38(12) :** 3218-3225

DA SILVA ALMEIDA J R G, DE SÁ P G S, DE OLIVEIRA MACEDO L A R, DE SIQUEIRA FILHO J A, DE OLIVEIRA V R & BARBOSA FILHO J M 2013 Phytochemistry of the genus *Selaginella* (Selaginellaceae) *Journal of Medicinal Plants Research* **7(25)** : 1858-1868

DALL'ACQUA S, TOME F, VITALINI S, AGRADI E & INNOCENTI G 2009 *In vitro* estrogenic activity of *Asplenium trichomanes* L extracts and isolated compounds *Journal of Ethnopharmacology* **122 :** 424-429

DALLI A K, SAHA G & CHAKRABORTY U 2007 Characterization of antimicrobial compounds from a common fern *Pteris biaurita. Indian Journal of Experimental Biology* **45 :** 285-290

DAS K & EINSTEIN J W 2007 Samambaia – The future focus for Indian researchers in the treatment of psoriasis *Thai Journal of Pharmaceutical Sciences* **31 :** 45-51

DAS S, DAS J, PAUL A, SAMADDER A & KHUDA-BUKHSH A R 2013 Apigenin, a bioactive flavonoid from *Lycopodium clavatum*, stimulates nucleotide excision repair genes to protect skin keratinocytes from ultraviolet B-induced reactive oxygen species and DNA damage *Journal of Acupuncture and Meridian Studies* **6(5) :** 252-262

DE BRITTO A J, GRACELIN D H S & KUMAR P B J R 2012 *Pteris biaurita* L : a potential antibacterial fern against *Xanthomonas* and *Aeromonas* bacteria *Journal of Pharmacy Research* **5(1) :** 678-680

DE BRITTO A J, GRACELIN D H S & RATHNA KUMAR P B J 2013 Qualitative and quantitative analysis of phytochemicals in *Marsilea minuta* (Linn) *International Journal of Pharmacy and Biological Sciences* **4(1)** : 800-805

DE MELLO ANDRADE J M, DOS SANTOS PASSOS C, RUBIO M A K, MENDONÇA J N, LOPES N P & HENRIQUES A T 2016 Combining *in vitro* and in silico approaches to evaluate the multifunctional profile of rosmarinic acid from *Blechnum brasiliense* on targets related to neurodegeneration *Chemico-biological Interactions* **254** : 135-145

DEHDARI S & HAJIMEHDIPOOR H 2018 Medicinal Properties of *Adiantum capillus-veneris* Linn in Traditional Medicine and Modern Phytotherapy : A Review Article Iranian *Journal of Public Health* **47(2)** : 188

DELONG J, HODGES D M, PRANGE R, FORNEY C, TOIVENON P, BISHOP M C, ELLIOT M & JORDAN M 2011 The unique fatty acid and antioxidant composition of Ostrich fern (*Matteuccia struthiopteris*) fiddle heads *Canadian Journal of Plant Science* **91(5)** : 919-930

DEVI K, RAJESH R, VASANTHA N V S & SATHIA GEETHA V 2015 Anti-parasitic action of *Actinopteris radiata*, *Acrostichum aureum* and *Hemionitis arifolia. Pteridological Research* **4(1) :** 1-9

DHIMAN A K 1998 Ethnomedicinal uses of some pteridophyitc species in India *Indian Fern Journal* **15(1-2) :** 61-64

DIXIT R D & VOHRA J N 1984 A dictionary of the pteridophytes Flora of India series-4 *Botanical Survey of India* Howrah

DE MONTE F H M, DOS SANTOS JR JG, RUSSI M, LANZIOTTI V M N B, LEAL L K A M & DE ANDRADE CUNHA G M 2004 Antinociceptive and anti-inflammatory properties of the hydroalcoholic extract of stems from *Equisetum arvense* L in mice *Pharmacological Research* **49(3) :** 239-243

ĐURĐEVIÃ L O, MITROVIÃ M I, PAVLOVIÃ P A, BOJOVIÃ S R, JARIÃ S N, OBERAN L J, GAJIÃ G O, KOSTIÃ O L 2007 Total phenolics and phenolic acids content in leaves, rhizomes and rhizosphere soil under Ceterach officinarum DC *Asplenium trichomanes* L and *A adiantum nigrum* L in the Gorge of Si?evo (Serbia) *Ekológia (Bratislava)* **26(2) :** 164-173

FARRÀS A, CÁSEDAS G, LES F, TERRADO E M, MITJANS M & LÓPEZ V 2019 Evaluation of Anti-Tyrosinase and Antioxidant Properties of Four Fern Species for Potential Cosmetic *Applications Forests* **10(2)** : 179

FRANCISCO M S & DRIVER G C 1984 Anti-microbial activity of phenolic acids in *Pteridium aquilinum. American Fern Journal* **743 :** 87-96

GARCIA F, PIVEL J P, GUERRERO A, BRIEVA A, MARTINEZ-ALCAZAR M P, CAAMANO-SOMOZA M & GONZALEZ S 2006 Phenolic components and antioxidant activity of Fernblock (R), an aqueous extract of the aerial parts of the fern *Polypodium leucotomos. Methods and Findings in Experimental and Clinical Pharmacology* **28(3) :** 157-160

GHORPADE P N, DONGARE S T M & KALE M V 2015 Phytochemical analysis of four *Cheilanthes* species from Northern Western Ghats of India *Research Journal of Pharmaceutical, Biological and Chemical Sciences* **1(2)** : 92-100

GLEÑSK M, TICHACZEK-GOSKA D, ÚRODA-POMIANEK K, WLODARCZYK M, WESOLOWSKI C A & WOJNICZ D 2019 Differing antibacterial and antibiofilm properties of Polypodium vulgare L rhizome aqueous extract and one of its purified active ingredients–osladin *Journal of Herbal Medicine* 100261

GOGOI R 2002 Ethnobotanical studies of some ferns used by the Garo tribals of Meghalaya *Advances in Plant Sciences* **15 (2)** : 401-405

GOSWAMI H K, SEN K & MUKHOPADHYAY R 2016 Pteridophytes : evolutionary boon as medicinal plants *Plant Genetic Resources* **14(4)** : 328-355

GRACELIN D H S, BRITTO A & KUMAR B J R P 2013 Qualitative and quantitative analysis of phytochemicals in five *Pteris* species *International Journal of Pharmacy and Pharmaceutical Sciences* **5(1)** : 105-107

GRACELIN S, HERIN D, DE BRITTO A J, KUMAR R & JEYA P B 2012 Antimicrobial potency of five south Indian ferns against *Xanthomonas campestris. Journal of Biopesticides* **5 :** 196

GREPIN F & GREPIN M 1984 La médicine tahitienne traditionnelle–Raau Tahiti Polynésie française : Edition du Pacifique

GUO J P, PANG J, WANG X W, SHEN Z Q, JIN M & LI J W 2006 *In vitro* screening of traditionally used medicinal plants in China against enteroviruses *World Journal of Gastroenterology* **12(25) :** 4078

GUPTA S K, GHOSAL M, BISWAS R, SAHA B K, DAS A P & MANDAL P 2014 Evaluation of *in vitro* antioxidant activity of methanolic extracts of some ferns from Mawsynram of Meghalaya, India *International Journal of Current Science* **12 :** E87-E97

HAIDER S, KHARBANDA C, ALAM M S, HAMID H, ALI M, ALAM M, NAZREEN S & ALI Y 2013 Anti-inflammatory and anti-nociceptive activities of two new triterpenoids from *Adiantum capillus-veneris* Linn *Natural Product Research* **27(24)** : 2304-2310

HALDER K & CHAKRABORTY S 2018 An account of Antioxidant Potential in Pteridophytes : A Biochemical Perspective *International Journal of Bioinformatics and Biological Sciences* **6(1)** : 15-24

HE J, CHEN X Q, LI M M, ZHAO Y, XU G, CHENG X, PENG L Y, XIE M J, ZHENG Y T, WANG Y P & ZHAO Q S 2009 Lycojapodine A, a novel alkaloid from *Lycopodium japonicum. Organic Letters* **11(6)** : 1397-1400

HE J, WU X D, LIU F, LIU Y C, PENG L Y, ZHAO Y, CHENG X, LUO H R & ZHAO Q S 2014 Lycopodine-type alkaloids from *Lycopodium japonicum. Natural Products and Bioprospecting*

4(4) : 213-219

HIMA BINDU N, DEVI P S, RUKMINI K & CHARYA M A 2012 Phytochemical screening and antibacterial activity of *Hemionitis arifolia* (Burm) Moore *Indian Journal of Natural Products and Resources* **3(1)** : 9-13

HIRASAWA Y, MORITA H, SHIRO M & KOBAYASHI J I 2003 SIEBOLDINE A, a Novel Tetracyclic Alkaloid from *Lycopodium sieboldii*, Inhibiting Acetylcholinesterase *Organic Letters* **5(21) :** 3991-3993

HO R, GIRAULT J P, RAHARIVELOMANANA P & LAFONT R 2012 E-and Z-isomers of new phytoecdysteroid conjugates from French Polynesian *Microsorum membranifolium* (Polypodiaceae) fronds *Molecules* **17(10) :** 11598-11606

HO R, TEAI T, BIANCHINI J P, LAFONT R & RAHARIVELOMANANA P 2011 Ferns : from traditional uses to pharmaceutical development, chemical identification of active principles In "*Working with Ferns*" Eds Kumar A, Fernández H & Revilla M Publishers: Springer, New York, NY pp 321-346

HO R, TEAI T, GIRAULT J P, BIANCHINI J P, LAFONT R & RAHARIVELOMANANA P 2008 Nutraceutical interest of phytoecdysteroid in *Microsorum* species of French *Polynesia. Planta Medica* **74(09) :** SL94

HOANG L S & TRAN H P T 2014 *In vitro* antioxidant and anticancer properties of active compounds from methanolic extract of *Pteris multifida Poir* leaves *European Journal of Medicinal Plants* **4(3) :** 292-302

HORT M A, DALBÓ S, BRIGHENTE I M C, PIZZOLATTI M G, PEDROSA R C & RIBEIRO?DO?VALLE R M 2008 Antioxidant and hepatoprotective effects of *Cyathea phalerata Mart* (Cyatheaceae) Basic and Clinical Pharmacology and Toxicology **103(1) :** 17-24

HSEU T H 1981 Structure of Angiopteroside mono-hydrate, a Fern Glycoside from *Angiopteris lygodiifolia. Acta Crystallographica* **B37 :** 2095-2098

HUANG J, LIAW C C, HUANG Y C, HWANG T L, YANG Y L, WU S H, HSU M H, WANG J P & CHEN S C 2010 Acetogenin and prenylated flavonoids from *Helminthostachys zeylanica* with inhibitory activity on superoxide generation and elastase release by neutrophils *Planta Medica* **76(05) :** 447-453

HUANG Y L, YEH P Y, SHEN C C & CHEN C C 2003 Antioxidant flavonoids from the rhizomes of *Helminthostachys zeylanica. Phytochemistry* **64(7) :** 1277-1283

HUSSEIN H M, HAMEED I H & IBRAHEEM O A 2016 Antimicrobial activity and spectral chemical analysis of methanolic leaves extract of *Adiantum capillus-veneris* using GC-MS and FT-IR spectroscopy *International Journal of Pharmacognosy and Phytochemical Research* **8(3)** : 369-385

HUSSON G P, VILAGINDS R & DELAVEAU P 1986 Research into antiviral properties of a few natural extracts *Annales Pharmaceutiques Francaises* **44 :** 41-48

IBRAHEIM Z Z, AHMED A S & GOUDA Y G 2011 Phytochemical and biological studies of *Adiantum capillus-veneris* L *Saudi Pharmaceutical Journal* **19(2)** : 65-74

IMPERATO F 1991 Xanthone 2, 4-di-C-glycosides from *Asplenium adiantum-nigrum. Phytochemistry* **30(11) :** 3839-3840

ISHAQ M S, HUSSAIN M M, SIDDIQUE AFRIDI M, ALI G, KHATTAK M & AHMAD S 2014 *In vitro* phytochemical, antibacterial, and antifungal activities of leaf, stem, and root extracts of *Adiantum capillus-veneris. The Scientific World Journal* : 1-7

JAIN S K, SINGH T, PANDE M & NEMA N 2014 Neuropharmacological screening of fronds of

Adiantum capillus-veneris linn *Der Pharmacia Lettre* **6(3)** : 167-75

JARIAL R, SHARD A, THAKUR S, SAKINAH M, ZULARISAM A W, REZANIA S, KANWAR S S & SINGH L 2018 Characterization of flavonoids from fern *Cheilanthes tenuifolia* and evaluation of antioxidant, antimicrobial and anticancer activities *Journal of King Saudi University-Science* **30(4)** : 425-432

JASMIN T, BAPPY M S, LODH D & RAHMATULLAH 2017 An ethnomedicinal note on the use of *Pteris ensiformis* Burmf (Pteridaceae) for healing bone fracture *Asian Journal of Pharmacognosy* **1(2)** : 21-22

JIANG M Z, YAN H, WEN Y & LI X M 2011 *In vitro* and *in vivo* studies of antioxident activities of flavonoids from *Adiantum capillus-veneris* L *African Journal of Pharmacy and Pharmacology* **5(18)** : 2079-2085

JOHNSON M, JEEVAS M M & JANAKIRAMAN N 2017 Antibacterial potentials of *Adiantum* species against the UTI pathogens *Journal of Microbiology and Experimentation* **4(1)** : 00104

JUNEJO J A, GHOSHAL A, MONDAL P, NAINWAL L, ZAMAN K, SINGH K D & CHAKRABORTY T 2015 *In-vivo* Toxicity Evaluation and Phytochemical, Physicochemical Analysis of *Diplazium esculentum* (Retz) Sw leaves a traditionally used *North-Eastern Indian Vegetable Advances in Bioresearch* **6(5) :** 175-181

KALE M V 2015a Qualitative and quantitative analysis of *Cyathea gigantea* ferns from South Western Ghats *Research Journal of Life Sciences, Bioinformatics, Pharmaceuticals and Chemical Sciences* **1(4)** : 183-187

KALE M V 2015b GC-MS analysis of phytocomponents on whole plant extracts *Adiantum capillus-veneris* L-a potential folklore medicinal plant *Research Journal of Life Sciences, Bioinformatics, Pharmaceuticals and Chemical Sciences* **2 :** 117

KALPANA DEVI R, RAJESH N V, VASANTHA S & SATHIA GEETHA V 2015 Anti-parasitic action of *Actinopteris radiata*, *Acrostichum aureum* and *Hemionitis arifolia*. *Pteridological Research* **4 :** 1-9

KANG D G, YIN M H, OH H, LEE D H & LEE H S 2004 Vasorelaxation by amentoflavone isolated from *Selaginella tamariscina*. *Planta Medica* **70(08) :** 718-722

KAPOOR R & KANWAR S S 2015 Phytochemical-screening, antibacterial and antioxidant potential of some Pteridophytes and Angiosperms from Shimla region, Himachal Pradesh *ENVIS Bulletin Himalayan Ecology* **23 :** 119

KASABRI V, AL-HALLAQ E K, BUSTANJI Y K, ABDUL-RAZZAK K K, ABAZA I F & AFIFI F U 2017 Antiobesity and antihyperglycaemic effects of *Adiantum capillus-veneris* extracts : *in vitro* and *in vivo* evaluations *Pharmaceutical Biology* **55(1)** : 164-172

KATHIRVEL A, RAI A K, MAURYA G S & SUJATHA V 2014 *Dryopteris cochleata* rhizome: a nutritional source of essential elements, phytochemicals, antioxidants and antimicrobials *International Journal of Pharmceutical Sciences* **6(2) :** 179-188

KERRY R G, PRADHAN P, DAS G, GOUDA S, SWAMY M K & PATRA J K 2018 Anticancer Potential of Mangrove Plants: Neglected Plant Species of the Marine Ecosystem In "*Anticancer plants : Properties and Application*" Eds Akhtar M & Swamy M Springer, Singapore pp 303-325

KHAN M R & OMOLOSO, A D 2008 Antibacterial and antifungal activities of *Angiopteris evecta* Fitoterapia **79(5)** : 366-369

KIM J, CHO C, TAI B, YANG S, CHOI G S, KANG J & KIM Y 2015 Soluble epoxide hydrolase inhibitory activity of selaginellin derivatives from *Selaginella tamariscina*. *Molecules* **20(12)** : 21405-21414

KIMURA K & NORO Y 1965 Pharmacognostical studies on Chinese drug "Gu-sui-bu" I Consideration on "Gu-sui-bu" in old herbals (Pharmacognostical studies on fern drugs XI) *Syoy akugaku Zasshi* **19 :** 25-31

KIMURA N, KAINUMA M, INOUE T, CHAN EWC, TANGAH J, BABA K, OSHIRO N & OKAMOTO C 2017 Botany, uses, chemistry and bioactivities of mangrove plants V : *Acrostichum aureum* and *A speciosum. International Society for Mangrove Ecosystems* **15(1)** : 1-6

KIRAN P M, RAJU A V & RAO B G 2012 Investigation of hepatoprotective activity of *Cyathea gigantea* (Wall ex Hook) leaves against paracetamol-induced hepatotoxicity in rats *Asian Pacific Journal of Tropical Biomedicine* **2(5) :** 352-356

KONOSHIMA T, TAKASAKI M, TOKUDA H, MASUDA K, ARAI Y, SHIOJIMA K & AGETA H 1996 Antitumor promoting activities of triterpenoids from ferns *Biological and Pharmaceutical Bulletin* **19(7) :** 962-965

KOVGANKO N V, KASHKAN Z N & KRIVENOK S N 2004 Bioactive compounds of the flora of Belarus 4 Pterosins A and B from *Pteridium aquilinum. Chemistry of Natural Compounds* **40(3)** : 227-229

KRISHNAKUMAR S, MISVAR ALI K, PUTHUR S, DEVIKRISHNA C S & ANEESH E M Comparative analysis of antibacterial activity in selected species of terrestrial and aquatic pteridophytes *Biodiversity & Evaluation : Perspectives and Paradigm Shifts* 178-180

KUMAR A & KAUSHIK P 1999 Antibacterial effect of *Adiantum capillus-veneris* Linn *Indian Fern Journal* **16 :** 72-74

KUMAR R P, BABU K D & EVANS D A 2019 Isolation, characterization and mode of action of a larvicidal compound, 22-hydroxyhopane from *Adiantum latifolium* Lam against Oryctes rhinoceros Linn *Pesticide Biochemistry and Physiology* **153 :** 161-170

KUNERT O, SWAMY R C, KAISER M, PRESSER A, BUZZI S, RAO A A & SCHÜHLY W 2008 Antiplasmodial and leishmanicidal activity of biflavonoids from Indian *Selaginella bryopteris. Phytochemistry Letters* **1(4) :** 171-174

LAFONT R & DINAN L 2003 Practical uses for ecdysteroids in mammals including humans: and update *Journal of Insect Science* **3(1) :** 7

LAI H Y & LIM Y Y 2011 Antioxidant properties of some Malaysian ferns In "The 3rd International Conference on Chemical, Biological and Environmental Engineering" Abs Ed Pahang J IACSIT Press, Singapore

LAI H Y, LIM Y Y & KIM K H 2010 *Blechnum orientale* Linn–a fern with potential as antioxidant, anti-cancer and antibacterial agent BMC *Complementary and Alternative Medicine* **10(15) :** 1-8

LAI H Y, LIM Y Y & KIM K H 2017 Isolation and characterisation of a proanthocyanidin with antioxidative, antibacterial and anti-cancer properties from fern *Blechnum orientale. Pharmacognosy Magazine* **13(49) :** 31

LAI H Y, LIM Y Y & TAN S P 2009 Antioxidative, tyrosinase inhibiting and antibacterial activities of leaf extracts from medicinal ferns *Bioscience, Biotechnology and Biochemistry* **73(6)** : 1362

LANS C A 2006 Ethnomedicines used in Trinidad and Tobago for urinary problems and diabetes mellitus *Journal of Ethnobiology and Ethnomedicine* **2(1) :** 45

LATHA M H P 2016 Evaluation of antimicrobial properties of twenty South Indian medicinal plants *International Journal of Chemical and Life Sciences* **5(6) :** 1359-1364

LAWARE S & LIMAYE A 2012 *Adiantum* A medicinal herb: An antidiabetic and antioxidant potentials of *Adiantum* Lap Lambert, Academic Publishers, UK

LEE C H & SHIN S L 2011 Functional activities of ferns for human health In *Working with ferns*

Eds Fernández H, Kumar A and Revilla A *Springer*, New York, NY pp 347-359

LEE C W, CHOI H J, KIM H S, KIM D H, CHANG I S, MOON H T, LEE S Y, OH W K & WOO E R 2008 Biflavonoids isolated from *Selaginella tamariscina* regulate the expression of matrix metalloproteinase in human skin fibroblasts Bioorganic and Medicinal Chemistry **16(2) :** 732-738

LEE H B, KIM J C & LEE S M 2009 Antibacterial activity of two phloroglucinols, flavaspidic acids AB and PB, from *Dryopteris crassirhizoma. Archives of Pharmacal Research* **32(5) :** 655-659

LEE H S, OH W K, KIM B Y, AHN S C, KANG D O, SHIN D I, KIM J, MHEEN T L & AHN J S 1996 Inhibition of phospholipase C?1 activity by amentoflavone isolated from *Selaginella tamariscina. Planta Medica* **62(04)** : 293-296

LEE J, CHOI Y, WOO E R & LEE D G 2009 Isocryptomerin, a novel membrane active antifungal compound from *Selaginella tamariscina. Biochemical and Biophysical Research Communications* **379(3) :** 676-680

LEE S M, NA M K, AN R B, MIN B S & LEE H K 2003 Antioxidant activity of two phloroglucinol derivatives from *Dryopteris crassirhizoma. Biological and Pharmaceutical Bulletin* **26(9) :** 1354-1356

LEI T, JIANG H, CHI C, WU S & CEN Y 2010 A new biflavonoid from *Selaginella uncinata* (Desv) *Spring International Journal of Chemistry* **12(1)**

LEI Y F, CHEN J L, WEI H, XIONG C M, ZHANG Y H & RUAN J L 2011a Hypolipidemic and anti-inflammatory properties of Abacopterin A from *Abacopteris penangiana* in high-fat diet-induced hyperlipidemia mice *Food and Chemical Toxicology* **49(12) :** 3206-3210

LEI Y, FU W, CHEN J, XIONG C, WU G, WEI H & RUAN J 2011b Neuroprotective effects of Abacopterin E from *Abacopteris penangiana* against oxidative stress-induced neurotoxicity *Journal of Ethnopharmacology* **134(2) :** 275-280

LI B, NI Y, ZHU L J, WU F B, YAN F, ZHANG X & YAO X S 2015 Flavonoids from *Matteuccia struthiopteris* and their anti-influenza virus (H1N1) activity *Journal of Natural Products* **78(5) :** 987-995

LI B, ZHANG W D, HE Y R, LU L, KONG D Y & SHEN Y H 2012 New alkaloids from *Lycopodium japonicum. Chemical and Pharmaceutical Bulletin* **60(11) :** 1448-1452

LI X L, ZHAO Y, CHENG X, TU L, PENG L Y, XU G & ZHAO Q S 2006 Japonicumins A–D : four new compounds from *Lycopodium japonicum. Helvetica Chimica Acta* **89(7) :** 1467-1473

LIN C H, WU J B, JIAN J Y & SHIH C C 2017 (–)-Epicatechin-3-O-β-D-allopyranoside from Davallia formosana prevents diabetes and dyslipidemia in streptozotocin-induced diabetic mice *PLOS ONE* **12(3)** : 0173984

LIN L C & CHOU C J 2000 Three new biflavonoids from *Selaginella delicatula. The Chinese Pharmaceutical Journal* **52(4) :** 211-218

LIN L C, KUO Y C & CHOU C J 2000 Cytotoxic biflavonoids from *Selaginella delicatula. Journal of Natural Products* **63(5) :** 627-630

LINNAEUS C 1753 *Species plantarum*, vol 2 Holmiae [Stockholm]: impensis Laurentii Salvii LINNAEUS, C 1754 *Genera plantarum*, ed 5 Holmiae [Stockholm]: impensis Laurentii Salvii

LIU J S, YU C M, ZHOU Y Z, HAN Y Y, WU F W, QI B F & ZHU Y L 1986a Study on the chemistry of huperzine-A and huperzine-B *Acta Chimica Sinica* **44 :** 1035-1040

LIU J S, ZHU Y L, YU C M, ZHOU Y Z, HAN Y Y, WU F W & QI B F 1986b The structures of huperzine A and B, two new alkaloids exhibiting marked anticholinesterase activity *Canadian Journal of Chemistry* **64 :** 837-839

LIU Z D, ZHAO D D, JIANG S, XUE B, ZHANG Y L & YAN X F 2018 Anticancer Phenolics from

Dryopteris fragrans (L) *Schott Molecules* **23(3) :** 680

LONG H P, ZOU H, LI F S, LI J, LUO P, ZOU Z X, HU C P, XU K P & TAN G S 2015 Involvenflavones A–F, six new flavonoids with 3?-aryl substituent from *Selaginella involven. Fitoterapia* **105 :** 254-259

LU H, HU J, ZHANG L X & TAN R X 1999 Bioactive constituents from *Pteris multifida. Planta Medica* **65(06) :** 586-587

LUO X, LI C, LUO P, LIN X, MA H, SEERAM N P, SONG C, XU J & GU Q 2016 Pterosin sesquiterpenoids from *Pteris cretica* as hypolipidemic agents via activating liver X receptors *Journal of Natural Products* **79(12) :** 3014-3021

MA L Y, MA S C, WEI F, LIN R C, BUT P P H, LEE S H S & LEE S F 2003 Uncinoside A and B, two new antiviral chromone glycosides from *Selaginella uncinata. Chemical and Pharmaceutical Bulletin* **51(11) :** 1264-1267

MANJUNATH M, LAVANYA G, SIVAJYOTHI R & REDDY OV S 2011 Antioxidant and radical scavenging activity of *Actiniopteris radiata* (Sw) Link *Asian Journal of Experimental Sciences* **25(1)** : 73-80

MANJUNATH M, SHARMA P V G K & REDDY O V S 2008 *In vitro* evaluation of antibacterial activity of *Actiniopteris radiata* (Sw) Link *Journal of Pharmaceutical Chemistry* **2(2)** : 112-117

MANUBOLU M, GOODLA L, CHANDAR B G N, RAVILLA S & OBULUM V R 2013 Chemical Composition and Antibacterial Activity of Wax from *Actiniopteris radiata*s (Sw) Link *Journal of Essential Oil Bearing Plants* **16(3)** : 387-392

MANUBOLU M, GOODLA L, RAVILLA S, THANASEKARAN J, DUTTA P, MALMLÖF K & OBULUM V R 2014 Protective effect of *Actiniopteris radiata* (Sw) Link against CCl_4 induced oxidative stress in albino rats *Journal of Ethnopharmacology* **153(3)** : 744-752

MARTIN K P, SINI S, ZHANG C L, SLATER A & MADHUSOODANAN P V 2006 Efficient induction of apospory and apogamy *in vitro* in silver fern (*Pityrogramma calomelanos* L) *Plant Cell Reports* **25 :** 1300-1307

MATHAD P, CHANDRAKANT J & MODI R 2015 Phytochemical and antioxidant activity of *Actiniopteris radiata* linn - An important pteridophytic medicinal plant of Gulbarga region *International Journal of Research in Applied, Natural and Social Sciences* **3(2) :** 27-34

MATSUDA H, YAMAZAKI M, NARUTO S, ASANUMA Y & KUBO M 2002 Anti-androgenic and hair growth promoting activities of Lygodii Spora (spore of *Lygodium japonicum*) I Active constituents inhibiting testosterone 5?-reductase *Biological and Pharmaceutical Bulletin* **25(5)** : 622-626

MEHRA P N & MITTAL T C 1960 Indian substitutes of Male Fern *Pharmacognosy Nature* **186** : 722-723

MEHRA P N & MITTAL T C 1961a Pharmacognosy of Indian substitutes of Male Fern, Part I *Dryopteris ramosa* (Hope) CChr and *D chrysocoma* (Christ) CChr *Journal of Pharmacy and Pharmacognosy* **13 :** 300-308

MEHRA P N & MITTAL T C 1961b Significance of internal secretary glands in relation to filicin *Planta Medica* **9 :** 189-199

MEHRA P N & MITTAL T C 1962 Pharmacognosy of Indian substitutes of Male Fern - II *Dryopteris barbigera* and *Dryopteris cochleata Journal of Pharmaceutical Sciences* **51 :** 367-371

MENGANE S K 2016 Phytochemical Analysis of *Adiantum lunulatum. International Journal of Current Microbiology and Applied Sciences* **5(11) :** 351-356

MILOVANOVIÃ V, RADULOVIÃ N, TODOROVIÃ Z, STANKOVIÃ M & STOJANOVIÃ G 2007

Antioxidant, antimicrobial and genotoxicity screening of hydro-alcoholic extracts of five Serbian Equisetum species *Plant Foods for Human Nutrition* **62(3) :** 113-119

MIMICA-DUKIC N, SIMIN N, CVEJIC J, JOVIN E, ORCIC D & BOZIN B 2008 Phenolic compounds in field horsetail (*Equisetum arvense* L) as natural antioxidants *Molecules* **13(7) :** 1455-1464

MIR S A, MISHRA A K, RESHI Z A & SHARMA M P 2013 Preliminary phytochemical screening of some Pteridophytes from district Shopian (J&K) *International Journal of Pharmacy and Pharmaceutical Sciences* **5(4) :** 632-637

MISHRA P K, RAGHURAM G V, BHARGAVA A, AHIRWAR A, SAMARTH R, UPADHYAYA R, JAIN S K & PATHAK N 2011 *In vitro* and *in vivo* evaluation of the anticarcinogenic and cancer chemopreventive potential of a flavonoid-rich fraction from a traditional Indian herb *Selaginella bryopteris. British Journal of Nutrition* **106(8) :** 1154-1168

MITTAL T C 1961 Pharmacognosy of Indian substitutes of Male Fern-III *Dryopteris splendens* (Hk) OKtze *Indian Journal of Pharmacy* **23** : 249-253

MITTAL T C & BIR S S 2006 The Indian substitutes of Male Fern (*Dryopteris filix-mas* (L) Schott)-I Taxonomy and drug macroscopy *Indian Fern Journal* **23**: 133-187

MITTAL T C & BIR S S 2007 The Indian substitutes of Male Fern (*Dryopteris filix-mas* (L) Schott)-II Drug microscopy *Indian Fern Journal* **24 :** 1-53

MITTAL T C & MEHRA P N 1960 Preliminary chemical investigations on some Indian substitutes of Male Fern *Journal of Pharmacy and Pharmacognosy* **12 :** 317-319

MIZUSHINA Y, WATANABE I, OHTA K, TAKEMURA M, SAHARA H, TAKAHASHI N, GASA S, SUGAWARA F, MATSUKAGE A, YOSHIDA S & SAKAGUCHI K 1998 Studies on inhibitors of mammalian DNA polymerase α and β : Sulfolipids from a pteridophyte, *Athyrium niponicum. Biochemical Pharmacology* **55(4) :** 537-541

MOHAMAD S, ZIN N M, WAHAB H A, IBRAHIM P, SULAIMAN S F, ZAHARILUDDIN A S M & NOOR S S M 2011 Antituberculosis potential of some ethnobotanically selected Malaysian plants *Journal of Ethnopharmacology* **133(3) :** 1021-1026

MOORTHY K, VINODHINI R, SENTHILKUMAR B, PUNITHA T, SENBAGAM D & THAJUDDIN N 2014 Phytochemical analysis, in-vitro anti-microbial activity of Indian medicinal ferns *Adiantum lunulatum* and *Hemionitis arifolia. Journal of Pharmacy Research* **8(11) :** 1671-1676

MUBASHIR S & SHAH W A 2011 Phytochemical and Pharmacological Review Profile of *Adiantum venustum. International Journal of PharmTech Research* **3 :** 827-830

MUKHOPADHYAY R & GUPTA K 2005 Antifungal activity of the crude extracts and extracted phenols from gametophytes and sporophytes of two species of *Adiantum. Taiwania* **50(4)** : 272-283

MUNNA S, BASHA S C, REDDY P R, PRAMOD N, KUMAR Y P & BASHA G M 2014 Antitubercular activity of *Actiniopteris radiata* linn *Phytochemical Analysis* **10** : 12

MURAKAMI T & MACHASHI N T 1985 Chemical and chemotaxonomical Studies on Filices *Journal of the Pharmaceutical Society of Japan* **105(7) :** 640-648

MUSTARICHIE R, RAMDHANI D & ISKANDAR Y 2017 Characteristics and alopecia activity of pakis gajah *Angiopteris evecta* (Forst) Hoffm growing in galunggung mountainside, West java *Asian Journal of Pharmceutical and Clinical Research* **10(11)** : 337-340

NA M, JANG J, MIN B S, LEE S J, LEE M S, KIM B Y, OH W K & AHN J S 2006 Fatty acid synthase inhibitory activity of acylphloroglucinols isolated from *Dryopteris crassirhizoma. Bioorganic and Medicinal Chemistry Letters* **16(18) :** 4738-4742

NAIK J B & JADGE D R 2010 Anti-bacterial and anti-fungal activity of *Actiniopteris radiata* and

Caralluma adscendens. *International Journal of PharmTech Research* **2(3) :** 1751-1753

NAIR T, KALARIYA T & CHANDA S 2005 Antibacterial activity of some selected Indian medicinal floras Turkey *Journal of Biology* **29(1)** : 41-47

NATH K, BHATTACHARYA M K & KAR S 2016 Antibacterial activity of some ethno-botanically important ferns of Southern Assam, India *Taiwania* **61(3)** : 260-268

NAYAK N, RATH S, MISHRA M P, GHOSH G & PADHY R N 2013 Antibacterial activity of the terrestrial fern *Lygodium flexuosum* (L) Sw against multidrug resistant enteric- and uro-pathogenic bacteria *Journal of Acute Disease* **2 :** 270-276

NAZIM M D, ASLAM M & CHAUDHARY S S 2018 HANSRAJ (*Adiantum capillus-veneris*) - A Review *Journal of Drug Delivery and Therapeutics* **8(5)** : 105-109

NEJAD B S & DEOKULE S S 2009 Anti-dermatophytic activity of *Drynaria quercifolia* (L) J Smith Jundishapur *Journal of Microbiology* **2(1) :** 25

NGUYEN M T T, AWALE S, TEZUKA Y, LE TRAN Q, WATANABE H & KADOTA S 2004 Xanthine oxidase inhibitory activity of Vietnamese medicinal plants *Biological and Pharmaceutical Bulletin* **27(9) :** 1414-1421

NILANTHI S M L D, WIJAYARATHNA C D & HETTIARACHCHI G H C M 2012 *Angiopteris evecta* (Forst) Hoffm: a potential source for antibacterial activity In *Annual Research Symposium* University of Colombo

NILFOROUSHZADEH M A, JAVANMARD S H, GHANADIAN M, ASGHARI G, JAFFARY F, YAKHDANI A F, DANA N & FATEMI S A 2014 The effects of *Adiantum capillus-veneris* on wound healing: An experimental *in vitro* evaluation *International Journal of Preventive Medicine* **5(10)** : 1261

NONATO F R, BARROS T A A, LUCCHESE A M, OLIVEIRA C E C, DOS SANTOS R R, SOARES M B P & VILLARREAL C F 2009 Antiinflammatory and antinociceptive activities of *Blechnum occidentale* L extract *Journal of Ethnopharmacology* **125(1)** : 102-107

NONATO F R, NOGUEIRA T M O, DE ALMEIDA BARROS T A, LUCCHESE A M, OLIVEIRA C E C, DOS SANTOS R R, SOARES M B P & VILLARREAL C F 2011 Antinociceptive and antiinflammatory activities of *Adiantum latifolium* Lam: evidence for a role of IL-1? inhibition *Journal of Ethnopharmacology* **136(3) :** 518-524

NWILOH B I, MONAGO C C & UWAKWE A A 2014 Chemical composition of essential oil from the fiddleheads of *Pteridium aquilinum* L Kuhn found in Ogoni *Journal of Medicinal Plants Research* **8(1) :** 77-80

ONIGA I, TOIU A, MOGOSAN C & BODOKI E 2004 Preliminary investigations of *Phyllitis scolopendria* (L) Newman (Polypodiaceae) *Farmacia* **52 :** 48-54

OUYANG D, KONG D, XU H, NI X, CHEN J & YANG P 2009 Isolation and purification of apigenin and luteolin from *Pteris multifida* Poir by high-speed counter-current chromatography *Tianran Chanwu Yanjiu Yu Kaifa* **21 :** 822-825

OUYANG D, YANG P & KONG D 2008 Chemical constituents from *Pteris multifida. Poir Zhongguo Yiyao Gongye Zazhi* **39 :** 898-900

PAN C, CHEN Y G, MA X Y, JIANG J H, HE F & ZHANG Y 2011 Phytochemical constituents and pharmacological activities of plants from the genus *Adiantum* : A review Tropical *Journal of Pharmaceutical Research* **10(5)** : 681-692

PANDA S K 2014 Ethno-medicinal uses and screening of plants for antibacterial activity from Similipal Biosphere Reserve, Odisha, India *Journal of Ethnopharmacology* **151(1) :** 158-175

PAREJA, B 1988 Therapeutic properties of *Polypodium angustifolium* Boletin de la *Sociedad Quimica del Peru* **54 :** 89-95

PARIHAR P, PARIHAR L & BOHRA A 2004 Antifungal activity of *Cheilanthes albomarginata* Clarke and *Marsilea minuta* Linn against *Aspergillus flavus. Indian Fern Journal* **21 :** 140-143

PARIHAR P, PARIHAR L & BOHRA A 2010 *In vitro* antibacterial activity of fronds (leaves) of some important pteridophytes *Journal of Microbiology and Antimicrobials* **2(2)** : 19-22

PARRADO C, MASCARAQUE M, GILABERTE Y, JUARRANZ A & GONZALEZ S 2016 Fernblock (*Polypodium leucotomos* extract) : molecular mechanisms and pleiotropic effects in light-related skin conditions, photoaging and skin cancers, a review *International Journal of Molecular Sciences* **17(7) :** 1026

PASWAN S K, GAUTAM, A, VERMA, P, RAO, C V, SIDHU, O P, SINGH, A P & SRIVASTAVA, S 2017 The Indian Magical Herb 'Sanjeevani' (*Selaginella bryopteris* L)-A Promising Anti-inflammatory Phytomedicine for the Treatment of Patients with inflammatory Skin Diseases *Journal of Pharmacopuncture* **20(2)** : 93

PATIL D T, GURAV K D, KADAM A S, THITE S V, THOKE R B & KORE B A 2013 Qualitative analysis of secondary metabolites from some filicales members *International Journal of Research and Pharmaceutical Chemistry* **3 :** 300-302

PAUL K R, IRUDAYARAJ V, JOHNSON M & PATRIC D R 2011 Phytochemical and anti–bacterial activity of epidermal glands extract of *Christella parasitica* (L) H Lev *Asian Pacific Journal of Tropical Biomedicine* **1(1)** : 8-11

PAUL T, DAS B, APTE K G, BANERJEE S & SAXENA R C 2012 Evaluation of anti-hyperglycemic activity of *Adiantum philippense* Linn a pteridophyte in alloxan induced diabetic rats *Journal of Diabetes and Metabolism* **3(9)** : 1-8

PAULSAMY S, MOORTHY D, NANDAKUMAR K & SARADHA M 2013 Evaluation of *in vitro* antioxidant potential of methanolic extracts of the ferns, *Actiniopteris radiata* (Sw) Link and *Equisetum ramosissimum* Desf *International Journal of Research and Development in Pharmacy and Life Sciences* **2(3)** : 451-455

PÉTARD P 1986 Plantes utiles de Polynésie et Raau Tahiti Polynésie française : Haere po no Tahiti

PIZZOLATTI M G, BRIGHENTE I M C, BORTOLUZZI A J, SCHRIPSEMA J & VERDI L G 2007 Cyathenosin A, a spiropyranosyl derivative of protocatechuic acid from *Cyathea phalerata. Phytochemistry* **68(9) :** 1327-1330

PPG I 2016 A community-derived classification for extant lycophytes and ferns *Journal of Systematics and Evolution* **54 :** 563-603

PROESTOS C, CHORIANOPOULOS N, NYCHAS G J & KOMAITIS M 2005 RP-HPLC analysis of the phenolic compounds of plant extracts Investigation of their antioxidant capacity and antimicrobial activity *Journal of Agricultural and Food Chemistry* **53(4)** : 1190-1195

QI W, XIU-WEI Y, SHI-HAI Y, LEI Z & JING Y 2007 Chemical constituents of *Cibotium barometz. Natural Product Research and Development* **19(2) :** 240-243

QIN B, ZHU D Y, JIANG S H, XIANG G, LENG Y, GU Z P, WANG Y Q & SHAO X F 2006 Chemical constituents of *Pteris multifida* and their inhibitory effects on growth of rat prostatic epithelial cells *in vitro Chinese Natural Medicine* **4(6) :** 428-431

QIU Z C, DONG X L, DAI Y, XIAO G K, WANG X L, WONG K C, WONG M S & YAO X S 2016 Discovery of a new class of *Cathepsin K inhibitors* in *Rhizoma drynariae* as potential candidates for the treatment of osteoporosis *International Journal of Molecular Sciences* **17(12) :** 2116

RADULOVIÃ N, STOJANOVIÃ G & PALIÃ R 2006 Composition and antimicrobial activity of Equisetum arvense L essential oil *Phytotherapy Research* **20(1) :** 85-88

RAJA D P, MANICKAM V S, DE BRITTO A J, GOPALAKRISHNAN S, USHIODA T, SATOH M, TANIMURA A, FUCHINO H & TANAKA N 1995 Chemical and chemotaxonomical studies on *Dicranopteris* species *Chemical and Pharmaceutical Bulletin* **43(10) :** 1800-1803

RAJESH K D, VASANTHA S, RAJESH N V & PANNEERSELVAM A 2014 Qualitative and quantitative phytochemical analysis in four Pteridophytes *International Journal of Pharmaceutical Sciences Review and Research* **27 :** 408-412

RAJURKAR N S & GAIKWAD K 2012 Evaluation of phytochemicals, antioxidant activity and elemental content of *Adiantum capillus-veneris* leaves *Journal of Chemical and Pharmaceutical Research* **4(1)** : 365-374

RAKKIMUTHU R, NAVEENRAJ B, BENITTA L & DHANYA K 2018 Phytochemical screening and its antibacterial activity of the fern *Hemionitis arifolia* (Burm) Moore World *Journal of Pharmaceutical Research* **7(13)** : 603-609

RAMANITRAHASIMBOLA D, RAKOTONDRAMANANA D A, RASOANAIVO P, RANDRIANTSOA A, RATSIMAMANGA S, PALAZZINO G, GALEFFI C & NICOLETTI M 2005 Bronchodilator activity of *Phymatodes scolopendria* (Burm) Ching and its bioactive constituent *Journal of Ethnopharmacology* **102 :** 400-407

RAMESH N, VISWANATHAN M B, SARASWATHY A, BALAKRISHNA K, BRINDHA P & LAKSHMANAPERUMALSAMY P 2001 Phytochemical and antimicrobial studies on *Drynaria quercifolia. Fitoterapia* **72(8) :** 934-936

RANI D, KHARE P B & 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 Journal of Pharmaceutical Sciences* **72(6)** : 818

RANJAN V & VATS M 2016 Pharmacognostical and physico-chemical standardisation of whole plant of *Adiantum capillus-veneris* Linn *International Journal of Pharmceutical Sciences and Research* **7 :** 773-782

RANJAN V, VATS M, GUPTA N & SARDANA S 2014 Antidiabetic potential of whole plant of *Adiantum capillus-veneris* linn in streptozotocin induced diabetic rats *International Journal of Pharma and Chemical Research* **6 :** 341-347

RASCON-VALENZUELA L A, TORRES-MORENO H, VELAZQUEZ-CONTRERAS C, GARIBAY-ESCOBAR A & ROBLES-ZEPEDA R E 2017 Triterpenoids : Synthesis, uses in cancer treatment and other biological activities *In: "Advances in Medicine and Biology"* Eds Berhardt L V Publishers: Nova Science Publisher, Inc pp 139-181

RASTOGI S, PANDEY M M & RAWAT A K S 2018 Ethnopharmacological uses, phytochemistry and pharmacology of genus *Adiantum*: A comprehensive review *Journal of Ethnopharmacology* **215 :** 101-119

RAUTRAY S, PANIKAR S, AMUTHA T & RAJANANTHINI A U 2018 Anticancer activity of *Adiantum capillus-veneris* and *Pteris quadriaurita* L in human breast cancer cell lines *Molecular Biology Reports* **45(6)** : 1897-1911

ROSANDY A R, KAMAL N M, TALIP N, KHALID R & BAKAR M A 2017 Isolation of four steroids from the leaves of fern *Adiantum latifolium* Lam Malaysian *Journal of Analytical Sciences* **21(2) :** 298-303

RUPNATH K, NARASU M L & MALLIKARJUNA K 2016 Antioxidant, anti-diabetic and antimicrobial activity of different solvent extracts of *Actinopteris radiata* Link World *Journal of Pharmaceutical Research* **5(9)** : 873-878

SAH N K, SINGH S N P, SAHDEV S, BANERJI S, JHA V, KHAN Z & HASNAIN S E 2005 Indian herb ‘Sanjeevani’ (*Selaginella bryopteris*) can promote growth and protect against heat shock and apoptotic activities of ultra violet and oxidative stress *Journal of Biosciences* **30(4) :** 499-505

SAHA D, GHOSH S K, DAS T & RAHMAN H 2011 Effect of *Adiantum caudatum* in streptozotocin-induced diabetes mellitus in rats *International Research Journal of Pharmceutical and Applied Sciences* **1 :** 9-15

SAJEEV S, PRITHVIRAJ ADARSH D B & HEGDE S 2015 Phytoconstituents of *Nephrolepis hirsutula* and *Pityrogramma calomelanos*, two medicinal ferns of the Western Ghats *Indian Fern Journal* **32 :** 244-256

SALATINO M L F & PRADO J 1998 Flavonoid glycosides of Pteridaceae from Brazil *Biochemical Systematics and Ecology* **26(7) :** 761-769

SALEHI B, EZZAT S M, FOKOU P V T, ALBAYRAK S, VLAISAVLJEVIC S, SHARIFI-RAD M, BHATT I D, SHARIFI-RAD M, BELWAL T, AYATOLLAHI S A & KOBARFARD F 2018 Athyrium Plants-Review on Phytopharmacy Properties *Journal of Traditional and Complementary Medicine*

SANTHOSHKUMAR S & NAGARAJAN N 2014 Biological synthesis of silver nanoparticles of *Adiantum capillus-veneris* L and their evaluation of antibacterial activity against human pathogenic bacteria *International Journal of Pharmaceutical Sciences and Research* **59 :** 5511-5518

SCHUETTPELZ E, ROUHAN G, PRYER K & SROTHFELS C J 2018 Are there too many fern genera? *Taxon* **67(3)** : 473-480

SENGOTTUVEL T, KANNAPPAN N & SIVAKKUMAR T 2015 Phytochemical and GC–MS analysis of bioactive compounds present in the *Adiantum incisum* Forssk Der *Pharma Chemica* **7(8)** : 137-142

SHAH N C & SINGH S C 1990 Hitherto unreported phytotherapeutical uses from tribal pockets of Madhya Pradesh, India *Ethnobotany* **2 :** 91-95

SHARMA D, BHATIA V K, PATIL S & SHARMA P C 2013 Antimicrobial activity of selected cryptogams from Solan region *International Journal of Biological and Pharmaceutical Research* **4(6)** : 448-454

SHASHIKANTH J, REDDY A V & REDDY P R 2014 Pharmacognostical Studies of *Actiniopteris radiata* (Swartz) Link *Journal of Plant Science Research* **30(2) :** 141-146

SHEN Y C & CHEN C H 1994 Alkaloids from *Lycopodium casuarinoides.* Journal of Natural Products **57(6) :** 824-826

SHI Y S, ZHANG Y, HU W Z, ZHANG X F, FU X & LV X 2017 Dihydrochalcones and diterpenoids from *Pteris ensiformis* and their bioactivities *Molecules* **22(9) :** 1413

SHIOJIMA, K & AGETA, H 1994 Fern constituents: triterpenoids isolated from the leaves of *Adiantum edgeworthii* Structures of 19-hydroxyadiantone and fern-9(11)-en-25-oic acid *Chemical and Pharmaceutical Bulletin* **42 :** 45-47

SHINOZAKI J, SHIBUYA M, MASUDA K & EBIZUKA Y 2008 Dammaradiene synthase, a squalene cyclase, from *Dryopteris crassirhizoma. Nakai Phytochemistry* **69(14)** : 2559-2564

SHU J, LIU J, ZHONG Y, PAN J, LIU L & ZHANG R 2012 Two new pterosin sesquiterpenes from *Pteris multifida. Poir Phytochemistry Letters* **5(2) :** 276-279

SINGH H B 1999 Potential medicinal pteridophytes of India and their chemical constituents *Journal of Economic and Taxonomic Botany* **23 :** 63-78

SINGH H B 2003 Economically viable pteridophytes of India In "*Pteridology in the New Millennium*" (eds S Chandra & M Srivastava), Kluwer Academic Publishers, Netherlands, pp 421-446

SINGH M, SINGH N, KHARE P B & RAWATA K S 2008 Antimicrobial activity of some important *Adiantum* species used traditionally in indigenous systems of medicine *Journal of Ethnopharmacology* **115 :** 327-329

SINGH R S, THAKUR D, JHA V K, KUMAR U, PAL A K, SINGH P K & FULZELE D P 2018 Antibacterial Activity of *Selaginella bryopteris* Fronds Extract on Bacteria Isolated from Mastititic Milk *International Journal of Current Microbiology and Applied Sciences* **7 :** 4711-4715

SNOGAN E, VAHIRUA-LECHAT I, HO R, BERTHO G, GIRAULT J-P, ORTIGA S, MARIA A & LAFONT R 2007 Ecdysteroids from the medicinal fern *Microsorum scolopendria* (Burm f) *Phytochemical Analysis* **18 :** 441-450

SREENIVASULU V, BASHA S C, ADINARAYANA Y, LINGASWAMY V & KUMAR U P 2014 Anthelmentic activity of *Actiniopteris radiata* (Linn) *Journal of Global Trends in Pharmaceutical Sciences* **5(2)** : 1716-1718

STARK D, LARSEN J, LARSEN L A, OLAFSDOTTIR E S, WITT M & JAROSZEWSKI J W 2004 Selagoline, a new alkaloid from *Huperzia selago Natural Product Research* **18(3) :** 197-203

STAR A E & MABRY T J 1971 Flavonoid frond exudates from two Jamaican ferns, *Pityrogramma tartarea* and *P calomelanos. Phytochemistry* **10(11) :** 2817-2818

SU Y, WAN D Q & SONG W Q 2016 Dryofragin inhibits the migration and invasion of human osteosarcoma U2OS cells by suppressing MMP-2/9 and elevating TIMP-1/2 through PI3K/ AKT and p38 MAPK signaling pathways *Anti-Cancer Drug* **27 :** 660-668

SUJA S R, LATHA P G, PUSHPANGADAN P & RAJASEKHARAN S 2004 Evaluation of hepatoprotective effects of *Helminthostachys zeylanica* (L) Hook against carbon tetrachloride-induced liver damage in Wistar rats *Journal of Ethnopharmacology* **92(1) :** 61-66

SUN C M, SYU W J, HUANG Y T, CHEN C C & OU J C 1997 Selective cytotoxicity of ginkgetin from *Selaginella moellendorffii. Journal of Natural Products* **60(4) :** 382-384

SUN Y, YAN J, MENG H, HE C L, YI P, QIAO Y & QIU M H 2008 A New Alkaloid from *Lycopodium japonicum* Thunb *Helvetica Chimica Acta* **91(11) :** 2107-2109

SURESHKUMARA J, SILAMBARASANA R, BHARATIB K A, KRUPAA J, AMALRAJA S & AYYANAR M 2018 A review on ethnomedicinally important pteridophytes of India *Journal of Ethnopharmacology* **219 :** 269-287

TACKHOLM VIVI & GUNNAR 1973 (reprint) *Flora of Egypt* Vol 1-4 Originally published in *Foriad I* Univ Bulletin of the Faculty of Science, Vol 17, Cairo, 1941

TAPWAL A, GARG S, GAUTAM N & KUMAR R 2011 *In vitro* antifungal potency of plant extracts against five phytopathogens *Brazilian Archives of Biology and Technology* **54(6)** : 1093-1098

TAVEEPANICH S, KAMTHONG N, SAWASDIPUKSA N & ROENGSUMRAN S 2005 Inhibitory activities of angiopteroside for HIV-1 reverse transcriptase and lung cancer cell-line *Journal of Scientific Research* Chulalongkorn University **30(2) :** 187-192

TAYLOR R S 1996 Medicinal plants of Nepal : ethnomedicine, pharmacology, and phytochemistry Doctoral dissertation, University of British Columbia

TEAI HO, MEYBECK A & RAHARIVELOMANANA P 2015 UV-protective effects of phytoecdysteroids from *Microsorum grossum* extracts on human dermal fibroblasts *Natural Product Communications* **10(1) :** 33-36

THOMAS A, PETER P K J & CHANDRAMOHANAKUMAR N 2016 A profiling of anti-tumour potential of sterols in the mangrove fern *Acrostichum aureum International Journal of Pharmacognosy and Phytochemical Research* **8 :** 1828-1832

THOMAS T 2011 Preliminary antibacterial evaluation of fronds of *Pteris quadriaurita* Retz towards bacteria involved in dermatological diseases *Journal of Applied Pharmaceutical Science* **1(8) :** 214

UDDIN M G, MIRZA M M & PASHA M K 1998 The medicinal uses of pteridophytes of Bangladesh Bangladesh *Journal of Plant Taxonomy* **5(2)** : 29-41

UDDIN S J 2011 Cytotoxicity Screening of Bangladeshi Medicinal Plants and Isolation and Structural Elucidation of Novel Anti-Cancer Compounds from *Acrostichum aureum* Thesis B Pharm (Hons), Griffith University

UDDIN S J, GRICE D & TIRALONGO E 2012 Evaluation of cytotoxic activity of patriscabratine, tetracosane and various flavonoids isolated from the Bangladeshi medicinal plant *Acrostichum aureum. Pharmaceutical Biology* **50(10)** : 1276-1280

ULLAH S, JAN G, JAN F G, KHAN S, KHATTAK M & BIBI H 2018 Phytochemical analysis, antipyretic and antifungal activities of *Cyrtomium caryotideum. Biosciences Biotechnology Research Asia* **15(3) :** 577-589

VALIZADEH H, SONBOLI A, KORDI F M, DEHGHAN H & BAHADORI M B 2015 Cytotoxicity, antioxidant activity and phenolic content of eight fern species from *North of Iran Pharmaceutical Sciences* **21(1)** : 18

VASUDEVA S M 1999 Economic importance of pteridophytes *Indian Fern Journal* **16 :** 130-152

VETTER J 2018 Secondary Metabolites of Ferns In *Current Advances in Fern Research* Eds Fernández H Publishers : Springer, Cham pp 305-327

VIJAYALAKSHMI A & KUMAR Y K 2013 Evaluation of goitrogenic and antithyroidal effect of the fern *Adiantum capillus-veneris. Revista Brasileira de Farmacognosia* **23(5) :** 802-810

WANG G & ZHANG L M 2008 Study of the extract from *Pteris multifida* Poir on antitumor activity *Hebeisheng Kexueyuan Xuebao* **25 :** 52-54

WANG J, YAN Y T, FU S Z, PENG B, BAO L L, ZHANG Y L, HU J H, ZENG Z P, GENG D H & GAO Z P 2017 Anti-influenza virus (H5N1) activity screening on the phloroglucinols from rhizomes of *Dryopteris crassirhizoma. Molecules* **22(3) :** 431

WANG X J, LI L, SI Y K, YU S S, MA S G, BAO X Q, ZHANG D, QU J, LIU Y B & LI Y 2013a Nine new lycopodine-type alkaloids from *Lycopodium japonicum* Thunb *Tetrahedron* **69(30) :** 6234-6240

WANG X J, LI L, YU S S, MA S G, QU J, LIU Y B, LI Y, WANG Y & TANG W 2013b Five new fawcettimine-related alkaloids from *Lycopodium japonicum* Thunb *Fitoterapia* **91 :** 74-81

WANG X J, LIU Y B, LI L, YU S S, LV H N, MA S G, BAO X Q, ZHANG D, QU J & LI Y 2012a Lycojaponicumins D and E: two new alkaloids from *Lycopodium japonicum. Organic Letters* **14(22) :** 5688-5691

WANG X J, ZHANG G J, ZHUANG P Y, ZHANG Y, YU S S, BAO X Q, ZHANG D, YUAN Y H, CHEN N H, MA S G & QU J 2012b Lycojaponicumins A-C, three alkaloids with an unprecedented skeleton from *Lycopodium japonicum. Organic Letters* **14(10) :** 2614-2617

WANG X, WANG N, GAO H, ZHANG G, QIN L, WONG M & YAO X 2010a Phenylpropanoid and flavonoids from osteoprotective fraction of *Drynaria fortunei. Natural Product Research* **24 :** 1206-1213

WANG Y H, LONG C L, YANG F M, WANG X, SUN Q Y, WANG H S, SHI Y N & TANG G H 2009 Pyrrolidinoindoline alkaloids from *Selaginella moellendorfii. Journal of Natural Products* **72(6) :** 1151-1154

WANG Y H, SUN Q Y, YANG F M, LONG C L, ZHAO F W, TANG G H, NIU H M, WANG H, HUANG Q Q, XU J J & MA L J 2010b Neolignans and caffeoyl derivatives from *Selaginella moellendorffii. Helvetica Chimica Acta* **93(12) :** 2467-2477

WEI H-A, LIAN T-W, TU Y-C, HONG J-T, KOU M-C & WU M-J 2007 Inhibition of low-density lipoprotein oxidation and oxidative burst in polymorphonuclear neutrophils by caffeic acid and hispidin derivates isolated from sword brake ferns (*Pteris ensiformis* Burm) *Journal of Agricultural and Food Chemistry* **55 :** 10579-10584

WEI H, WU G, CHEN J, ZHANG X, XIONG C, LEI Y, CHEN W & RUAN J 2013 (2S)-5, 2?, 5?-trihydroxy-7-methoxyflavanone, a natural product from *Abacopteris penangiana*, presents neuroprotective effects *in vitro* and *in vivo Neurochemical Research* **38(8) :** 1686-1694

WEI H, WU G, SHI D, SONG S, ZHANG X, LEI Y & RUAN J 2012 Total flavan glycoside from *Abacopteris penangiana* rhizomes and its acid hydrolysate : characterisation and anti-benign prostatic hyperplasia potential *Food Chemistry* **134(4) :** 1959-1966

WHISTLER W A 1992 Polynesian Herbal Medecine Hawaii : National Tropical Botanical Garden

WHISTLER W A 1996 Samoan herbal medicine Hawaii : Isle Botanica

WILLS P J & ASHA V V 2006a Preventive and curative effect of *Lygodium flexuosum* (L) Sw on carbon tetrachloride induced hepatic fibrosis in rats *Journal of Ethnopharmacology* **107(1) :** 7-11

WILLS P J & ASHA V V 2006b Protective effect of *Lygodium flexuosum* (L) Sw (Lygodiaceae) against D-galactosamine induced liver injury in rats *Journal of Ethnopharmacology* **108(1)** : 116-123

WILLS P J & ASHA V V 2006c Protective effect of *Lygodium flexuosum* (L) Sw extract against carbon tetrachloride-induced acute liver injury in rats *Journal of Ethnopharmacology* **108(3) :** 320-326

WILLS P J, SURESH V, ARUN M & ASHA V V 2006 Antiangiogenic effect of *Lygodium flexuosum* against N-nitrosodiethylamine-induced hepatotoxicity in rats Chemico-biological *Interactions* **164(1-2) :** 25-38

WILLS P J & ASHA V V 2007 Protective mechanism of *Lygodium flexuosum* extract in treating and preventing carbon tetrachloride induced hepatic fibrosis in rats *Chemico-biological Interactions* **165(1) :** 76-85

WILLS P J & ASHA V V 2009 Chemopreventive action of *Lygodium flexuosum* extracts in human hepatoma PLC/PRF/5 and Hep 3B cells *Journal of Ethnopharmacology* **122(2)** : 294-303

WOYENGO T A, RAMPRASATH V R & JONES P J 2009 Anticancer effects of phytosterols *European Journal of Clinical Nutrition* **63(7)** : 813-820

WU B & WANG J 2011 Phenolic compounds from *Selaginella moellendorfii. Chemistry and Biodiversity* **8(9) :** 1735-1747

WU K C, HUANG S S, KUO Y H, HO Y L, YANG C S, CHANG Y S & HUANG G J 2017 Ugonin M, a Helminthostachys zeylanica constituent, prevents LPS-induced acute lung injury through TLR4-mediated MAPK and NF-?B signaling pathways *Molecules* **22(4) :** 573

WU M J, WENG C Y, WANG L & LIAN T W 2005 Immunomodulatory mechanism of the aqueous extract of sword brake fern (*Pteris ensiformis* Burm) *Journal of Ethnopharmacology* **98(1-2) :** 73-81

XU H X, KADOTA S, KUROKAWA M, SHIRAKI K, MATSUMOTO T & NAMBA T 1993 Isolation and structure of woodorien, a new glucoside having antiviral activity from *Woodwardia orientalis. Chemical and Pharmaceutical Bulletin* **41(10)** : 1803-1806

XU N, CAO Y, ZHOU L & JIA T Z 2011 Study on anti-oxidation of raw and processed *Cibotium barometz* Chinese Archives of Traditional *Chineses Medicine* **11 :** 2424-2426

YAMADA H, NISHIZAWA M & KATAYAMA C 1992 Osladin, a sweet princple of *Polypodium vulgare*: Structure revision *Tetrahedron Letters* **33(28) :** 4009-4010

YAMAUCHI K, MITSUNAGA T & BATUBARA I 2013 Novel quercetin glucosides from *Helminthostachys zeylanica* root and acceleratory activity of melanin biosynthesis *Journal of Natural Medicines* **67(2) :** 369-374

YAMAUCHI T, OYAMA N, YAMANE H, MUROFUSHI N, SCHRAUDOLF H, POUR M, FURBER M & MANDER L N 1996 Identification of antheridiogens in *Lygodium circinnatum* and *Lygodium flexuosum Plant Physiology* **111(3) :** 741-745

YAN J, ZHANG X M, LI Z R, ZHOU L, CHEN J C, SUN L R & QIU M H 2005 Three new triterpenoids from *Lycopodium japonicum* Thunb *Helvetica chimica acta* **88(2) :** 240-244

YANG C, SHAO Y, LI K & XIA W 2012 Bioactive selaginellins from *Selaginella tamariscina* (Beauv) spring Beilstein *Journal of Organic Chemistry* **8(1)** : 1884-1889

YANG J H, KONDRATYUK T P, MARLER L E, QIU X, CHOI Y, CAO H, YU R, STURDY M, PEGAN S, LIU Y & WANG L Q 2010 Isolation and evaluation of kaempferol glycosides from the fern *Neocheiropteris palmatopedata. Phytochemistry* **71(5-6)** : 641-647

YANG S F, CHU S C, LIU S J, CHEN Y C, CHANG Y Z & HSIEH Y S 2007 Antimetastatic activities of *Selaginella tamariscina* (Beauv) on lung cancer cells *in vitro* and *in vivo Journal of Ethnopharmacology* **110(3) :** 483-489

YANG S J, LIU M C, LIANG N, XIANG H M & YANG S 2013 Chemical constituents of *Cyrtomium fortumei* (J) Smith *Natural Product Research* **27(21)** : 2066-2068

YANG X, YUAN L, CHEN J, XIONG C & RUAN J 2014a Multitargeted protective effect of *Abacopteris penangiana* against carrageenan-induced chronic prostatitis in rats *Journal of Ethnopharmacology* **151(1)** : 343-351

YANG X, YUAN L, XIONG C, YIN C & RUAN J 2014b *Abacopteris penangiana* exerts testosterone-induced benign prostatic hyperplasia protective effect through regulating inflammatory responses, reducing oxidative stress and anti-proliferative *Journal of Ethnopharmacology* **157 :** 105-113

YAO C P, ZOU Z X, ZHANG Y, LI J, CHENG F, XU P S, ZHOU G, LI X M, XU K P & TAN G S 2018 New adenine analogues and a pyrrole alkaloid from *Selaginella delicatula. Natural Product Research* **4 :** 1-7

YONATHAN M, ASRES K, ASSEFA A & BUCAR F 2006 *In vivo* anti-inflammatory and anti-nociceptive activities of *Cheilanthes farinosa. Journal of Ethnopharmacology* **108 :** 462-470

YOUSAF B, LIU G, WANG R, QADIR A, ALI M U, KANWAL Q, MUNIR B & ABBAS Z 2016 Bisphenol A exposure and healing effects *of Adiantum capillus-veneris* L plant extract (APE) in bisphenol A-induced reproductive toxicity in albino rats *Environmental Science and Pollution Research* **23(12) :** 11645-11657

YUAN Q, WANG J & RUAN J 2012 Screening for bioactive compounds from *Adiantum capillus–veneris* L *Journal of The Chemical Society of Pakistan* **34(1)** : 207

YUAN Q, ZHANG X, LIU Z, SONG S, XUE P, WANG J & RUAN J 2013 Ethanol extract of Adiantum capillus-veneris L suppresses the production of inflammatory mediators by inhibiting NF-?B activation *Journal of Ethnopharmacology* **147(3)** : 603-611

YUMKHAM S D, ELANGBAM M, NONGMAITHEM R, NAOREM P D & SINGH P K 2018 Maiden hair ferns (*Adiantum* L, Pteridaceae–Vittarioideae) of North East India: diversity, phytochemistry and utilization *Genetic Resources and Crop Evolution* **65(4) :** 1269-1280

ZAKARIA Z A, GHANI Z D F A, NOR R N S R M, GOPALAN H K, SULAIMAN M R, JAIS A M M, SOMCHIT M N, KADER A A & RIPIN J 2008 Antinociceptive, anti-inflammatory, and antipyretic properties of an aqueous extract of *Dicranopteris linearis* leaves in experimental animal models *Journal of Natural Medicines* **62(2)** : 179-187

ZANGARA A 2003 The psychopharmacology of huperzine A: an alkaloid with cognitive enhancing and neuroprotective properties of interest in the treatment of Alzheimer's disease *Pharmacology, Biochemistry and Behavior* **75 :** 675-686

ZENG W, YAO C P, XU P S, ZHANG G G, LIU Z Q, XU, K P, ZOU Z X & TAN G S 2017 A new neolignan from *Selaginella moellendorffii* Hieron *Natural Product Research* **31(19) :** 2223-2227

ZHANG X, CHEN H L, HONG L, XU L L, GONG XW, ZHU D L, XU X H, ZHAO W, WANG F & YANG X L 2019 Three new hopane-type triterpenoids from the aerial part of *Adiantum capillus-veneris* and their antimicrobial activities *Fitoterapia* **133 :** 146-149

ZHANG Y L, LI J P & LI G Y 2014 Two new compounds from *Dryopteris fragrans. Zhong Yao Cai* **37 :** 599-602

ZHANG Z, ELSOHLY H N, JACOB M R, PASCO D S, WALKER L A & CLARK A M 2002 Natural products inhibiting *Candida albicans* secreted aspartic proteases from *Lycopodium cernum. Journal of Natural Products* **65 :** 979-985

ZHAO D D, ZHAO Q S, LIU L, CHEN Z Q, ZENG W M, LEI H & ZHANG Y L 2014 Compounds from *Dryopteris fragrans* (L) schott with cytotoxic activity *Molecules* **19 :** 3345-3355

ZHAO X, WU Z X, ZHANG Y, YAN Y B, HE Q, CAO P C & LEI W 2011 Anti-osteoporosis activity of *Cibotium barometz* extract on ovariectomy-induced bone loss in rats *Journal of Ethnopharmacology* **137(3) :** 1083-1088

ZHAO Z X, RUAN J L, JIN J, ZHU C C & LIN C Z 2010a Two new acetylated flavan glycosides from rhizomes of the fern *Abacopteris penangiana. Journal of Asian Natural Products Research* **12(12) :** 1015-1019

ZHAO Z, JIN J, RUAN J, ZHU C, LIN C, FANG W A & CAI Y 2007 Antioxidant flavonoid glycosides from aerial parts of the fern *Abacopteris penangiana. Journal of Natural Products* **70(10) :** 1683-1686

ZHAO Z, RUAN J L, JIN J, ZHU C C & LIU Y 2010b A novel anthocyanidin glycoside from the rhizomes of *Abacopteris penangiana. Fitoterapia* **81(8) :** 1171-1175

ZHENG J X, WANG N L, GAO H, LIU H W, CHEN H F, FAN M & YAO X S 2008 A new flavonoid with a benzoic acid substituent from *Selaginella uncinata. Chinese Chemical Letters* **19(9)** : 1093-1095

ZHENG J X, ZHENG Y, ZHI H, DAI, Y WANG N L, FANG Y X, DU Z Y, ZHANG K, LI M M, WU L Y & FAN M 2011 New 3', 8"-linked biflavonoids from *Selaginella uncinata* displaying protective effect against anoxia *Molecules* **16(8)** : 6206-6214

ZHENG J, ZHENG Y, ZHI H, DAI Y, WANG N, WU L, FAN M, FANG Y, ZHAO S & ZHANG K 2013 Two new steroidal saponins from *Selaginella uncinata* (Desv) Spring and their protective effect against anoxia *Fitoterapia* **88 :** 25-30

ZHENG J X, ZHENG Y, ZHI H, DAI Y, WANG N L, FANG Y X, DU Z Y, ZHANG K, WU LY & FAN M 2014 γ-Lactone derivatives and terpenoids from *Selaginella uncinata* and their protective effect against anoxia *Chemistry of Natural Compounds* **50(2)** : 366-369

ZHENG X D, HU H B & HU H S 2008a A new neolignan glycoside from *Pteris multifida* Poir *Bulletin of the Korean Chemical Society* **29 :** 1250-1252

ZHENG X D, HU H B & HU H S 2008b Two new neolignan glycosides from *Pteris multifida* Poir *Indian Journal of Chemistry* **47B :** 773-777

ZHENG X K, LI Y J, ZHANG L, FENG W S & ZHANG X 2011 Antihyperglycemic activity of *Selaginella tamariscina* (Beauv) spring *Journal of Ethnopharmacology* **133(2) :** 531-537

ZHENG X K, ZHANG L, WANG W W, WU Y Y, ZHANG Q B & FENG W S 2011 Anti-diabetic activity and potential mechanism of total flavonoids of *Selaginella tamariscina* (Beauv) Spring in rats induced by high fat diet and low dose STZ *Journal of Ethnopharmacology* **137(1) :** 662-668

ZHONG Z C, ZHAO D D, LIU Z D, JIANG S & ZHANG Y L 2017 A new human cancer cell proliferation inhibition sesquiterpene, dryofraterpene a, from medicinal plant *Dryopteris fragrans* (L) schott *Molecules* **22 :** 180

ZHONG-YUAN X U, YUAN Y A N, ZHEN-DE C H E N, ZHI-LIANG C H E N & KUN ZHANG 2004 Studies on the Chemical Constituents of *Cibotium Barometz* (?) *Pharmaceutical Journal of Chinese People's Liberation Army 5*

ZHU D Y TANG, X C & LIN C 2000 Huperzine, a derivate, their preparation and their use Chinese Patent 59196884X, 05/10/2000

•IVKOVIÃ S, SKORIÃ M, ŠILER B, DMITROVIÃ S, FILIPOVIÃ B, NIKOLIÃ T & MIŠIÃ D 2017 Phytochemical characterization and antioxidant potential of rustyback fern (*Asplenium ceterach* L) *Lekovite sirovine* **37 :** 15-20

ZOU H, XU K P, LI F S, ZOU Z X, LIU R, LIU R H, LI J, TAN L H & TAN G S 2014 Unciflavones A–F, six novel flavonoids from *Selaginella uncinata* (Desv) *Spring Fitoterapia* **99 :** 328-333

ZOU H, XU K P, ZOU Z X, LONG H P, WANG H, LI F S, LI J, KUANG J W, LI G & TAN G S 2013 A new flavonoid with 6-phenyl substituent from *Selaginella uncinata. Journal of Asian Natural Products Research* **15(1)** : 84-88

ZOU H, XU P S, LIU R, ZOU Z X, LI J, ZHONG A G, HU J Z, XU K P & TAN G S 2016 Selacyclicbiflavone A, an unusual macrocyclic biflavone from *Selaginella uncinata* (Desv) *Spring Tetrahedron Letters* **57(8)** : 892-894

ZOU Z X, XU K P, LI F S, ZOU H, LIU M Z, ZHANG Q, YU K, ZHAO L F, TAN L H & TAN G S 2013 A new pyrrole alkaloid from *Selaginella moellendorfii. Hieron Chinese Chemical Letters* **24(2) :** 114-116

ZOU Z, XU P, WU C, ZHU W, ZHU G, HE X, ZHANG G, HU J, LIU S, ZENG W & XU K 2016 Carboxymethyl flavonoids and a chromone with antimicrobial activity from *Selaginella moellendorffii. Hieron Fitoterapia* **111 :** 124-129

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SCREENING FOR MINERAL CONTENT OF FOUR PTERIDOPHYTES FROM NORTHERN WESTERN GHATS OF MAHARASHTRA (INDIA)

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ABSTRACT

The Western Ghats is one of the rich repositories of pteridophytic plant wealth. Pteridophytes thrive in microclimatic conditions with special preference for moist and shady places. Minor disturbance in their microclimate conditions can lead to loss of large number of species. In the present study we investigated four specie of pteridophytes, namely *Hypodematium crenatum* (Forssk.) Kuhn, *Blechnum orientale* L., *Lycopodiella cernua* (L.) Pic. Ser. and Bolbitis subcrenatoides Fraser-Jenk., to screen for mineral content, including : Moisture, Ash, Nitrogen, Phosphorus, Potassium, Calcium, Magnesium, Sulphur, Sodium, Zinc, Ferrous, Copper, Manganese, Molybdenum and Boron.

Key Words : Northern Western Ghats, Pteridophytes, Medicinal importance, Mineral contentl screening

INTRODUCTION

It has been suggested that the distribution of ferns is mostly determined by factors of climate and habitat due to relatively low limitations in ferns for dispersal and establishment (Wild 2005). Appropriate plant nutrition is crucial to plant health and for adequate growth of the plants with maximal productivity. Among the nutrients in plants N, P, K, Ca, Mg and S are in large quantities while Na, Zn, Fe, Cu, Mn, Mo, and B are in trace amount. Within this group of nutrients definitions exist 'Essential mineral element' and 'Mineral nutrients' the term was proposed by Arnon & Stout (1939). The determination of macro- and micro-nutrients in plant tissues is an important measure, used to analyze plant nutrient status, resistant to microbial infection, and to evaluate the possible requirements of soil type for their better growth. Ferns and Fern allies have engaged the attention of the botanists and horticulturists because of their beauty and graceful foliage. Besides, these have been successfully used in the past, in Ayurvedic, Unani, Siddha, Homeopathic and other preparations. For their use as horticultural plants or in the medicinal preparations, ferns are being removed from their natural shady habitats in the forests (Shaikh & Dongare 2010), which draw our attention towards the conservation of these much neglected groups. Because of many threats from natural causes and anthropogenic activities, conservation of these valuable plants becomes a heavy task. Accordingly, mineral content screening of these species will enrich the database of pteridophytes.

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MATERIALS AND METHODS

The material was collected from different localities of Northern Western Ghats of Maharashtra which is one of the richest diversity place for pteridophytes. In the present investigation four species of pteridophytes, namely *Hypodematium crenatum subsp. crenatum* (Forssk.) Kuhn*, Blechnum orientale* L., *Lycopodiella cernua* (L.) Pic. Ser. and *Bolbitis subcrenatoides* Fraser-Jenk. were collected for mineral content analyses. The specimens were identified by the literature on Pteridophytic flora, monographs, research articles *viz.* Beddome (1884), Baltter & d'Almeida (1922), Flora of South India by Manickam & Irudayaraj (1992), Ghosh *et al.* (2004), Fraser-Jenkins (2008), Fraser-Jenkins et al. (2017). Moisture was measured using thermo-hygrometer (M288CTH). Plant species collected were washed with water to remove soil and debris, then oven-dried at 60^0C, and powdered material was acid digested in nitric acid to get extract, and this extract is used to estimate different inorganic constituents from the filtrate.

RESULTS AND DISCUSSION

The mineral contents of each extract are presented separately in Figs. 1 to 15, *viz.* Moisture, Ash, Nitrogen, Phosphorous, Potassium, Calcium, Magnesium, Sulphur, Sodium, Zinc, Ferrous, Copper, Manganese, Molybdenum and Boron. Element concentration in four pteridophytes (whole) were measured by relative methods of AAS using multi-element standards as comparators these are listed. In order to compare the concentration of main elements of each species for N, P, K, Ca, Mg, S, Na, Zn, Fe, Cu, Mn, Mo, and B, these are plotted in separate figures (Figs.1-15). In *B. orientale* the percentage moisture content is highest (4.9%) followed by *B. subcrenatoides, H. crenatum* and lowest in *L. cernu*a (2.2%) (Fig.1). Highest ash produced in *L. cernua* (12%) followed by *B. subcrenatoides*, *B. orientale* and lowest in *H. crenatum* (2.5%) (fig. 2). Highest Nitrogen content present in *B. subcrenatoides* (4.03%) followed by *B. orientale, L. cernua* and lowest in *H. crenatum* (0.5%) (Fig. 3). Nitrogen is the primary essential macro-element. Total nitrogen reflects the total plant growth (Gallacher and Sprent, 1978). Nitrogen content required for optimal growth it varies between 2% to 5 % of the plant dry weight and it depends on the plant species developmental stage and organ of the plant (Marschner, 1986) as we know nitrogen is one of the most important elements found in all essential compounds such as proteins, nucleic acids, vitamins, some of the plant hormones viz. IAA and cytokinin, etc and hence involved in most of the biochemical reactions. Highest Phosphorus content present in *H. crenatum* (0.28%) followed by *B. orientale. L. cernua* and lowest in *B. subcrenatoides* (0.03%) (Fig4.). In the absence of phosphorus, life processes are simply impossible because of the fact that it is an essential constituent of nucleic acids, phospholipids which are building blocks of membranes; Phosphorus is a component of biological energy currency

ATP. Highest Potassium content present in *B. subcrenatoides* (1.75%) followed by *H. crenatum, B. orientale* and lowest in *L. cernua* (0.36%) (Fig. 5). This macronutrient is required in high concentrations for many plant species; it is the most abundant inorganic cation in plant cells (Schachtman and Liu, 1999). It also plays significant role in plant growth and developmental processes such as photosynthesis, translocation of protein and carbohydrates, stability of ribosomes, protein synthesis, nitrogen turnover and activation of enzymes, stomatal movement, and cell extension. Potassium is also necessary for starch synthesis, glycolysis, oxidative phosphorylation, photophosphorylation and adenine synthesis (Evans and Sorger, 1966). As potassium is highly mobile element (Mengel and Krikby, 1982), a positive correlation between the ability of a plant to resist water stress and potassium content. Plants deficient in potassium are thus less able to absorb water (Hubac *et al.,* 1986) in terrestrial plants the optimum values for K are 1.0% of dry weight. Our values are in conformity with Shetty (1971) who observed that K values range from 0.99 to 1.93% under non-saline conditions in *A. aureum*. Highest Calcium content present in *B. subcrenatoides* (2.63%) followed by *H. crenatum, B orientale* and lowest in *L. cernua* (0.54%) (Fig 6). Calcium is an essential plant nutrient which is required for various structural roles in the cell wall and membranes and needed for structural integrity of chromosomes and cell division. It is relatively immobile. The calcium content of plants varies between 0.1 and > 5.0% of dry weight depending on the growing conditions, plant species and plant organ (Marschner, 1986). The sufficient or normal level of calcium for the growth of plant is 1-4% (Munson 1998). The role of Ca2+ in membrane stability is not only of importance in ion uptake but also in other metabolic processes (Mengel and Kirkby, 1982). Calcium protects plants from the injurious effects of hydrogen ions (Rains *et. al*., 1964). Highest Magnesium content is present in *B. subcrenatoides* (5.85%) followed by *H. crenatum, B orientale* and lowest in *L. cernua* (1.2%) (Fig 7). Mg is a small, mobile and strongly electropositive divalent cation in the plants. The average values of Mg for optimum growth in land plants 0.2% (Epstein 1965). It is a structural constituent of chlorophyll and is needed for nucleic acid synthesis. It plays a crucial role in various physiological processes. The most well known role of Mg is its contribution to the center of the chlorophyll molecule, although chlorophyll Mg is relatively in small fraction of the total Mg content of a plant. It stabilizes the ribosomal particles in the configuration necessary for protein synthesis (Mengel and Kirkby, 1982). Highest Sulphur content present in *B. subcrenatoides* (1.91%) followed by *H. crenatum*, *B. orientale* and lowest in *L. cernua* (0.38%) (Fig. 8). Sulphur is essential in forming plant proteins because it is a constituent of certain amino acids. It is actively involved in metabolism of the B-vitamins, biotin, and thiamine and co-enzyme A, it aids in chlorophyll formation stabilizing protein structure. Highest sodium content present in *B. subcrenatoides* (2.42%) which is followed

Figures (1-15) : Mineral Content screening of four pteridophytes from Northern Western Ghats of Maharashtra.

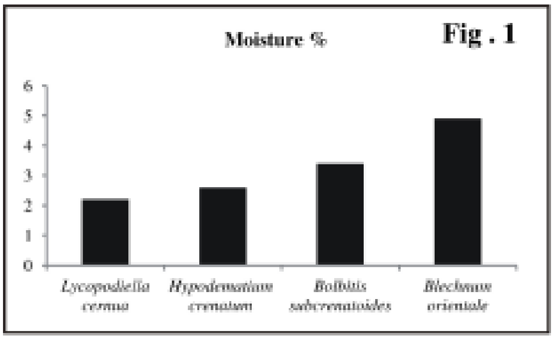


Fig . 1

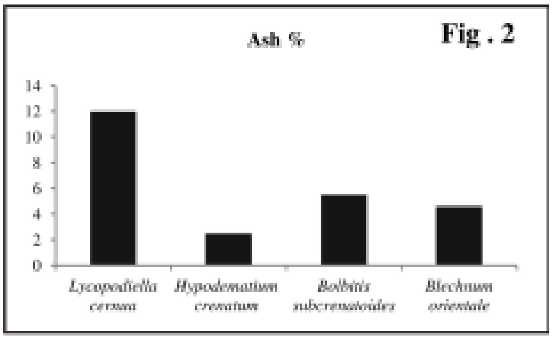


Fig . 2

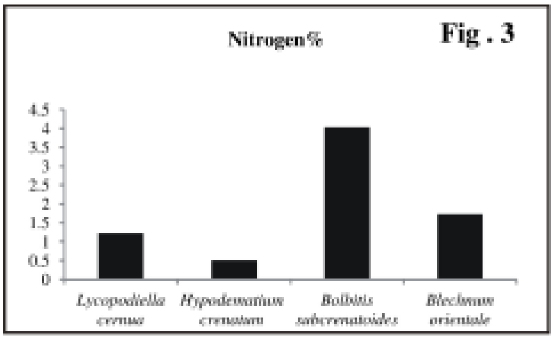
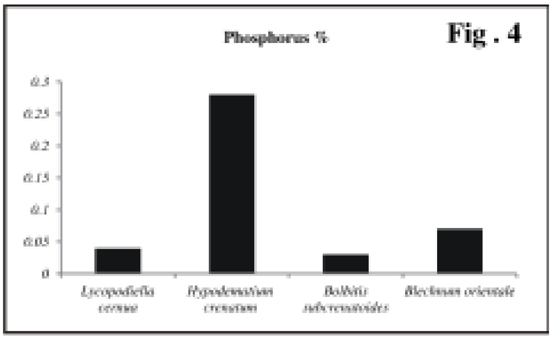


Fig . 3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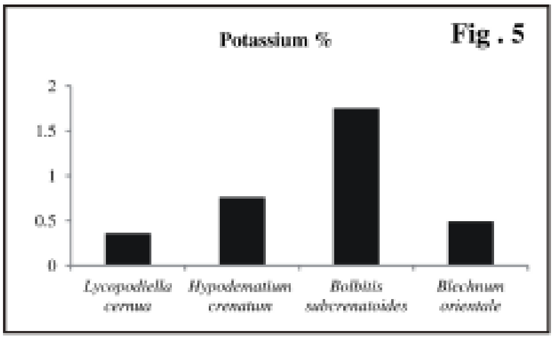
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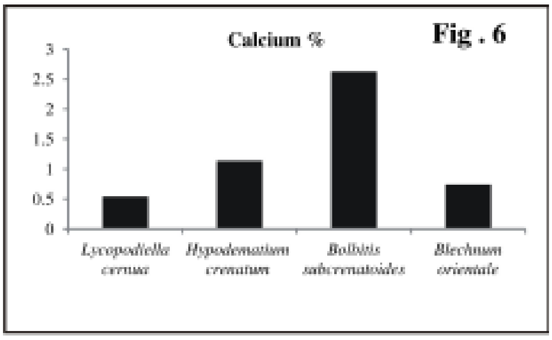
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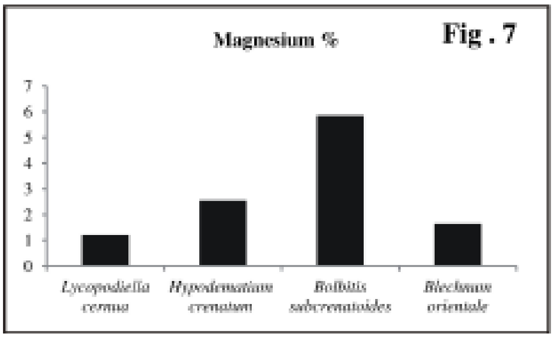
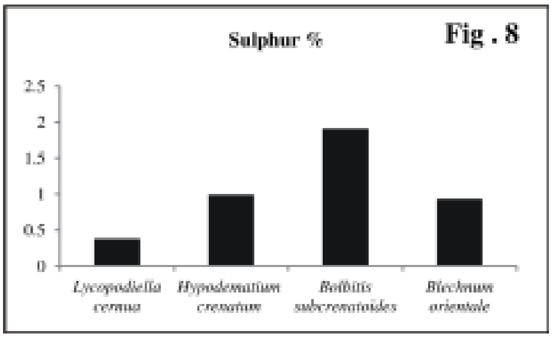


Fig . 7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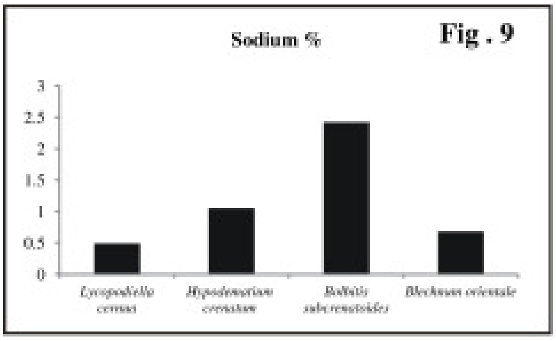

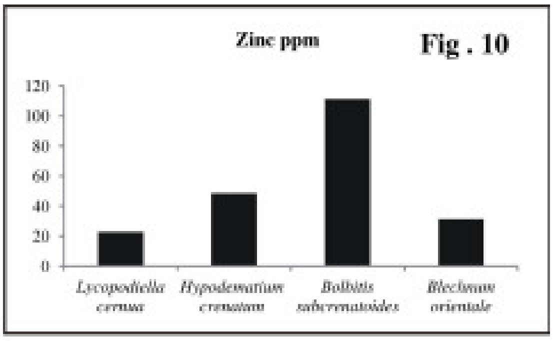

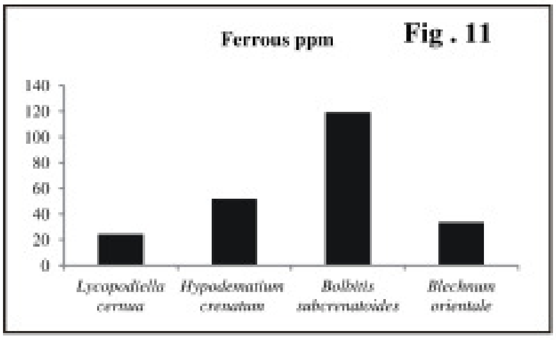

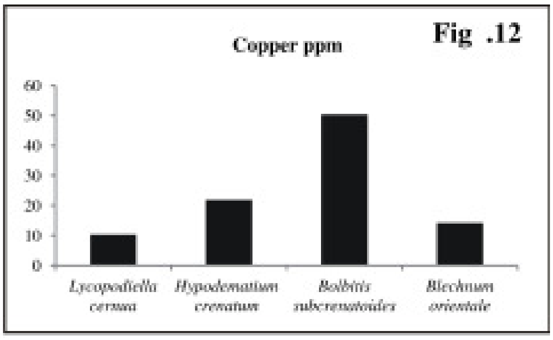

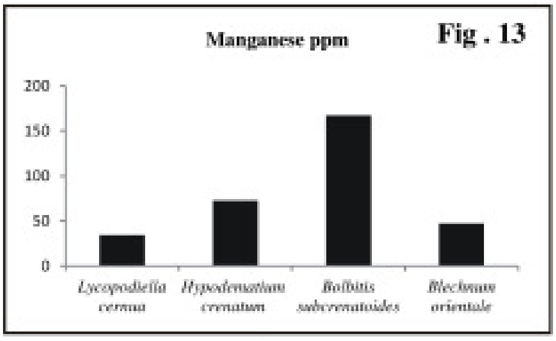

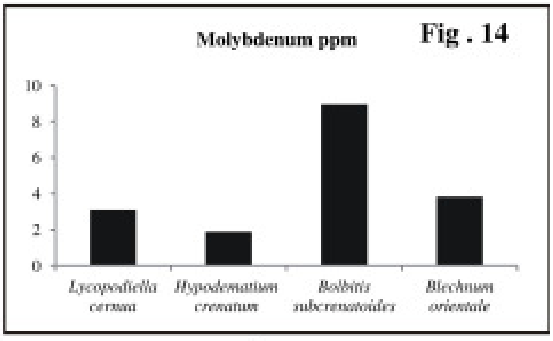

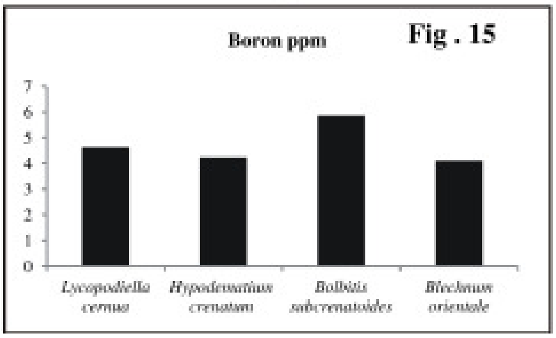

Figs. 1-15 : 1. Moisture (%), 2. Ash (%), 3. Nitrogen (%), 4. Phosphorus (%), 5. Potassium (%), 6. Calcium (%), 7. Magnesium (%), 8. Sulphur (%), 9. Sodium (%), 10. Zinc ppm, 11. Ferrous ppm, 12. Copper ppm, 13. Manganese ppm, 14. Molybdenum ppm, 15. Boron ppm by *H. crenatum, B. orientale* and lowest in *L. cernua* (0.49%) (Fig. 9). Sodium is useful for the plants and can also promote plant growth in relatively low concentrations (Marschner, 1995). It is beneficial to plant growth when present in traces. The role of Na in maintaining favorable water balance has also been suggested by (Rains 1972). When the water supply is limited, it improves the water balance of the plants via stomatal regulation. Under drought conditions, the stomata of plants supplied with sodium close more rapidly than plants supplied with potassium only and after stress release exhibit a substantial delay in opening. Shetty (1971) noted that Na+ uptake is dependent on climate and the place where the fern is growing. He also observed that in *A. aureum*, leaves contain more Na than other parts indicating that leaves are the store houses of sodium. His recorded values of Na in *A. aureum* range from 0.61 to 1.2 g 100-1 g dry tissue. Kale (2008) also recorded similar observations in 14 species of pteridophytes. It appears that Na is beneficial to plant growth when present in traces. Highest zinc present in *B. subcrenatoides* (111.38 ppm) which followed by *H. crenatum, B. orientale* and lowest in *L. cernua* (22.85 ppm) *(*Fig.10). Zinc is an essential micronutrient. It is found in substrate in very small quantities. It acts as an activator of many enzymes. It is required in traces for normal metabolism. It is required for the activity of various types of enzymes including Dehydrogenases, Aldolases, Isomerases, Transphosphorylases and RNA and DNA polymerases. Zinc is also essential for carbohydrate metabolism and regulation of consumption of sugars, nitrogen metabolism, protein synthesis, auxin synthesis, particularly IAA synthesis, as well as for sexual fertilization and development of reproductive parts. (Ozaki *et al.,* 2000) observed wide distribution of Zn, ranging from 0.69 to 1900 ppm. The highest Ferrous present in *B. subcrenatoides* (119.34 ppm) and lowest in *L. cernua* (24.48 ppm) which followed by *H. crenatum, B. orientale* (Fig.11). Ozaki *et al.*, (2000) studied 96 pteridophytes and observed that the concentrations of Fe ranges from 13 ppm to 5300 ppm It has been reported that in the leaf 80% of Fe is located in the chloroplasts (Marschner, 1995). According to Epstein (1965) the average values for Fe in land plants are 0.011 mg per 100 g dry tissue. Highest Copper content is present in *B. subcrenatoides* (50.31 ppm) which is followed by *H. crenatum, B. orientale* and lowest in *L. cernua* (10.32 ppm) (Fig.12). Cu is a micronutrient and hence required by the plants in minor quantities. Copper is highly toxic to plant in higher concentration. It is regarded as essential micronutrient because, it is a component of several metalloenzymes and it appears to act as an intermediate electron acceptor in the direct oxidation of substrate by molecular oxygen. Photosynthesis and respiration are two major processes in plants, which determines the plant productivity and copper plays important role in both these processes. The normal range of copper content in agricultural crops is reported to be 5 to 30 mg kg-1 dry weight (Gupta, 1979). It reacts with amino acids, proteins and other biopolymers producing stable complexes. It is an important constituent of a number of enzymes such as polyphenol oxidase, cytochrome oxidase, ascorbic acid oxidase and tyrosinase. It also plays an important role in nitrogen metabolism, lignin synthesis, enhances the cell wall strength and adds in prevention of wilting. De Britto *et al.,* (1994) reported the content of copper ranging from 0.0001 to 0.0009 mg/g in Theylpteroid ferns. Highest Manganese present in *B. subcrenatoides* (167.31 ppm) which is followed by *H. crenatum, B. orientale* and lowest in *L. cernua* (34.32 ppm) (Fig.13). Manganese is an essential element in respiration and nitrogen metabolism acts as an activator; it is essential cofactor for superoxide dismutase. It is also involved in the synthesis of chlorophyll. Highest Molybdenum content present in *B. subcrenatoides* (8.97 ppm) and lowest in *H. crenatum* (1.9 ppm) which is followed by *B. orientale, L. cernua* (Fig.14). Although Mo is a metal, it occurs in aqueous solution mainly as molybdate anion, it is relatively mobile in plants and higher concentration can be found in roots than leaves. It is essential in nitrogen fixation and nitrate reduction and for plant growth. Range of concentration for higher plants is from 0.10-10 ppm. Highest Boron content is present in *B. subcrenatoides* (5.85 ppm) which is followed by *L. cernua, H. crenatum* and lowest in *B. orientale* (4.77 ppm). Helps in protein synthesis, formation of plant hormones, promotes maturity, help in water relation in plant.

Out of nearly 1200 species of pteridophytes occurring in India, 170 species have been informed to be used as food, flavor, dye, medicine, bio-fertilizers, oil, fiber and biogas production. The medicinal importance of pteridophytes against bacteria, fungi, virus, cancer, rheumatism, diabetes, inflammation, fertility, diuretic pesticides, and as hepato-protective and sedative, has been reported. Besides sugar, starch, proteins and amino acids, ferns contain a variety of alkaloids, glycosides, flavonoids, terpenoids, sterols, phenols, sesquitorpens etc. as potential components used in various industries (Manickam & Iradayaraj, 1992, Goswami et al. 2016). Nitrogen is required to develop proper green colour in ferns; weather primary macronutrients Nitrogen (N), Phosphorus (P), Potassium (K) are needed for growth of ferns, three secondary macronutrients: Calcium (Ca), Sulphur (S), Magnesium (Mg) are also important for growth of fern and fern allies. The micronutrients/ trace minerals: which required by pteridophytes are Boron (B), Manganese (Mn), Iron (Fe), Zinc (Zn), Copper (Cu), Molybdenum (Mo).

CONCLUSION

These plants have a great medicinal value as it has been reported to have versatile phytochemical constituents. The data on mineral content analyses will be useful for knowing the micro- and macro-elemental details of these species. Further this will help in uses of these pteridophytes in different food, medicines and other uses. The pteridophyte species along with rhizome are an abundant source of phytochemicals, which would enrich today's opportunities in pharmaceuticals, nutraceuticals and food applications for human strength.

ACKNOWLEDGMENT

The authors are thankful to DST- SERB, New Delhi for funding a major research project entitles as "Ecological Status of pteridophytes from the Northern Western Ghats of Maharashtra" under the scheme Start Up Research Grant (Young Scientist) and also to Scientist experts from BSI and Indian fern Society members for helping in identification of plants and also to the Principal, Abasaheb Marathe Arts & New Commerce, Science College, Rajapur. Dist: Ratnagiri, for providing laboratory facilities.

REFERENCES

ARNON & STOUT 1939 The essentiality of certain elements in minute quantity for plants with special reference to copper *Plant Physiology College of Agriculture University of California* 1939

BEDDOME R H 1883 *A Handbook to the Ferns of British India* Ceylon and Malay Peninsula Thackar Spink & Co Calcutta Reprint Ed 1978 Today and Tomorrows Printers and Publishers New Delhi pp 500

BLATTER E & J F D'ALMEIDA 1922 *The Ferns of Bombay* P B Taraporevala Sons & Co 190 Hornby Road Fort Bombay pp 223

DE BRITTO A, MANICKAM V S & GOPALAKRISHNAN S 1994 Phytochemical studies on members of *Theylpteridaceae* of the Western Ghats South India *Ind Fern J* **11** : 116-123

EPSTEIN E 1965 Mineral metabolism In : *Plant Biochemistry* J Bonner and J E Varner (eds) New York Academic Press pp 438-466

EVANS H J & SORGER G J 1966 Role of mineral elements with emphasis on the univalent cations *Ann Rev Plant Physiol* **17** : 47-77

FRASER-JENKINS C R 2008 *Taxonomic Revision of Three Hundred Indian Subcontinent Pteridophytes with a Revised Census* List Bishen Singh Mahendrapal Singh Dehara Dun pp 685

GALLACHER A E & SPRENT J I 1978 The effect of different water regimes on growth and nodule development of green house grown *Vicia faba J Exp Bot* **29(109)** : 413-423

GOSWAMI H K, KAKALI SEN & MUKHOPADHYAY R 2016 Pteridophytes : evolutionary boon as medicinal plants *Plant Genetic Resources* **14(4)** : 328-355

GUPTA U C 1979 Copper in agricultural crops In: *Copper in the Environment Part I : Ecological cycling J O Nriagu (ed)* John Wiley & Sons New York pp 255-288

GHOSH S R, B GHOSH, A BISWAS & R K GHOSH 2004 The Pteridophytic Flora of Eastern India 1 *Flora of India Ser 4* Botanical Survey of India Kolkata pp 591

HUBAC C, GUERRIER D & BOUSQUET U 1986 Effect of four red light on malate and potassium contents in cotton leaves : Relation to drought resistance *Physiol Plant* **66(1) :** 37-40

KALE M V 2008 Phytochemical studies in the dimorphic leaves of some pteridophytes Ph D thesis submitted to Shivaji University, Kolhapur (Mah-India)

MANICKAM V S & IRUDAYARAJ V 1992 *Pteridophyte Flora of the Western Ghats – South India* B I Publications New Delhi

MARSCHNER H 1986 *Mineral nutrition of higher plants* Pub Academic Press New York

MARSCHNER H 1995 *Mineral nutrition of higher plants* 2nd Ed (Publ) Academic Press Inc : San Diego pp 889

MENGEL K & KIRKBY E A 1982 *Principles of Plant Nutrition* IIIrd ed (Publ) Int Potash Inst Bern Switzerland

MUNSON R D 1998 Principles of Plant Analysis In: *Handbook of Reference Methods for Plant Analysis (eds)* Kalra Y P (Publ) Soil and Plant Analysis Council Inc pp 1-24

OZAKI T, SHUICHI E, YOSHITAKA M, SHIZUKO A & YOSHIHIRO M 2000 A survey of trace elements in Pteridophytes *Biological Trace Element Research* **74** : 259-272

RAINS D W 1972 Salt transport by plants in relation to salinity *Ann Rev Plant Physiol* **23** : 367-388

RAINS D, WALTER W, SCHMID E & EPSTEIN E 1964 Absorption of Cations by Roots Effects of Hydrogen Ions and Essential Role of Calcium *Plant Physiol* **39** : 274-278

SCHACHTMAN D & LIU W 1999 Molecular pieces to the puzzle of the interaction between potassium and sodium in plants *Trends in Plant Sci* **4(7)** :281–287

SHAIKH S D & DONGARE M 2010 Effects of Mining on the Diversity of the Pteridophytes from the Western Ghats of Maharashtra (India) *World Applied Sciences Journal* **11(12)** : 1547-1551

SHETTY G P 1971 Physiology of growth and salt tolerance of plants Ph D Thesis submitted to Shivaji University Kolhapur (India)

WILD M 2005 Does lack of available suitable habitat explain the patchy distributions of rare calcicole fern species? *Ecography* **28(2)** : 191-196

Indian Fern J. **36 :** 89-94 (2019) ISSN 0970-2741

SPORE MORPHOLOGY OF FOUR SPECIES OF PTERIDOPHYTES FROM NORTHERN WESTERN GHATS OF MAHARASHTRA (INDIA)

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ABSTRACT

The Western Ghats, one of the World's 12 mega-biodiversity hotspots, is having rich diversity of flora and fauna with many endemic and RET species due to its geographical location. It is with a highly predictable climate has a rich pteridophytic flora. In the present study, we investigated five rare, endangered and threatened fern species from Northern Western Ghats of Maharashtra were examined. Spore size, shape, ornamentation and colour will be helpful in morphotaxonomy for the accurate identification, conservation and cataloguing the basic data. This study reports spore morphology and their Scanning Electron Microscopy *of four species, Hypodematium crenatum* (Forssk.) Kuhn*, Blechnum orientale* L., *Osmunda hugeliana* Presl. *Psilotum nudum* (L.) P. Beauv, *Bolbitis subcrenatoides* Fraser-Jenk.

Key Words : Northern Western Ghats, Pteridophytes, RET, SEM, Spores

INTRODUCTION

Spore morphology as a distinctive taxonomic character of high significance in assessing phylogeny and relationships of ferns by Devi (1977). Palynology data are very useful for taxonomic purposes at all level of fern family and it's below, Yea et al., 2000). Nayar & Devi (1965) described spore morphology of 10 species of grammitid ferns from India. Vijayakanth and Sahaya Sathish (2016) also studies spore morphology of pteridophytes from Kolli Hills, Eastern Ghats, Tamil Nadu. The present investigation adds more details to previous studies for spore morphology of the ferns from Belgaum district; In the recent years, however the pteridological studies have pulled out in various parts of the country, many questions related to the pteridophytic diversity of the Western Ghats remain unexplained and hence, more studies are required for developing *in situ* and *ex situ* conservation strategies for this wonderful and important group of plants. Hence the present study taken to account of SEM of spores of five rare, endangered and threatened species of pteridophytes from Northern Western Ghats of Maharashtra region, *viz. Hypodematium crenatum* (Forssk.) Kuhn*, Blechnum orientale* L., *Osmunda hugeliana* Presl. *Psilotum nudum* (L.) P. Beauv, *Bolbitis subcrenatoides* Fraser-Jenk.

MATERIAL AND METHODS

Fully mature plants are collected from various localities in Western Ghats of

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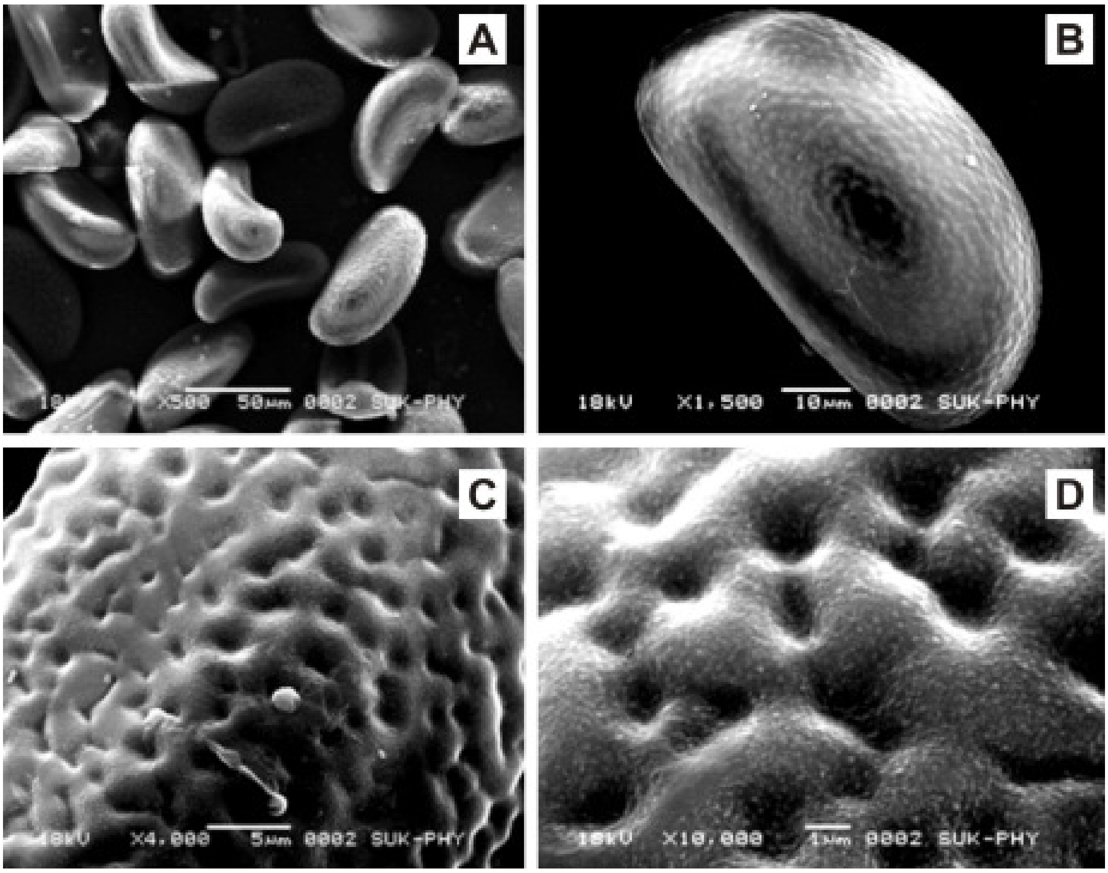
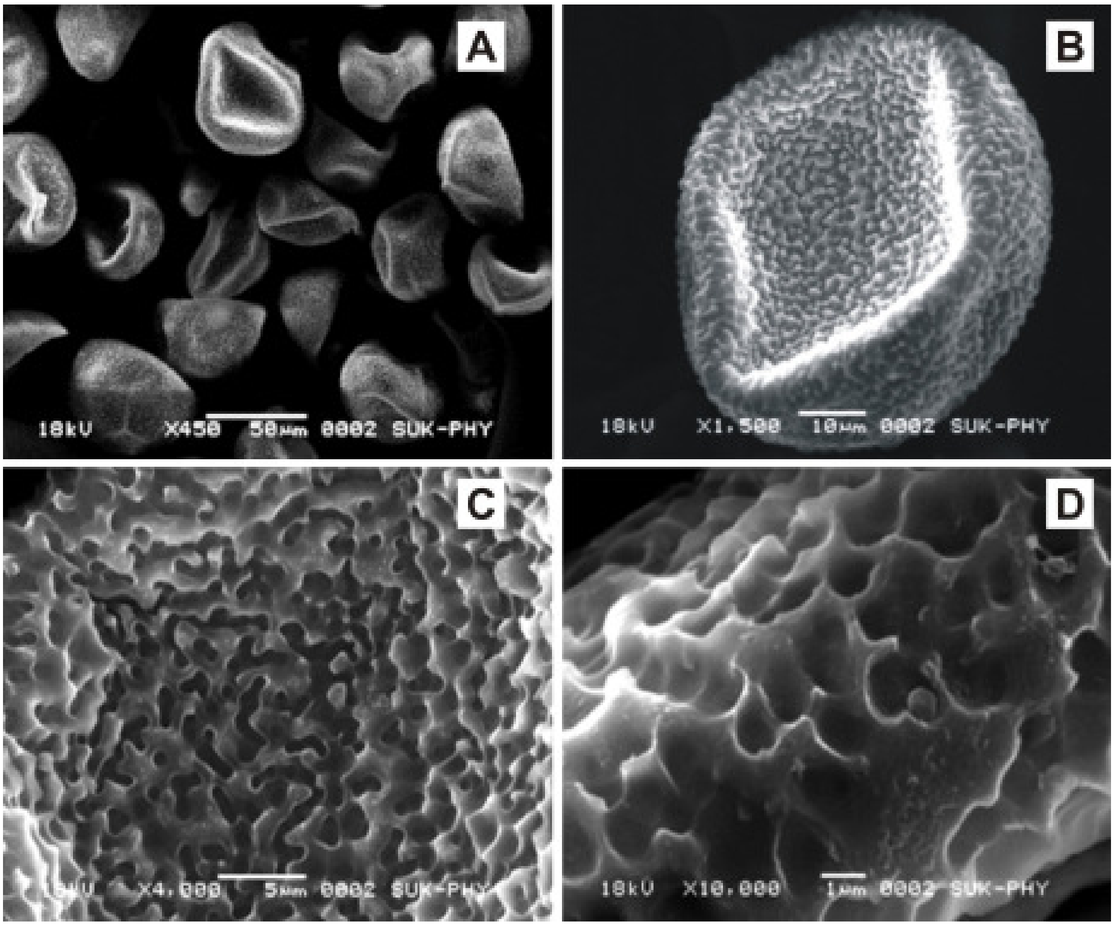


Figures 1 (A-D) : Scanning electron micrographs of fern spores of *Psilotum nudum* (L.) P. Beauv. (**A.** Spores, **B.** Proximal view, **C.** Distal view, **D.** Enlarged surface)

Maharashtra The specimens were identified by the different Pteridophytic flora and online published articles. *Hypodematium crenatum* (Forssk.) Kuhn, *Blechnum orientale* L., *Osmunda hugeliana* Presl. *Psilotum nudum* (L.) P. Beauv, *Bolbitis subcrenatoides* Fraser-Jenk.. Habitat and the morphometric details were documented in the field. Fresh material was fixed in FAA for further studies. Spores were collected and washed two times with absolute alcohol and air dried then stored for SEM analysis. After SEM analysis spore description analyzed by A textbook of Palynology (Bhattacharya et al. 2011) The herbarium vouchers were prepared from each locality.

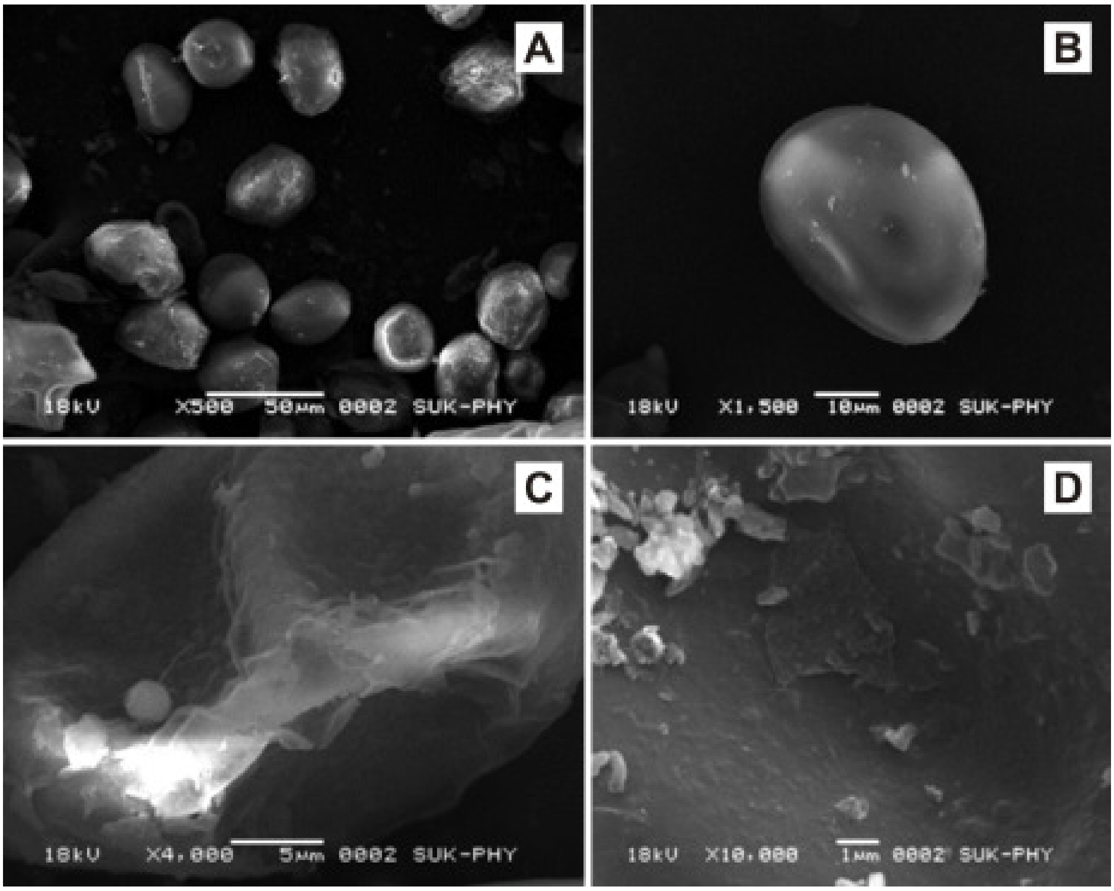
RESULTS AND DISCUSSION

Psilotum nudum is a homosporous ptridophyte, with numerous spores, variable in shape, mostly rod or oval shaped, slightly elongated, hyaline and obtuse at both the ends, smooth or sometimes triangular and constricted on one or two sides; 71 x 40 μm, exine



Figures 2 (A-D) : SEM of spores of *Osmunda hugeliana* C. Presl (**A.** Spores, **B,C.** Distal view, **D.** Enlarged surface)

surface is verrucate to tuberculate (Fig. 1). ***Osmunda hugelina*** has trilete spores, tetrahedral to globose in shape, size 61X50 µm, colour light brown, circular in amb variation is observed in size, exine is densely granulose prominent and papillate (Fig. 2). ***Blechnum oriantale*** spores are monolete, spherical to ovoid, 30 x 40 µm, yellowish-brown, spore appears elliptic in polar view, exine slightly rugulate to low-medium perforate surface while perine is smooth, loose, devoid of any folds (Fig. 3). ***Hypodematium crenatum*** spores are monolete, bilateral, size 32 x 45 µm, colour reddish brown, spores appear oblong in polar view and convex in distal view, exine smooth, perine densely granulate, and folded into thin often sinulate folds which are broadly conical (Fig. 4). ***Bolbitis subcrenatoides*** is a dimorphic fern,; spores are monolete, spheroidal, 49 x 38 µm, perisopre is rough with folds or widely undulate (Fig. 5).



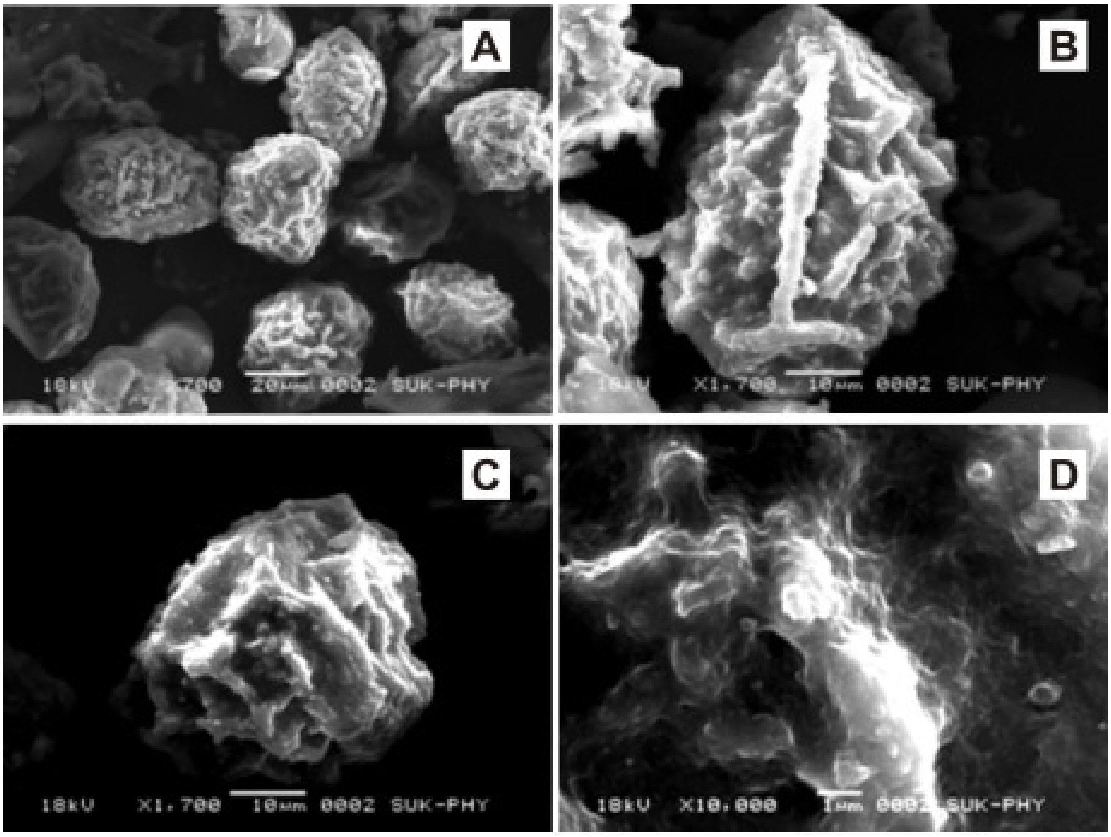
Figures 3 (A-D) : Scanning electron micrographs of fern spores of *Blechnum orientale* L. (**A.** Spores, **B.** Distal view, **C.** Proximal view, **D.** Enlarged surface)

TABLE 1 : Summary of spore morphology with special emphasis on type, shape, size and colour

Name of species	Spore type	Shape	Size µm	Colour
Psilotum nudum	Monolete	Oval to Reniform	71x40	Light yellow
Osmunda hugeliana	Trilete	Globose-Tetrahedral	61x50	Light Brown
Blechnum orientale	Monolete	Spherical to Ovoid	30x40	Yellowish-Brown
Hypodematium crenatum	Monolete	Bilateral	49x38	Reddish- Brown
Bolbitis subcrenatoides	Monolete	Spheroid	32x36	Pale brown

CONCLUSION

The findings of the present study include the colour, shape (amb), size (range of equatorial diameter), laesurae (type and length), surface ornamentation and micro-sculpture

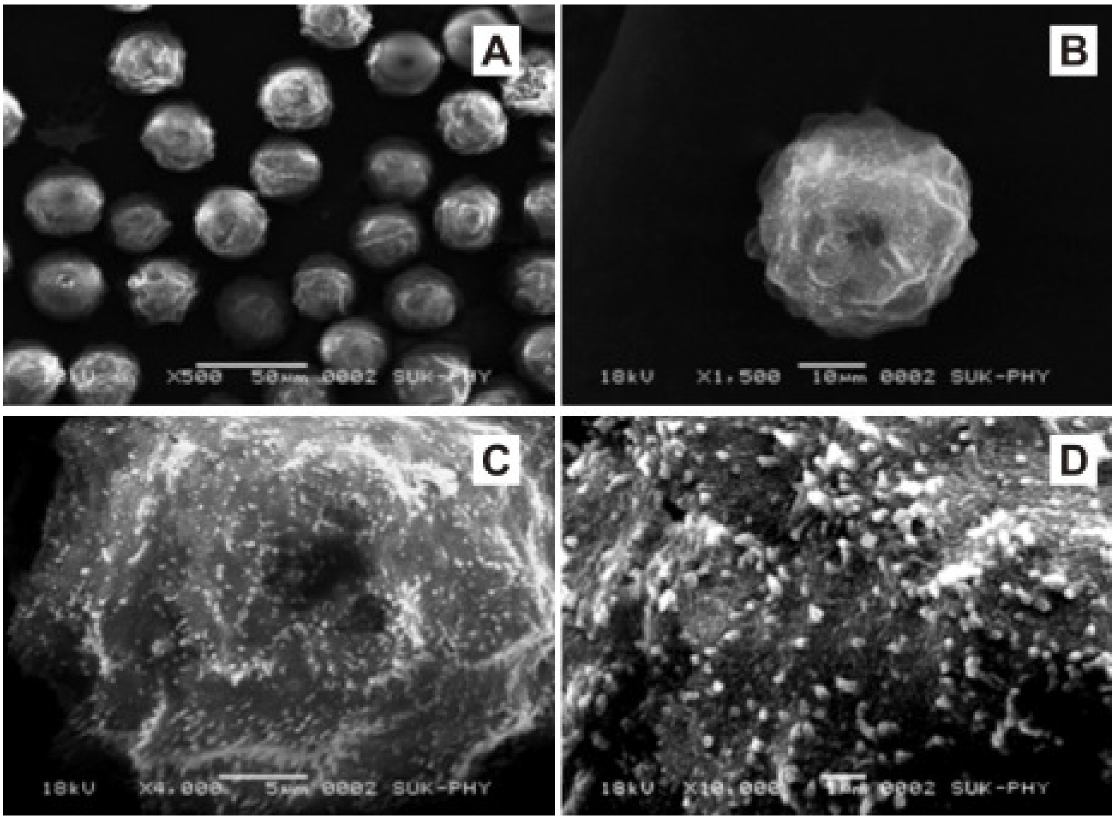


Figures 4 (A-D) : Scanning electron micrographs of fern spores of *H. crenatum* (Forssk.) Kuhn (**A.** Spores, **B.** Proximal view, **C.** Distal view, **D.** Enlarged surface)

of spores which includes proximal, distal and enlarged surface view. This study provides unique information on morphological characters of fern spores collected from Northern Western Ghats of Maharashtra. The morphogical data of spores may be useful for palynologists and allergic studies.

ACKNOWLEDGMENTS

The authors are thankful to DST- SERB, New Delhi for funding a major research project entitles as “Ecological Status of Pteridophytes from the Northern Western Ghats of Maharashtra” under the scheme Start Up Research Grant (Young Scientist) and also to Scientist and experts from BSI and Indian Fern Society for helping in identification of plants. Authors are also thankful to the Principal, Abasaheb Marathe Arts & New Commerce, Science College, Rajapur. Dist: Ratnagiri, for providing laboratory facilities.



Figures 5 (A-D) : Scanning electron micrographs of fern spores of *Bolbitis subcretanoides* Fraser-Jenk. (**A.** Spores, **B, C.** Distal view, **D.** Enlarged surface)

REFERENCES

BHATTACHARYA K, MAJUMDAR M R & GUPTA-BHATTACHARYA S 2011 A *Textbook of Palynology* (*Basic and Applied)* New Central Book Agency (P) Ltd Kolkata

DEVI S 1977 *Spore in Indian Fern* Todays & Tomorrows Printers & Publications New Delhi

NAYAR B K & SANTHA DEVI 1965 Spore Morphology of Indian Ferns *Grana* **6(1)** : 121-127

P VIJAYAKANTH & S SAHAYA SATHISH 2016 Vol 4 (Issue 1) Page 10

P VIJAYAKANTH & S SAHAYA SATHISH 2016 Vol 4 (Issue 1) Page 10

STUDIES ON THE SPORE MORPHOLOGY OF PTERIDOPHYTES FROM KOLLI HILLS, EASTERN GHATS, TAMIL NADU, INDIA

VIJAYAKANTH P & SAHAYA SATHISH 2016 Studies on the spore morphology of pteridophytes from Kolli Hills Eastern Ghats Tamil Nadu India *International Journal of Research in Engineering and Biosciences* **4(1) :** 1-12

YEA C L, CHEN M K, HO Y L 2000 SEM studies on spore in Taiwanese fern genera I, Athyrioids *Taiwania* **45(2) :** 181-200

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TAXONOMY AND CYTOLOGY OF *THELYPTERIS LEBEUFII* (BAKER) PANIGRAHI

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ABSTRACT

Thelypteris lebeufii (Baker) Panigrahi (Thelypteridaceae). [= *Christella lebeufii* (Bak.) Holtt.], an invasive species, has been collected from a semi-natural forest of Hooghly district, West Bengal- a part of the lower Gangetic plains of India. Taxonomic circumscription of the species has been provided in detail with its distributional divergence in the flood plain as well as open land of forest-floor. The associated plants are mainly *Thelypteris dentata* (Forssk.) E. P. St. John and *Thelypteris prolifera* (Retz.) C. F. Reed. in the flood prone areas but in the forest-floor areas and at forest edge, it is accompanied by *Diplazium esculentum* (Retz.) Sw. The plant outcompetes the other associated components and easily invades through its long creeping rhizome. The cytology of the plant is reported here for the first time. Meiotic plate count was recorded as n=36.

Key Words : *Thelypteris lebeufii* (Baker) Panigrahi, cytology.

INTRODUCTION

Thelypteridaceae is a large family of ferns with about 1000 species containing 8% of all known ferns. Several workers have contributed immensely towards understanding the classification and taxonomy of family Thelypteridaceae (Ching 1963, Copeland 1947, Iwatsuki 1963-1965, Nayar 1970, Khullar 2000, Khare *et al.* 1983, Sledge 1981, Pichi Sermolli 1977, and many others). However the most important contribution regarding the generic concept within Thelypteridaceae was brought out through a series of publications by Holttum (1969,1970, 1971a-c, 1977, 1982). In India the family is represented by 80 species and 16 hybrids (Fraser-Jenkins *et al.* 2017). Molecular phylogentic work by Smith *et al.* (2006) accepted five genera in the family Thelypteridaceae. For convenience a single genus concept has been accepted as proposed by Smith, Kramer, and others who sink the many similar genera in the genus *Thelypteris* (Almedia *et al.* 2016). Data from three chloroplast genes (rps4, trnS spacer, trnL spacer; 1350 base pairs) for 27 of the recognized segregates show family Thelypteridaceae to be monophyletic and sister to an unresolved alliance of Blechnoid, Athyrioid, Onocleoid and Woodsioid ferns (Smith & Cranfill 2002).

Family Thelypteridaceae is characterized mainly by: short or long creeping rhizome, presence of two vascular strands at the base uniting to form a 'U'- shaped strand at the upper side of the petiole, pinnate-pinnatifid or bipinnatifid frond, presence of hairs and glands throughout, indusiate or exindusitae sorus, open pinnate and/or anastomosing veins

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Corresponding author E-mail : * itskakali@gmail.com, ** sp.khullar@gmail.com in the sinus membrane, chromosome base number variable x = 27-36.

Thelypteris lebeufii (Bak.) Panigrahi has also been treated under the genus *Christella.* The genus *Christella* was established by Léveillé (1915) without designation of the Type species. It was a large complex genus; some species have been proved to be members of *Dryopteris* and *Athyrium* (Holttum 1971b). Holttum (1971b) typified and redefined *Christella* as a genus with more or less reduced lower pinnae, no spherical glands on lamina or glands/hairs on the capsule of the sporangia (Li *et al.* 2013). Another feature of the genus *Christella* is generally anastomosing veins (but even this is a variable character). Schuettpelz *et al.* (2016) separate *Christella,* containing 70 species including *Christella parasitica* as its type species, and *Cyclosorus*, as separate taxa, the latter having 2 species. Holttum (1976) described fifty one species of *Christella.*

Fraser-Jenkins *et al.* (2017) mention the distribution for *Thelypteris lebeufii* from: INDIA: (Assam state, Manipur, Mizoram, Nagaland, Tripura, Uttarakhand, Uttar Pradesh, West Bengal). For ASIA: Bangladesh, Cambodia, Myanmar, Nepal, Thailand, S. China and S.E. Asia). To-date there is no record of the chromosome number of this species.

MATERIALS AND METHODS

Material of *Thelypteris lebeufii* was collected from Hooghly district, West Bengal. Dry specimens have been preserved in the Herbarium Department of Botany, University of Kalyani. (Provenances of the specimen: A-26, 22/05/17, Anish Bhattacharya and Kakali Sen). A few plants have been planted and maintained in the experimental garden of the Department of Botany, University of Kalyani.

Macroscopic and microscopic study was carried out with the help of simple microscope, stereo-microscope (Olympus). The micro-morphology and cellular details are imaged with Nikon E200. For chromosome study, 2-3 fresh pinnae bearing young sori were collected between 8.00 to 8.15 a.m. and fixed in Carnoy's fixative (acetic acid - ethyl alcohol in 1:3 ratio) then kept for a day in refrigerator. Immature or developing sori were crushed to get a countable meiotic plate. The collected sporangia from the sori were crushed and stained with the help of aceto-carmine stain and observed under Compound trinocular microscope (Nikon eclipse, E200).

TAXONOMIC DESCRIPTION OF THE SPECIES

Thelypteris lebeufii (Baker) Panigrahi — Notes Roy. Bot. Gard. Edinburgh 33: 498. 1975

Christella lebeufii (Baker) Holttum in Nayar & Kaur, Companion Beddome's Handb. Ferns Brit. India 206. 1974

Collection Site: Hoogly district, West Bengal

Habitat : Terrestrial, found in flood plain areas as well as open flat land of forest floor.

Association and ecological notes : In flood land areas *Thelypteris prolifera*

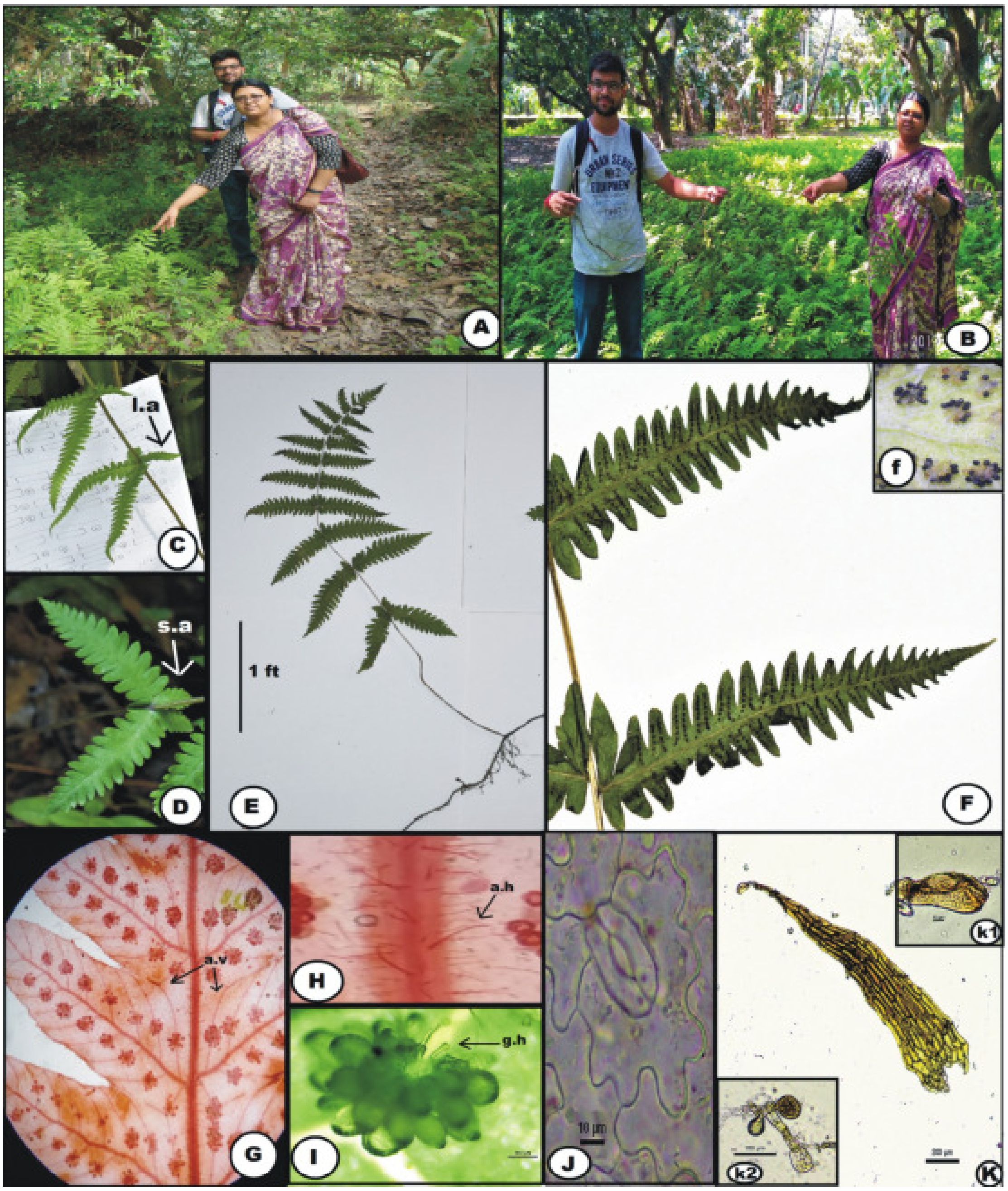

Fig. 1 [A-K] : Habitat diversity of *Thelypteris lebeufii* **(A)** In flood land **(B)** In open forest floor **(C)** Flood land species showing large auriculation (l.a) **(D)** Forest floor species showing short auriculation (s.a) **(E)** Entire Plant with horizontal rhizome **(F)** Pinna showing sorus (f-enlarged view) **(G)** Portion of pinna showing anastomosing veins (a.v.). **(H)** Acicular hair (a.h.) **(I)** Glandular hair on the indusium (g.h) **(J)** Stomata **(K)** Rhizome scale showing glandular tip (k1), detached branched gland (k2)

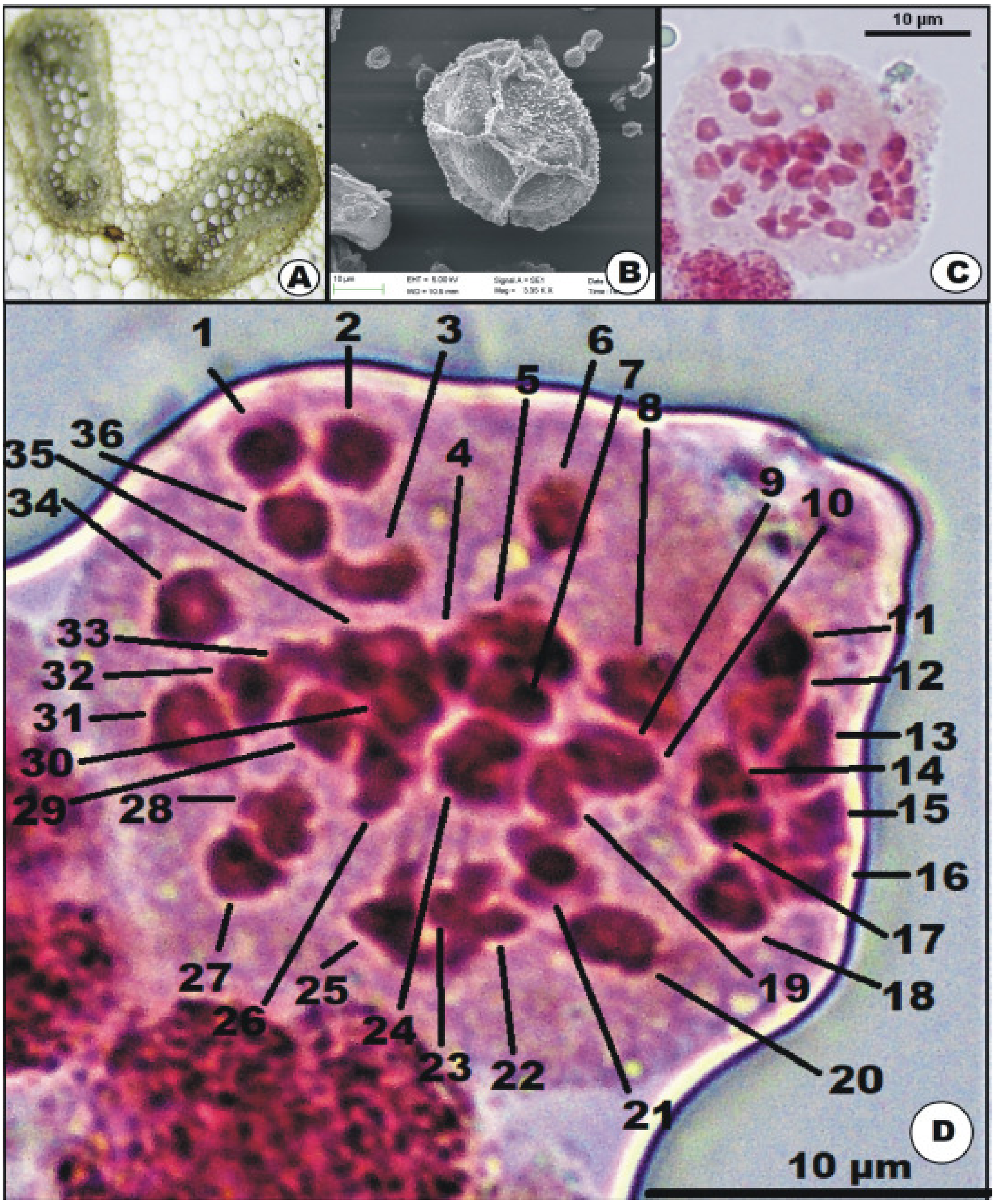

Fig. 2 [A-D] : (A) T.S of petiole **(B)** Spore **(C)** Meiotic plate , n = 36, **(D)** Explanatory to Meiotic plate at C, enlarged to show count of 36 pairs of chromosomes at diakinesis.

and *Thelypteris dentata* are found growing in association with this species. But in the forest-floor *Diplazium esculentum* and *Thelypteris prolifera* plants are present at the edge of the forest. The rhizome grows continuously and out competes the plants in association.

Macro-morphology : Plant terrestrial, grows along banks of canals, that separate the forest land **(Fig.-1 A)** into small sector (get flooded during rains). Also grows on the forest floor flat land areas **(Fig.-1B).** Plant height varies from 30-63.5 cm., Roots are present on the ventral surface of the rhizome generally in pairs, each one from opposite side of the rhizome, thin fibrous, not longer than 3.5 cm (flood plain) or 10 cm. (forest floor), Rhizome deep brown, long creeping 30 cm (flood prone areas) to 300 cm. **(Fig.-1 B)** (in forest floor open land), 1-2 cm in dia, dichotomously branched at the apices, scales present, deciduous with the rhizome maturity, but the growing end covered with dense scales, scales bicolorous, non clathrate, glandular at the tip, basifixed, margin entire **(Fig.1 K, k1**). Stipe length variables (26 cm. mean) thin, flexible/very delicate, covered with hair, hair acicular, brown in color. Stipe- lamina length ratio 1.4, at very young stage few scales are there at the base of the stipe, cellular details like the rhizome scale. Rachis thin, delicate, brown in color, having a dorsal groove. Lamina longer than stipe, L 37.4cm , W-16.6cm; the fertile fronds are usually noticeably taller than the sterile and the diagnostic lowest acroscopic pinnule in lower and mid pinnae can become very long sometimes, up to a third or nearly half the length of the pinna; pinnate-pinnatifid, pinnate at the basal and middle segments and pinnatifid at the apex, oblong-lanceolate, texture herbaceous, pinna length 8 cm., W-1.8 cm., pinna sessile **(Fig. 1F),** subopposite to alternate, lanceolate, basal one to two pair slightly reduced, basal-most pinna deflected to the lower side, basal 2-3 pairs of pinna with abruptly large basal most acroscopic segment sometimes giving the butterfly like appearance. In the open forest floor the segment is not much enlarged **(Fig. 1 D);** but in the flood land areas the segment is strikingly enlarged **(Fig.1 C);** apex acuminate; margin deeply lobed about ¾ th to the costa, lobes regular slightly oblique, sessile, subopposite, apex of the lobe obtuse to acute, no. of lobes 15-39 pairs, no. of veins in lobes 12 pairs. Sori superficial, medianly placed on the both side of the tertiary vein and diverging at the base **(Fig.-1 F),** sporangia deep black color at the maturity, indusium present but indusium is very short cannot cover the entire mass of the sporangium, indusia with acicular and glandular hair **(Fig. 1 I**); Sori ripening: July-September.

Micro-morphology : Epidermal cells deeply lobed, stomata polocytic type(Fig.-1 J), guard cell length 30 mm, width – 20 mm ; stomatal index 29%. Two types of hairs present acicular and glandular, Acicular hairs present on both the surface of the lamina, costae, costules, veins and interveinal region, glandular hairs on costa and costules (Fig. 1 I), venation open pinnate type, 1-1.5 pairs of excurrent tertiary veins anastomose at the sinus (Fig.1 G). Spores monolete, size P x E 29 x 20.85 mm; perisporic, perine 4.25 mm in thickness and exine 1.94 mm thick; with a prominent wing like ridges and rugulose surface (Fig. 2 B).

Cytology: In meiotic plates 36 bivalents are recorded at diakinesis, establishing n=36 **(Fig. 2 C, D).** Each sporangium yields 64 spores. The species is therefore a diploid sexual.

Anatomy: Two horse shoe shaped bundle at the base of the petiole **(Fig.2 A)** gradually merges when goes to the upper side. upwards, to a U-shape in transverse section.

DISCUSSION

The species *Thelypteris lebeufii* (*Christella lebeufii)* is not much known in detail from India. It was probably misidentified, in India, as *Thelypteris procera* (D. Don) Fraser-Jenk. (*T. procera* has a narrower lamina base, deeper-cut and narrower segments and markedly longer, thicker white hairs beneath the pinnae. (Fraser-Jenkins *pers. comm.* to SPK).

A detailed taxonomic description as well as the ecology and cytology of the species has been provided. The chromosome count of *Thelypteris lebeufii* was so far unknown (Löve *et al.* 1977, Bir & Verma 2010). The present cytological record of the species is therefore the first cytological count for this species. *Thelypteris lebeufii* has a gametic count of n=36 making this species a diploid sexual.

The species is 'invasive" in nature. It outcompetes the other plants present in its vicinity and reduces the inter-specific competition. *Thelypteris lebeufii* (*Christella lebeufii*) is scattered in N.E. India and Bangladesh and rare in S.E. and C. Nepal and also at Dudhwa in U.P. Even found as far west as Katima swamp, Tanakpur, Uttarakhand (Fraser-Jenkins *et al.* 2017).

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REFERENCES

ALMEIDA T E, HENNEQUIN S, SCHNEIDER H, SMITH A R, BATISTA JAN, RAMALHO AJ, PROITE K & SALINO A 2016 Towards a phylogenetic generic classification of Thelypteridaceae : Additional sampling suggests alterations of neotropical taxa & further study of paleotropical genera *Molecular Phylogenetics & Evolution* **94** : 688-700

BIR S S & VERMA S C 2010 Chromosome atlas of the Indian Pteridophytes Bishen Singh Mahendra Pal Singh, 1-346

COPELAND E B 1947 Genera filicum *Chronica Botanica Co,Waltham, Mass*, USA; London : 213-216

CHING R C 1963 A reclassification of the family Thelypteridaceae from the mainl& of Asia *Acta Phytotax* Sin **8** : 289–335

FRASER-JENKINS C R, GANDHI K N, KHOLIA B S & BENNIAMIN A 2017 *An annotated checklist of Indian Pteridophytes* Bishen Singh Mahendra Pal Singh, Dehra Dun pp 562

HOLTTUM R E 1969 Studies in the family Thelypteridaceae The genera *Phegopteris, Pseudophegopteris* & *Macrothelypteris* Blumea-Biodiversity *Evolution & Biogeography of Plants*, **17(1)** : 5-32

HOLTTUM R E 1971a Studies in the family Thelypteridaceae III A new system of genera in the Old

World *Blumea,* **19** : 17–52

HOLTTUM R E 1971b Studies in the Family Thelypteridaceae III A new system of genera in the Old World *Blumea-Biodiversity, Evolution & Biogeography of Plants*, **19(1) :** 17-52

HOLTTUM RE 1971c Typification of the fern-genus Christella Léveillé *Taxon* : 533-536

HOLTTUM R E 1976 Studies in the family Thelypteridaceae XI The genus *Christella* Lévillé, sect *Christella Kew Bulletin* **31** : 293–339 https://doiorg/102307/4109177

HOLTTUM R E 1977 The family Thelypteridaceae in the Pacific & Australasia Allertonia pp 169-234

HOLTTUM R E 1980 The Fern-family Thelypteridaceae in Malaya Thelypteridaceae in Malaya, *Royal Botanic Gardens, Kew* : 1-30

HOLTTUM R E 1982 Thelypteridaceae *Flora Malesiana-Series 2, Pteridophyta*, **1(1)** pp 1-653

HOLTTUM R E, SEN U & MITTRA D 1970 Studies in the family Thelypteridaceae II A comparative study of the type-species of *Thelypteris* Schmidel, *Cyclosorus* link, & *Ampelopteris* Kunze Blumea-Biodiversity, *Evolution & Biogeography of Plants,* **18(1) :** 195-215

HOLTTUM R E & CHANDRA P 1971 New Species of Thelypteridaceae from India, Ceylon & Burma *Kew Bulletin,* **26**(1): 79-82

IWATSUKI K 1963 Taxonomic studies of pteridophyta VII A revision of the genus *Stegnogramma* emend *Acta Phytotax Geobot* **19** : 112–126

IWATSUKI K 1965 Taxonomy of the thelypteroid ferns, with special reference to the species of Japan & adjacent regions IV Enumeration of the species of Japan & adjacent regions *Mem Coll Sci Univ* Kyoto, B **31** : 125–197

IWATSUKI K 1964 Taxonomy of the Thelypteroid ferns, with special reference to the species of Japan & adjacent regions, III Classification Mem Coll Sci Univ Kyoto B, **31** : 11-40

KHULLAR S P 2000 *An Illustrated Fern Flora of the West Himalaya* **(Vol II)** *International Book Distributors* Dehra Dun, India

LÖVE A, LÖVE D & PICHI SERMOLII REG 1977 Cytotaxonomical atlas of the Pteridophyta Cramer Fl-9490 Vaduz

NAYAR B K 1970 A phylogenetic classification of the homosporous ferns *Taxon* **19 (2)**: 229-236 DOI: 102307/1217958

PICHI SERMOLLI REG 1977 Tentamen Pteridophytorum genera in taxonomicum ordinem redigendi *Webbia*, **31(2)** : 313-512

SCHUETTPELZ E, CHEN C W, KESSLER M, PINSON J B, JOHNSON G, DAVILA A, COCHRAN A T, HUIET L & PRYER K M 2016 A revised generic classification of vittarioid ferns (Pteridaceae) based on molecular, micromorphological, & geographic data *Taxon* **65** : 708–722

SLEDGE W A 1981 Thelypteridaceae of Ceylon Bull Brit Mus Nat Hist Bot **8(1)** : 1-54

SMITH A R & CRANFILL R B 2002 Intrafamilial relationships of the Thelypteroid ferns (Thelypteridaceae) *American Fern Journal*, **92(2)**:131-150
https://doiorg/101640/0002-8444(2002)092[0131:IROTTF]20CO;2

SMITH A R, PRYER K M, SCHUETTPELZ E, KORALL P, SCHNEIDER H & WOLF P G 2006 A classification for extant ferns *Taxon,* **55(3)** : 705-731

ZHONG-YANG L I, ZHAO-RONG H E & ZHANG X C 2013 A taxonomic revision of *Cyclosorus* subgenus *Cyclosoriopsis* (Thelypteridaceae) from China *Journal of Systematics & Evolution*, **51(5)** 609-638

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ORGANOGENESIS FROM THE CORM APEX OF *ISOETES* L. (LYCOPOD) COLLECTED FROM RAJASTHAN, INDIA AND COMMENTS ON TAXONOMY OF *ISOETES* SPECIES IN RAJASTHAN

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ABSTRACT

Isoetes is a small herbaceous plant with an underground reduced stem (corm/ rhizomorph), green acicular ligulate leaves and hetesporous sporangia. Roots arise in rows and shows bifurcations. Four species are reported from the state of Rajasthan. Plants are amphibious and terrestrial found in plains, ravines and hills. The corm apices are either pyramidal or massive humps with covering of a row of cells. The leaf initials originate either as a protuberance on the lateral sides of the pyramidal apex or by a slit formation in the massive hump. The ligule initial originates as a big sized cell on the inner side of the leaf primordium. It divides fast and becomes a filamentous structure. Its lateral flaps develop later on. The sporangium initials also originate on the adaxial side of the 3rd leaf primordium a below the ligule. Vascular supply becomes visible in the 2nd leaf primordium. The present investigation will improve our knowledge about the behaviour of the corm of *Isoetes.*

Key Words : Corm apex organization, Isoetes

INTRODUCTION

Isoetes L. (Quillwort/Merlin's grass) is a unique lycopod (Sharma & Purohit 2011) distributed almost throughout the world and is represented by variable number of species. Motley & Vendryes (1833) reported 47 species, Pfeiffer (1922) 64 species, Hickey et al. (2003) over 350 species, while Srivastava et al. (2010) considered 250 species. Shukla et al. reported approximately 17 species of *Isoetes* in India. Gena & Bhardwaj (1984) described three new species of *Isoetes* (*I. tuberculata*, *I. reticulata* and *I. rajasthanensis*) from the state of Rajasthan. Sharma & Bohra (1978) had reported the presence of *I. coromandelina* L.f. from Dausa (Rajasthan). In total there are four species in the state.

In respect of the genus *Isoetes* in India, the treatment of Fraser-Jenkins *et al.* (2017) offers several questions on taxonomy as they recognize very few species (just four) occurring in India. Three out of the four species reported from Rajasthan, *I. tuberculata* Gena & Bhardwaja is treated as a synonym of *I. coromandelina* L.f. subsp. *coromandelina.* And, both *I. reticulata* Gena & Bhardwaja and *I. rajasthanensis* Gena & Bhardwaja are mentioned as synonym of *I. sahyadri* Mahab. ex L. N. Rao. In the opinion of Verma (2018, p. 21) 'taxonomy of entire genus *Isoetes* in India necessitates an in-depth reassessment in view of fewer species being recognized in India by Fraser-Jenkins (2016) and Fraser-Jenkins *et al.* (2017)'. In the present study all the four Rajasthan species are treated as distinct, till

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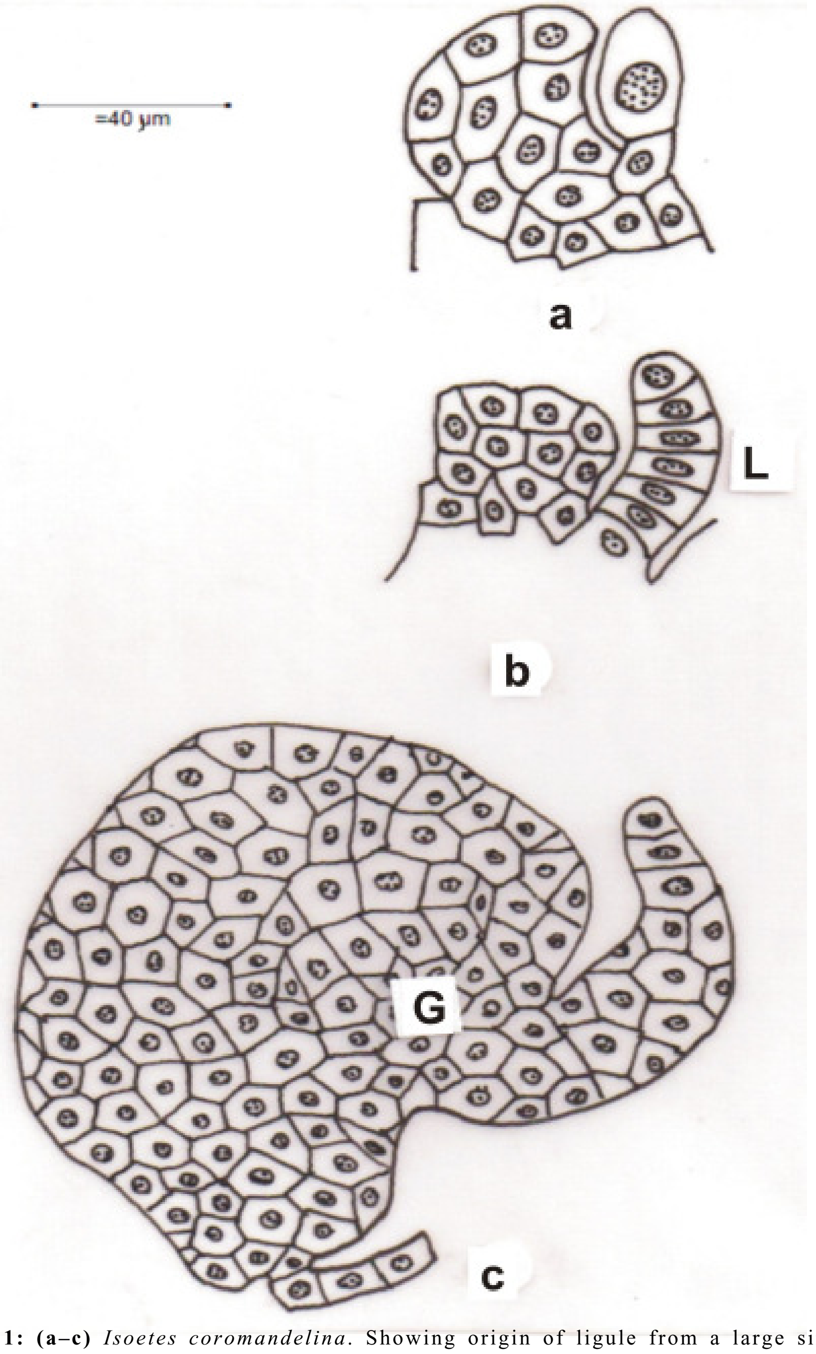

Fig. 1: (a–c) *Isoetes coromandelina*. Showing origin of ligule from a large single cell **(a),** Becomes filamentous **(b),** and then a many cells thick long, curved ligule (L) attached to a massive glossopodium (G) **(c)**. **(Bar Figs. a - c = 40µm).**

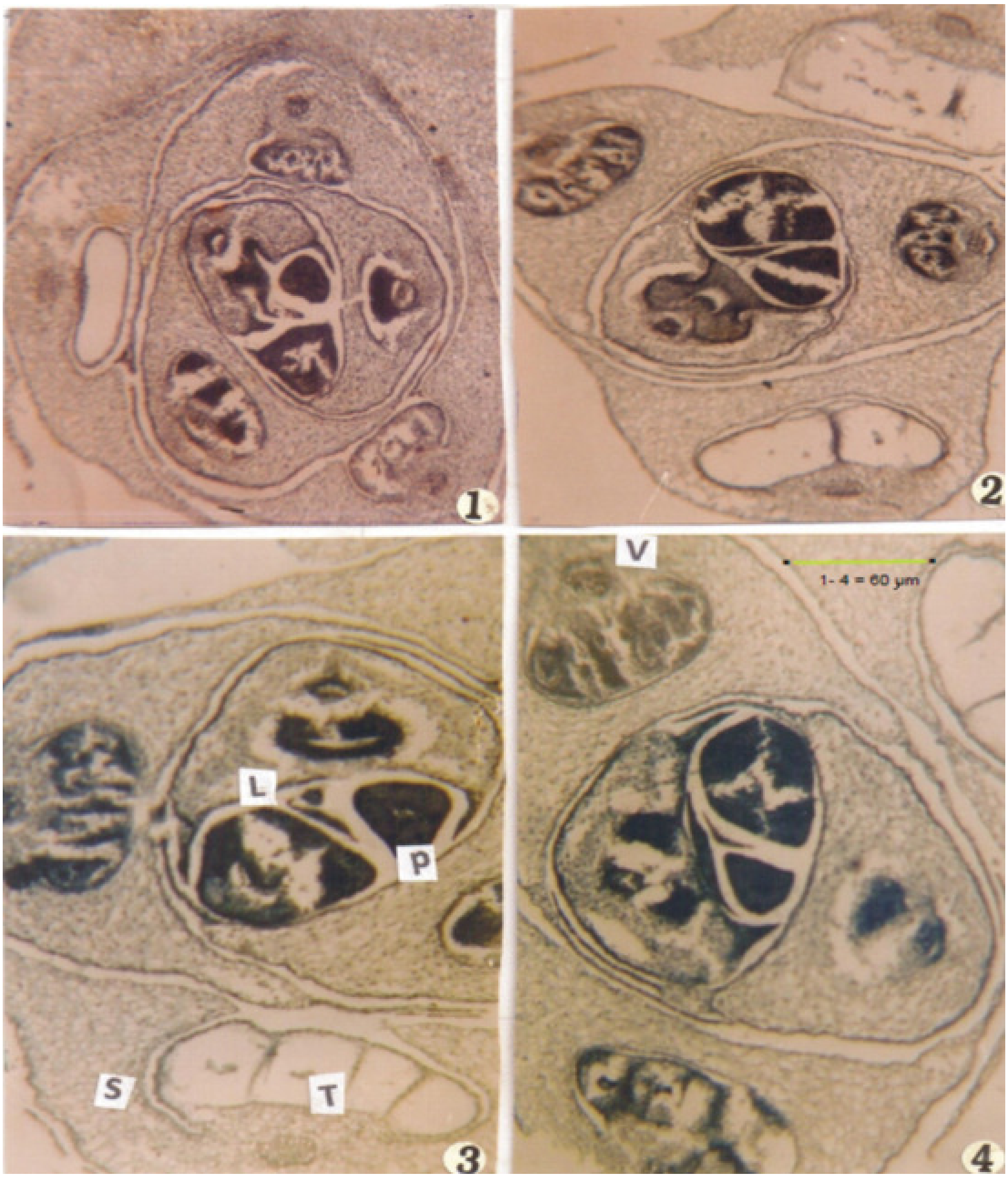

Plate I. Figs. 1–4. *Isoetes* rajasthanensis. Cross sections through corm apex showing leaf primordia arranged in a multiple of three in each whorl. Outer ones show imbricate estivation and presence of sporangia with trabeculae. **(Bar Figs. 1-4 = 60μm).**

(Abbreviation: S- Sporangium, T- Trabeculae, P-Leaf primordium, L-Ligule, V- Vascular strand)

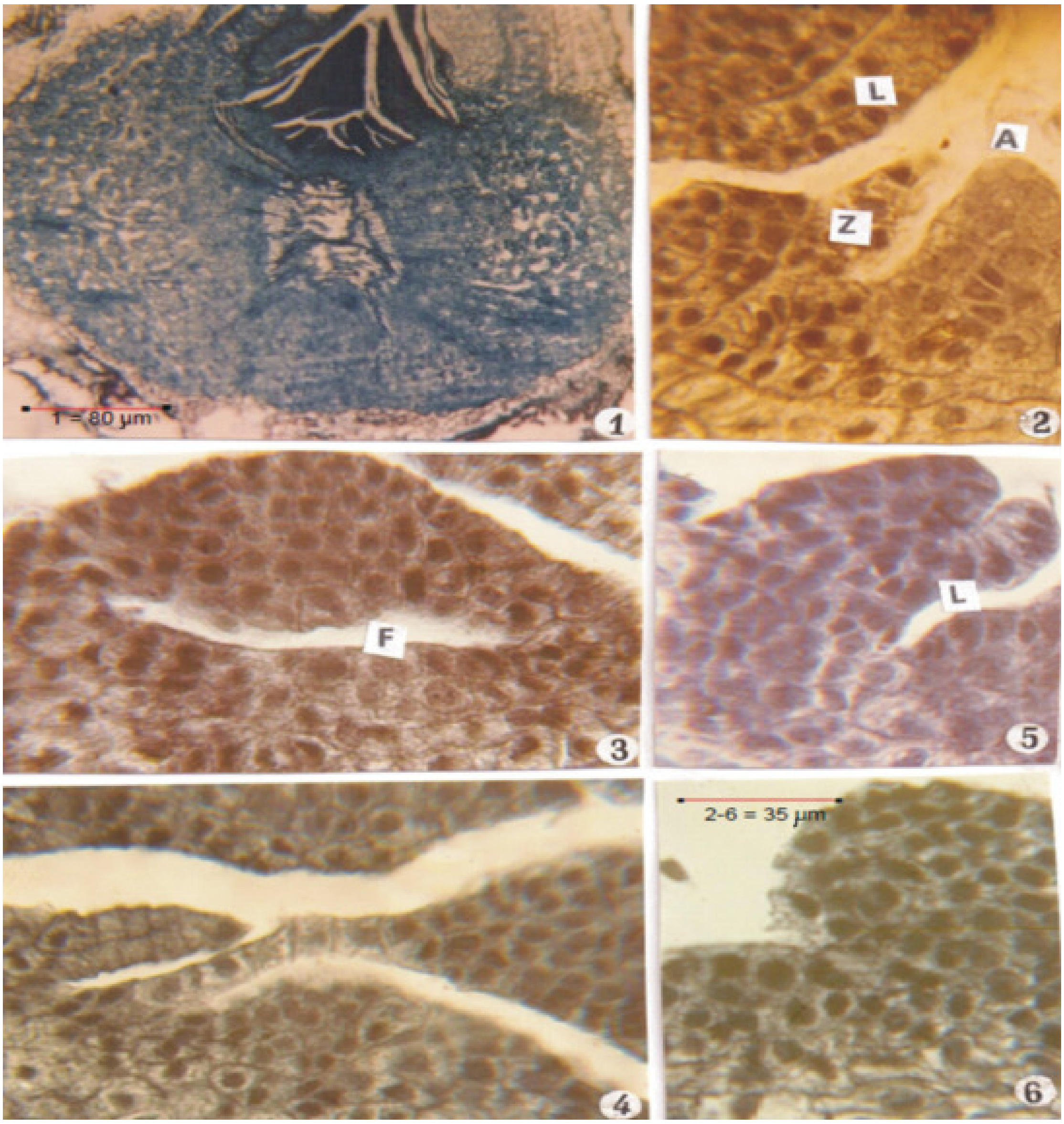

Plate II. Figs. 1–6 : 1. *Isoetes reticulata*. A vertical section through the corm showing a pyramidal corm apex and young leaves with ligules. **2**. Same, an enlargement. **3**. *Isoetes coromandelina*. A massive humpy shoot apex with a horizontal slit to differentiate the leaf primordium. **4**. Same, enlarged to show widening of slit and formation of leaf primordium. **5**. Same, young leaf primordium with small curved ligule. **6**. Same, a massive corm apex and originating leaf primordium**. (Bar , Fig. 1= 80µm, Figs. 2-6 = 35µm).**

(Abbreviations: F- Slit, L-Ligule, Z- Apical scale, A-Pyramidal corm apex) further taxonomic studies.

Peculiar, and interesting, anatomy of this lycopod has been known since long. Hofmeister (1862), Scott & Hill (1900), etc. noticed the presence of a single apical cell in the corm of *Isoetes* species similar to anatomy of other pteridophytes, viz. *Equisetum, Osmunda, Glechenia* etc. But many other pteridologists believe in the presence of a row of cells or in groups in the corm of *Isoetes* (Heglemaier 1874, West & Takeda 1915, Paolillo 1963, Bhambie 1953, 1962, 1963, Sharma & Purohit 2001, Sharma et al. 2008). Paolillo (1963) studied the anatomy of *I. howellii* Engelm. while Bhambie (1957, 1962, 1963) described the origin and development of leaf and ligule and anatomy of corm of *I. coromandelina.* La Matte (1933, 1937) studied *I. lithophyla* Pfeiffer and paid attention on young stages of embryo development and orientation. Sharma and Purohit (2001) described the morphology of labium and velum of *Isoetes* and suggested a new interpretation. Sharma and Bohra (2002) called ligule of *Isoetes* a prophyllar structure. Sharma (2005) published a paper on the anatomy of *Isoetes* description and interpretation and discussed in brief origin of leaf and ligule from the corm apex. He (Sharma 2013, 2015) also observed haploid abortive embryoids within the megaspores of *Isoetes*. The cross sections through the apical portions of the corm are rarely seen in literature. The longi sections provides two methods regarding the origin of leaf i.e. lateral sides of pyramidal apex and by slit formation in the massive humpy apex of the corm of *Isoetes.*

MATERIAL AND METHODS

In the state of Rajasthan *Isoetes* grows and survives during the months of rainy season i.e. July to September. The material of *I. coromandelina* L.f. was collected from Dausa near Jaipur. It has a thick corm (3-5 cm in diameter) with 40-70 cm long, 20-25 green acicular leaves (Sharma & Bohra 1978, Sharma *et al*. 1985). *I. tuberculata* Gena and Bhardwaj (1984) is an aquatic large-sized plant, similar to *I. coromandelina,* was collected from Atru, district Baran and Jhalawar. *I. reticulata* Gena and Bhardwaj (1984) is a small-sized quillwort found growing on wet soil along the margins of ditches containing water at Atru. *I. rajasthanensis* Gena and Bhardwaj (1984) is a medium-sized plant found growing in wet soil at open places at Mt. Abu, Chittorgarh, Menal, etc., places in Rajasthan. The four species differ from one another in morphology, anatomy, ecology and physiological behavior in photosynthesis (Sharma & Harsh 1995) and phytochemistry (Rathore & Sharma 1991)

The material was washed properly with water and preserved in F.A.A. After 3-5 days transferred to 70% alcohol and then processed for microtomy as suggested by Johansen (1940). For stanning the combination of safranin and haemotoxylin was used and mounted in dilute Canada balsam.

DESCRIPTION AND DISCUSSION

The description is based on the study of cross sections and longi sections cut through the apices of corms of the four species of *Isoetes* found in the state of Rajasthan.

Cross sections – In all species studied the cross sections through the apical portion of the corm are more or less similar. In the central portion of the section there are seen three young leaves primordia (Plate-I, figs.1,3). The smallest is triangular with blunt corners and has in the centre a narrow indistinct or distinct vascular strand (V). The second primordium is little bigger in size to the first one and an arrow or irregular shaped cavity develops in it (Plate-I, figs.1,4) . In the third primordium the size increases further and the cavity takes an irregular shape. Two small lateral wings or flaps develop on adaxial sides (Plate-I, figs.1-4). The ligule initials are seen inner to the leaf primordial (Plate-I, figs.2-4) as laterally elongated structure. The primordia are arranged in a clockwise (Plate-I, figs.1,3) or anticlockwise (Plate-I, figs.2,4), spiral and in multiple of three spiral. The second whorl of leaves i.e. 4th, 5th and 6th , have distinct lateral flap and show imbricate estivation. The vascular strand becomes distinct. The sporangium initials develop on the adaxial side inner to the vascular strand. The trabeculae differentiate in 6th -7th leaf primordium. Sharma *et al.* (1987) had described ontogeny of sporangium in *I. coromandelina* on the basis of study of longi-sections of young leaves. The present study gives further support to the earlier findings.

Longi-sections – Longi or vertical section through the corm (Plate- II, fig.1) reveal the presence of a row of cells covering both in pyramidal (Plate- II, fig.2) e.g. *I. reticulata* and hump-shaped corm apex e.g. *I. coromandelina* corm (Plate- II, fig.3). In the former the leaf initials originate on the side of the pyramidal apex as a small protuberance while in the latter the massive cellular body makes the apex of the corm (Plate-II, fig.6). A horizontal slit appears (Plate-II, fig.3) at the base of the multicellular thick corm apex. The slit increases laterally and widens to differentiate the leaf primordium (Plate-II, fig.4) from the corm apex which is at this stage is more or less horizontal and has a distinct one cell thick covering layer (Plate-II, figs.3,4). In addition to the leaf primordium multicellular scales are also produced from the corm apices. The ligule initial originates quite early from the basal portion of the leaf primordium (Plate II, fig.5). From lateral sides of the leaf primordium differentiate a large sized cell which produces one cell thick filamentous structure (Fig. 1 a-c). It is curved slightly in the beginning but later on becomes a straight filamentous structure which produces lateral flaps of the mature ligule. Sporangium initials originate below the ligule on adaxial side from the leaf primordium.

From the above description it is clear that the corm apex produces leaf primordia which are the source or sites of production of ligules, labia and sporangia.

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REFERENCES

BHAMBIE S 1957 Studies in Pteridophytes I – The shoot apex of *Isoetes coromandelina* L. *J Indian Bot Soc* **36**: 491-502

BHAMBIE S 1962 Morphological and anatomical studies on *Isoetes* and other related genera *Agra Univ Res J* **10**: 233-236

BHAMBIE S 1963 Studies in Pteridophytes III – On the structure and development of the leaf and sporophyll of *Isoetes coromandelina* L.f. *Proc Nat Inst Sci India* **29**B 169-190

FRASER – JENKINS C R 2016 A revised checklist of Indian pteridophytes- I *Indian Fern J* **33**:193-205

FRASER- JENKINS C R, GANDHI K N, KHOLIA B S & BENNIAMIN A 2017 *An annotated checklist of Indian pteridophytes*, Part I Bishen Singh Mohinder Pal Singh Dehra-Dun Pp 562

GENA C B & BHARDWAJ T N 1984 Three new species of *Isoetes* L. from Rajasthan *J Bombay Nat Hist Soc* **81**:165-168

HEGLEMAIER F 1874 Zur kenntniss einiger Lycopodinen *Bot Zig* **32**: 481-488, 497-505, 513-524

HICKEY R D, TAYLOR W C & LUEBKE N T 1989 The species concept in pteridophytes with special reference to *Isoetes Amer Fern J* **79**: 78-79

HOFMEISTER W 1862 On the germination, development, and fructification of the higher Cryptogamia, and on the fructification of the Coniferae. *Ray Soc London,* Publ. **22,** Chapter XII (*Isoetes lacustris*)*:* 336-375

JOHANSEN D A 1940 *Plant Microtechnique* McGraw Hill New York & London

LA MATTE C 1933 Morphology of the megagametophyte and the embryo – sporophyte of *Isoetes lithophila Amer J Bot* **20**: 217-233

LA MATTE C 1937 Morphology and orientation of the embryo of *Isoetes* L. *Ann Bot* (n.s.) **1**: 695-715

MOTELAY L & VENDRYES A 1883 Monographie des Isoeteae *Actes Soc Linn Bord* **36**: 309-406

PAOLILLO D J Jr 1963 *The development anatomy of Isoetes* L. Illnois Biological Monograph **31**: 1-130

PFEIFFER N E 1922 Monograph of the Isoetaceae *Ann Missouri Bot Gard* **9**: 79-232

RATHORE D & SHARMA B D 1991 Pteridophytes of Rajasthan Phytochemistry of *Isoetes Indian Fern J* **7**: 121-122.

SCOTT D H & HILL T G 1900 The structure of *Isoetes hystrix Ann Bot* 14: 413-454

SHARMA B D 2005 Anatomy of *Isoetes* – Description and interpretations *Bionature* **25**: 21-35

SHARMA B D 2013 Discovery of *in situ* apogamous abortive embryos inside the megaspores of *Isoetes* L. *Phytomorphology* **63**: 153-156

SHARMA B D 2015 Variations in haploid embryonic bodies within megaspores of *Isoetes* L. – (Lycopsida) *Phytomorphology* **65**: 84 - 88

SHARMA B D & BOHRA D R 1978 *Isoetes* of Rajasthan – anatomy of rhizomorph of *Isoetes coromandelina* L. *Acta Bot Indica* **6** (suppl.): 122-127

SHARMA B D & BOHRA D R 2002 The ligule of *Isoetes* – a prophyllar structure *Phytomorphology* **52**: 17-22

SHARMA B D & HARSH R 1995 Diurnal acid metabolism in submerged aquatic plant *Isoetes tuberculata Amer Fern J* **85**: 58-60.

SHARMA B D & PUROHIT S N 2001 Morphology of labium/ velum in *Isoetes* L. *Phytomorphology* **51**: 57-61

SHARMA B D & PUROHIT S N 2011 *Isoetes* – a unique Lycopod *Indian Fern J* **28**: 76-84

SHARMA B D, BOHRA D R & VYAS M S 1985 Sporogenesis in *Isoetes* L. *Bionature* **5**: 9-13

SHARMA B D, SINGH R & RATHORE D 1987 Sporangium ontogeny in *Isoetes coromandelina* L.f. *Indian Fern J* **4**: 77-81

SRIVASTAVA G K, CHAUHAN D K & TIWARI P S 2010 Evolution, origin and diversification of Isoetalean clade (Abstract) *International Symposium on Fern and fernallies (IHBT) Palampur* (India), p. 25.

SHUKLA P K, SRIVASTAVA G K & RAJGOPAL P K 2005 Two new species of the genus *Isoetes* L. (Isoetaceae, Lycopods) from India *Taxon* **54**(1): 109-118

VERMA, S.C. 2018. Opportunities and challenges of exploring ferns and lycophytes in the genomics age: A brief overview of some issues. In: *Pteridology Today*: *Challenges and Opportunities*. [eds. Verma, S. C. et al.] (Proceedings of the Symposium held at BSI, WRC, Pune, March 3-4, 2017). *Botanical Survey of India*, Kolkata. pp 8-32.

WEST C & TAKEDA H 1915 On *Isoetes japonica* A Br *Linn Soc London Trans Bot* II **8**: 333-376

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RECENT ADVANCES IN FERN RESEARCH : A BRIEF REVIEW

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ABSTRACT

Ferns existing today represent a genetic inheritance of great value as they include species of ancient vascular plants of more than 410 million years. Spores, gametophytes and sporophytes have been cultured either for basic research or practical purposes. Most of the published works until recently provide information about the existing biodiversity in ferns, referring to aspects such as their morphology, systematics, ecology, evolution, phylogenetics, with no explicit references to the latest advances in the research done in ferns. Plant biotechnology can play an important role in (a) the contribution of ferns to the understanding of plant development, (b) propagation, conservation and control of genetic variability in ferns, (c) environmental biotechnology: ecotoxicology and bioremediation in ferns, (d) therapeutical/ medicinal applications, and (e) scope of Ferns in Horticulture and Economic Development.

Ceratopteris richardii Brongn., an aquatic fern, has been used as an experimental system for studies on molecular and gene expression changes that occur in gametophytes during polarity development. Molecular approaches are used to characterize proteins mediating morphogenic changes in plants. *In vitro* culture techniques from spore to sporophyte can provide mass propagation of endangered ferns and help their conservation. Modern techniques are used to determine genetic variability for the propagation and conservation of ferns. This has provided insights into population biology and genetics of ferns. Ferns like *Pteris vittata* L. an arsenic hyperaccumulator can play important role in phytoremediation. Medicinal and therapeutical applications of ferns using biotechnological tools can provide new dimensions to Pteridology. A review is presented, focusing on recent advances.

Key Words : Ferns, Tissue culture, cryopreservation, apogamy and apomixis

INTRODUCTION

Chapman (2009) estimates that there are ca. 12,000 species of Ferns and Fern allies, having a global geographic range across which species frequently compete successfully with angiosperms. These plants were previously grouped together as Pteridophyta but are now classified into two distinct groups, Monilophytes (Ferns) and Lycophytes (for literature and recent reviews see Raghavan (1989), Mehltreter *et al.* (2010), Fernández *et al.* (2010), Ibars & Estrelles (2012), Vicent *et al.* (2014), Bui *et al.* (2018), Cheema (2018), Verma (2005, 2017, 2018), Kumar & Kotiya (2018). According to Moran (2015, p.5), 'worldwide, there are about 13,600 species of ferns and lycophytes'. For the Indian subcontinent, Fraser-Jenkins *et al.* (2017) consider that 'altogether there are 1114 indigenous taxa and 43 exotics'. There are also an additional 100 sterile F1 hybrids known (p.4).

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Ferns have been cultivated for their ornamental foliage. Ferns also have been in use for food, as ornamental plants, valuable unexplored chemicals and for the phytoremediation of contaminated soils (Goswami *et al.* 2016).

The conventional method employed for propagation of ferns has been by a runnerset procedure. But ferns derived through this method produced a single growth centre from where only a few fronds developed at a time. In contrast, the ferns derived through tissue

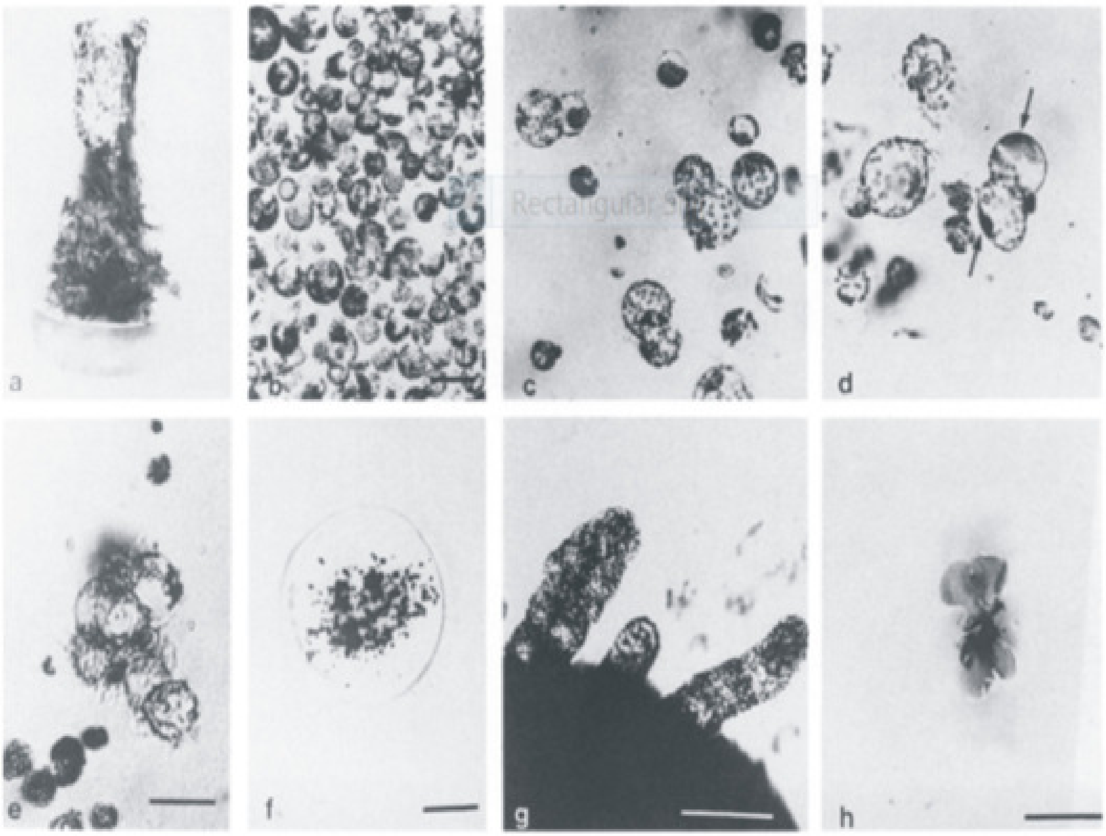


Plate 1 (a-h): Isolation and regeneration of the protoplasts derived from juvenile sporophytic leaflets of *Lygodium japonicum* (Thunb.) Sw. -**(a)** Sporophytes with young leaflet originating from prothallia transferred into a new medium, **(b)** Freshly isolated protoplasts. (bar is 50 pm), **(c)** First cell division, 5 days after start of culture, **(d)** First cell division, stained with acetic orcein, (arrow indicates nucleus), **(e)** A micro-aggregate after 2 weeks of culture. (bar is 50 pm), **(f)** Mass production of colonies after 1.5 month of culture. Colour of colony is brown. (bar is 10 mm), **(g)** Prothallia-like protuberances initiating form callus aggregates (bottom and black portion). Cells originating from callus tissues are green and have organized structures. (bar is 100 ~m), **(h)** Cordate regenerants derived from a callus tissue (bar is 5 mm)

[Source: Maeda, M., Nakamura, M., Masuda, K., & Sugai, M. (1990). Division and gametophytic tissue formation from protoplasts of young sporophytes in *Lygodium japonicum. Plant Cell Reports* **9**: 113–116. Reproduced with permission by Licence No. 4557600431359).

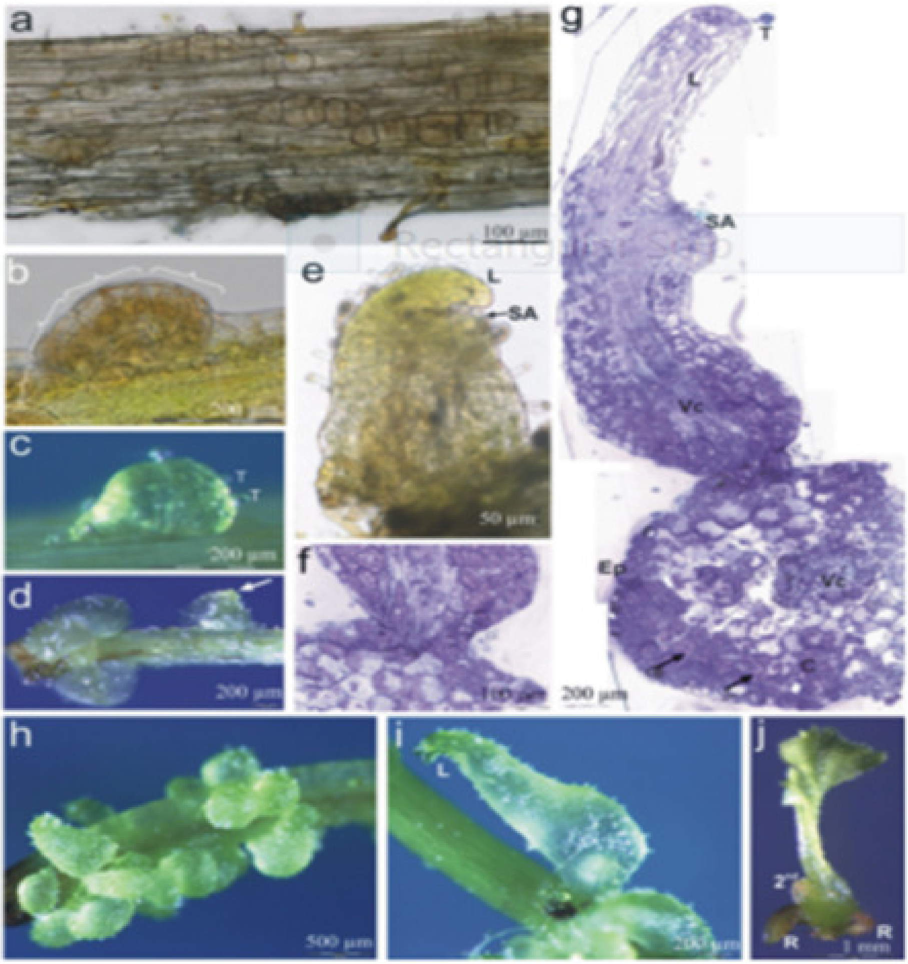


Plate 2 (a-j): Light microscopy evidence for somatic embryo origin and development in *Cyathea delgadii*. **(a)** Numerous pro-embryos following several anticlinal, periclinal and inclined cell divisions of single epidermal cells of stipe explant cultured on hormone-free medium, in darkness, **(b)** Four-segmented somatic pro-embryo developed directly on the surface of stipe, **(c)** Trichomes located on one side of immature, multicellular somatic embryo, **(d)** Differentiation of the embryonic leaf (arrow), **(e)** A somatic embryo showing the first leaf and primordium of the second leaf (squashed specimen). **(f)** Junction between somatic embryo and initial stipe explant showing epidermal origin of embryo (semi-thin section stained with toluidine blue). (**g**) Longitudinal section of well-developed somatic embryo showing the first leaf, shoot apex and primordium of the second leaf, as well as transverse section of the stipe explant; 6 weeks of culture (arrows indicate amyloplasts). **(h)** Numerous somatic embryos with first leaf after 6 weeks growth **(i)** Partly green, differentiated lamina of the first leaf of juvenile sporophyte. **(j)** Somatic embryo-derived young sporophyte showing extended lamina of primary frond and primordium of second leaf, as well as two roots, following development in the presence of light. C cortex, Ep epidermal cells, L first leaf, R root, SA shoot apex, T trichomes, Vc vascular cylinder.

(Source: Mikula, A., Pozoga, M., Tomiczak, K., & Rybczynski, J. J. (2015). Somatic embryogenesis in ferns: a new experimental system. *Plant Cell Reports*, 34(5), 783–794. This is an open access article distributed under the terms of the Creative Commons CC BY license, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. Open access using after due acknowledgement).

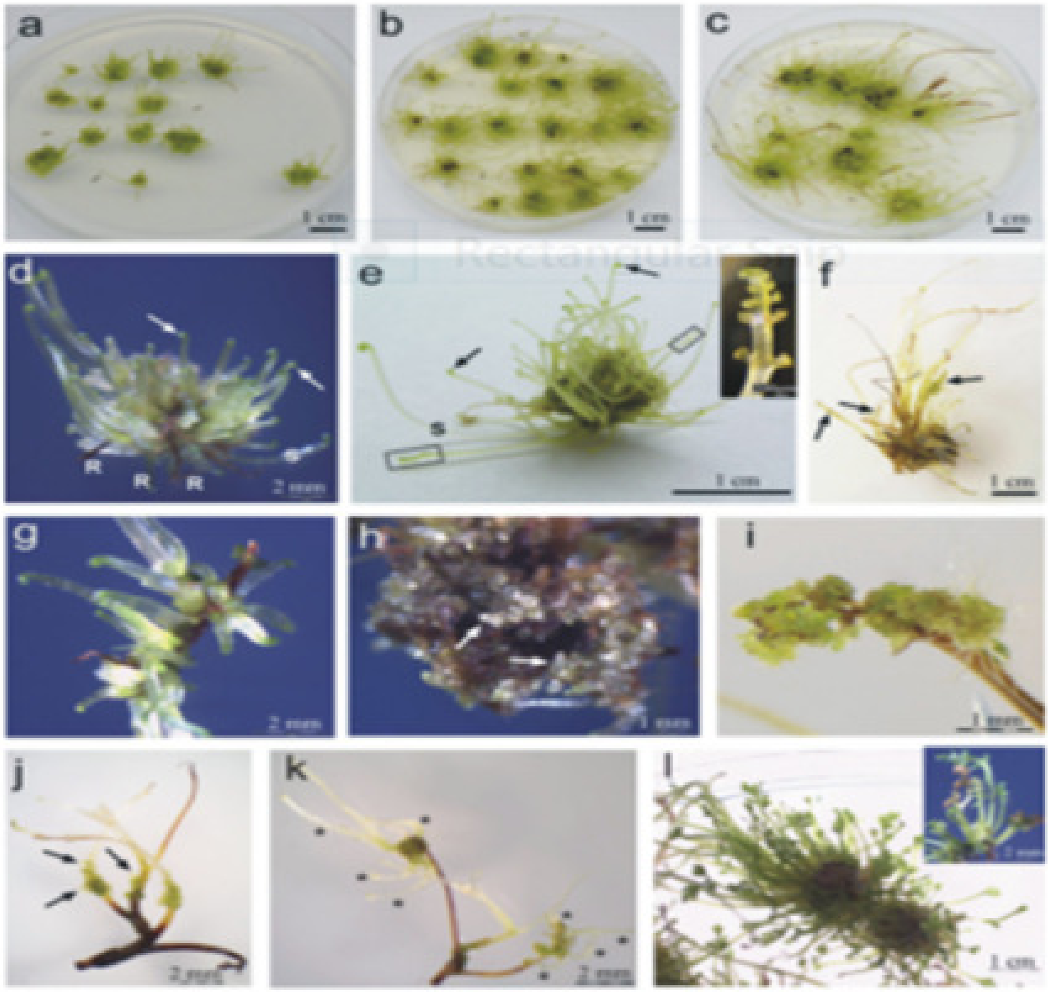


Plate 3 (a-l): Progress of somatic embryo production in *Cyathea delgadii* during long-term culture. General view of a culture maintained in darkness for: **(a)** 3 months, **(b)** 5 months, **(c)** and 11 months. **(d)** Numerous young sporophytes with roots and croziers (arrows), after 3 months. **(e)** Typical fronds with long stipes and croziers (arrows), with brown tissue at their bases; a few laminae that have developed further (rectangle and small picture), after 5 months. **(f)** Spontaneous production of somatic embryos on aging fronds (arrows), after 7 months. **(g)** Further development of spontaneously induced somatic embryos. **h.** Somatic embryos derived from the brown tissue (arrows), after 8 months. **i.** Yellow and green callus on surface of lamina. **(j)** Yellow and green callus on surface of stipes with differentiated somatic embryos (arrows). **(k)** Young sporophytes (asterisks) formed by secondary, spontaneous somatic embryogenesis. **(l)** Image of sporophytes after 2 week-long light exposure. R root, S stipe (colour figure online, open access).

(Source: Mikula, A., Pozoga, M., Tomiczak, K., & Rybczynski, J. J. (2015). Somatic embryogenesis in ferns: a new experimental system. *Plant Cell Reports,* 34(5), 783–794. This is an open access article distributed under the terms of the Creative Commons CC BY license, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. Open access using after due acknowledgement).

culture techniques produced several growth centers, and from each growth center numerous fronds were produced, thus giving an attractive look to the plants (Murashige 1977, see also Neumann *et al.* 2009). Their demand as indoor plants have been increasing. Studies regarding the *in vitro* culture of ferns have mainly focused on spore germination and micropropagation, with an eye toward the ornamental plant market (Bharati *et al*. 2013). Nevertheless, the *in vitro* culture could contribute to the understanding of sporophyte *in vitro* development and establish the appropriate conditions to improve volatile compound production, enabling plant multiplication and eliminating any biotic or abiotic factors that could have a negative effect on the desired metabolic profile.

Verma (2018) has rightly pointed out in his latest review on *opportunities and challenges of exploring ferns and lycophytes in the genomics age* that "The genomics age demands the researches to be focussed, collaborative, and curiosity-driven" (p.8). It is proposed to present a brief overview of the importance of ferns, their economic potential, in understanding the basics of differentiation, to develop methods of conservation and

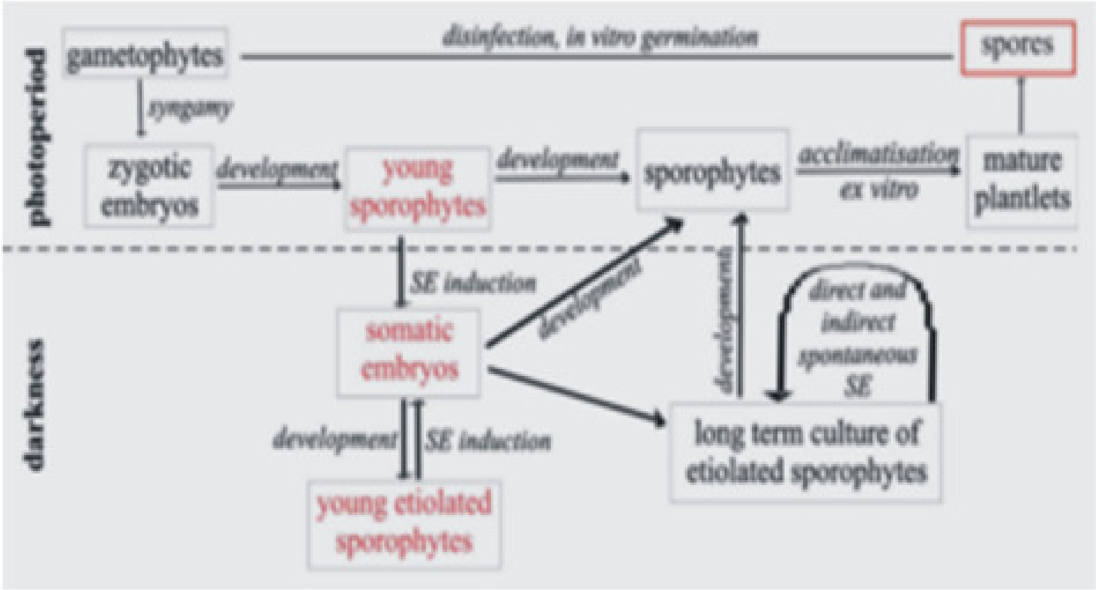


Plate 4 : Schematic diagram representing the course of the newly described somatic embryogenesis process for *Cyathea delgadii*: commencing with spores, passing through the gametophyte stage, followed by induction of zygotic and somatic embryogenesis and finally, the production of mature plantlets initially grown in vitro and later under ex vitro conditions. SE somatic embryogenesis, initial explants are shown in red (color figure online, open access). (Source: Mikula, A., Pozoga, M., Tomiczak, K., & Rybczynski, J. J. (2015). Somatic embryogenesis in ferns: a new experimental system. *Plant Cell Reports*, 34, 783–794. This is an open access article distributed under the terms of the Creative Commons CC BY license, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. Open access using after due acknowledgement).

Plate 5

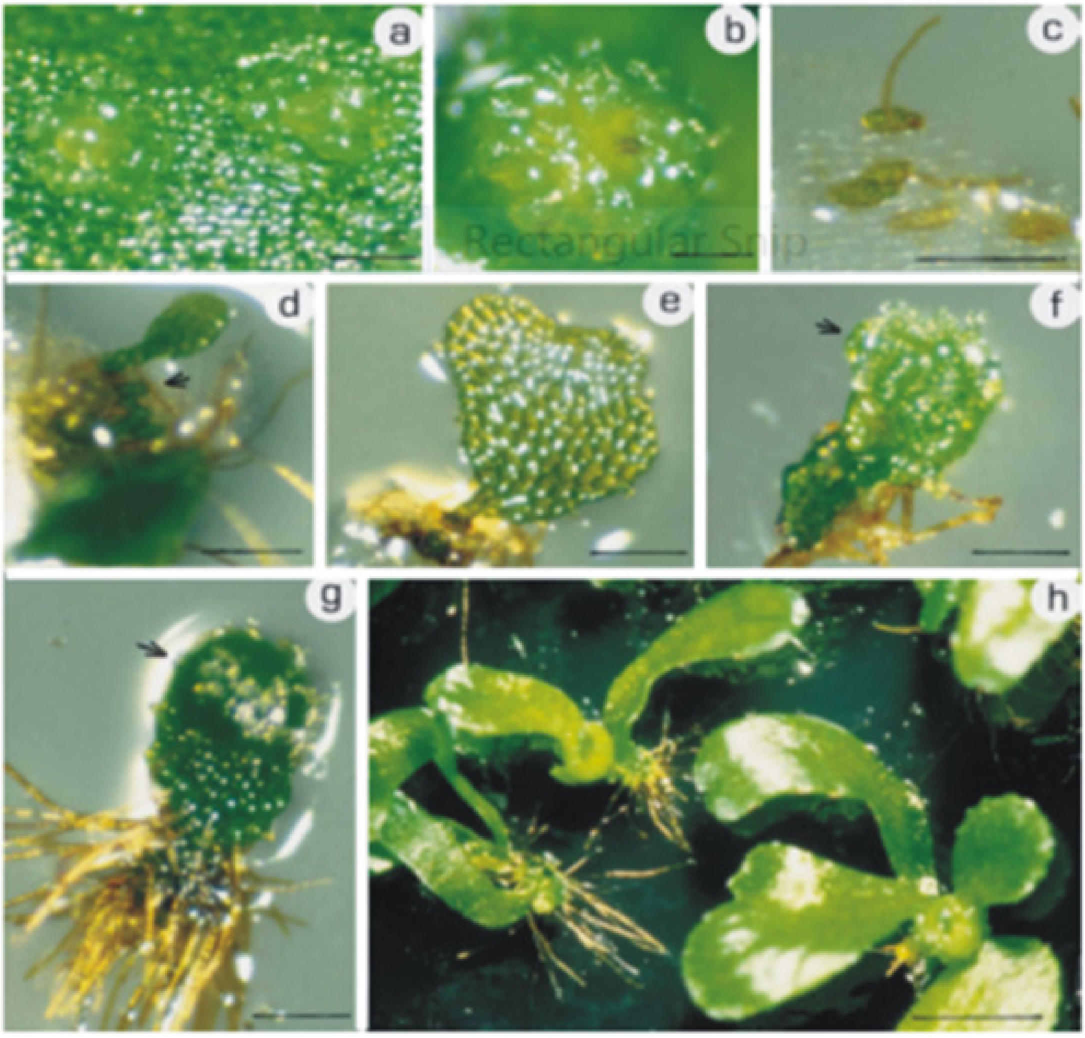


Plate 5 (**a–h**) **:** Regeneration of sporophytes from leaf cell aggregates of *Platycerium bifurcatum* (Cav.) C. Chr. with cell aggregates of above 500–1000 cells (**a, b**) or cell aggregates of less than 100 cells (**c–h**) [bars 200 µm (**a–g**) 500 µm (**h**)]. **a.** Budding in unique pattern from a cell aggregate. **b.** A fully developed bud covered by scales. **c.** Incipient regenerant cells distinguished from surrounding cells by their green color and hypertrophy. Some rhizoids have formed. **d.** Several bipolar protonema developed from incipient regenerant cells (arrow). One protonema bears a plate of approximately 20 cells on its distal end. **e.** A more developed aposporous gametophyte with a cordate plate. **f.** Early sporophyte development on an aposporous gametophyte (arrow). **g.** A well-formed bud on an aposporous gametophyte (arrow). More rhizoids were formed at this stage. **h.** Young sporophytes developed from buds on gametophytes.

(Source: Teng, L., & Teng, C. (1997). *In vitro* regeneration patterns of *Platycerium bifurcatum* leaf cell suspension culture, *Plant Cell Reports* 16: 820–824. Reproduced with permission no 4559121050805).

propagation, and in the age of genomics to understand their interrelationships and bring out unresolved areas in fern biology. Somatic embryogenesis in ferns: a new experimental system has been included in this review (Mikula *et al.* 2015). Extensive support and guidance of Prof. S. C. Verma is gratefully acknowledged.

ISSUES FOR THE BRIEF REVIEW

(1) The contribution of ferns to the understanding of plant development

Ferns with characteristic alternation of two independent generations in their life cycle, gametophyte and sporophyte, provide excellent material for study of plant physiology, stress tolerance, genetics, genomics and understanding evolutionary trends. Overview of the phenomenon, genetics, and evolutionary potential has been presented by Mehra (1975, 1989, Verma (2005, 2017, 2018) and Fernández (2018).

(2) Propagation, conservation and control of genetic variability in ferns

***(a) In vitro* propagation :** Plant tissue culture methods of *in vitro* culture could contribute to increase sporophyte production of desirable species. Pioneer researches were

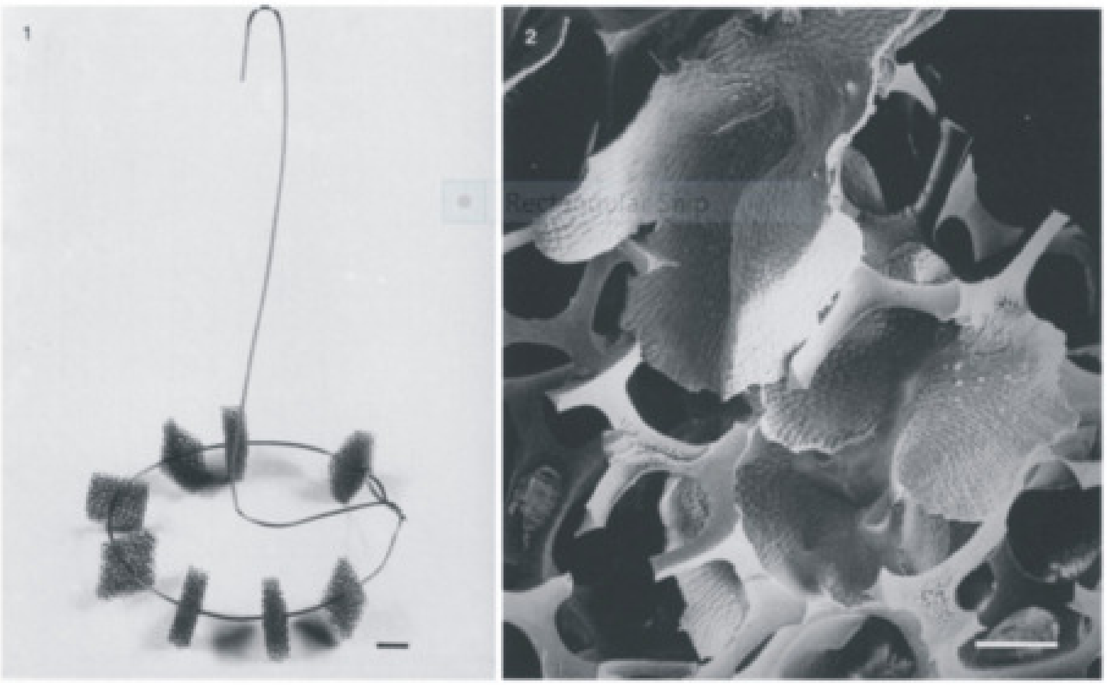


Plate 6 (Figs. 1,2): (1). Wire loop supporting pieces of polyurethane foam of the type used in immobilised cultures (bar =0.5 era). **(2)**. Gametophytes of *Anemia phyllitidis* (L.) Swartz colonising foam 8 weeks after culture inoculation (bar = 0.5 ram).

(Source: Douglas, G. E. and E. Sheffield (1990). A new technique for the culture of fern gametophyte, *Plant Cell Reports*, 8: 632-634. Reproduced with permission No. 4557620561292).

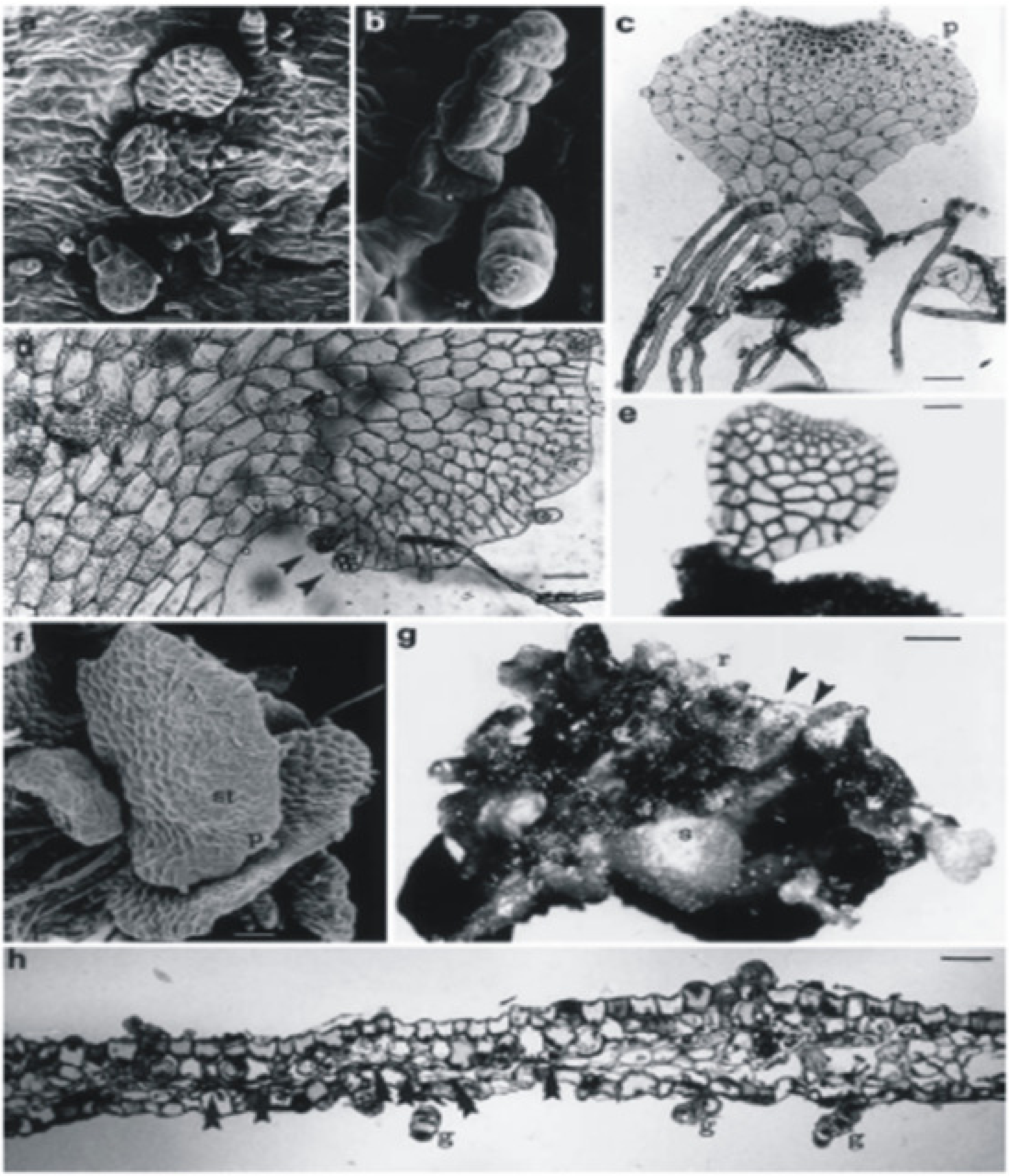
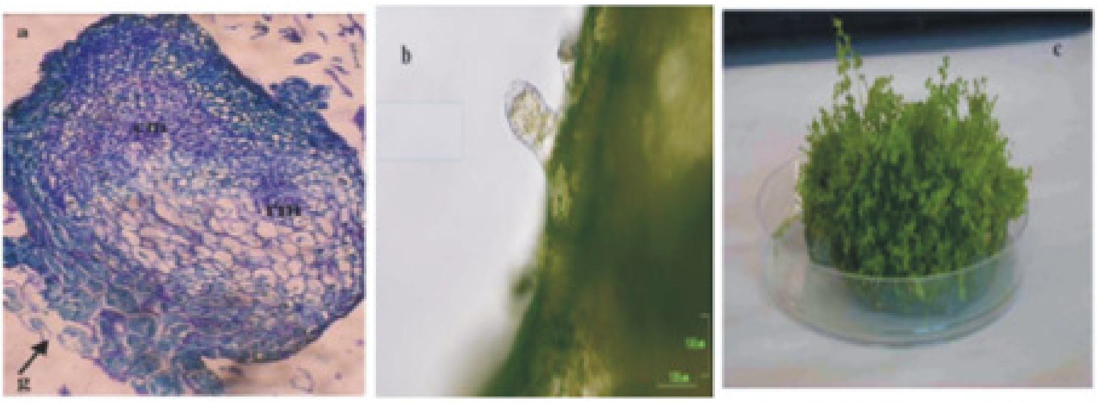


Plate 7 (a–h): The development of apospory on wounded leaves cultured on medium supplemented with 0.01% sucrose. **a.** Different developmental stages and shapes of aposporous gametophytes after 30 days of culture. Note the attachment of aposporous gametophytes to the leaf with one epidermal cell (arrows). Bar: 0.1 mm. **b.** Early developmental stage of aposporous gametophytes developed from a single cell of a leaf lamina after 30 days of culture. Note the longitudinal divisions in the subterminal cells and the single-cell origin (arrow). Bar: 20 µm. **c.** Heart-shaped aposporous gametophyte with rhizoids (r) and papillae (p) after 60 days of culture. Bar: 0.1 mm. **d.** Antheridia (arrowheads) developed on the lamina or margin of aposporous gametophytes after 60 days of culture. Bar: 0.1 mm. **e.** Attachment of aposporous gametophytes to the leaf with more than one epidermal cell after 60 days of culture. Bar: 0.1 mm**.** **f.** Intermediates between sporophytes and gametophytes after 60 days of culture. Note the heart-shaped structure, rhizoids (r), papillae (p), and stomata (st). Bar: 0.1 mm. **g.** Aposporous gametophytes on wounded leaves after 40 days of culture. Gametophytes (g), rhizoids (r), and shoots (s) were observed. Note wounding (arrows). Bar: 1 mm. **h.** Transversely sectioned wounded leaf with aposporous gametophytes (g) after 30 days of culture. Note destruction of subepidermal tissue (arrows). Epidermal cells show no, or only a few, symptoms of destruction. Bar: 0.1 mm

(Source: J. Ambro•ic-Dolinšek, Camloh, M., Bohanec, B., & Zel, J. (2002). Apospory in leaf culture of staghorn fern (*Platycerium bifurcatum*) Plant Cell Reports (2002) 20:791–796. Reproduced with permission License Number 4557620983852).



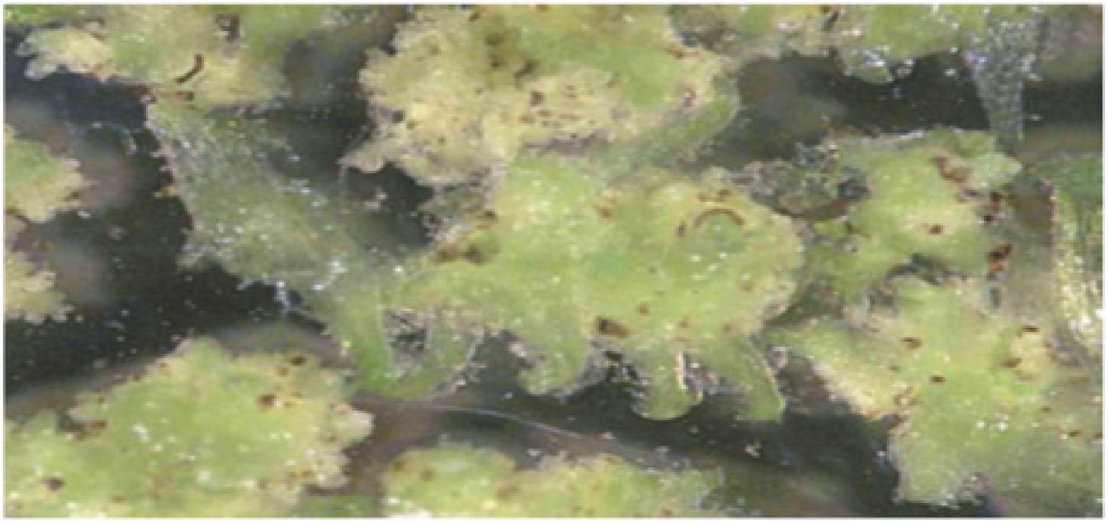


Plate 8 (a-c) : Apogamy in homogenised gametophytes of *Dryopteris affinis*. **(a)** Longitudinal section of embryo: g, gametophyte; rm, root meristem; cm, apical meristem (60×). **(b)** Gametophyte forming antheridia. **(c)** Apogamous sporophytes in gametophytes cultured on MS solid medium with NAA of 5.37 µM for 3 months. (Source : Plant Cell Reports 25 : 85-91, reproduced with permission, No. 4557621462637)

Plate 8 Fig. D : Sporophyte regeneration from callus tissue induced in homogenised gametophytes of *Dryopteris affinis* ssp. *affinis* cultured in MS liquid medium with BA of 4.44 µM for 2 months and then subcultured on a hormone-free medium. (Source : Mendez *et al.* (2006) Exogenous and endogenous growth regulators on apogamy in *Dryopteris affinis* (Lowe) Fraser-Jenkins ssp. *affinis*, Plant Cell Reports 25 : 85-91, reproduced with permission No. 4557621 462637) - http://doi.org/10.1007.s00299-005-0041-1

Plate 9

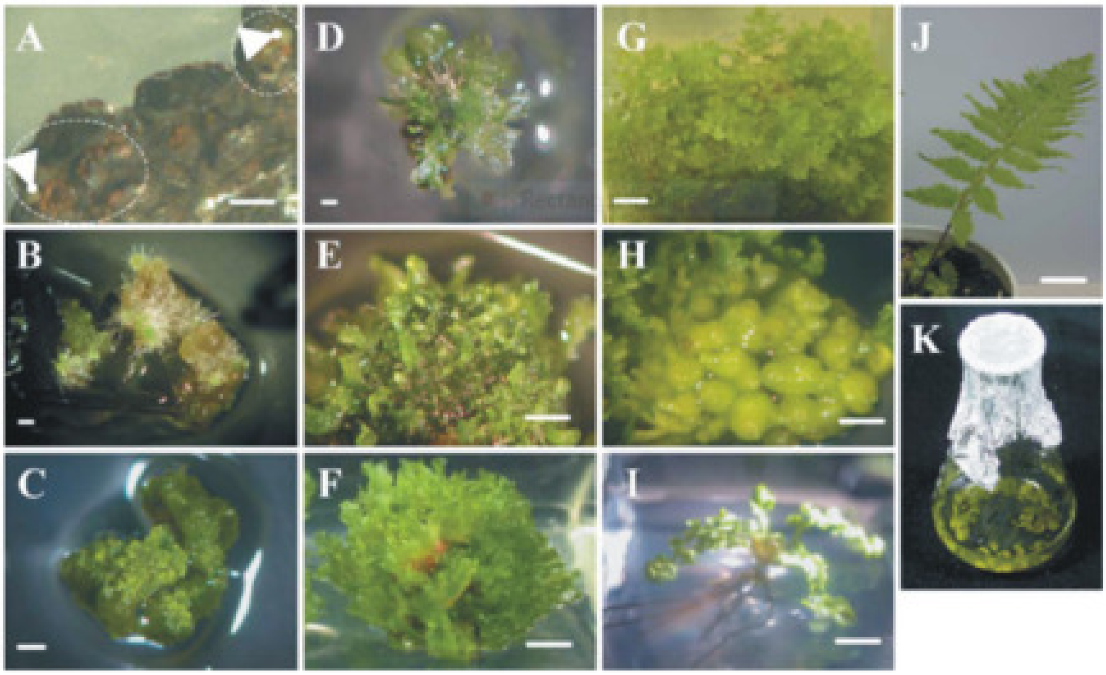


Plate 9 (A-K): Typical appearance of the induced callus and the re-generated plantlets of *Athyrium yokoscense*. **A, B.** Callus formation (arrow heads) from the spores and/or prothallium without release from the sporangium (dotted circle) on the frond. **C.** Growth of green and compact callus. **D-F.** Multiplication and growth of the prothallium-like organs (PLO) developed from the callus (f the P-stage fern). **G.** Sporophytes developed from PLOs. **H.** Embryogenic callus (EC) formation and the juvenile plantlets regenerated from ECs. **I.** Growth of the regenerated plantlets with roots developed from EC (the S-stage fern). **J.** The mature plant of *A. yokoscense* grown on soil. **K**. Liquid culture of the green and compact callus (the C-stage fern). Bars in figures represent 1 mm (A-D), 1 cm (E-G), 3 mm (h) and 5 cm (J), respectively.

(Source: Yoshihara T., *et al.* (2005). Induction of callus from a metal hypertolerant fern, *Athyrium yokoscense*, and evaluation of its cadmium tolerance and accumulation capacity, *Plant Cell Reports*. 23: 579–585. Reproduced with permission No. 4559121448631)

carried out at the department of Botany, Panjab University, Chandigarh led and professed by late Professor Pran Nath Mehra and his students (Mehra 1975, 1989, See Cheema 2018). Morphogenesis in ferns has been induced by homogenization or mechanical disruption of gametophytes and sporophytes, and subsequent culture in soil or synthetic medium (Fernández *et al.* 1993, 1997). Sara & Manickam (2005) published *in vitro* propagation of the critically endangered fern *Cyathea crinita* (Hook.) Copel. Some recent publications and reviews have summarized the *in vitro* propagation of ferns (Ibars & Estrelles 2012, Bui *et al.* 2017, Cheema 2018).

Excised leaf primordia of *Osmunda cinnamomea* L. (Steeves, 1966), *Adiantum pedatum* L. and other ferns (Wetmore 1970) have been grown to adult plantlets in axenic cultures. Propagation of ferns (*Nephrolepis*s sp.) through tissue culture has been achieved

Plate 10

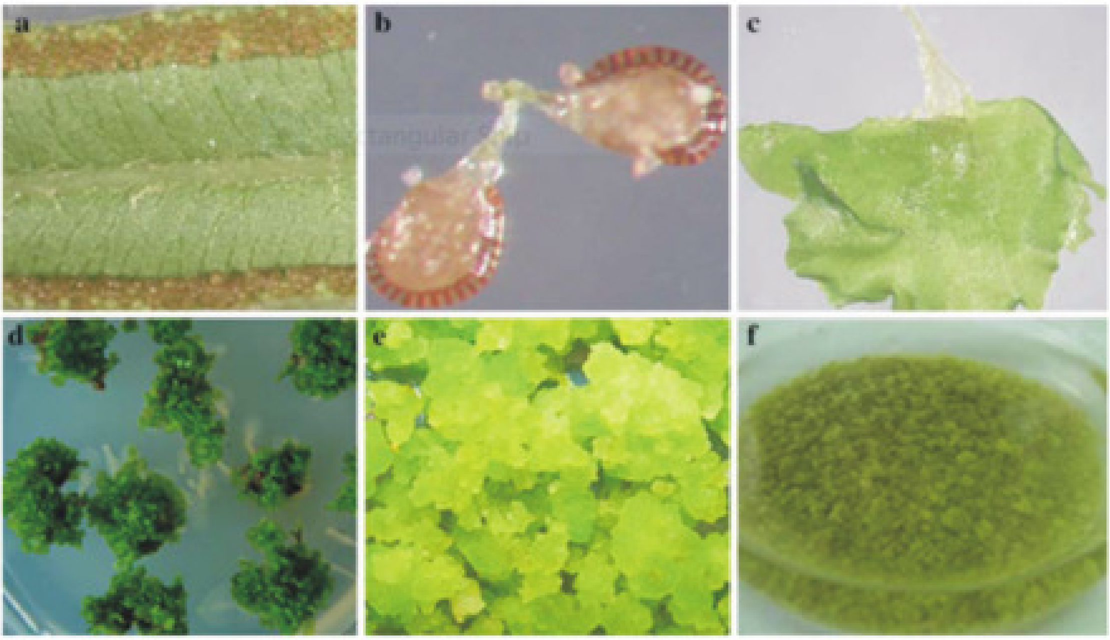


Plate 10 (a-f): The spores, gametophytes, and callus of *P. vittata*. **a.** The underside of a *P. vittata* sporophyll. **b**. Sporangia containing the haploid spores. **c.** Gametophyte and its rhizoids. **d**. Gametophytes grown on solid medium. **e**. Callus grown on solid medium. **f**. Callus grown on liquid medium.

(Source: Yang, *et al.* (2007). Hyperaccumulation of arsenic by callus, sporophytes and gametophytes of *Pteris vittata* cultured in vitro. *Plant Cell Reports* 26: 1889–1897. Reproduced with permission no 4557630914446)

by Padhya & Mehta (1982) from stolon segments, in three species namely, *Nephrolpis cordifolia* (L.) C. Presl., *N. exaltata* (L.) Schott, and *N. acuta* (Schkuhr) C. Presl., and in *Osmunda cinnamomea* L. by Haight & Kuehnert (1969). The very young shoot primordia could thus be effectively used as propagules for rapid multiplication. All the *Nephrolepis* plants propagated through tissue culture techniques exhibited uniformity in their quality. Recently, callus induction and plantlet regeneration in ferns have been reported from gametophytic tissue of *Dryopteris affinis* (Lowe) Fraser-Jenkins. (Fernández & Revilla 2003) and from sporophytic tissue of rhizomes in *Platycerium cornarium* (O. F. Müll.) Desv. and *Platycerium bifurcatum* (Cav.) C. Chr. (Dolinsek & Camloh 1997). Moreover, large-scale propagation of these ferns in short time was possible. Both these factors would contribute to commercial feasibility of this approach by fern growers (Padhya & Mehta 1982).

The mechanism of culture and regeneration of clone gametophytes, using *in-vitro* methods has been described recently (Johari & Singh 2018). These clone gametophytes of *Cyathea spinulosa* Wall. *ex* Hook., *Pronephrium nudatum* (Roxb.) Holttum, *Anemia* *rotundifolia* Schrad., perform sexual expression and mating to augment the sporophyte production and their hardening and acclimatization (Singh *et al.* 2017, see Johari & Singh 2018).

Sporophytic fern tissues respond to *in vitro* culture with the production of calli (Partanen 1972) or gametophytes (von Aderkas 1986). Kaul & Kochhar (1985) reported the simultaneous production of both gametophytes and calli from mature pinnae of *Pteris vittata* L. cultured *in vitro*. They suggested that growth media are important in determining the developmental morphology of plant tissues cultured *in vitro*.

Working with *Microgramma vacciniifolia* (Langsd. & Fisch.) Copel., Hirsch (1975) showed that the ratio of sporophytes to gametophytes increased with increasing percentage of sucrose in the medium. Kaul & Kochhar (1985) using medium with sorbitol also, demonstrated that nutrition, rather than osmotic potential, was responsible for the induction of either.

(b) In vitro multiplication of edible ferns : Ostrich fern, *Matteuccia struthiopteris* (L.) Tod., produces edible fiddlehead and has great economic importance. The species is also used as a garden ornamental (von Aderkas 1984, 1985). The conventional method of asexual reproduction is through the production of new rhizomes from detached meristems present on old rhizomes (Wardlaw 1943). However, this method is very slow and produces only one to four new rhizomes per year. Plant tissue culture provides a method of rapid multiplication. *In vitro* propagation of *Matteuccia struthiopteris* (Ostrich fern) on solid media was achieved by Dykeman & Cumming (1985) and Hicks & von Aderkas (1986) who regenerated plantlets; the shoots from these plantlets were subsequently subcultured for further multiplication. Thakur *et al.* (1998) reported on another multiplication system, meristematic nodule (MN) propagation, which uses a combination of solid and liquid media for a very rapid and efficient regeneration of *M. struthiopteris*.

(c) In vitro multiplication of medicinal ferns : *Drynaria quercifolia* (L.) J. Smith (syn. *Polypodium quercifolia* L.*)* is commonly called the 'Oak Leaf fern', grows naturally in Mangalore, South India. It is a slow-growing, epiphytic fern growing on tree trunks, is known to have therapeutic uses. The fronds are pounded and used as a poultice for swellings (Ambasta 1992). Aqueous extracts possess antibacterial properties. It is used to treat tuberculosis, hectic fever, dyspepsia, phthisis, and as an expectorant and antihelminthic (Chatterjee & Prakashi 1991). The rhizome paste is applied to the forehead to relieve headache, and its extracts have been used as a bitter tonic for bowel inflammation (Chopra *et al.* 1992). *In vitro* culture and the production of ecdysteroids has been reported from *Pteridium aquilinum* (L.) Kuhn (Bracken Fern) (Macek *et al.* 1994).

Anemia tomentosa (Sav.) Sw. var. *anthriscifolia* (Schrad.) Mickelis, an aromatic fern with a pleasant woody aroma has antimycobacterial activity (Castilho *et al.* 2018). Pinto *et al.* (2013) characterized volatile essential oils from an *in vitro* culture of this plant. Castilho *et al.* (2018) studied the effect of two plant regulators—indole-3-acetic acid and jasmonic acid – on *Anemia tomentosa* var. *anthriscifolia in vitro* plant development and the production of volatile compounds.

(d) Protoplast culture : Isolated protoplasts of *Lygodium japonicum* (Thunb.)

Sw., were cultured in MS medium and developed cordate prothallia bearing both antheridia and archegonia (Plate 1) (Maeda *et al.* 1990).

(e) Somatic embryogenesis in ferns : Mikula *et al.* (2015) discovered that the tree fern *Cyathea delgadii* Pohl ex Stemberg offers an effective model for the reproducible and rapid formation of somatic embryos on hormone-free medium (Plates 2, 3 and 4). Somatic embryogenesis (SE) in both primary and secondary explants was induced on Murashige and Skoog medium without the application of exogenous plant growth regulators. The transition from somatic embryo to juvenile sporophyte was quick and proceeded without interruption caused by dormancy. The established suspension culture system is also a promising tool for analysing the molecular basis of different regeneration patterns as well as the early apogamy from the aposporous gametophytes.

The early stage of SE was characterized by sequential perpendicular cell divisions of an individual epidermal cell of etiolated stipe explants. These resulted in the formation of a linear pro-embryo. Later their development resembled that of the zygotic embryo. We defined three morphogenetic stages of fern somatic embryo development: linear, early and late embryonic leaf stage. The transition from somatic embryo to juvenile sporophyte was quick and proceeded without interruption caused by dormancy. Following 9 weeks of culture, the efficiency of somatic embryogenesis reached 12–13 embryos per responding explants.

(f) Suspension culture : Leaf cell suspensions of *Platycerium bifurcatum* (Cav.) C.Chr. (the Staghorn Fern) exhibited two different regeneration patterns which were closely related to the size of cell aggregates (Teng & Teng 1997). Large cell aggregates of above 500–1000 cells regenerated sporophytes directly [cell–sporophyte (Cell–S pattern)] (Plate 5, a, b). Single cells and aggregates of up to 100 cells developed aposporous gametophytes which later gave rise to sporophytes. It was suggested that a threshold size of cell aggregates separates the two regeneration patterns (Plate 5, a-h).

Platycerium bifurcatum (Cav.) C. Chr. is ornamental fern species in Taiwan. This species can be propagated sexually through spore germination. LIAO, and WU (2011) described propagation method through initiation of green globular bodies (GGBs) from juvenile leaf explants of *in vitro* grown sporophytes a *Platycerium bifurcatum* (Cav.) C. Chr.

The GGB culturing system has been applied to many fern species, including *Nephrolepis* spp. (Amaki & Higuchi, 1991), *Asplenium nidus* L. (Higuchi & Amaki, 1989), *Adiantum raddianum* C. Presl, *Pteris ensiformis* Burm. f., *Rumohra adiantiformis* (G. Forst.) Ching (Amaki & Higuchi, 1991), *Blechnum spicant* L. (Fernández *et al.*, 1996), and *Polypodium cambricum* L. (Bertrand *et al.*, 1999) (for details see LIAO & WU 2011)

(g) Immobilization of plant cell suspension cultures : The immobilization of plant cell suspension cultures employing various matrices has been well documented (*e.g.,* Yeoman 1987) and polyurethane foam has been used by a number of workers including Lindsey *et al.* (1983). The immobilization of gametophytes is clearly successful in terms of growth and hence as a culture system for the bulk production of gametophytic tissue. Spores of *Anemia phyllitidis* (L.)

Swartz and *Pteridium aquilinum* (L.) Kuhn developed into gametophytes on immobilize in foam by a completely passive process. Initially, rhizoids appear to become entangled within the foam and then as cell division leads to growth of the gametophyte, the pores within the foam become full of gametophyte tissue (Plate 6) (Douglas & Sheffield 1990).

2. Apospory and Apogamy

Apospory : Apospory is a morphogenetic process that is defined as the formation of gametophytes from sporophytic tissue in the absence of meiosis or sporulation (Raghavan 1989). In fern species, various aspects of the induction and subsequent development of aposporous gametophytes have been studied (Raghavan 1989), and several factors have been found to enhance apospory, including the culture media with either no sucrose or only low concentrations of it. Ambrozic *et al.* (2003) studied set of conditions which regularly and reproducibly induce apospory. They reported that in addition to the juvenility of explants, other important factors for apospory formation are the combination of a low sucrose concentration in the medium (0.01%) and wounding of the leaf. They also studied origin, morphology, and ploidy of aposporous gametophytes produced on juvenile leaves of the fern *Platycerium bifurcatum* (Cav.) C. Chr. The gematophytes originated from the leaf and were still connected to the leaf by one or more epidermal cells (**Plate 7**). This experimental system is useful for genetic and molecular approaches that can yield insights into the regulation mechanisms of apospory. There may be a set of genes regulating the induction of gametophytic cells from the sporophytic tissue. In this context, Mehra's (1975, 1989) 'Gene Block Hypothesis' assumes significance (see Verma 1975). The DNA content of aposporous gametophytes was similar to diploid sporophytes.

Kwa *et al.* (1990) reported production of first and second generation aposporous gametophytes from *Pyrrosia piloselloides* (L.) Price via frond strips cultured *in vitro*. Production of aposporous gametophytes from frond strips of *Davallia canariensis* (L.) Sm. (Somer *et al.* 2010), and *Drymoglossum piloselloides* (L.) C. Presl (synonym of *Pyrrosia piloselloides* (L.) M. G. Price, has also been reported (Kwa *et al.* 1988).

Apogamy : The production of sporophytes from vegetative cells of a gametophyte without the intervention of sex organs is termed apogamy. Mehra & Sulkalyan (1969) induced apogamy in the haploid and diploid gametophytes of *Ampelopteris prolifera* (Retz.) Copel. Apogamous roots were differentiated in *Nehprolepis cordifolia* from the haploid and diploid gametophytes on medium containing 2% sucrose (Sulkalyan & Mehra 1977, see also Palta & Mehra, 1983 in 4x *Pteris vittata* L.; Verma 2017, 2018). Explanation in genetic terms is still waiting for the unusual observation of Lang (1898, 1929) on the bearing of sporangia directly on the gametophyte of *Scolopendrium vulgare* L. The concept of gene-block hypothesis by Mehra (1975,1989) and of the conceived 'morphogenetic switch' by Bell (1992) may allow experimentation to discover the 'morphogenetic trigger'. Verma (1975, 2017), and Grusz (2016) have discussed several issues regarding apogamy in ferns, which still offer challenges to resolve (Cordle *et al.* 2012, Bui *et al.* 2017).

According to Salvo (1990), apogamous embryos are formed by proliferation of one or more vegetative cells near the apical notch and they parallel the normal embryo development. In the early days, the induction of apogamy in ferns was carried out using soil-grown gametophytes but in later years, studies have been conducted mainly on gametophytes grown on sterile culture media (Kwa *et al.* 1995). *Dryopteris affinis* (Lowe) Fraser-Jenk. ssp. *affinis* is a diploid fern with an apomictic life cycle and it probably originates from the crossing of *D. wallichiana* (Spreng.) Hyl. and *D. oreades* Fomin. When cultured *in vitro*, apogamy in this species is evident as gametophyte develops a brown meristematic area near the apical indentation that evolves into a new sporophyte. Sexual reproduction is not possible due to the lack of archegonia (Fernández *et al.* 1996a). The total suppression of archegonia on gametophytes of obligate apogamous ferns, or the presence of non-functional archegonia in some ferns, like *Pteris cretica* L. (Laired & Sheffield 1986), calls for its genetic basis.

Whittier (1964) reported that apogamy in *Pteridium aquilinum* (L.) Kuhn was induced by light whereas the actual development of the apogamous sporophyte was controlled by light, succinic acid or sugar. Kwa *et al.* (1995) described the role of IAA in the production of apogamous sporophytes from gametophytes of *Platycerium coronariurn* (J. Koenig ex O. F. Müll.) Desv. cultured *in vitro*. Sporophytes arose mainly from the centre of the newly regenerated gametophyte clumps after 3 weeks of culture (See also Mehra 1975, Cordle *et al.* 2012)

In the case of *Dryopteris affinis*, apogamy is reported *in vitro*, i.e. a sporophyte is developed without the process of sexual reproduction from gametophytes (Vashishta 1997, Mendez *et al.* 2006). Two-month-old gametophytes produced a brown meristematic area near the apical notch and there developed one sporophyte per gametophyte (**Plate 8**) (Fernández *et al.* 1996),

3. Genetic transformation of ferns

Transgenesis of ferns was first demonstrated in *P. vittata* and *C. thalictroides* (Muthukumar *et al.* 2013). They selected the spores as the plant material for *Agrobacterium* -mediated transformation. In addition to this spores, 5-day-old germinating spores, and 15-day-old gametophytes were used in the particle bombardment transformation (see also Kumar & Kotiya, 2018). Plackett *et al.* (2015) achieved genetic transformation of *Ceratopteris richardii* Brongn. using broad range of bombardment and recovery conditions (see also Bui *et al.* 2018). Using similar techniques transformation in *Adiantum capillus-veneris* L. has also been achieved (Kawai-Toyooka *et al.* 2004). Direct transformation of gametophytes enabled the study of candidate gene functions in apogamy, the asexual alternation from the gametophyte to the sporophyte generation (Bui *et al.* 2018).

Gametophyte life starts when spore uptake water, their coat breaks and unequal first cell division takes place, and prothallial and rhizoidal initials are formed. Until now, there is only limited information concerning perennial growth of gametophyte through vegetative proliferation, which increased its life span and formation of both sex organs, when met with favourable conditions for life (Khare *et al.* 2005

In general, two methods of fern propagation have been developed: sexually and asexually by offshoots. The first one consists in sterile spore germination and consecutive culture of two next generations. There are number of papers describing gametophyte and sporophyte culture of various non-tree ferns having different aim of studies. The list includes: *Microgramma vacciniifolia* (Langsd. & Fisch.) Copel. (Hirsch 1975), *Anemia phyllitidis* (L.) Sw. (Douglas & Sheffield 1990; Scheffield *et al.* 2001), *Pteridium aquilinum* (L.) Kuhn (Douglas & Sheffield 1990; Scheffield *et al.* 1997, 2001), *Athyrium filix–femina* (L.) Roth (Sheffield *et al.* 2001), *Dryopteris expansa* (C. Presl) Fraser-Jenk. & Jermy (Sheffield *et al.* 2001), *Platycerium coronarium* (J. Koenig ex O.F. Müll.) Desv. (Kwa *et al.*1995), *Asplenium trichomanes* L., *Asplenium scolopendrium* L. (Pangua *et al.* 1994), *Schizaea pusilla* Pursh (Kiss and Swatzell 1996), *Microsorum punctatum* (L.) Copel. (Srivastava *et al.* 2008), *Dregaria fortunei* Kunze (Chang *et al.* 2007), *Osmunda regalis* L. (Fernández *et al.*1997), *Matteucia struthiopteris* (l.) Todaro (Zenkteler 2006), and numerous endangered serpentine fern species of Poland (Marszal & Kromer 2000; Kromer *et al.* 2006).

In 1987, two papers from different laboratories concerning *in vitro* multiplication of tree ferns: *Cyathea dregei* Kunze (Finnie & van Standen 1987) and *Cyathea gigentia* (Wall. ex Hook.) Holttum (Padhya 1987) were published. Padhya (1987) paper described tree fern multiplication of *C. gigentia in vitro* using living explants: leaflet primordia and apical domes from garden grown plants. Each leaflet primordium was grown and finally developed into complete rooted frond. However, culture of apical meristems required higher sucrose concentration and twice higher NAA concentration. All regenerated, of cryostorage strategy for tree ferns (Mikula *et al.* 2010).

4. Environmental biotechnology: ecotoxicology and bioremediation in ferns:

Heavy metal tolerance : Generally, the ability of plants to tolerate and accumulate heavy metals is recognized in a variety of ways, such as immobilization, exclusion, chelation and compartmentalization (Fediuc & Erdei 2002, Prabhu *et al.* 2016). The fern *Athyrium yokoscense* (Fr. & Sav.) C. Chr. shows hyper-resistance to high concentrations of heavy metals (*e.g.* Zn, Cd, Pb and Cu) and accumulates the element in the plant body at considerably high concentrations [*e.g.* about 4,000 mg kg/ dry weight (DW) Cd, and 6,000 mg/ kgDW or more for Cu and Zn (Morishita & Boratynski 1992). In order to evaluate the Cd tolerance and accumulation abilities of *A. yokoscense*, Yoshihara *et al.* (2005) developed a simplified and standardized experimental system using *in vitro* callus and regenerated plantlet culture (**Plate 9**). The callus of a metal hyper-tolerant fern, *Athyrium yokoscense*, was induced from the spores generated on a small sectioned frond *in vitro* (**Plate 10**) (Yoshihara *et al.* 2005). The callus and regenerated tissues were exposed to Cd, every tissue tolerated at least 1 mM Cd for >1 month indicating that Cd tolerance of this fern is basically independent of the plant parts and the developmental stages. *A. yokoscense* grew vigorously under at least 1 mM of Cd without any visible damage.

Arsenic (As) is a metalloid that is highly toxic to microbes, plants, animals, and humans (Kaise *et al.* 1985, Prabhu *et al.* 2016). Phytoremediation is based on the discovery of hyper-accumulators and the improved understanding of the mechanisms of hyper-accumulation. In 2001, Chinese brake fern (*Pteris vittata* L.) was first reported to be an As hyper-accumulator; the fronds of this plant can accumulate up to 23 g kg^{-1} of As when growing on As-spiked soil (Ma *et al.* 2001, Yang *et al.* 2007) (**Plate 10).** This discovery opened up the possibility of phytoremediation of As-contaminated soil and groundwater (Tu *et al.* 2001). The ability to accumulate arsenic and the large biomass of *P. vittata* callus in liquid medium make it possible to test the feasibility of using *P. vittata* callus to remediate As-contaminated water.

Hyper-accumulation of arsenic by callus, sporophytes and gametophytes of *Pteris vittata* cultured *in vitro* was reported by Yang *et al.* (2007). *P. vittata* callus has potential in As-contaminated water remediation because it has both As hyper-accumulation and adsorption abilities. Thus *P. vittata* callus suspension culture provides a novel system for the analysis of As hyper-accumulation and a material with great potential in the remediation of As-contaminated water.

5. Therapeutical/medicinal applications

Pteridophytes possess secondary phytochemicals such as phenols, flavonoids and steroids which show antimicrobial properties. The antimicrobial activity in the extracts of 114 species of pteridophytes belonging to 61 genera and 27 families was studied and the results revealed that 64% of the samples examined possessed antimicrobial activity (Banerjee and Sen 1980). The extract of the fern, *Nephrolepis* sp. when mixed with a-D-oligogalacturonides promoted the production of an antibiotic compounds (Basile *et al.* 1997). *Cheilanthes viridis*, which is one of the most commonly used ferns in the treatment of wounds in Eastern Cape, South Africa possessed very good antimicrobial activity (Grierson & Afolayan 1999). Several ferns show antibacterial activity e.g. *Christella parasitica*, *Microlepia speluncae*, *Pteris multifida*, *Microsorum pteropus*, *Adiantum caudatum*, *Pteris vittata*. (see Nath *et al.* 2018). Six different ferns i.e. *Drynaria fortunei*, *Pseudodrynaria coronans*, *Davallia divaricata*, *D. mariesii*, *D. solida,* and *Humata griffithiana* are part of chinese medicine "Gu-Sui-Bu". Their fleshy rhizomes are used as source of medicine inflammation, cancer, ageing, blood stasis, physique ache and bone injuries.

6. Scope of Ferns in Horticulture and Economic Development

Singh & Johari (2018) reviewed scope of ferns in horticulture and economic development. They suggested that *Nephrolepis tuberosa* 'Ghora Patti Fern' are used as essential constituent in flower and foliar industry and a few ferns including *Diplazium esculentum* 'Dhekiya', *Ophioglossum reticulatum* 'Ekpatiya', *Ampelopteris prolifera* 'Macchinure' are ultimate food-stuff of many tribal communities.

7. Genes from Ferns in Agriculture - A possibility

Whitefly (*Bemisia tabaci*) damages field crops by sucking sap and transmitting viral disease. It infests several hundred plant species, including economically important crops. Shukla *et al.* (2018) reported that expression of an insecticidal fern protein in cotton protects against whitefly. They reported the identification of a protein (Tma12) from an edible fern, *Tectaria macrodonta* (Fée) C. Chr., which is insecticidal to whitefly and interferes with its life cycle at sublethal doses. Transgenic cotton lines which expressed Tma12 at were resistant to whitefly infestation with no detectable yield penalty under controlled field conditions (Shukla *et al.* 2018 see also Fernández *et al.* 2010).

CONCLUSION

Ferns ancient vascular plants of more than 300 million years exhibit diversity. Different aspects of morphology, systematics, ecology, evolution, phylogenetics have been carried out but researches on its biotechnological aspects are lacking. Plant biotechnology can play an important role in the contribution of ferns to the understanding of plant development their propagation, conservation and control of genetic variability in ferns. Besides environmental biotechnology: ecotoxicology and bioremediation in ferns and their therapeutical/medicinal applications have been presented. *In vitro* culture techniques from spore to sporophyte can provide mass propagation of endangered ferns and help their conservation. Medicinal and therapeutical applications ferns have also been indicated in the present review.

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REFERENCES

ADERKAS von P 1984 Economic history of Ostrich fern *Matteuccia struthiopteris*, the edible fiddlehead *Econ Bot* 38:14–23

ADERKAS von P 1985 The edible fiddlehead – Matteuccia struthiopteris (ostrich fern) *Proc R Soc Edinburgh Sect B* 86:151

AMAKI, W & H HIGUCHI 1991 A possible propagation system of *Nephrolepis, Asplenium*, *Pteris, Adiantum* and *Rumohra* (Arachniodes) through tissue culture Acta Hortic 300: 237-243

AMBASTA, S P 1992 *The useful plant of India* New Delhi: CSIR Publications and Information Directorate 918 pp

AmbroZiC-DolinSek, J, Camloh, M, Bohanec, B & Zel, J 2003 Apospory in leaf culture of staghorn fern (*Platycerium bifurcatum*) *Plant Cell Reports*, *20*, 791–796 http://doiorg/101007/s00299-001-0403-2

BANERJEE, R D & SEN, S P 1980 Antibiotic activity of Pteridophytes *Econ Bot* 34:284-98

Basile, A, Spagnuolo, V, Giordano, S, Sorrentino, C, Lavitola, A & Castaldo, R C 1997 Induction of antibacterial activity by a-Doligogalacturonides in *Nephrolepis* sp (pteridophyta) *Int J Antimicrob Agents* 8:131-34

BELL, P R 1992 Apospory and apogamy: Implications for understanding the plant life cycles *Int J Plant Sci* 153: S123-S136

BHARATI, SK, MANABENDRA, DT, & BEHARI, M P 2013 *In vitro* propagation in Pteridophytes: A review *Int J Res Ayurveda Pharm*4:297–303

BUI, LT et al 2017 A fern *AINTEGUMENTA* gene mirrors *BABY BOOM* in promoting apogamy in *Ceratopteris richardii* (*The Plant Journal*, online doi: 101111/tpj13479), pp 1-34

BUI, L T, LONG, H, IRISH, E E, CORDLE, A R, & CHENG, C L 2018 The power of gametophyte transformation *Current Advances in Fern Research*, 271–284 https://doiorg/101007/978-3-319-75103-0_13

CASTILHO, C V V, NETO, J F F, LEITÃO, S G, BARRETO, C S, PINTO, S C, & DA SILVA, N C B 2018 *Anemiatomentosa* var *anthriscifolia in vitro* culture: sporophyte development and volatile compound profile of an aromatic fern *Plant Cell, Tissue and Organ Culture*, *133*, 311–323 http://doiorg/101007/s11240-018-1383-z

CHANG, H-C, AGRAWAL, DC, KUO, C-L, WEN, J-L, CHEN, C-C, AND TSAY, H-S 2007 *In vitro* culture of *Drynaria fortunei*, a fern species of Chinese medicine “Gu-Sui-Bu” *In Vitro Cell Dev Biol Planta* 41:133–139

CHAPMAN, AD 2009 Numbers of Living Species in Australia and the World Report for the Australian Biological Resources Study Canberra, Australia September 2009 http://wwwenvironmentgovau/biodiversity/abrs/publications/other/species- numbers/indexhtml

CHEEMA, H K 2018 Ferns are an excellent experimental system for *in vitro* morphogenesis In: *Pteridology Today*: *Challenges and Opportunities* [eds Verma, S C et al] (Proceedings of the Symposium held at BSI, WRC, Pune, March 3-4, 2017) Botanical Survey of India, Kolkata pp 101-108

CHATTERJEE, A & PRAKASHI, S C 1991 *The treatise on Indian medicinal plants*vol:1 New Delhi: CSIR Publications and Information Directorate; 1-172 pp

CHOPRA, R N, NAYAR, S L & CHOPRA, I C 1992 *Glossary of Indian Medicinal Plants* CSIR New Delhi: Publications and information directorate; Pp 1-330

CORDLE, A R, IRISH, E E & CHENG, CL 2012 Gene expression associated with apogamy commitment in *Ceratopteris richardii Sex Plant Reprod* 25: 293–304

DOLINSEK, A & CAMLOH, M 1997 Gametophytic and sporophytic regeneration from bud scales of the fern *Platycerium bifurcatum* (Cav) C Chr *in vitro Ann Bot*80:23–28

DOUGLAS, G E & SHEFFIELD, E 1990 A new technique for the culture of fern gametophytes *Plant Cell Reports*, 8(10), 632–34 http://doiorg/101007/BF00270071

DYKEMAN B W & CUMMING B G 1985 *In vitro* propagation of ostrich fern *Matteuccia struthiopteri Can J Plant* Sci 65:1025–1032

FEDIUC, E & ERDEI, L 2002 Physiological and biochemical aspects of cadmium toxicity and protective mechanisms induced in *Phragmites australis* and *Typha latifolia J Plant Physiol* 159: 265–271

Fernández, H 2018 Current Advances in Fern Research Springer Germany Pp 544

FERNÁNDEZ, H, BERTRAND, AM & SACHEZ-TAMES, R 1996 Micropropagation and phase change in

Blechnum spicant and *Pteris ensiformis Plant Cell Tissue Org Cult* 44: 261-265

FERNÁNDEZ, H, BERTRAND, A M & SANCHEZ-TAMES, R 1996Influence of tissue culture conditions on apogamy in *Dryopteris affinis ssp affinis Plant Cell Tiss Organ Cult* 45:93–97

FERNÁNDEZ, H, BERTRAND, A M, & SÁNCHEZ-TAMÉS, R 1996a Influence of culture conditions on apogamy in *Dryopteris affinis* ssp *affinis Plant Cell Tiss Org Cult* 45:93–97

FERNÁNDEZ, H, BERTRAND, A, & SÁNCHEZ-TAMES, R 1997 Gemmation in cultured gametophytes of *Osmunda regalis Plant Cell Rep*orts, 16:358–362

FERNÁNDEZ, H & REVILLA, M A 2003 *In vitro* culture of ornamental ferns *Plant Cell Tiss Organ Cult* 73:1–13;

FERNÁNDEZ, H, KUMAR, A & REVILLA, MA 2010 Working with Ferns: Issues and Applications Germany Springer Pp 350

FRASER-JENKINS, C R GANDHI, K N, KHOLIA, B S & BENNIAMIN, A 2017 An annotated checklist of Indian Pteridophytes Part-1 Bishen Singh Mahendra Pal Singh, Dehra-Dun Pp 562

FERNÁNDEZ, H, AM, BERTRAND, & R SACHEZ-TAMES 1996 Micropropagation and phase change in *Blechnum spicant* and *Pteris ensiformis* Plant Cell Tissue Org Cult 44: 261-265

FINNIE, J F & VAN STADEN, J 1987 Multiplication of tree fern *Cyathea dregei* Hort Sci 22 : 665

GOSWAMI, H K, SEN, K & MUKHOPADHYAY, R 2016 Pteridophytes: evolutionary boon as medicinal plants *Plant Genetic Resources* 14 : 328-355

GRIERSON, D S & AFOLAYAN, A J 1999 Antibacterial activity of some indigenous plants used for the treatment of wounds in the Eastern Cape, South Africa *J Ethnopharmacol* 66 : 103-06

GRUSZ, A 2016 A current perspective on apomixis in ferns *J Syst Evol* 54 : 656-665

HAIGHT, TH, & KUEHNERT, CC 1969 Developmental potentialities of leaf primordia of Osmunda cinnamomea V Toward greater understanding of the final morphogenetic expression of isolated set I cinnamon fern leaf primordia *Can J Bot* 49 : 481-488

HEGDE, S, MENON, V K, NORONHA, R, & D'SOUZA, L 2008 Callus culture and an unconventional pattern of sporophyte regeneration in Drynaria quercifolia, -a medicinal fern *In Vitro Cellular & Developmental Biology Plant,* 42, 508–513 http://doiorg/101079/ivp2006810

HICKS, G & VON ADERKAS, P 1986 A tissue culture of the Ostrich fern, Matteuccia struthiopteris (L) Todaro *Plant Cell Tissue Organ Cult* 5 : 199-204

HIGUCHI, H & W AMAKI 1989 Effects of 6-benzylaminopurine on the organogenesis of *Asplenium nidus* L through in vitro propagation *Sci Hort* 37 : 351-359

HIRSCH, A M 1975 Production of aposporous gametophytes and calli from Pteris vittata L pinnae strips cultured in vitro *Plant Physiol* 56 : 390-393

IBARS, A M, & ESTRELLES, E 2012 Recent developments in ex situ and in situ conservation of ferns *Fern Gazette,* 19, 67-86

KAISE, T, WATANABE, S & ITOH K 1985 The acute toxicity of arsenobetaine *Chemosphere* 14 : 1327-1332

KAUL, K KOCHHAR, TS 1985 Growth and differentiation of callus cultures of Pinus Plant Cell Reports, 180-183 http://doiorg/101007/BF01690259

KAUL, K & KOCHHAR, T S 1991 Production of aposporous gametophytes and calli from Pterisvittata L pinnae strips cultured in vitro *Plant Cell Reports,* 10 : 392-393

KAWAI-TOYOOKA H, KURAMOTO C, ORUI K, MOTOYAMA K, KIKUCHI K, KANEGAE T, & WADA M 2004 DNA interference: a simple and efficient gene-silencing system for high-throughput functional analysis in the fern *Adiantum Plant Cell Physiol* 45 : 1648-1657

KHARE, P B, BEHERA, S K, SRIVASTAVA, R, & SHUKLA, SP 2005 Studies on reproductive biology of a threatened tree fern Cyathea spinulosa Wallex Hook *Curr Sci* 89 : 173–177

KROMER, K, MARSZAL-JAGACKA, J, KEMPINSKA, K, NOWAK, T, ZOLNIERZ, L, POTURALA, D, &

D SWIERKOSZ, K 2006 *In vitro* propagation and ex situ preservation of endangered ferns from Lower Silesia *Bot Guidebook* 29 : 143-155

KISS, J Z, & SWATZELL, L J 1996 Development of the gametophyte of the fern *Schizaea pusilla J Microsc* 181 : 213-221

KUMAR, A & A KOTIYA 2018 Plant Biotechnology and its applications in propagation, conservation and genetic diversity of ferns In : *Pteridology Today : Challenges and Opportunities* (Eds Verma, S C *et al.*) (Proceedings of the Symposium held at BSI, WRC, Pune March 3-4, 2017) *Botanical Survey of India* Kolkata pp 80-90

KWA, S H, WEE, Y C, & LOH, C S 1988 *Drymoglossum piloselloides* (L) Presl frond strips, *Plant Cell Reports* 7 : 142–143

KWA, S H WEE, Y C & LOHC S 1990 Production of first and second generations aposporous gametophytes from Pyrrosia piloselloides (L) Price frond strips cultured *in vitro Plant Cell Reports* 8 : 530-533

KWA, S H, WEE, Y C & LOH, C S 1995 IAA induced apogamy in Platycerium coronarium (Koenig) Desv gametophytes cultured *in vitro Plant Cell Reports* 14 : 598-602

LAIRD, S & SHEFFIELD, E 1986 Antheridia and archegonia of the apogamous fern Pteris cretica *Ann Bot* 57(2) : 139-143

LANG, W H 1898 On apogamy and the development of sporangia upon fern prothalli *Philosophical Transactions of the Royal Society of London Series B,* 190 : 187-238

LANG, W H 1929 On a variety of Scolopendrium vulgare that bears sporangia on the prothallus *Ann Bot* 43(170) : 355-374

LIAO, Y K & WU, Y H 2011 *In vitro* propagation of Platycerium bifurcatum (Cav) C Chr via green globular body initiation *Botanical Studies* 52 : 455-463

LINDSEY, K, YEOMAN, MM, BKICK, G M & MAVITUNA, F 1983A novel method for the immobilization and culture of plant cells *FEBS Lett* 15 : 143-14

MA LQ, KOMAR, KM, TU, C, ZHANG, W, CAI, Y, & KENNELLEY, ED 2001 A fern that hyperaccumulates arsenic *Nature* 409-579

MACEK, T, & VANEK, T 1994 *Pteridium aquilinum* (L) Kuhn (Bracken Fern): *In Vitro* Culture and the Production of Ecdysteroids In : Bajaj YPS (eds) *Medicinal and Aromatic Plants* VI Biotechnology in Agriculture and Forestry, vol 26 Springer, Berlin, Heidelberg

MAEDA, M, SUGIMOTO, Y, NAKAMURA, M, MASUDA, K, KANEKO, H, & SUGAI, M 1990 Division and gametophytic tissue formation from protoplasts of young sporophytes in fern *Lygodium japonicum Plant Cell Reports*, 9(3), 113–116http://doiorg/101007/ BF00232083

MARSZAL, J, & KROMER, K 2000 The use of *in vitro* culture methods for the protection of rare and endangered serpentine fern species *Bull Bot Gardens Museums Collections* 9 : 141-146

MEHLTRETER, K, WALKER, LR & SHARPE, JM 2010 Fern Ecology Cambridge University Press, New York

MEHRA, P N 1975 Some aspects of differentiation in cryptogams *Res Bull Panjab Univ* (Chandigarh, India) 23 : 221-242 [of 1972, released 1975]

MEHRA, P N 1989 Some Aspects of Differentiation in Flowering Plants Raj Bandhu Industrial Co, C-61, Mayapuri Industrial Area, Phase II, New Delhi, pp 1-35

MENÉNDEZ, V, VILLACORTA, N F, REVILLA, M A, GOTOR, V, BERNARD, P, & FERNÁNDEZ, H 2006 Exogenous and endogenous growth regulators on apogamy in *Dryopteris affinis* (Lowe) Fraser-Jenkins ssp *affinis Plant Cell Reports*,25: 85–91 http://doiorg/ 101007/s00299-005-0041-1

MIKUL, A, MAKOWSKI, D, WALTERS, C & RYBCZYNSKI, J J 2010 Exploration of Cryo-methods to Preserve Tree and Herbaceous Fern Gametophytes [Chapter 13, p 173-192] In: '*Working with Ferns : Issues and Applications*' H Fernandez *et a*l (eds), Springer, Germany Pp 350 DOI: 101007/ 978-1-4419-7162-3_13

MIKULA, A, POZOGA, M, TOMICZAK, K, & RYBCZYNSKI, J J 2015 Somatic embryogenesis in ferns: a new experimental system *Plant Cell Reports*, 34, 783–794 http://doiorg/101007/s00299-015-1741-9

MIKULA, A, & RYBCZYNSKI, J J 2006 Preliminary studies on cryopreservation and strategies of *Cyathea australis* gametophyte development in vitro *Bot Giudebook* 29 : 133-142

MIKULA, A, JATA, K, & RYBCZYNSKI, J J 2009 Cryopreservation strategies for *Cyathea australis* (RBR) Domin CryoLetters 30 : 429-439

Murashige, T, & Skoog, F 1965 A revised medium for rapid growth and bioassays with

MORAN, R C 2015 An overview of ferns and lycophytes Opening Symposium Abstract (p5) In 'Next Generation Pteridology' [An International Conference on Lycophyte and Fern Research], Smithsonian Institution and US Botanic Garden, Washington DC; June 1-5, 2015 *Book of Program and Abstracts,* Pp 74

MORISHITA, T, & BORATYNSKI, JK1992 Accumulation of cadmium and other metals in organs of plants growing around metal smelters in Japan *Soil Sci Plant Nutr* 38 : 781-78

MURASHIGE, T 1977 In: Barz W, Reinhard E, Zenk ~IH (eds) *Plant tissue culture and its biotechnological application,* Springer-Verlag, Berlin Heidelberg, New York pp: 392-402

NATH, K, BHATTACHARYA, M K, & KAR, S 2018 Antimicrobial Potential of Ethnomedicinal Ferns of Southern Assam, India *Indian Journal of Pharmaceutical Sciences*, *80*, 556–560 https://doiorg/104172/pharmaceutical-sciences1000392

NETMORE, R H 1970 In: Hillman N (ed) Papers in *Plant Physiology* 525-43

NEUMANN, K, KUMAR, A & AND IMANI, J 2009 Plant Cell and Tissue Culture - A Tool in Biotechnology Basics and Application Germany Springer 333 pp

PANGUA, E, LINDSAY, S, & D DYER, A 1994 Spore germination and gametophyte development in three species of *Asplenium Ann Bot* 73 : 587–593

PADHYA, M A 1987 Mass propagation of ferns through tissue culture *Acta Hort* 212:645–649

PLACKETT, A R G, RABBINOWITSCH, E H, & LANGDALE, J A 2015 Protocol: Genetic transformation of the fern *Ceratopteris richardii* through microparticle bombardment *Plant Methods*, 11(1) : 1-10 http://doiorg/101186/s13007-015-0080-8

PRABHU, S G, SRINIKETHAN, G, HEGDE, S 2016 Potential of Pteridophytes in heavy metal phytoremediation *International Journal of Research in Engineering and Technology* 5 : 1-9

RAGHAVAN, V 1989 *Developmental biology of fern gametophytes* Cambridge University Press, Cambridge

SARA, S CATHARIN & MANICKAM, V S 2005 *In vitro* propagation of the critically endangered fern *Cyathea crinita* (Hook) Copel *Asian J Microbiol Biotech Env Sci* 7 : 527-536

SHEFFIELD, E, DOUGLAS, GE, & COVE, D J 1997 Growth and development of fern gametophytes in an airlift fermentor *Plant Cell Reports* 16 : 561–564

SHEFFIELD, E, DOUGLAS, GE, HEARNE, SJ, HUXHAM, S, & WYNN, JM 2001 Enhancement of fern spore germination and gametophyte growth in artificial media *Am Fern J* 91 : 179-186

SRIVASTAVA, R, SRIVASTAVA, J, BEHERA, SK, & KHARE, PB 2008 *In vitro* studies on development of gametophyte, sex-ontogeny and reproductive biology of a threatened fern, *Microsorium punctatum* (L) Copel *Indian J Biotechnol* 7 : 266-269

SHUKLA, A K *et al* 2016 Expression of an insecticidal fern protein in cotton protects against whitefly *Nature Biotechnology* (advance online publication 5 Sept 2016), pp 1-9

STEEVES T A 1966 In : Cutter EC (ed) *Trends in plant morphogenesis,* Longmans London 200-219

TENG, W L, & TENG, M C 1997 *In vitro* regeneration patterns of *Platycerium bifurcatum* leaf cell suspension culture *Plant Cell Reports*, 16 : 820-824 http://doiorg/101007/s002990050327

THAKUR, R C, HOSOI, Y & ISHII, K 1998 Rapid *in-vitro* propagation of *Matteuccia struthiopteris* (L) Todaro - An edible fern *Plant Cell Reports*, 18 : 203–208 http://doiorg/101007/s002990050557

TU, C, MA, LQ & BONDADA, B 2001 Arsenic accumulation in the hyperaccumulator Chinese brake and its utilization potential for phyto-remediation *J Environ Qual* 31 : 1671-1675

VASHISHTA, P C, 1997 ed Botany Part IV *Pteridophyta* (Vascular Cryptogams), 5th ed, New Delhi Chand S and Company Ltd 390 pp

VERMA, S C 2005 Compartmentalization of the fern genome and the gene block hypothesis revisited *Bionature* 25 (1&2) : 41-55

VERMA, S C 2017 Fresh look at the cytology, genetics and evolutionary potential of agamospory in homosporous ferns *Bionature* 37 : 86-106

VERMA, S C 2018 Opportunities and challenges of exploring ferns and lycophytes in the genomics age: A brief overview of some issues In: *Pteridology Today* : *Challenges and Opportunities* [eds Verma, S C *et al*] (Proceedings of the Symposium held at BSI, WRC, Pune, March 3-4, 2017) *Botanical Survey of India*, Kolkata pp 8-32

VICENT, M, GABRIEL Y GALÁN, J M & AINOÜCHE A 2014 Insight into fern evolution : a mechanistic approach to main concepts and study techniques *Botanica Complutensis,* 38 : 7-24

WARDLAW, C W 1943 Experimental and analytical studies of pteridophytes I Preliminary observations in the development of buds on rhizomes of the ostrich fern *Matteuccia struthiopteris* Tod *Ann Bot NS* 7 : 171–184

WHITTIER, D P 1964 The Influence of Cultural Conditions on the Induction of Apogamy in *Pteridium* gametophytes *Amer J Bot* 51: 730-736

YANG, X, CHEN, H, XU, W, HE, Z, & MA, M 2007 Hyperaccumulation of arsenic by callus, sporophytes and gametophytes of *Pteris vittata* cultured *in vitro Plant Cell Reports*, 26 : 1889-1897 http://doiorg/101007/s00299-007-0388-6

YANG, X, CHEN, H, XU, W, HE, Z, & MA, M 2007Hyperaccumulation of arsenic by callus, sporophytes and gametophytes of *Pteris vittata* cultured *in vitro Plant Cell Reports*, 26 : 1889–1897 http://doiorg/101007/s00299-007-0388-6

YEOMAN, MM 1987 Bypassing the plant *Ann Bot* 60 : 157-174

YOSHIHARA, T, TSUNOKAWA, K, MIYANO, Y, ARASHIMA, Y, HODOSHIMA, H, SHOJI, K, & GOTO, F 2005 Induction of callus from a metal hypertolerant fern, *Athyrium yokoscense*, and evaluation of its cadmium tolerance and accumulation capacity *Plant Cell Reports*, 23 : 579–585 http://doiorg/101007/s00299-004-0877-9

ZENKTELER, E 2006 Micropropagation of *Matteucia struthiopteris* (L) Tod through meristem proliferation from rhizomes *Biodiversity Research Conservation* 1-2 : 167-173

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PHENOLOGY AND LEAF LIFESPAN OF AN ENDANGERED FERN *ANGIOPTERIS SOMAE* (MARATTIACEAE)

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ABSTRACT

Angiopteris somae (Hayata) Makino & Nemoto is an endemic and endangered fern in Taiwan. We investigated monthly the phenology of population of this fern that was located in middle Taiwan from January 2002 to December 2008. Results showed that *A. somae* is a perennial fern, and all sampled plants survived across the study period. Fertile leaves (98%) mostly emerged during spring and early summer (March to June). They released spores mainly (86%) in winter (December to February) in contrast to the summer-autumn release pattern of most tropical ferns. On the other hand, most sterile leaves (91%) emerged during April to September. The number of emerging fertile leaves, used to represent the emergent seasonality, did not correlate with monthly precipitation (MP), temperature (MT), and day length (MD), while sterile leaves had significant correlation with these three environmental factors. The correlation of the monthly number of spore-releasing leaves was significantly negative with respect to MT and MD, but not with respect to MP. The mean annual number of emergent leaves per plant was 1.97, which is low compared to other fern studies. Leaf senescence mainly occurred from April to September in a significantly seasonal pattern with 85.7% fertile and 72.7% sterile leaves senescing in this period. The numbers of senescent fertile leaves significantly correlated with MP, MT, and MD, whereas sterile leaves only significantly correlated with MP and MT, not MD. The mean count of living leaves per plant ranged from a low of 4.64 (February) to a high of 5.56 (May), a seasonal pattern that had significant correlation with MP, MT, and MD. Leaves of *Angiopteris somae* had long leaf lifespans. The mean lifespans of sterile and fertile leaves were 40.7 and 25.6 months respectively based on direct observation; 53.3 months and 23.8 months respectively estimated by turnover rate. Although this species is categorized as monomorphic due to the similar morphology of its fertile and sterile leaves, the timing of phenophases and lifespans of these two types of leaves are significantly different. Eleven typhoons attacked this studied area in five of seven monitoring years. The effect of typhoons on phenological traits of this species is stated and discussed. This study, demonstrates that all monitored phenophases have significant seasonality and winter is the best time of year to harvest mature spores of this endangered species for culturing and *ex-situ* conservation.

Key Words : Circular statistics, Leaf emergence, Leaf senescence, Spore release, Seasonality, Taiwan

INTRODUCTION

Studies of plant phenology identify the timing and duration of specific plant growth and fertility responses to seasonal changes in such climate factors as temperature, rainfall,

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and daylength. Such observations can also be used for elucidating the ecological and reproductive biology of a plant species (Newstrom & Frankie 1994, Mehltreter 2008). This kind of study also provides helpful knowledge for plant conservation but is often neglected and less practically applied, especially for ferns.

The phenology of ferns is most strongly affected by abiotic factors because of their independence from pollinations and dispersers (Wagner & Gómez 1983). Most ferns display seasonal phenological patterns. The occurrences of their phenophases are usually correlated with climatic conditions that ensure the population survival and regeneration (Mehltreter 2008). Fern phenology has been increasing explored in recent decades (reviewed in Lee *et al*. 2018). However, most fern phenological studies were conducted over a relatively short time span (e.g., one to three years), and thus long-term phenological information is less available. A long-term phenological study provides an opportunity to explore unexpected implications and make intriguing discovery (Halleck *et al.* 2004) for that can lead to further studies and/or hypothesis proposals, especially for those ferns with long-lived leaves. In fact, a long-term phenological study could offer much valuable information on survival, annual variation of phenophases, the impact of external climatic factors (Morellato *et al.* 2000), including natural disturbance such as hurricane (Sharpe 2010, Sharpe & Shiels 2014), and suitable collecting spore season for fern species (Odland 1995; Ying & Huang 1995). All of these data are basic knowledge that is necessary for the conservation of threatened ferns.

For ferns, leaves are their main photosynthetic as well as spore producing organs. Thus, ferns' leaf lifespans (LLS) have relevant impacts on their sporeling recruitment and population fluctuation. Mehltreter and Sharpe (2013) compare documented LLS of 71 fern species, but most of those data do not distinguish fertile LLS from sterile ones, and that might lead to a deviated conclusion (Lee *et al*. 2018). Differences between fertile and sterile leaves not only appear in LLS but also in the phenophases (Nagano & Suzuki 2007), especially of dimorphic ferns (Sharpe & Jernstedt 1990, de Paiva Farias *et al*. 2018). However, the distinction of this "behavior", as mentioned by Wagner & Wagner (1977), is seldom recognized in monomorphic ferns (see examples in Lee *et al*. 2018).

Angiopteris somae (Hayata) Makino & Nemoto (= *Archangiopteris somai* Hayata) is a long-lived monomorphic fern that grows on shady moist soils in low-elevation forests (Plates 1 & 2). It is endemic to Taiwan, sparsely distributed with less than 1000 mature plants, and is categorized as endangered based on the criteria of IUCN (2003) (Wang *et al.* 2012). Its phenological traits have never been studied before.

Because circular statistics could calculate phenological variables, such as the mean occurrence date and concentration degree of a phenophase (divergence from a random or uniform distribution) (Morellato *et al.* 2010), this method can get a fair interpretation for a species growth and is applied to analyze the phenological data in this study. We conducted a long-term (7 years) phenological survey on *A. somae* 1) to monitor variations in

Plate 1. ***Angiopteris somae*** **:** habitat (a), the population indicated by an arrow; a close-up of the population (b); a pulvinus on the stipe (c). Photographed by Pei-Hsuan Lee.

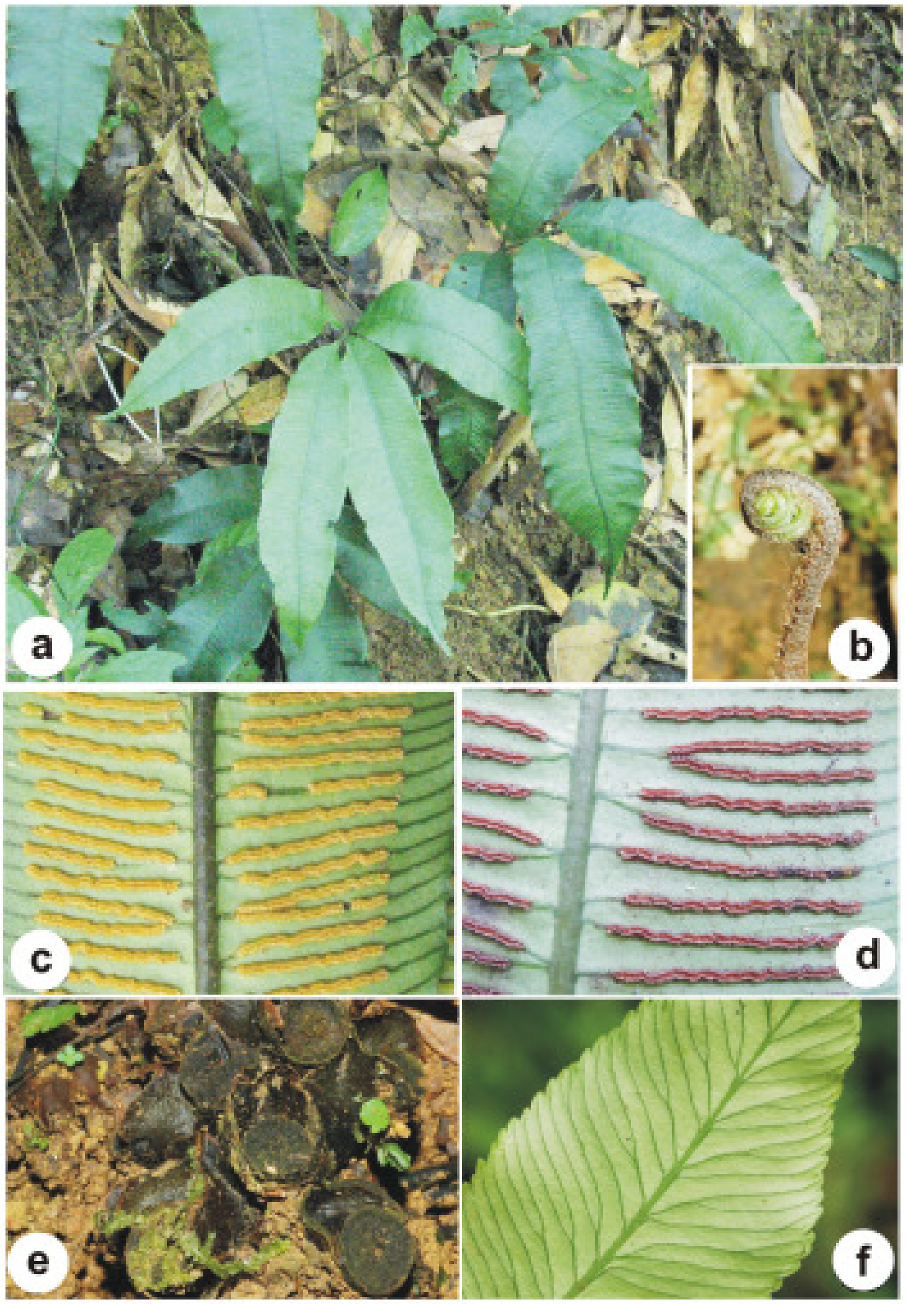


Plate 2. ***Angiopteris somae*** **:** habit (a); crozier (b); mature sporangia (c); spore-released (d); leaf base and stipules (e); abaxial surface of pinna (f). a–c, e, & f, Photographed by Pi-Fong Lu; d by Pei-Hsuan Lee.

phenophase seasonality and leaf lifespan and differences between those of fertile and sterile leaves, 2) to explore influences of typhoon on phenophases, 3) to analyze the correlation of phenophases with environmental factors, and 4) to identify a time of year most suitable for spore harvesting to facilitate propagation and *ex situ* conservation of this threatened species.

MATERIALS AND METHODS

Study site and investigation

The study site was located in a shady valley under a subtropical broadleaf forest, which is managed by the Lienhuachih Research Center (LRC) of Taiwan Forestry Research Institute in central Taiwan (23°55'43'' N, 120°54'00''E, alt. ca. 680 m). The forest is dominated by trees in the Fagaceae and Lauraceae families.

Ten plants of *A. somae* were sampled. All leaves were labeled with a small plastic tag when they had emerged and expanded to ca. 1 cm tall. Five phenophases i.e., emergence and senescence of both fertile and sterile leaves and spore release, were observed early in every month (1st–10th day of each month) from January 2002 to December 2008. In addition, the size and the number of pinnae of fully expanded leaves were recorded. Leaf lifespans (LLS) were determined by direct observation from their emergence to senescence (when a leaf totally turned brown) and by indirect estimate from leaf turnover rate (LLS = (the mean annual number of living leaves / the mean number of emergent leaves per year) ×12 month; Seiler 1981, Tanner 1983).

Emergence of the fern leaf was signaled by the appearance of a coiled leaf (crozier) that then took one to two months to fully expand. Leaf senescence was the end process of leaf growth, when leaf turned brown. Degree of sporangium openness was used to represent spore release, i.e., ca. 5% of sori having open sporangia indicates the start of spore release. Although a leaf may release spores for a span of up to three months, the spore release dates in this study reflect the start of that release period and indicate the time of spore complete maturation.

Environmental data

Environmental data were obtained from the LRC weather station (23°55'07'' N, 120°53'07''E, alt. 681m), ca 1.8 km away from the study site. Annual precipitation varied every year during the study period and ranged from 1,410 to 4,302 mm with a mean of 2,672 mm. Eleven typhoons attacked this area during this study period (Table 1). The annual precipitation showed a significantly positive correlation with the number of typhoons (r = 0.88**). All typhoons attacked during July to September in different years. The mean annual temperature was 19.9–20.5°C with a mean of 20.1°C, with min/max monthly mean temperatures of 14.5/24.4°C (January/July). Mean annual day length was 12.2 hrs, with a maximum monthly value in June (13.6 hrs) and a minimum in January (10.8 hrs). The season classification follows Walter *et al.* (1975). Perhumid season, with monthly precipitation more than 100 mm, appeared in April to September. Other months belong to

TABLE 1 : The mean annual temperature, accumulative precipitation and typhoon in Lienhuachih area during the study period

Year	Temperature (^{0}C)	Precipitation (mm)	Typhoon
2002	20.4	1410.0	
2003	20.3	1622.3	
2004	20.0	2656.5	Mindulle
2005	19.9	2721.4	Haitang, Matsa, Talim
2006	20.4	3067.4	Ewiniar; Bilis
2007	20.1	2924.5	Sepat
2008	19.9	4302.5	Kalmaegi, Fung-Wong, Sinlaku, Jangmi
Average	20.1	2672.1	

relative humid season, of which the monthly precipitation is less than 100 mm but more than the predicted evaporation, i.e., mean monthly temperature*2. Dry season, with monthly precipitation less than 100 mm and less than the predicted evaporation, did not occur during typhoon years but was present in non-typhoon years (February and November, 2002–2003) (Fig. 1).

Data analysis

For circular statistics each monitoring date was first assigned to a Julian day: e.g., 1st Jan = 1 day; 31st Dec = 365 or 366 days, depending on whether it was a common year or leap year. Then the formula of Zar (2010) was used for calculating the corresponding angular direction.

$$a = ((360°)(X)) / k$$

where a = angular direction, X = Julian days, k =365 (or 366 in leap year)

Then circular statistics were used to calculate the mean angle $\boldsymbol{a}$ (= mean of angular direction) and vector $\boldsymbol{r}$. Length of vector $\boldsymbol{r}$, a measure of concentration approaching the mean angle, has no unit and varies from 0 (when occurrence times of phenophases are distributed uniformly throughout the year) to 1 (when occurrence times are concentrated at one single date). Rayleigh test was used to detect the significance of vector $\boldsymbol{r}$ (Morellato *et al.* 2000, 2010). The Watson-Williams test (F) was performed (Kanji 2006) to compare the mean angles $\boldsymbol{a}$ of occurrence times of phenophases between sterile and fertile leaves (methods see Morellato *et al.* 2000, 2010).

Because phenophases were observed at different times rather than angles, the mean angle was converted to a corresponding date (Zar 2010). Pearson product-moment correlation coefficient was used to test correlations (r) between the timings of phenophases (indicated by leaf numbers of occurrence) and environmental data.

RESULTS

Emergence of leaves

A total of 138 new leaves, including 64 fertile and 74 sterile ones, emerged during the 7 years for the 10 monitored plants at a mean rate of 1.97 leaves plant^{-1} year^{-1}. Mean annual production of leaves varied from year to year and ranged from 1.40 (2003) to 2.70 per plant (2008) (Table 2).

Different numbers of new leaves emerged in all months except January and February when none appeared. Almost all fertile leaves (98%) emerged during March to June, whereas most sterile leaves (91%) emerged during April to September (Fig. 2a). Emergence dates of both fertile and sterile leaves were seasonal, with mean dates on 17 April (vector ***r*** = 0.90**) and 30 June (vector ***r*** = 0.55**), respectively, and were significantly different (Table 3).

TABLE 2 : Annual leaf numbers of different phenophases per plant in *Angiopteris somae*. F= fertile leaf; S= sterile leaf.

Year	Emergence			Senescence			Living			Releasing spores
	F	S	Sum	F	S	Sum	F	S	Sum	
2002	0.60	1.30	1.90	2.20	1.00	3.20	1.78	2.38	4.16	1.10
2003	0.90	0.50	1.40	0.90	1.10	2.00	1.28	2.53	3.81	0.40
2004	0.30	2.10	2.40	0.70	0.30	1.00	0.68	2.96	3.64	0.10
2005	0.60	1.50	2.10	0.20	1.30	1.50	0.98	3.97	4.95	0.50
2006	0.90	0.90	1.80	0.20	0.40	0.60	1.56	4.31	5.87	0.30
2007	1.10	0.40	1.50	0.20	1.20	1.40	2.38	4.16	6.54	0.50
2008	2.00	0.70	2.70	1.20	1.30	2.50	3.43	3.48	6.91	1.40
Mean	0.91	1.06	1.97	0.80	0.94	1.74	1.73	3.40	5.13	0.61

TABLE 3: Data of circular analysis of seasonality in *Angiopteris somae*. n_f = number of fertile leaves, n_s = number of sterile leaves, *a* = mean angle, *r* = vector *r*, concentration approaching *a*.

	Fertile leaves			Sterile leaves			Watson-Williams tests
	n_f	Mean date (*a*)	*r*	n_s	Mean date (*a*)	*r*	*F*
Emergence	64	17, Apr (107)	0.90**	74	30, Jun (179)	0.55**	13.82**
Senescence	56	2, Jul (181)	0.42*	66	15, Aug (224)	0.45**	4.09*
Spore release	43	11, Jan (11)	0.77**				

* $p<0.05$, ** $p<0.01$

In fertile leaves, the number of monthly emerging leaves did not correlate with monthly precipitation (MP), temperature (MT), or day length (MD), while sterile leaves had significant correlations with these three environmental factors (Table 4).

Senescence of leaves

A total of 122 senescent leaves, including 56 fertile and 66 sterile ones, were recorded in this study. Mean number of senescent leaves were 1.74 per plant annually, slightly lower than that of emergence (1.97). Annual senescent leaves ranged from 0.6 (in 2006) to 3.2 per plant (in 2002) (Table 2).

Although leaves withered almost throughout year, senescence mainly occurred in perhumid season (from April to September) (Fig. 2b) and expressed a significantly seasonal pattern, i.e., 85.7% and 72.7% fertile and sterile leaves senesced in this period, respectively. Mean dates of senescence of fertile and sterile leaves were significantly different occurring on 2, July (vector ***r*** = 0.42^{*}) and 15, August (vector ***r*** = 0.45^{**}) respectively (Table 3).

Numbers of monthly senescent fertile leaves were significantly positively correlated with MP, MT, and MD, but counts of monthly senescent sterile leaves had significant correlations only with MP and MT, not with MD (Table 4).

TABLE 4 : The Pearson correlation coefficients (*r*) between monthly climatic factors with the mean monthly leaf number of each phenophase.

	Precipitation	Temperature	Day length
Emergence			
fertile	-0.05^{ns}	0.11^{ns}	0.29^{ns}
sterile	0.81^{**}	0.86^{**}	0.87^{**}
all	0.28^{ns}	0.43^{ns}	0.58^{*}
Senescence			
fertile	0.67^{*}	0.58^{*}	0.61^{**}
sterile	0.56^{*}	0.65^{*}	0.40^{ns}
all	0.72^{**}	0.72^{**}	0.59^{*}
Living			
fertile	0.66^{*}	0.75^{**}	0.83^{**}
sterile	0.78^{**}	0.84^{**}	0.62^{*}
all	0.78^{**}	0.86^{**}	0.84^{**}
Spore release	-0.51^{ns}	-0.83^{**}	-0.64^{*}

^{ns} $p>0.05$, * $p<0.05$, ** $p<0.01$

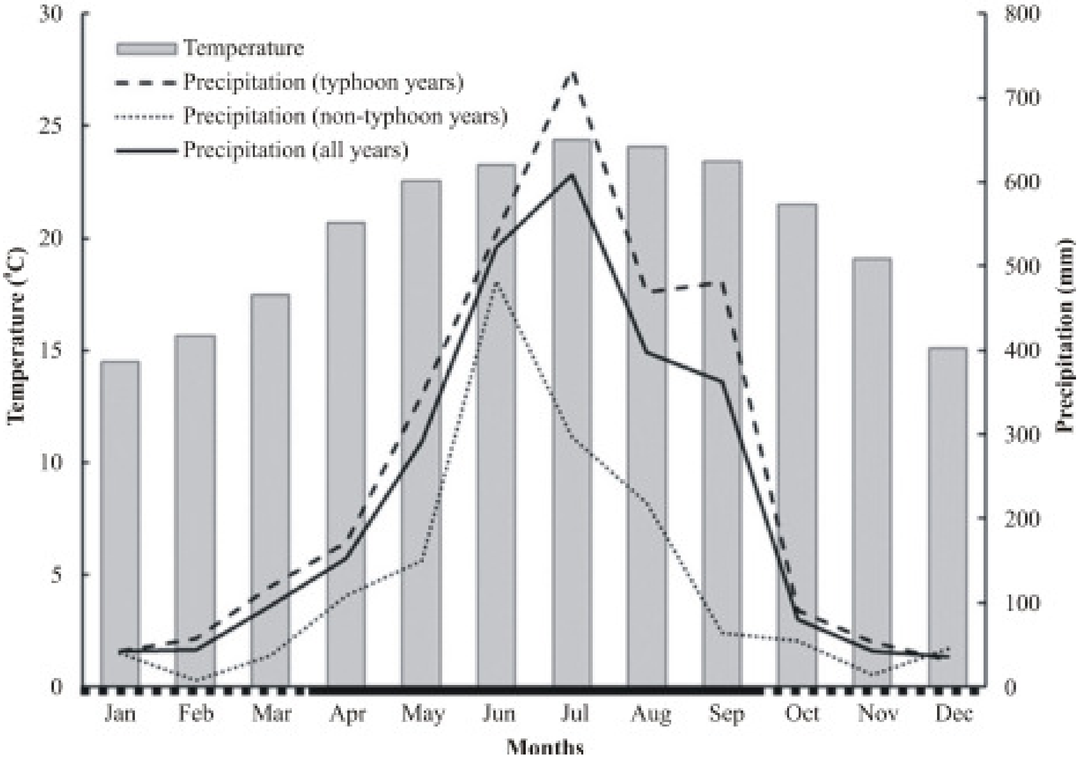
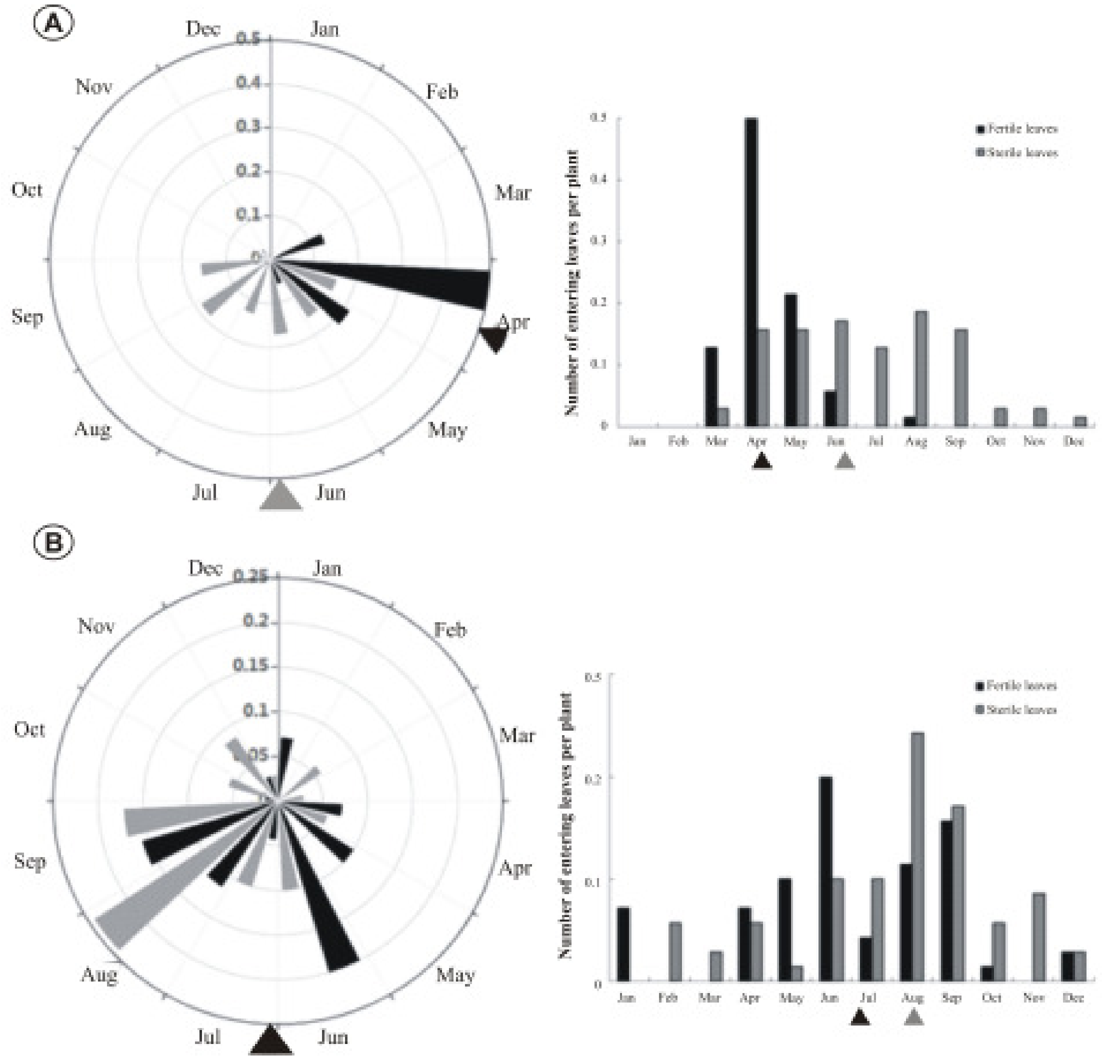


Figure 1 : Climate diagram at Lienhuachih climate station (23°55'07" N, 120°53'07" E, alt. 681 m), Taiwan, during 2002–2008 (all years), with mean temperature 20.1^{0}C and mean annual precipitation 2,672 mm. During typhoon years, the perhumid period, with monthly precipitation more than 100 mm, from Apr. to Sep., is indicated by solid line; and relative humid period, with monthly precipitation less than 100 mm but more than the predicted evaporation (mean monthly temperature*2), is indicated by dotted line on the horizontal axis. During nontyphoon years, patterns are same as above except Feb. and Nov. which were classified as a dry period.

Living leaves

Mean annual number of living leaves per plant was 5.13, including 1.73 fertile and 3.40 sterile leaves, in the study period. Annual variation in living leaf count per plant showed a distinctive pattern over time with a gradual decrease in the first 3 years and then a gradual increase in the latter 4 years, with the lowest mean per plant living leaf count 3.64 in 2004 and the highest 6.91 in 2008 (Table 2).

The monthly mean of living leaves per plant ranged from 4.64 (February) to 5.56 (May). There were more living leaves in perhumid season than those in relative humid season (from October to the next March) (5.14–5.56 vs. 4.64–5.10 per plant). Mean monthly counts of sterile leaves were greater than those of fertile leaves (Fig. 2c). Both monthly fertile and sterile living leaf counts had significant correlations with MP, MT, and MD (Table 4).


A
Dec
Jan
Feb
Mar
Apr
May
Jun
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Aug
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Oct
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0.5
0.4
0.3
0.2
0.1
0
Number of entering leaves per plant
Fertile leaves
Sterile leaves
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
B
0.25
0.2
0.15
0.1
0.05
0.5
0.2
0.1
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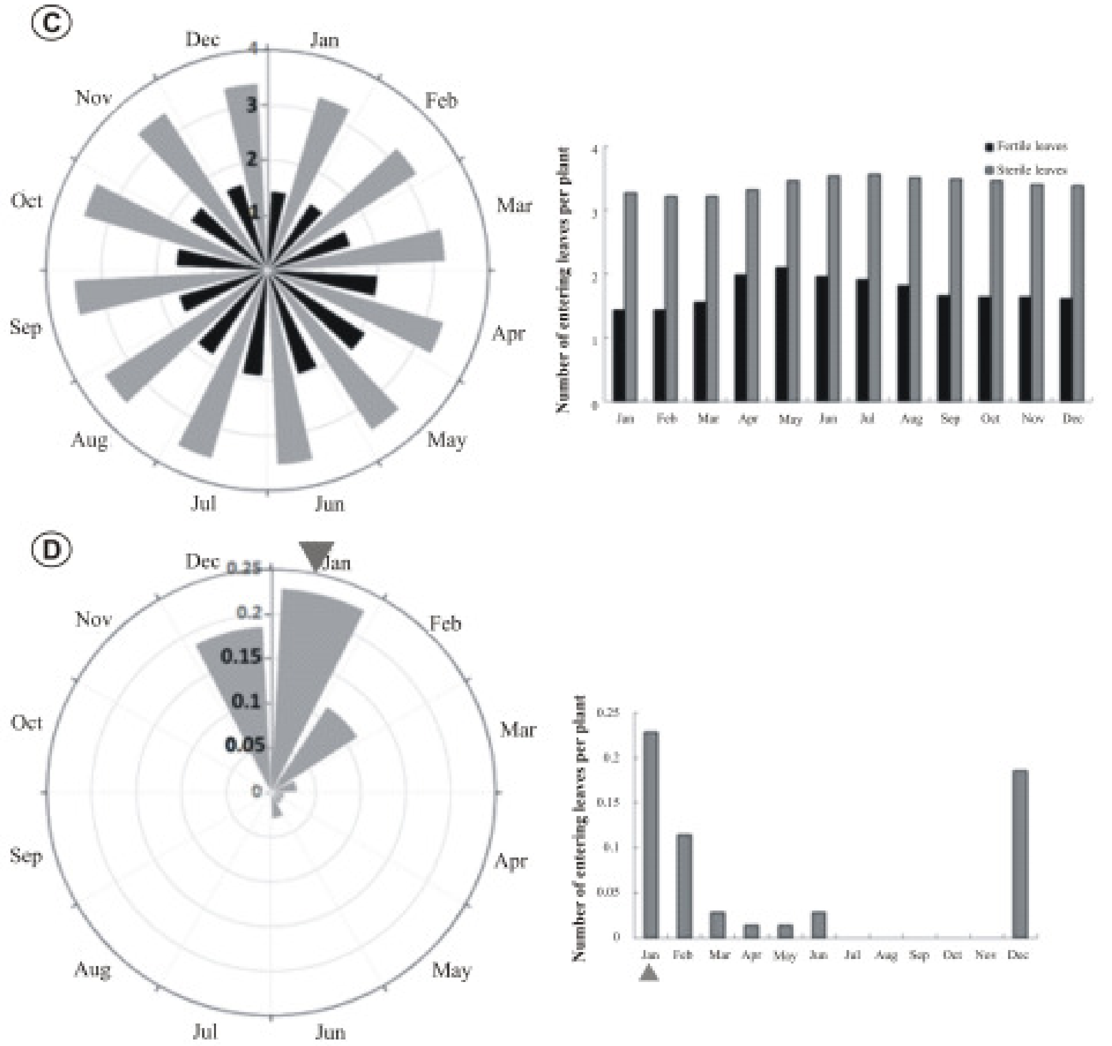

Figure 2 : The seasonality of different phenological phases of leaf emergence **(a)**, senescence **(b)**, living leaves **(c)**, and spore release **(d)**. Numbers along circulars indicate the mean leaf numbers per plant of each month for different phenophases. Each phenophase is presented by rose chart (left) and bar chart (right). Arrows indicate the mean occurrence date of each phenophase.

Fertile vs. sterile leaf morphology

Fertile leaves usually had longer stipes than sterile leaves. Other morphological traits (blade length, blade width, and the number of pinna) of fertile and sterile leaves did not show significant differences although all of them of fertile leaves were larger than the latter (Table 5).

Leaf lifespans (LLS)

The estimated mean LLS was 32.5 months based on the turnover rate method. It was slightly lower than that of direct observation (34.6 months), but the difference was not significant (p=0.32). According to the direct observation of senescence date minus emergence date, the minimum and maximum LLSs were coincidently the same, with 9 and 61 months, respectively; whereas those were 18.2 and 52.3 months, respectively, estimated by turnover rate method. Furthermore, sterile leaves had longer average LLS than fertile ones' either counted by direct observation (40.7±13.0 vs. 25.6±15.6 months) or estimated by turnover rate (53.3±36.5 vs. 23.8±6.3 months) (Table 6). The differences of sterile or fertile LLS between values of direct observation and turnover rate estimation were not significant (p=0.20, 0.33, respectively). Other data of LLS are shown in Table 6. Given that the fertile LLS equals to 25.6 months, and based on estimates of mean dates of phenophases shown in Table 3, on average a fertile leaf lives ca. 16.8 months after its spores released, or about two third of its whole life.

Spore release

A total of 43 leaves with spore release were recorded. Mean number of leaves with spore release was 0.61 per plant annually and ranged from 0.10 (in 2004) to 1.40 per plant (in 2008) (Table 2). Spore release, indicated by leaf numbers, exhibited significant seasonality (vector $\boldsymbol{r}$ = 0.77), mainly (86%) concentrated in December–February (Fig. 2d), with the mean date of 11, January (Table 3). The monthly number of leaves with spore release was significantly negative correlated with MT and MD, but not correlated with MP (Table 4).

TABLE 5: Comparison between the sizes (mean±SE (min–max)) of fertile and sterile leaves of *Angiopteris somae*.

	Fertile leaves (n = 32)	Sterile leaves (n = 61)
Stipe length (cm)	45.2±10.0^a (26–70)	29.0±5.5^b (16–39)
Blade length (cm)	31.7±3.9^a (23–40)	26.6±3.7^a (19–36)
Blade wide (cm)	33.3±6.1^a (20–48)	29.4±4.6^a (15–42)
No of pinna	4.8±0.7^a (4–6)	4.5±0.6^a (4–6)

* Different letter indicates significant difference on the same line (t-test, p<0.05)

Comparison of parameters monitored between typhoon and nontyphoon year

During this monitoring period, no typhoon came to the studying site in the first two years, and then one to four typhoons attacked in each of the following five years (Table 1). None of the ten monitored plants died during this period. Amount of mean annual precipitation in typhoon years was significantly larger than in nontyphoon years, while the mean annual temperature was not (Table 7). Numbers of emergent, senescent, living, and spore-releasing leaves were larger or smaller between nontyphoon and typhoon years, but all of them were not significant different. The occurrence mean dates of each phenophase were also not significantly different between nontyphoon and typhoon years except the mean dates of spore release.

DISCUSSION

Seasonality of leaves

There is a significant difference between the timing of the leaf-emergence seasons of fertile and sterile leaves of *A. somae,* in this whole-year humid site, i.e., either perhumid or relative humid. This difference is similar to that seen in forests of northern and northeastern Taiwan that are also in whole-year humid areas (Lee *et al*. 2009a, b). In contrast, the emergence timing of sterile and fertile leaves of about half of the monomorphic species of ferns observed was not different in a monsoon forest of southern Taiwan that featured with dry-humid alternation seasonality (Lee *et al*. 2016, 2018).

TABLE 6 : Leaf lifespans of *Angiopteris somae* estimated by direct observation and turnover rate (unit : months).

	Fertile	Sterile	All
Direct measurement			
# of leaves	25	37	62
Mean±SE*	25.6±15.6^{a}	40.7±13.0^{c}	34.6±15.8^{b}
Max	61	61	61
Min	9	9	9
Medium	21	43	38
Turnover rate**			
Mean±SE*	23.8±6.3^{a}	53.3±36.5^{c}	32.5±10.8^{b}
Max (year)	35.6 (2002)	124.8 (2007)	52.3 (2007)
Min (year)	17.1 (2003)	16.9 (2004)	18.2 (2004)
Medium	20.8	57.5	39.1

* Different letter on the same row indicates significant difference (*t*-test, $p<0.05$)

** The average of 10 plants across seven monitored years.

In addition to the difference in leaf-emergence seasons, the emergent period of fertile leaves was much more intensive than sterile ones (vector ***r*** = 0.90** vs. 0.55**) in *A. somae*. Emergence of fertile leaves in higher concentrations has been found in many studied dimorphic ferns and monomorphic ferns (Lee *et al*. unpublished).

Similar to the emergence of leaves, the senescent seasons of fertile and sterile leaves also exhibited significantly differences. However, both of their occurrence times overlapped considerably and mainly occurred in the perhumid season with high temperature and heavy precipitation. The significant difference of seasonality resulted from the senescence numbers in each month and this is also indicated by their discrete mean dates.

Spore release

Spore release of most ferns appeared in late spring to early autumn (e.g., Lee *et al.* 2009b, 2016). In contrast, *A. somae* released spores mainly in the cooler and drier winter, an unfavorable season for spore germination immediately after their release. Spores of a monomorphic fern, *Asplenium scolopendrium* L. var. *americanum* (Fern.) Kartesz and Gandhi, exhibited a higher germination rate following the vernalization (a requirement for plants to produce new buds with cool condition) treatment (–15^{0}C freezer for 90 d) relative to the control (~20^{0}C during the freezing period) (Testo & Watkins 2013). In our spore culture experience, the germination rate of spores of *A. somae* also increased after vernalization treatment (fresh leaves with mature spores stored at 4^{0}C for 2 month) (unpublished data). This shows that spore maturation (indicated by spore release here) of *A. somae* in winter and subsequent vernalization may favor spore germination and gametophyte growth in the following warm and wet season.

Contrary to other monomorphic species documented by Lee *et al.* (2009 a, b), the seasons of leaf emergence and spore release are not closely "synchronized" in *A. somae*. In most monomorphic ferns, spore release pattern usually corresponds to the seasonality in leaf emergence patterns, following fertile leaf emergence by a few (ca. 1–4) months. In *A. somae*, however, spore release is delayed (ca. 9 months) into a later season, and thus the seasonality of fertile leaf emergence does not correspond to the seasonal pattern of spore release.

Leaf lifespan (LLS)

Mehltreter & Sharpe (2013) stated that both direct measurement (emergence to senescence) and indirect estimation (based on leaf count and production rates) of LLS require close observation at least one year. It is reasonably assumed that direct measurement usually obtains more precise lifespan data than the estimation by the turnover rate (indirect estimation). In this study, although the mean LLS of *A. somae* was slightly higher based on direct measurement than the indirect estimate (34.6 vs. 31.2 mo), the difference is not statistically significant. Counting lifespans of fertile and sterile leaves separately, LLS measured by direct observation was higher or lower than by turnover rate estimation. It

TABLE 7 : Comparison of climate data, growth parameters, and phenophases of *Angiopteris somae* between nontyphoon and typhoon years. All parameters between nontyphoon year and typhoon year are not significantly different unless specifically noted.

	Nontyphoon years (2002–2003)	Typhoon years (2004–2008)	All years (2002–2008)
Mean annual precipitation (mm)[1]	1516^{b}	3134 ± 637^{a}	2672 ± 964^{a}
Mean annual temperature (^{0}C)	20.4	20.0±0.2	20.1±0.2
# of emergence leaves plant^{-1}year^{-1}			
Fertile leaves	0.75	0.98±0.65	0.91±0.55
Sterile leaves	0.90	1.12±0.68	1.06±0.68
All leaves	1.65	2.10±0.47	1.97±0.61
# of senescence leaves plant^{-1}year^{-1}			
Fertile leaves	1.55	0.50±0.44	0.80±0.78
Sterile leaves	1.05	0.90±0.50	0.94±0.42
All leaves	2.60	1.40±0.71	1.74±0.89
# of living leaves			
Fertile leaves	1.53	1.81±1.12	1.73±0.93
Sterile leaves	2.46	3.78±0.55	3.40±0.79
All leaves	3.99	5.58±1.32	5.13±1.33
# of spore-released leaves plant^{-1}year^{-1}	0.75	0.56±0.50	0.61±0.46
Mean date (*a*); vector ***r*** of phenophase[2]			
Emergence of fertile leaves	11, Apr (100); 0.89**	19, Apr (108); 0.90**	17, Apr (107); 0.90^{**}
Emergence of sterile leaves	6, Jul (185); 0.68**	28, Jun (177); 0.51**	30, Jun (179); 0.55^{*}
Senescence of fertile leaves	28, Jun (177); 0.62**	21, Jul (200); 0.18^{ns}	2, Jul (181); 0.42^{**}
Senescence of sterile leaves	21, Aug (230); 0.52**	12, Aug (221); 0.43**	15, Aug (224); 0.45^{**}
Spore releasing[3]	14, Feb (45); 0.83**	24, Dec (354); 0.87**	11, Jan (11); 0.77**

[1] : Different letters on the same row indicate significant difference (*t*-test, $p<0.05$)

[2] : Significance of vector ***r*** is detected by Rayleigh test (Morellato *et al.* 2000, 2010)

[3] : Significantly different between nontyphoon year and typhoon year detected by Watson-Williams test

suggests that obtaining LLS by these two methods leads to a similar (no significant difference) result giving a long enough monitoring period.

Direct measurement requires a longer time to collect leaf stages with studies lasting at least twice the mean lifespan, which is often unknown when planning the study. In contrast, indirect estimation of leaf lifespan is a relatively economical and timesaving method and thus has been widely applied (Seiler 1981, Tanner 1983, Bittner & Breckle 1995, Sharpe 1997, Mehltreter & Sharpe 2013, Silva *et al.* 2018). However, estimating leaf lifespans does result in the loss of information about individual variation and biased range of lifespans. For example, the maximum sterile LLS, 124.8 months, estimated in 2007 is noticeably deviated from the mean and medium values. That results from the very low emergent leaf number but high living leaf number in that monitoring year. Apparently estimating the LLS of a fern by turnover rate in a short period risks a misjudged conclusion.

Compared to the data set of LLS of 71 fern species (Mehltreter and Sharpe 2013), the mean LLS of *A. somae* are fairly longer, only shorter than a Mexican epiphytic monomorphic fern *Terpsichore asplenifolia* (L.) A. R. Sm., with the mean LLS for fertile leaves of 4.9 years (ca. 59 months) (Monge Gonzalez 2007). Vincent (2006) suggested that plant species with longer LLS are likely to have a sequence of slower ageing of leaves as a result of a slower photosynthetic metabolism. This would coincide with the physiological characteristic of *A. somae* with a low photosynthesis capacity (Wong *et al.* 2012, Weng & Wong. 2015).

Dimorphic vs. monomorphic

The leaf morphology of sterile and fertile leaves was similar except that the stipes of fertile leaves were significantly longer than sterile ones. The ratio of fertile leaves LLS/ sterile leaves LLS of *A. somae*, 0.63 (25.6/40.7), is lower than other monomorphic species (0.68–1.76), but far larger than dimorphic species (0.10–0.39) (Lee *et al.* 2018). The sterile LLS of *A. somae* is significantly longer than the fertile LLS. In dimorphic ferns, fertile leaves die soon after investing energy in producing spores (Watkins *et al.* 2016), while the fertile leaves of *A. somae* continuously live in green and presumably photosynthesize after releasing spores, serving as a potential source of nourishment as well as reproduction. These fertile leaves do not completely exhaust energy during producing spores as seen in dimorphic ferns. Therefore, in this respect *A. somae* is more properly categorized into a monomorphic fern.

Although morphologically similar the fertile and sterile leaves of *A. somae* have very different phenophases of emergence and senescence between sterile and fertile leaves, as in dimorphic ferns, e.g., *Danaea geniculata* (de Paiva Farias *et al*. 2018), *Plagiogyria adnata* & *P. dunii* (Lee *et al*. 2009b). The possibility of this “behavior” differences is noted by Wagner & Wagner (1977), but the difference extent is only documented with exemplary detailed studies like this one. Therefore, we recommend that the phenology of both leaf types should be separately analyzed for both dimorphic and monomorphic ferns.

Effects of typhoons

Typhoon is a very important disturbance event in many forest ecosystems (Everham & Brokaw 1996, Wang *et al.* 2016). During last 5 years of our 7-year phenological survey period, 11 typhoons passed over the study site. Except for the amount of precipitation which greatly increased and the much earlier occurrence of spore maturation (indicated by releasing here) during the typhoon years, all monitored parameters were not significantly different, but some trends are interesting and noted below.

The annual mean numbers of living leaves and emergent leaves of *A. somae* correspondingly increased during the typhoon years. It is suggested that *A. somae* received more sunlight that could have triggered the initiation of leaf emergence and increased the rate of fertile leaf production. Typhoons in Taiwan are a type of wind-initiated disturbance accompanied by large amounts of precipitation that result in the formation of large gaps in the canopy and deposition of larger amounts of leaf litter (personal observation). Those canopy gaps let more light shine on the floor. Simultaneously, nitrogen availability might increase when higher temperatures in canopy gaps accelerate decomposition of organic matter (Takafumi *et al.* 2010), and thereafter more nutrients could be available for leaf emergence/growth. A similar response to light is also reported in *Matteuccia struthiopteris* (L.) Todaro, commonly found in shady habitats and increased the number of leaves when irradiance levels are increased (Prange 1980). Sharpe & Shiels (2014) discovered that two understory ferns, *Thelypteris deltoidea* (Sw.) Proctor and *Cyathea borinquena* (Maxon) Domin, can considerably increase the production of spore-bearing leaves when light levels increase. They also found that adding debris may have a positive effect but only in a combination with added light. The larger number of senescent leaves in nontyphoon years than in typhoon years is probably due to the relative drought condition resulting from less precipitation in the former. An increase in leaf mortality in less rainfall years is also found in some tree fern species (Silva *et al*. 2018).

An increase in light caused by typhoon also leads to a more even leaf production throughout the year, i.e., less seasonality (Angulo-Sandoval *et al.* 2004). The phenophase difference of leaf emergence between typhoon and nontyphoon years in this study does not reflect a same response. It indicates that light (and other factors) brought by typhoon does not affect the seasonality of the leaf production for *A. somae*.

Spore release is affected by temperature and humidity. Low temperature may delay spore release (Arosa *et al*. 2009). Spores of *A. somae* released ca. seven weeks earlier in typhoon years than in nontyphoon years. It perhaps contributed to the higher temperature of microhabitat caused by more light resulting from typhoons. Minimum precipitation happened in February and December to January for nontyphoon year and typhoon year, respectively. Most spores released (indicated by the mean dates and vector ***r***) correspondently occurred in the driest (least precipitation) seasons of these two climate patterns.

The above inferences regarding those phenomena might be too simple. After all, evaluations of plant character responses to disturbance must include the combined interacting responses of the comprehensive elements of that ecosystem (Zimmerman *et al.* 1996, Watson & Estes 2011). Besides, two nontyphoon years obviously are insufficient to collect long-term phenological data to get a solid reference. Here we have only pointed out some intriguing issues for more consideration in future studies.

Conservation

Ex-situ conservation is important to the preservation of an endangered species, especially for those not located in a protected area, such as *A. somae*. Although leaf-base stipules of *A. somae* provide useful materials for its *ex-situ* propagation (Chiou *et al.* 2006), the resulting vegetative offspring lack genetic variation from their parents. The number of available stipules is also low because of limited population sizes and relatively low annual leaf production rates. On the other hand, spore culture provides an efficient method to increase the number and genetic heterogeneity of descendants and should be regarded as the best choice for *ex situ* conservation of *A. somae* (Chou *et al.* 2007). In this study, we found that winter is the most suitable season for collecting mature spores of *A. somae* for further culture and to be used in its *ex situ* conservation.

CONCLUSION AND FUTURE ASPECT

The relevance of phenological research has been recognized for decades. However, most phenological studies, especially on ferns, have been short-term, ending after only one or two years and may not present a complete phenological picture for a species, possibly resulting in our misunderstanding possible long-term changes and disturbance effects.

Seven-year monitoring of *Angiopteris somae* in our study is the longest fern phenological study currently reported in the world. Our results show the annual averages and variations of different phenophases, including leaf emergence and senescence and spore release, and lifespans of both fertile and sterile leaves of this species. The correlations of those phenophases with environmental factors are presented as well. Those long-term data are comprehensive and potentially useful. More exploration and further analyses of those data will raise additional intriguing features, which will be useful for elucidating more related biological phenomena and application in the future.

In addition to the need for more long-term studies, the formation of a broad geographical network is also encouraged to further facilitate the development and understanding of fern phenology (Lee *et al.* 2018). Many phenological studies with diverse representation of various climate conditions have been done in Taiwan (e.g., Lee *et al.* 2008, 2009a, b, 2016). South to Southeastern Asia, with rich tropical to subtropical fern diversity, is another ideal region for conducting this kind of broad-scale phenological research. This region is also inhabited many *Angiopteris* species, a genus in the Marattiales that is an ancient fern lineage, and could therefore be a candidate group for such study. Phenological data for *A. somae* collected in this study set a valuable base for such future approach.

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REFERENCES

ANGULO-SANDOVAL P, FERNÁNDEZ-MARI´N H, ZIMMERMAN J K & AIDE T M 2004 Changes in patterns of understory leaf phenology and herbivory following hurricane damage *Biotropica* **36** : 60-67

AROSA M L, QUINTANILLA L G, RAMOS J A, CEIA R & Sampaio H 2009 Spore maturation and release of two evergreen Macaronesian ferns, *Culcita macrocarpa* and *Woodwardia radicans*, along an altitudinal gradient *American Fern Journal* **99** : 260-272

BITTNER J & BRECKLE S W 1995 The growth rate and age of tree fern trunks in relation to habitats *American Fern Journal* **85** : 37-42

CHIOU W L, HUANG Y M & CHEN C M 2006 Conservation of two endangered ferns, *Archangiopteris somai* and *A. itoi* (Marattiaceae : Pteridophyta), by propagation from stipules *Fern Gazette* **17** : 271-278

CHOU H M, HUANG Y M, WONG S L, HSIEH T H, HSU S Y & CHIOU W L 2007 Observations on gametophytes and juvenile sporophytes of *Archangiopteris somai* (Marattiaceae) endangered fern in Taiwan *Botanical Studies* **48** : 205-213

DE PAIVA FARIAS R, DA COSTA L E N, LEÃO BARROS I C & MEHLTRETER K 2018 Leaf phenology of *Danaea geniculata* (Marattiaceae) in submontane tropical forest, Brazil *American Fern Journal* **108** : 35-46

EVERHAM E M & BROKAW N V L 1996 Forest damage and recovery from catastrophic wind *The Botanical Review* **62** : 113-185.

HALLECK L F, SHARPE J M & ZOU X 2004 Understorey fern responses to post-hurricane fertilization and debris removal in a Puerto Rican rain forest *Journal of Tropical Ecology* **20** : 173-181

KANJI G K 2006 100 *Statistical Tests (3rd Edition)* SAGE Publications Ltd, London

LEE P H, HUANG Y M & CHIOU W L 2008 The phenology of *Osmunda claytoniana* L in the Tataka area, Central Taiwan *Taiwan Journal of Forestry Science* **23** : 71-79

LEE P H, CHIOU W L & HUANG Y M 2009a Phenology of three *Cyathea* (Cyatheaceae) ferns in Northern Taiwan *Taiwan Journal of Forestry Science* **25** : 1-10

LEE P H, LIN T T & CHIOU W L 2009b Phenology of 16 species of ferns in a subtropical forest of northeastern Taiwan *Journal of Plant Research* **122** : 61-67

LEE P H, CHEN S W, CHIOU W L & HUANG Y M 2016 Phenology of 13 fern species in a tropical monsoon forest of southern Taiwan *The International Journal of Plant Reproductive Biology* **8** : 87-97

LEE P H, HUANG Y M & CHIOU W L 2018 Fern phenology. In: FERNÁNDEZ H (ed.) *Current Advances in Fern Research*. Springer, Gewerbestrasse, Switzerland Pp 381-399

MEHLTRETER K 2008 Phenology and habitat specificity of tropical ferns. In: Ranker T A &

HAUFLER C H (eds) *Biology and Evolution of Ferns and Lycophytes* Cambridge University Press, New York Pp 201-221

MEHLTRETER K & SHARPE J M 2013 Causes and consequences of the variability of leaf lifespan of ferns *Fern Gazette* **19** : 193-202

MONGE GONZÁLEZ L 2007 *Fenología de tres especies de helechos epifitos sobre dos grupos de hospederos en Las Cañadas, Huatusco, Veracruz* Bachelor thesis, Universidad Veracruzana, Facultad de Biología, Xalapa

MORELLATO L P C, ALBERTI L F & HUDSON I L 2010 Applications of circular statistics in plant phenology : case studies approach. In: HUDSON I L & KEATLEY M R (eds) *Phenological Research, Methods for Environmental and Climate Change Analysis* Springer, New York Pp 339-359

MORELLATO L P C, TALORA D C & TAKAHASI A 2000 Phenology of Atlantic rain forest trees : a comparative study *Biotropica* **32** : 811-823

NAGANO T & SUZUKI E 2007 Leaf demography and growth pattern of the tree fern *Cyathea spinulosa* in Yakushima Island *Tropics* **16** : 47-57

NEWSTROM L E & FRANKIE G W 1994 A new classification for plant phenology based on flowering patterns in low land tropical rain forest trees at La Selva, Costa Rica *Biotropica* **26** : 141-159

ODLAND A 1995 Frond development and phenology of *Thelypteris limbosperma*, *Athyrium distentifolium*, and *Matteuccia struthiopteris* in Western Norway *Nordic Journal of Botany* **15** : 225-236

PRANGE R K 1980 Responses of the ostrich fern, *Matteuccia struthiopteris* (L) Todaro, to lime, soil moisture, and irradiance *Proceedings of the Nova Scotian Institute of Science* **30** : 171-181

SEILER R L 1981 Leaf turnover rates and natural history of the Central American tree fern *Alsophila salvinii American Fern Journal* **71** : 75-81

SHARPE J M 1997 Leaf growth and demography of the rheophytic fern *Thelypteris angustifolia* (Willdenow) Proctor in a Puerto Rican rainforest *Plant Ecology* **130** : 203-212

SHARPE J M 2010 Long term monitoring of five uncommon tropical forest understory ferns in Puerto Rico *Indian Fern Journal* **27** : 242–253

SHARPE J M & JERNSTEDT J A 1990 Leaf growth and phenology of the dimorphic herbaceous layer fern *Danaea wendlandii* (Marattiaceae) in a Costa Rican rain forest *American Journal of Botany* **77** : 1040-1049

SHARPE J M & SHIELS A B 2014 Understory fern community structure, growth and spore production responses to a large-scale hurricane experiment in a Puerto Rico rainforest *Forest Ecology and Management* **332** : 75-86

SILVA M M, DE PAIVA FARIAS R, DA COSTA L E N & BARROSA I C L 2018 Leaf phenological traits of the tree fern *Cyathea praecincta* (Cyatheaceae) in a Brazilian lowland tropical forest *Australian Journal of Botany* **66** : 618-627

TAKAFUMI H, KAWASE S, NAKAMURA M & HIURA T 2010 Herbivory in canopy gaps created by a typhoon varies by understory plant leaf phenology *Ecological Entomology* **35** : 576-585

TANNER E V J 1983 Leaf demography and growth of tree fern *Cyathea pubescence* Mett ex Kuhn in Jamaica *Botanical Journal of Linnean Society* **87** : 213-227

TESTO W L & WATKINS J E Jr 2013 Understanding mechanisms of rarity in pteridophytes: competition and climate change threaten the rare fern *Asplenium scolopendrium* var. *americanum* (Aspleniaceae) *American Journal of Botany* **100** : 2261-2270

VINCENT G 2006 Leaf life span plasticity in tropical seedlings grown under contrasting light regimes

Annals of Botany **97** : 245-255

WAGNER W H & GÓMEZ L D 1983 Pteridophytes. In: JANZEN D H (ed.) *Costa Rican Natural History*. University of Chicago Press. Pp 311-318

WAGNER W H & WAGNER F S 1977 Fertile-sterile leaf dimorphy in ferns *Gardens Bulletin Singapore* **30** : 251-267

WALTER H, HARNICKELL E & MUELLER-DOMBOIS D 1975 *Climate diagram maps of the individual continents and the ecological climate regions of the Earth* Springer-Verlage, Berlin

WANG J C, CHIOU W L & CHANG H M (eds) 2012 *A preliminary red list of Taiwanese vascular plants* Endemic Species Research Institute & Taiwan Society of Taiwan Society of Plant Systematics Nantou, Taiwan

WANG X, WANG W & TONG C 2016 A review on impact of typhoons and hurricanes on coastal wetland ecosystems *Acta Ecologica Sinica* **36** : 23-29

WATKINS J E JR, CHURCHILL A C & HOLBROOK N M 2016 A site for sori: ecophysiology of fertile-sterile leaf dimorphy in ferns American *Journal of Botany* **103** : 1-11

WATSON J & ESTES J A 2011 Stability, resilience, and phase shifts in rocky subtidal communities along the wet coast of Vancouver Island, Canada *Ecological Monographs* **81** : 215-239

WENG J H & WONG S L 2015 Photosynthetic light responses of fern species adapted to different light regimes. In: TUFT J (ed) *Fern and Shrub* Nova Science Publishers Inc, NY Pp 57-76

WONG S L, CHEN C W, HUANG H W & WENG J H 2012 Using combined measurements for comparison of light induction of stomatal conductance, electron transport rate and CO2 fixation in woody and fern species adapted to different light regimes *Tree Physiology* **32** : 535-544

YING S S & HUANG Y M 1995 Phenological study on *Sphaeropteris lepifera* at Su-Au area *Memoirs of the College of Agriculture National Taiwan University* **35** : 451-464 (in Chinese with English abstract)

ZAR J H 2010 *Biostatistical Analysis (5th edition)* Prentice Hall, New Jersey

ZIMMERMAN J K, WILLIG M R, WALKER L R & SILVER W L 1996 Introduction : disturbance and Caribbean ecosystems *Biotropica* **28** : 414-423

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PTERIDOPHYTES FROM HIGH ELEVATION PLATEAUX IN THE NORTH WESTERN GHATS OF MAHARASHTRA, INDIA

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ABSTRACT

Pteridophytes, the ferns and allies, have specific habitats including occurrence on plateaux and rock-outcrops, but their diversity and ecology in plateau-ecosystems have not yet been sufficiently studied and reported. In the present investigation, 10 different plateaux of the North-Western Ghats of Maharashtra have been studied with respect to diversity, distribution and pteridophyte-microhabitats during 2010-2016. This study has revealed significant findings concerning 43 taxa at species and infraspecific ranks occurring in different microhabitats on the plateaux. Of these, *Adiantum philippense* L. subsp. *teestae* Verma & Fras.-Jenk. is being newly reported from Maharashtra state and *Aleuritopteris formosana* (Hayata) Tagawa is rare. Two species, namely, *Nephrolepis cordifolia* (L.) C. Presl and *Selaginella repanda* (Desv. *ex* Poir.) Spring are newly reported from North-Western Ghats in Maharashtra. Critical observations on endemic and newly recorded taxa are also mentioned. Of these, two Indian endemic species viz., *Isoetes dixitii* Shende and *Isoetes panchganiensis* G. K. Srivastava, D. D. Pant & P. K. Shukla occur only on the open plateaux and proposed to have Endangered (EN) status according to IUCN criteria B2(a).

Key Words : Pteridophytes, Plateaux, Western Ghats, Endemic, Ecological indicators, IUCN.

Abbreviations : MS – Maharashtra state; WG – Western Ghats

INTRODUCTION

Plateaux and rock outcrops are well known but less studied with majority of reports coming from Africa, America, Australia and very few from India (Porembski *et al.*, 1994, 2000; Burke, 2005a & b; Porembski & Watve, 2005; Jacobi *et al.*, 2007; Watve, 2013). The vegetation, microhabitats and community dynamics of some selected plateaux in the Western Ghats have been studied by Porembski & Watve (2005), Watve (2008, 2013), Lekhak & Yadav (2012) and Rahangdale & Rahangdale (2014). All these studies are related to the angiosperm diversity on the plateaux, their endemism and interrelationship/adaptability to these special habitats.

Angiosperms are main plant group considered in almost all the studies related to plateaux and rock outcrops, as they are ubiquitous in nature and the most successful plant group. Angiosperms contribute to major vegetation in any sort of habitats; in turn they provide suitable microclimate to the taxa of other plant groups.

The 'mesas' (plateaux) are generally isolated from the mainland but most of the plateaux in the Western Ghats are surrounded by some vegetation or ecological niches. These surrounding areas and biotypes on them are indispensable factors of any plateau; because the biota from surrounding area greatly influences the plateau biota as well as ecological

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conditions on it. If a plateau is surrounded by good forests, the climate on the plateau remains moist and cooler, than on those without surrounding forests. The diversity of biota on plateau is always greatly influenced by multiple environmental factors like soil type, altitude, geographic position, geomorphology and micro-environments. Vegetation composition and its patterns were studied by transect method on the plateaux in North Western Ghats and Konkan region by Watve (2013) revealing the angiosperm diversity on the plateaux and plant community composition in each microhabitat. Rahangdale & Rahangdale (2014) compared two plateaux at Durgawadi and Nane Ghat in terms of floristic diversity and found that there are about 63% differences among them, despite these plateaux are along the Crestline of WG at about 10km aerial distance away, with nearly similar climatic conditions. The floristic differences were attributed to the richness of microhabitats. More diverse the microhabitats, more is the diversity. Both these studies did not cover pteridophyte diversity. Thus, complete plant diversity on the plateaux in the Western Ghats in MS is not yet revealed.

The pteridophytes are special plants preferring cool, moist, shady habitats in general and do not prefer extreme climatic conditions of plateaux/rock outcrops which are known for it; but still any conclusion without considering pteridophyte flora of a region/site could be misleading because the pteridophytes are specialized to particular habitats. Thus, their presence or absence could be better exploited to interpret the environmental variables.

The studies of plateaux involving pteridophyte diversity are very few. Ribeiro *et al.*, (2007) enlisted 9 species of pteridophytes belonging to 6 families from vegetation of high elevation plateaux of Brazil; while from ironstone outcrops of Brazil, Jacobi *et al.*, (2007) reported 12 species of 6 families and reported 'poikilohydry' – an ability to survive to almost complete desiccation in *Polypodium* L. species.

It is evident from the literature that, the Western Ghats are rich in pteridophytes (Almeida 1972, Beddome 1864, 1870, 1892; Dixit 1984, Manickam & Rajkumar 1999, Dixit & Sinha 2001, Manickam & Irudayraj 2003, Naik 2006, Chadha *et al.* 2008, Fraser-Jenkins 2008a, Fraser-Jenkins *et al.* (2017, 2018), Singh *et al.* 2012), but the emphasis is related only to the floristic accounts. The reports of pteridophytes related to plateaux are not there, except the description of *Isoetes sahyadriensis* Mahab. from hill top of Panchagani (Mahabale, 1938), *Isoetes dixitii* Shende from Panchagani hill (Shende, 1945) and *Isoetes panchganiensis* G.K. Srivastava, D.D. Pant & P.K. Shukla from the same locality (Srivastava *et al.*, 1993). The present author (Rahangdale & Rahangdale, 2011) has reported *Botrychium lanuginosum* Wall. *ex* Hook. & Grev. as a new record for Maharashtra from Durgawadi plateau as an occasional epiphyte, while Rawat (2012) reported *Aleuritopteris rufa* (D.Don) Ching as new report for Maharashtra from Panchgani area on the basis of single plant specimen. Some attempts are also made to bring out the records of endemic and threatened taxa by Dixit (1984) in the form of a 'Census of Indian Pteridophytes' and companion to this census by Chandra (2000). Chandra *et al.* (2008) reported a summary of threatened pteridophytes of India, while Shukla *et al.* (2002), Fraser-Jenkins (2008b) and Benniamin *et al.* (2008) dealt with different aspects of the endemic and pseudo-endemic taxa of pteridophytes from India.

Of the literature available on plateaux, only Watve (2013) mentioned three species of *Isoetes* L. as endemic to India, two of which are on the authority of Shukla *et al.* (2002). This fact strongly indicates that, the documentation of pteridophytes related to the plateaux is not done, which is a lacuna in the biodiversity documentation of the plateaux from India.

The present study records diversity of pteridophytes on and around the plateau microhabitats from Western Ghats of Maharashtra along with characteristics of the plateaux and notes on some of the taxa.

TABLE 1 : The locations studied during the present study

Plateau	Village	District	Type of habitats observed	Altitude range
High level Basalt				
1. Anjaneri	Anjaneri	Nashik	Exposed rock surface, Rock crevices, Rock crevices, Plateau tree cover, seasonal pools, Soil covered areas	960-1032m
2. Harishchandragarh	Pachanai	Ahmednagar	Exposed rock surface, Crevices Plateau tree cover, seasonal pools, Soil covered areas, Boulders	1250-1325 m
3. Ajnawale	Ajnawale	Pune	Exposed rock surface, soil covered area, Sacred Grove	700m
4. Durgawadi	Durgawadi	Pune	All as 1, Boulders, Sacred grove	882-1156m
5. Ahupe	Ahupe	Pune	All as 1, Sacred grove	916m
6. Kharpud	Kharpud	Pune	Grassland, Savana type tree cover and ERS, Soil filled depressions, pools	743m
7. Thakarwadi	Thakarwadi	Pune	Boulders, Rock crevices, soil covered area and ponds	846m
High level Ferricrete				
8. Panchgani	Panchgani	Satara	Rock crevices, seasonal pools, ERS	1313m
9. Kas	Kas	Satara	All as 1	1030-1139m
10. Panhala	Panhala	Kolhapur	Seasonal pools, ERS, Soil filled depressions, Forest	1105m

STUDY AREA

The study area comprises 10 high elevation plateaux spread over the stretch of Western Ghats in Maharashtra state taking representative areas from Nashik, Ahmednagar, Pune, Satara and Kolhapur districts, viz., Anjaneri, Harishchandragarh, Ajnawale, Durgawadi, Ahupe, Kharpud, Thakarwadi, Pachgani, Kas and Panhala fort. The details of plateaux studied are given in the Table 1, and locations could be positioned in Plate I, Fig. 1, adopted from GoogleEarth.

The basaltic plateaux of Anjaneri, Harishchandragarh, Ajnawale, Durgawadi and Ahupe have nearly same type of topography and vegetations at the hill tops and slopes associated with them. The annual rainfall in the area of these plateaux ranges between 1500 – 2000 mm. On these plateaux, forest types or plateau tree cover is composed by *Memecylon – Terminalia – Atalantia – Syzygium – Actinodaphne* type broad-leaved montane forest and associated taxa with some variations except Kharpud and Thakarwadi plateaux. Kharpud and Thakarwadi plateaux are also high elevation basaltic plateaux with black cotton soil, but Kharpud plateau have Savannah like topography and very sparse tree cover of *Acacia* sp. supporting more wet habitat covered by grasses (Plate I, Fig. 2), while the Thakarwadi is quite dry outcrop located in the rain shadow of WG with annual rainfall range of 600 – 1000 mm. Both these plateaux are subjected to grazing by goat and cattle herds. Panchagani, Kas and Panhala are high level ferricretes at the hill tops with nearly flat outcrop. Panchagani plateau is now floristically almost destroyed due to tourism (Watve 2013), but the remnants of some elements could be located here and there.

METHODS

These plateaux were studied during 2010 to 2016 for exploration of pteridophyte diversity, especially during the months of June to February to cover possibly all the pteridophytes existing in the study area. Entire plant specimens were collected with roots, rhizome, fronds, in vegetative as well as in reproductive stages. Some characters such as rhizome, scales, stipe and rachis colour, indusium and hairiness were noted in the field, and then the specimens were processed for herbarium preparation following the method given by Jain & Rao (1977). Before poisoning the observations related to surface morphology, sporangia, indusium and spores were noted and microphotographs were taken on Lawrence & Mayo Stereo-zoom microscope and Research microscope with Nikon Coolpix 6000 digital camera.

All the herbarium specimens were carefully checked in the laboratory and their identification has been confirmed with the help of floras, manuals, monographs (Blatter & Almeida 1922, Almeida 1972, Santha Devi 1981, Beddome 1864, 1870, 1892, Dixit 1984, 1992, Manickam & Rajkumar 1999, Borthakur *et al.* 2000, Dixit & Sinha 2001, Manickam & Irudayraj 2003, Singh & Panigrahi 2005, Fraser-Jenkins 2008a, Pardeshi 2009) and published literature in scientific journals. The voucher specimens are deposited in Herbarium

TABLE 2 : Details of the Pteridophytes on Plateaux and associated microhabitats from Western Ghats as per PPG I.

S. N.	**Family**	**Botanical Name**	**Microhabitats**	**Voucher Specimen No.**	**Occurrence on the sites studied**										**Frequency % & Frequency class**
					Anj	**Har**	**Ajn**	**Dur**	**Ahu**	**Kha**	**Tha**	**Pch**	**Kas**	**Pan**	
1.	Lycopodiaceae P. Beauv. in Mirb.	*Huperzia hamiltonii* (Spreng.) Trevis.	Epiphytic in Sacred groves and plateau forest	0223-0232				O	F						20, A
2.	Isoetaceae Dumort.	*Isoetes dixitii* Shende	Soil covered area	0002-0005		F	C	F	C				C		50, C
3.		*Isoetes panchganiensis* G. K. Srivastava, D. D. Pant & P. K. Shukla	Soil covered area at the margin of pools	0015-0016								R?		F	20, A
4.		*Isoetes sahyadriensis* Mahab.	Soil covered area	—								R?			10, A
5.	Selaginellaceae Willk.	*Selaginella delicatula* (Desv. *ex* Poir.) Alston	Slopes among grasses	0088-0100	F	F		O	F	O			F	O	70, D
6.		*Selaginella proniflora* (Lam.) Baker	Slopes among grasses	0112, 0115	R	F	R	O	F	R			R	O	80, D
7.		*Selaginella repanda* (Desv. *ex* Poir.) Spring #	Slopes among grasses	0107-0110					R	R					20, A
8.	Ophioglossaceae Martinov	*Ophioglossum ostatum* R.Br.	Soil covered area	0017-0029, 0594-0596	O	O	C	O	O	F	O		O	C	90, E
9.		*Ophioglossum gramineum* Willd.	Soil covered area	0030-0033	R	C	O	F		C	R		R	R	80, D
10.		*Ophioglossum parvifolium* Grev. & Hook. in Hook	Soil covered area	0034-0043	C	C	O	F	R	C	F		F	O	90, E

11.		*Ophioglossum reticulatum* L.	Bushes	0044-0057				O		C			F	F	40, B
12.		*Botrychium lanuginosum* Wall. *ex* Hook & Grev.	Epiphytic	0130-0132, 0548				O	R						20, A
13.	Osmundaceae Martinov	*Osmunda hilsenbergii* Grev. & Hook.	Bank of water body	001									R		10, A
14.	Lygodiaceae A. Roem.	*Lygodium flexuosum* (L.) Sw.	Slopes, Bushes	0281-0294		R								R	20, A
15.	Marsileaceae Mirb.	*Marsilea minuta* L.	Seasonal ponds	0325-0349	R		R	C			R	F	O	O	70, D
16.	Pteridaceae E.D.M. Kirchn.	*Actiniopteris radiata* (Sw.) Link.	Rock crevices	0203-0210		F		R			C				30, B
17.		*Adiantum capillus-veneris* L.	Moist Rock cliffs	0143-0159				R	O					F	30, B
18.		*Adiantum incisum* Forssk. subsp. *incisum*	Under storey & Slopes	0160-0164, 0165-0166				F						O	20, A
19.		*Adiantum incisum* Forssk. subsp. *indicum* (J. Ghatak) Fraser-Jenk.$	Slopes	0190-0193	R	R					R			F	40, B
20.		*Adiantum philippense* L. subsp. *philippense*	Slopes, Bushes & Boulders	0167-0172, 0173-0175	O	O			O						30, B
21.		*Adiantum philippense* L. subsp. *teestae* S.C. Verma & Fraser-Jenk.*	Slopes	0176-0189	O				O		C				30, B
22.		*Aleuritopteris albomarginata* (C.B. Clarke) Ching	Rock crevices	0446-0458		O		O	O			O	O	O	60, C
23.		*Aleuritopteris anceps* (Blanf.) Panigrahi	Slopes	0485-0486	O			O	R	R					40, B

24.		*Aleuritopteris bicolor* (Roxb.) Fraser-Jenk.	Slopes, under storey, cliffs	0459-0481	F	F	R	C	C	F		C	C	C	90, E
25.		*Aleuritopteris formosana* (Hayata) Tagawa	Crevices on cliff & Slopes	0465, 0468, 0470, 0585		R		O	F						30, B
26.		*Aleuritopteris rufa* (D.Don) Ching	Moist rock crevices	0487-0488		R		R				R			30, B
27.		*Pityrogramma calomelanos* (L.) Link.	Exposed soil calcium rich	0306-0324, 0554-0556		R	R							R	30, B
28.		*Pteris blumeana* J. Agardh.	Slopes on fringes of tree cover, Streams	0431-0434	F	F	R	O	R	R			R	O	80, D
29.		*Pteris venusta* Kunze.	Forest margins	0386-0400		R			O						20, A
30.	Dennstaedtiaceae Lotsy	*Pteridium revolutum* (Blume) Nakai	Soil rich slopes	0276-0280	O	C		C	C			O	C	O	70, D
31.	Aspleniaceae Newman	*Asplenium yoshinagae* Makino subsp. *austroindicum* Fraser-Jenk.	Epiphytic on tree trunk and boulder	0211-0220		O		F	F				O	R	60, C
32.	Blechnaceae Newman	*Blechnum orientale* L.	Wet shady places	0233-0237									R		10, A
33.	Athyriaceae Alston	*Athyrium falcatum* Bedd.	Among Boulders	0523-0525, 0543-0544	R		R	F	F						40, B
34.		*Athyrium hohenackerianum* (Kunze) T. Moore	Among Boulders, slopes	0498- 0506	F		R	F	F	R			O	R	70, D
35.	Thelypteridaceae Ching ex Pic. Serm.	*Thelypteris parasitica* (L.) Tardieu.	Soil rich wet area	0250-0258										R	10, A

36.		*Thelypteris dentata* (Forssk.) E.P.St. John.	Soil rich wet area	0238-0249									O	O	20, A
37.	Hypodematiaceae Ching	*Leucostegia truncata* (D. Don) Fraser-Jenk.	Epiphytic	0264-0273					C						10, A
38.	Dryopteridaceae Herter	*Bolbitis beddomei* Fraser-Jenk. & Gandhi	Under storey	0084-0085		R			R						20, A
39.	Nephrolepidaceae Pic. Serm.	*Nephrolepis cordifolia* (L.) C. Presl #	Rock surface under forest cover	0599-0600					R	R					20, A
40.	Tectariaceae Panigrahi	*Tectaria coadunata* (Wall. *ex* Hook & Grev.) C. Chr.	Under storey in Fringe vegetation, slopes in shade	0350-0373	C	C		R	F			O	R	R	70, D
41.	Davalliaceae M.R. Schomb. ex A.B. Frank	*Davallodes squamata* (Decne.) Mazumdar	Epiphytic	0221-0222	R			O	C						30, B
42.	Polypodiaceae J. Presl & C. Presl	*Lepisorus nudus* (Hook.) Ching	Epiphytic	0133-0142, 0565-0566	F	F		C	C				F	F	60, C
43.		*Microsorum membranaceum* (D. Don) Ching	Epiphytic	0059-0081, 0562-0564	C	O	R	C	C			R	F	F	80, D

The taxa up to genus level are arranged according to PPG I and the taxa at lower ranks alphabetically. * New records to Maharashtra state by present author, $ probable sp., and # New for Western Ghats and extended distributional record in Maharashtra state. R? = not observed by author. Anj = Anjaneri, Har = Harishchandragarh, Ajn = Ajanawale, Dur = Durgawadi, Ahu = Ahpe, Kha = Kharpud, Tha = Thakarwadi, Pch = Panchgani, Pan = Panhala. The voucher specimens mentioned in the table are deposited in the herbarium of author's institute.

of A. W. College, Otur. The taxonomic treatment to the taxa recorded is applied following Pteridophyte Phylogeny Group I (PPG I) for family levels and the correct scientific names as per Fraser-Jenkins (2008a) and accordingly presented in this paper.

RESULTS AND DISCUSSION

The study revealed that the pteridophyte community on and around the plateaux in Western Ghats of Maharashtra consists of a total 43 taxa comprising of 42 species and 3 subspecies within them. These taxa belong to 25 genera and 19 families. Among them family Pteridaceae is the largest with 14 taxa followed by Ophioglossaceae (5 taxa) and Isoetaceae and Selaginellaceae with 3 taxa each (Table 2). These 43 taxa constitute about 35.83% of total 120 pteridophytes reported for Maharashtra (Naik, 2006) and almost 45% of the taxa distributed in Western Ghats of Maharashtra. Author of present study himself enlisted 60 species from Pune district during his work on a Project (Rahangdale, 2013). It is noteworthy that, these 43 taxa are located at the microhabitats on and around the plateaux. The taxa recorded include 3 endemic and 6 rare species as per the reports by Chandra *et al.* (2008) and Fraser-Jenkins (2008b). *Huperzia hamiltonii* once abundant in the north Western Ghats (Mahabale & Chaudhari, 1987) is now rarely observed and the only locations remaining for the species are Durgawadi and Ahupe (Rahangdale & Rahangdale 2018).

The plateaux under study are representatives of different eco-climatic regions found in the Western Ghats and show variability in the microhabitats to some extent. The observations recorded about habitats in the present study are presented in the table 1 with respect to occurrence of pteridophytes in particular (special sense). Each microhabitat on a plateau is not independent of the other, because there is great interaction taking place among them, though the flora is quite different from each other or also overlapping to some extent. Therefore, some of the species with adaptive nature could inhabit more than one microhabitats. The microhabitats which are commonly occupied by pteridophytes are discussed here.

Narrow gaps among the boulders on the plateaux are very suitable microhabitat for a number of pteridophyte species, because humus is enriched here and direct effect of light, wind currents and rain is restricted by the boulders from all or some sides. They are also covered by lichens and mosses further enriching the gaps with nutrients and water. The most common taxa inhabiting such gaps are, *Adiantum philippense, A. philippense* subsp. *teestae, Asplenium yoshinagae* subsp. *austroindicum, Actiniopteris radiata, Aleuritopteris bicolor, Athyrium falcatum* and *A. hohenackerianum*. Associated with these taxa are some angiosperms in these gaps, viz., *Ceropegia media* (Huber) Ansari*, C. lawii* Hook. f.*, Curcuma pseudomontana* Grah.*, Pimpinella adscendens* Dalz., *P. heyneana* (Wall. ex DC.) Kurz.*, Plectranthus mollis* (Ait.) Spr.*, Iphigenia indica* (L.) A. Gray ex Kunth, *I. pallida* Baker and *I. stellata* Blatt. On the surface of boulders among mosses sometimes *Asplenium yoshinagae* subsp. *austroindicum, Lepisorus nudus* and *Microsorum membranaceum* are observed along with some orchid species like, *Conchidium braccatum* (Lindl.) Brieger and

PLATE I: Fig. 1. Ten plateaux in North Western Ghats comprising study area; adopted from Google Earth and labelled. **Fig. 2.** Savannah type vegetation at Kharpud Plateau.

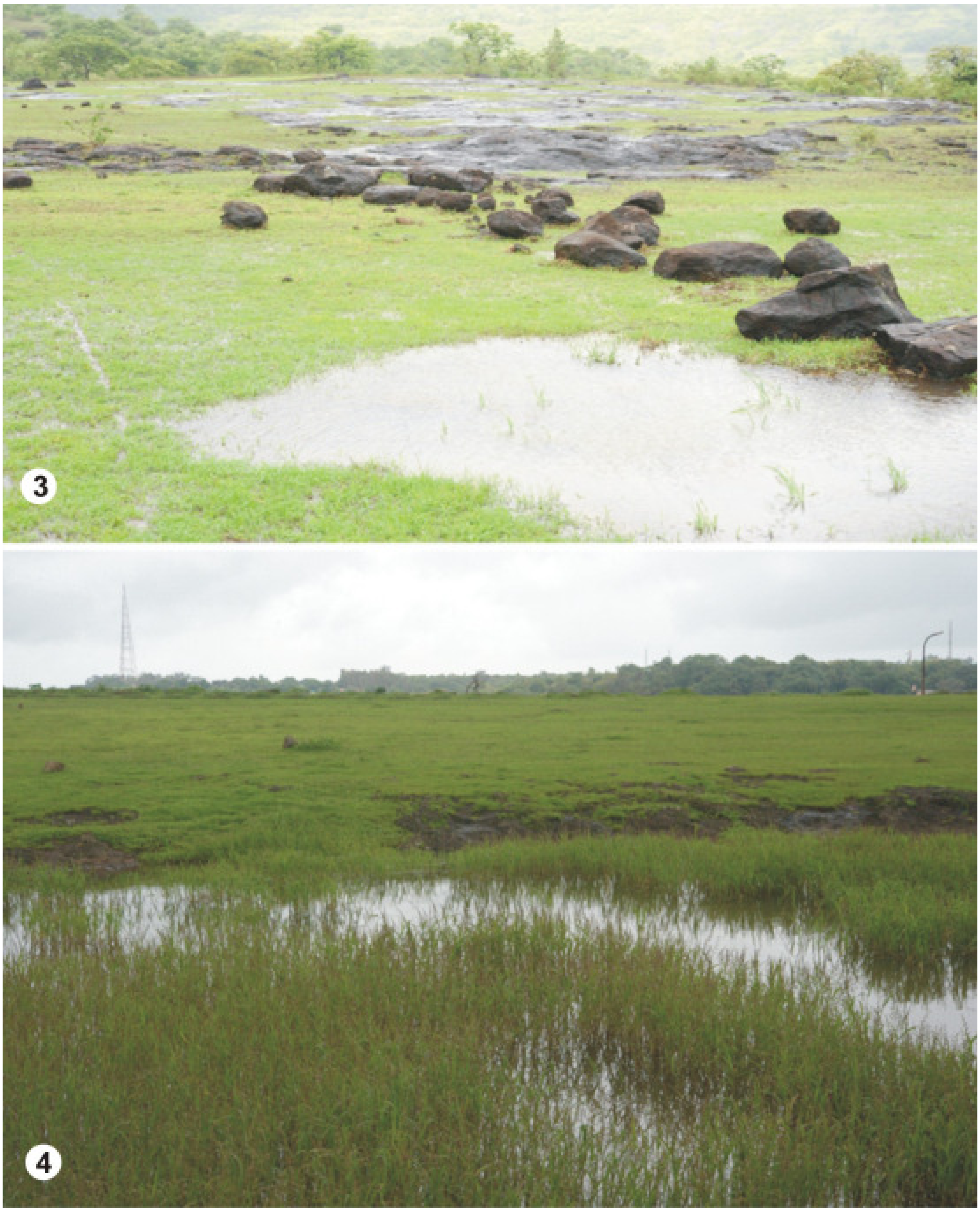

PLATE II. Fig. 3. Plateau vegetation at **Ajnavale**, locality of *Isoetes dixitii* Shende**. Fig. 4.** A view of Panhala Plateau.


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PLATE III. Fig. 5. *Bolbitis beddomei* Fraser-Jenk. & Gandhi growing on leaf litter on forest floor. **Fig. 6.** *Aleuritopteris formosana* (Hayata) Tagawa growing in rock crevice.

PLATE IV: Fig. 7. *Isoetes dixitii* Shende at Durgawadi plateau with the seedlings of *Smithia* sp. **Fig. 8.** *Huperzia hamiltonii* (Spreng.) Trevis growing on tree branch in association with *Lepisorus nudus* (Hook.) Ching, and grasses in sacred grove.

Dendrobium herbaceum Lindl.

Cliffs and Crust Edges having crevices dripping with water from top surface during rainy season are ideal habitats for many of the taxa. These microhabitats are generally found to be inhabited by *Athyrium falcatum, A. hohenackerianum, Adiantum philippense, Aleuritopteris albomarginata, A. anceps, A. bicolor, A. formosana, Selaginella delicatula* and *S. proniflora.* These taxa share the microhabitat with some grasses and other angiosperms like *Heracleum grande* (Dalz. & Gibs.) P. K. Mukh., *Pinda concanenssis* (Dalz.) P.K. Mukh. & Constance, *Ceropegia lawii* Hook. f., *Chlorophytum glaucum* Dalz., *Utricularia striatula* J. E. Sm., *Begonia crenata* Dryand., *Sonerila scapigera* Hook., *Arthraxon jubatus* Hack., *A. lancifolius* (Trin.) Hochst., *Arundinella metzii* Hochst. ex Miq. and *Jansenella griffithiana* (C. Muell.) Bor.

Exposed Rock Surfaces and soil-covered areas are the flat or uneven rock surfaces. These are exposed to direct sunlight and rock surfaces covered with some mosses and a thin layer of soil. During rainy season such areas are covered by mosses, grasses and other ephemerals. On such habitats the taxa, *Isoetes dixitii, Ophioglossum gramineum*, *O. parvifolium* and *O. costatum* are found on ferricrete as well as basaltic outcrops. The microhabitat is also commonly occupied by the angiosperm flora viz., *Arthraxon meeboldii* Stapf., *Arundinella metzii* Hochst. ex Miq., *A. spicata* Dalz., *Smithia bigemina* Dalz., *S. purpurea* Hook., *Sporobolus indicus* (L.) R. Br., *Eriocaulon achiton* Koern., *E. elenorae* Fyson, *E. stellulatum* Korn., *Utricularia albocaerulea* Dalz., *U. graminifolia* Vahl. and *U. striatula* J.E. Sm. after the death of aerial portion of these pteridophytes. At Kas plateau *I. dixitii* shares the habitat with *Aponogeton satarensis* Sundararaghavan, A.R. Kulkarni & S.R. Yadav along the margins of ephemeral pools/depressions during June to July.

Isoetes panchganiensis occupies almost exposed rock surfaces on the margins of seasonal pools with gentle slopes. It sometimes undergoes submergence. During the present study, it could not be located in its type locality but collected from Panhala. Unlike it, *Isoetes dixitii* does not undergo submergence because of slopes occupied by the former one. *I. sahyadriensis* could not be located during the present study and even repeated efforts by Pant & Srivastava (1962), Srivastava *et al.* (1993) and Shukla *et al.* (2002) were fruitless to collect the species from type location and elsewhere in similar localities. In this paper it is included only on the basis of original report by Mahabale (1938) and lectotypification of it by Fraser-Jenkins (2015). *I. sahyadriensis* does not coincide with former two species and reported to occur during close of monsoon on the margins of ponds amidst *Rotala-Ammania-Eriocaulon* association; while former two species are found during the onset of monsoon. Fraser-Jenkins (2015) lectotypified the specimen at Savitribai Phule Pune University, Pune; collected by Late T.S. Mahabale to *I. sahyadriensis* Mahab. It is mentioned that, the specimen is very young and observation of megaspores or velum is not possible; still it is justifiable as it is named so by T.S. Mahabale. He further epitypified the holotype of *I. panchananii* D.D. Pant & G.K. Srivastava to *I. sahyadriensis*. The critical study of protologues of *I. sahyadriensis* (Mahabale 1938) *I. dixitii* (Shende 1945), *I. panchananii* (Pant & Srivastava 1962) and even *I. sampathkumarnii* L.N. Rao (Rao 1944) show there are some overlapping characters among these taxa, but there are quite distinctness among them with peculiar characters of each species. Therefore, epitypification of holotype of *I. panchananii* from Reva district of Madhya Pradesh to *I. sahyadriensis* may not be justifiable because there are clear differences of characters between these two taxa, with respect to corm lobes and megaspore ornamentation. These characters are qualitative characters in genetics point of view, which remain constant across the generations. The discussion on this issue may be diverting from main emphasis of this research therefore, it would be discussed under other heading later. The question that remains is, whether the taxon *I. sahyadriensis* still exists? Yes, it may be; but the type location is nearly destroyed biologically due to tourist activities; and it needs more critical observations and emphasis to recollect the specimens from neighbouring localities.

I. dixitii was considered as an extinct taxon since 1997 (RBG, Kew Extinct plant index, 2013). A specimen of it was deposited at RBG, Kew by Mrs. Sumati S. Patil collected in August 1973 from Kas plateau. During present study, author has collected the specimens of this taxon from Duragawadi, Ajnawale (Plate II, Fig. 3), Ahupe (in Pune district) and Kas (in Satara district) plateaux and on comparisons with specimens of *I. panchganiensis* from Panhala (Kolhapur district); *I. coromandelina* L. f., *I. indica* Pant & Srivastava and *I. panchananii* Pant & Srivastava from three locations of Gondia district of Vidarbha region of Maharashtra; it stands separate form all other species. Thus, *I. dixitii* Shende exists and distributed in the Western Ghats of Maharashtra in Satara and Pune Districts on high altitude plateaux.

Seasonal Ponds are bowl like large depressions filled with water during monsoon and usually dry during summer (Plate II, Fig. 4). Gradual slopes of such pools are occupied by *Isoetes panchganiensis* and *Marsilea minuta*. *Marsilea minuta* also sustain its growth even in deep waters at some plateaux. *Isoetes sahyadriensis* was reported to occur in such habitats. Seasonal ponds are also occupied by common aquatic angiosperm species, *Nymphoides indica* (L.) Kuntze, *Persicaria glabra* (Willd.) Gomez, *Rotala densiflora* (Roth ex Roem. & Schult.) Koehne, *Isachne bicolor* Naik & Patunkar, *I. borii* Hemadri, *I. elegans* Dalz., and *I. globosa* (Thunb.) O. Ktze.

Plateau shrub and tree cover is mainly composed by *Memecylon umbellatum* Burm. *f.*, *Atalantia racemosa* Wight in Hook., *Maytenus rothiana* (Walp.) Lobreau-Collen, *Gnidia glauca* (Fresen.) Gilg., and *Actinodaphnae gullavara* (Buch.-Ham ex Nees) M.R. Almeida on the basal strata having lot of fissures and little amount of soil. The vegetation is responsible for development of good microclimate for light loving epiphytes, *Asplenium yoshinagae* subsp. *austroindicum*, *Lepisorus nudus*, *Microsorum membranaceum*. The terrestrial taxa are *Athyrium falcatum*, *A. hohenackerianum*, *Ophioglossum reticulatum*, *Adiantum philippense*, *Aleuritopteris albomarginata*, *A. anceps*, *A. bicolor*, *Selaginella* *delicatula*, *S. proniflora* and *Tectaria coadunata.* The under storey taxa occupying the boulders or soil surface are *Pteris venusta* and *P. blumeana.* This microhabitat supports the rich diversity of pteridophytes observed on the plateaux. The terrestrial pteridophytes are found amongst the herbaceous angiosperms like *Curcuma pseudomontana* Grah., *Impatiens balsamina* L., *I. dalzellii* Hook. *f.* & Thoms., *I. minor* (DC.) Bennet, *I. oppositifolia* L., *Jansenella griffithiana* (C. Muell.) Bor, *Senecio bombayensis* Balakr., *S. dalzellii* C.B.Cl., and *S. hewrensis* (Dalz.) Hook. *f.*.

Sacred groves and forests on deep soils present on the plateaux and slopes provide a different type of ecological niche for the pteridophytes. Many moisture and shade loving species occupy this type of habitat involve, epiphytes like, *Davallodes squamata*, *Asplenium yoshinagae* subsp. *austroindicum, Botrychium lanuginosum*, *Leucostegia truncata*, *Huperzia hamiltonii*, *Lepisorus nudus* and *Microsorum membranaceum* sharing the tree trunks and branches with mosses and grasses like *Andropogon pumilus* Roxb., *Arthraxon jubatus* Hack. and *Garnotia tenella* (Arn. ex Miq.) Jan. The under storey taxa occupying the boulders or soil surface are *Bolbitis beddomei, Pteris venusta* and *P. blumeana. Nephrolepis cordifolia* was also found to occur on the large moss covered boulders under the dense shade of trees in this microhabitat.

On the forest fringes and little openings, terrestrial species form under storey vegetation of *Adiantum incisum*, *Bolbitis beddomei, Aleuritopteris bicolor*, *Lygodium flexuosum*, *Nephrolepis cordifolia, Pteris venusta*, *P. blumeana* and *Tectaria coadunata. Bolbitis beddomei* occurs among rocks and boulders found under storey at Harishchandragarh and Ahupe while *Tectaria coadunata* form pure stands at Durgawadi and Ahupe and also recorded at three more locations in Pune district extending up to Varandha ghat region. *Pteridium revolutum* forms monotonous dense vegetation on the slopes and forest openings and generally attain a height of 2 meters.

The drainage paths on the plateaux running from forest or sacred grove and having nearly round the year wetness are found to be occupied by *Blechnum orientale* and *Osmunda hilsenbergii* under shade of trees with forest floor rich in leaf litter. These species are found only at the Kas plateau area. On the moist open streams and drainage paths the opportunistic species *Thelypteris dentata* and *Thelypteris parasitica* establish themselves.

The taxa recorded from the plateaux and around related habitats include *Adiantum philippense* subsp. *teestae* is an addition to the flora of Maharashtra. *A. philippense* subsp. *teestae* S.C. Verma & Fraser-Jenk. is a consistently small-sized diploid sexual member of the *A. philippense* complex (Verma & Fraser-Jenkins 2008, Fraser-Jenkins *et al.* 2017). *Aleuritopteris formosana* is found on the cliffs amidst grasses at Durgawadi, Ahupe and Harishchandragarh. Two taxa viz., *Selaginella repanda* and *Nephrolepis cordifolia* which were previously recorded from Melghat and Chandrapur in Vidarbha region of MS are recorded for first time from Western Ghats in Maharashtra. These species are showing further extended distribution in the West side of state.

The *Aleuritopteris rufa* is recently recorded from the Panchgani area on the basis of single plant specimen (Rawat 2012). During the present study this taxon has been collected from Harishchandragarh, Durgawadi, Ahupe and Pratapgarh fort South to Mahabaleshwar (not covered in present study). The altitude range for this taxon is varying from 600 m to 1200 m ASL. It occupies the moist rock crevices in little cool places or along the streams and also on the gaps between the rocks of fort walls of Pratapgarh along with *Aleuritopteris albomarginata*. The population size is of more than 80 plants at each location.

Distribution of taxa on plateaux

Present study showed that, 9 taxa viz., *Aleuritopteris bicolor*, *Lepisorus nudus*, *Microsorum membranaceum*, *Ophioglossum costatum*, *O. gramineum*, *O. parvifolium*, *Pteris blumeana, Selaginella proniflora* and *Tectaria coadunata* are more frequent taxa in plateau vegetation in the stretch of Western Ghats in Maharashtra. Among the least frequent taxa are *Blechnum orientale*, *Bolbitis beddomei* (Plate III, Fig. 5), *Botrychium lanuginosum*, *Thelypteris parasitica*, *Lygodium flexuosum* and *Osmunda hilsenbergiii* (Table 2).

The taxa viz., *Bolbitis beddomei*, *Botrychium lanuginosum*, *Aleuritopteris formosana* (Plate III, Fig. 6)*, A. rufa, Isoetes dixitii* (Plate IV, Fig. 7) and *I. panchganiensis* should be considered to be rare in Maharashtra state because of their small population size and scattered distribution. *Isoetes dixitii* and *I. panchganiensis* are endemic and here considered to be categorised as 'Endangered' applying criteria B2(a) of IUCN (2006) as their extent of occurrence (EOO) is on the area <500 km^2 and area of occupancy (AOO) is <10 km^2 as well as the number of locations are <5. In all these cases the most possible threat is habitat destruction as the land use pattern is changing very fast.

Ecological roles played by the Pteridophytes on the special habitats (Plateaux)

The pteridophytes are specialized in terms of their ecological requirements and have limited utilities as compared to the angiosperms; but the role played by them is invaluable if we think in long term. They inhabit the sites like steep slopes, withered rocks, excavated lands and barren rocky surfaces with very little soil (examples for which are mentioned in table 2), which are not suitable to the growth of higher plants. The profuse fibrous roots bind the soil particles together and resist the erosion causing factors such as wind and rain drops. This results into the reduced rate of surface runoff of rain water, filtration of water and holding the humus and soil on the slopes.

As they require special climatic conditions, their occurrence at a particular location could be exploited as indicator of certain ecological conditions; e.g., *Aleuritopteris albomarginata, A. rufa, Botrychium lanuginosum, Davallodes squamata* and *Huperzia hamiltonii* (Plate IV, Fig. 8) are the best indicators of cool and moist climatic conditions, while presence of *Adiantum capillus-veneris*, *Thelypteris parasitica* and *Thelypteris dentata* indicate round the year water seepage. Some taxa, *Aleuritopteris bicolor*, *A. rufa*, *Lepisorus* *nudus* and *Selaginella repanda* show poikilohydry. The recently disturbed habitats along the slopes are generally occupied by *Pityrogramma calomelanos.* This species also needs free water during active growth state especially during rainy season. These facts could be of great importance to formulate or prioritise the habitat conservation measures. Considering these facts the pteridophytes are indispensable group of plants and provide invaluable services to the ecosystem.

Threats to the taxa on plateaux

In general the plateaux are subjected to human interference in the form of overgrazing, trampling by cattle and tourists, felling of trees around plateaux for firewood, household usage and for other developmental activities, levelling of private land for cultivation of crops or constructions, harvesting of Myrobalans from trees and excavation of minor ores or boulders. All these activities lead to secondary threats like landslides and loosening of rocks.

Felling of old trees & branches, Myrobalan harvesting are the major and serious threats to the delicate epiphytes viz., *Huperzia hamiltonii*, *Botrychium lanuginosum*, *Davallodes squamata*, *Leucostegia truncata*, *Lepisorus nudus*, *Microsorum membranaceum.* Overgrazing, trampling by cattle & tourists and levelling of land are the threats to the taxa occupying soil covered areas on plateaux viz., *Isoetes dixitii*, *I. panchganiensis*, *Ophioglossum costatum*, *O. gramineum*, and *O. parvifolium.* Overall, threat of habitat destruction in any form is a matter of concern towards conservation of the pteridophytes on plateaux. Individual harvesting is not generally observed, except *Tectaria coadunata*, of which rhizomes are harvested as medicine.

Among the plateaux, Anjaneri, Harishchandragarh and Kas are now little protected to some extent as Anjaneri is declared as community reserve; Kas is being regulated by State Forest Department, while Harishchandragarh is less approachable. Kharpud, Ajnawale, Durgawadi, Ahupe and Panhala plateaux are still facing overgrazing, trampling due to tourist activities. Most of the area of Thakarwadi plateau is under private ownership and subjected to quarrying, levelling of slopes for cultivation and overgrazing. The Panchgani plateau is floristically almost destroyed due to tourist activities, only fringes and crests of the mesa are having some taxa surviving.

CONCLUSION

On the basis of results from the present study it can be concluded that, plateaux in the Western Ghats in Maharashtra harbour a significant number of pteridophytes, which are indispensable part of the biodiversity of the plateaux. The pteridophytes play very significant role in the plateau ecosystems and therefore any study of the plateaux could not be considered as complete without them. Present study brings on the record one more taxon as new addition to the flora of Maharashtra state while two taxa are newly reported to the Western Ghats in Maharashtra as extended distribution.

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REFERENCES

ALMEIDA M R 1972 Contribution to the Studies of Vascular Plants of Maharashtra : Revision of the Pteridophytes of BombayVol 1 & 2(*M Sc Dissertation*), University of Bombay

BEDDOME R H1864 *The Ferns of Southern India* Higginbotham & Co, MadrasPpXV+1-88+ Plates CCLXXI(reprint ed1984 Bishen Singh Mahendra Pal Singh, Deharadunpp XV+88+Plates CCLXXI

.... 1870 *The Ferns of British India*Grantz Brothers, Adelphi Press, Mount Road, MadrasPpXIV+180+ Plates CLXXX

.... 1892 *Handbook to the Ferns of British India, Ceylon and the Malay Peninsula with supplement*Thacker, Spink & Co, CalcuttaPpXIV+500+110 Supl + Plates 300

BENNIAMIN A, IRUDAYARAJ V & MANICKAM V S 2008 How to identify rare and endangered ferns and fern allies *Ethnobotanical Leaflets* **12** : 108-117

BLATTER E & ALMEIDA J fd' 1922 *The Ferns of Bombay* D B Taraporwala Sons & Co Bombay

BORTHAKUR S K, DEKA S & NATH K K2000 *Illustrated Manual of Ferns of Assam* Bishen Singh Mahendra Pal Singh, Deharadun Pp 468

.... 2005b Biodiversity patterns in arid, variable environments *Mountain Research and Development* **25(3)** : 228-234

CHADHA J, CHANDER H & KUMAR B 2008 Endemic Pteridophytes of India : Distribution and threat status In: Rawat, GS (ed) *Special Habitats and Threatened Plant of India ENVIS Bulletin: Wildlife and Protected Areas* Wildlife Institute of India, Deharadun **11(1)** : 229-232

CHANDRA S 2000 Companion to A census of Indian pteridophytes *Taiwania* **45(1)** : 38-65

.................., FRASER-JENKINS C R, KUMARI A & SRIVASTAVA A 2008 A summary of the status of threatened Pteridophytes of India *Taiwania* **53(2)** : 170-209

DIXIT R D 1984 *A Census of the Indian Pteridophytes* Flora of India series IV Botanical Survey of India, Howrah Pp 177

.... 1992 *Selaginellaceae of India* Bishen Singh Mahendra Pal Singh, Deharadun Pp 196

.... & SINHA B K 2001 *Pteridophytes of Andaman and Nicobar Islands* Bishen Singh Mahendra Pal Singh, Deharadun Pp 155

FRASER-JENKINS C R 2008a *Taxonomic Revision of Three hundred Indian Subcontinental*

Pteridophytes with a Revised Census List Bishen Singh Mahendra Pal Singh, Deharadun Pp 685

.... 2008b Endemics and pseudo-endemics in relation to the distribution patterns of Indian Pteridophytes *Taiwania* **53(3)** : 264-292

.... 2015 Lectotypification and epitypification of *Isoetes sahyadriensis* (Isoetaceae) from SW India *Indian Journal of Forestry* **38(3)** : 2321-232

FRASER-JENKINS C R, GANDHI K N, KHOLIA B S & BENNIAMIN A 2017 *An Annotated Checklist of Indian Pteridophytes*, Part-1 Bishen Singh Mahendra Pal Singh, Dehra-Dun

FRASER-JENKINS C R GANDHI K N & KHOLIA B S 2018 *An Annotated Checklist of Indian Pteridophytes*, Part-2 Bishen Singh Mahendra pal Singh Dehra-Dun

IUCN, (STANDARDS AND PETITIONS WORKING GROUP) 2006 Guidelines for using IUCN red list categories and criteria Version 62 http://wwwappiucnorg/webfiles/doc/SSC/RedList/RedList Guidelines.pdf

JACOBI C M, CARMO F F, VINCENT R C & STEHMANN J R 2007 Plant communities on ironstone outcrops: a diverse and endangered Brazilian ecosystem *Biodiversity and Conservation* **16** : 2185-2200

JAIN S K & RAO R R 1977 *Field & Herbarium Methods* Today & Tomorrow's Printers & Publishers, Delhi Pp 157

LEKHAK M M & YADAV S R 2012 Herbaceous vegetation of threatened high altitude lateritic plateau ecosystems of Western Ghats, southwestern Maharashtra, India *Rheedea* **22(1)** : 39-61

MAHABALE T S 1938 On a new species of *Isoetes* in India *Current Science* **7(2)** : 62-63

.... & CHAUDHARI K K (Ed) 1987 *Maharashtra State Gazetteer – General State Series, Botany – Part IV: Botany and Flora of Maharashtra* Government of Maharashtra, Bombay Pp 255-274

MANICKAM V S & RAJKUMAR S D 1999 *Polymorphic Ferns of Western Ghats - South India* Bishen Singh Mahendra Pal Singh, Deharadun Pp 302

.... & IRUDAYARAJ V 2003 *Pteridophyte Flora of Nilgiris, South India* Bishen Singh Mahendra Pal Singh, Deharadun Pp 192

NAIK V N (Ed) 2006 *Maharashtra State Gazetteer – Botany and Flora of Maharashtra* Government of Maharashtra, Mumbai (in Marathi) Pp 87-264

PANT D D & SRIVASTAVA G K 1962 The genus *Isoetes* in India *Proceedings of National Institute of Sciences, Part B- Biological sciences* **28** : 242-280

PARDESHI V N 2009 *The Manual of Ferns of India* Saraswati Printing Press Aurangabad Pp 145

POREMBASKI S & WATVE A 2005 Remarks on the species composition of Ephemeral Flush Communities on paleotropical rock outcrops *Phytocoenologia* **35(2&3)** : 389-401

.................., BECKER U & SEINE R 2000 Islands on islands: habitats on Inselbergs *Ecological Studies* 146: 49–67 In: Porembski, S & W Barthlott (eds) *Inselbergs - Biotic Diversity of Isolated Rock Outcrops in Tropical and Temperate Regions* Ecological studies 146 Springer, Heidelberg Pp 524

.................., BARTHLOTT W, DORRSTOCK S & BIEDINGER N 1994 Vegetation of rock outcrops in Guinea: granite inselbergs, sandstone table mountains and ferricretes - remarks on species numbers and endemism *Flora* **189** : 315-326

RAHANGDALE S R 2013 *Inventorization and digitization of Pteridophyte diversity from district Pune* Pp 85 Project report submitted to UGC, New Delhi (unpublished)

.... & RAHANGDALE S S 2011 *Botrychium* Swartz: A new genus record from Maharashtra state *The Indian Forester* **137(12)** : 1462-1463

.... & .... 2018 *Biodiversity of Durgawadi Plateaus* Department of Forests, Government of Maharashtra Pp 114

RAHANGDALE S S & RAHANGDALE S R 2014 Plant species composition on two rock outcrops from the northern Western Ghats, Maharashtra, India *Journal of Threatened Taxa* **6(4)** : 5593–5612 http://dxdoiorg/1011609/JoTTo36165593-612

RAO L N 1944 A new species of Isoetes from Bangalore, Mysore State *Current Science* **11** : 286-287

RAWAT V K 2012 *Aleuritopteris rufa* (D Don) Ching- A new record for the pteridophyte flora of Maharashtra *Phytotaxonomy* **12** : 171-172

RBG KEW 2013 http://www.rbgkew.org online database for extinct plants index dated 6th May 2013

RIBEIRO K T, MEDINA B M O & SCARANO F R 2007 Species composition and biogeographic relations of the rock outcrop flora on the high plateau of Itatiaia, SE-brazil *Revista Brasilica Botanica* **30(4)** : 623-639

SANTHA DEVI 1981 *Reference Manual of Fern Spores* National Botanical Research Institute, Lucknow Pp 90

SHENDE D V 1945 A new species of *Isoetes* from the Bombay presidency *Journal of the University of Bombay* **B14** : 50-52

SHUKLA P K, SRIVASTAVA G K & SHUKALA S K 2002 The quillworts (*Isoetes*) of India : Distribution, endemism and species radiation *Biodiversity and Conservation* **11** : 959-973

SINGH S & PANIGRAHI D G 2005 *Ferns and Fern Allies of Arunachal Pradesh* Vol 1 & 2 Bishen Singh Mahendra Pal Singh, Deharadun Pp 881

SINGH S K, SRIVASTAVA G K, SRIVASTAVA M & SHUKLA P K 2012 *Selaginella crassipes* (Selaginellaceae), a new report from India *Taiwania* **57(3)** : 283-287

SRIVASTAVA G K, PANT D D & SHUKLA P K 1993 The genus *Isoetes* in India *American Fern Journal* **83(4)** : 105-119

VERMA S C & FRASER-JENKINS C R 2008 *Adiantum philippense* L The correct name for *A lunulatum* Burm F, and its subspecies *Perspectives in pteridophytes*, pp 65-92, Bishen Singh Mahendra Pal Singh, Dehradun, India

WATVE A 2008 Rocky Outcrops as Special Habitats in North Western Ghats, Maharashtra In : Rawat, GS (ed) *Special Habitats and Threatened Plants of India ENVIS Bulletin: Wildlife and Protected Areas* Wildlife Institute of India, Dehradun **Vol 11(1)** : 147-153

.... 2013 Status review of Rocky plateaus in the northern Western Ghats and Konkan region of Maharashtra, India with recommendations for conservation and management *Journal of Threatened Taxa* **5(5)** : 3935-3962

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NEW COMBINATION, DISTRIBUTIONAL RECORD AND TYPIFICATIONS IN INDIAN DAVALLIACEAE

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ABSTRACT

Based on updated understanding of generic classification of fern family Davalliaceae, a new combination is made for *Davallodes squamata*, a species originally described from Maharashtra, India. Tamil Nadu is also added as new distributional record for *Davallodes squamata*. Two Indian species *Davallia griffithiana* and *D. hookeri* were lectotypified.

Key Words : Davalliaceae, *Davalli*a, new combination, new report, lectotype.

INTRODUCTION

There have been longstanding problem about generic classification of fern family Davalliaceae. Number of genera recognized was up to ten (see comparative table in Tsutsumi *et al.* 2008, p. 45). But a tendency of reduction of number genera were noted (Nooteboom 1994, Tsutsumi *et al.* 2008). Christenhusz *et al.* (2011) accepted two genera, viz., *Davallia* Sm. and *Davallodes* (Copel.) Copel.

Gymnogrammitis Griff. and *Leucostegia* C.Presl are now excluded from Davalliaceae (Tsutsumi *et al.* 2008, PPG I 2016). Recent molecular phylogenetic study (Tsutsumi *et al.* 2016) supported recognition of single large genus *Davallia*. Genus *Katoella* Fraser-Jenk., erected by Fraser-Jenkins *et al.* (2015) didn't get support from molecular data and synonymised into *Davallia* by Tsutsumi *et al.* (2016).

To follow this updated treatment for Indian species of Davalliaceae, we noted that, a new combination for *Davallodes squamata* (Decne.) Mazumdar under *Davallia* is needed. Here we provided new combination below.

We first time report here *Davallodes squamata* from Kolli hills, Tamil Nadu (Fig. 1 a-h), in addition to its previous report from Maharashtra (Fraser Jenkins 2008).

Also, to fix the application of the names we selected types for two Indian species *Davallia griffithiana* Hook. and *D. hookeri* (Bedd.) X.C.Zhang, originally described from specimens collected from India.

NEW COMBINATION & DISTRIBUTIONAL RECORD FOR *DAVALLODES SQUAMATA*

Davallia squamata* (Decne.) Mazumdar & P.Vijaykanth *comb. nov. (Fig. 1 a-h)

Cystopteris squamata Decne., Voy. Inde [Jacquemont] 4(Bot.): 178. 1844.

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Araiostegia squamata (Decne.) Fraser-Jenk., Taxon. Revis. Indian Subcontinental Pteridophytes 354. 2008. *Davallodes squamata* (Decne.) Mazumdar, Phytotaxa 158(3): 297. 2014. *Katoella squamata* (Decne.) Fraser-Jenk., Kandel & Pariyar, Ferns Fern-Allies Nepal 1: 34. 2015.

Lectotype (designated by Mazumdar 2014, p. 297): INDIA. Maharashtra: North Western Ghats [as "a Carli ad Candala"], September, *V. Jacquemont 599* (P00645160 left hand specimen; Isolectotypes P00645160 right hand specimen, P00645161, P00645162 images!).

Distribution : India (Maharashtra & Tamil Nadu).

Voucher specimen : Tamil Nadu. Kuzhivalavu, 21.06.2015, P. Vijayakanth 391A (CCSH)

Nooteboom (1994) sank *Davallia squamata* and *Davallia beddomei* Hope as synonyms of *Davallia pulchra* D.Don, but kept separate by Fraser-Jenkins (2008) that we follow here and also provide detailed photos of different parts of *Davallia squamata* plant (Fig. 1 a-h).

TYPIFICATIONS

***Davallia griffithiana* Hook.,** Sp. Fil. [W.J. Hooker] 1. 168 t. 49 B. 1846. *Humata griffithiana* (Hook.) C.Chr., Contr. U.S. Natl. Herb. 26. 293. 1931.

Lectotype (designated here): India. Meghalaya: ["Khasya"], *W. Griffith s.n.* (K000061848). Syntypes: Indian: Arunachal Pradesh: Mishmi hills ["Mishmee"], *W. Griffith s.n.* (K000061848); Bhutan ["Bootan"], *W. Griffith s.n.* (K000061847, P01466789); India. *W. Griffith s.n.* (GH00020953); India. *W. Griffith s.n.* (US00135420).

In the protologue of this name Hooker (1846: 168) mentioned "Hab. Northern India, Assam, *n.* 910, and b. Khasiya, *Mr. Griffith*". Khasia mountain was previously part of Assam during British India, but now under Meghalaya. Griffith's collections (original material), annotated by Hooker exist in K. We select Griffith's collection K000061848 as lectotype. Specimen K000061846 (India, Meghalaya ["Khasiya"]) is the type of "*Davallia griffithiana* b" that Hooker also mentioned.

***Davallia hookeri* (Bedd.) X.C.Zhang**, Lycophytes Ferns China 567. 2012. *Acrophorus hookeri* T.Moore ex Bedd., Ferns Brit. India t. 95. 1866. *Acrophorus hookeri* T. Moore, Index Fil. (T. Moore) 2. 1857 (nom. nud.). *Davallia clarkei* Baker, Syn. Fil. (Hooker & Baker), ed. 2. 91. 1874.

Lectotype (designated here) : India. Himachal Pradesh: Sirmour, 9-11000 feet, *T. Thomson* 315 (K000512216).

Beddome (1866) validated Moore's (1857) invalidly published name *Acrophorus hookeri* T.Moore (nom. nud.). In the protologue of this name Beddome (1866: 95) mentioned that he saw plants or specimens from localities "Khasya, Sermur, Sikkim".

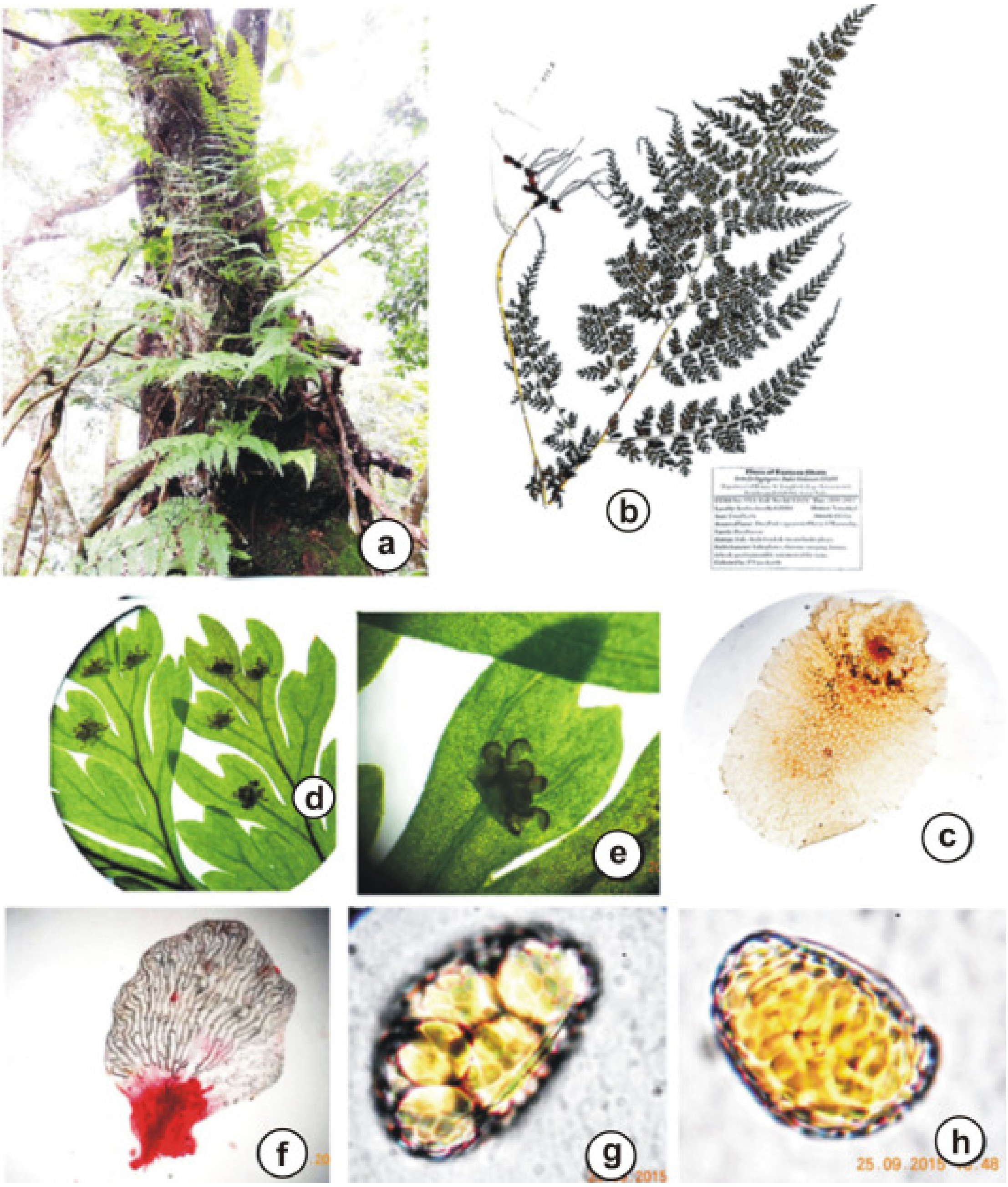

Figure 1. ***Davallia squamata*** **(Decne.) Mazumdar & P.Vijaykanth, a.** Habit, **b.** Herbarium, **c.** Rhizome scale (40x), **d.** Leaf (20x), **e.** Sporangium (40x), **f.** Indisium (40x), **g-h.** Spores (45x).

ACKNOWLEDGEMENT

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REFERENCES

BEDDOME R H 1866 *The Ferns of British India* Vol 1 Gantz Brothers, Madras

CHRISTENHUSZ M J M ZHANG X C & SCHNEIDER H 2011 A linear sequence of extant families and genera of lycophytes and ferns *Phytotaxa* **19** : 7-54

FRASER-JENKINS C R 2008 *Taxonomic revision of three hundred Indian subcontinental Pteridophytes with a revised Census-List* Bishen Singh Mahendra Pal Singh, Dehra Dun

FRASER-JENKINS C R, KANDEL D R & PARIYAR S 2015 *Ferns and fern-allies of Nepal-1* National Herbarium and Plant Laboratories, Department of Plant Resources, Ministry of Forests and Soil Conservation, Kathmandu

HOOKER W J 1846 *Species Filicum* Vol 1. W Pamplin, London

MAZUMDAR J 2014 Nomenclatural note on three ferns from India *Phytotaxa* **158(3)** : 297-298

MOORE T 1857 *Index Filicum* W. Pamplin, London

NOOTEBOOM H P 1994 Notes on Davalliaceae II. A revision of the genus Davallia *Blumea* **39** : 151-214

PPG I 2016 A community-derived classification for extant lycophytes and ferns *Journal of Systematics and Evolution* **54(6)** : 563-603

TSUTSUMI C, CHEN C W, LARSSON A, HIRAYAMA Y & KATO M 2016 Phylogeny and classification of Davalliaceae based on chloroplast and nuclear markers *Taxon* **65 (6)** : 1236-1248

TSUTSUMI C, ZHANG X C & KATO M 2008 Molecular Phylogeny of Davalliaceae and Implications for Generic Classification *Systematic Botany* **33(1)** : 44-48

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FERN ECOLOGY AND CLIMATE CHANGE

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ABSTRACT

Climate change has been documented worldwide and is already resulting in measurable changes to oceanic and terrestrial ecosystems particularly in polar regions and the tropics. In the past decade technology has made it possible for the accumulation and analysis of large datasets of climate data that allow climate models to predict the effect of various levels of warming on climate-driven events within the next century. Major losses of plant biodiversity are predicted to occur through species range shifts caused by climate-driven warming of current ranges. Although considerable biodiversity data about organisms have been collected over the past hundred years, there are parts of the world and groups of organisms that are underrepresented. For data that have been collected, much of it has not been standardized and digitized in a form that can be input to the large databases that now inform climate models. The western hemisphere (and Australia) have better documented climate models and species occurrence data than the rest of the world. Advances in fern systematics has resulted in taxonomic standardization, but ferns have been under-represented in plant trait and occurrence datasets and are currently missing from major phenological databases. Documenting fern floristic and phenological research results in public databases, digitizing herbarium specimens and participation in citizen science programs that collect current and future plant occurrence and phenological data on ferns requires a shift in pteridological research focus. Research encompassing question-driven research, long-term monitoring and conservation of ferns will now take place in a world where habitats may be rapidly changing. Diverse research teams must take steps in collaboration to provide the necessary data to maintain current levels of fern biodiversity in a future that includes an as yet unknown level of global warming.

Key Words : Global warming, pteridophytes, biodiversity, phenology, conservation

INTRODUCTION

Temperature increase is the most common indicator of climate change. Rising temperatures have been documented since the industrial revolution and changes worldwide are monitored and analyzed under the auspices of the Intergovernmental Program on Climate Change (IPCC : https://www.ipcc.ch/). Although the shift to global warming is most evident in the warming and ice melting that is occurring in the polar regions, warming is taking place on land and at sea all up and down the latitudinal gradient from pole to pole. Organisms have existed at a fixed location on the earth for eons with gradual changes in climate that were only detectable over very long time periods. Now changes are happening within the space of few generations (IPCC 2014) and local and regional populations of ferns

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can be expected to be affected by these global patterns of change. For example, in the northeastern part of the United States where I live it is now certain that the temperature of the nearby Gulf of Maine is rising faster than in oceans almost anywhere else in the world (Saba *et al*. 2016). Such increases in ocean temperature result from regional and worldwide changes in the hydrologic cycle that are changing the locations of offshore fishing grounds with serious implications for a local economy based on its fishing industry.

Oceanic temperatures can have a huge influence on nearby land weather events. Furthermore, every temperate forest that is traversed by rivers that flow into the Gulf of Maine is carpeted with a diverse assemblage of ferns that in many ways determine the composition of the forest above. These forests have a huge role in recycling water through the atmosphere through transpiration and root uptake, a process entwined with changes in temperature and other climate events worldwide. If historical forest ecosystem cycles are disrupted it can affect the resident fern communities to the extent that species are lost or their role in providing an optimal habitat for tree seedlings (George & Bazzaz 2012) will be disrupted as well.

Climate changes are now affecting regions that have been identified as being particularly sensitive to climate variability including tropical rainforests (Seddon *et al.* 2016), home to the majority of fern species. In a national symposium on pteridophytes and climate change Verma (2018) urged collaboration among herbaria and ecosystem research entities in India and a focus on all three elements of the fern life cycle (spore, gametophyte and sporophyte). At that same symposium Rajagopal (2018) noted that addressing the potential effects of climate change is particularly important in India where both the Himalayas and the Western Ghats are recognized as being among the most threatened biodiversity hot spots in the world (Rajagopal 2018). Here we review the latest research on climate change predictions and discuss effects and potential research and conservation initiatives for future research on fern biodiversity and phenology. Cooperation among researchers with a variety of skill sets will be needed to achieve the goal of maintaining global fern biodiversity as evidenced by the increasing number of authors of studies cited here, the variety of sources of climate change data, and the high proportion of open access citations on the subject.

Current worldwide climate change status

The IPCC was established in 1988 by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) and continues to facilitate worldwide climate change discussions and make informed recommendations on all related issues of scientific and economic import. The most recent synthesis and recommendations were presented in their 5th report (IPCC 2014) and outlined the physical basis of climate change and documented a post-industrial (1880-2012) increase in worldwide temperature of 0.85°C. The next major synthesis report with recommendations is scheduled for 2022 with interim scientific and economic reports commissioned by the IPCC to inform its next synthesis report. In order to provide information for recommendations on target global temperature limits, a recently released IPCC special report (Masson-Delmotte *et al*. IPCC 2018) addressed the impacts on global warming of 1.5°C and 2.0°C above preindustrial levels by 2100.

As rising worldwide temperatures are already documented at thousands of individual weather stations throughout the world, computer technology has continued to advance to the point where these meteorological data can be aggregated over time and at a global scale to provide the basis for climate models predicting future temperature change scenarios (e.g. WorldClim, CliMond, CGIARr-CSI etc.: see Šímová *et al*. 2018). These models increase in credibility as more and more data points are aggregated from such automated observing stations as the National Ecological Observatory Network (NEON, Thorpe *et al.* 2016) in the USA, however climate data are not uniformly available throughout the world, nor are all climate models equally effective. For example, Soria-Auza *et al.* (2010) note that the climate dataset Saga (but not WorldClim) was able provide sufficient climate data for the species distribution modelling software MaxEnt to accurately predict range boundaries of ferns in tropical and dry areas of Bolivia. Climate change predictions are based to a large extent on unchanging abiotic factors such as global topography, ocean locations and depth and solar radiation. It has become increasingly clear since the dawn of the industrial age that it is the atmospheric layer around our earth that exerts the greatest control over climate. Until relatively recent technological advances, even recording weather information was relatively time consuming and maintaining equipment expensive. Acceptance of scientific conclusions regarding the much more complex climate effects of increasing CO_2 in the atmosphere worldwide has been very difficult to achieve.

Maintaining species diversity is considered one of the essential elements of dealing with the effect of climate change and is the focus of an IPCC 2018 report chapter on natural systems (Hoegh-Gildberg *et al.* IPCC 2018). Documenting climate change and its effects on biota requires repeated observations over time at varying times scales that depend on the lifespan of individuals or the length of climate cycles. It has been less than 40 years since programs supporting long term ecological studies were established (not without controversy) and started to recognize that ecosystems do change over time (e.g. Luquillo Puerto Rico Long Term Ecological Research (LTER) site, (Harris *et al.* 2012). Until recently loss of diversity to habitat disappearance has simply meant lack of suitable space on the earth as human activities such as deforestation and development replace the natural landscape. Fragmented ecosystems retain only part of their intrinsic levels of biodiversity and climate change adds more levels of complication to that "diversity loss" (Silva *et al.* 2018).

Hoegh-Gildberg *et al.* (IPCC 2018) present predictions of such biodiversity losses using the best currently available scientific information on both oceanic and terrestrial biomes. Each of their conclusions are qualified as having high, low or medium confidence levels because in many areas there is insufficient data about climate parameters and/or biota available. We will focus on their results and recommendations in two areas affecting land-based plants (including ferns): 1) biome shifts and changes in species ranges and abundance, and 2) phenology (seasonality in growth and reproductive processes of a species). Additionally, I will discuss the shifting focus needed in fern research and conservation efforts to ensure that in spite of climate-driven habitat loss, any of the over 12,500 species of ferns and lycophytes in the world (Hessler and Schmitt, 2019) continue to be available for protection or re-introductions when and where possible.

BIODIVERSITY

Changes in climate can affect all organisms by changing the habitats in the locations in which they naturally evolved. Future losses of area in the distribution ranges for plants have been estimated under different temperature increase scenarios : a 24% (18-30%) loss at 1.5°C, a 30% (23-38%) loss at 2.0°C and a 46% (30-55%) loss 3.5°C increase above pre-industrial levels by 2100 (Warren *et al.* 2018). These estimates do not include additional effects of more violent weather events although Hoegh-Gildberg *et al.* (IPCC 2018) do specifically mention the possible collapse of the monsoon system over India under conditions of variable warming patterns of land masses and the ocean. Warren *et al.* (2018) also mention the possible loss of conductivity among historical and future range locations and emphasize that differential declines in individual species ranges would have an effect on ecosystem function. Although the role of fern communities is currently almost completely ignored in forest ecosystem studies throughout the world, any data that are digitally available have been welcomed into comprehensive climate change models (e.g. Šímová *et al.* 2018). Here we discuss the kinds of data needed and the digital forms it must be in to ensure that predictions for range changes and biodiversity of ferns species are as accurate as possible. Current predictions of range change are based on the assumption that current locations occupied by a species are the optimal climatic niche for that species (Colwell 2008). Therefore, predicting effects of climate change on a species distribution uses niche modelling to identify current and future suitable climate envelopes under different temperature change scenarios (Pouteau *et al.* 2016). While the earth overall will be warming in response to the capture of greenhouse gasses within our atmosphere, it is clear that the changes at specific locations on the earth will vary. Even in different areas with similar temperature changes, other non-thermal abiotic factors may dictate that species within a community may move in different directions at different rates (Gibson-Reinemer & Rahel 2015). For plants, even more than for mammals and birds, biodiversity is mainly at risk because of the relative inability of plants to move rapidly in response to changes in their environment (Warren *et al.* 2018).

There are two natural gradients of temperature increase where climate change driven by higher temperatures can affect the range of a species: 1) the latitudinal temperature gradient where high temperatures at the equator decrease toward to polar regions and/or 2) elevational gradients in mountainous areas, where high temperatures at the base give way upslope to lower temperatures at the top. According to Colwell *et al.* (2008) temperatures decrease much more rapidly as elevation increases (5.2°C to 6.5°C over 1000 m elevation) than as latitude increases (6.9°C per 1000 km at 45° N and S latitude and over a much greater distance in the tropics). Chen *et al.* (2011) estimated median decadal range shifts of 11.0 m in upward in elevation and 16.9 km pole-ward in latitude.

Latitudinal range changes

Increasing temperatures in tropical lowlands will result in unparalleled loss of diversity under unprecedented warming conditions as species ranges of existing biota advance toward the poles (Colwell *et al.* 2008). Much of the range data on plant species were collected during times when there was no thought of possible climate change, only the need to document where in the world different species of ferns could be found. For example, species range maps, once established and published in a flora (e.g. Mexico states: Mickel & Smith, 2004), were assumed to be fairly static and the limitations on accuracy only the result of insufficient time and effort available for more field work. Distribution data was often very general and habitat descriptions, if present, were brief and rarely included temperature ranges for a species. Lacking our current computer technology, many observations were made as written field notes and possibly supplemented with identification vouchers in the form of herbarium specimens. Ancillary field notes were often destroyed, lost or became inaccessible on outdated data storage media.

Current efforts are focused on accumulating massive worldwide datasets of the location data for individuals of a species (plant occurrences) that define the species' range boundaries. Herbarium specimens were originally collected for their value in floristic and systematic studies but their location entries also provide vital information about biodiversity. Concentrated digitization efforts are underway at many herbaria throughout the world (Besnard *et al*. 2018) with a recent estimate of 3100 herbaria worldwide (97 in India) with over 390 million specimens (Thiers 2018). The digitization process is relatively expensive as it requires not only the machinery and software but also staff to move herbarium specimens around. The Plant Press (newsletter of the U. S. National Herbarium), reported in December 2018 that they had digitized half their collection (including pteridophytes) of over 5 million specimens and using their "Botany Digitization Conveyer Belt" expected to complete the project in three more years. While duplication of specimens may ensure that parts of smaller collections are represented in such large datasets, this is certainly not always the case, so smaller herbaria should be reviewing their own holdings against digitized specimens in global databases to identify specimens in need of digitization. There are several programs including one called "WeDigBio" that mobilize public participation in various steps of the digitization process thus reducing the cost of such projects (Ellwood *et al.* 2018). A recent assessment of digitized herbaria has found some interesting sampling biases that need to be accounted for when such data are used to assess biodiversity. These include "specimens collected near roads and herbaria, specimens collected more frequently in biological spring and summer, specimens of threatened species collected less frequently, and a disproportionately large percentage of specimens collected by a very few individuals" (Daru *et al.* 2018).

In 2001 the Global Biodiversity Information Facility (GBIF; https://www.gbif.org/), an international network of countries and organizations, was established to continually amass species occurrence observations and to provide public access to that dataset that now numbers over 250 million plant occurrences. Plant occurrence data in GBIF come not only from digitized herbaria (e.g. Missouri Botanical Garden (Tropicos) with over 4 million specimens), but also from floristic work (e.g. Himalayas; Rana & Rowat 2017) and many other sources. Data from "Living Atlas" programs, originally developed in Australia (https://collections.ala.org.au/datasets) for natural history input, but now established in a number of countries including The Biodiversity Atlas – India (https://www.bioatlasindia.org/) have also become part of GBIF through which fern groups can organized "biodiversity data marathons". Most recently anyone with a smart phone can record an individual organism's identification with a geolocated image that can be input using the iNaturalist app (https://www.inaturalist.org/). The master GBIF database is continually updated and as of 29 June 2019 ferns and lycophyte occurrences in India numbered 20,726 out of worldwide total of 541,770 vascular plant occurrences (https://www.gbif.org/occurrence/search?country=IN), but only 8 fern and 1 lycophytes occurrence records came from iNaturalist images. Current taxonomy for ferns is periodically provided to GBIF from the *Checklist of ferns and lycophytes of the world* (https://worldplants.webarchiv.kit.edu/ferns/) maintained by Hessler & Schmitt (2019) and as of 29 June 2019 the list included 1,036 species for India. The nomenclature used in this checklist is based mainly on taxonomic conclusions of Pteridophyte Phylogeny Group (PPG I: 2016) and the list for India references eight sources including Khullar (1994, 2000) and most recently Fraser-Jenkins *et al.* (2017, 2018).

Datasets of interest can be selected from GBIF and downloaded in Excel readable formats for analysis (often through modules in the free R programming language (https://www.r-project.org/)). For example, the Botanical Information and Ecology Network (BIEN) dataset of plant characteristics was established in 2008 (http://bien.nceas.ucsb.edu/bien/) and includes GBIF location data, mostly from the western hemisphere, combined with data from other sources to inform modelling questions about climate change. BIEN data was then the basis of a research project that identified climate sensitive traits of plant species throughout their range within North, Central and South America at a grid size of 200 km x 200 km (Šímová *et al.* 2014).

Elevational range changes

Local topography can affect the grid size used for plant occurrence locations based on latitudinal/longitudinal georeferencing such that a plant location within a 200 km x 200 km grid square on the earth increases in surface area as slopes increase. In mountainous areas temperatures can also be highly variable depending on the steepness, height and aspect of an elevational gradient. Based on data from an elevational gradient that includes epiphytes and three animal groups, Colwell *et al.* (2008) predicted that range shifts in elevation will be far more common in the tropics than latitudinal shifts, and that though mountaintop extinctions will occur, lower elevation diversity will be maintained as ranges of lowland species move up the slopes. Studies predicting effects of climate change in Taiwan forests by Hsu *et al.* (2012) have shown that epiphytic fern species associated with middle and upper elevations are more sensitive to higher temperatures than lowland species. Pouteau *et al.* (2016) found that fern species diversity and abundance along an elevational gradient are indicators of climate change in Tahiti. Using climate modelling they identified 37 fern species in Tahiti for which models can not locate a future overlapping suitable climate envelope and island endemics there occupy narrow ranges that have the greatest vulnerability to range shrinkage and/or loss (Pouteau *et al.* 2016). Kessler *et al.* (2011) show that fern diversity is lower at high elevations, and that fern richness patterns were related directly (or indirectly through energy availability and ecosystem productivity) to climatic conditions on elevational gradients. In a recent summary of years of work on characteristics of fern diversity along elevation gradients, Kessler *et al.* (2016) noted the need for addressing the paucity of ecological data available on variation in parameters defining the niches of fern species. Without such information, it is impossible to predict or plan for availability of suitable habitat upslope as global temperatures rise.

One area where vegetation change along steep elevation gradients has been directly related to climate change is in the Himalayan alpine flora in the Hengduan mountains of China, an area where temperature increases over at least the past 30 years have been among the highest in the world (Salick 2019). In a 7-yr study of elevational changes in biodiversity Salick *et al.* (2019) found increases in species richness, density and diversity (especially among endemics) that were associated with warmer temperatures, southern aspects and higher elevations. Colonizing plants appear to have come from other alpine areas, where they otherwise may have been lost as the temperatures in their original high mountain habitats increased. Unlike latitudinal temperature gradients, elevational gradients are subject to much more environmental variation such as degree of slope and aspect which makes it more difficult to generalize about climate change effects. Nevertheless, they may provide an alternate route to survival of formerly lowland species, especially in the tropics (Colwell *et al.* 2008).

Improving fern range shift predictions

Accurate delineation of current species ranges is the basis for predicting and planning for climate-driven range shifts. Because so much herbarium data has already been digitized and uploaded onto GBIF it would be advisable to assess the quality of fern data for India. Stropp *et al.* (2016) provide a road map for evaluating the quality of plant occurrence data on GBIF with an analysis of all of the herbarium records with species name, date and collection location for Africa that were on GBIF in October 2012. Starting by performing such a review of Indian herbarium records on GBIF would determine how to prioritize the collection of additional range limit information and illuminate the challenges of analyzing such datasets. Information from these herbarium specimens can also be used for setting a baseline and tracking future trends in climate effects on fern phenology.

Additional historical information can provide a baseline for "natural" species ranges and current observations provide insight into the effects that climate change is having now. Historical records of fern observations with known latitude, longitude and elevation should be searched out and added to major plant occurrence datasets. Early checklists of plants from long-term public or culturally important sites and educational institutions are especially valuable. The authors of floristic works wherein fern species distributions are broadly described may have personal knowledge of more specific latitudinal and/or elevational range boundaries (e.g. West Himalaya: Khullar 1994, 2000). Some of this information may also exist in the field notes of collectors or ecologists, but perhaps has not yet been digitized. Some fern species have been already been declared threatened (Mehltreter 2010) based on criteria unrelated to climate change through efforts to improve the IUCN Red List for ferns (Brummitt *et al.* 2016) and country-wide mapping (e.g. New Zealand: Mountier *et al.* 2018). Organized efforts by the whole fern community could be mobilized to use iNaturalist to input current locations of the distribution of fern species in areas where relatively few observations appear in GBIF. Where digitizing herbarium data is not feasible, field trips to under-reported areas and physically recording georeferenced locations of ferns at range boundaries through Biodiversity Atlas – India activities or using the app iNaturalist also could be implemented. A campaign using iNaturalist to increase the numbers of fern observations by local participants has recently begun in Amazonia (Moulatlet *et al.* 2019) could serve as a model for similar projects elsewhere. Well-illustrated guidebooks (e.g. Sikkim: Kholia, 2010, 2014; South India filmy ferns: Hameed *et al.* 2003) for ferns in all parts of the country, made available online if possible, would enhance the potential for "citizen scientist" participation.

The main objective of describing range boundaries for a species in as much detail as possible and making it digitally available is so that climate-driven models can assess the current climate and other habitat features of a species range and use this information to predict successful range shift possibilities (Hoegh-Gildberg *et al.* IPCC 2018). If suitable habitat for a range extension is identified, the problem then becomes insuring that the species can move to and survive there (Littlefield *et al.* 2019). Barriers to connectivity from a shrinking range to a different but climatically suitable habitat include distance, dispersal limitations, topographic barriers, anthropogenic barriers (Silva *et al.* 2018), obligate community relationships (e.g. epiphyte host plants) etc. and these should be identified in climate-driven range shift models (Littlefield *et al.* 2019). Understanding potential range shift patterns would then enable the implementation of a vulnerability assessment that can predict which species of ferns are most at risk from total loss of current and potential habitat. Fortini *et al.* (2013) provide details on how such a vulnerability assessment is developed and demonstrate how valuable it has been for planning plant conservation efforts on the islands of Hawaii.

Conducting experimental research on the effects of different levels of temperature rise is another important part of understanding the limitations of fern responses to climate change at the ecosystem, population and plant level; some possible approaches are shown in the following examples. 1) Ecosystem temperature manipulation: Temperatures in treatment plots were raised 4°C above control plots in a long-term (5 yrs) rainforest warming experiment (Cavaleri *et al.* 2015; https://www.forestwarming.org/) begun in September 2016 after a year of baseline observations of all layers of the experimental and control plots in a tropical rainforest in Puerto Rico. Herbaceous layer censuses and measurements included the fern *Blechnum occidentale* in the plots, and although after a year of warming there were no significant effects on its cover, density, mortality, size, or fertility (unpublished data) that could change with four more years of warming and observations. 2) Population transplants: Macel *et al.* (2017) conducted a transplant experiment (also possible with fern sporophytes) with a plant (Austrian yellow-cress) that had already exhibited poleward range expansion in Europe. Plants from the new range were always larger, even when planted back into the core range, suggesting an evolved increase in vigor in their new range. 3) Warming effects on gametophytes: Lab experiments have looked at the effects of warmer temperatures on gametophyte growth in six fern species, finding negative effects of high temperatures on the gametophyte size and the success of sporophyte germination of the one rare species in the group (*Asplenium scolopendrium* var. *americanum*: Testo and Watkins 2013). While other factors could contribute to the rarity of this fern species, it is clearly going to be challenged by climate change. Guidelines for studies of spore, gametophyte and sporophyte storage and culture directed at preserving ferns and lycophytes into a future with climate change are being developed (see chapters 7-14 in Fernández *et al.* 2010) while limits of cryopreservation for spores are tested (e.g. *Pteris vittata* > 21 yrs: Ballesteros & Pence 2018). These examples are but a few of the kinds of question-driven studies that need to be done with many different fern species to anticipate the effects of climate warming on a species range and to provide useful information for conservations measures.

PHENOLOGY

Changes from the historical seasonal timing of the individual phases of growth of plants, leaves or reproductive parts of a plant may anticipate a range change. Sensitivity to climate warming has been documented in phenological observations occurring 2.8 ± 0.35 days per decade later in the northern hemisphere, changes that are even visible from satellites (Hoegh-Gildberg *et al.* IPCC 2018). For plants that rely on a specific temperature (rather than daylength or relief from moisture stress) to begin their growing season, such changes may result in significant challenges for a species and have become particularly apparent in the Arctic zone (Oberbauer *et al.*, 2013). As indicators of the effects of climate change on biota, phenological data have become important in predicting species' response to potential range changes and collecting data on animals as well as plants can identify potential trophic mismatches where plants and their associated pollinators or herbivores are no longer seasonally in synch (Hoegh-Gildberg *et al.* IPCC 2018). The same types of technological advances in data collection, storage and analysis that have positioned plant occurrence datasets to make substantial contributions to climate change science have also led to a revolution in the way phenological data is collected and used today. More modern methods for collecting, analyzing and presenting the information in these large datasets are needed as noted throughout a recent book *Phenological research: Methods for environmental and climate change analysis* edited by Hudson and Keatley (2010). A very recent issue of open access articles in the journal *Applications in Plant Science* (https://bsapubs.onlinelibrary.wiley.com/toc/21680450/2019/7/3) is devoted to the "emerging frontiers in phenological research" (Ellwood *et al.* (2019). Phenological data that can be used to inform climate change models can come from a variety of sources: 1) phenology networks of individual observers, webcams, aerial observatories and even satellites as well as digitized and 2) herbarium sheets (Tang *et al.* 2016).

Phenology networks

Real-time phenological observations can now be collected by both professionals and volunteer "citizen scientists" over time and analyzed to elucidate climate change effects on biota. Networks of observers were active and reporting in scientific journals during the mid-1800's, though only a few lasted more than 10 years. A worldwide phenological network associated with agrometeorology stations was established in 1953 and this has evolved into or inspired the growth of networks with diverse goals and methods in many parts of the world (Koch 2010). Standardized definitions of seasonal events in the life of a plant and protocols that are flexible enough for a multitude of plant forms and observers of different backgrounds throughout the world are needed for quality input to climate change predictions (Morellato *et al.* 2010).

For terrestrial observations the nationwide phenology monitoring program in the USA (National Phenology Network (USA-NPN)) was established in 2007 (Denny *et al.* 2014) and has led the way in developing standards for coordinated phenological study. This program has recruited hundreds of volunteers to record their observations of key phases of the annual growth cycle for selected species (currently 968 plants and 376 animals) in order to assess the effects of climate change. They use standardized methods and definitions to ensure quality of the data. Plants experience a series of phenophases (e.g. initial growth, leaves present, flowers present etc.) throughout the active growth period that are unique to each species (Morellato *et al.* 2010). Phenological observations are based on recording the status of various parts of a plants rather alternative systems based on different monitoring criteria such as first flowering date (Elmendorf *et al.* 2016). Phenophase measurement protocols are defined within a systems analysis framework called the Plant Phenology Ontology (PPO) as described by Stucky *et al.* (2018). This set of phenophase definitions relies on a "presence/absence" assessment of a plant or its parts (e.g. true leaves present vs true leaves absent), a system which has been formally adopted by USA-NPN, NEON and a number of other observer networks. Phenophase observations are made by trained volunteers and submitted online. Detailed documentation of data definition, collection and analysis ensure that only high-quality data are entered (Rosemartin *et al.* 2018) and available to the public; maps of the country where changes are shown in real time are displayed at their well-designed website (https://www.usanpn.org/). Unlike the global plant occurrence datasets (e.g. GBIF) that include data on all vascular plants, thus far only gymnosperms and angiosperms have had phenophases defined through the PPO (Stucky *et al.* 2018). Ferns were not included although the USA-NPN network is designed to be open to adding additional species in the future and efforts to establish phenophase definitions for fern reproductive structures (see Lee *et al.* 2018, Huang *et al.* 2019) in accordance with their standards are currently under discussion.

Following the example of the USA-NPN, similar terrestrial networks of volunteers have been started elsewhere (e.g. United Kingdom : https://naturescalendar.woodlandtrust.org.uk/). SeasonWatch has also been established in India (https://www.seasonwatch.in). This project, which enlists the participation of various schools in India focusses only on trees, with all data and training materials available online including a very clear handbook with data collection methods and images of phenophases for each tree (Quader *et al.* 2012). It should be noted that citizen science data benefits from quality assessments to insure credibility of the information (Freitag *et al.* 2016). The USA National Ecological Observatory Network (NEON) will also be making phenological observations as well as collecting data on plant occurrences for at least 30 years and are located in areas of little disturbance and with supplemental air surveillance. Trained technicians will make regular observations of marked individuals of selected species of plants and have chosen to use monitoring protocols and phenophase definitions developed by the USA-NPN (Elmendorf *et al.* 2016).

Tang *et al.* (2016) describe a "network of networks" as the ideal integrative, cross-scale measurement and modelling approach to phenology worldwide. They espouse using the various research units of the International LTER (ILTER) network of research programs to simultaneously explore a number of lines of phenological research to obtain much needed species level data on for climate-driven models. They recommend remote sensing at the global and regional level, stand (plot) based observations with cameras and spectro-radiometers, and manual observations of plants, leaves and reproductive organs to monitor phenophases. In concert with monitoring activities Tang *et al*. (2016) also recommend establishing much needed experiments to assess the roles of climate (temperature, photoperiod and winter chilling), resources (water, nutrient, light) and genetics and evolution on species phenological patterns. Researchers making direct observations in biological science, geoscience, micrometeorology and ecophysiology have a history of working separately but much more could be accomplished if these four elements of climate change research data collections co-located their observing apparatus and collaborated worldwide (Richter 2018), especially considering the urgency of a rapidly warming climate situation.

Integrating phenological data collected from such a variety of sources worldwide is also critical. A Global Plant Phenology knowledge base (https://www.plantphenology.org/) has begun to address this need (Brenskelle *et al.* 2019). It currently uses a table of present/ absence phenophases including those developed by USA-NPN. Models that predict plant responses to climate change worldwide will only succeed when plant phenological data collected from a variety of sources and in a variety of formats can be described through a rigorously developed set of standardized definitions (Brenskelle *et al*. 2019).

Phenology data from herbarium specimens

Herbarium specimen collectors record the date of their collection, but rarely any information about the seasons. Furthermore, the emphasis is on collecting mature leaves from adult plants with reproductive structures present. However, the reproductive status of the plant may be inferred from a careful review of the plant specimen itself (MacGillivray *et al*. 2010). Methods for gleaning phenological information have recently be developed that cut down on the time and effort involved once specimens are digitized and Willis *et al.* (2017) note that flowering phenophases are most often related to climate change. Lorieul *et al*. (2019) describe a technique for detecting the presence of reproductive structures from digitized specimens with reproductive structures present. The detection rate for ferns was 95.7%, only slightly lower than 96.3% for flowering plants for a herbarium collection that included ferns (~9% of the specimens tested) and that not only included label information but also images of the specimens. The high success rate for detecting reproductive material on fern specimens may be related to the consistency with which fern collectors have adhered to guidelines to 1) include reproductive leaf material in a specimen collection and 2) ensure that at least part of a spore-bearing leaf has been oriented to show the reproductive structures when pressing the plant material. MacGillivray *et al.* (2010) note that the period of reproduction based on herbarium specimen observations may appear to be shorter and start later than in observer studies as collection dates may not generally coincide with the first appearance of reproductive structures. Interpreters of phenological information from herbarium specimens must also account for temporal biases such as collecting only when the necessary taxonomic characters are visible (Willis *et al.* 2017) though studies comparing observational and herbarium dates found first flowering dates to be only 3 days later in herbarium data (Davis *et al.* 2015). If this is a consistent pattern, year-to-year differences will still be meaningful in assessing climate change impacts.

Fern phenology initiatives

The need for more standardization and geographic diversity in fern phenological studies has been recommended by both Mehlteter (2008) and Lee *et al.* (2018) in their reviews of the field. Although standardized phenophases have been developed that can be applied to fern leaves (e.g. initiation, expanding, senescence) , phenophase definitions for fern sporophyte reproductive structures are needed. Although the number of fern species is limited in the USA where the USA-NPN project was funded, the network's protocols are going worldwide and will serve multiple types of plant phenological data from multiple sources (Brenskelle *et al.* 2019). Observations of phenophases of fern reproductive organs such as spore leaf emergence and senescence (see de Pavia *et al.* 2018 for review) and additionally spore maturity and release (e.g. Lee *et al.* 2016, Huang *et al.* 2019) have appeared in the fern phenology literature. Adding phenophases and protocols for selected ferns to those plant species currently monitored through the Global Plant Phenology knowledge base (https://www.plantphenology.org/) could contribute unique insights into climate effects on phenology. Ferns comprise a higher percentage of plant biodiversity in the tropics as well as in the already threatened Pacific islands (Pouteau 2016) and are abundant in the herbaceous layer in temperate forested ecosystems (George and Bazzaz 1992). Trophic level phenological mismatches do not complicate predictions of range shift success as ferns have no need for pollinators and experience limited herbivory in their current ranges (although it will be important to detect and predict the effects of possible unsynchronized differences with ranges shifts in the canopy above terrestrial ferns or the host plants of epiphytic ferns).

Establishing standardized protocols for observing phenophases in ferns would also increase the chances of ferns being included in observations networks (e.g. NEON) and perhaps a collaboration with SeasonWatch, now oriented toward trees in India, could be pursued. Using their data collection protocols and converting their captivating and informative species descriptions (Quader *et al.* 2010) for use with ferns could be a next step in accumulating fern phenology data from citizen scientists in India. A program of periodic observations of phenophase dates of a select set of fern species with widespread distribution could perhaps then be coordinated among members of the Indian Fern Society either independently or through a program like SeasonWatch. As more and more herbarium specimens of Indian ferns are digitized and added to GBIF, research projects that use current technology and modelling techniques for analyzing the phenological information available from specimens could also become a priority of established research institutions with long-term datasets and an interest in ferns. Fern studies at long-term research sites could also increase their impact on global climate predictions through membership in networks and collaboration with programs such as ILTER and worldwide environmental observation networks (EONs: Lindenmayer *et al.* 2018).

Fern phenophases of at least 225 species have been reported to date (Lee *et al.* 2018) these data are summarized in published phenological studies (e.g. recent work by Punetha *et al.* 2018, de Pavia Farias *et al.* 2018, Lee *et al.* 2016). Temporal trends are identified from summary graphs of means with relevant time intervals (weeks, mos., seasons, yrs.) that could be visually or quantitatively compared to graphs of temperature, precipitation and humidity levels. When published (or submitted in a thesis (e.g. Monge Gonzáles 2007)), original data has been retained by the researcher unless required by a journal or NSF to be deposited in a public database. No one anticipated the need to document phenological responses to rapid changes in habitat temperatures on a global scale. Reassessing those data, georeferencing and reframing them in a standard fern phenophase format, collaborating on a global climate-based comparison and then depositing them in a public digital database would establish a baseline for revisiting the original sites to evaluate climate change effects. It would also ensure that more fern data are available in public databases that are mined for species data for climate-change modelling research. When authors of fern journal articles submit supporting data to a data repository, it can be reframed again and again (with the author's permission if possible) to answer different questions as the need arises, as it has with climate change. Examples of temporal fern studies that are based on publicly available data are annual leaf count observations (3 years) from Ecuador (Kessler *et al.* 2014, Dryad Digital Repository (https://datadryad.org/resource/doi:10.5061/dryad.sj4q1)) and seasonal and annual leaf counts (~20 yrs, including spore leaves) from Puerto Rico (Sharpe, 1997 Luquillo LTER Data Catalog (https://luq.lter.network/data/luqmetadata75)).

SUMMARY AND CONCLUSIONS

Climate change should be the primary focus of fern research in the future because of the high levels of anticipated range losses for plants in light of current warming trends that could result in a world that a 3-4°C warmer than preindustrial levels by the year 2100 (Masson-Delmotte *et al.* IPCC 2018). Unless steps are taken to reduce those levels to well below 1.5°C, the effect on biota, both marine and terrestrial, will be catastrophic (Hoegh-Gildberg *et al.* IPCC 2018). Although climate change predictions that will inform policy are beginning to address the complexity of exploring potential scenarios, they are lacking in basic species level information of many groups of organisms including ferns. Both technical and non-technical limitations are preventing the accession of much needed data on fern species ranges and phenology into the mega datasets that drive climate-change prediction models. Some of these data already exist just not in a digitized accessible form, and future observations and research will need to fill in the rest.

Research goals for some fern ecologists could change : floristics becomes a study of not just of current ranges, but potential future ranges; biogeography becomes a study not just of why plants are where they are, but of where they may be in the future; phenology becomes the study of identifying today's temporal trends as well as connecting past and future patterns of seasonality in an uncertain future. Taking steps to identify safe locations for ferns in botanical gardens and other research sites should become a priority as ranges shrink and conductivity is lost. Research and experiments are needed to focus on currently threatened fern species to assess the climate requisites for spore germination and growth of fern gametophytes and sporophytes.

Climate change is happening. Keeping tabs on the work of the IPCC and its committees is essential. Translating their results and studies into a new perspective on what kind of work needs to be done to ensure the maintenance of the unique features of an area (or country)'s fern diversity, and within what time frame this work needs to be done is essential. Establishing the vulnerability of ferns and their habitats and making plans for where they will go in the future is mandatory. Cooperation and economies of scale will become even more important as the magnitude of a worldwide (rather than regional or local) environmental crisis is precipitated by climate change. Ferns can provide a unique perspective on climate change, but not unless the data are out there. The time to redirect the field of fern ecology toward active participation in populating big datasets with fern observations while inviting participation from the public is NOW.

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REFERENCES

BALLESTEROS D & V C PENCE 2018 Fern conservation : Spore, gametophyte & sporophyte *ex situ* storage, *in vitro* culture and cryopreservation. In *Current Advances in Fern Research* Ed H Fernández. Publisher : Springer International Publishing, Cham, Switzerland Pp 227-250

BESNARD G, M GAUDEUL, S LAVERGNE, S MULLER, G ROUHAN, A P SUKHORUKOV, A VANDERPOORTEN & F JABBOUR 2018 Herbarium-based science in the twenty-first century *Botany Letters* **165** : 323-327 (https://www.tandfonline.com/doi/full/310.1080/23818107.23812018.21482783).

BRENSKELLE L, B J STUCKY, J DECK, R L WALLS & R P GURALNICK 2019 Integrating herbarium specimen observations into global phenology data systems *Appl Plant Sci* **7** : e1231 (https://bsapubs.onlinelibrary.wiley.com/doi/1210.1002/aps1233.1231)

BRUMMITT N, E ALETRARI, M M SYFERT & M MULLIGAN 2016 Where are threatened ferns found? Global conservation priorities for pteridophytes *J Syst Evol* **54** : 604-616

CAVALERI M A, S C REED, W K SMITH & T E WOOD 2015 Urgent need for warming experiments in tropical forests *Glob Change Biol* **21** : 2111-2121 (https://onlinelibrary.wiley.com/doi/epdf/2110.1111/gcb.12860)

CHEN I-C, J K HILL, R OHLEMÜLLER, D B ROY & C D THOMAS 2011 Rapid range shifts of species associated with high levels of climate warming *Science* **333** : 1024-1026

COLWELL R K, G BREHM, C CARDELÚS, A C GILMAN & J T LONGINO 2008 Global warming, elevational range shifts & lowland biotic attrition in the wet tropics *Science* **322** : 258-261

DARU B H, D S PARK, R B PRIMACK, C G WILLIS, D S BARRINGTON, T J S WHITFIELD, T SEIDLER, P W SWEENEY, D R FOSTER, A M ELLISON & C C DAVIS 2018 Widespread sampling biases in herbaria revealed from large-scale digitization *New Phytol* **217** : 939-955 (https://nph.onlinelibrary.wiley.com/doi/pdf/910.1111/nph.14855)

DAVIS C C, C G WILLIS, B CONNOLLY, C KELLY & A M ELLISON 2015 Herbarium records are reliable sources of phenological change driven by climate and provide novel insights into species phenological cueing mechanisms *Amer J Bot* **102** : 1599-1609 (https://bsapubs.onlinelibrary.wiley.com/doi/full/1510.3732/ajb.1500237)

DE PAIVA FARIAS R, L E N DA COSTA, I C L BARROS & K MEHLTRETER 2018 Leaf phenology of *Danaea geniculata* (Marattiaceae) in a submontane tropical forest, Brazil *Amer Fern J* **108** : 35-46

DENNY E G, K L GERST, A J MILLER-RUSHING, G L TIERNEY, T M CRIMMINS, C A F ENQUIST, P GUERTIN, A H ROSEMARTIN, M D SCHWARTZ, K A THOMAS & J F WELTZIN 2014 Standardized phenology monitoring methods to track plant and animal activity for science and resource management applications *Int J Biometeorol* **58** : 591-601 (https://www.usanpn.org/files/shared/files/Standardized%520phenology%520monitoring%520methods%520Denny%520et%520al%202014.pdf

ELLWOOD E R, P KIMBERLY, R GURALNICK, P FLEMONS, K LOVE, S ELLIS, J M ALLEN, J H BEST, R CARDER, S CHAGNOUX, R COSTELLO, M W DENSLOW, B A DUNCKEL, R LAFRANCE, J L MARTINEC, A N MILLER, J MINNAERT-GROTE, T NATH, P OBOYSKI, D L PAUL, K D PEARSON, N D PENTCHEFF, M A ROBERTS, C E SELTZER, P S SOLTIS, R STEPHENS, P W SWEENEY, M VON KONRAT, A WALL, R WETZER, C ZIMMERMAN & A R MAST 2018 Worldwide engagement for digitizing biocollections (WeDigBio): The biocollections community's citizen-science space on the calendar *BioScience* **68** : 112-124 (https://academic.oup.com/bioscience/article/168/112/112/4797259)

ELLWOOD E R, K D PEARSON & G NELSON 2019 Emerging frontiers in phenological research *Appl Plant Sci* **7** : e1234 (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6426156/pdf/APS3-7-e01234.pdf)

ELMENDORF S C, K D JONES, B J COOK, J M DIEZ, C A F ENQUIST, R A HUFFT, M O JONES, S J MAZER, A J MILLER-RUSHING, D J P MOORE, M E SCHWARTZ & J F WELTZIN 2016 The plant phenology monitoring design for The National Ecological Observatory Network *Ecosphere* **7** : e01303 (https://esajournals.onlinelibrary.wiley.com/doi/01310.01002/ecs01302.01303)

FERNÁNDEZ H, A KUMAR & M A REVILLA 2010 *Working with ferns : Issues and applications* Springer, New York

FORTINI L, J PRICE, J JACOB, A VORSINI, J BURGETT, K BRINCK, F AMIDON, S MILLER, S 'OHUKANI' OHI' A GON III, G KOOB & E PAXTON 2013 A landscape-based assessment of climate change vulnerability for all native Hawaiian plants. Hawai'i Cooperative Studies Unit, University of Hawai'i at Hilo, Hilo HI USA pp 134 (https://hilo.hawaii.edu/hcsu/documents/TR44_Fortini_plant_vulnerability_assessment.pdf)

FRASER-JENKINS C R, K N GANDHI, B S KHOLIA & A BENNIAMIN 2017 *An Annotated Checklist of Indian Pteridophytes Part 1 : Lycopodiaceae to Thelypteridaceae* Bishen Singh Mahendra Pal Singh Dehra Dun, India

FRASER-JENKINS C R, K N GANDHI, B S KHOLIAK & A BENNIAMIN 2018 *An Annotated Checklist of Indian Pteridophytes, Part 2 : Woodsiaceae to Dryopteridaceae* Bishen Singh Mahendra Pal Singh Dehra Dun, India

FREITAG A, R MEYER & L WHITEMAN 2016 Strategies employed by citizen science programs to increase the credibility of their data *Citizen Science : Theory and Practice* **1** : 1-11 (http://dx.doi.org/10.5334/cstp.5336)

GEORGE L O & F A BAZZAZ 2012 The herbaceous layer as a filter determining spatial pattern in forest tree regeneration. In *The herbaceous layer in forests of eastern North America Second Edition* Ed F S Gilliam Publisher : Oxford University Press, New York Pp 340-355

GIBSON-REINEMER D K & F J RAHEL 2015 Inconsistent range shifts within species highlight idiosyncratic responses to climate warming *PLoS ONE* **10** : (https://journals.plos.org/plosone/article/file?id=10.1371/journal.pone.0132103&type=printable)

HAMEED C A, K P RAJESH & P V MADHUSOODANAN 2003 *Filmy ferns of South India* Penta Book Publishers & Distributors Calicut, India

HARRIS N L, A E LUGO, S BROWN & T HEARTSILL SCALLEY 2012 *Luquillo Experimental Forest : Research history and opportunities* USDA Forest Service

HESSLER M & B SCHMITT 2019 *Checklist of ferns and lycophytes of the world* With special support from Ralf Knapp (https://worldplants.webarchiv.kit.edu/ferns/)

HOEGH-GILDBERG O, D JACOB, M TAYLOR, M BINDI, S BROWN, I CAMILLONI, A DIEDHIOU, R DJALANTE, K L EBI, F ENGELBRECHT, J GUIOT, Y HIJOKA, S MEHROTRA, A PAYNE, S I SENEVIRANTNE, A THOMAS, R WARREN & G ZHOU IPCC 2018 Impacts of 1.5°C of global warming on natural and human systems. In *An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development & efforts to eradicate poverty*. Eds V Masson-Delmotte, P Zhai, H O Pörtner, D Roberts, J Skea, P R Shukla, A RPirani, W Moufouma-Okia, C Péan, R Pidcock, S Connors, J B R Matthews, Y Chen, X Zhou, M I Gomis, E Lonnoy, T Maycock, M Tignor & T Waterfield (https://www.ipcc.ch/sr15/chapter/chapter-3/)

HSU R C-C, W L M TAMIS, N RAES, G R DE SNOO, J H D WOLF, G OOSTERMEIJER & S-H LIN 2012 Simulating climate change impacts on forests and associated vascular epiphytes in a subtropical island of East Asia. *Divers and Distrib* **18** : 334-347 (https://onlinelibrary.wiley.com/doi/epdf/310.1111/j.1472-4642.2011.00819.x)

HUANG Y-M, P-H LEE & W L CHIOU 2019 Phenology and leaf lifespan of an endangered fern *Angiopteris somae* (Marattiaceae) *Indian Fern J* **36** : xx-xx

HUDSON I L & M R KEATLEY 2010 *Phenological Research : Methods for environmental and climate change analysis* Dordrecht Springer

IPPC 2014 *Climate Change 2014 : Synthesis Report Contributions of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* Eds Core Writing Team, R K Pachauri and L A Meyer IPPC, Geneva, Switzerland

KESSLER M, J KLUGE, A HEMP & R OHLEMÜLLER 2011 A global comparative analysis of elevational species richness patterns of ferns *Glob Ecol Biogeogr* **20** : 868-880

KESSLER M, L SALAZAR, J HOMEIER & J KLUGE 2014 Species richness-productivity relationships of tropical terrestrial ferns at regional and local scales *J Ecol* **102** : 1623-1633 (https://besjournals.onlinelibrary.wiley.com/doi/1610.1111/1365-2745.12299)

KESSLER M, D N KARGER & J KLUGE 2016 Elevational diversity patterns as an example for evolutionary and ecological dynamics in ferns and lycophytes *J Syst and Evol* **54** : 617-625

KHOLIA B S 2010 *Ferns and Fern-allies of Sikkim - A Pictorial Handbook Part-I* Department of Forests, Environment, Wildlife Management, Government of Sikkim and Botanical Survey of India, Gangtok India

KHOLIA B S 2014 *Ferns and Fern-allies of Sikkim Himalaya - A Pictorial Handbook. Part-II* Department of Forests, Environment, Wildlife Management, Government of Sikkim and Botanical Survey of India, Gangtok India

KHULLAR S P 1994 *An illustrated fern flora of the West Himalaya, Volume I* International Book Distributors, Dehra Dun India

KHULLAR S P 2000 *An illustrated fern flora of the West Himalaya, Volume II* International Book Distributors, Dehra Dun India

KOCH E 2010 Global framework for data collection – data bases, data availability, future networks, online databases. In *Phenological Research* Eds I L Hudson and M R Keatley. Publishers : Springer, Dordrecht Pp 23-61

LEE P H, S W CHEN, W L CHIOU, Y M HUANG & H Y LIU 2016 Phenology of 13 fern species in a tropical monsoon forest of southern Taiwan *Int J Plant Reproductive Biol* **8** : 87-97 (http://www.ijprb.com/vol%2008%2020(2001)/pdf%2011.pdf)

LEE P H, Y M HUANG & W L CHIOU 2018 Fern phenology. In *Current Advances in Fern Research* Ed H Fernández. Publishers : Springer International Publishing, Cham, Switzerland Pp 381-400

LINDENMAYER D B, G E LIKENS & J F FRANKLIN 2018 Earth observation networks (EONs) : Finding the right balance *Trends Ecol Evol* **33** : 1-3

LITTLEFIELD C E, M KROSBY, J I MICHALAK & J J LAWLER 2019 Connectivity for species on the move : Supporting climate-driven range shifts *Front Ecol Environ* **17** : 270-278

LORIEUL T, K D PEARSON, E R ELLWOOD, H GOËAU, J F MOLINO, P W SWEENEY, J M YOST, J SACHS, E MATA-MONTERO, G NELSON, P S SOLTIS, P BONNET & A JOLY 2019 Toward a large-scale and deep phenological stage annotation of herbarium specimens : Case studies from temperate, tropical and equatorial floras *Appl Plant Sci* **7** : e1233 : (https://bsapubs.onlinelibrary.wiley.com/doi/epdf/10.1002/aps3.1233)

MACEL M, T DOSTÁLEK, S ESCH, A BUCHAROVÁ, N M VAN DAM, K TIELBÖRGER, K J F VERHOEVEN & Z MÜNZBERGOVÁ 2017 Evolutionary responses to climate change in a range expanding plant *Oecologia* **184** : 553-554 (https://link.springer.com/article/510.1007/s00442-00017-03864-x)

MACGILLIVRAY F, I L HUDSON & A J LOWE 2010 Herbarium collections and photographic images : Alternative data sources for phenological research. In *Phenological research : Methods for environmental and climate change analysis* Eds I L Hudson and M R Keatley Publishers : Springer, New York Pp 425-461

MASSON-DELMOTTE V, P ZHAI, H O PÖRTNER, D ROBERTS, J SKEA, P R SHUKLA, A RPIRANI, W MOUFOUMA-OKIA, C PÉAN, R PIDCOCK, S CONNORS, J B R MATTHEWS, Y CHEN, X ZHOU, M I GOMIS, E LONNOY, T MAYCOCK, M TIGNOR & T WATERFIELD, Eds IPCC 2018 Summary for Policymakers. In *An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change,* *sustainable development & efforts to eradicate poverty*. Publishers : World Meteorological Organization, Geneva, Switzerland pp 32 (https://www.ipcc.ch/sr15/chapter/summary-for-policy-makers/)

MEHLTRETER K 2008 Phenology and habitat specificity of tropical ferns. In *Biology and Evolution of Ferns and Lycophytes* Eds T A Ranker & C H Haufler Publishers : Cambridge University Press, Cambridge UK Pp 203-223

MEHLTRETER K 2010 Fern conservation In [eds], *Fern Ecology* Eds K Mehltreter, L R Walker & J S Sharpe Publishers : Cambridge University Press, Cambridge UK Pp 323-359

MICKEL J T & A R SMITH 2004 The Pteridophytes of Mexico *Mem N Y Bot Gard* **88** : 1-1054

MONGE GONZÁLEZ M L 2007 Fenologia de tres especies de helechos epifitos sobre dos grupos de hospederos en Las Canadas, Huatusco, Veracruz, Universidad Veracruzana, Xalapa. Veracruz, Mexico Thesis

MORELLATO L P C, M G G CAMARGO, F F D'EÇA NEVES, B G LUIZE, A MANTOVANI & I L HUDSON 2010 The influence of sampling, method, sample size & frequency of observations on plant phenological patterns and interpretation in tropical forest trees. In *Phenological research : Methods for environmental and climate change analysis* Eds I L Hudson and M R Keatley Publishers : Springer, New York Pp 99-121

MOULATLET G M, G ZUQUIM & H TUOMISTO 2019 The role of soils for pteridophyte distribution in tropical American forests *Fern Gaz* **21** : 1-20

MOUNTIER C F, B S CASE, L R PERRIE, P BROWNSEY, A M PATERSON, T J CURRAN & H L BUCKLEY 2018 Patterns of range size in New Zealand ferns and lycophytes *N Z J Bot* **42** : 248-261

OBERBAUER S F, S C ELMENDORF, T G TROXLER, R D HOLLISTER, A V ROCHA, M S BRET-HARTE, M A DAWES, A M FOSAA, G H R HENRY, T T HØYE, F C JARRAD, I S JÓNSDÓTTIR, K KLANDERUD, J A KLEIN, U MOLAU, C RIXEN, N M SCHMIDT, G R SHAVER, R T SLIDER, Ø TOTLAND, C H WHAREN & J M WELKER 2013 Phenological response of tundra plants to background climate variation tested using the International Tundra Experiment *Philos Trans R Soc B* **368** : 20120481 (http://dx.doi.org/20120410.20121098/rstb.20122012.20120481)

POUTEAU R, J Y MAEYER, P BLANCHARD, J H NITTA, M TEROROTUA & R TAPUTUARAL 2016 Fern species richness and abundance are indicators of climate change on high-elevation islands : Evidence from an elevational gradient on Tahiti (French Polynesia) *Clim Change* **138** : 143-156

PTERIDOPHYTE PHYLOGENY GROUP P P G I 2016 A community-derived classification for extant lycophytes and ferns *J Syst Evol* **54** : 563-603

PUNETHA N, J N PANT, R PUNETHA & K BHAKUNI 2018 Phenology of a temperate fern *Dryopteris wallichiana* (Sprng) Hyl (Dryopteridaceae) in Uttarakhand India *Curr Sci* **115** : 1805-1809

QUADER S, S SRREDHARAN, A ELASSERY, R KUMAR, A SHETTY, P SANKARAN & S ROY 2012 *SeasonWatch Handbook : The Calendar of Nature ; Tracking seasons through trees with SeasonWatch* SeasonWatch, Bangalore India

RAJAGOPAL P K 2018 Western Ghats and pteridophytes *Indian Fern J* **35** : 15-22

RANA S K & G S ROWAT 2017 Data Base of the Vascular Plants of the Himalaya. In GBIF Wildlife Institute of India (https://www.gbif.org/dataset/0bddc88d-8586-4889-9340-4a86eb63abe4)

RICHTER D D, S A BILLINGS, P M GROFFMAN, E F KELLEY, K A LOHSE, W H MCDOWELL, T S WHIE, S ANDERSON, D D BALDOCCHI, S BANWART, S BRANTLEY, J J BRAUN,

Z S BRECHEISEN, C W COOK, H E HARTNETT, S E HOBBIE, J GALLARDET, E JOBBAGY, H F JUNGKUNST, C E KAZANSKI, J KRISHNASWAMY, D MARKEWITZ, K O'NEILL, C S RIEBE, P SCHROEDER, C SIEBE, W L SILVER, A THOMPSON, A VERHOEF & G ZHANG 2018 Ideas and perspectives : Strengthening the biogeosciences in environmental research networks *Biogeosciences* **15** : 4815-4832 (https://doi.org/4810.5194/bg-4815-4815-2018)

ROSEMARTIN A H, E G DENNY, K L GERST, R L MARSH, E E POSTHUMUS, T M CRIMMINS & J F WELTZIN 2018 *USA National Phenology Network observational data documentation* US Department of the Interior, US Geological Survey, Reston, Virginia (https://pubs.usgs.gov/of/2018/1060/ofr20181060.pdf)

SABA V S, S M GRIFFIES, W G ANDERSON, M WINTON, M S ALEXANDER, T L DELWORTH, J A HARE, M J HARRISON, A ROSATI, G A VECCHI & R ZHANG 2016 Enhanced warming of the Northwest Atlantic Ocean under climate change *J Geophys Res Oceans* **121** : 118-132 (https://agupubs.onlinelibrary.wiley.com/doi/pdf/110.1002/2015JC011346)

SALICK J, Z FANG & R HART 2019 Rapid changes in eastern Himalayan alpine flora with climate change *Amer J Bot* **106** : 520-530

SEDDON A W R, M MACIAS-FAURIA, P R LONG, D BENZ & K J WILLIS 2016 Sensitivity of global terrestrial ecosystems to climate variability *Nature* **531** : 229-231

SHARPE J M 1997 Leaf growth and demography of the rheophytic fern *Thelypteris angustifolia* (Willdenow) Proctor in a Puerto Rican rainforest *Plant Ecol* **130** : 203-212

SILVA V L, I T MALLMANN, V GRAEFF, J L SCHMITT & K MEHLTRETER 2018 Phytosociological contrast of ferns and lycophytes from forest fragments with different surrounding matrices in southern Brazil *Braz J Biol* **79** : 495-504 (http://www.scielo.br/pdf/bjb/v479n493/1519-6984-bjb-1519-6984186077.pdf)

ŠÍMOVÁ I, C VIOLLE, J C SVENNING, J KATTGE, K ENGEMANN, B SANDEL, R K PEET, S K WISER, B BLONDER, B J MCGILL, B BOYLE, N MORUETA-HOLME, N J KRAFT, P M VAN BODEGOM, A G GUTIÉRREZ, M BAHN, W A OZINGA, A TÖSZÖGYOVÁ & B J ENQUIST 2018 Spatial patterns and climate relationships of major plant traits in the New World differ between woody and herbaceous species *J Biogeogr* **45** : 895-916 (https://onlinelibrary.wiley.com/doi/full/10.1111/jbi.13171)

SORIA-AUZA R, M KESSLER, K BACH, P BARAJAS-BARBOSA, M LEHNERT, S K HERZOG & J BÖHNER 2010 Impact of the quality of climate models for modelling species occurrences in countries with poor climatic documentation : A case study from Bolivia *Ecol Modell* **221** : 1221-1229

STROPP J, R J LADLE, A C M MALHADO, J HORTAL, J GAFFURI, W H TEMPERLEY, J O SCØIEN & P MAYAUX 2016 Mapping ignorance : 300 years of collecting flowering plants in Africa *Glob Ecol Biogeogr* **25** : 1085-1096 (https://onlinelibrary.wiley.com/doi/epdf/10.1111/geb.12468)

STUCKY B J, R GURALNICK, J DECK, E G DENNY, K BOLMGREN & R L WALLS 2018 The plant phenology ontology : A new informatics resource for large-scale integration of plant phenology data *Front Plant Sci* **9** : 1-12 (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5938398/pdf/fpls-5938309-5900517.pdf)

TANG J & C KÖRNER 2016 Emerging opportunities and challenges in phenology : A review *Ecosphere* **7(8)** Article e01436 : 1-17 (https://esajournals.onlinelibrary.wiley.com/doi/pdf/10.1002/ecs1002.1436)

TESTO W L & J E J WATKINS 2013 Understanding mechanisms of rarity in pteridophytes :

Competition and climate change threaten the rare fern *Asplenium scolopendrium* var *americanum* (Aspleniaceae) *Amer J Bot* **100** : 2261-2270 (https://bsapubs.onlinelibrary.wiley.com/doi/pdf/2210.3732/ajb.1300150)

THIERS B 2019 (and continually updated) *Index Herbariorum* (http://sweetgum.nybg.org/science/ih/herbarium-list/?AddPhysCountry=India)

THORPE A S, D T BARNETT, S C ELMENDORF, E L S HINKLEY, D HOEKMAN, K D JONES, K E LEVAN, C L MEIER, L F STANISH & K M THIBAULT 2016 Introduction to the sampling designs of the National Observatory Network Terrestrial Observation System *Ecosphere* **7** : 1-11 (https://esajournals.onlinelibrary.wiley.com/doi/pdf/10.1002/ecs1002.1627)

VERMA S C 2018 Global warming and pteridophyte biodiversity : Threats and issues. In "National Symposium on Pteridological Studies in India: Perspectives and Modern Approaches in Relation to Environment and Climate Change" Eds S C Verma *et al*. Publisher : Director, Botanical Survey of India, Itanagar Arunachal Pradesh, India Pp 3-5

WARREN R, J PRICE, E GRAHAN, N FORSTENHAEUSLER & J VANDERWAL 2018 The projected effect on insects, vertebrates and plants of limiting global warming to 1.5°C rather than 2°C *Science* **360** : 791-795 (https://science.sciencemag.org/content/360/6390/6791/tab-pdf)

WILLIS C G, E R ELLWOOD, R B PRIMACK, C C DAVIS, K D PEARSON, A S GALLINAT, J M YOST, G NELSON, S J MAZER, N L ROSSINGTON, T H SPARKS & P SOLTIS 2017 Old plants, new tricks : Phenological research using herbarium specimens *Trends Ecol Evol* **31** : 531-546

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MEIOTIC ABNORMALITIES AND B-CHROMOSOMES IN *DRYOPTERIS NIGROPALEACEA* FRASER-JENKINS FROM JAMMU

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ABSTRACT

Dryopteris nigropaleacea Fraser-Jenkins was selected to study its detailed meiotic behaviour because of prevalence of apomixis, hybridization and polyploidy in the genus *Dryopteris*. Plants were collected from 18 localities of Jammu for evaluation of its cytological status. Chromosome counts revealed the existence of diploid sexual ($2n$ = 82) as reported by previous workers. However, meiotic irregularities such as chromosome stickiness, unoriented bivalents, laggards, bridges, formation of micronuclei leading to spore sterility were investigated for the first time. B chromosomes were also present in few SMCs.

Key Words : *Dryopteris,* Diploid, Abnormality, B-Chromosomes, Jammu

INTRODUCTION

The genus *Dryopteris* belongs to family Dryopteridaceae, comprising 250 species with distribution in the Americas, Europe, Africa, and the Pacific islands, with the highest species diversity in eastern Asia (Sessa *et al.* 2017). In India, Himalayas are an important centre of distribution of the *Dryopteris* species (Mehra & Loyal 1965). Hybridization and polyploidization play an important role in their evolution, resulting in vague delimitation of species in closely related taxa (Werth & Windham 1991).

Fronds and rhizomes of different species are used as vermifuge, rheumatism, epilepsy, body cooling, sciatica, analgesic, antibacterial, antiviral, anti-inflammatory, uterine bleeding, mumps and skin problems (Sureshkumar *et al.* 2018). Bioactive constituents and ethnomedicinal studies on *D. nigropaleacea* has not been done yet. Earlier it was studied by workers as *D. odontoloma* but it was identified as *D. nigropaleacea* later through taxonomic observations by C. R Fraser-Jenkins (1982). The rhizomes of *D. odontoloma* were found to be active against *Mycobacterium phlei*, *Salmonella typhi* and *Vibrio cholera* (Banerjee & Sen 1980). People of Deoprayag area of Garhwal area of Uttarakhand use young crosiers as vegetable or pickle (Gaur & Bhat 1994).

During our endeavour of cytomorphological reassessment of medicinal ferns from Jammu, we recorded diploid population of *D. nigropaleacea*. In this study, chromosome number and meiotic behavior of 18 populations collected from different localities of Jammu are presented.

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MATERIALS AND METHODS

Plants of *D. nigropaleacea* were collected from 18 localities of Jammu during monsoons (July to September). Voucher specimens were deposited at the Herbarium, Department of Botany, Punjabi University, Patiala, India (PUN). To obtain spore mother cells (SMCs) undergoing meiosis, fronds with young sporangia were fixed in Carnoy's fixative (ethanol: chloroform: glacial acetic acid, 6:3:1 v/v) for 24 h at room temperature and then transferred to 70% ethanol and stored under refrigeration until use. To study meiotic course, SMCs are squashed in 1% acetocarmine. To study chromosome number and meiotic abnormalities, slides were properly analyzed from different localities. The mode of reproduction was confirmed by counting number of spores per sporangia. Observations on number of spores per sporangium were made following procedure of Huang *et al*. (2011). Photomicrographs were taken from temporary slides with a Magnus MLX Plus photomicrography system (Olympus).

RESULTS

Dryopteris nigropaleacea Fraser-Jenkins can be found growing on small stream banks, within altitudinal range of 1600-2800m, distributed frequently in Afghanistan, Bhutan, Nepal, Pakistan and India. Rhizomes are ascending, long and scaly. Fronds are tufted, monomorphic and deciduous. Stipes are stramineous, up to 20 cm long, base scaly and fibrillose, scales are long, ovate-lanceolate, apex acuminate, black-brown to blackish, glossy, rapidly becoming scattered higher up the stipe, smaller and narrower, rachis is stramineous nearly glabrous except for small, scattered, narrow, paler ones. Lamina 2-pinnate, elongated triangular-lanceolate, ca. up to 48 cm long and 17 cm broad, base truncate, apex acute, crispaceous in texture, lower surface glaucous, upper surface blue-green, matt, glabrous, pinnae are up to ca. 20 pairs, 11 cm long and 3.5 cm broad, contiguous, alternate, petiolate, elongated triangular-lanceolate, apex acute to acuminate, middle pair largest, pinnulate, pinnules many, ca. 15 pairs, 2 cm long, 0.7 cm broad, alternate, basal shortly petiolate, upper adnate, somewhat long, narrow, elliptical-oblong, falcate, basiscopic pinnules elongate than acroscopic ones, apex rounded, margin unlobed to deeply lobed, lobes up to 7 pairs, narrow, rectangular, pinnule (lobes) apices usually rounded, sometimes acute, bearing acute teeth, costa grooved adaxially, scanty scaly abaxially. Veins are 4-6 pairs per pinnule, free and forked. Sori are indusiate, crowded, 3-4 pairs per pinnule in two rows, one on each side of costa, close to costa, round, indusial are reniform, thin, shriveling markedly, often deciduous with narrow sinus. Spores are dark brown, perinate, perine pale-brown and regular (Fraser-Jenkins, 1982).

Meiotic studies of *D. nigropaleacea* Fraser-Jenkins (Fig. 1a) collected from 18 localities revealed the species to be diploid sexual (n=41). In few SMCs, B-chromosomes were observed in the material from Patnitop. Meiotic abnormalities were found to be present in all the accessions.

The study of meiosis in SMCs revealed 41 bivalents at Diakinesis (Fig. 1b) and M I (Fig. 1c), clearly exhibiting its diploid status. Plants showed abnormal meiotic behavior which includes stickiness, unoriented bivalents, interbivalent connections, laggards, bridges and micronuclei at tetrad stage (Table 1). Stickiness (Fig. 1d) is prevalent at all stages in almost all plants ranging from mild to intense. Meiotic course in accessions collected from Patnitop, Budhal, Batote and Dudaj showed stickiness in more than 25% of the observed SMCs, while accession collected from Chandimarh showed the minimum, *i.e.* 6 %. Another abnormality observed in some SMCs was interbivalent connections. Interbivalent connections were observed at M I within range of 2-30% in SMCs (Fig. 2b). The maximum incidence was seen in the case of plants collected from Gorasarkari (30%). The presence of unoriented bivalents at diakinesis and at M I was found in plants of 17 accessions of this species. Usually one or two unoriented bivalents were seen failing to orient themselves on the equatorial plate at M I. The percentage of SMCs with unoriented bivalents at M I (Fig. 2a) range from 3-16%. Similarly, chromatin bridges (Fig. 2d, 3a) were found at A I/A II, T I/T II (2-12%) accompanied with intense chromatin stickiness. The presence of chromatin bridges was observed in 16 accessions in which maximum percentage was in Patnitop and Parori Gujjran (13%). Abormal segregation of chromosomes at A I and A II leads to formation of laggards (Fig. 2c) at A I/A II (2-11%) belonging to 14 accessions. Observations on SMCs also revealed that micronuclei were generally present at tetrad stage (Fig. 4a), varying in number and size, resulting from fragments or lagging chromosomes. Such meiotic abnormalities lead to abnormal sporogenesis leading to aborted (Fig. 4c) as well as heterogenous spores (Fig. 4d) besides normal spores (Fig. 4b). Spore abortion index (30%) is highest in plants collected from Patnitop (2026 m) followed by Dhara Mohara (29.61%). B chromosomes were observed at diakinesis (Fig. 3b), M I (Fig. 3c) and A I (Fig. 3d) in SMCs of few plants (Patnitop). Detailed comparative data of 18 accessions of *D. nigropaleacea* is given in Table 1.

In the present study, some spores are found to be of variable shapes as well as sizes. The maximum average spore length was 52.91×41.89μm and minimum average spore length was 43.78×32.43μm. Spore fertility determined through stainability test (1:1 glyceroacetocarmine) revealed maximum 30% sterile spores with unstained or poorly stained and shriveled cytoplasm.

DISCUSSION

Earlier workers reported the species to be diploid sexual (Bir & Verma 2010). Diploid sexual cytotype, 41_{II} was recorded under *D. odontoloma* from Nainital (Verma &

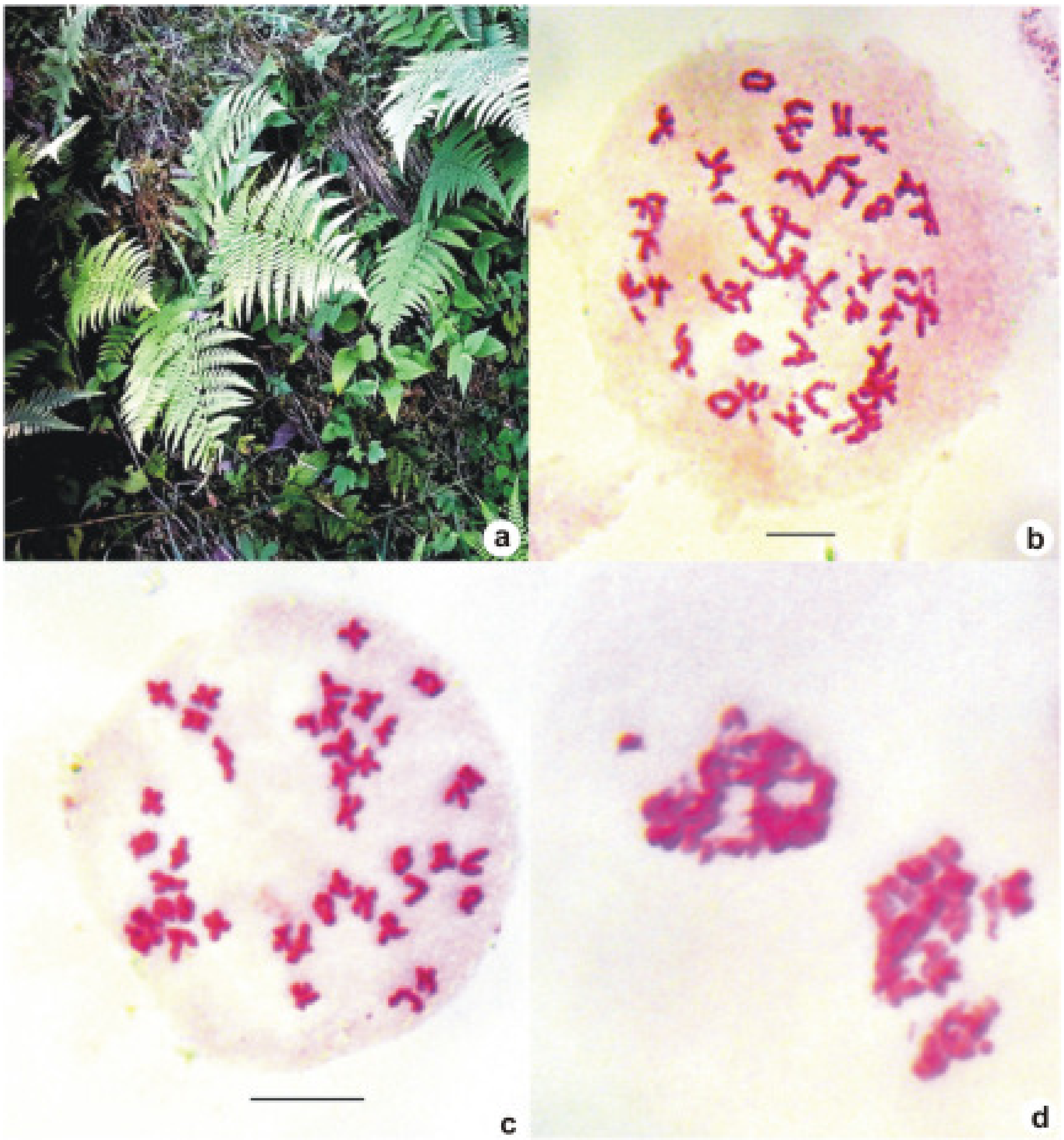

Figure 1. **(a)** *D. nigropaleacea* in its natural habitat (PUN 580), **(b)** SMC with 41_{II} at Diakinesis (PUN 577), **(c)** SMC with 41_{II} at M I (PUN 569), **(d)** Stickiness at A I (PUN 571).

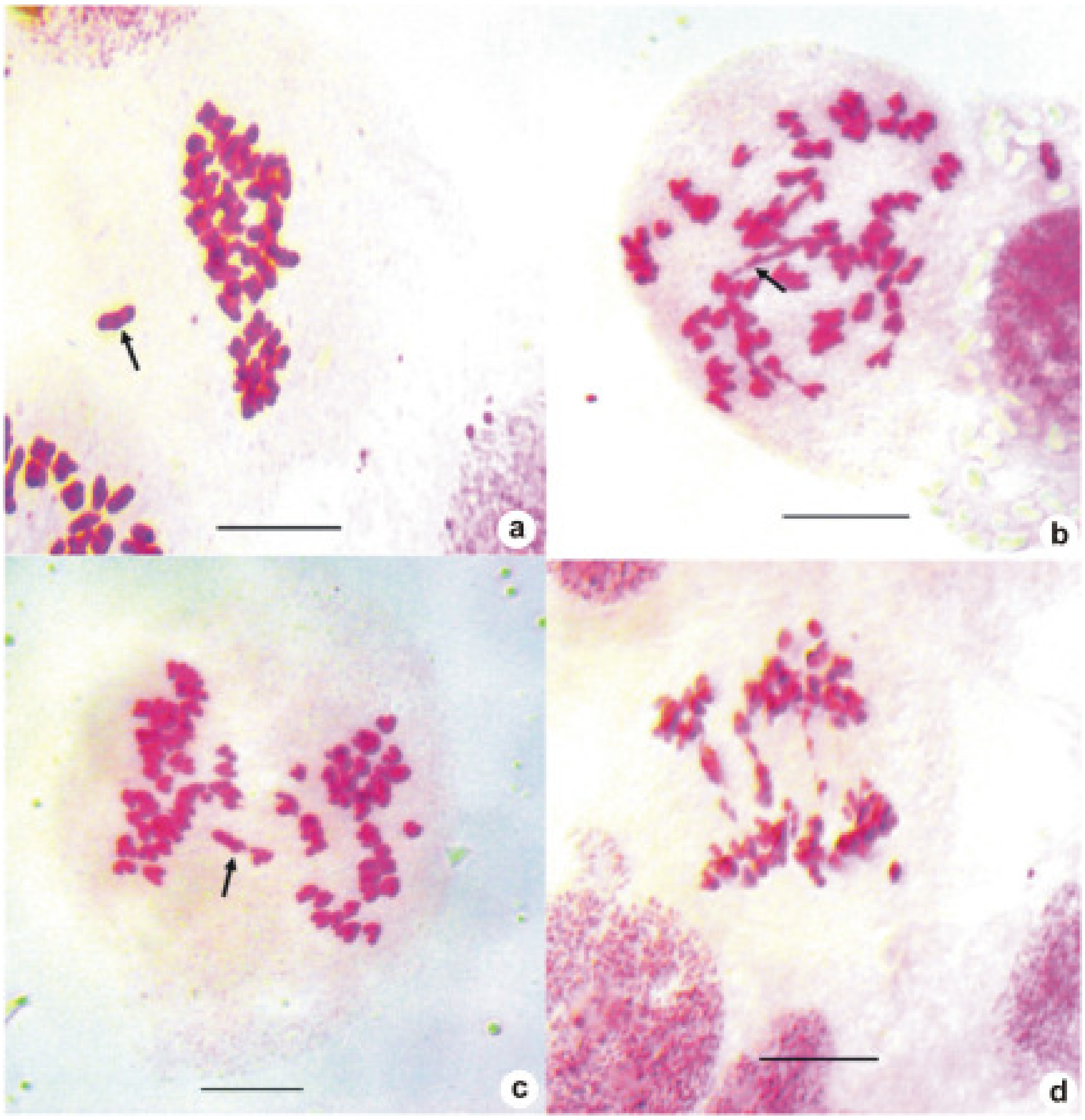

Figure 2. **(a)** Unoriented bivalent at M I (arrowed) (PUN 566), **(b)** SMC with interbivalent connections (arrowed) (PUN 576), **(c)** SMC with laggards at A I (arrowed) (PUN 567), **(d)** Chromatin bridges at A I (PUN 570).

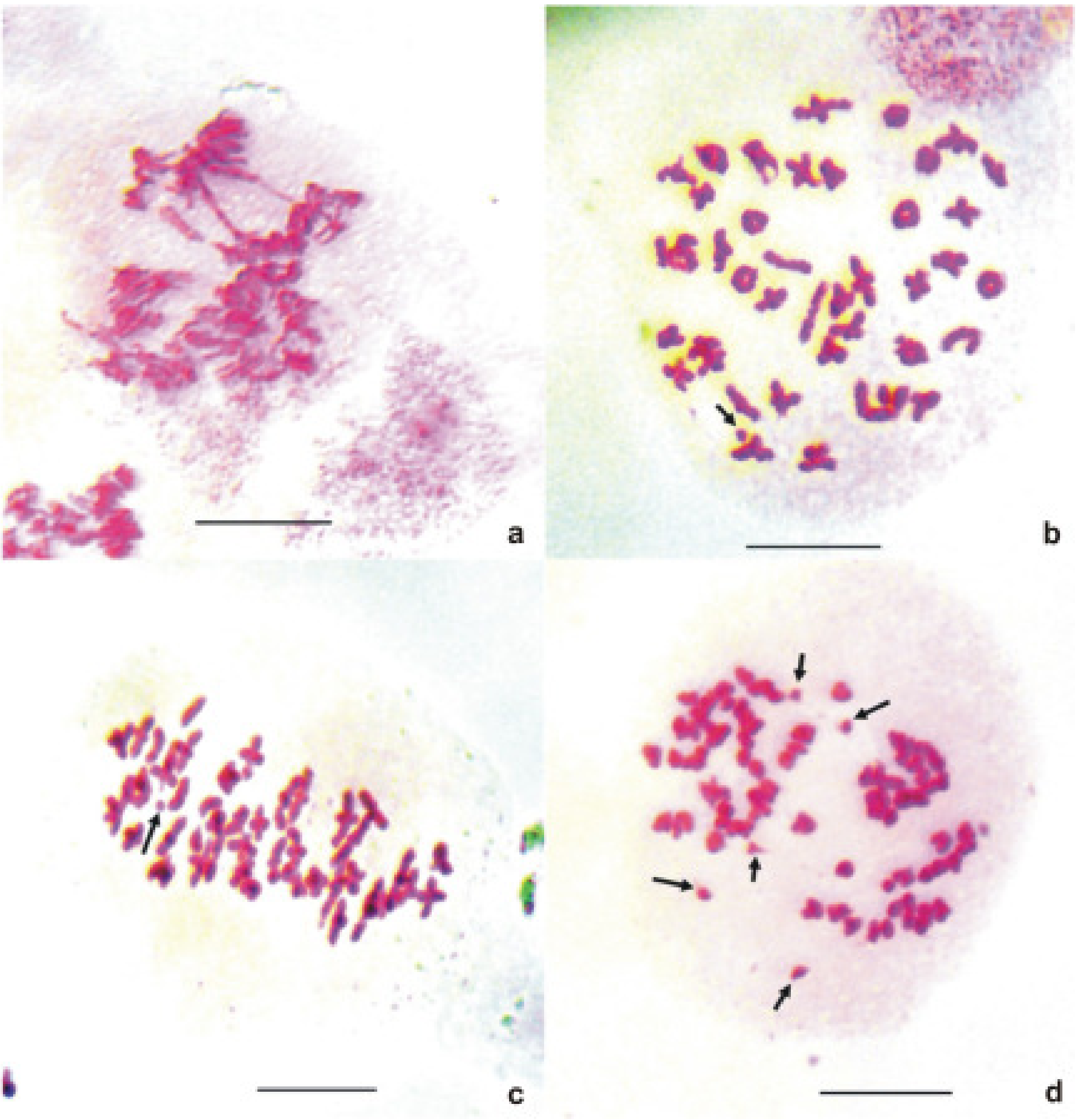

Figure 3. **(a)** Multiple bridges at A II (PUN 565), **(b)** B-chromosome at diakinesis (arrowed) (PUN 565), **(c)** B-chromosome at M I (arrowed) (PUN 565), **(d)** B-chromosome at A I (arrowed) (PUN 565).

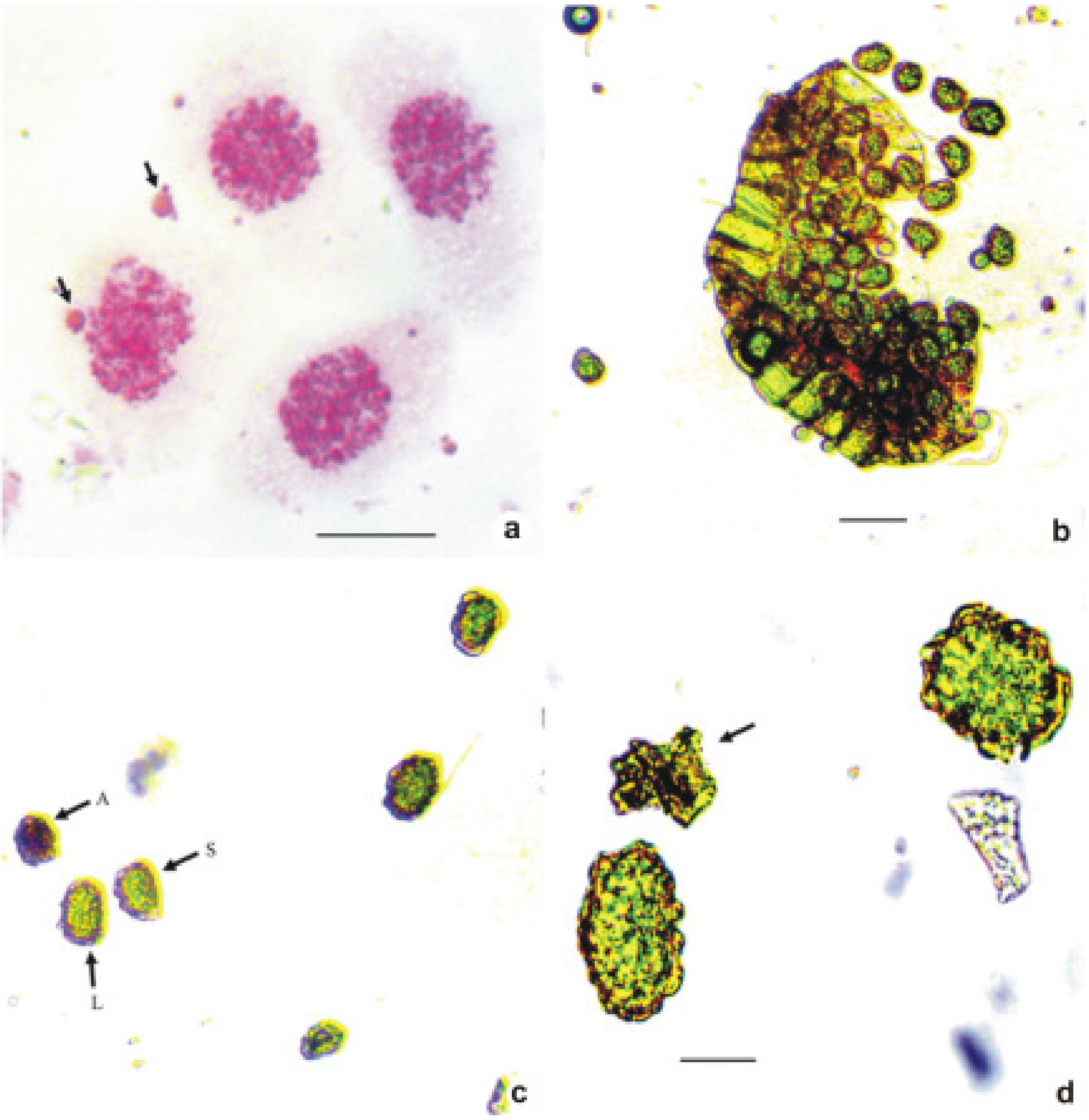

Figure 4. (a) Micronuclei at tetrad stage (arrowed) (PUN 581), **(b)** Normal spores at 10x (PUN 571), **(c)** Heterogenous spores arrowed as L (large), S (small) and aborted spores (A) at 10x (PUN 572), **(d)** Normal and aborted spores (arrowed) at 40x (Scale 10µm) (PUN 578).

Loyal 1960a), Mussoorie (Mehra & Loyal 1965), Kumaon (Punetha 1989) and from Shimla (Gibby 1985), Chamoli Garhwal, Kullu, Katrain and Manali (Khullar 1988). In the present study, we have confirmed the previous reports. However, in some accessions abnormalities such as stickiness, unoriented bivalents, interbivalent connections, laggards and bridges were recorded. It is quite unusual for diploid sexual to undergo such abnormal meiotic course. It does affect the spore fertility, though mildly, in the present case.

Meiosis ensures the faithful transmission of chromosomes and meiotic errors result in various genomic variations including variation in the chromosome structure, number and ploidy level (Wagenaar 1968, Bennetzen 2002, Cohen 2002, Hunt & Hassold 2002, Page & Hawley 2003, Cai & Xu 2007). The prevalence of chromosome stickiness ranges from mild (involving few chromosomes) to intense (where entire chromosome complement is involved). It has been observed in all accessions within range of 6-37%. Some interpretations which are considered responsible for stickiness include improper folding of chromosomal fibres (McGill *et al*. 1974), gene (Dewitte *et al*. 2010) and low temperature (Eriksson 1968). Chromosome stickiness and pycnosis also co-occurred as reported by Caetano-Pereira *et al*. (1995), de Souza and Pagliarini (1997). Unoriented bivalents as observed in present case (3-17%) can be resulted from impaired attachment of kinetochores to spindle fibres (Nicklas & Ward 1994). Lagging bivalents was another observation in some spore mother cells which were found to be present in 2-17% of SMCs. Laggards might arise due to delayed terminalization of chiasma (Pagliarini 1990). Chromatin bridges observed in some SMCs (2-12%) might occur due to inversions (Rothfels & Mason 1975), interlocking of bivalents (Bhattacharjee 1953) or failure of terminalization of chiasmata in a bivalent leading to stretching of chromosomes between poles (Saylor & Smith 1966). Numerous micronuclei at tetrad stage were observed leading to abnormal sporogenesis i.e heterogenous spores. Sterility is the ultimate consequence of any interference in the meiotic program (Brownfield & Kohler 2010). Abnormal meiosis leads to abortion of maximum up to 30% of spores. The cause of these abnormalities can be environmental, genetical or physiological, but it does affect the plant species.

More important is the observation of B-chromosomes in some SMCs of *D. nigropaleacea* from Patnitop. We observed that size of B-chromosomes is smaller than A's as reported in all the previous studies. In our case, B-chromosomes might be originated as by product of meiotic abnormalities that were present at different meiotic stages. As fragments of As can be generated from errors in crossing over and spindle malfunction (Jones, 1995). It has been estimated that B-chromosomes are present in 15% of all eukaryotic species of different taxa (D'Ambriosio *et al*. 2017). In ferns, five cases of B-chromosomes are known (Jones, 1995) and the smallest Bs were reported in *Ophioglossum*, about 1.4µm (Goswami & Khandelwal 1980). In pteridophytes,, B-chromosomes were reported in *Regnellidium diphyllum* Lindm. grown in Lucknow (Jain &

TABLE 1 : Localities with altitude, accession number, percentage of meiotic abnormalities along with spore fertility percentage

Locality with altitude	PUN*	Abnormal SMCs %						Spore Fertility %
		Sticki-ness	Unoriented bivalents at M I	Laggards at A I/ A II	Bridges at A I/ A II/T I/ T II	Inter-bivalent connections at M I	Micro-nuclei at tetrad stage	
JK: Patnitop, 2026m	565	27.78	16.67	11.11	12.50	8.33	13.89	70.00
JK: Kishtwar, 1626m	566	17.64	7.84	9.80	3.92	5.88	–	77.47
JK: Bhaderwah, 1614m	567	18.60	4.65	6.98	4.65	13.95	2.33	75.71
JK: Parori Gujjran, 2553m	568	16.67	4.17	16.67	12.50	8.33	–	72.23
JK: Gorasarkari, 3665m	569	15.15	12.12	6.06	6.06	30.30	9.90	71.47
JK: Rehean, 2753m	570	10.00	15.00	5.00	5.00	10.00	–	76.25
JK: Budhal, 2093m	571	36.84	10.53	–	–	–	–	74.00
JK: Shadra Sharief, 1640m	572	10.71	10.71	3.57	3.57	3.57	–	78.09
JK: Surankote Poonch, 1370m	573	11.11	11.11	2.78	2.78	5.56	2.78	77.12
JK: Dhara Mohara, 2070m	574	14.29	9.52	9.52	9.52	4.76	11.90	70.39
JK: Sangliani, 1726m	575	12.00	6.00	2.0	2.00	4.00	2.00	73.12
JK: Nori Chamb, 1829m	576	14.81	3.70	3.70	3.70	7.41	3.70	73.28
JK: Chandimarh, 1880m	577	6.25	6.25	–	–	9.38	–	76.65
JK: Dhera Gali, 2186m	578	19.57	10.87	4.34	2.17	–	6.52	77.34
JK: Batote, 1562m	579	25.64	–	10.26	7.69	–	5.13	78.38
JK: Dudaj, 2812m	580	27.90	9.30	4.65	2.33	6.98	6.98	75.30
JK: Darhal, 1552m	581	17.39	4.34	–	4.35	2.17	–	74.90
JK: Koteranka, 1672m	582	10.71	3.57	–	7.14	–	–	75.15

PUN = Punjabi University, Patiala, JK = Jammu and Kashmir, SMCs = Spore mother cells, M I = Metaphase I, A I = Anaphase I, A II = Anaphase II, T I = Telophase I, T II = Telophase II.

Raghuvanshi 1973). Another genus with reports of B-chromosomes is *Isoetes*, in case of *I. coromandelina*, *I. dixitei* Schende, *I. panchananii* Pant & Srivastava revealing +1 f (fragment) [2n=22+1f, 33+1f, 44+1f, 55+1f, 66+1f) (Verma 2018). The presence of B-chromosomes in *I. pantii* Goswami & Arya, product of natural hybridization between *I. coromandelina* (n = 11+1B) and *I. sampathkumarini* (n=33+1B) was reported by Goswami (2005). On molecular level, genomic analysis demonstrated that they are derived from fragments of multiple A-chromosomes as in case of *Secale cereale* (Martis *et al.* 2012). B-chromosomes have served as useful tools to study and manipulate the genome of maize (Han *et al.* 2018). So, studies on origin, diversity, composition and complexity of B-chromosomes have been underestimated and clear understanding of these is necessary.

Meiotic studies of this species should be combined with the pharmacological screening for the phloroglucinol, terpenoids and flavonoids as identified from the other species of genus *Dryopteris* (Mehra &Mittal 1960, 1961, 1962, Mittal 1961, Mittal & Bir 2006, 2007).

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REFERENCES

BANERJEE R D & SEN S P 1980 Antibiotic activity of pteridophytes *Economic Botany* **34 :** 284-298

BENNETZEN J L 2002 Mechanisms and rates of genome expansion and contraction in flowering plants *Genetica* **115 :** 29-36

BHATTACHARJEE S K 1953 Cytogenetics of *Lens esculenta* Moench *Caryologia* **5 :** 159-167

BIR S S & VERMA S C 2010 *Chromosome Atlas of the Indian Pteridophytes* Bishen Singh Mahendra Pal Singh, Dehradun, India

BROWNFIELD L & KÖHLER C 2010 Unreduced gamete formation in plants : mechanisms and prospects *Journal of Experimental Botany* **62 :** 1659-1668

CAETANO-PEREIRA C M, PAGLIARINI M S, BRASIL E M & MARTINS E N 1995 Influence of aluminium in causing chromosome stickiness in maize microsporocytes *Maydica* **40 :** 325-330

CAI X & XU S S 2007 Meiosis-driven genome variation in plants *Current Genomics* **81 :** 151-161

COHEN J 2002 Sorting out chromosome errors *Science* **296 :** 2164-2166

D'AMBROSIO U, ALONSO-LIFANTE M P, BARROS K, KOVARIK A & MAS DE XAXARS G 2017 B-chrom : a database on B-chromosomes of plants, animals and fungi *New Phytologist* **216 :** 635-642

DE SOUZA A M & PAGLIARINI M S 1997 Cytomixis in *Brassica napus* var *oleifera* and *Brassica campestris* var *oleifera* (Brassicaceae) *Cytologia* **62 :** 25-29

DEWITTE A, EECKHAUT T, VAN HUYLENBROECK J & VAN BOCKSTAELE E 2010 Meiotic aberrations during 2nd pollen formation in Begonia *Heredity* **104:** 215-223

ERIKSSON G 1968 Temperature response of pollen mother cells in *Larix* and its importance for pollen formation *Studia Forestalia Suecica* **63 :** 1-132

FRASER-JENKINS C R 1982 *Dryopteris nigropaleacea* Fraser-Jenkins *Bol Soc Brot ser* **55 :** 238

GAUR R D & BHATT B P 1994 Folk utilization of some pteridophytes of Deoprayag area in Garhwal Himalaya: India *Economic botany* **48 :** 146-151

GIBBY M 1985 Cytological observations on Indian subcontinent and Chinese *Dryopteris* and *Polystichum* (Pteridophyta: Dryopteridaceae) *Bull Brit Mus (Nat Hist) Bot Series* 1 **14 :** 1-42

GOSWAMI H K 2005 Intra-genomic importance of B-chromosomes *Bionature* **25 :** 11-19

GOSWAMI H K & KHANDELWAL S 1980 Chromosomal elimination in natural populations of *Ophioglossum Cytologia* **45 :** 77-86

HAN F, LAMB J C, MCCAW M E, GAO Z, ZHANG B 2018 Meiotic studies on combinations of chromosomes with different sized centromeres in maize *Frontiers in Plant Science* **9 :** 785

HUANG Y M, HSU S Y, HEIEH T H, CHOU H M & CHIOU W L 2011 Three *Pteris* species (Pteridaceae, pteridophyta) reproduce by apogamy Botanical Studies **52 :** 79-87

HUNT P A & HASSOLD T J 2002 Sex matters in meiosis *Science* **296 :** 2181-2183

JAIN S J & RAGHUVANSHI S A 1973 Cytogenetic study of *Regnellidium diphyllum* with special reference to supernumeraries *Caryologia* **26 :** 469-481

JONES R N 1995 B chromosomes in plants *New Phytologist* **131 :** 411-434

KHULLAR S P, SHARMA S S & VERMA S C 1988 In Bir SS (*ed*) SOCGI Plant Chromosome Number Reports VI *Journal of Cytology and Genetics* **23 :** 38-50

MARTIS M M, KLEMME S, BANAEI-MOGHADDAM A M, BLATTNER F R & MACAS J 2012 Selfish supernumerary chromosome reveals its origin as a mosaic of host genome and organellar sequences Proceedings of National Academy of Sciences USA **109 :** 13343-13346

MCGILL M, PATHAK S & HSU T C 1974 Effects of ethidium bromide on mitosis and hromosomes : A possible material basis for chromosome stickiness *Chromosoma* **47 :** 157-167

MEHRA P N & LOYAL D S 1965 Cytological investigations in the Himalayan *Dryopteris* Adanson *Caryologia* **18 :** 461-498

MEHRA P N & MITTAL T C 1960 Indian substitutes of Male Fern *Pharmacognosy Nature* **186** : 722-723

MEHRA P N & MITTAL T C 1961 Pharmacognosy of Indian substitutes of Male Fern, Part I *Dryopteris ramosa* (Hope) C Chr and *D chrysocoma* (Christ) C Chr *Journal of Pharmacy & Pharmacognosy* **13** : 300-308

MEHRA P N & MITTAL T C 1962 Pharmacognosy of Indian substitutes of Male Fern - II *Dryopteris barbigera* and *Dryopteris cochleata*. *Journal of Pharmaceutical Sciences* **51** : 367-371

MITTAL T C 1961 Pharmacognosy of Indian substitutes of Male Fern-III *Dryopteris splendens* (Hk) O Ktze *Indian Journal of Pharmacy* **23** : 249-253

MITTAL T C & BIR S S 2006 The Indian substitutes of Male Fern (*Dryopteris filix-mas* (L) Schott)-I Taxonomy and drug macroscopy. *Indian Fern Journal* **23** : 133-187

MITTALT C & BIR S S 2007 The Indian substitutes of Male Fern (*Dryopteris filix-mas* (L) Schott)-II Drug microscopy *Indian Fern Journal* **24** : 1-53

NICKLAS R B & WARD S C 1994 Elements of error correction in mitosis : microtubule capture, release and tension *Journal of Cell Biology* **126 :** 1241-1253

PAGE S L & HAWLEY R S 2003 Chromosome choreography: the meiotic ballet *Science* **301 :** 785-789

PAGLIARINI M S 1990 Meiotic behavior and pollen fertility in *Aptenia cordifolia* (Aizoaceae) *Caryologia* **43 :** 157-162

PUNETHA N 1989 Cytological observations on ferns of Kumaon NW Himalayas In: Trivedi *et al.* (*eds*) *Plant Science in India* Today and Tomorrow's Printers & Publishers, New Delhi, India. pp 327-333

ROTHFELS K H & MASON G F 1975 Achiasmate meiosis and centromere shift in *Eusimulium aureum* (Diptera-Simuliidae) *Chromosoma* **51 :** 111-124

SAYLOR C L & SMITH W B 1966 Meiotic Irregularity in Species and Interspecific Hybrids of Pinus *American Journal of Botany* **53 :** 10

SESSA E B, JUSLÉN A, VÄRE H & CHAMBERS S M 2017 Into Africa: Molecular phylogenetics and historical biogeography of sub?saharan African woodferns (*Dryopteris*) *American Journal of Botany* **104 :** 477-486

SURESHKUMAR J, SILAMBARASAN R, BHARATI K, KRUPA J, AMALRAJ S & AYYANAR M 2018 A review on ethnomedicinally important pteridophytes of India *Journal of Ethnopharmacology* **219 :** 10

VERMA S C & LOYAL D S 1960 Chromosome counts in some ferns from Nainital *Current Science* **29 :** 69-70

VERMA S C 2018 Opportunities and challenges of exploring ferns and lycophytes in the genomics age : A brief overview of some issues. In *Pteridology Today : Challenges and Opportunities* (Proceedings of the Symposium held at BSI, WRC, Pune) [eds S C Verma *et al.*], Botanical Survey of India, Kolkata pp 8-32

WAGENAAR E B 1968 Meiotic restitution and the origin of polyploidy II. Prolonged duration of metaphase I as causal factor of restitution induction *Canadian Journal of Genetics and Cytology* **10 :** 844-852

WERTH C R & WINDHAM M D 1991 A model for divergent, allopatric speciation of polyploid pteridophytes resulting from silencing of duplicate-gene expression *American Naturalist* **137 :** 515-526

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EVIDENCE OF REPRODUCTIVE FLEXIBILITY AND FACULTATIVE AGAMOSPORY IN *PTERIS VITTATA* L.

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ABSTRACT

Reproductive flexibility is envisaged in *Pteris vittata* L. subsp. *vittata*, the Chinese Brake Fern, based on unusual spore count per sporangium, variation in spore size, variable spore features in a material from Pithoragarh, spontaneous apogamy in gametophyte cultures, and above all the most important observation of 64-spored and 32-spored sporangia in an individual (in the same preparation, in fact). The spores in 32-spored sporangium are distinctly larger and these spores are suspected to be the outcome of Döpp-Manton pathway of agamospory. It should appear that the gene-blocks controlling sporogenesis, each for sexual pathway and for Döpp-Manton pathway (in agamospory) exist in its genetic make-up, and either of these could get switched-on depending upon the nature of 'stress' being experienced. It also suggests that apogamy could originate within a sexual species, via pre-meiotic restitution mitosis and subsequent abandoning of homologous chromosome pairing and recombination; pairing occurring between sister chromosomes.

Key Words : Reproductive flexibility, facultative apogamy, *Pteris vittata*

INTRODUCTION

In homosporous ferns, the spores comprise the principal means of reproduction, whether the species are sexual or apogamous. In agamosporous species the spores produced are chromosomally unreduced, i.e. their nucleus contains the full 'sporophytic' (2n) genomic complement. This is achieved commonly through a process of restitution of pre-meiotic mitosis (Döpp-Manton pathway (i.e. via pre-meiotic endomitosis, PE, as named by Grusz 2016) and, less commonly, through a modified 'ameiotic' process, called the Braithwaite pathway (Walker 1966, 1979) (or as meiotic first division restitution/MFDR by Grusz 2016). The two systems of agamospory are fully illustrated and described by Walker (1979, 1985), Raghavan (1989), Haufler (2014) and Grusz (2016), and some issues have been discussed by Verma (1979, 2017). It should be emphasized that in the prevalent Döpp-Manton pathway of agamospory the spores are produced in *tetrads*, while in Braithwaite pathway they are produced in *diads*.

In both types of agamospory, the number of spores produced per sporangium are half of the usual number found in their related sexual species. Thus, if a sexual species in a genus of higher, or leptosporangiate, ferns, for example the genus *Pteris*, produces 64 spores in a sporangium, the apogamosporous ones produce 32, relatively large-sized, spores.

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This is obviously true only when the archesporial development up to the 8-celled stage is regular, and all of these cells further undergo a similar course of developmental events, either through the Döpp-Manton pathway/ PE or the Braithwaite pathway/MFDR, both processes ending up in 32 diplospores. In varying proportions, however, some sporangia of agamosporous species develop normally into 16 spore-mother-cells and in such cells the meiotic chromosomal associations display true homologies, and the data help in cytogenetic analyses of the taxa (Manton 1950, Mehra 1961, Mehra & Khullar 1977, Walker 1979, Verma & Khullar 1965, Verma 2000, 2017).

It is generally assumed that in sexually reproducing ferns the archesporial initial during development ends up into 16 spore-mother cells, [or in some genera into 8 spore-mother-cells, as in case of *Lindsaea*] and all of these smc:s undergo regular meiosis to form 64 viable spores. But, a possibility can be visualized where any departure in the pathway will end up in the production of lesser number of spores or a mix of normal and abortive spores! The Chinese Brake fern, *Pteris vittata* L., has assumed special significance ever since the discovery by Ma *et al.* (2001) of its unmatched ability to uptake and hyper-accumulate arsenic. Recently this species has been shown to also hyper-accumulate Selenium (Feng & Wei 2012), hence a potential candidate for phyto-remediation of Selenium contamination due to industrial activities, besides its well-known use in remediation of Arsenic contaminated soils/water bodies. It also has unmatched ability to naturalize in non-native countries [for world distribution see IUCN Red Data site] and has assumed, by invasion, sub-cosmopolitan presence. In USA, it is common in Florida (and other southern states), and in May 2014 Dr. Klaus Mehltreter sent SCV two pictures of *P. vittata* occupying unusual/ inhospitable locations in New Orleans, USA (Plate I). The wide adaptability potential leading to worldwide distribution in itself reflects its invasiveness and reproductive flexibility (Bondada *et al.* 2006, Yang *et al.* 2010). *Pteris vittata* has obvious long-distance dispersal and distinct set of colonization capabilities, and invasiveness; all of these issues call for in-depth analyses of intraspecific variation in its mating systems, generation of new genotypes on the lines of De Groot *et al.* (2012a, b) and Lott *et al.* (2003).

From cytological investigations, *P. vittata* (s.l.) has turned out to be a huge species-complex with several cytotypes (2x sexual, 3x, 4x sexual, 4x sterile, 5x, 5x apogamous, and 6x sexual (Wang 1989, Chang *et al.* 1992, Chao *et al.* 2012, Mumpuni *et al.* 2015, Verma 2013b). However, the most common form is the tetraploid sexual (n = 58). The Chinese brake fern is an important species for exploring its multifaceted biology, including taxonomy and reproduction. Fraser-Jenkins (2008) and Fraser-Jenkins *et al.* (2017) have recognized infra-specific sub-species, one of which, subsp. *emodi* Fraser-Jenk. commonly inhabiting humid sites, is also tetraploid. According to Fraser-Jenkins *et al.* (2017), the south Indian populations are entirely *P. vittata* subsp. *vittata*. The present study records some unusual observations reported in literature and a fresh observation from Palayamkottai (S.

India) that conceives high probability of reproductive flexibility of *P. vittata* subsp. *vittata*, suggestive of facultative agamospory.

Unusual Reports from Literature in *Pteris vittata*

Amongst the earlier publications the important one is of Srivastava *et al.* (1995) who examined spores of *Pteris vittata* from different locations in India (Asansol, Coimbatore, Dalhousie, Dehra Dun, Mussoorie, Pithoragarh), and Taroko (Hawaiian Hsien). The spore size (P x E) at the lower end varied among locations from 30 x 40 µm to 42.5 x 50 µm, and at the higher end it varied from 34 x 58 µm to 45 x 58 µm. Verma & Mani Selvan (2001) analyzed within-species variation in spore size based on equatorial diameter of 1000 spores of single individuals of some species. The data on spore size when plotted against frequency revealed a pattern fitting a normal/ Gaussian curve. It was interpreted as an inbuilt system in ferns to promote variation in sexuality of gametophytes, in turn promoting inter-gametophytic mating. Srivastava *et al.* (1995) described the spores as 'tetrahedral and trilete or bilateral and monolete' although these are commonly reported as only tetrahedral and trilete. 'All the spores of wild plants from Asansol, Coimbatore, Dalhousie and Mussoorie showed a fair amount of constancy in their features, being mostly tetrahedral-trilete, and their sporangia having 1-4 abortive spores. On the contrary, sporangia of plants from Pithoragarh showed a variable form, where number of trilete (tetrahedral, tetrads) spores vary from 22 to 51. In addition some circular spores are also present with their proximal face showing trilete mark, their number may vary between 1 to 4 or rarely 13 per sporangium.' 'A large number of sporangia from Pithoragarh may have 4-18 abortive spores (p.421). 'The total number of spores per sporangium was found to be 46 to 64 (estimated number of functional spore mother cells 12 or 16). However the factors behind this inconstancy of their numbers and forms are not clear' (p. 421, Srivastava *et al.* 1995). The variation amongst spores of *P. vittata* of widely different locations as recorded by Srivastava *et al.* (1995) remains to be explained still.

As far as the co-occurrence of both forms of spores, trilete-tetrahedral and monolete bilateral, are concerned, these can be derived from post-meiotic simultaneous cytokinesis in ferns (Verma & Khullar 1976). Devi (1974) observed that the frequency of bilateral spores increased when wild plants were brought under cultivation (wild plants had fewer bilateral spores). Such a situation of increase in the frequency of bilateral spores was not confirmed by Srivastava *et al.* (1995) when plants were brought under cultivation. The data listed on 15 sporangia in Table 3 of Srivastava *et al.* (1995, p.421) on spore output and form of spores (trilete, large and small bilateral spores) and number of abortive spores in plants from Pithoragarh are indeed complicated. It requires a serious in-depth revisit of Pithoragarh populations for any plausible interpretation.

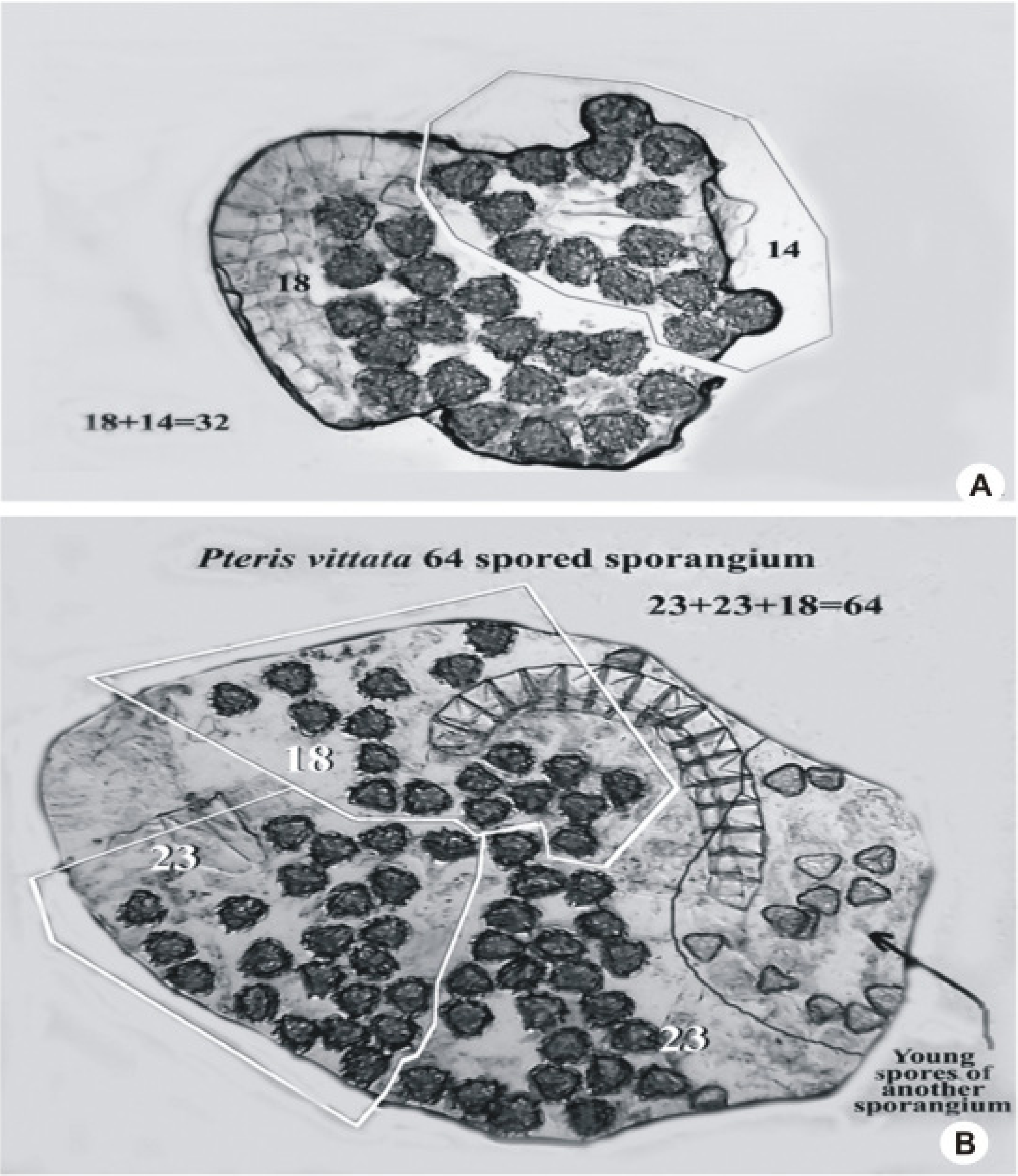
Morphology of spores and Spore size

In India, Nayar & Devi (1966,1968) investigated spore morphology of the Pteridoid

PLATE I

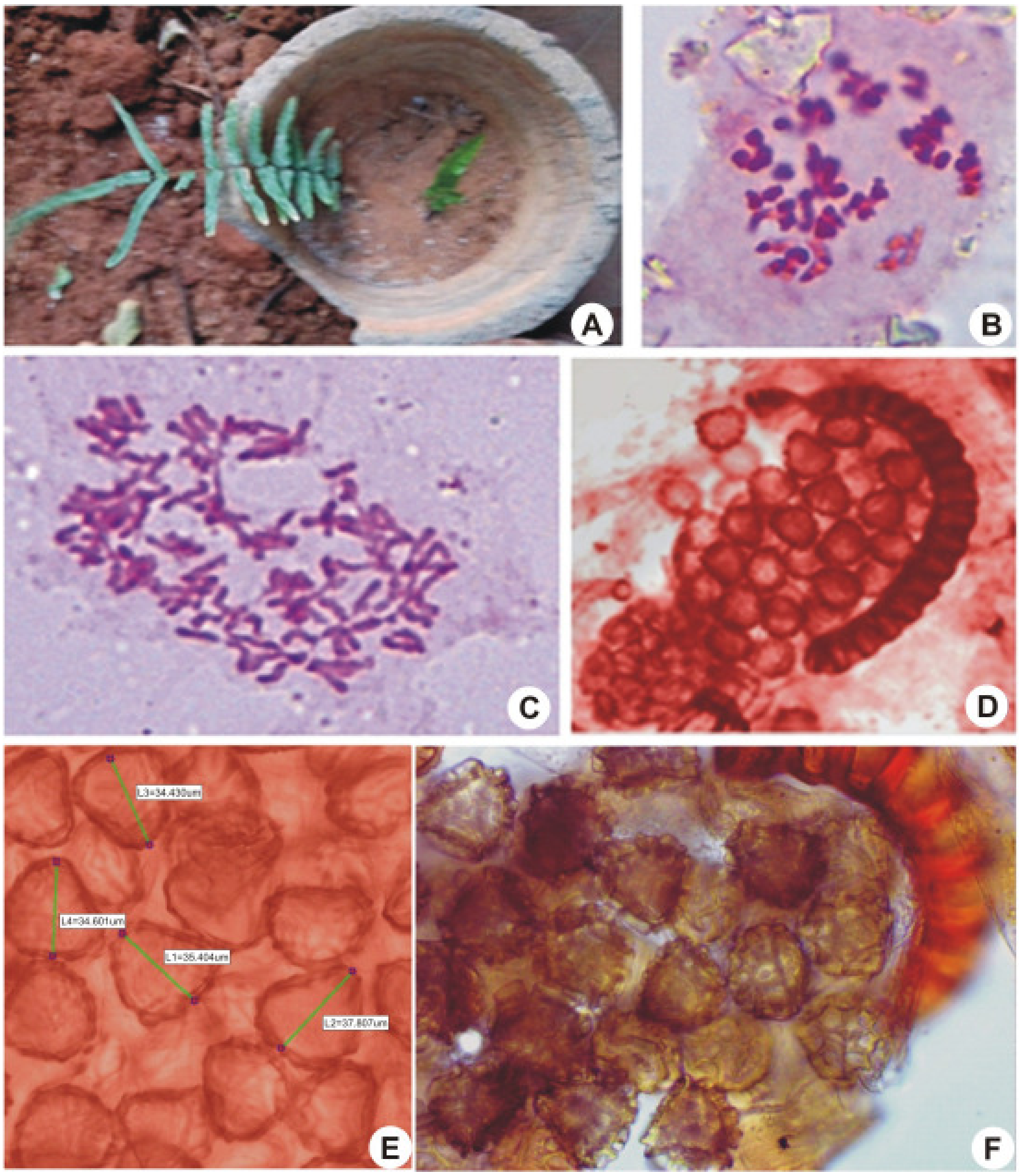
Figs. A (upper), B (lower) : *Pteris vittata* L., inhabiting wall crevice, at New Orleans, USA, photographs sent by Dr. Klaus Mehltreter to SCV in March 2014. [20.3. 2014 Dear Dr. Verma, I just remembered that I have seen *P. vittata* in New Orleans during the last botanical congress. This species invades the old walls of the town].

PLATE II



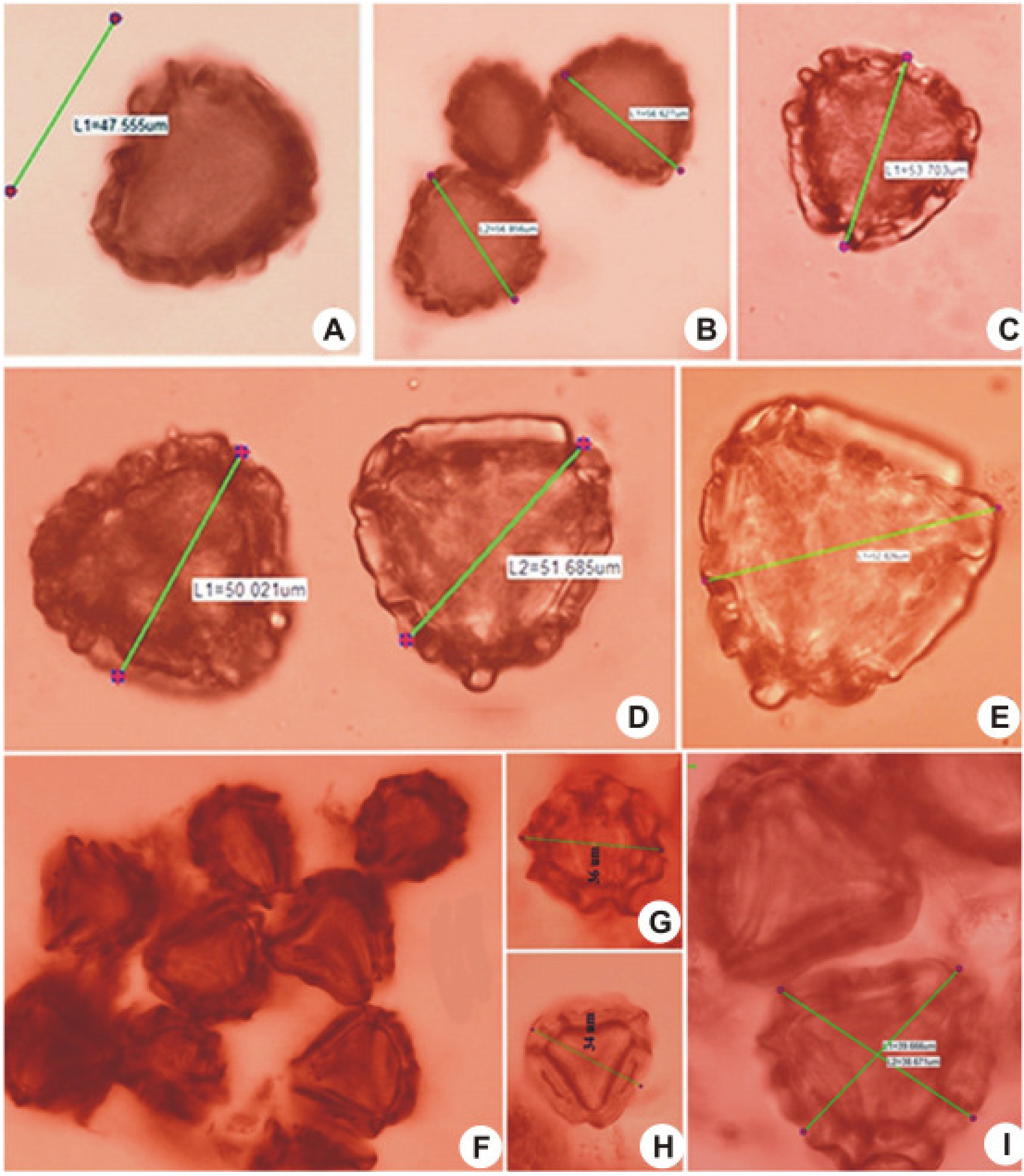
Figs. A, B : *Pteris vittata* L. subsp. *vittata* (Palyamkottai, TN) showing sporangia with 32 spores (**A**), and with 64 spores (**B**), from the same individual.

PLATE III



Figs. A-F : *Pteris vittata* L. from Palayamkottai, with 64- and 32- spored sporangia, **A**. Potted plant, **B**. Spore-mother-cell (16-celled sporangia) at meiosis, with n=c.58, **C**. mitosis in leaf-tip-cell [from crozier] 2n=ca.116, **D & F**. 32-Spored sporangia, **E.** Spores of uniform size from 64- spored sporangium.

PLATE IV



Figs. A-E : Spores from 32-spored sporangia (47.55 to 54.62 µm), and **F-I.** Spores from 64-spored sporangia (34-39.66 µm) of Palayamkottai *Pteris vittata* L. (at different magnifications) to show their relative size variation in their equatorial diameter.

ferns. Recently there has been detailed studies on the morphology of spores of *Pteris* species including *P. vittata*, and these discuss the variability and its importance in taxonomy and evolution within the genus *Pteris* (Chao *et al.* 2014, Palacios-Rios *et al.* 2017, Chao & Huang 2018, Singh & Khare 2018). From these, it seems desirable to investigate morphological variation in spores of *P. vittata* from different niches it inhabits and also between cytotypes. An important report on morphological variation is of Devi (1974). The wild plants of *Pteris vittata* at Lucknow (then identified as *P. longifolia* L., following Beddome, FSI, 1863-64, t. 33) showed exclusively trilete-tetrahedral spores, whereas the plants under cultivation in the fernery of NBRI, Lucknow revealed intriguing data: "the spore mass consists of the normal trilete-tetrahedral ones, together with monolete, bilateral ones and a few intermediate forms, the bilateral type being dominant and forming about 60% of the total spore mass.' (Devi 1974, p. 1). Trilete spores measured 32-40 x 56-72 µm in diameters (P x E), whereas the size of monolete-bilateral spores was 48 x70 µm. Devi (1974) discussed and argued that "the complete absence of bilateral (monolete) spores in wild plants of *Pteris longifolia* (= *P. vittata*), compared with their dominance among the spores of the cultivated forms studied, suggests that the biotic factor of cultivation may have induced a mutation. The cultivated specimens may be only spore mutants, however, with no relation to interspecific breeding.." (p.1,3). Wild plants when brought under cultivation (upon transplantation) showed gradual increase in the production of bilateral spores, exclusive production of trilete spores was maintained only for a short period after transplantation to the fernery (Devi 1974). Obviously such disturbance, transplantation, had caused a major change in form of spores. Such studies need to be repeated. It may be added that the shift in morphology of spores is possible due to prevalent post-meiotic simultaneous cytokinesis in pteridophytes, as discussed by Verma & Khullar (1976, 1978). Morphological diversity of spores within *P. vittata* needs to be evaluated *vis-a-vis* diverse niches the species occupies. It may have some bearing on spore size as well [see observations of Khare *et al.* (2014), from Patna, discussed later].

Kobir & Sen (1989) investigated the spore morphology of 17 species and recognized some four types, where *P. vittata* belonged to type IVB. The significant and unique observation was the clubbing of spores before release from the sporangium, in five species, including *P. vittata*. They summarized it as "Clubbing of two or more spores by perisporic matrix or strands before dehiscence of the sporangium in five species is an important phenomenon which obviously facilitates the development of juxtaposed gametophytes after dispersal enhancing the chances of intergametophytic fertilization" (p. 133). Such studies are required to be revisited to discover the clubbing of spores as a factor in invasiveness of *P. vittata*.

Spore size : Data on Spore size wherever available are summarized in Table 1 which reflect enormous variation. Bondada *et al.* (2006) studied plants of *P. vittata* from central Florida (USA) and recorded the spore size as *length* 38.2 ± 1.3 µm and

TABLE 1 : Spore size in *Pteris vittata* L.

S. No.	Source	Polar (dia.) Spore length (μm)	Equatorial (dia) Spore length (μm)	Reference
1.	Florida (USA)	38.2 ±1.3	41.1 ± 2.8	Bondada *et al.* 2006
2.	Australia (south coast)	43.0-62.0 (mean 50.0)	30.0-43.0 (mean 39.0)	Source APSA*
3.	Patna-1 (Khajpura)	21·26 ± 1·63	28· 11 ± 1· 16	Khare *et al.* 2014
4.	Patna-2 (Patliputra)	19.26 ± 1.52	27.01 ± 1.12	Khare *et al.* 2014
5.	Patna-3 (Saguna more)	18.06 ± 1.43	25.12 ± 1.12	Khare *et al.* 2014
6	S. Jakarta (Indonesia) (5x, apogamous, 32 spores)	41.7 - 51.9	43.7 - 54.3	Puspitasari *et al.* 2015
7.	Goalpara, Assam	32-(38)-40	44-(46)-52	Nayar & Devi 1966
8.	Mexican/Mesoamerican	34.0	44.62	Palacios-Rios 2017
9.	Argentina (Jujuy)	50-80	30-45	Martínez 2010
10.	Patiala	–	43.983 ± 5.71	Beri & Bir 1995
11.	Belgaum (district), Karnataka	36.0	44.0	Thesis+
12.	W. Ghats	40.0	52.0	Thesis++
13.	Pithoragarh (Uttarakhand)	44.85 ±3.31	46.02±3.48	Singh *et al.* 2018
14.	Coorg (Karnataka)	49.53± 3.65	49.92 ±5.75	Singh *et al.* 2018
15.	Lucknow (Uttar Pradesh)	47.58 ± 8.58	49.92±8.23	Singh *et al.* 2018
16a.	Palayamkotai (TN, S. India)-64 spored		Av. 35.50	Present report
16b.	16b. Palayamkotai (TN, S. India)-32 spored		Av. 54.20	Present report

Lucknow (NBRI in cultivation) 32-40 x 56-72 (trilete), Monolete-bilateral 48 x 70 (Devi 1974)

*APSA : Australian Pollen Spore Atlas

++ Source shodhganga.inflibnet.ac.in, Chapter 5, Micromorphology

(material from herbarium specimen at St. Xaviers College, Palayamkottai (chapter 5 of thesis, author not revealed)

+ *shodhganga.inflibnet.ac.in › bitstream › 12_chapter_04 (author not revealed)*

breadth 41.1 ± 2.8 μm. In case of *P. vittata* from Jujuy, Argentina, Martinez (2010) reported the diameters (P x E) as 50-80 x 30-40 μm.. Srivastava *et al.* (1995) recorded spore size variation within and among locations: e.g. 30.0-34 x 40 (44) 58 μm (Dehra Dun, Uttarakhand) to 42.5 - 45.0 x 50 (54)- 58 μm (Asansol, W. Bengal).

Nayar & Devi (1966) reported spore size in *P. vittata* from Golpara (Assam) as 38 x 46 µm (range 32-40 x 44-52). Based on plants in cultivation at NBRI, Lucknow, Devi (1974, p.1) reported the spore size (P x E) range of tetrahedral spores as 32-40 x 56-72 µm under the name *P. longifolia* L. (= *P. vittata* subsp. *vittata*). The bilateral spores are 48 x 70 µm. In contrast, the wild plants of *P. longifolia* (= *P. vittata*) lacked bilateral spores, as mentioned earlier (see Devi 1974).

Some reports on spore size of *Pteris vittata* (Table 1) conveys the extent of variation in spore size, which is expected to reflect variation in growth and sexuality of gametophytes, and also the eventual size/ robustness of gametophytes. Within individuals/ species variation in spore size has been shown, exemplified in some species by Verma & Mani Selvan (2001), that has a bearing on sexuality/ reproductive biology of their gametophytes.

In Table 1, there is one entry on spore size on plants from Lucknow [subsp. *vittata*] by Singh *et al.* (2018) with P X E diameters as 47.58 ± 8.58 and 49.92±8.23 µm with large standard deviation. Thus the equatorial diameters of the studied Lucknow population would seemingly vary from 39.0 to 58.15 µm which in itself is huge variation asking for its effects on reproduction. The Lucknow populations of the Chinese Brake fern requires spore measures based on spores from single individuals, and a minimum of 10 individuals.

Fern spores, including that of *Pteris vittata*, are wind-dispersed. An important element of long-distance dispersal is the size of spores. Variation in spore size within individuals or populations, in a way, would determine how far or how near the spores will land. It is an important factor for the invasive colonizer *P. vittata,* which though native of China has achieved sub-cosmopolitan distribution. Recently, Gómez-Noguez *et al*. (2017) in their publication titled *'Experimental measurements of terminal velocity of fern spores*', stated that "the dispersal of diaspores is a key process for successful reproduction, survival and evolution of plants. To model the dispersal of biological propagules (e.g., spores, pollen) it is necessary to measure their terminal velocity (Vt) in air. In this study, they used a new method based on video image analysis to measure Vt of spores of seven fern taxa. The average Vt of fern spores was 7.0 cm s–1, but varied among species from 1.6 to 11.3 cm s–1" (p. 59). It would be worthwhile to apply their model to spores of *Pteris vittata* subsp. *vittata*.

Do Environmental Conditions affect spore size!

Khare *et al.* (2014) reported unusually small-sized spores from three locations at Patna (Patna 1,2 & 3; Table 1). They collected spores from three different localities : (1) Garden area in Khajpura, considered it as more or less unpolluted, and taken to represent as control, (2) Near the sewage- plants exposed to pollutants of Patliputra industrial area, and (3) crevices of old house walls exposed to automobile exhaust and different garbage from the 'saguna more area'. It is not only the spore-size that seems to be affected by polluted environment, but also the germination percentage which shows perceptible decline in Patna-2 (60.4%; 39.6 % abortive) and Patna-3(50.6%; 49.4 % abortive) as compared to Patna-1(80.8%; 19.2% abortive) (Khare *et al*. 2014). These authors raised gametophytes by inoculating 'in modified Moore's medium supplemented with Nitch's trace element', cultures 'maintained at 22 ± 0°c with 16 hrs of illumination in 24 hrs cycle under constant source of 1000 lux' (Khare *et al*. 2014). They observed differences in germination time in hours after inoculation (74, 82, 96 hrs respectively). Also, they observed various types of abnormalities in gametophyte growth and sexual features, all of these tend to point towards the consequence of polluted conditions on spore size, their germninability, gametophyte growth and sexuality. Their study is worth repeating.

A Suggestive Possibility : The very small diameters of the spores from three locations of Patna stand distinctly apart from all other reports listed in Table 1, and it is suspected that Patna populations of *P. vittata* may turn out to be diploid sexual! It would be profitable to investigate the cytology of these Patna populations. If these turn out to be tetraploid sexual, the small size of spores would then be correlated as an effect of polluted environment!

Spore output per sporangium as an indicator of 'agamospory'

Ever since cytological studies in pteridophytes were taken up in right earnest beginning 1950 with Manton's treatise *'Problems of cytology and evolution in the pteridophyta'*, it became obvious that in leptosporangiate ferns the taxa that produced half the usual number of spores characteristic of that genus reproduced habitually apogamously, and the classical example was fully elaborated in *Pteris cretica* L. by Manton herself. Although the decision on the mode of reproduction, whether sexual or apogamous, depends not only on spore output per sporangium (64 versus 32 in genus *Pteris*) but complete cytological analyses to show that both generations possess the same chromosome number ('n' = 2n), as a result of modified sporogenesis in apogamous ferns that yield diplospores, in half the number of sexual species. Whereas Manton (1950), Manton & Sledge (1954) and Walker (1962) utilized the spore output per sporangium as a reliable indicator of the type of reproduction in the concerned taxon, Walker (1979, p.118) emphasized, however, that 'the only sure way of detecting agamospory is by cytological analysis and obtaining the same chromosome number in both sporophyte and gametophyte. There are many other useful indicators but they are indicators only and are not universal in application -being valid for some groups of species but not for others and almost all are liable to breakdown. One of the commonest indicators quoted in literature is spore number per sporangium, in which the presence of 64 spores is taken to denote sexual reproduction, whilst 32 is taken to point to the presence of agamospory'. This method has been widely used for inferring agamospory in Indian ferns (Bir & Verma 2010).

Nearly 10% of the investigated ferns are estimated to be obligate agamosporous, and a large majority of the agamosporous species follow the Döpp-Manton pathway of modified sporogenesis, and produce chromosomally unreduced spores (Grusz 2016 , Verma

2017). In such species there also occur a variable proportion of sporangia that still follow the normal sequence to result in 16-celled sporangia, which give rise to 'crumpled, non-viable spores' in contrast to well-filled viable spores from the 8-celled sporangia of Döpp-Manton Pathway. Meiotic analysis of smc:s from such sporangia is extremely important in cytogenetics (Mehra 1961, Khullar & Mehra 1972, Verma & Khullar 1965, Walker 1979, Verma 2000, 2017). Here the chromosome pairing is based on true homologies (Manton 1950, Walker 1979, Verma 2000, 2017). The occurrence of such sporangia in whatever frequency, serves as an additional indicator of agamospory, e.g. in species of *Pteris* (Walker 1962, Verma & Khullar 1965).

Resolving The Puzzle of Unexpected Spore Counts in *P. vittata* from Mangalore, S. India)!

P. vittata (s.l.) is a huge cytological complex (**Wang 1989,** Bir & Verma 2010, Verma 2013b), but the commonest cytotype is the tetraploid sexual (n = 58). Amongst the several subspecies recognized by Fraser-Jenkins *et al.* (2017), there occurs only subsp. *vittata* in S. India (Fraser-Jenkins *et al.* 2017), which is commonly tetraploid sexual and morphologically variable, although diploid sexual (n=29) and hexaploid sexual (n=87) forms are also reported from S. India (see Bir & Verma 2010, Verma 2013b). In 2013, Dr. Smitha Hegde (then at Aloysius College, Mangalore) was requested to make a count of spores per sporangium in randomly collected plants of *P. vittata*. The data supplied (also reported in Verma 2013b) are entirely unexpected and puzzling (Table 2). A total of 10 plants were sampled and four observations were made in each. Curiously none of the counts recorded 64 spores per sporangium, and the plant from Sulthan battery road stands out sharply with

TABLE 2 : Spore output per sporangium of *Pteris vittata* [subsp. *vittata*] from Mangalore, S. India (Courtesy Prof. Smitha Hegde, Mangalore)

S. No.	Site of collection	No. of spores per sporangium				Average
		1	2	3	4	
1.	College campus (Aloysius)	60	52	61	57	57.5
2.	Urva- compound	48	56	57	59	55
3.	Hoigebail	55	49	63	60	56.75
4.	Urva	41	58	62	61	55.5
5.	Kudroli- Bhagavathi temple	59	61	63	61	61
6.	Sulthan battery road	54	44	43	48	47.25
7.	Behind administrative block	56	59	61	60	59
8.	Matadhakani road- opp syndicate bank	58	62	57	61	59.5
9.	Bunts hostel- towards C.V Nayak Hall	48	51	55	50	51
10.	Kudupu temple road	48	54	53	51	51.5

a mean of 47.25 spores (c.48; Table 2). A possibility arises whereby the pathway of sporogenesis may not be similar in all sporangia! A variable number of spore-mother-cells would result! Spore size variation amongst spores of a single sporangium from such plants is desired and will hold promise.

It is equally, if not more, interesting to mention that spore count of the *P. vittata* plants in cultivation at the Roxburgh Botanical Garden of Allahabad University (probably from Asansol, see **Srivastava *et al.* 1995**, Verma 2013b). Dr. Sarvesh K. Singh, through the courtesy of Prof. G.K. Srivastava (Allahabad) made the spore counts per sporangium and intimated that 'in 10 counts, 7 of these showed 32 spores per sporangium and the remaining 3 had 48 spores per sporangium, and contained mostly trilete and fewer monolete spores. The dimensions of spores in 32-spored sporangia were, for example, in one case, were *length* 60.75 µm, *breadth* 54 µm for trilete spores, and *length* 56 µm and *breadth* 35 µm for monolete ones' (Verma 2013b, p.). The large size and the number 32 may point toward a high probability of agamospory in these plants, and the 48 spored sporangia resulted from following probably a mixed sporogenesis pathway (normal and Döpp-Manton pathways!). The observations of Ekrt & Koutecky (2015) on pentaploid hybrid *Dryopteris x critica* are revealing and relevant. In the pentaploid hybrid the number of spores per sporangium varied from 31-64, and 'it was possible to detect formation of either only aborted spores or various mixtures of aborted and well-developed reduced spores and unreduced diplospores' (p. 97, Ekrt & Koutecky 2015). They made an important conclusion that "both sexual reduced and apomictic unreduced spores can be produced by a single individual, and even within a single sporangium" (p.97, Ekrt & Koutecky 2015). There is an obvious interest in pursuing in-depth studies in *P. vittata* on spore count, spore size, chromosome number determinations and chromosome behaviour at meiosis. Particular studies are required in cases with 48-spored sporangia to discover newer possibilities.

Simultaneous of occurrence of 64-spored and 32-spored sporangia within the same plant

Assuming 64-spored sporangia to convey sexual reproduction and 32-spored sporangia pointing agamospory, their co-existence within the same individual would reflect a case of natural facultative agamospory. A probability can be visualized in 48-spored sporangia (Table 2) where presumably at the 8-celled stage of sporogenesis, 4 cells follow the Döpp-Manton Pathway (restitution mitosis) resulting in four '4n' spore-mother-cells, and the other four cells follow the normal pattern resulting in eight '2n' smc:s. Meiosis in such smc:s (4 + 8) will end up in 48 spores.

Such a possibility reflects mixed sporogenesis pattern, as conceived by Ekrt & Koutecky (2015) in the pentaploid *Dryopteris* hybrid. Spore output and intra-sporangium variation in spore size would be desirable for analyses. In the situation of 48 spores, one-third of the spores would be expected to be distinctly larger, being unreduced diplospores. Investigations on these lines are to be expected in the future. Because both the normal sequence of events and the Döpp-Manton pathway sequence co-exist in several agamosporous species (16-celled sporangia and 8-celled sporangia) [Bir & Verma 2010], it is not improbable that the 'two kinds of events' get switched-on within a single sporangium, as visualized in pentaploid hybrid by Ekrt & Koutecky (2015). In species known to reproduce sexually, it is likely that different sporangia may proceed either way! to result in reduced 64 spores or unreduced 32 spores. Let fresh investigations dwell on such issues.

REPORTING 64-SPORED AND 32-SPORED SPORANGIA IN AN INDIVIDUAL OF *PTERIS VITTATA SUBSP. VITTATA* FROM PALAYAMKOTTAI, S. INDIA

Dr. V. Irudayaraj was asked to make spore counts per sporangium in local population at Palayamkottai (Tamil Nadu) of *P. vittata* subsp. *vittata* in order to compare with the data conveyed by Dr. Smitha Hegde (Table 2). He conveyed SCV in May 2018 about the curious observation of the presence of both 64-spored sporangia and 32-spored sporangia in the same individual, and further this unexpected observation was recorded within the same slide (Plate II). The investigated population of *P. vittata* was growing along a cement sewage canal of ca. 2 feet depth along road side beside a building of All India Radio station, Palyamkottai. The sewage canal is not persistently wet with sewage water, and it is mostly a dried one or rarely with little flow of sewage water. In rainy season there are fairly grown plants. Cytology of the plant revealed it to be a tetraploid (n=c.58, 2n=c.116, Plate III). The spores of 32-spored sporangia are distinctly large (av. 54.20 μm) as compared to spores of 64-spored sporangia (av. 35.50 μm) [Plates II, III, IV]. The spores are tetrahedral-trilete, implying that sporogenesis events for the 32-sporangia followed the Döpp-Manton pathway. It can be assumed that 32-spored sporangia release unreduced spores and these spores will germinate to bear sporophytes apogamously. The observations would suggest a natural case of facultative apogamy. A plant producing exclusively 32-spored sporangia was also identified and isolated (Plate III) for further study. This interesting observation of 64/32- spored sporangia in an individual plant of *P. vittata* suggestively indicates facultative apogamy, a term commonly being used (inappropriately in our opinion) for experimentally-induced apogamy in otherwise sexual species (Raghavan 1989). The present case of 64/32 spored sporangia in an individual of *P. vittata* is truly a case of facultative apogamy in nature. It is required to be pursued. It may be recalled that Verma (2013a) reported a case of spontaneous apogamy in a gametophyte culture of otherwise sexual tetraploid *P. vittata*.

Gametophyte Biology holds the key to reproductive flexibility and genotype diversity

Genetic variation within and among populations of ferns would be dependent upon their gametophytes to the extent these express any portion of the genomes they convey. *Pteris vittata* is a native of China and Wan *et al.* (2009) investigated *'Sexual Propagation of Pteris Vittata L. Influenced by pH, Calcium, and Temperature*' from China. During naturalization in various parts of the word the requirements of soil pH, Calcium and temperature are bound to evolve, which needs to be investigated together with their influence on gametophyte sexuality. Within-plant variation in spore size is an in-built characteristic to generate differences in sexuality of gametophytes that allows mating system flexibility (Verma & Mani Selvan 2001). It is known that amongst the homosporous ferns the frequency of gamtophytic selfing is higher in polyploids (Masuyama & Watano 1990, Verma 2003) and the common tetraploid *Pteris vittata* is no exception. The findings of De **Groot *et al.* (2012 a, b)** regarding the importance of selfing in fern mating systems after long distance colonization will find application in *P. vittata*. The occurrence, in varying frequencies, of only archegonia-bearing prothalli in its trigametophytic system reflects, however, that some intergametophytic mating is ensured (Verma & Kapur 1972, Verma 2003).

Akomolafe *et al.* (2015) investigated gametophyte development in *Pteris vittata* from spores 'collected from the fern garden of the Department of Botany, Obafemi Awolowo University, Ile-Ife', Nigeria. Their report that 'gametophyte development starts inside the spore and they are hairy at maturity (30 to 70 days) (p. 613),[illustrated in their Plate 1, C & E; p. 614], is important and needs a revisit. We suspect the term spore was used by them to convey sporangium, as appears from their illustrations. Germination of spores within the sporangium is an exceptional finding, requiring affirmation.

Khare *et al.* (2014) made elaborate studies on the gametophyte generation of *Pteris vittata* generated from spores of three locations in Patna, and impressed upon the amongst-source variability in the gametophyte generation. Besides, they reported the presence of 6-8 zygotes on each prothallus of the Patna-1 sample, an important observation already reported by Verma & Kapur (1972), where it was one of the later fertilizations that developed into juvenile sporophyte (Verma & Kapur 1972). It should appear that *P. vittata* has a mechanism permitting competition amongst zygotes on a gametophyte, ensuring survival of adaptive genotypes, apart from the possibility of single spore establishment in newer habitats.

Multiple fertilization on a gametophyte is precursor to simple polyembryony, and polyembryony has been documented in several sexual ferns (Mottier 1925, Klekowski 1970, 1972, Lloyd 1974). That the feature of polyembryony in ferns appears to be a genomic trait, is reflected by the report of polyembryony even in two apogamous ferns, *Pteris cadieri* Christ and *P. grevilleana* Wall. ex J. Agardh by Chao *et al.* (2010).

Another variable in reproductive flexibility of *Pteris vittata* is the facultative ability of the association of arbuscular mycorrhiza (AM) with the sporophyte and the gametophyte (Prashar & Dhanda 2017, Dhanda & Prashar 2018). Martinez *et al.* (2012) worked with *Pteris vittata* from Buenos Aires city (Argentina) and expressed that arbuscular mycorrhiza (AM) 'may significantly shorten the period when the small plants are especially susceptible to drought, allowing them to adapt better to the environment' (p. 858).

DISCUSSION

Approximately 10% of the investigated ferns are known to reproduce apogamously through unreduced spores (diplospory), produced commonly via Döpp-Manton pathway or less commonly via Braithwaite pathway (Grusz 2016, Verma 2017). All the species are stated to be obligate apogamous. The term facultative apogamy has been construed to convey the experimental induction of apogamy in sexual species, for probing several questions (Manton 1950, Manton & Walker 1954, Mehra & Sulklyan 1969, Palta & Mehra 1983, Mehra 1975, Bouharmont 1972 a, b, c, Bell 1992, and many more). Until 1977 (Lovis 1977) there was one report by Lloyd (1973) on *'Facultative apomixis and polyploidy in Matteuccia orientalis*', Amer. Fern J. 63: 43-48.

Truly speaking, facultative apomixis means the co-occurrence of both sexual and apogamous modes of reproduction from spores of a single individual. This important discovery by R.M. Lloyd, in a tetraploid plant of *Matteuccia orientalis*, based on elegantly designed elaborate breeding experiments, did not catch the attention of fern cytogeneticists, presumably for reasons of its extreme rarity! Almost all conclusions on apogamous reproduction in ferns are based on spore output per sporangium, which is half of the usual number characteristic of that genus. For example, if a fern genus (e.g. *Pteris*) is known to produce 64 spores, its agamosporous species would produce 32 spores per sporangium, commonly through the Döpp-Manton pathway (in tetrads), well-explained by Manton (1950) and Walker (1979). Thus, an individual within a species reproducing both sexually and apogamously (i.e. truly facultative reproduction) is expected to possess two types of sporangia, those producing 64 spores and those producing 32 distinctly larger spores. Such a case characterized by 64/32 spores is reported to occur in *Asplenium aff. hallbergii* (Dyer *et al.* 2012). The observations of Dyer *et al.* (2012) are required to be quoted in verbatim- " The *A. aff. hallbergii* specimens (RD85 and RD90) are nested within the *A. hallbergii* lineage, but appear physically larger in size and show up to four nuclear copies, implying that they could be tetraploid variants (Fig. 2.4 and Fig. 2.5 of Dyer *et al*., 2012). One of these specimens (RD90) produced both 32- and 64-spored sporangia. Both types of spores appeared normal and viable. This would suggest that RD90 is producing both reduced and unreduced spores and thus might be a facultative apomict, though separate cultivation experiments are necessary to test this hypothesis" (p. 1525).

The present case of *P. vittata* subsp. *vittata* from Palayamkottai (TN) adds to the list of suspected facultative apomixis, necessitating further experimentation. The suspected Döpp-Manton sporogenesis occurring within otherwise sexual species raises fresh approach toward the origin of apogamospory.

Origins of Apogamospory

Verma (2017) has discussed in detail the 'still unresolved' issue of the origins of agamospory in ferns. Whereas a 'hybrid origin' is generally favoured, it also includes the factors of polyploidy and female sterility. It is realized that 'for faithfully regulated operation of obligate agamospory necessitates a highly coordinated system of 'linked' genes/ or a 'gene complex' that assures sequential switching-on of at least three features across the two generations, gametophyte and sporophyte : **(i)** restitution of pre-meiotic mitosis (in the common Döpp-Manton Scheme) forming chromosomally unreduced (2n) spores via regular bivalent-forming meiosis, **(ii)** spores develop into gametophytes either completely lacking archegonia, or when present (few cases) these are non-functional (Mehra 1938, Laird & Sheffield 1986), and **(iii)** the development of embryo from vegetative cells, commonly behind the notch meristem, to complete the 2n - 2n alternation of the two morphological generations in the fern life cycle' (Verma 2017, p. 10,11). The perceived *'gene complex'* conferring agamospory, remains elusive. The presence in obligate apomicts of both the 16-celled (normal sequence sporogenesis) and the 8-celled sporangia (Döpp-Manton pathway) indicates that the fern genome is highly complex comprising the faculty to switch-on either of the 'sequences', presumably controlled by within/without environmental fluctuations, homozygosity of mutant genes (due to intra-gametophytic selfing in its mixed mating system), or intra-specific hybridity or combination of these factors. The possibility of agamospory originating in originally sexual species is envisaged already in some diploid apomicts, e.g. in diploid apomict *Pteris cretica* (Verma & Khullar 1965) and in diploid apomict *Adiantum lunulatum* (= *A. philippense*) [Khullar & Mehra 1972, Mehra & Khullar 1977), based on high extent of homologous chromosome pairing in smc of their 16-celled sporangia (see Bir & Verma 2010). Diploid sexual taxa are reported in *Pteris cretica* from Kathmandu, Nepal by Roy *et al*. (1971) and in *A. philippense* (under *A. lunulatum*) from Maharashtra (Mahabale & Kamble 1981) and from Kerala (Irudayaraj & Manickam 1987). There would seemingly be high probability of the origin of agamospory within sexual species. It is possible, because, as proposed, the genome of ferns are inherently equipped with the genetic components or gene complexes for both types of sporogenesis (regular and Döpp-Manton pathway); although under favourable environments only the regular system operates. Hybrids may show up both sexual and apomictic pathways even within the same sporangium, as reported by Ekrt & Koutecky (2016) in pentaploid *Dryopteris* hybrid. Lloyd (1973) reported facultative apomixis in a tetraploid individual of *Matteuccia orientalis*, and Dyer *et al*. (2012) reported 64/32 spores in an individual of *Asplenium x hallbergii*. The present discovery in tetraploid *Pteris vittata* subsp. *vittata* not only adds to the list but also emphasizes the possession of both types of 'gene complexes' in their genomes. What makes these gene complexes to get switched on, so as to produce the condition of 64/32 spores in an individual requires to be determined.

Pteris vittata subsp. *vittata,* known to be native of China, has spread widely to almost all parts of the world. In modern times, human-mediated environmental changes have increased gradually the selection pressure for the capacity in plants (here ferns) to colonize new areas over longer distances. Under some 'unfavourable' environment conditions either of the hypothesized 'gene-complexes' may get operative to get a foothold to new locations. It would be interesting to pursue investigations to discover whether the spores from 32-spored sporangia establish through apogamy and the resultant individuals regain the potential of sexuality and begin producing 64 spores! It would be an absorbing and rewarding study.

Apomixis in ferns and angiosperms, and the Issue of reversion to sexuality

The term apomixis embraces all types of asexual reproduction. Cordle *et al.* (2011) have made an explicit comparison of agamosprous reproduction in ferns (obligate apogamy) with apomixis in angiosperms. It is known that the phenomenon of obligate apogamy in ferns and apomixis in the angiosperms differ. In ferns, there is 'direct generation of sporophyte from gametophyte prothallus cells', and in angiosperms the embryos produced are either aposporous 'developed from nucellus or integument cell autonomously' or adventitious embryo 'developed from nucellus or integument cell adjacent to the fertilized embryo' (Cordle *et al.* 2011). . In ferns, unreduced spores are produced by the sporophyte by *abnormal sporogenesis* (via Döpp-Manton pathway or Braithwaite pathway), whereas in angiosperms diplosporous embryo is 'developed from an unreduced-egg-like cell from *abnormal gametogenesis*' (see Fig. 3.2, in Cordle *et al.* 2011, p.30). Nevertheless, it is still worth exploring origins of agamospory in ferns keeping also in view as to what is known in the angiosperms. That the interpretation of so-called bivalents at meiosis in smc:s of 8-celled sporangia, of apogamous ferns, as '*autobivalents*' draws support from the report of edo-duplicational meiosis in *Allium odorum* by Håkansson & Levan (1957), although, earlier, Manton (1950) had correctly interpreted these bivalents as between sister chromosomes of premeiotic restitution mitosis.

For angiosperms, Tucker & Koltunow (2009) considered theories that explain the origin of apomictic processes from sexual progenitors. While angiosperms appear to be predisposed to shift from sex to apomixis, there is also evidence of reversions to sexuality. Such reversions may result from genetic or epigenetic destabilization events accompanying hybridization, polyploidy, or other cytogenetic alterations. Because of increased within-plant genetic and genomic heterogeneity, range expansions and diversifications at the species and genus levels may occur more rapidly upon reversion to sexuality (Hojsgaard *et al.* 2014). Variation for apomictic reproduction in diploid *Paspalum rufum* has also been explained. It has been concluded that at early stages both reproductive routes were developmentally unstable, but apomixis was progressively stabilized through the developmental programme under the proper (epi)genetic background at the polyploid level (Delgado *et al.* 2014). Such kinds of explanations need to be considered in ferns, and it would be of interest to find whether the plants develop apogamously from spores of the 32-sporangia of *P. vittata* (Palayamkottai), and progeny then reverts to sexual reproduction! Further studies are required to screen several populations of *P. vittata* in and around Palayamkottai, and raising plants from spores of 32-spored sporangia.

CONCLUDING REMARKS

The discovery of 64/32 spored sporangia in an individual of *Pteris vittata* subsp. *vittata* from Tamil Nadu (S. India) impresses upon the complexity of the fern genome possessed inherently of dual possibilities in sporogenesis. The element of 'trigger' to switch on either of the sporogenesis pathways requires investigations. Besides, it imposes on us to revisit critically spore output per sporangium and spore size variation within and between sporangia, in especially colonizing species for revealing unexpected findings. The large spore size variation in the Lucknow population of *P. vittata* (subsp. *vittata*), reported by Singh & Khare (2018, Table 1) may reveal something interesting on further study. The origin of agamospory within sexual species is a distinct possibility.

It would be important to isolate spores of 32-spored sporangia of *P. vittata* and study their gametophyte biology. If these give rise to gametophytes without archegonia and bear embryo sporophyte apogamously, natural facultative apogamy will get established, adding to the solitary case of facultative apomixis in tetraploid *Matteuccia orientalis*, analysed by Lloyd (1973). Still more interesting would be a study on the nature of sporogenesis in the plants developed apogamously from 32-spored sporangia, and to discover reversion to sexuality or facultative apomixis! *Pteris vittata* subsp. *vittata* holds promise for further study.

REFERENCES

AKOMOLAFE G F, OLOYEDE F A & FAJUKE A A 2015 Gametophyte morphology and sexual development in *Pteris vittata* L. *ARPN Journal of Science and Technology* **5**(12) : 612-615

BEDDOME R H 1863-1864 The Ferns of Southern India and Ceylon. [1-38. t. 1-110 (1863), t. 111-271 (1864)], Second ed. 1873; 1-88, t. 1-271. Gantz Brothers, Madras. (Reprinted : 1970, Today & Tomorrow's Printers & Publishers, New Delhi)

BELL P R 1992 Apospory and apogamy: Implications for understanding the plant life cycles

BERI A & BIR S S 1995 Effect of temperature during storage on viability of spores of *Pteris vittata* L. *Proc. Indian Natn Sci Acad* **B61**(4) : 315-322

BIR S S & VERMA S C 2010 *Chromosome Atlas of Indian Pteridophytes* (1951-2009). Bishen Singh Mahendra Pal Singh, Dehradun

BONDADA B, TU C & MA LENA 2006 Surface structure and anatomical aspects of Chinese brake fern (*Pteris vittata*; Pteridaceae), *Brittonia* **58**(3) : 217-228

BOUHARMONT J 1972a Meiosis and fertility in apogamously produced diploid plants of *Asplenium trichomanes*. *Chromosomes Today* **3** : 253-258

BOUHARMONT J 1972b Meiosis in apogamously produced diploid plants of *Asplenium septentrionale*. *Br. Fern Gaz* **10** : 237-240

BOUHARMONT J 1972c Originede la polyploidiechez *Asplenium ruta-muraria* L. *Bull Jard Bot Nat Belg* **42** : 375-383

CHANG Y-J, SHIEH J-L & TSAI J-L 1992 Studies on the karyotype of the fern genus *Pteris* from Taiwan *Proc Sem Asian Pterid* **II** : 93-109

CHAO Y-S & HUANG Y-M 2018 Spore morphology and its systematic implication in *Pteris* (Pteridaceae). *PloS one*, ***13***(11), PMC6261128, e0207712; pp 1-22 [doi:10.1371/journal.pone.0207712]

CHAO Y-S, LIU H-Y, CHIANG Y-C & CHIOU W-L 2012 Polyploidy and speciation in *Pteris*

(Pteridaceae) *J Botany*, volume **2012** : pp 1-7 (online open access)

CHAO Y-S, LIU Ho-Yih, HUANG Yao-Moan & CHIOU Wen-Liang 2010 Reproductive traits of *Pteris cadieri* and *P. grevilleana* in Taiwan: Implications for their hybrid origin. *Botanical Studies* **51** : 209-216

CHAO Y-S, ROUHAN G, AMOROSO V B & CHIOU W-L 2014 Molecular phylogeny and biogeography of the fern genus *Pteris* (Pteridaceae). *Ann Bot* **114** : 109-124

CORDLE A R, BUI L T, IRISH E E & CHENG C-L 2011 Laboratory-induced apogamy and apospory in *Ceratopteris richardii*, In *Working with Ferns: Issues and Applications*, (eds Helena Fernández, Ashwani Kumar & Maria Angeles Revilla), Springer Chap 3, pp 25-36

DE GROOT G A, DURING H J, ANSELL S W, SCHNEIDER H & BREMER P 2012a Diverse spore rains and limited local exchange shape fern genetic diversity in a recently created habitat colonized by long-distance dispersal. *Ann Bot* **109** : 965-978

DE GROOT G A, VERDUYN B, WUBS E R J, ERKENS E R J & DURING H J 2012b Inter- and intraspecific variation in fern mating systems after long distance colonization: the importance of selfing *BMC Plant Biology* 2012, **12**(3): 1-12 (online)

DELGADO L, GALDEANO F, SARTOR M E, QUARIN C L, ESPINOZA F & ORTIZ J P 2014 Analysis of variation for apomictic reproduction in diploid *Paspalum rufum*. *Annals of Botany* **113 :** 1211-1218

DEVI S 1974 On the occurrence of bilateral spores in cultivated *Pteris longifolia* L. *Grana* **14**: 1-3

DHANDA R & PRASHAR I B 2018 Endophytic fungi from pteridophytes. In "*Pteridology Today : Challenges & Opportunities*" [eds S C Verma *et al.*] BSI Publication, Kolkata Pp 157-162

DYER R J, SAVOLAINEN V & SCHNEIDER H 2012 Apomixis and reticulate evolution in the *Asplenium monanthes* fern complex. *Ann Bot* **110** : 1515-1529

EKRT L & KOUTECHY P 2016 Between sexual and apomictic: unexpectedly variable sporogenesis and production of viable polyhaploids in the pentaploid fern of the *Dryopteris affinis* agg. (Dryopteridaceae). *Ann Bot* **117** : 97-106

FENG R W & WEI C Y 2012 Antioxidative mechanisms on selenium accumulation in *Pteris vittata* L., a potential selenium phytoremediation plant *Plant Soil Environ* **58**(3) : 105-110

FRASER-JENKINS C R 2008 *Taxonomic revision of three hundred Indian subcontinental pteridophytes with a revised census-list* pp 685 Bishen Singh Mahendra Pal Singh, Dehra Dun

FRASER-JENKINS C R 2017 A revised checklist of Indian Pteridophytes-1 *Indian Fern J* **33** : 193-205

FRASER-JENKINS C R, GANDHI K N, KHOLIA B S & BENNIAMIN A 2017 *An Annotated Checklist of Indian Pteridophytes* Part-1 (Lycopodiaceae to Thelypteridaceae) pp 562. Bishen Singh Mahendra Pal Singh, Dehra Dun [Released on 28-12-2016]

GÓMEZ-NOGUEZ F, LEÓN-ROSANO L M, MEHLTRETER K, OROZCO-SEGOVIA A, ROSAS I & PÉREZ-GARCÍA B 2017 Experimental measurements of terminal velocity of fern spores. *Amer Fern J* **107**(2) : 59-71

GRUSZ A 2016 A current perspective on apomixis in ferns *J Syst Evol* **54** : 656-665

HÅKANSSON A & LEVAN A 1957 Endo-duplicational meiosis in *Allium odorum*. *Hereditas* **43** : 179-200

HAUFLER C H 2014 Ever since Klekowski: Testing a set of radical hypotheses revives the genetics of ferns and lycophytes *Am J Bot* **101**(12) : 2036-2042

HOJSGAARD D, KLATT S, BAIER R, CARMAN J G & HORANDL E 2014 Taxonomy and biogeography of apomixes in angiosperms and associated biodiversity characteristics *Crit Rev*

Plant Sci **33 :** 414-427

IRUDAYARAJ V & MANICKAM V S 1987 In Bir S S (ed) SOCGI *Plant Chromosome Number Reports* V *J Cytol Genet* **22** : 156-163

KHARE P, BISWAS M & PRASAD S K 2014 Study of the gametophytes of *Pteris vittata* L. collected from different localities of Patna to show the effect of pollution on them *IOSR J Pharmacy & Biological Sci* **9**(2) : 5-13

KHARE P B & KAUR S 1983 Intraspecific polyploidy in *Pteris vittata* Linn. *Cytologia* (Tokyo) **48**(1) : 21-25

KHULLAR S P & MEHRA P N 1972 Cytotaxonomy of western Himalayan ferns. I. Schizaaecous series *Res Bull Sci (n s) Panjab Univ* **23** : 189-204

KLEKOWSKI E J Jr 1970 Populational and genetic studies of a homosporous fern-Osmunda regalis *Amer J Bot* **57** : 1122-1138

KLEKOWSKI E J Jr 1972 Evidence against genetic self incompatibility in the homosporous fern *Pteridium aquilinum* Evolution **26** : 66-73

KOBIR H & SEN U 1989 Spore variation in *Pteris* L. *Indian Fern J* **6** : 133-139

LAIRD S & SHEFFIELD E 1986 Antheridia and archegonia of the apogamous fern *Pteris cretica Ann Bot* **57**(2) : 139-143

LLOYD R M 1973 Facultative apomixis and polyploidy in *Matteuccia orientalis Amer Fern J* **63**(2) : 43-48

LLOYD R M 1974 Reproductive biology and evolution in the Pteridophyta *Ann Missouri Bot Gard* **61** : 318-331

LOTT M S, VOLIN J C, PEMBERTON R W & AUSTIN D F 2003 The reproductive biology of the invasive ferns *Lygodium microphyllum* and *L japonicum* (Schizaeaceae) : Implications for invasive potential *Amer J Bot* **90**(8) : 1144-1152

LOVIS J D 1977 Evolutionary patterns and processes in ferns *Adv Bot Res* **4** : 220-415

MA L Q, KOMAR K M, TU C, ZHANG W & CAI Y 2001 A fern that hyperaccumulates arsenic *Nature* **409** : 579

MAHABALE T S & KAMBLE S Y 1981 Cytology of ferns and other pteridophytes of western India *Proc Indian Natn Sci Acad* **B47**(2) : 260-278

MANTON I 1950 *Problems of Cytology and Evolution in the Pteridophyta*. Cambridge Univ Press, Cambridge Pp 316

MANTON I & SLEDGE W A 1954 Observations on the cytology and taxonomy of the Pteridophyte flora of Ceylon *Phil Trans R Soc London* **238B** : 127-185

MANTON I & WALKER S 1954 Induced apogamy in *Dryopteris dilatata* and *D filix-mas* and significance for the interpretation of two species *Ann Bot* (n s) **18** : 377-383

MARTINEZ A E, CHIOCCHIO V, EM L T, RODRIGUEZ M A & GODEAS A M 2012 Mycorrhizal association in gametophytes and sporophytes of the fern *Pteris vittata* (Pteridaceae) with *Glomus intraradices Rev Biol Trop* **60**(2) : 857-865

MARTINEZ O G 2010 Gametófitos y esporófitos jóvenes de cautro especies de helechos del género *Pteris* (Pteridaceae) naturalizadas en America *Rev Biol Trop* (*Int J Trop Biol*) **58**(1) : 89-102

MASUYAMA S & WATANO Y 1990 Trends for inbreeding in polyploid pteridophytes *Plant Species Biol* **5** : 13-17

MEHRA P N 1938 Apogamy in *Adiantum lunulatum* Burm., Part I (Morphological) *Proc Indian Acad Sci* - Section **B**, **8** : 192-201

MEHRA P N 1961 Cytological evolution of ferns with particular reference to Himalayan forms *Proc 48th Indian Sci Congress* (Part II, Presidential Address), **48** : 130-153

MEHRA P N 1975 Some aspects of differentiation in cryptogams Res Bull Panjab University (N S) **23** : 221-242

MEHRA P N & KHULLAR S P 1977 Biosystematics of the *Adiantum lunulatum* complex in India with special reference to W. Himalayan Taxa *Cytologia* **42** : 501-511

MEHRA P N & SULKALYAN D S 1969 *In vitro* studies on apogamy, apospory and controlled differentiation of the rhizome segments of the fern *Ampelopteris prolifera* (Retz) Copel. *Bot J Linn Soc* **62** : 431-443

MOTTIER D M 1925 Polyembryony in certain Polypodiaceae and Osmundaceae *Bot Gaz* **80** : 331-336

MUMPUNI M, CHIKMAWATI T & PRAPTOSUWIRYO T N 2015 Polyplodi intraspsifik *Pteris vittata* L. (Ptridaceae) di pulau Jawa *Floribunda* **5**(2) : 53-59

NAYAR B K & DEVI S 1966 Spore morphology of the Pteridaceae I. The pteridoid ferns *Grana* **6**(3) : 476-502

NAYAR B K & DEVI S 1968 Spore morphology of the Pteridaceae IV. Taxonomic and phyletic considerations *Grana* **8**(2-3) : 517-535

PALACIOS-RIOS M, CARMEN P, GABRIEL Y, GALÁN J M & NOA J 2017 Spore types in Mexican and Mesoamerican species of *Pteris* L. (Pteridaceae) *Grana* **56**(4) : 241-256

PALTA H K & MEHRA P N 1983 *In vitro* induction of polyhaploid and octoploid *Pteris vittata* L. and their meiosis *Caryologia* **36** : 325-332

PRASHAR I B & DHANDA R K 2017 Fungal associations in pteridophytes *Indian Fern J* **34** : 104-116

PUSPITASARI D S, CHIKMAWATI, T. & PRAPTOSUWIRYO, T. N. 2015 Gametophyte morphology and development of six species of *Pteris* (Pteridaceae) from Java Island Indonesia. *J. Tropical Life Sciences* **5**(2): 98-104

RAGHAVAN V 1989 *Developmental Biology of Fern Gametophytes*. Cambridge University Press, Cambridge, New York

ROY R P, SINHA B M B & SAKYA A R 1971 Cytology of some ferns of Kathmandu valley *Brit Fern Gaz* **10**(4) : 193-199

SINGH V J & KHARE P B 2018 Comparative morphology of *Pteris vittata* Linn. from three phyto-geographical regions *Indian Fern J* **35** : 130-138

SRIVASTAVA M, SRIVASTAVA G K & NAUTIYAL D D 1995 Spore morphology of some species of *Pteris* L. *Birbal Sahni Centenary Volume* **1995** (Lucknow) : 409-436

TUCKER M R & KOLTUNOW M G 2009 Sexual and asexual (apomictic) seed development in flowering plants : molecular, morphological and evolutionary relationships *Functional Plant Biol* **36** : 490-504

VERMA S C 1979 Apogamous systems in ferns and subsexuality : A Discussion. In *'Glimpses in Plant Research'* (ed P K Nair), Vikas Publishing House, Delhi, Volume **4** : 84-97

VERMA S C 2000 An appraisal of some issues in the evolutionary cytogenetics of homosporous ferns *Bionature* **20** : 55-74

VERMA S C 2003 Some aspects of reproductive biology of the gametophyte generation of homosporous ferns. Chapter 31, In *'Pteridology in the New Millennium'* (eds S Chandra & M Srivastava), Kluwer Academic Publishers, Netherlands Pp 455-484

VERMA S C 2013a A note on spontaneous apogamy in gametophyte cultures of *Pteris vittata* L. *Indian Fern J* **30** : 221-223

VERMA S C 2013b Advocating critical revisiting of the Chinese ladder brake fern-complex in India *Indian Fern J* **30** : 224-254

VERMA S C 2017 Fresh look at the cytology, genetics and evolutionary potential of agamospory in homosporous ferns *Bionature* **37**(2) : 86-106

VERMA S C & KAPUR S K 1972 Genetic systems in homosporous ferns-III, Comparative study of breeding system in three Adiantaceous ferns. In *'Biology of Land Plants'* (ed Y S Murty, Sarita Prakashan, Meerut), Pp 227-240

VERMA S C & KHULLAR S P 1965 Cytogenetics of the western Himalayan *Pteris cretica* complex *Ann Bot* **29** (No. 116) : 673-681

VERMA S C & KHULLAR S P 1976 Adaptive significance of simultaneous cytokinesis in pteridophytes. *Phtomorphology* **26** : 96-102

VERMA S C & KHULLAR S P 1978 Some considerations of spore morphology and evolutionary biology in ferns *Int Palyno Conf Proceedings* IV, Birbal Sahni Institute of Paleobotany, Lucknow, **1** : 143-151

VERMA S C & MANI SELVAN P 2001 Intraspecific variation in spore-size of homosporous ferns and its implications on fern mating systems *Bionature* **21**(1) : 1-9

WALKER T G 1962 Cytology and evolution in the fern genus *Pteris Evolution* **16** : 27-43

WALKER T G 1966 Apomixis and vegetative reproduction in ferns. In : Hawkes J G, ed *Reproductive Biology and Taxonomy of Vascular Plants* Hampton, Middlesex : *Bot Soc Brit Isles*, 152-161

WALKER T G 1979 *The Cytogenetics of Ferns* Chap 4, In : Dyer, A F (Ed) '*The Experimental Biology of Ferns*', Academic Press, New York Pp 87-132

WALKER T G 1985 Some aspects of agamospory in ferns — the Braithwaite system *Proc Royal Soc Edinb* **86B** : 59-66

WAN X-M, LIE M, HUANG Z-C, CHEN T-B & LIU Y-R 2009 Sexual Propagation of *Pteris vittata* L. Influenced by pH, Calcium, and Temperature *Int J Phytoremediation* **12**(1) : 85-95

WANG Z-R 1989 A preliminary study on cytology of Chinese *Pteris Acta Phytotax Sincica* **27**(6) : 421-438

YANG DONG-MEI, WANG FA-GUO & XING FU-WU 2010 Studies on sexual reproductive characteristics of *Pteris vittata* L. in soil culture *Amer Fern J* **100**(4) : 2019-229

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OPHIOGLOSSUM GUJARATENSE PATIL, KACHHIYAPATEL, PATEL AND RAJPUT (OPHIOGLOSSACEAE) – A NEW RECORD FOR RAJASTHAN, INDIA

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ABSTRACT

Ophioglossum gujaratense Patil, Kachhiyapatel, Patel and Rajput, a new species of *Ophioglossum* L., recently reported from Panchmahal district of Gujarat state of India, has now been recorded from Mainal in district Chittorgarh of Rajasthan, India. The detailed morphology, distribution, ecology, conservation status and photographs are given herewith.

Key Words : *Ophioglossum gujaratense*, Mainal, Rajasthan

INTRODUCTION

The cosmopolitan genus *Ophioglossum* L. of family Ophioglossaceae is represented by more than 45 species (Clausen 1938, Pichi-Sermoli 1954, Wieffering 1964, Yadav and Goswami, 2010). In contrast, PPG I (2016), accepted 41 species. Of which 17 species are reported from India (Mahabale 1962, Wieffering 1964, Panigrahi & Dixit 1969, Dixit 1984, Khullar 1994, Goswami 2008, Sharma *et al.* 2008, Yadav and Goswami 2010, Fraser-Jenkins *et al.* 2017, Patil *et al.* 2018, Patel *et al.* 2018, Patel & Reddy 2019). 7 species of this genus (viz. *O. costatum* R. Br., *O. gramineum* Willd., *O. indicum* Yadav & Goswami, *O. lusitanicum* L., *O. parvifolium* Grev. & Hook., *O. petiolatum* Hook. and *O. reticulatum* L.) are found in Rajasthan (Mital 1968, Sharma & Singh 1984, Gena 1998, Yadav & Tripathi 2002, Yadav 2010, Yadav and Goswami 2010, Yadav & Meena 2011, Yadav 2015, Yadav 2018). The botanical excursion carried out during 2017-18 in search of pteridophytes of Rajasthan, authors came across a unique specimen of *Ophioglossum*, which was different from the species reported earlier from the state. After thorough survey of the literature and critical study of morphological characters, it was identified as *Ophioglossum gujaratense* Patil, Kachhiyapatel, Patel and Rajput, recently described from the Gujarat state of India. Therefore, it is reported in the present paper as a new distributional record for Rajasthan.

MATERIALS AND METHODS

Material was collected from Mainal, Chittorgarh, Rajasthan. Field observations such as habitat, associated plant species, altitude and latitude and height from the sea level were recorded. Morphological observations were made on fresh as well as herbarium material. All the measurements were recorded in matric scale. Venation pattern was observed by

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clearing FAA fixed leaves in 10% NaOH solution for 24 hours, washed in water and kept in saturated solution of chloral hydrate until transparent (Arnott 1959). Species identification was done following standard literature (Khullar 1994, Goswami *et al.* 2008, Sharma *et al.* 2008, Yadav and Goswami 2010, Fraser-Jenkins 2017, Patil *et al.* 2018, Kachhiya Patel *et al.* 2018, Patel & Reddy 2019). Voucher specimens were deposited in the Herbarium, Mewar University, Gangrar, Chittorgarh, Rajasthan, India.

OBSERVATIONS AND DISCUSSION

Taxonomic Treatment

Ophioglossum gujaratense Patil, Kachhiyapatel, Patel and Rajput, Phytotaxa 351 (4): 273-280 (Plate I Fig. A-F & Plate II Fig. A-F)

Plants terrestrial, 1.1-2.5 cm in height; rhizome tuberous, subterranean, stoloniferous, 0.3-0.5 cm long, 0.2-0.3 cm broad; roots fleshy, brownish, arising from the entire surface of rhizome in acropetal succession; common stalk 0. 2-0. 7 cm with leaf sheath, white, remain buried in the soil, Tropophyll 1-4, parallel to and touching or slightly above the soil surface, thickish, 0.7-0.9 cm long and 0.5-0.6 cm broad, elliptic, elliptic-lanceolate, glabrous, entire, acute, base cuneate; venation reticulate with free vein endings, principal veins forming large primary areoles in which are included secondary areoles in the middle portion of the leaf; fertile segment 1.1-2.2 cm long arising from the junction of common stalk and lamina, peduncle 0.7-1.5 cm long, cylindrical, strobilus 0.4-0.6 cm long, thick, with two lateral rows of sporangia with or without sterile tip, sporangia 6-12; spores 19-28 μm in diameter, trilete, sporoderm verrucose under LM

Fertile : July-August

Distribution :

INDIA: It has recently been described as the new species from Panchmahal district of Gujarat state of India.

Rajasthan : Mainal, Chittorgarh district.

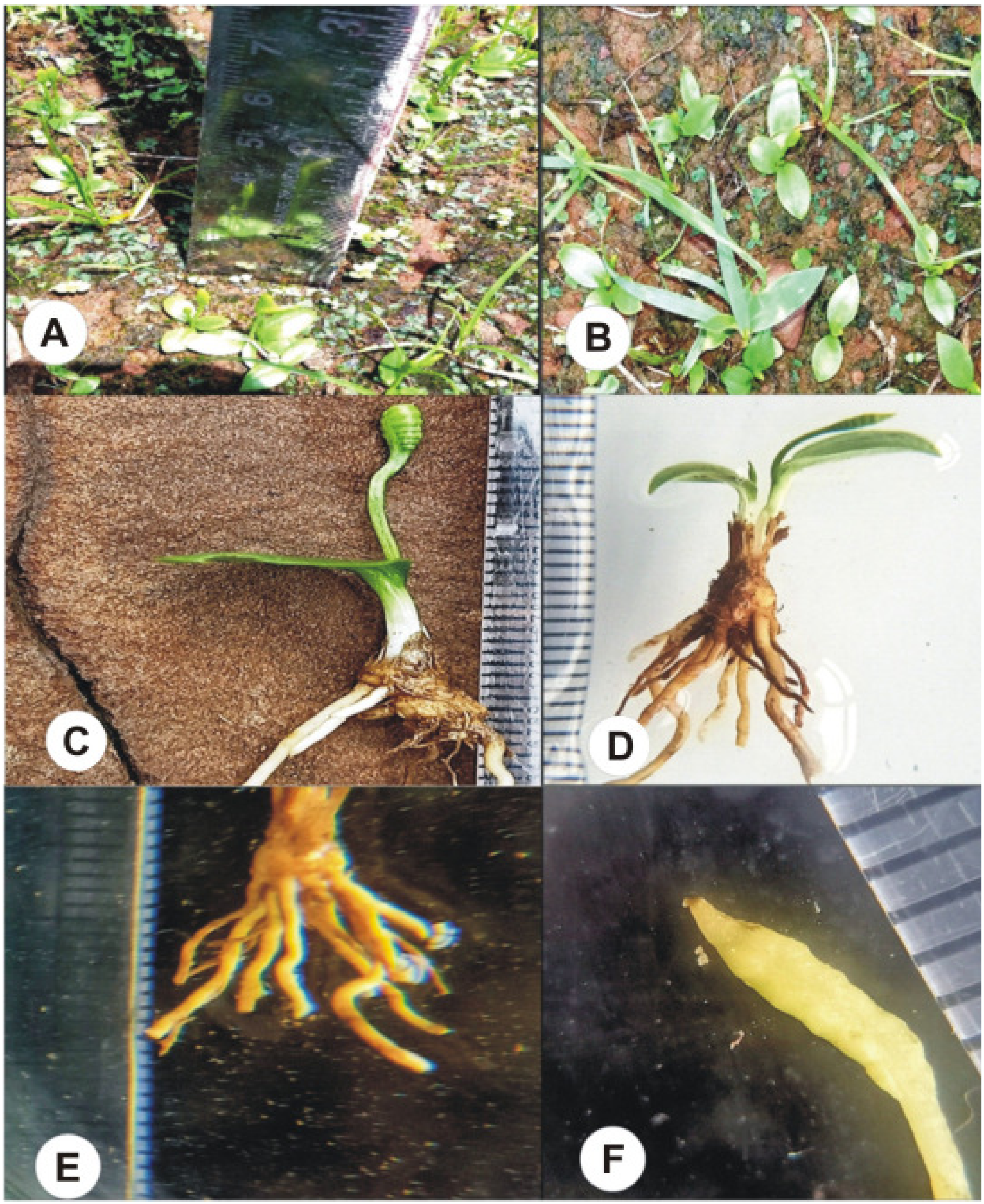
Ecology : Species grows in association of *O. parvifolim* Grev. & Hook. *O. gramineum* Willd. (Plate II Fig. D), *Borreria articularis* (L.) Will. and the grasses on damp soil.

Conservation Status : Since this taxon has been recorded from the single locality and therefore, the survey of other parts of Rajasthan is needed to get the complete picture of its distributional range in the state, thus, at present, the species has been treated as Data Deficient (DD) following IUCN criteria.

Specimen examined : India, Rajasthan, Chittorgarh district, Mainal, 25^0 5'15" N 75^o 10' 01" E, 513 m, 04.08.2018, B. L. Yadav 016MUCR (Mewar University, Chittorgarh, Rajasthan)

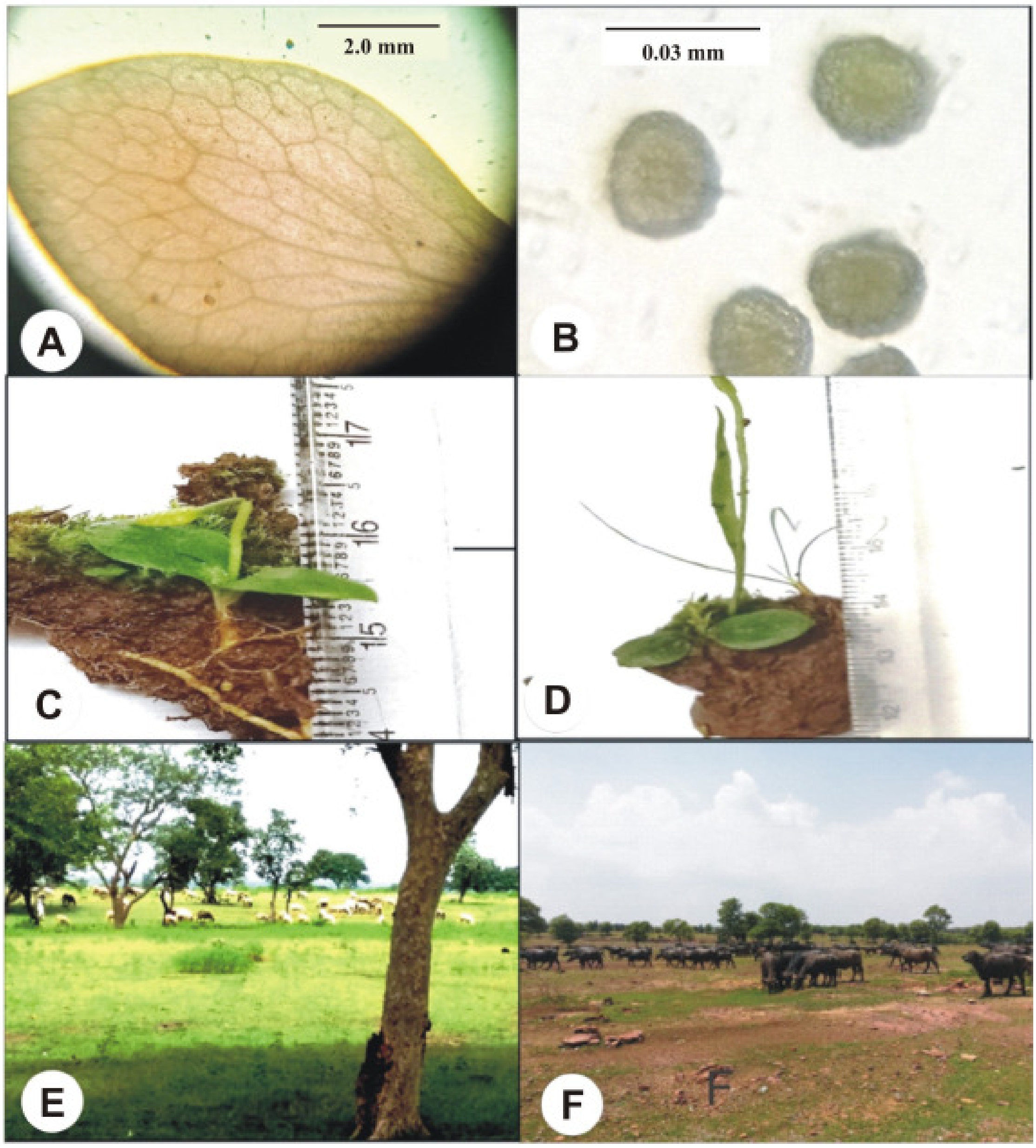
O. gujaratense Patil, Kachhiyapatel, Patel and Rajput has been collected from 200-300 m msl from Gujarat (Patil *et al.* 2018) while it grows at 500 m msl in Rajasthan. The Mainal locality in district Chittorgah of Rajasthan is the part of plateau region and is

PLATE I



Figs. A-F. *Ophioglossum gujaratense* : **A, B** - Habitat, **C** - Habit, **D** - Common stalk with leaf sheath, **E** - Tuberous rhizome, **F** - Spike

PLATE II



Figs. A-F *Ophioglossum gujaratense* : **A** - Venation, **B** - Spores (19-28 µm), **C** - Subterranean common stalk & rhizome, **D** - Contiguous Occurrence of *O. gramineum* & *O. gujaratense,* **E, F** - Heavy pressure of grazing richest in *Ophioglossum* L. supporting the occurrence of five species (*O. costatum* R. Br., *O. gramineum* Willd., *O. indicum* Yadav & Goswami, *O. parvifolium* Grev. & Hook. and *O. petiolatum* Hook.) of this genus but facing the pressure of heavy grazing (Plate II Fig. E, F) which has detrimental effect on the growth and development of natural vegetation. Therefore, steps for the protection of this locality where these species are growing should be taken up.

O. gujaratense Patil, Kachhiyapatel, Patel and Rajput differ from *O. parvifolium* Grev. & Hook. and *O. nudicaule* L. f. in having the distinct sheathing leaf base and from that of *O. polyphyllum* Braun in having the tropophylls parallel to the substratum, common stalk subterranean, and tropophyll elliptic. The similarities and differences among *O. parvifolium* Grev. & Hook., *O. nudicaule* L. f., *O. polyphyllum* Braun and *O. gujaratense* Patil, Kachhiyapatel, Patel and Rajput, have been reported by Patil *et al.* (2018).

Another species namely *Ophioglossum aletum* Patel, Reddy and Goswami has also been reported from Dang district of Gujrat (Patel *et al.* 2018) which is larger sized than *O. gujaratense.* The latter one has tropophyll 1-4, elliptic, elliptic lanceolate, horizontal to the substratum, common stalk entirely subterranean with sheathing leaf base, spores trilete in contrast to former species which has tropophyll 1-2, ovate, ovate oblong or deltoid not horizontal, common stalk partially subterranean without sheath, and spores alete (Patel *et al*. 2018).

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REFERENCES

ARNOTT J H 1959 Leaf clearings *Turtox News* **37** : 192

CLAUSEN R T 1938 A monograph of the Ophioglossaceae *Mem Torrey Bot Club* **19** : 1-117

DIXIT R D 1984 *A Census of the Indian Pteridophytes* Series IV. Botanical Survey of India, Govt of India, New Delhi

FRASER-JENKINS C R, GANDHI K N, KHOLIA B S & BENNIAMIN A 2017 *An Annotated Checklist of Indian Pteridophytes Part-I (Lycopodiaceae to Thelypteridaceae)* pp 562 Bishen Singh Mahendra Pal Singh, Dehra Dun

GENA C B 1998 Systematics and taxonomy of pteridophytes of Rajasthan Fifty years of Pteridology in India *Indian Fern J* **15** : 139-148

GOSWAMI H K 2008 Biology of *Ophioglossum* L. In '*Biology of Pteridophytes*–I. *Ophioglossum* Linnaeus', Eds. H K Goswami, S C Verma & B D Sharma, 2008 *Bionature Monograph*, Catholic Press, Ranchi, pp 1-73

GOSWAMI H K, VERMA S C & SHARMA B D 2008 *Biology of Pteridophytes*–I. *Ophioglossum* Linnaeus Bionature Monograph Catholic Press, Ranchi Pp 135

KACHHIYAPATEL R N, PATIL S M, PATEL S K & RAJPUT K S 2018 Genus *Ophioglossum* L. from Western Part of India with special reference to Gujarat State *Notulae Scientia Bioloicae* **10(3)** : 373-378

KHULLAR S P 1994 *An Illustrated Fern Flora of the West Himalaya* (Vol. **I**) International Book Distributers, Dehra Dun (India)

MAHABLE T S 1962 Species of *Ophioglossum* in India Their taxonomy and phylogeny *Bull Bot Surv India* **4** : 71-84

MITAL P L 1968 Ferns and fern allies of Rajasthan III Hitherto unrecorded species of *Ophioglossum* from Rajasthan *Bull Bot Surv India* **10** : 171-176

PICHI-SERMOLI R E G 1954 Adumbratio florae Acthiopicae 3 Ophioglossaceae, Osmundaceae, Schizaeceae *Webbia* **9** : 623-660

PANIGRAHI G & DIXIT R D 1969 Studies in Indian pteridophytes IV the family Ophioglossaceae in India *Proc Nat. Inst Sci India* **35B** : 230-266

PATEL M & REDDY M N 2019 Revealing a new species of *Ophioglossum* (Ophioglossaceae-Pteridophyta) from India with palynological and phylogenetic implications *Botany Letters* DOI 10.1080/23818107.2019.1636405

PATEL M, REDDY M N & GOSWAMI H K 2018 A terrestrial large-sized *Ophioglossum aletum :* New species from Gujarat, *India Indian Fern J* **35 :** 318-331

PATIL S M, KACHHIYAPATEL R N, PATEL R S & RAJPUT K S 2018 *Ophioglossum gujaratense*, a new species from Gujarat state India *Phytotaxa* **351(4)** : 273-280 doi: 10.11646/phytotaxa 351.A

PPG-I 2016 A community-derived classification for extant lycophytes and ferns *Journal of Systematic and Evolution* **54(6)** : 563-603

SHARMA B D & SINGH R 1984 *Ophioglossum* L in Rajasthan: Morphology and anatomical studies *Indian Fern J* **1** : 97-104

SHARMA B D, BOHRA D R, SUTHAR O P & HARSH R 2008 *Ophioglossum* in India-A Review In '*Biology of Pteridophytes*–I. *Ophioglossum* Linnaeus', Eds. H K Goswami, S C Verma & B D Sharma, 2008 Bionature Monograph, Catholic Press, Ranchi, pp 75-96

WIEFFERING J H 1964 A preliminary revision of the Indo-Pacific species of *Ophioglossum* (Ophioglossaceae) *Blumea* **12** : 321-337

YADAV B L 2010 Study on the distribution and current status of pteridophytes in Rajasthan India *J Fairylake Bot Garden China* **9(3)** : 35-39

YADAV B L 2015 Pteridophytic Diversity in Hadauti region of Rajasthan, India *The Journal of Biodiversity*, *Photon* **115** : 432-440, 2015

YADAV B L 2018 Observation on some Indian species of *Ophioglossum* L. from Rajasthan In *Pteridology Today Challenges and Opportunities* Eds: S C Verma, S P Khullar, A Benniamin, P Lakshminarasimhan & Paramjit Singh 2018 *Botanical Survey of India* pp 243-254

YADAV B L & MEENA K L 2011 Observations on fern genus *Ophioglossum* L. from Rajasthan India *Indian Fern J* **28** : 57-75

YADAV B L & GOSWAMI H K 2010 A new pink brown *Ophioglossum* L. from India *Bull Natl Mus Nat Sci* Ser B **36(4)** : 155-159

YADAV B L & TRIPATHI M K 2002 *Ophioglossum* Linn. in Rajasthan-Taxonomy and Distribution In *Advances in Pteridology* Ed. P C Trivedi, Pointer Publisher, Jaipur pp 248-267

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ANTIBACTERIAL POTENTIAL OF DIFFERENT PLANT PARTS OF *DAVALLIA GRIFFITHIANA* HOOK., *BLECHNUM ORIENTALE* L. AND *PHYMATOSORUS CUSPIDATUS* D. DON ON SOME PATHOGENIC BACTERIA

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ABSTRACT

Pteridophytes are frequently used from time immemorial for horticultural as well as ethno-medicinal purposes. Plant extracts from different plant parts in different solvents have antibacterial potentials against some pathogenic bacteria. The variations of the potential property from the different plant parts are recorded and inhibition zones are quite responsive to determine the appropriate dosage for their applications. The present study includes recording the use of three plants which are widely distributed in Rongtong and its adjoining areas of Darjeeling district and grow almost throughout the years and easily can be collected in huge masses. The study also established the importance of this neglected group of plants and creates interest for their in-situ conservation to preserve biodiversity.

Key Words : Antagonistic potential, Plant extracts, Pathogenic bacteria

INTRODUCTION

People of India, China and many other countries used plants in medicinal practices since thousands of years. Atharvaveda, which is based on Ayurvedic medicine of India, dating back from 2000 BC recorded plants used as drugs, clay tablets used in Mesopotamia (1700 BC) and the Eber Papyrus in Egypt (1550 BC) (Sneader, 2005). Charak and Sushruta (600 BC) recognised ferns having medicinally importance, among them *Dryopteris filix-mas*, the male fern, used as vermifuge. Several Indian workers like Chopra (1933), Puri & Arora (1961) also described some ferns with medicinal uses.

Pteridophytes are the oldest vascular plants being recorded from the Silurian – Devonian period and are still perpetuating successfully (Edwards & Feehan, 1980; Stewart & Rothwell, 1993). Throughout the world, there are 10,000 species of ferns and lycophytes and among these 10% are present in India (Fraser -Jenkins 2008). From ancient time still, they played an important role in folk medicine (Dixit 1974), Homeopathy and Ayurvedic and the knowledge is transferred from different tribal inhabitants to new generations. Pteridophytes are also used in the Unani system of medicines (Uddin *et al.*1998). It has been observed that pteridophytes are rarely infected by microbial pathogens, which may be one of the important factors for the evolutionary success of pteridophytes and for their survival (Page 1979; Sharma & Vyas 1985). They are the least explored plant group comparing to others group of plants. Highly diversified fern and fern allies are found in

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tropical and sub-tropical regions whereas limited distribution was found in temperate zone and they are distributed through longitudinal gradient. Several researchers from time to time from world showed the therapeutic properties of certain fern species (Singh 1999,2003).

Crude extracts of major plant parts such as stem, leaf, root, fruit and seeds are used for screening of anti-microbial responses but pteridophytes are lower group of plants and they do not contain such type of parts (fruits and seeds). Ferns are non-flowering plants having underground part, rhizome and aerial part, fronds. Fern extracts has been found to have anti-microbial activity against both Gram positive and Gram-negative organisms (Banerjee & Sen 1980, Sen & Nandi 1980, Ganguly *et al.* 2011). According to Lee & Shin (2011), microorganisms grows in various substrates and even in anti-microbial agents such as antibiotic sprays, packing materials, toothpaste and handwash which are used to sanitize our living environment against undesirable microbes. Ferns contain many useful phytochemicals (secondary metabolites) such as phenols, alkaloids, flavonoids, triterpenoid compounds, varieties of amino acids and fatty acids (Zeng-fu *et al.* 2008); and may be due to these phytochemicals pteridophyte shows antibacterial activity (Gehlot & Bohra 1995).

Davallia griffithiana Hook**.** is used for many purposes in Chinese medicine (Lahiri *et al.* 2016). The fresh fronds of *Blechnum orientale* are used as a poultice for boils in Malaya; the rhizome is used as an anthelmintic in China, eaten during scarcity of food in Malaya, as cure for intestinal worms, bladder complaints in India, Polynesia and as diaphoretic, aromatic in Philippines (Dixit & Vohra 1984). Hot decoction of pinnae is applied externally over abscess to liberate pus and for its antiseptic action. Rhizome is used as anthelminthic in China and used to cure intestinal wounds and typhoid. Fresh decoction is applied once a day, till abscess dries up (Shil & Dutta Choudhury 2009). In Indo-China, fronds of *Phymatosorus cuspidatus* D. Don are used in boils and filariasis; whole fronds are used to ward off bed bugs whereas the young fronds are used for curing chronic diarrhoea (Mannan *et al.* 2008). Fronds are also used in influenza, diarrhoea, stomach ache, weakness and strains in Fiji (Cambie & Ash 1994). In Samoa, rhizomes and leaves are used in various ailments (Whistler, 1992). Leaves or rhizomes are used in pneumonia, gonorrhoea, leucorrhoea, stomach ache, sterility, dislocations and fractures (Pétard 1972). In New California rhizome juice used in sinusitis (Grépin & Grépin 1984) and poisoning occasioned by eating fish (Bourdy *et al.* 1992) and fronds are used as an anti-rheumatism liniment (Rageau 1983).

MATERIALS AND METHODS

Materials used

1. Plants

(a) ***Davallia griffithiana*** Hook. (Davalliaceae) is a terrestrial fern (Plate I, Figure 2, A; 3, A). Rhizomes are long, creeping, and densely scaly. Fronds distantly oriented, deltoid-pentagonal, tripinnate to quadric-pinnatifid, acuminate. Stipes long, articulate, grooved dorsally, tough, glaborous. Rachis is similar to stipes. Costae winged, oblique or unequal deltoid-lanceolate. Sori terminal on veins, indusium half cup shaped, upper half of the margin free, thick, wider than long, entire to subentire, brownish.

(b) *Blechnum orientale* L. (Blechnaceae) is also a terrestrial fern (Plate I, Figure 2, B: 3, B). Stocks are erect. Stipes tufted, erect, auriculate pinnae throughout, veins indistinct, dense, unbranched or branched at the base, rarely joining at the middle, all reaching the margin. Sori continuous along the costules, except towards the apex and base.

(c) *Phymatosorus cuspidatus* D. Don (Polypodiaceae) (Plate I, Figure 2, C; 3, C) is an epiphyte, with wide, creeping and glabrescent rhizomes. It is found growing in the crowns or trunks of trees and on rocks, at low and medium altitudes. Stipes are scattered. Fronds are variable in size, from simple lanceolate to deeply pinnafid. Costae are prominent but the venation is hardly visible. Sori are very large, shallowly immersed and conspicuous on the upper surface, in single rows along the main veins, or scattered, but not numerous.

2. Bacteria

(a) *Bacillus subtilis* (MTCC NO. 1610)
(b) *Escherichia coli* (MTCC NO. 736),
(c) *B. spizizenii* (ATCC NO. 6633) and
(d) *Staphylococcus aureus* (ATCC NO. 25923)

3. Controls

(a) Positive Control – Streptomycin (10 mcg)
(b) Negative Control – DMSO (Dimethyl Sulfoxide)

Methods :

Collection of Plant Materials

Different parts of the plants (rhizome and leaves) of *Davallia griffithiana* Hook., *Blechnum orientale* L. and *Phymatosorus cuspidatus* D. Don were collected from departmental garden, Rongtong and its adjoining area (Plate I, Figure 1) (Latitude → $26^0$40'N-$27^0$00'N; Longitude →87°55'E-$88^0$10'E) of Darjeeling district, East Himalayan region for a period of last 15 days of February, 2019. The plants were authenticated with the help of published literatures (Khullar 1994, 2000).

Preparation of Plant Extract

This routine procedure was followed as Nath *et al.* (2016) with slight modification. The plant materials were washed, sterilized with 70% alcohol, shade dried and powered. 1 gm. of powder was extracted through hot percolation method with 20 ml. of the solvents such as methanol and ethanol with 50% and 80% gradient for 72 hrs. After 72 hrs. the samples were crushed and centrifuged at 3000 rpm for 15 mins. The supernatants were taken (Plate I, Figure 4) and kept in hot-air oven at 40°C to allow the solvents to evaporate. The dry plant extracts were mixed with 1 ml. of DMSO and stored at 4°C.

The Inoculum

The inoculum for anti-bacterial assay was prepared by inoculating freshly grown bacterial culture in sterilized nutrient broth (NB) and incubated for 24 hrs at 35°C in shaker incubator.

Anti-Bacterial Activity

This routine procedure was followed as Manhas *et al.* (2018). The NA plates were welled by sterile cork borer having 3 mm diameter and seeded with bacterial inoculums with sterile cotton swab. The plates were inoculated with this swab, first in horizontal direction then in a vertical direction, which ensure the even distribution of bacteria throughout the plates and were allowed to dry for 10 mins. Plant solvents were added to these well and incubated at 35°C for 24 hours. The antimicrobial activity was expressed as the inhibition zone (IZ) produced by the plant extracts which was formed after the incubation and measured with transparent ruler in mm.

OBSERVATIONS

1. Anti-Bacterial Activity of Leaf Extracts of *D. griffithiana*

When leaf extracts were used against *B. subtilis, E. coli, S. aureus* and

TABLE 1 : Inhibition Zone Produced by Leaf and Rhizome Extracts of *D. griffithiana*

Name of the Bacteria	Solvent Gradation	Inhibition Zone	
		For L. E.	For R. E.
Bacillus subtilis	50%M	9 mm	7 mm
	80%M	10 mm	6 mm
	50%E	9 mm	6 mm
	80%E	8 mm	7 mm
Escherichia coli	50%M	-	5 mm
	80%M	6 mm	7 mm
	50%E	5 mm	6 mm
	80%E	6 mm	7 mm
Staphylococcus aureus	50%M	-	7 mm
	80%M	-	7 mm
	50%E	-	7 mm
	80%E	-	8 mm
Bacillus spizizenii	50%M	-	-
	80%M	8 mm	-
	50%E	-	-
	80%E	-	-

Note : M – Methanol, E – Ethanol, L. E. – Leaf Extracts, R. E. – Rhizome Extracts

B. spizizenii then 80% methanolic leaf extract showed highest inhibition zone against *B. subtilis* and *B. spizizenii* and it was around 10 mm, 8 mm respectively. The leaf extracts also showed IZ against *B. subtilis* but in case of *E. coli* it did not show the standard IZ whereas against *S. aureus* leaf extracts had no anti-bacterial activity (Plate II, Figure 5) (Table 1).

2. Anti-Bacterial Activity of Rhizome Extracts of *D. griffithiana*

The rhizome extracts showed more or less similar results when they were used against *B. subtilis, E. coli* and *S. aureus* and the highest IZ was found in 80% ethanolic extract against *S. aureus* which was around 8 mm. But against *B. spizizenii* rhizome extracts did not show any inhibition zone (Plate II, Figure 6) (Table 1).

3. Anti-Bacterial Activity of Leaf Extracts of *B. orientale*

The leaf extracts were less effective against *Bacillus* sp. but against *E. coli,* and *S. aureus* extracts were highly effective. Among them 50% ethanolic leaf extract was highly inhibited against *E. coli* and *B. spizizenii* and it was around 14 mm. 80% methanolic and 50% ethanolic extracts were also effective against *E. coli* and *S. aureus* (Plate II, Figure 7) (Table 2).

TABLE 2 : Inhibition Zone Produced by Leaf and Rhizome Extracts of *B. orientale*

Name of the Bacteria	Solvent Gradation	Inhibition Zone	
		For L. E.	For R. E.
Bacillus subtilis	50%M	4 mm	7 mm
	80%M	6 mm	7 mm
	50%E	7 mm	5 mm
	80%E	5 mm	5 mm
Escherichia coli	50%M	5 mm	-
	80%M	13 mm	11 mm
	50%E	14 mm	6 mm
	80%E	-	5 mm
Staphylococcus aureus	50%M	-	9 mm
	80%M	10 mm	12 mm
	50%E	10 mm	8 mm
	80%E	8 mm	9 mm
Bacillus spizizenii	50%M	-	-
	80%M	-	-
	50%E	14 mm	-
	80%E	-	-

Note : M – Methanol, E – Ethanol, L. E. – Leaf Extracts, R. E. – Rhizome Extracts

4. Anti-Bacterial Activity of Rhizome Extracts of *B. orientale*

The rhizome extracts of *B. orientale* were effective against *B. subtilis, E. coli* and *S. aureus*. But the extracts did not show any inhibition zone against *B. spizizenii*. 80% methanolic extract showed the highest inhibition zone against *E. coli* and *S. aureus* and these were around 11 mm and 12 mm respectively (Plate III, Figure 8) (Table 2).

5. Anti-Bacterial Activity of Leaf Extracts of *P. cuspidatus*

The leaf extracts of *P. cuspidatus* showed inhibition zone against all the tested bacteria but it was not the standard inhibition zone. Extracts gave standard inhibition zone against only *Bacillus* sp. among them 80% ethanolic extract gave highest inhibition zone and it was around 10 mm (Plate III, Figure 9) (Table 3).

6. Anti-Bacterial Activity of Rhizome Extracts of *P. cuspidatus*

The rhizome extracts gave standard inhibition zone against *B. subtilis* and *S. aureus* 50% and 80% methanolic and 50% ethanolic extracts showed inhibition zone and it was 7 mm (Plate III, Figure 10) (Table 3).

TABLE 3 : Inhibition Zone Produced by Leaf Extracts of *P. cuspidatus*

Name of the Bacteria	Solvent Gradation	Inhibition Zone	
		For L. E.	For R. E.
Bacillus subtilis	50%M	8 mm	7 mm
	80%M	9 mm	7 mm
	50%E	7 mm	7 mm
	80%E	10 mm	-
Escherichia coli	50%M	8 mm	5 mm
	80%M	6 mm	5 mm
	50%E	6 mm	-
	80%E	6 mm	-
Staphylococcus aureus	50%M	6 mm	-
	80%M	6 mm	7 mm
	50%E	-	-
	80%E	-	-
Bacillus spizizenii	50%M	7 mm	-
	80%M	7 mm	-
	50%E	7 mm	-
	80%E	6 mm	5 mm

Note : M – Methanol, E – Ethanol, L. E. – Leaf Extracts, R. E. – Rhizome Extracts

PLATE I

Figure 1 : Map of Darjeeling district (where the collection sites are marked in red circle) (www.mapsofindia.com)

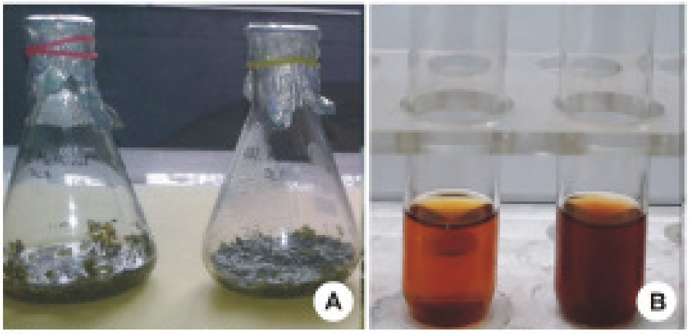

Figure 4 : Preparation of plant extracts. A - Plant parts were dipped in Solvents, **B** - Plant Extracts of different parts of fern

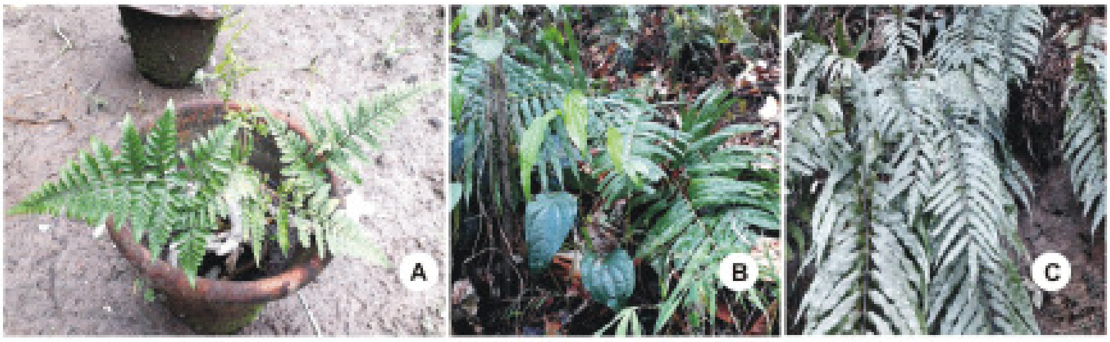

Figure 2 : Natural habitat of ferns. (**A** - *D. griffithiana* from Departmental Garden which is terrestrial, **B** - *B. orientale* from Rongtong is also terrestrial, **C** - *P. cuspidatus* from Chunbhatti is epiphyte)

Figure 3 : Herbarium of the ferns (**A** - *D. griffithiana*, **B** - *B. orientale* and **C** - *P. cuspidatus*)

PLATE II

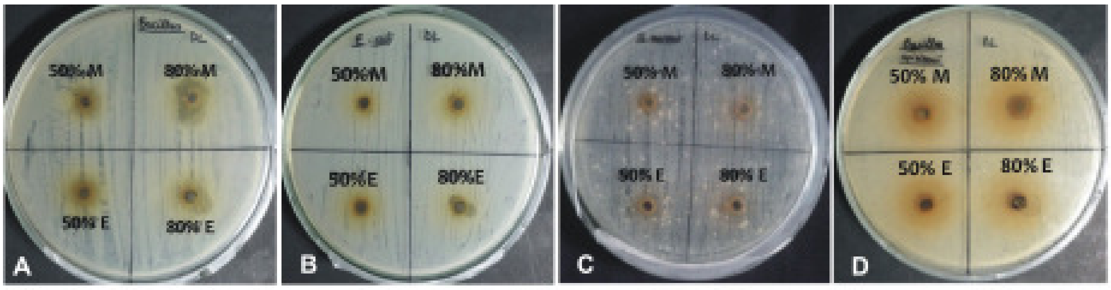

Figure 5 : Zone of inhibition produced due to effect of methanolic and ethanolic leaf extracts of *D. griffithiana* by **(A)** *B. subtilis;* **(B)** *E. coli;* **(C)** *Staphylococcus aureus*; **(D)** *B. spizizenii*

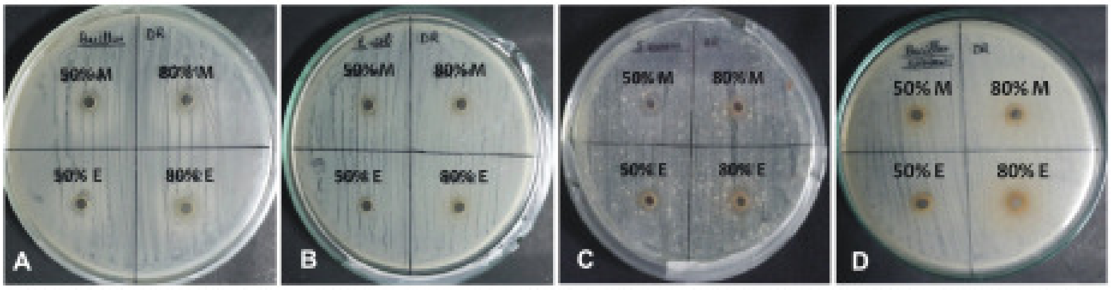

Figure 6 : Zone of inhibition produced due to effect of methanolic and ethanolic rhizome extracts of *D. griffithiana* by **(A)** *B. subtilis*; **(B)** *E. coli*; **(C)** *Staphylococcus aureus*; **(D)** *B. spizizenii*

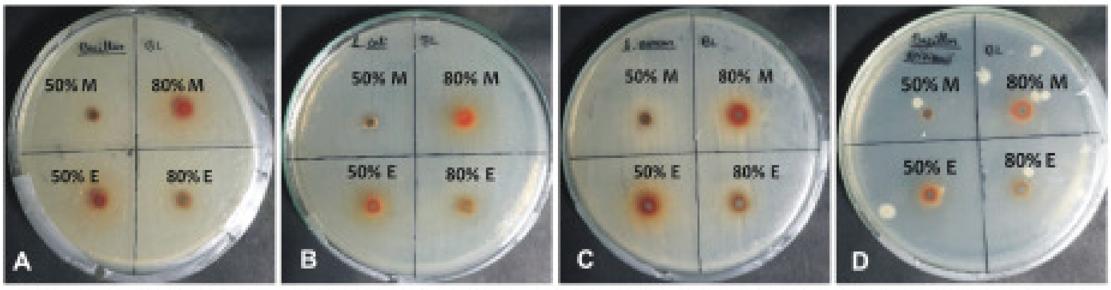

Figure 7 : Zone of inhibition produced due to effect of methanolic and ethanolic leaf extracts of *B. orientale* by **(A)** *B. subtilis*; **(B)** *E. coli*; **(C)** *Staphylococcus aureus*; **(D)** *B. spizizenii*

DISCUSSION

In the present study it was found that the leaf extracts showed more antibacterial activity than rhizome extracts. Here 80% methanolic leaf extract of *Davallia griffithiana* and 80% ethanolic leaf extracts of *Phymatosorus cuspidatus* showed the highest inhibition zone against *Bacillus subtilis* and it was around 10 mm whereas positive control showed 18 mm inhibition zone (Plate III, Figure 11, A). 80% methanolic and 50% ethanolic leaf extracts of *Blechnum orientale* also gave highest inhibition zone against *E. coli* and it was around 13 mm and 14 mm respectively which was moderately close to positive control

PLATE III

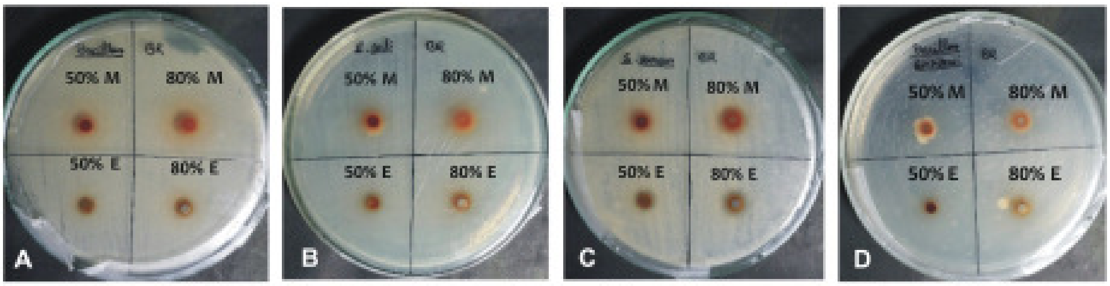

Figure 8 : Zone of inhibition produced due to effect of methanolic and ethanolic rhizome extracts of *B. orientale* by **(A)** *B. subtilis;* **(B)** *E. coli*; **(C)** *Staphylococcus aureus*; **(D)** *B. spizizenii*

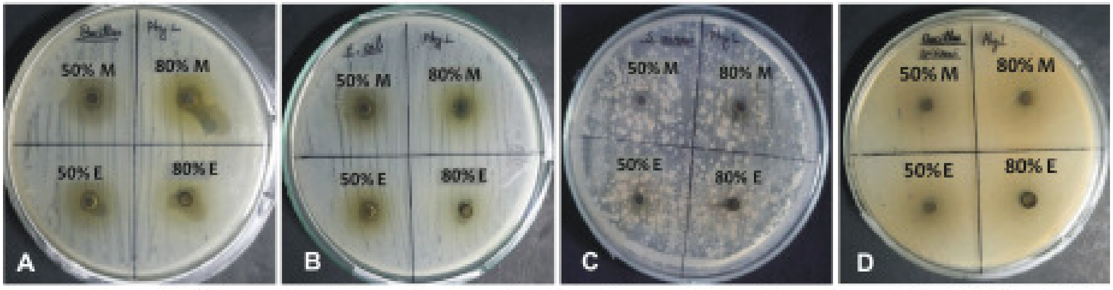

Figure 9 : Zone of inhibition produced due to effect of methanolic and ethanolic leaf extracts of *P. cuspidatus* by **(A)** *B. subtilis*; **(B)** *E. coli*; **(C)** *Staphylococcus aureus*; **(D)** *B. spizizenii*

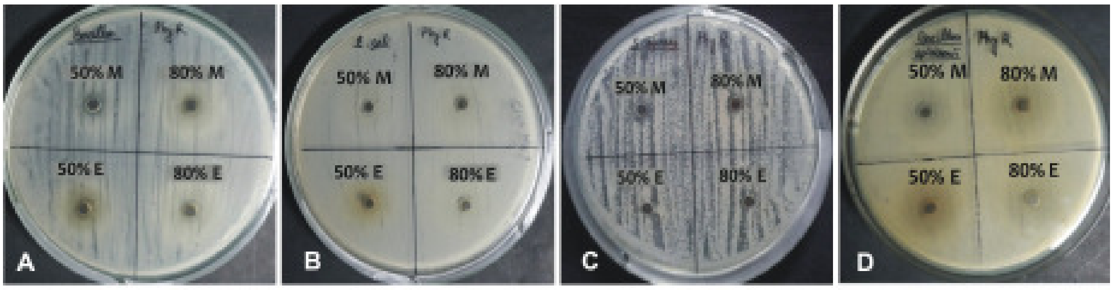

Figure 10 : Zone of inhibition produced due to effect of methanolic and ethanolic rhizome extracts of *P. cuspidatus* by **(A)** *B. subtilis*; **(B)** *E. coli*; **(C)** *Staphylococcus aureus*; (D) *B. spizizenii*

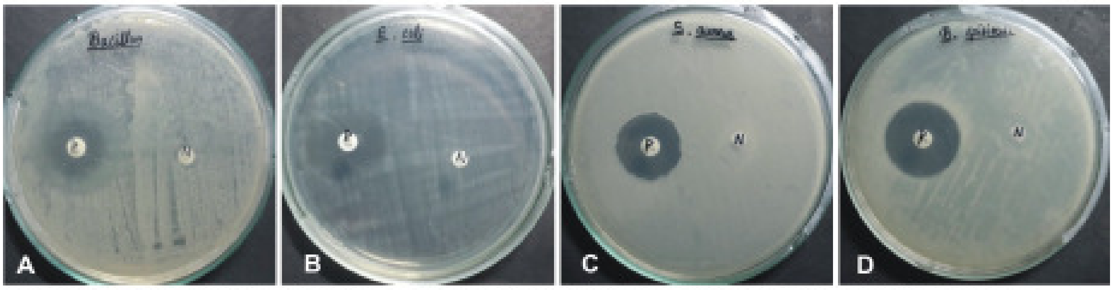

Figure 11 : Zone of inhibition produced by positive control used streptomycin (denoted as P) and no inhibition zone was produced by negative control used DMSO (denoted as N) by **(A)** *B. subtilis*; **(B)** *E. coli*; **(C)** *Staphylococcus aureus*; **(D)** *B. spizizenii*

i.e., 21 mm (Plate III, Figure 11, B). Antibacterial activities of some Pteridophytes commonly found in Rajasthan were studied by Parihar & Bohra (2001a-b, 2002a-b). But 50% ethanolic leaf extract of *Blechnum orientale* also inhibited the growth of *Bacillus spizizenii* and it was around 14 mm though positive control showed 26 mm IZ (Plate III, Figure 11, D). Although 80% methanolic rhizome extract of *Blechnum orientale* gave the highest IZ against *Staphylococcus aureus* and it was around 12 mm whereas positive control showed 22 mm IZ (Plate III, Figure 11, C). According to Banerjee & Sen (1980) and Kumar & Kaushik (2009) various pteridophytic plants have antibacterial activity. Leaf contains more secondary metabolites than rhizome to overcome different stress conditions or to avoid the microbial attack, so they showed more anti-bacterial activity than rhizome.

It was also found from this present study that methanolic extracts shows more antibacterial activity than ethanolic extracts. The 80% methanolic leaf extracts of *Davallia griffithiana* showed highest inhibition zone against *Bacillus subtilis* whereas 80% methanolic leaf and rhizome extract of *Blechnum orientale* also showed highest IZ against *E. coli,* it was around 13 mm and 11 mm respectively. Thomas (2010) also found that methanol extract inhibits the growth of *E. coli.* The highest IZ was showed by 80% methanolic rhizome extract of *Blechnum orientale* against *Staphylococcus aureus*. But ethanolic extracts were also having same effective against *Bacillus spizizenii*. Davvamani *et al.* (2005) found that ethanolic extract of *Dicranopteris linearis* showed good inhibition against some microbes. Gehlot and Bohra (1995) suggested that the antibacterial activity of pteridophytes may be due to the presence of phytochemicals or alkaloids in them. Among the phytochemicals, phenol is mainly responsible for the antimicrobial activity and it was studied by Guha *et al.* (2004).

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REFERENCES

BANERJEE R D & SEN S P 1980 Antibiotic activity of Pteridophytes *Ecol Bot* **34(3)** : 284-298

BOURDY G, CANABALION P, AMADE P & LAURENT D 1992 Traditional remedies used in the Western Pacific for the treatment of ciguatera poisoning *J Ethnopharmac* **36** : 163-174

CAMBIE R C & ASH J 1994 *Fijian Medicinal Plants* CSIRO, Australia; 23-24

CHOPRA R N 1933 *Indigenous Drugs of India : Their Medical and Economic Aspects* The Art Press 20, British Indian Street, Calcutta

DAVVAMANI S N, GOWRISHANKAR J, ANBUGANAPATHI G, SRINIVASAN K, NATARAJAN D, PERUMAI G, MOHANASUNDARI C & MOORTHY K 2005 Studies on Antimicrobial Activities of certain Medicinal Ferns against selected Dermatophytes *Indian Fern J* **22** : 191-195

DIXIT R D 1974 Fern - A much neglected group of medicinal plants *J Res Indian Med* **9** : 74-90

DIXIT R D & VOHRA J N 1984 *A Dictionary of the Pteridophytes of India* Botanical Survey of India Howrah

EDWARDS D & FEEHAN J 1980 Records of *Cooksonia*-type sporangia from late Wenlock Strata in Ireland *Nature* **287** : 41-42

FRASER-JENKINS C R 2008 Endemics and Pseudo-endemics in relation to the distribution patterns of Indian pteridophytes *Taiwania* **53(3)** : 264-292

GANGULY G, SARKAR K & MUKHOPADHYAY R 2011 Phytochemistry and Antimicrobial Activity of Crude Extract and Extracted Phenol from an Epiphytic Fern *Arthromeris himalayensis* (Hook) Ching *Bioresearch Bulletin* **5** : 311-315

GEHLOT D & BOHRA A 1995 Antibacterial activities of leaf extracts of some ferns from Pachmarhi Hills *National Symposium on Researches in Pteridology Abs of Papers Oct 5-7* pp 118

GRÉPIN F & GRÉPIN M 1984 La Médecine Tahítiennne Traditionnelle Raau Tahiti *Société Nouvelle des* Editions du Pacifique, Papeete, Tahiti, pp 151

GUHA (GHOSH) P, MUKHOPADHYAY R, PAL P K & GUPTA K 2004 Antimicrobial activity of crude extracts and extracted phenols from gametophyte and sporophytic plant parts of *Adiantum capillus-veneris* L *Allelopathy J* **13(1)** : 57-66

KHULLAR S P 1994 *An Illustrated Fern Flora of West Himalaya Vol I.* International Book Distributor Dehra Dun, India

KHULLAR S P 2000 *An Illustrated Fern Flora of West Himalaya Vol II.* International Book Distributor, Dehra Dun, India

KUMAR A & KAUSHIK P 2009 Antibacterial effect of two aquatic pteridophytes *Indian Fern J* **26** : 161-165

LAHIRI I, GURUNG C, BHANDARI J B & HEGDE S 2016 Morpho-anatomical and Bio-chemical characterisation of *Davallia griffithiana* Hook *Indian Fern J* **35** : 212-221

LEE C H & SHIN S L 2011 Functional Activities of Ferns for Human Health 347-359 In : FERNANDEZ H, KUMAR A & REVILLA M A (Eds) *Working with Ferns*, *Issues and Applications*, Springer, New York, Dordrecht, Heidelberg, London

MANHAS S, ATTRI C, SETH M K & SETH A 2018 Determination of Phytochemical Constituents and Evaluation of Antimicrobial Activity of Medical Fern *Christella dentata Indian Fern J* **35** : 169-178

MANNAN M M, MARIDASS M & VICTOR B 2008 A review on the potential uses of ferns *Ethnobot Leaflets* **12** : 281-285

NATH K, BHATTACHARYA M K & KAR S 2016 Antibacterial activity of ferns in southern Assam *Taiwania* **61(3)** : 260-268

PAGE C N 1979 Experimental Aspects of Fern Ecology In : A F Dyer (Ed) *The Experimental Biology of Ferns*, pp 551-558, Academic Press, London

PARIHAR P & BOHRA A 2001a Effect of some pteridophytic plants found in Rajasthan on the growth of *Escherichia coli* National Conference on Emerging Areasin Plant Sciences Oct 5-6, 2001, Abstract of Papers, p 16

PARIHAR P & BOHRA A 2001b Effect of some pteridophytic plants found in Rajasthan on the growth of *Escherichia coli* National Conference on Emerging Areasin Plant Sciences, Oct 5-6, 2001, Abstract, pp 72-74

PARIHAR P & BOHRA A 2002a Antibacterial efficacy of some pteridophytic plants (found in Rajasthan) against human pathogenic bacteria – *Staphylococcus aureus* National Seminar on role of antimicrobials for sustainable horticulture Jan 20, 2002 Abstract pp 13-15

PARIHAR P & BOHRA A 2002b Antibacterial efficacy of various pteridophytic plants extract against *Escherichia coli* : a study *in vitro Ecobios* **1(1)** : 7-9

PÉTARD P 1972 Raau Tahiti : The use of Polynesian medicinal plants in Tahitían medicine South Pacific Commission, *Noumea* New Caledonia

PURI G S & ARORA R K 1961 Some medicinal ferns from Western India *Indian Forest* **8** : 179-183

RAGEAU J 1983 Fichier des Plantes Médicinales de Tahiti et de Polynésie. *Orstom, Bondy*

SEN S P & NANDI P 1980 Antibiotics from the pteridophytes *Sci Cult* **16(3)** : 328-329

SHARMA B D & VYAS M S 1985 *Bull of Bot survey of I*ndia **27** : 90-91

SHIL S & DUTTA CHOUDHURY M 2009 Ethnomedicinal importance of Pteridophytes Used by Reang tribe of Tripura, North East India, *Ethnobot Leaflets* **13** : 634-643

SINGH H B 1999 Potential medicinal pteridophytes of India and their chemical constituents *J Econ Tax Bot* **1** : 63-78

SINGH H B 2003 Economically viable pteridophytes of India In CHANDRA S & SRIVASTAVA M (Eds) *Pteridology in the New Millennium* NBRI Golden Jubilee volume pp 421-446 Kluwer Academic Publishers, The Netherlands

SNEADER W 2005 Drug Discovery : a History (Chichester, UK : Wiley)

STEWART W N & ROTHWELL G W 1993 *Paleobotany and the evolution of plants* Second edition, Cambridge University Press, UK

THOMAS T 2010 Antibacterial action of Rhizomes of *Blechnum orientale* L. *Indian Fern J* **27** : 73-77

UDDIN M G, MIRZA M M & PASHA M K 1998 The medicinal uses of pteridophytes of Bangladesh *Bangladesh J Plant Taxon* **5(2) :** 29-41

WHISTLER W A 1992 Polynesian Herbal Medicine National Tropical Botanical GardenLawai, Kaua-I, pp 238

ZENG-FU L I, HUIL H, HANG-YI Z & JUN-CHEN Z 2008 Review on the extraction of flavonoids from fern *J Samm Univ* **25** : 22

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ARTHROMERIS WALLICHIANA (SPRENG.) CHING : ETHNO-TAXONOMICAL REVIEW

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ABSTRACT

The Pteridophytes, consisting of the ferns and fern-allies are one of the oldest land plant groups on earth and constitute vast group of vascular Cryptogams. *Arthromeris wallichiana* is a species in the genus *Arthromeris* which contains approximately 15 to 20 species and belongs to the family Polypodiaceae. The genus was instituted by J. Smith (1875). The entire plant of this species is used as medicine in Ayurveda and Unani. It is commonly found on humid rocks (prefers moist soil) in shade, epiphyte also and commonly known as Chhepaare Unyu / Harachur. Its uses are well documented and also indicated for specific disorders.

Key Words : *Arthromeris wallichiana*, Diversity, Medicinal, Pteridophytes, Darjeeling, India.

INTRODUCTION

Arthromeris wallichiana (Spreng.) Ching is native to China and North India. The genus *Arthromeris* (T.Moore) J.Sm. (Polypodiaceae) is represented by about 20 species, distributed in tropical and subtropical Asia (Zhang *et al*. 2013). Nine species of *Arthromeris* are already reported as occurring in India (Fraser-Jenkins 2008, 2012), namely, *A. cyrtomioides* S.G.Lu & C.D.Xu (synonym: *A. notholaenoides* V.K.Rawat & Fraser-Jenk.), *A. himalayensis* (Hook.) Ching (synonym: *A. himalayensis* (Hook.) Ching var. *niphoboloides* (C.B.Clarke) S.G.Lu), *A. lehmannii* (Mett.) Ching (synonyms: *A. venusta* (J.Sm.)J.Sm. and *A. lungtauensis* Ching), *A. mairei* (Brause) Ching, *A. tatsienensis* (Franch. & Bureau ex Christ) Ching, *A. tenuicauda* (Hook.) Ching, *A. tomentosa* W.M.Chu, *A. wallichiana* (Spreng.) Ching and *A. wardii* (C.B.Clarke) Ching. Species of fern belonging to this genus were placed by earlier pteridologists (Clarke 1825, Moore 1857, Beddome 1833, Hooker 1866) under the genera *Polypodium*, *Pleopeltis* and *Phymatodes*. Only three species referable to this genus, *i.e., A. himalayanse* (Hook.) J. Smith, *A. tenuicaudata* (Hook.) Ching and *A. wallichiana* (Spr.) Ching have been reported by Mehra & Bir (1964) from Darjeeling and Sikkim Himalayas. Nayar & Devi (1964) investigated spore morphology of these three species. Rao & Srivastava (1974) studied the morphology & anatomy of *Arthromeris wallichiana*. The present work deals with the morphology, anatomy, ethno-botanical and ecology of *A. wallichiana* (Spreng.) Ching.

TAXONOMIC TREATMENT

Arthromeris wallichiana (Spreng.) Ching, Contr. Inst. Bot. Natl. Acad. Peiping.

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2(3): 92. 1933.

Rhizome long-creeping, very thick, somewhat fleshy, densely scaly; scales brown (Plate I Fig. d), cuspidate-subulate, base broad, margin distantly toothed, acuminate apex, stramineous to pale brown, glaucous, glabrous, narrowly lanceolate, fimbriate-hairy. Stipes up to 30 cm long, stramineous to pale brown, thick, glabrous. Lamina pinnate (Plate I Fig.1 a, Plate II Fig.2), up to 40 x 30 cm, ovate lanceolate, texture coriaceous, glossy, glabrous; pinnae c 8 pairs, 15 x 4 cm, opposite but lower ones alternate, sessile, base cuneate or rounded, lower surface pale green or bluish-green, margin with a thick cartilaginous line, generally strongly repando-undulate, basal pinnae the largest, other pinnae gradually decrescent towards the terminal one; terminal pinna similar to the lateral ones; lateral veins prominent (Plate I Fig. b), reaching the margin, almost parellel, smaller veins anastomosing to form many irregular areoles; areoles with simple or forked free veinlets.

Location : Collected from Barbotey Rock Garden (2,134 meters) in Darjeeling area.

NepaliLocal Name : Chhepaare Unyu / Harachur

ECOLOGY

Altitude 1500-2700 m, Grows on humid rocks (prefers moist soil) in shade and epiphyte also.

DISTRIBUTION

HIMACHAL PRADESH: Shimla: Glen; Narkanda; Mt. Shall. **UTTARAKHAND:** Dehra Dun: Chakrata, Deoban; Mussoorie, Jabberkhet; Lal Tibba. **TEHRI GARHWAL:** Dhanolti. **CHAMOLI GARHWAL:** Kalimath; Pothibasa Dugalbitta Pandukeshwar; VinayaKchatti; Hanumanchatti. **NAINITAL:** Nainital, Dhobi Khud. **ALMORA:** Ranikhet, Jhula devi Temple; Jagesh war; Binsar en route Khali State. **PITHORAGARH:** Champawat, Gangolihat; Askot; Didihat; Deochula; Loharkhet; Shankdhura; Berinag; Bogdwar. **INDIA:** Arunachal Pradesh; Manipur; Meghalaya; Nagaland; Tripura; Sikkim; W. Bengal, Darjeeling hills; **GENERAL:** Bhutan; China; Myanmar Nepal; Tibet; Vietnam.

SORI AND SPORES

Sori (Plate II Fig. 3) large, globose orbicular, medial solitary between lateral veins: exindusiate, in one row on either side of costa: 1 on each side of costa, sporangia (Plate I Fig. c), globose, brown, naked, superficial, without any paraphyses. The spores are monolete (Plate II Fig. 4), bilateral, elliptical in equatorial view, and plano-convex in polar view. They are light/ dark brown in colour, 27.0-33.0 x 43.7-52.4 µm, non-perinate, exine densely tuberculate and granulose. The leasura is 40/z long. The exine is thick, double-layered.

PLATE I

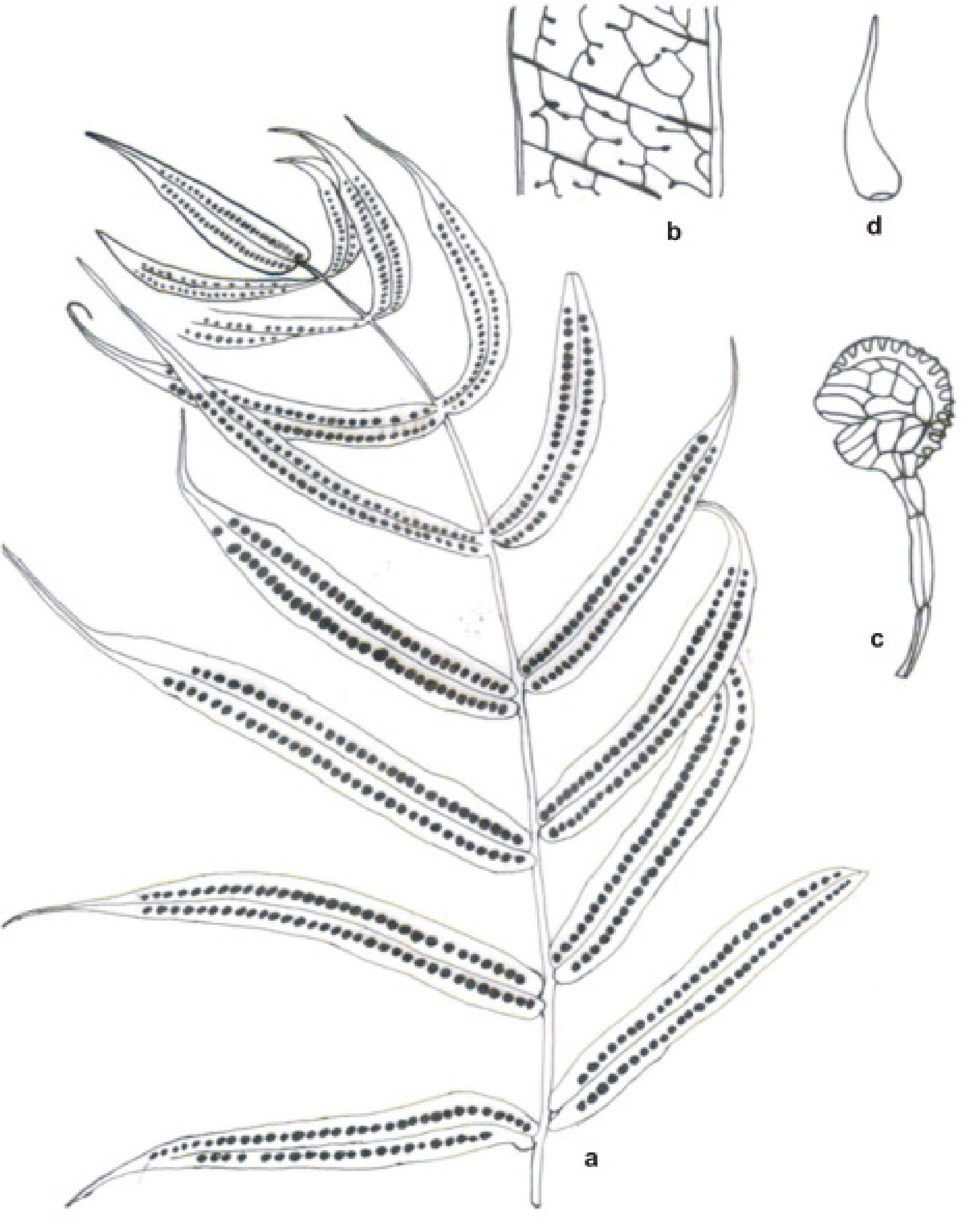
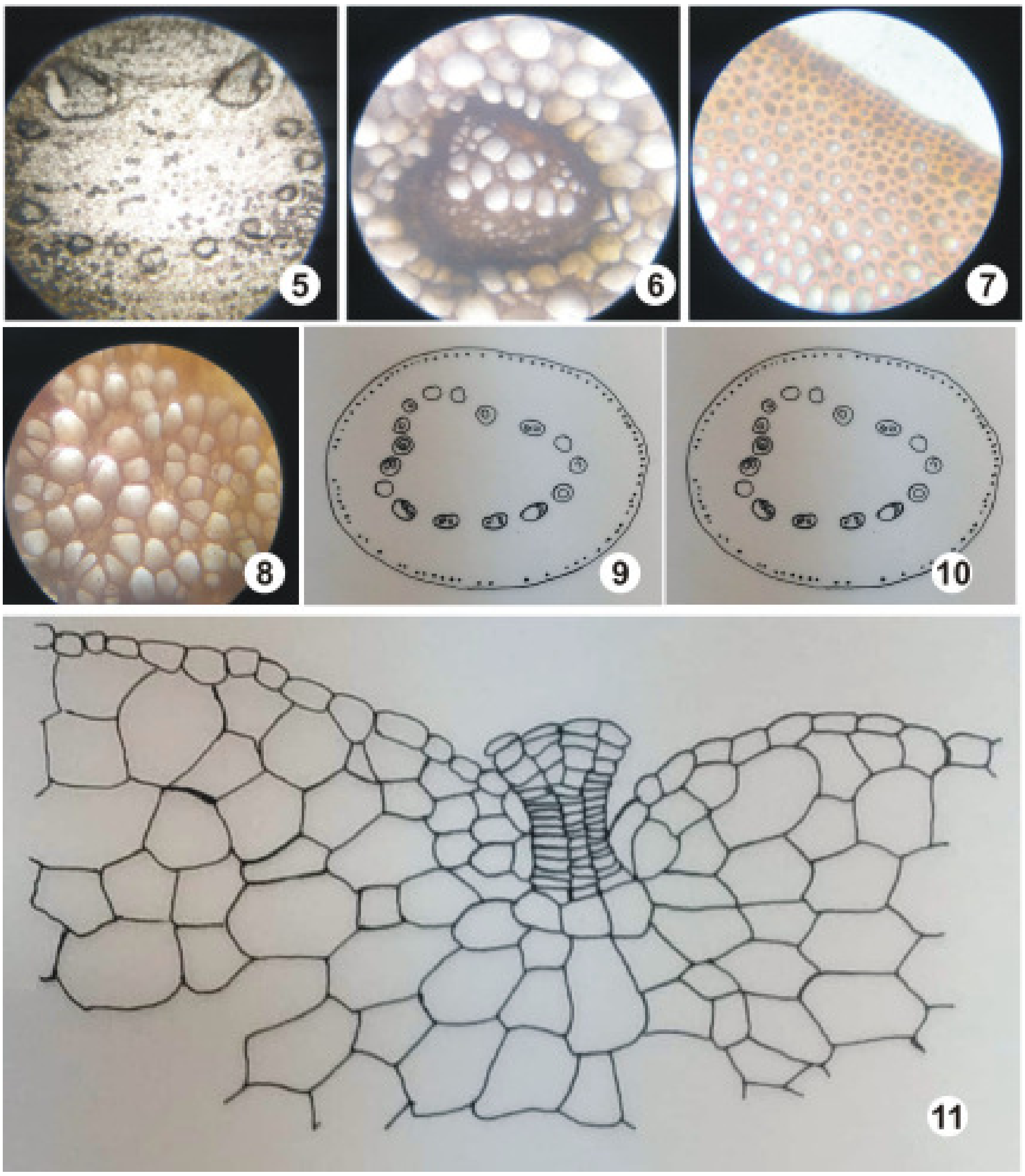


Fig. 1, a-d : a. Habit Plant, **b.** Magnified part showing venation, **c.** Sporangium, **d.** Rhizome scale

PLATE II

Figs. 2-4 : 2. Habit *Arthromeris wallichiana* (Spreng.) Ching, **3.** Sporophyll, **4.** Monolete Spores

PLATE III



Figs. 5-11 : 5. T.S. of petiole 5x **6.** T.S. a part of petiole 45x **7.** Cellular part showing endodermis & outer Cortex 45x **8.** Cellular part showing inner Cortex 45x **9.** T.S. Rhizome **10.** T.S. Meristele of Rhizome **11.** Ground tissue.

ANATOMY

Rhizome creeping, blackish in color, round in outline (T.S) (Plate III Fig-9), dictyostelic meristelic, embedded in circular, each strand bicolateral or concentric, metaxylem tracheids develop uni/ bi-seriate pits, fronds Unipinnate (Plate I Fig.-a), petioles consists of many vascular bundles arranged in a incomplete ring (Plate III Fig. 5,6), each bundle encircled by lignified cells, Xylem of adaxial petiolar bundles without any hook, The ground tissue is undifferentiated and made up of large parenchymatous cells (Plate III Fig. 13), The endodermis and pericycle are clear. The petioles has single layered epidermis followed by broad sclerenchymatous outer cortex (Plate III Fig.7) and parenchymatous inner cortex (Plate III Fig. 8), Phloem surrounds the Xylem, pericycle is 1-5 cells thick and endodermis is lignified. In leaf (T.S.) the apical portion of the pinna shows T-shaped Xylem, lignified endodermis. The lamina shows thick lower and upper epidermis. Lower epidermis has Stomata.

MEDICINAL PROPERTIES

Tender young fronds are cooked and used as a vegetable. Leaf paste applied externally for sprains, paste mixed with egg albumen applied to fractured bone and used for calcinosis. Bitter taste, Boiled rhizome after grinding with added rice water is drunk to check dysentery. Paste obtained by crushing pinnae applied externally in the form of poultice on fractured bones after setting up the bones. The root is antiseptic. A paste of the roots is applied as a poultice to wounds and boils. Fronds used as fodder.

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REFERENCES

BORTHAKUR S K, DEKA P AND NATH K K 2001 *Illustrated manual of ferns of Assam* Bishen Sing Mahendra Pal Singh, Dehradun

BIR S S & VERMA S C 2010 *Chromosome atlas of the Indian Pteridophytes* Bishen Singh Mahaendra Pal Singh, Dehra Dun

CAIUS J F 1935 Medicinal and poisonous Ferns of India *Bom Nat Hist Soc* **83** : 341-361

CHANDRA S 2000 *The ferns of India* (Enumeration, Synonyms & Distribution) International Book Distributors, Dehradun

CHHETRI D R, BASNET D, CHOU P F, KALIKOTAY S, CHHETRI G & PARAJULI S 2005 Current status of ethnomedicinal plants in the Darjeeling Himalaya *Curr Sci* **89**(2) : 264-268

CHOWDHURY A, SARKAR S & CHOWDHURY M 2016 Diversity Ecology and Utilization of Tea Garden Pteridophytes at Duras in West Bengal, India *Int Res J Biological Sci* **5** : 47-53

COPELAND E B 1947 *Genera Filicum*, Waltham, Mass., U.S.A.

DIXIT R D 1984 A Census of the Indian Pteridopytes *Bot Surv India,* Dept. of Environment, Howrah

DAS A P & MANDAL S 2003 Some Medicinal Plants of Darjeeling Hills, *WWF-India*, West Bengal State Office, Kolkata

DAS A P 2004 Floristic studies in Darjiling Hills *Bull Bot Surv India* **43**(1-4) : 1-18

FRASER-JENKINS C R 2008 *A Taxonomic Revision of Three Hundred Indian Subcontinental Pteridophytes with a Revised Census List*, A new picture of fern taxonomy in the Indian Subcontinent, pp 685, Bishen Singh & Mahendra Pal Singh, Dehra Dun

FRASER-JENKINS C R 2012 Rare and Threatened Pteridophytes of Asia 2. Endangered Species of India – the Higher IUCN Categories, *Bull Natl Mus Nat Sci, Ser B*, **38(4)** : 153-181.

GANGULY G, TIWARY B & MUKHOPADHYAY R 2013 Phytochemical analysis and antibacterial activity of crude extracts and extracted phenols from a litho-epiphytic fern arthromeris wallichiana (spreng) Ching *Bionature*, **33**(1), 1-7.

GANESAN SATHIYARAJ, THANGAVELU MUTHUKUMAR & KONGANAPURUM CHELLAPPAN RAVIDRAN 2015 Ethnomedcinal importance of ferns and fern allies traditionally used by tribal people of Palani Hills (Kodaikanal), Westerns Ghats, South India *Journal of Medicinal Herbs and Ethnomedicine*, 4-9.

HOOKER J W 1868 Synopsis Filicum, Hardwicks, London

KHARE P 1965 On the morphology and anatomy of two species of *Lepisorus* (J Smith) Ching - *L thunbergianus* (Kaulf) Ghing and *L excavatus* (Bory) Ching, *Canadian Jour Bot* **43** : 1583-89

KHULLAR S P 1994 An Illustrated fern Flora of West himalaya, **Vol I** International Book Distributors, Dehra Dun, India, Pp i-xxxx + 506

MOORE T 1857 Index Filicum, *Pamplin*, London

MEHRA P N & BIR S S 1964 Pteridophytic flora of Darjeeling and Sikkim Himalayas *Res Bull* Punjab Uni Sci **15** : 169-182

MAZUMDAR JAIDEEP 2015 New distributional records of *Arthromeris elegans* Ching in India and Bhutan and lectotypification of *A. himalayensis* (Hook.) Ching (Polypodiaceae) *Telopea* **18** : 159-163

NAYAR B K 1961a *"Ferns of India. III. Microsorium" Bull Nat Bet Gardens*, **58** : 1-38

NAYAR B K 1961b "Studies in Polypodiaceae VII Pyrrosia Mirbel," *lndian Bet Soc* **40** : 164-83

NAYAR B K 1964 *"Ferns of India: Lammophyllum" Bull Nat Bet Gardens* (LKO), No 106, 1-15

NWOSU M O 2002 Ethnobotanical studies on some pteridophytes of Southern Nigeria *Econ Bot* **56** : 255

PALIT DEBNATH & GURUNG S 2008 Some phytoremedies used traditionally by Gurungs in Darjeeling, West Bengal, India *Pleione* **2** : 71-174

PANDE H C & PANDE P C 2002 *An Illustrated Fern Flora of Kumaun Himalaya* **Vol I & II** Bisen Singh Mahendra Pal Singh, Dehradun

RAI S K & BHUJEL R B 2002 Ethnic uses of some monocotyledonous plants in the Darjeeling Himalayan region, *In* : *Perspective of plant Diversity* by AP das (Ed), Bisen Singh Mahendra Pal Singh, Dehradun, India pp 635-644

RAI S K & BHUJEL R B 2007 Dye and gum yielding plants of Darjeeling Himalaya, India In *Advances in Ethnobotany* (ed A P Das) pp 219-228 Bishen Singh Mahendra Pal Singh, Dehradun

RAI S K & BHUJEL R B 1999 Notes on some less known ethnomedicinal plants from the Darjeeling Himalayas *J Hill Res* **12(2) :** 160-163

RAO A S & SRIVASTAVA P 1974 On the morphology and anatomy of *Arthromeris wallichiana* (Spr) Ching, *Proc Indian Acad Sci* **79**B(2) : 53-58

RAWAT V K, BENNIAMIN A, KUMAR B, PATIL S & JOSHI P 2018 The genus *Arthromeris* in North-East India : Diversity, distribution and ecology *Indian Fern J* **35 :** 179-195

SRIVASTAVA SHOBHIT KUMAR & JONNADA A V PRASADA RAO 2019 A study of the ferns used as traditional Medicine by Indigenous People in Darjeeling West Bengal, India *Journal of Applied science Computation* **06**(1) : 1409-1413

VASUDEVA, S M 1999 Economic importance of Pteridophytes *Indian Fern J* **16**(1-2) : 130-152

Indian Fern J. **36 :** 260-276 (2019) ISSN 0970-2741

A CHECKLIST OF PTERIDOPHYTES OF KUDREMUKH NATIONAL PARK, CENTRAL WESTERN GHATS, KARNATAKA, INDIA

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ABSTRACT

The Western Ghats Passing through Karnataka state is also a rich repository of Pteridophytes diversity. The Kudremukh National Park encompasses a wealthy variety of flora and fauna. A significant portion of the park remained unexplored. To fill this lacuna and to obtain knowledge on the floristic diversity of this area, the present study has been undertaken. The main aim of this work is to bring out a comprehensive list of Pteridophytes of this unexplored area through extensive and intensive field studies. On the basis of present field observation, study of herbarium specimens *viz*; BLAT, MGMC, BSI and SUH, published literature and present study revealed the occurrence of 123 species.

Key Words : Checklist, Pteridophytes, Kudremukha, Karnataka

INTRODUCTION

The world flora comprises of approximately 12, 000 species of Pteridophytes of which there are 1107 species in India. Nearly 10% species of world's Pteridophytes occur in India. (Fraser-Jenkins *et al.*, 2017).

Some noticeable studies which have been carried out in the Central Western Ghats include the collection and listing in 1922, Blatter & Almeida included 90 species of ferns from Uttara Kannada district. Alston (1945) recorded 58 species of *Selaginella* from India of which four species have been recorded from Karnataka. Thirty eight species of Pteridophytes from Kemmangundi forest of Karnataka were reported by Deepa *et al.* (2013). Smitha and Sudha published a field guide to the fern of Karnataka (2013). Devendra *et al.*, 2016, reported an endemic fern *Elaphoglossum stigmatolepis* (Fee) T. Moore as a new record of Karnataka. However, the only comprehensive work on the pteridophytes of Karnataka has been done by Rajagopal & Bhat (1998). They have surveyed the pteridophytes diversity of Karnataka State between 1988-1995 resulting in the publication of "Pteridophytic Flora of Karnataka State, India" (2016). However, there has been no in depth studies on the taxonomy, diversity, and ecology of pteridophytes especially with respect to Kudremukh National Park.

Field surveys have been undertaken frequently covering different seasons of the Kudremukh National Park. These areas were comprehensively visited and surveyed periodically during 2013-2018. The present study revealed the occurrence of 123 species of ferns including 12 species of fern allies' in the Kudremukh National Park, Karnataka. All the collected and identified species have been classified and arranged according to Smith *et*

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al., 2008. For nomenclature Pichi-Sermolli, 1958, Fraser Jenkins *et al.*, 2017; 2018 have been followed. The present study also revealed that many species have been collected from the Kudremukh National Park for the first time from the state of Karnataka.

CHECKLIST OF PTERIDOPHYTES

LYCOPODIACEAE

HUPERZIA J. J. Bernh. in Schrad. J. Bot. 1800 (2): 126; 1801.

1. *Huperzia hamiltonii* (Spreng.) Trevis.
Specimen examined: Mullodi, 28-12-2017, DT, 207944, BSI.
Distribution: Karnataka; KNP; Kurinjal Peak.
2. *Huperzia phyllantha* (Hook. & Arnott) Holub.
Specimen examined: Kudremukh, 01-11-2014, DT, 202361, BSI.
Distribution: Karnataka: KNP; Kudremukh.
Note: This species is similar to *Huperzia phlegmaria* Roth. but they can be segregated by the cones and vegetative foliage.
3. *Huperzia squarrosa* (Forst.) Trevis.
Specimen examined: On the way to Kudremukh Peak, 28-12-2017, DT, 207945, BSI.
Distribution: KNP; Chikmagalur, Bhagvathi Nature camp river side.
Notes: Only one gathering of this species could be made. The size of the pinnules in *H. squarrosa* is highly variable.

LYCOPODIELLA Holub Preslia 36: 20, 22; 1964.

4. *Lycopodiella cernua* (L.) Pic. Serm.
Specimen examined: Kerekatte, 26-11-2015, DT, 197964, BSI.
Distribution: Karnataka: KNP; Kemmangundi, Dakshina Kannada, Kerekatte.

SELAGINELLACEAE

SELAGINELLA P. Beauv. Prodr. Fam. Aetheogam. 101; 1805.

5. *Selaginella ciliaris* (Retz.) Spring.
Specimens examined: Kurinjal Peak, 18-11-2015, DT, 197915, BSI.
Distribution: Karnataka: KNP; Udupi, Kurinjal.
6. *Selaginella delicatula* (Desv.) Alston.
Specimens examined: Kadambi falls, 19-11-2015, DT, 197930, BSI.
Distribution: Karnataka: KNP; Dakshina Kannada, Udupi, Kadambi Falls.
7. *Selaginella miniatospora* (Dalz.) Baker.
Specimens examined: Udupi, Karkala, 11-09-1990, PKR, 296, MGMC.
Distribution: Karnataka: KNP; South Kanara, Kudremukh.
8. *Selaginella plana* (Desv. ex Poir) Hieron.
Specimens Examined: Udupi, 01-03-1992, PKR, 594, MGMC.

Distribution: Karnataka: KNP; Udupi.

9. *Selaginella proniflora* (Lam.) Baker.
Specimens Examined: Valikunja, 11-10-2017, DT, 202785, BSI.
Distribution: Karnataka; KNP; Udupi,Valikunja.

10. *Selaginella tenera* (Hook. & Grev.) Spring.
Specimens Examined: Chikmagalur, Kudremukha, 01-11-2014, DT, 202357, BSI.
Distribution: Karnataka; KNP; Chikamgaluru, Dakshina Kannada, Kudremukha.
Notes: Occasional throughout the present area. Rare along road-sides in shade.

ISOETACEAE

ISOETES L., Sp. Pl. **2:** 1100; 1753.

11. *Isoetes coromandelina* L.
Specimens Examined: Charmadi Ghat, 27-10-1990, PKR, 364, MGMC.
Distribution: Karnataka: KNP; Chikmagalur.

12. *Isoetes udupiensis* P. K.Shukla, G. K. Srivast., S. K. Shukla & P.K. Rajagopal
Specimens Examined: Alevoor, Karnataka, 13-10-2000, P. K. Rajagopal, P. K. Shukla, 8399, MGMC.
Distribution: Karnataka: KNP; Udupi.
Note- *Isoetes udupiensis* grows in mud habitat.

OPHIOGLOSSACEAE

BOTRYCHIUM Swartz, in Schrad. J. Bot. 1800 (2): 8, 110; 1801.

13. *Botrychium daucifolium* Wall. ex Hook. & Grev.
Specimen examined: Kadambi falls, 27-09-2016, DT, 202460, BSI.
Distribution: Karnataka; KNP; Charmadi Ghat, Chikmagalur, Kudremukh Peak, Kadambi Falls to Bhagvathy Forest Road.
Notes: During the present survey it was collected from the Kadambi falls to Nature camp forest road, on the way to Kudremukh peak near a stream; these gatherings represent the first *In situ* population of the species.

14. *Botrychium lanuginosum* Wall. ex Hook. & Grev.
Specimens Examined: Bababudan hills, 30-10-2017, AB, 207631, 207631, BSI.
Distribution: Karnataka; KNP; Bababudan hills, Chikmagalur.

OPHIOGLOSSUM L. Sp. Pl. 2: 1062; 1753.

15. *Ophioglossum costatum* R. Br.
Specimens Examined: Udyavar, Udupi, Padekallu temple on rocks, 15-08-1993, P. K. Rajagopal, 721A, MGMC.
Distribution: Karnataka; Bijapur, Dakshina Kannada, Udupi, Hassan.

16. *Ophioglossum reticulatum* L.
Specimens Examined: Dakshina Kannada, Ajekar, Karkala, 28-08-1989, P. K.

Rajagopal, 93, MGMC.
Distribution: Karnataka; KNP; Ajekar, Karkala, Dakshina Kananda.

MARATTIACEAE

ANGIOPTERIS Hoff. Comm. Soc. Reg. Sc.12 (1973-1974) Cl. Phys. 29; 1796.

17. *Angiopteris helferiana* C. Presl.
Specimen examined: Samse, 27-09-2016, DT, 202459, BSI.
Distribution: Karnataka; KNP; Chikmagalur, Dakshina Kannada, Kerekatte, Kudremukh, Karkala, Belthangady.

OSMUNDACEAE

OSMUNDA L. Sp. Pl. 2**:**1063; 1753.

18. *Osmunda hilsenbergii* Grev. & Hook.
Specimen examined: Kurinjal Peak road, Near Bridge 30-10-2014, DT, 202332, BSI.
Distribution: Karnataka; KNP; Chikmagalore, Jogigundi, Karkala road, Gangamoola.
Note: In early literature this was referred as *O. regalis* L. which was corrected as *O. hugeliana* C. Presl by Fraser-Jenkins (2008) to be replaced by the present name.

HYMENOPHYLLACEAE

HYMENOPHYLLUM Sm., Mem. Acad. Roy. Sci., Turin **5:** 418, 9; 1793.

19. *Hymenophyllum denticulatum* Sw.
Specimen examined- Kudremukh Peak, 30-10-2014, DT, 202312, BSI.
Distribution: Karnataka: Kudremukh National Park, On the way to Kudremukha peak.
20. *Hymenophyllum gardneri* Van. Den. Bosch.
Specimen examined: Gangamoola, 25-09-2016, DT, 202444, BSI.
Distribution: Karnataka; Chikmagalur, Gangmoola.

TRICHOMANES L., Sp. Pl. **2:** 1097; 1753, *nom. cons.*

21. *Trichomanes intramarginale* Hook. & Grev.
Specimens examined: On the way to Valikunja, Near Haradi Falls, 11-10-2017, DT, 202779, BSI.
Distribution: Karnataka: Dakshina Kannada
22. *Trichomanes indicum* (Hameed & Madhus.) Hameed, Rajesh & Madhus.
Specimen examined: Kudremukh range, 25-09-2016, DT, 202445, BSI.
Distribution: India: Karnataka: Kurinjal peak.
23. *Trichomanes obscurum* Blume
Specimens examined: On the way to Kudremukh peak, 18-11-2015, DT, 197924, BSI.

Distribution: India: Karnataka: Kudremukh, Chikmagalur, Kerekatte, Sringeri.

Notes: *Trichomanes obscurum* terrestrial on wet ground or cave like recesses in shade, near streams in dense evergreen forests.

24. *Trichomanes plicatum* (Bosch) Bedd.

Specimens Examined: Chikmagalur, 30-10-2014, DT, 202316, BSI.

Distribution: Chikmagalur, Dakshina Kannada.

Notes: *Trichomanes plicatum* is one of the most muddled filmy fern species.

25. *Trichomanes proliferum* Blume

Specimens examined: Valikunja, 11-10-2017, DT, 202769, BSI.

Distribution: Karnataka: Valikunja.

26. *Trichomanes sublimbatum* (Muller Berol.) Bosch

Specimens examined: Jogi Gundi water falls, 26-11-2016, AB, 202623, BSI.

Distribution: Karnataka: Jogigundi.

Notes: It is a rare species in Karnataka; this species has prominent stipes and lack clear distinction between indusial tube and mouth.

GLEICHENIACEAE

DICRANOPTERIS Bernh., in Schrader, Neues J. Bot. **1** (2): 38; 1805 ('1806').

27. *Dicranopteis linearis* (Burm. f.) Underw.

Specimens Examined: Karkala road near, Lakhya dam, 01-11-2014, 202363, BSI.

Distribution: Karnataka: Chikmagaluru, Dakshina Kannada.

LYGODIACEAE

LYGODIUM Swartz Schrad. J. Bot. 1800 (2): 7, 106; 1801.

28. *Lygodium flexuosum* (L.) Sw.

Specimen examined: Malakibetta, 24-11-12015, DT, 197951, BSI.

Distribution: Karnataka: Dakshina Kannada, Udupi.

29. *Lygodium microphyllum* (Cav.) R. Br.

Specimen examined: Bhagvathy, Ganeshkatti, 28-12-2017, DT, 207940, BSI.

Distribution: Karnataka: Hassan, Chikmagalur, Kudremukh.

MARSILEACEAE

MARSILEA L., Sp. Pl. **2**: 1099-1100; 1753.

30. *Marsilea minuta* L.

Specimens Examined: Dakshina Kannada, 01-11-1988, P. K. Rajagopal, 19, MGMC.

Distribution: Karnataka: Dakshina Kannada.

SALVINIACEAE

SALVINIA Seguier, FI. Vernon. 3: 52; 1754.

31. *Salvinia molesta* Mitch.

Specimens examined: Udupi, 01-11-1988, P. K. Rajagopal, 20, MGMC.

Distribution: Karnataka: Dakshina Kannada, Udupi.

AZOLLA Lamark., Encycl. Meth. Bot. **1:** 343; 1783.

32. *Azolla pinnata* R. Br.
Specimens examined: Dakshina Kannada, Udupi, Indrali paddy fields, 06-08- 1989, P. K. Rajagopal, 61, MGMC.
Distribution: Karnataka: Dakshina Kannada.

CYATHEACEAE

CYATHEA Sm., Mem. Acad. Roy. Sci., Turin 5: 416; 1793.

33. *Cyathea gigantea* (Wall. ex Hook.) Holttum
Specimens Examined: Near Kadambi falls, 30-10-2014, DT, 202307, BSI.
Distribution: Karnataka: Chikmagalur, Dakshina Kannada.
34. *Cyathea nilgirensis* Holttum
Specimens Examined: Kurinjal Peak, 30-10-2014, DT, 202348, BSI.
Distribution: Karnataka: Kurinjal Peak. Kemmangundi, Chikmagalur.
35. *Cyathea spinulosa* Wall. ex Hook.
Specimens Examined: Kurinjal Peak road, 31-10-2014, DT, 202339, BSI.
Distribution: Karnataka-Chikmagalur.

LINDSAEACEAE

LINDSAEA Dryand. ex Sm., Mem. Acad. Roy. Sci., Turin 5: 413; 1793.

36. *Lindsaea ensifolia* Sw.
Specimens Examined: S. K. Border, Karkala Road, 27-11-2015, DT, 197966, BSI.
Distribution: Karnataka: Udupi, Dakshina Kannada, Chikmagalur.
37. *Lindsaea heterophylla* Dryand.
Specimens Examined: On the way to Kurinjal peak near bridge, 18-11-2015, DT, 197912, BSI.
Distribution: Karnataka: Charmadi, South Kannada, Chikmagalur, Kemmangundi.

SPHENOMERIS (L.) Maxon. J. Washingt. Acad. Sci. **3** (5): 144; 1913.

38. *Sphenomeris chinensis* (L.) Maxon
Specimens Examined: Samse road, Chikmagalur, 24-09-2016, DT, 202440, BSI.
Distribution: Karnataka: Charmadi, Chikmagalur, Kemmangundi, Dakshina Kannada.

DENNSTAEDTIACEAE

MICROLEPIA C. Presl., Tent. Pterid. 124, 4, f. 21-23; 1836.

39. *Microlepia speluncae* (L.) T. Moore
Specimens Examined: Karkala Road, 27-11-2015, DT, 197967, BSI.
Distribution: Karnataka: Chikmagalur, Kemmangundi.

PTERIDIUM Gled. ex Scop., Fl. Carniol. 169; 1760.

40. *Pteridium revolutum* (Blume) Nakai
Specimens Examined: Kadambi falls, 19-11-2015, DT, 197936, BSI.
Distribution: Karnataka: Chhikmagalur.

PTERIDACEAE

ADIANTUM L., Sp. PI. 2: 1094; 1753.

41. *Adiantum capillus–veneris* L.
Specimens Examined: S. K. Border, Karkal road, 30-11-2014, DT, 198000, BSI.
Distribution: Karnataka: Chikmagalur.

42. *Adiantum concinnum* Humb. & Bonpl. ex Willd.
Specimens Examined: Kudremukh town road, 02-11-2014, DT, 202372, BSI.
Distribution: Karnataka; Chikmagalur, Kudremukh.

43. *Adiantum incisum* Forssk.
Specimens Examined: S. K. Border, Karkala road, 30-11-2014, DT, 197999, BSI.
Distribution: Karnataka: Chikmagalur. Kemmangundi.

44. *Adiantum latifolium* Lam.
Specimens Examined: Belthangady, 27-11-2016, DT, 202536, BSI.
Distribution: Karnataka: Marakaje, Vittal, Dakshina Kannada, Belthangady, Navoor, Someshwara Agumbe Road.

45. *Adiantum philippense* L.
Specimens Examined: Valikunja, 11-10-2017, DT, 202773, BSI.
Distribution: Karnataka-Charmadi, Mudigere, Chikmagalur, Udupi, pilarkaan, Dakshina Kannada, Kudremukh, Chikmagalur, Valikunja.

46. *Adiantum raddianum* C. Presl
Specimen examined: On the way to Kudremukh Peak, 24-10-2016, DT, 202435, BSI.
Distribution: Karnataka: Belgaum, Chikmagalur.

ALEURITOPTERIS Fee Mem. Fam. Foug. 5 Gen. Fil.: 153; 1852.

47. *Aleuritopteris bicolour* (Roxb.) Fraser-Jenk.
Specimens examined: Gulgunjimane, 27-11-2016, DT, 197998, BSI.
Distribution: Karnataka- Kudremukh.

48. *Aleuritopteris tenuifolia* (Burm. f.) Sw.
Specimen examined: Valikunja, 11-10-2017, DT, 202777, BSI.
Distribution: Karnataka- Valikunja, Game road, Muniyal, Ajekar, Dakshina Kannada.

ANTROPHYUM Kaulf., Enum. Fil. 197; 1824.

49. *Antrophyum plantgineum* (Cav.) Kaulf
Specimens examined: Chikmagalur, way to Kudremukh peak, 26-11-2016, DT, BSI.
Distribution: Karnataka: Kemmangundi, KNP, Chikmagalur, Hassan.

DORYOPTERIS J. Sm., J. Bot. (Hooker) **3**: 404; 1841.

50. *Doryopteris concolor* (Langsd. & Fisch.) Kuhn
Specimens Examined: Charmadi Ghat, 10-10-2017, DT, 202796, BSI.
Distribution: Karnataka: Charmadi Ghat.

MICKELOPTERIS Fraser-Jenk., gen.nov.

51. *Mickelopteris cordata* (Roxb. ex Hook. & Grev.) Fraser-Jenk., Annotated Checklist Indian Pteridophytes Part-1 (Lycopodiaceae to Thelypteridaceae); p 247; 2017.
Parahemionitis cordata Roxb. ex Hook. & Grev.
Specimens Examined: Near Bhagwathi Nature Camp, 05-10-2017, DT, 202757, BSI.
Distribution: Karnataka: Chikmagalur-Mudigere road, Chikmagaluru, Dakshina Kannada and KNP.

PITYROGRAMMA Link, Handb. Erken. Gewasche (Link) **3:** 19; 1833.

52. *Pityrogramma calomelanos* (L.) Link var. *calomelanos*
Specimen examined: Bhadra river side, 17-11-2015, DT, 197904, BSI.
Distribution: Karnataka: Kemmangundi, Chikmagalur, Udupi, Manipal, Kumar Parvatha, Dakshina Kannada.
53. *Pityrogramma calomelanos* var. *austro-americana* Domin
Specimen examined: Near tribal temple, bhagvathy camp river side, 03-11-2014, DT, 202382, BSI.
Distribution: Karnataka: Bhagvathy camp, Chikmagalur, Udupi, Panduramakki.

PTERIS L., Sp. Pl. **2:** 1073; 1753.

54. *Pteris argyraea* T. Moore
Specimen examined: on the way to Kudremukh Peak, 02-11-2014, DT, 202373, BSI.
Distribution: Karnataka: Bababudan hills, Kudremukh, Chikmagalur.
55. *Pteris arisanensis* Tagawa
Specimen examined: Girigedde, Kumaraparvatha, 29-12-1990, PKR, 448, MGMC.
Distribution: Karnataka-Chikmagalur, Kumarparvatha, Udupi.
56. *Pteris biaurita* L. Subsp. *walkeriana* Fraser- Jenk. & Dom. Rajkumar
Specimen examined: Karkala Wildlife Range, Udupi, 24-12-2017, DT, 207926, BSI.
Distribution: Karnataka: Bababudan, Kodagu, Chikmagalur, Kudremukh, Udupi.
57. *Pteris blumeana* J. Agardh
Specimen examined: Malakibetta, 24-11-2015, DT, 197955, BSI.
Distribution: Karnataka: Udupi, Kodagu, Chikmagalur, Shimoga.
58. *Pteris scabripes* Wall. ex J. Agardh.
Specimen examined: On the way to Kudremukh Peak, 27-09-2016, DT, 202463, BSI.

Distribution: Karnataka: Kemmangundi, Bababudan hill, & Attigundi, Chikmagalur, on the way to Kudremukh Peak.

59. *Pteris venusta* Kunze

Specimen examined: On the way to Kudremukh Peak, 02-11-2014, DT, 202374, BSI; Charmadi Ghat, 27-11-2016, AB, 195655, BSI.

Distribution: Karnataka: Chikmagalur, Kemmangundi, Dakshina Kannada, Charmadi Ghat, Kodgu, Belthangady, Navoor, Shimoga, Mysore, B.R. Hills, Castle rock, Kaiga.

60. *Pteris vittata* L. Subsp. *vittata.*

Specimen examined: Near Bhagvathy Camp, 17-11-2015, DT, 197907, BSI; Abbi Falls, Madikeri, 21-03-2017, AB, 195688, BSI.

Distribution: Karnataka: Dakshina Kannada, Udupi, Kudremukh, Kodagu, Madikeri, Mysore, Uttara Kannada, Castle rock.

VITTARIA Sm., Mem. Acad. Roy. Sci., Turin **5:** 413; t. 9, f. 5. 1793.

61. *Vittaria elongata* Sw.

Specimen examined: On the way to Kerekatte, 11-10-2017, DT, 202794, BSI.

Distribution: Karnataka: Chikmagalur, Mudigere, Hebri, Hiriyadka, Neelavara, Dakshina Kannada, Banuhalla, Hassan, Agumbe, Shimoga, Yellapur, Uttara Kannada.

ASPLENIACEAE

ASPLENIUM L. , Sp. Pl. **2:** 1078; 1753.

62. *Asplenium aethiopicum* (Burm. f.) Bech.

Specimens examined: Kudremukh Forest, 27-11-2016, DT, 202558, BSI; Irfu Falls, 24-03-2017, AB, 202683, BSI.

Distribution: Karnataka: Hasssan, Kodagu, Mysore, Suntikoppa, B. R. Hills, Kudremukh.

63. *Asplenium cheilosorum* Kunze ex Mett.

Specimen examined: on the way to Kurinjal peak, 31-10-2014, DT, 202344, BSI.

Distribution: Karnataka- Kemmangundi, on the way to Kurinjal peak, Chikmagalur, Genkalbetta, Hassan, Surlabbi, Kodagu.

64. *Asplenium crinicaule* Hance

Specimen examined: Kerekatte, 27-11-2015, DT, 197965, BSI.

Distribution: Karnataka: Hassan, Shimoga, Belthangady, Kigga, Banuhlla, Kempuhole, Hullahalli.

65. *Asplenium decrescens* Kunze

Specimen examined: Kudremukh range, 23-09-2016, DT, 202406, BSI; Pushpagiri Wildlife Sanctauary, 24-09-2017, AB, 207667, BSI.

Distribution: Karnataka: B. R. Hills, Kodagu, Mercara, Kudremukha, Someshwara, Kolar, Nandi Hills.

66. *Asplenium ensiforme* Wallich ex Hook. & Grev.
Specimens examined: Kudremukh, 24-12-1994, PKR, 786, MGMC.
Distribution: Karnataka: Chikmagalur, Kudremukh.

67. *Asplenium erectum* Bory ex Willd.
Specimens examined: Chikmagalur, Kemmangundi, Shanker Shola, 14-12-1965, Raju, 36, MGMC.
Distribution: Karnataka: Chikmagalur.

68. *Asplenium formosum* Willd.
Specimen examined: S K Border, 03-10-2017, DT, 202738, BSI.
Distribution: Karnataka: Chimagalur, Bababudan Hills, Kodagu, Coorg, Kudremukh Peak.

69. *Asplenium inaequilaterale* Bory ex Willd.
Specimen examined: Kerekatte, 25-11-2015, DT, 197963, BSI.
Distribution: Karnataka: Chikmagalur, Babbabudan giri, Kudremukha, Kodagu, Coorg.

70. *Asplenium yoshinagae* Makino subsp. *indicum* (Sledge) Fraser-Jenk.
Specimen examined: On the way to Kudremukh peak, 30-10-2014, DT, 202309, BSI.
Distribution: Karnataka: Chikmagalur, Hassan, Charmadi, Kodagu, Mysuru, Shimoga, Uttara Kannada, Kudremukh NP.

71. *Asplenium nidus* L.
Specimen examined: Kerekatte, 28-11-2015, DT, 197972, BSI.
Distribution: Karnataka: Chikmagalur, Sringeri, Shrimane falls, Shimoga, Kareghat, Sirsi, Jog falls, KNP.

THELYP TERIDACEAE

THELYPTERIS Schmidel, in Keller, Icon. PI., ed. 3, 45. t. 11, 13; 1763. nom. cons.

72. *Thelypteris arbuscula* (Willd.) K. Iwats.
Specimen examined: Kudremukh peak, Chikmagalur, 23-12-2017, DT, 207901, BSI.
Distribution: Karnataka- Kudremukh Peak.

73. *Thelypteris articulatum* (Houlston & T. Moore) Tagawa & K. Iwats.
Specimens examined: Chikmagalur, S. K. Border, 27-11-1994, PKR, 763, MGMC.
Distribution: Karnataka: Chikmagalur.

74. *Thelypteris caudipinna* Ching
Specimens Examined: On the way to Kurinjal Peak, 31-10-2014, DT, 202340, BSI.
Distribution: Karnataka: Chikmagalur, Kemmangundi, Mullyangiri, Bababudan Hills, Hassan, Bisle Ghats, Kodagu, Shimoga, Kumarparvatha, Agumbe, Jogigundi, Kudremukha, Kerekatte, Belthagady.

75. *Thelypteris dentata* (Forssk.) E. P. St. John
Specimen examined: Kurinjal Peak, 31-10-2014, DT, 202334, BSI.
Distribution: Karnataka: Udupi, Hassan, Mysore, B. R. Hills, Hulikal Ghats, Dakshina Kannada, Kaiga.

76. *Thelypteris erubescens* (Wall. ex Hook.) Ching
Specimens examined: Kerekatte forest, 28-11-2015, DT, 197971, BSI.
Distribution: Karnataka: Kudremukh National Park.

77. *Thelypteris hispidula* (Decne.) C.F.Reed
Specimens examined: S. K. Border, 28-10-1989, PKR, 156, MGMC, Kurinjal peak, 31-10-2014, DT, 202335, BSI.
Distribution: Karnataka: Hassan, Chikmagalur, Kudremukha NP.

78. *Thelypteris ochthodes* (Kunze) Ching
Specimen eximined: Kudremukh river side, 17-11-2015, DT, 197908, BSI.
Distribution: Karnataka: Chikmagalur, Kemmangundi, Dakshina Kannada.

79. *Thelypteris parasitica* (L.) Tardieu.
Specimen examined: Kudremukh Forest, 01-11-2014, DT, 202362, BSI.
Distribution: Karnataka: Bangalore, Nandi Hills, Chikmagalur, Kemmangundi, Dakshina Kannada, Kumarparvatha, Dharwad, Hassan, Shimoga, Agumbe, Uttara Kannda, Kaiga.

80. *Thelyptreris terminus* (J. Sm. ex Hook.) Tagawa & K. Iwats.
Specimen examined: Belthangady, on the way to Bolle falls, 26-11-2016, DT, 202531, BSI.
Distribution: Karnataka- Belthangady, on the way to bolle falls, Chikmagalur, Kodagu, Shimoga.

81. *Thelypteris torresiana* (Gaudich.) Alston
Specimens Examined: Malakibetta, 29-11-2015, DT, 197975, BSI.
Distribution: Karnataka: Hassan, Shiradi Ghat, Kodagu, Madikeri, Shimoga, Agumbe, Kudremukh-samse.

82. *Thelypteris tylodes* (Kunze) Ching
Specimen examined: Kerekatte, 28-11-2015, DT, 197971, BSI.
Distribution: Karnataka: Chikmagalur, Shimoga, Kodagu, Kudremukh NP.

WOODSIACEAE

ATHYRIUM Roth. Tent. FI. Germ. **3** (1): 31, 58-59; 1800.

83. *Athyrium hohenackerianum* (Kunze) T. Moore
Specimens Examined: On the way to Bhagvathy to gangamoola road, 25-09-2016, DT, 202446, BSI.
Distribution: Karnataka: Aldur, Chikmagalur, Seetha Nadi, Hebri, Udupi, Belthangady, Dakshina Kannada, Sakleshpur, Bisle Ghat, Hassan, Sampaji, Mercara, Kodagu, Lakkavali, Agumbe, Hulikal Ghat, Shimoga, Castle rock and Kaiga, Uttara

Kannada, Kudremukha.

84. *Athyrium falcatum* Bedd.
Specimens examined: Chikmagaluru, 26-10- 1991, PKR 548, MGMC.
Distribution: India: Karnataka: Chikmagalur, Bangalore.

DIPLAZIUM Sw. Schrad. J. Bot. **1800**(2): 61; 1801.

85. *Diplazium brachylobum* Sledge
Specimens examined: S. K. Border, 22-11-2015, DT, 197946, BSI.
Distribution: Karnataka: Chikmagalur, Dakshina Kannada.

86. *Diplazium esculentum* (Retz.) Sw.
Specimens Examined: Bhadra river side, Chikmagalur, 17-11-2015, DT, 197905, BSI.
Distribution: Karnataka: Shimoga, Uttara Kannada, Chikmagalur.

BLECHNACEAE

BLECHNUM L. Sp. PI**. 2:** 1077; 1753.

87. *Blechnum orientale* L.
Specimen examined: Kadambi Falls, 19-11-2015, DT, 197926, BSI.
Distribution: Karnataka: Castle, rock, Shimoga, Chikmagalur, Kodagu.

DRYOPTERIDACEAE

ARACHNIODES Blume , Enum. PI. Jav. 241; 1828.

88. *Arachniodes aristata* (G. Forst.) Tindale
Specimen examined: Kurinjal peak, 18-11-2015, DT, 197921, BSI.
Distribution: Karnataka: Kodagu, Chikmagalur, Kudremukh, B. R. Hills, Mysore.

89. *Arachniodes tripinnata* (Goldm.) Sledge
Specimens examined: Udupi, 19-05-I960, R. S. Raghavan, 62730, BSI.
Distribution: Karnataka: Chikmagalur, Shimoga.

BOLBITIS Schott. Gen. Fil. **3**: t. 14; 1835.

90. *Bolbitis appendiculata* (Willd.) K. Iwatz.
Specimens examined: Kurinjal peak way, 01-11-2014, DT, 202354, BSI.
Distribution: Karnataka: Uttara Kannada, Mysore, Chikmagalur.

91. *Bolbitis appendiculata* var. *asplenifolia* (Bory) Sledge.
Specimen Examined: Kerekatte Forest, 25-11-2015, DT, 197960, BSI.
Distribution: Karnataka: Chikmagalur, Dakshina Kannada.

92. *Bolbitis presliana* (Fee) Ching
Specimens examined: Kudremukh to Someshwara, 25-11-2016, AB, 195642, BSI.
Distribution: Karnataka: Castle rock, Shimoga, Coorg, Mysore, Udupi.

93. *Bolbitis semicordata* (Baker) Ching
Specimens examined: Kudremukh Range, 24-09-2016, DT, 202437, BSI.
Distribution: Karnataka: Mysore, Kudremukha, Dakshina Kannada, Kumar parvatha,

Agumbe, Kodagu.

94. *Bolbitis subcrenatoides* Fraser-Jenk.
Specimens examined: Belthangady, 27-11-2016, DT, 202543, BSI.
Distribution: Karnataka: Chikmagaluru, Belthangady, Kempuhole, Castle Rock, and Shiradi Ghat.

DRYOPTERIS Adans. Fam. Plant. **2:** 20, 551; 1763.

95. *Dryopteris austroindica* Fraser-Jenk.
.Specimen examined: Chikmagalur, 23-12-2017, DT, 207905, BSI.
Distribution: Karnataka: Chikmagalur.
96. *Dryopteris cochleata* (D. Don) C. Chr.
Specimen examined: Kerekatte forest, 30-11-2015, DT, 197993, BSI.
Distribution: Karnataka: Bababudan hills, Genikalbetta, Chikmagalur, Kudremukha, Belthnagady, Hullahalli, Charmadi Ghat, Hassan, Madikeri, Kodagu, B. R. Hills, Mysore, Agumbe, Kotachadri, Shimoga, Castle Rock, Uttara Kanara.
97. *Dryopteris hirtipes* (Blume) Kuntze
Specimen examined: On the way to Kudremukh Peak, Chikamgalur, 27-11-2016, DT, 202559, BSI.
Distribution: Karnataka: BR Hills, Mysore, Kudremukha, Kemmangundi, Chikmagalur.
98. *Dryopteris sparsa* (Buch.-Ham. ex D. Don) Kuntze
Specimen examined: Bhagvathy nature camp, 03-11-2014, DT, 202381, BSI.
Distribution: Karnataka: Chikmagalur.

ELAPHOGLOSSUM Schott ex Smith, Hook. J. Bot. **4:** 148; 1841.

99. *Elaphoglossum nilgiricum* Krajina ex Sledge
Specimens examined: Dakshina Kannada, Charmadi Ghat, 17-04-1978, Saldanha, KFP 794, JCB.
Distribution: Karnataka: Chikmagalur.
100. *Elaphoglossum stigmatolepis* (Fee) T. Moore
Specimens examined: Kudremukh, Kadambi falls to Bhagwathy nature camp forest road side, 24-11-2015, DT, 197952, BSI.
Distribution: India: Karnataka: Chikmagalur, Kudremukh.

LEUCOSTEGIA C. Presl, Tent. Pterid.: 95, t. 4, f. 11; 1836.

101. *Leucostegia immersa* (Wallich ex Hook.) Presl
Specimens examined: Charmadi Ghat, 26-10-2016, DT, 1979544, BSI.
Distribution: Karnataka: Babbudan hills, Kemmangundi, Chikmagalur, Devarunde, Charmadi Ghat, Hassan, Talakavery, Kodagu, Gerusoppa, Uttara Kannada.

LOMARIOPSIDACEAE

NEPHROLEPIS Schott, Gen. Fil. t. 3; 1834.

102. *Nephrolepis auriculata* (L.) Trimen
Specimens examined: On the way to Kudremukh peak, 30-10-2014, DT, 202306, BSI.
Distribution: Karnataka: Hassan, Mysore, Chikmagalur.

103. *Nephrolepis multiflora* (Roxb.) Jarrett
Specimen examined: Dakshina Kannada, SK border to Sringeri, 29-10-2015, DT, 202307, BSI.
Distribution: Karnataka: Shimoga and Dakshina Kanada.

TECTARIACEAE

TECTARIA Cavanilles, Anal. Hist. Nat. **1**: 115; 1799.

104. *Tectaria coadunata* (J. Sm.) C. Chr.
Specimen examined: Kurinjal Peak, 31-10-2104, DT, 202347, BSI.
Distribution: Karnataka: Chikmagalur, B. R. Hills, Mysore, Kodagu, Someshwara, Kudremukh, Charmadi, Muthodi, Hassan, Madikeri, Kaiga.

105. *Tectaria fuscipes* (Wall. ex Bedd.) C. Chr.
Specimen examined: S. K. border road, 03-11-2014, DT, 202393, BSI.
Distribution: Karnataka: Castle rock, Chikmagalur.

106. *Tectaria paradoxa* (Fee) Sledge
Specimens examined: On the way to bolle falls, Belthangady, 26-11-2016, DT, 202516, BSI.
Karnataka: Chikmagalur.

107. *Tectaria polymorpha* (Wall. ex. Hook.) Copel.
Specimen examined: Malakibetta, 24-11-2015, DT, 197956, BSI.
Distribution: Karnataka: Chikmagalur, B. R. hills, Kodagu, Kudremukha, Udupi, Dakshina Kannada.

108. *Tectaria wightii* (Clarke) Ching
Specimen examined: On the way to Kudremukh Peak, 31-10-2014, DT, 202336, BSI.
Distribution: Karnataka: Chikmagalur.

DAVALLIACEAE

ARAIOSTEGIA Copel., Philipp. J. Sci. **34:** 240; 1927.

109. *Araiostegia pulchra* (D. Don) Copel.
Specimens examined: On the way to Kudremukh eak, 30-10-2014, DT, 202310, BSI.
Distribution: Karnataka: Chikmagalur.

POLYPODIACEAE

DRYNARIA (Bory) J. Smith, J. Bot. **4:** 60; 1841, *nom. cons.*

110. *Drynaria quercifolia* (L.) Js. Sm.
Specimen examined: Kudremukh road side, 29-10-2014, DT, 202302, BSI.

Distribution: Karnataka: Hebri, Dakshina Kannada, Bagi, Hassan, Mysore, Kota Chadri, Shimoga and castle, Uttara Kannada.

GRAMMITIS Sw. Schrad. J. Bot. **1800** (2): 3, 17; 1801.

111. *Grammitis medialis* (Baker) Sledge
Specimens Examined: On the way to Kudremukh peak, Near Stream, 04-10-2017, DT, 202749, BSI.
Distribution: Karnataka: Hassa, Kodagu, Chikmagalur.

LEPISORUS (J. Smith) Ching, Bull. Fam. Mem. Inst. Biol. **4:** 47; 1933.

112. *Lepisorus amaurolepidus* (Sledge) Bir & Trikha
Specimen examined: Panduramakki, Chikmagalur, 05-10-2017, DT, BSI.
Distribution: Karnataka: Kudremukh, Kemmangundi and Coorg.

113. *Lepisorus nudus* (Hook.) Ching
Specimen examined: Kurinjal peak, 18-11-2015, DT, 197911, BSI.
Distribution: Karnataka: Castle rock, Chikmagalur, Coorg, Bababudan hills, Kemmangundi, Banuhalla, Hettur, Hassan, Mercara, Bhagamandala, Kodagu, B. R. Hills, Mysore, Shimoga.

LEPTOCHILUS Kaulf. Enum. Fil. 147; 1824.

114. *Leptochilus axillaris* (Cav.) Kaulf.
Specimens Examined: Belthangady, Navoor, 26-11-2016, DT, 202509, BSI.
Distribution: Karnataka: Chikmagalur, Belthangady.

115. *Leptochilus decurrens* BI.
Specimens examined: Kurinjal peak, 31-10-2014, DT, 202342, BSI.
Distribution: Karnataka: Chikmagalur.

116. *Leptochilus lanceolatus* Fee
Specimens examined: On the way to Kurinjal Peak, 18-11-2015, DT, 197914, BSI.
Distribution: Karnataka: Chikmagalur, Kudremukh.

LOXOGRAMME (Blume) C. Presl, Tent. Pterid. 214; 1836.

117. *Loxogramme involuta* (D. Don) Presl
Specimen examined: Kadambi falls, 03-11-2014, DT, 202391, BSI.
Distribution: Karnataka: Chikmagalur, Kudremukha.

MICROSORUM Link., Hort. Berol. 2:10; 1833.

118. *Microsorum membranaceum* (D. Don) Ching
Specimen examined: Kurinjal peak, 31-10-2014, DT, 202327, BSI.
Distribution: Karnataka: Bababudan hills, Chikmagalur, Yedakumari, Hassan, Bhagamandala, Kodagu, Honnametti, B. R. Hills, Mysore, Hulikal Ghat, Agumbe, Shimoga, Jog Falls, Uttara Kannada.

119. *Microsorum pteropus* (Blume) Copel
Specimen examined: Kudremukh, Chikmagalur, 26-09-2016, DT, 202457, BSI.

Distribution: India: Karnataka: Chikmagalur.

120. *Microsorum punctatum* (L.) Copel.
Specimen examined: Irfu falls, 24-03-2017, AB, 202678, BSI.
Distribution: Karnataka- Sringeri, Kigga, Chikmagalur, Bisle Ghat, Shiradi Ghat, Hassan, Kundadari Hill, Agumbe, Shimoga, Jog Falls, Uttara Kannada.

PYRROSIA Mirbel Hist. Nat. Veg. **3.** 471; **5:** 91; 1802.

121. *Pyrrosia lanceolata* (L.) Farwell
Specimens Examined: Udupi, 20-08-1990, PKR, 286, MGMC.
Distribution: Karnataka: Udupi, Dakshina Kannada, sampaje, Kodagu, Agumbe, Yedur, Shimoga.

122. *Pyrrosia porosa* (Presl.) Hovenkamp
Specimens examined: Chikmagalur, Charmadi Ghat, 17-09-1990, PKR, 317, MGMC.
Distribution: Karnataka: Charmadi Ghat, Chikmagalur, Devarunde & Devihalli, Hassan, Mercara, Tadiyandamole, Shuntikoppa, Kodagu, B. R. Hills, Chamundi Hills, Mysore, Tumkur.

SELLIGUEA Bory., Dict. Class. Hist. Nat. 6: 587; 1824.

123. *Selliguea oxyloba* (Wallich ex. Kunze) Fraser-Jenkins
Specimens examined: On the way to Kudremukh peak, 02-11-2014, DT, 202378, BSI.
Distribution: Karnataka: Shimoga, Chikmagalur and Kodagu.

RESULTS AND DISCUSSION

The present study revealed the occurrence of 123 species of ferns and fern allies in the Kudremukh National Park, Karnataka. This accounts for 11.1 per cent of total Indian fern and fern allies in around 0.02 per cent of the total geographical area of the country. Altogether 123 taxa 24 families under 49 genera, out of 24 families, seven families *viz*; Pteridaceae (21 species), Dryopteridaceae (14 species), Polypodiaceae (14 species), Thelypteridaceae (11 species), Aspleniaceae (10 species), Hymenophyllaceae (8 species) and Selaginellaceae (6 species) are dominant in the study area, There are totally 49 genera, of which Pteridaceae and Polypodiaceae are the families with a higher number of genera 8 each respectively. The main aim of the study is to bring out the importance of Kudremukh National Park so as to conserve the existing biodiversity here. *Ex-situ* is also playing major role in conservation.

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College, Udupi for responses to specific enquiries concerning the distribution of Kudremukh National Park fern. I would also like to thank Karnataka Forest Department for permitting to collect plant specimens from the park.

REFERENCES

ALSTON A H G 1945 An enumeration of the Indian species of Selaginella *Proc Nat Inst Sci India* Vol **11(3) :** 211-234

BLATTER E & ALMEIDA J F 1922 *The Ferns of Bombay* D B Taporevala Sons & Co, Bombay

DEEPA J, PARASHURAMA T R, KRISHNAPPA M & NATARAJA S 2013 Pteridophytic flora of Kemmangundi forest, Karnataka, South India *Annals Plant Sciences* **02(11)** : 484-488

DEVENDRA TRIPATHI, BENNIAMIN A & JESUBALAN 2016 New record of Endemic Fern : *Elaphoglossum stigmatolepis* (Fee) T. Moore (Lomariopsidaceae) for the state of Karnataka *Indian J Forestry* **39(2)** : 1-8

FRASER JENKINS C R, GANDHI K N, KHOLIA B S & BENNIAMIN A 2017 An Annotated Checklist of Indian Pteridophytes Part-1, II (Lycopodiaceae to Polypodiaceae), Bishen Singh Mahendra Pal Singh, Dehradun

FRASER JENKINS C R, GANDHI K N & KHOLIA B S 2018 An Annotated Checklist of Indian Pteridophytes Part-1, II (Lycopodiaceae to Polypodiaceae), Bishen Singh Mahendra Pal Singh, Dehradun

KHULLAR S P 1994 An Illustrated Fern Flora of West Himalaya Vol 1 International Book Distributors, Dehra Dun

PICHI-SERMOLLI R E G 1958 The higher taxa of the Pteridophyta and their classification - In Systematics of today (ed O Hedberg) - Uppsala Univ Arsskrift

RAJAGOPAL P K & BHAT K G 2016 Pteridophytes of Karnataka State, India Vinayaka Prakashna, Udupi pp 233

RAJAGOPAL P K & GOPALKRISHNA BHAT 1998 Pteridophytic flora of Karnataka state, India *Indian Fern Journal*, **15** : 1-28

SMITH A R, PRYER K M, SCHUETTPELZ E, KORALL P, SCHNEIDER, H & WOLF P G 2008 Fern Classification In: *Biology and Evolution of Ferns and Lycophytes* (T A Ranker and C H Haufler Eds), UK, Cambridge University Press pp 417-467

SMITHA HEGDE & SUDHA SAJEEV 2013 A collection of selected ferns of Karnataka St Aloysius College Mangalaore

Indian Fern J. **36 :** 277-282 (2019) ISSN 0970-2741

CYTOLOGICAL OBSERVATIONS ON *THELYPTERIS DENTATA* (FORSSK.) E.P.ST. JOHN

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ABSTRACT

Thelypteris dentata (Forssk.) E.P.St.John (Synonym: *Christella dentata* Forssk., Family Thelypteridaceae), is a very common weed in the Lower Gangetic Plains and has been collected from Hoogly district, West Bengal. A chromosome count of n=72 bivalents is observed which shows the tetraploid status of the taxa. Morphological characters are also studied showing similarity with previously reported tetraploid cytotype of the taxa reported from other parts of India.

Key Words : *Thelypteris dentata*, chromosome count, tetraploid cytotype.

INTRODUCTION

Thelypteris dentata (Forssk.) E.P.St. John (Synonym: *Christella dentata* Forssk., Family Thelypteridaceae) is a very common weed and is pantropical in distribution. It grows in open habitat, along road-sides and in garden fences as well as areas in shade, below the tree canopy of semi-natural forests and forming thickets with other weeds.

Christella dentata has been treated as *Thelypteris dentata* here. Earlier it had been treated in the genus *Christella.* The genus *Christella* was established by Léveillé (1915) without designation of the type species. It was a large complex genus; some species have been proved to be members of *Dryopteris* and *Athyrium* (Holttum, 1971b). Holttum (1971b) typified and redefined *Christella* as a genus with more or less reduced lower pinnae, no spherical glands on lamina or glands/hairs on the capsule of the sporangia (Li *et al,* 2013). Another feature of the genus *Christella:* generally with anastomosing veins (but even this is a variable character). Holttum (1976) described fifty-one species of *Christella* from Old World. Schuettpelz *et al.* (2016) separate *Christella* containing 70 species including *Christella parasitica* as its type species and *Cyclosorus* as a separate genus with 2 species. The name was coined by St. John (1936) and later followed by Iwatsuki (1965), Fraser-Jenkins(1991) and others. Recently the single genus concept of *Thelypteris* is accepted so in this manuscript name *Thelypteris dentata* is followed for convenience (Almedia *et al.* 2016; Fraser-Jenkins *et al.* 2017).

This species has been found to be highly variable with regard to the number of basal reduced pinnae, distribution of hairs, lobbing of pinnae and size of the entire plant (Holttum, 1976; Sledge, 1981; Manickam and Irudayaraj, 1992). Wagner (1950) stated that this species was naturalized in Hawaii and is not expected to be morphologically uniform throughout its geographical range. Earlier Ching (1938) observed that the American plants

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may not be morphologically identical with Asiatic ones. The adventive nature of this plant was known since 1947, recorded from Central America, and several new world localities (Wagner, 1950; Strother and Smith, 1970; Smith, 1971).

Pteridophyte taxa show polyploidy, hybridization and polymorphism up to a remarkable range. Polymorphism is a characteristic feature of the Tropics where a great variety of niches exist due to diverse climatic, edaphic and topological factors. The cytological data that is level of ploidy may be helpful to unveil the extent of polymorphism. Study of intraspecific polyploidy may be important for analyzing the problems of speciation because a species is an evolutionary dynamic entity. It is always important to have comparisons between different cytotypes in morphological characters, geographical study and ecological niches (Manickam and Rajkumar, 1999). Manton (1950) expressed that the value of cytological records for wild species of known origin is very great both as a contribution to the understanding of the way plants behave in nature and also for the purpose of comparison of floras. Till date the ploidy and chromosome number of this species as reported from different parts of India and abroad are as follows: (Table 1).

Morphology of the plant varies with its ploidy level especially in respect to its spore size, stomata size (as reported earlier) and also the number of chloroplast per cell. Previously reported tetraploid taxa from different regions of India are more or less similar (Manickam and Rajkumar, 1999). In the previous literature where diploid sexual species of *Thelypteris dentata* was recorded, not provided with any description detail or the voucher specimen detail.

The present attempt is undertaken to explore the ploidy level of the *Thelypteris dentata* (*Christella dentata*) as the species is very common in Lower Gangetic Plains and also to record if morphological variation is present from the already known cytotype.

MATERIAL AND METHODS

Young developing sori were fixed in Carony's fixative from the field of Mankundu, Hoogly and brought to laboratory for chromosome study. Vaucher specimen was deposited in the Department of Botany,University of Kalyani. Provenances of the specimen is: A-25, 22/05/17, Anish Bhattacharya and Kakali Sen.

Macroscopic and microscopic characters were studied with the help of simple microscope and stereo-microscope (Olympus). The micro-morphology and cellular details are imaged with Nikon E200. For chromosome study, 2-3 fresh pinnae bearing young sori were collected between 8.00 to 8.15 a.m. and fixed in Carnoy's fixative (aceto-alcohol in 1:3 ratio) then kept for a day in refrigerator. Immature or the sori in the developing stage were crushed to get a countable meiotic plate. The collected sporangia from the sori were crushed and stained with the help of aceto-carmine stain, then observed and photographed under Compound trinocular microscope (Nikon eclipse, E200). The spore number per sporangium was also counted.

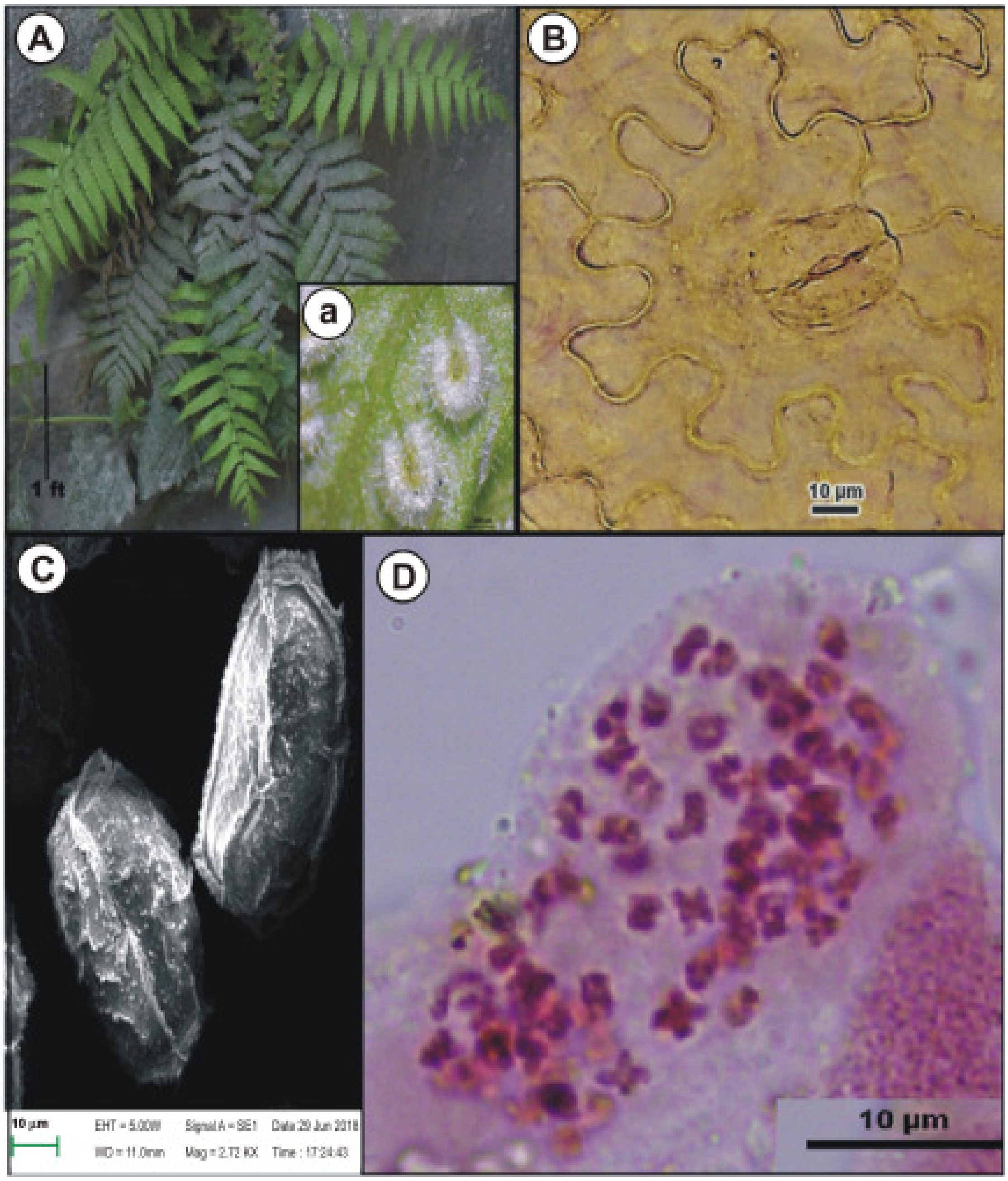

Fig.1 : (A) Showing the habitat with enlarged view of the young sori (1), **(B)** Stomata, **(C)** Spore, **(D)**The chromosome plate showing n=72.

TABLE 1 : Ploidy and chromosome number of *Thelypteris dentata* as reported from different parts of India and abroad

Species	**Chromosome No.**	**Ploidy**	**Source**	**References**
T. dentata	n = 72	tetraploid	N-E India, East and West Himalaya, Central India, South India	Chromosome Atlas of the Indian Pteridophytes, (Bir and Verma, 2010
T. dentata	n = 36	diploid	Uttarakhand, Punjab, Meghalaya	Loyal, 1961; Ghatak 1961
T. dentata	n = 72	tetraploid	Madeira and Sri Lanka	Manton and Sledge, 1954.
T. dentata	n = 72	tetraploid	New Zealand	Lange *et al*, 2004.

RESULT AND DISCUSSION

Thelypteris dentata (Forssk.) E.P.St. John

Rhizome short, ascending, apex scaly, scales brown, 0.5-1 cm long, lanceolate, margin more or less entire, **numerous unicellular hair present on scale**. Stipe length variable (10-20 cm), thick, dia. 0.2 cm or more, hair glandular and acicular, light brown hairy, hairs white, short, unicellular, acicular, base of the stipe scaly, scale are like rhizome but linear and becoming sparse and filiform, rachis hairy, lamina pinnate, large (length 30-45 cm, width 12-20 cm); (Fig1. A) oblong lanceolate, pinnatifid, texture herbaceous, e-glandular, hairy on both surfaces (but very few), hairs short, acicular, fronds monomorphic, pinnae 10-14 pairs, length- 7-9 cm, width- 1.5-2.2 cm, (Fig.1.A.1) subopposite to alternate, sessile, lanceolate, base truncate, apex acuminate, margin lobed about ½ or a little more to the costae, lobes regular, slightly oblique, subfalcate, rounded, sometimes basal acroscopic lobe in lower pinnae enlarged into a well developed auricle, basal 1-2 pairs of pinna reduced, sometimes single pinnae present at the basal part. When present singly, basal 2-3 pinna reduced, pinna distant, lowest pinna 2-5 cm long**. Pinnule apex obtuse**, veins free but at the basal pair of veins, united with the adjacent pair, anastomose. Rachis hairy, both in upper and lower region, costa hairy but lower than rachis both in upper and lower region, costules and veins are hairy (very few), lower surface is more hairy than rachis, very less in interveinal area. Indusia hairy, reniform, non-green. **Sori are arranged parallel to the vein in pinnule**. **Spores** dark-brown, ellipsoidal, length 38.2 µm, width 27.65 µm. Aperture- monolete, 2/3 to ¾ to the length. Spore surface reticulate, thin perispore. **Sixty four spores present per sporangium present.**

The chromosomes photograph of younger developing sori was revealed that n = 72 in diakinesis stage. (Fig.1. B,C). **The species is widespread in open disturbed habitat as garden weed or in the roadside land.**

Previously *Christella dentata* was reported as n = 36 from Meghalaya, Khasiya-

Jayantia hills, Ghatak,1961a; Uttarakhand, Nainital (Loyal,1961 a, b); Punjab, Amritsar (Loyal 1961a); Meghalaya, Gauhati-Shilong road at 58th km point, Ghatak,1961b; and all these are diploid sexual species of *Christella dentata* but no spore count was recorded. Also n=72 was reported from several places viz. Uttarakhand, Nainital, (Verma and Loyal, 1960) Punjab, Uttarakhand, and West Bengal Darjeeling, (Loyal 1961a, b) and from south India and Central India (Bir and Verma, 2009). Panigrahi and Manton (1958) classified a large group as *Cyclosorus parasiticus* complex and added *Christella dentatus* in that as *Cyclosorus dentatus*, collected from Ceylon and Madeira (n=72). Lange *et al,* 2004 worked on it mentioned that in New Zealand there are two kinds of *Christella dentata* having tetraploid chromosome, Brownsey & Perrie, 2016, mentioned that these two differ in rhizome, one having short creeping or erect rhizome, another one having long creeping rhizome.

Present report is based on the specimen collected from Hoogly district, West Bengal that is situated in lower gangetic plains of West Bengal. Present report shows n=72 i.e. tetraploid, sexual cytotype of *Christella dentata.* The specimen shows no difference from the tetraploid cytotype as reported from other parts of India.

Most cytological reports show this species to be a tetraploid, this cytotype of *T. dentata* is widely distributed throughout India that is from Western India, N-E India, Central India and Southern part of India, E. and W. Himalaya. So it can be concluded that tetraploid cytotype of the genus is more stable to survive in the open and disturbed habitat in the areas of human settlements, road side areas or in garden fences with other common weed in India and in the other parts of the world. The diploid cytotype is confined only in north-east part of India and needs further investigation regarding its morphological description as the previous reports show no mention of it.

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REFERENCES

ALMEIDA T E, HENNEQUIN S, SCHNEIDER H, SMITH A R, BATISTA JAN, RAMALHO A J, PROITE K & SALINO A 2016 Towards a phylogenetic generic classification of Thelypteridaceae : Additional sampling suggests alterations of neotropical taxa & further study of paleotropical genera *Molecular Phylogenetics & Evolution* **94** : 688-700

BIR S S & VERMA S C 2010 Chromosome atlas of the Indian pteridophytes, 1951-2009 Bishen Singh Mahendra Pal Singh

CHING R C, 1938 A revision of the Chinese and Sikkim-Himalayan Dryopteris with reference to some species from neighbouring regions *Bull Fan Mem Inst Biol Bot Ser*, **8(5)** : 275-334

FRASER-JENKINS C R 1991 The ferns and allies of the far west Himalaya, Pakistan systematics **5(1-2)** : 85-120

GHATAK J 1961a Some meiotic counts on the ferns from the Khasia Jainta Hills Proc *48th Indian Sci Congr,* Part III : 270

GHATAK J 1961b Problems involved in the proper identification of the ferns *Bull Bot Survey India* **3** : 79-82.

HEENAN P B, DE LANGE, P J, CAMERON E K, OGLE C C & CHAMPION P D 2004 Checklist of dicotyledons, gymnosperms, and pteridophytes naturalised or casual in New Zealand : additional records 2001-2003 *New Zealand Journal of Botany* **42(5)** : 797-814.

HOLTTUM R E 1976 Studies in the family Thelypteridaceae XI The genus Christella Lévillé, sect *Christella Kew Bulletin* **31** : 293-339 https://doi.org/10.2307/4109177

HOLTTUM R E 1971 Studies in the Family Thelypteridaceae III A new system of genera in the Old World *Blumea-Biodiversity, Evolution & Biogeography of Plants*, **19(1) :** 17-52

IWATSUKI K 1965 Taxonomy of the thelypteroid ferns, with special reference to the species of Japan & adjacent regions IV Enumeration of the species of Japan & adjacent regions *Mem Coll Sci Univ* Kyoto, B **31** : 125-197

LOYAL 1961a Cytological studies in Himalayan Thelypteridaceae-II. *Cytology of Cyclosorus Link. Abacopteris Fee and Ampelopteris Kunze Proc 48th Ind Sci Cong Part III Section 6 Botany* : 266-267

LOYAL D S 1961b In PN Mehra "Chromosome number in Himalaya Ferns" *Res Bull (NS) Punjab Univ Sci* **12(1-2)** : 139-164

LOYAL D S 1961 Cytological studies in Himalayan Thelypteridaceae II. Cytology of Cyclo sorus Link, Abacopteris Fee and Ampelopteris Kunze. Proc. Indian Sci. Congr. Assoc. 48th Session, Roorke Part III : 226-267

MANTON I 1950 Problems of cytology and evolution in the Pteridophyta *Problems of cytology and evolution in the Pteridophyta*

MANTON I & SLEDGE W A 1954 Observations on the cytology and taxonomy of the pteridophyte flora of Ceylon *Philosophical Transactions of the Royal Society of London Series B, Biological Sciences* : 127-185

MANICKAM V S & IRUDAYARAJ V 1992 *Pteridophyte flora of the western ghats, South India*. BI publications

MANICKAM V S & RAJKUMAR S D 1999 *Polymorphic ferns of the western Ghats, South India* Bishen Singh Mahendra Pal Singh

PANIGRAHI G & MANTON I 1958 Cytological and taxonomic observations on some members of the *Cyclosorus parasiticus* complex *Botanical Journal of the Linnean Society*, **55(363) :** 729-743

SLEDGE W A 1981 The Thelypteridaceae of Ceylon *Bull Brit Mus Nat His (Bot)* **8** : 1-54

SCHUETTPELZ E, CHEN C W KESSLER M, PINSON J B, JOHNSON G, DAVILA A, COCHRAN A T, HUIET L & PRYER K M 2016 A revised generic classification of vittarioid ferns (Pteridaceae) based on molecular, micromorphological, & geographic data *Taxon* **65** : 708-722

SMITH A R 1971 Systematics of the neotropical species of Thelypteris Section Cyclosorus Univ Calif Publ Bot **59 :** 1-136

STROTHER J L & SMITH A R 1970 Chorology, collection dates, and taxonomic responsibility *Taxon* **19(6)** : 871-874

VERMA S C & LOYAL D S 1960 Chromosome counts in some ferns from Naini Tal *Current Science* **29(2)** : 69-70

WAGNER W H Jr 1950 Ferns naturalized in Hawaii Occasional papers of Bernice P Bishop Museum Honlulu Hawaii **20(8)** : 95-210

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THELYPTERIS TRIPHYLLA (SW.) K. IWATS. [THELYPTERIDACEAE] - A NEW RECORD FOR THE FERN FLORA OF JALPAIGURI DISTRICT, WEST-BENGAL, INDIA

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ABSTRACT

Thelypteris triphylla (Swartz) K. Iwatsuki is reported from the district Jalpaiguri of West Bengal. This species is rarely found and known only from two areas of the district. The detailed description, illustrations of the plant, stomata, scale, spores are provided to enhance the identification process.

Key Words : Fern, Stomata, Scale, Spore, Jalpaiguri.

INTRODUCTION

The genus *Pronephrium* C. Presl belongs to the family Thelypteridaceae, of about 68 species, of these – 8 species are reported from India (Dixit, 1984). Fraser-Jenkins *et al.* 2017 includes the genus *Pronephrium* within the large genus *Thelypteris.* According to Fraser-Jenkins *et al.* (2017) Family Thelypteridaceae consists of one genus, *Thelypteris* which is represented in India by 83 species (Fraser-Jenkins (2016).

Thelypteris triphylla (Sw.) K. Iwats. (syn. *Pronephrium triphyllum*) was reported earlier from Dulkhajar (Indo-Nepal Border), Darjeeling District of West Bengal (Fraser-Jenkins *et al.*, 2017). During the present survey of Jalpaiguri district of ferns and fern-allies – a total number of 46 Pteridophytes is collected, out of these *Thelypteris triphylla* (Sw.) K. Iwats. a new report from Raipur Tea garden (latitude 26°36'20.14"N and longitude 88°40'35.42"E) and Sipchu-Chapramari forest Range adjoining regions (latitude 26°56’56.33” N and longitude 88°51’40.06” E) in the month of December’18. The district Jalpaiguri is a transition area between Duars and Terai region. It is very close to Indo-Bhutan hills with 3044 KM^2 total geographical area. The district has latitude of 26°32’36.52” N and longitude of 88°43’13.89”E with an average elevation of 180 meter above sea level. Geographically the district is situated in the northern part of West-Bengal. The average rainfall of this area is 3000 mm per annum.

Since the publication of Bengal plants by David Prain (Prain 1903) a lot of work has been done on Pteridophytes. In Eastern Himalayan region initial work on Pteridophytes is performed by Mehra and & Bir (1964); Sikdar *et al.* (1983); Ghosh *et al.* (2004); Paul (2016). The present study was done on foot hills and plains of Eastern Himalayan regions of Jalpaiguri district of West Bengal, India.

MATERIALS AND METHODS

After collecting the species were preserved in FAA for routine laboratory work.

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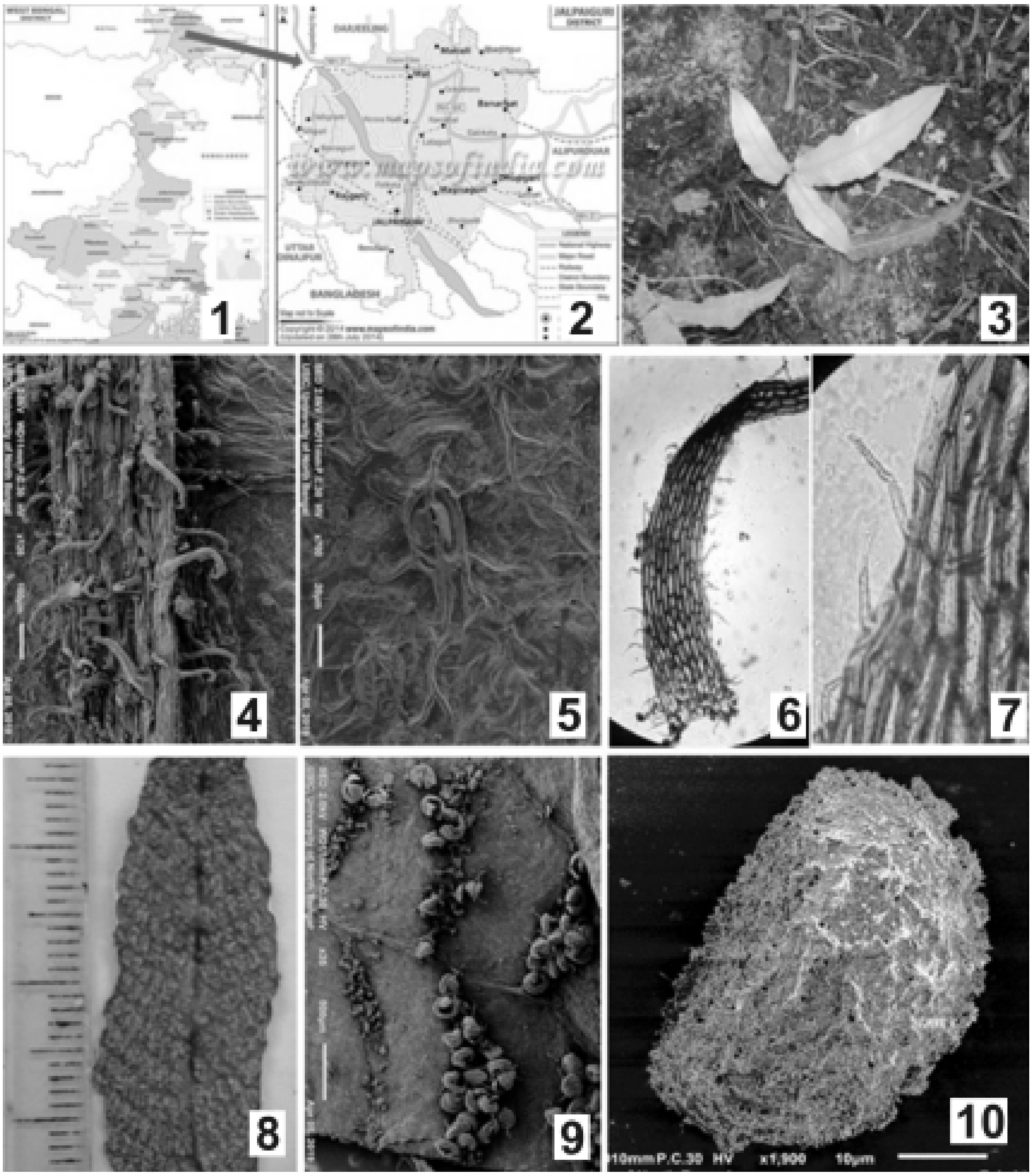
The herbarium of the said specimen was deposited at “NBU Herbarium” in NBU with accession no.10649. After proper examination and literature study (Chandra, 2000, Borthakur *et al.*, 2001, Ghosh *et al.*, 2004, Fraser-Jenkins *et al.*, 2017, and Singh & Panigrahi 2005) it was identified as *Thelypteris triphylla* (Swartz) K. Iwatsuki. Routine procedure is followed for morphological studies under simple and compound microscope for leaf epidermis, scale and petiole. Epidermal clearing was made by heating a piece of leaf dipped into 5% NaOH at 55°C in a test tube. It was washed thoroughly in water and bleached by sodium hypochlorite solution (10%). The cleared leaf material was now stained by 1% Aqueous-Safranine, dehydrated and made permanent for further observations. Spore morphology is based on acetolysis preparation of spore (Erdtman, 1952 & 1969). For SEM (JEOL microscope Model No. JSM-IT100) study dry spores were mounted on carbon tape of brass stub.

DESCRIPTION

Thelypteris triphylla **(Sw.) Iwats.**

Thelypteris triphylla (Sw.) K. Iwats. In mem. Coll. Sci. Univ. Kyoto B, 31: 190. 1965; Syn.: *Meniscium triphyllum* Sw. in Schrad. J. Bot. 1800. (2): 16. 1801; *Phegopteris triphylla* (Sw.) Mett., Lechl. 2: 27. 1859; Bedd., Ferns South India, t. 56. 1864 & Handb. Ferns Brit. India: 397. pl.231. 1883; *Nephrodium triphyllum* (Sw.) Diels, Nat. Pflanzenfam. 1(4): 178. 1899; *Dryopteris triphylla* (Sw.) C. Chr., Ind. Fil.: 298. 1905; *Abacopteris triphylla* (Sw.) Ching in Bull. Fan Mem. Inst. Biol. 8: 241. 1938; *Cyclosorus triphyllus* (Sw.) Tardieu-Blot ex Tardieu-Blot et Ching in Notul. Syst. 7: 77. 1938; Copel., Gen. Fil.: 143. 1947, et Fern Fl. Philip.2: 371. 1960; *Pronephrium triphyllum* (Sw.) Chandra in Bull. Bot. Surv. India.13: 274. 1971; *Pronephrium triphyllum* (Sw.) Holtt., Blumea, 20(1). 122. 1972; Nayar in Nayar and Kaur, Comp. Bedd. Handb.: 212. 1974; Sledge in Bull. Br. Mus. Nat. Hist. (Bot.) 8: 47. 1981; Baishya & Rao, Ferns & Fern-allies Meghalaya, 86. 1982; Kaur & Chandra in New Botanist 12: 101. 1985; Jamir & Rao, Ferns Nagaland, 261. 1988; Manickam & Irudayaraj, Pterid. Fl. West. Ghats-S. India, 185.t.140.1988; *Pronephrium nakaikei* R. D. Dixit & Bal Krishna, *Indian Fern J.* 7(1 & 2): 1-4, t. 1-3.1990 (as “nakaikeium”). **Rhizome** long, 0.5 cm thick, creeping, slender covered with scales, root hairs blackish-brown in colour; **Scales** (3 ×1 mm) linear-lanceolate (PLATE I, Fig.6), apex acuminte, apex with deciduous gland, margin entire, hairy (PLATE I, Fig.7), clathrate scales present at the base of the petiole, dark-brown in colour; **Stipes** in sterile lamina 6-20×0.2-0.3 cm, it is sometime longer in fertile lamina, slender, grooved above, flattened below; green to brownish in colour, covered with dense hair; **Lamina** (7-18×5-11 cm), dark-green at adaxial side and light green at abaxial side, ovate in shape trifoliate; lateral pairs of pinnae 3-10×1.5-2.5 cm, lanceolate, opposite, petiolate (0.5-2 cm), apex acuminate, attenuate at the base, undulate to serrate margin, costules & veins distinctly prominent abaxially, veinlets obliquely spreading and parallel, costules are dense hairy (PLATE I, Fig.4); all veins of adjacent costules meet at the centre; texture subcoriaceous;

PLATE I



Figs. 1 & 2. Location site of the plant; **3.** Habit of the plant; **4.** Costule with hair; **5.** SEM of stomata; **6.** A scale, ×22; **7.** Margin of scale, ×90; **8.** Fertile lamina; **9.** SEM of Sori orientation through veinlets; **10.** SEM of a spore stomata copolocytic (PLATE I, Fig.5); lamina adaxially glabrous but abaxially with hooked hairs along costae and veinlets, intercostal areas with scattered hairy hooked; **Sori** developing along the veinlets of the lamina, oblong to slightly curved (PLATE I, Fig.9), ex-indusiate, coenosori; **Sporangia** with 2 hairy hooked; **Spores** 38×22 µm,monolete, reniform, regulate (PLATE I, Fig.10), exine spinulose.

DISTRIBUTION

India : West-Bengal, S. India, Sikkim, Assam, Arunachal Pradesh; **Sri Lanka**, **Myanmar**, **Thailand**, **Malaysia**, **China**, **Japan**, **Taiwan**, **Philippines**, **Australia**.

DISCUSSION

The above specimen (Plate I, Fig. 3) was found less in population in respect to other fern genera (out of 15 in that area). During the present work it was observed urbanization, over population and construction of roads might be the cause of destruction of the natural habitat of plants along with this fern. The flora needs well exploration and identification of the ecologically and ethno-botanically important ferns and requires maintaining some conservation strategies.

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REFERENCES

CHANDRA S, FRASER-JENKINS C R, KUMARI A & SRIVASTAVA A 2008 A Summary of the Status of Threatened Pteridophytes of India *Taiwania*, **53(2)** : 170-209

ERDTMAN G 1952 Pollen Morphology and Plant Taxonomy-Angiosperms, Chron Bot Co, Waltham, Massachusettes

ERDTMAN G 1969 An Introduction to the Study of Pollen Grains and Spores Copenhagen, Denmark : Munksgaard

FRASER-JENKINS C R, GANDHI K N, KHOLIA B S & BENNIAMIN A 2017 An annotated checklist of Indian Pteridophytes Bishen Singh Mahendra Pal Singh Dehradun

GHOSH S R, GHOSH B, BISWAS A & GHOSH R K 2004 The Pteridophytic flora of Eastern India Vol. 1 Botanical Survey of India Kolkata

MEHERA P N & BIR S S 1964 Pteridophytic flora of Darjeeling and Sikkim Himalayas Res *Bull* (No 3) Punjab Univ **15** : 69-81

PAUL T K, BASU S K & SARKAR A 2016 Some notable Pteridophytes of Buxa-Duar, Jalpaiguri district, West Bengal *J Econ Taxon Bot* **36(3)** : 609-617

PRAIN D 1903 *Bengal Plants* Vol 1 & 2 Bishen Singh Mahendra Pal Singh Dehradun

SARNAM SINGH & PANIGRAHI 2005 Ferns and fern-allies of Arunachal Pradesh, Vol 1&2 Bishen Singh Mahendra Pal Singh Dehradun

SIKDAR J K, BASU S K & SAMANTA D N 1983 A sketch on the Pteridophytic flora of Jalpaiguri district, West Bengal *J Econ Taxon Bot* **4(3)** : 667-668

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REPORTING *ANOGRAMMA REICHSTEINII* FRASER-JENK. (PTERIDACEAE) FROM EAST KUMAON (WEST HIMALAYA)

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ABSTRACT

Occurrence of *Anogramma reichsteinii* Fraser-Jenk. from Pithoragarh, the eastern part of Uttarakhand state, is reported, suggesting its extended distribution range in Kumaon.

Key Words : *Anogramma reichsteinii*, distribution, Kumaon

INTRODUCTION

The genus *Anogramma* is represented in the Indian subcontinent by two species, namely *A. leptophylla* (L.) Link and *A. reichsteinii* Fraser-Jenk. (Fraser-Jenkins *et al.* 2017), and these small-sized species are believed to be 'annual' because the sporophyte withers while the gametophyte perennates through tubers. In literature on Indian ferns up to 1994 (Khullar 1994) the two taxa were clubbed into one species, *A. leptophylla*. The west Himalayan taxon, from Mussoorie, Dalhousiae and Nainital identified as *A. leptophylla*, is a much smaller plant when compared to the true European (and S. Indian) *A. leptophylla*. Fraser-Jenkins (1997) segregated the delicate and very small-sized W. Himalayan *Anogramma* as taxonomically distinct from the European *A. leptophylla* and named it *A. reichsteinii* Fraser-Jenk. mentioning Nainital as its type locality (S. side of Nainital University, N. of Tollital Bazar, Nainital; Uttarakhand, Fraser-Jenkins 1997; Fraser-Jenkins *et al.* 2017). Interestingly, the W. Himalayan taxon, erstwhile named as *A. leptophylla* (now = *A. reichstemnii*) is chromosomally a tetraploid, as worked from Mussoorie, Dalhousiae and Nainital (Mehra & Verma 1960, Verma & Khullar 1965, Khullar & Mehra 1972) whereas the relatively much large-sized European *A. leptophylla* is diploid sexual (Rasbach & Reichstein 1990). We report the occurrence of *A. reichsteinii* from Pithoragarh, further east in Kumaon, which extends its distribution. It may be mentioned that Fraser-Jenkins *et al.* (2015) also reported *A. reichsteinii* from Mugu, West Nepal.

THE COLLECTION FROM PITHORAGARH

The first author (RP) spotted a population of *A. reichsteinii* in her private garden at Pithoragarh (alt. 1563 m, lat. 29.58° N, long. 80.20° E) growing in crevices of a retaining wall (Fig. 1 A) along with a population of its prothalli at different stages of growth, and are intermixed with mosses and liverworts (Fig 1 B). It was felt necessary to put on record its eastward distribution in Kumaon region (Uttarakhand, India).

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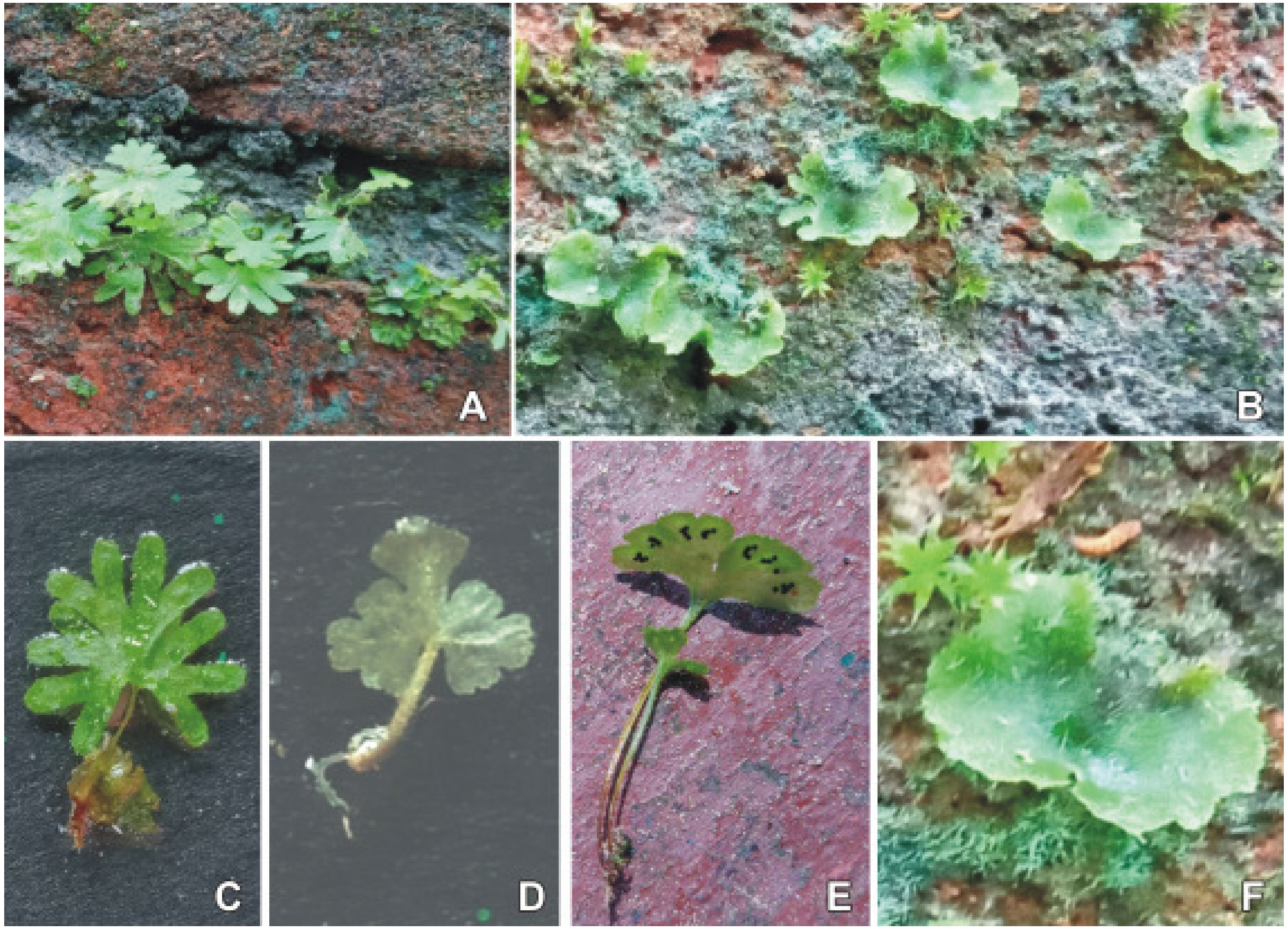

Plate I. *Anogramma reichsteinii* . **A**-Natural population on a retaining wall. **B**. A Population of gametophytes on retaining wall. **C.** A juvenile leaf attached with the prothallus. **D**-A juvenile leaf, **E**. A fertile leaf with linear sori. **F**. A prothallus on retaining wall.

TAXONOMIC NOTES

Anogramma reichsteinii Fraser-Jenk., *New Sp. Syndr. Indian Pteridol.* 35. 1997; Fraser-Jenkins, Kandel & Pariyar, *Ferns & Fern allies Nepal* **1**: 254 – 255. 2015; Fraser-Jenkins, Gandhi, Kholia & Benniamin, *Annot. Checklist Indian Ptrid.* 1: 234. 2017.

Rhizome very small, rudimentary, attached with translucent gametophyte; frond very small, up to 2.5 cm long, tufted on the gametophyte if more than one frond is present; stipe up to 1 cm long; lamina 1.5 to 2.0 cm long, 1.8 cm wide, lobed due to repeated dichotomy, delicate, green, number of lobes up to 10, sparsely hairy on upper surface; hairs 2 to 3-celled long; veins simply forked; sori elongated on veins, on undersurface of lamina; spores trilete or globose, 45-53 μm in diameter.

Anogramma reichsteinii is the smallest amongst the ferns. The number of species in the genus *Anogramma* vary from 5 (Nakazato & Gastony 2003) to 8 (Tryon *et.al.* 1990). Kachhiyapatel *et.al.* (2017, 2018) reported its presence in Peninsular India (from Gujarat.) and they detailed some interesting features.

Considering its threatened status Benniamin *et al.* (2018) recently raised its sporophytes under laboratory conditions using *in vitro* methods of spore germination.

SOME FURTHER COMMENTS

The taxon *A. reichstenii* is strictly a rainy-season fern, the leaves of which often die at the onset of autumn in subtropical Himalayan climate. Authors believe that the spores of this fern on arrival here in the summer formed large, caudate, bi-lobed gametophytes (Fig. 1, B & F) which measured 0.5 cm in length and 0.8 cm in width. Presence of a juvenile and one small leaf (Fig.1 C, D), observed on a large number of gametophytes is suggestive of a recent sexual reproductive event. Fertile leaves were rare (Fig. 1, E). Kachhiyapatel *et al.* (2017) reported its occurrence on rock crevices at humid places at relatively lower elevations than in west Himalaya.

Various studies on different aspects of the life cycle of *A. leptophylla* (= *A. reichsteinii*) in India (Mehra & Sandhu 1976, Cheema 1980, Benniamin *et al.* 2018) and in other parts of world (*A. leptophylla s.s.*; Pangua *et al.* 2011) reveal some interesting reproductive features of the perennating gametophytes.

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REFERENCES

BENNIAMIN A, SUNDARI M S, SINGH B & JESUBALAN D 2018 *In vitro* germination and ontogeny of an endangered annual fern *Anogramma reichsteinii Indian Fern J* **35** : 356-365

CHEEMA H K 1980 *In vitro* morphogenetic studies on the gametophyte of *Anogramma leptophylla*

(Sw) Link *Curr Sci* **49 :** 593- 594

FRASER-JENKINS C R 1997 *New Species Syndrome in Indian Pteridology and the Ferns of Nepal* International Book distributors, Dehra Dun Pp 404

FRASER-JENKINS C R, GANDHI K N, KHOLIA B S & BENNIAMEN A 2017 *An Annoted Checklist of Indian Pteridophytes* part-**1** (*Lycopodiaceae* to *Thelypteridaceae*) Bishen Singh Mahendra Pal Singh Dehra Dun Pp 562

FRASER-JENKINS C R, KANDEL D R & PARIYAR S 2015 *Ferns and Fern – allies of Nepal* **1** National Herbarium and Plant Laboratories, Department of Plant Resources, Kathmandu Pp 492

KACHHIYAPATEL R N, RAJPUT K S & FRASER-JENKINS C R 2017 Some observations on *Anogramma reichstienii* (Pteridaceae) from Peninsular India *Indian Fern J* **34** : 73-84

KACHHIYAPATEL R N, RAJPUT K S & FRASER-JENKINS C R 2018 *Anogramma reichsteinii* Fraser-Jenk : An extended distribution into Gujarat state In : Verma S C Khullar, S P Benniamin, A Lakshminarasimhan P & Singh P (Eds.) *Pteridology Today* : *Challenges and Opportunities* pp 215-218 Botanical Survey of India Kolkata India

KHULLAR S P 1994 *An Illustrated Fern Flora of West Himalaya* **1** International Book Distributors Dehra Dun Pp 506

KHULLAR S P & MEHRA P N 1972 Cytotaxonomy of W Himalaya Ferns I : Schizaeaceous series *Res Bull Panjab Univ n.s.* **23** : 89-204

MEHRA P N & SANDHU R S 1976 Morphology of the fern *Anogramma leptophylla Phytomorphology* **26 :** 60-76

MEHRA P N & VERMA S C 1960 Cytotaxonomic observations on some Western Himalayan Pteridaceae *Caryologia* **13** : 619-650

NAKAZATO T & GASTONY G J 2003 Molecular phylogenetics of *Anogramma* species and related genera (Pteridaceae: Taenitidoideae) *Syst Bot* **28 :** 490-502

PANGUA E, PEREZ-RUZAFA I & PAJARON S 2011 Gametophyte features in a peculiar annual fern, *Anogramma leptophylla Ann Bot Fennici* **48 :** 465-472

TRYON R M, TRYON A F & KRAMER K U 1990 Pteridaceae In: KRAMER K U & GREEN P S (eds) in KUBITZKI, K (ed) *The Families and Genera of Vascular Plants* **1** (*Pteridophyta and Gymnosperms*) 230-256 Narosa Publishing House, Tokyo; Springer Verlag, Berlin, Heidenberg

VERMA S C & KHULLAR S P 1965 Cytology of some western Himalayan Adiantaceae (sensu Alston) with cytotaxonomic comments *Caryologia* **18** : 85-106

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INTERACTION OF A LEPIDOPTERAN *ELOPHILA OBLITERALIS* WALKER WITH FLOATING FERN *AZOLLA PINNATA* R. BR. IN THE PADDY FIELD OF WEST BENGAL, INDIA

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ABSTRACT

A unique kind of fern-insect interaction in the paddy fields of West Bengal, India is described. The interaction was recorded between the floating fern *Azolla pinnata* R. Br. and a lepidopteran *Elophila obliteralis* Walker. *Azolla* balls were found to be floated in the paddy field. Larval phases of the insect made oval 'case' like structures primarily with *Azolla* leaves and secondarily with other weeds *i.e. Marsilea*, *Lemna etc*. and live inside. The case was woven with the aid of mucilaginous secretion of its mouthparts. Moist waterproof microclimate is thus created within the leaf case. This appears to be an exceptional adaptive strategy of a lepidopteran insect. The findings were recorded from three different districts of West Bengal during the period 2014-2019 through extensive field survey. The leaf balls were collected in plastic containers and brought to the laboratory to see the feeding behavior and the metamorphosis of the larva. Complete life cycle and feeding behavior of the insect was studied in laboratory and in the field through regular visits. The insect completed many cycles before the paddy was harvested (in the month of July to October). A tritrophic relation was established among the insect–*Azolla* and the rice plant. *Elophila obliteralis* (having tracheal respiratory system) adapted to survive in the aquatic environment by creating terrestrial microclimate using *Azolla pinnata* is a rare type of an interaction and first time reported from India by this present communication.

Key Words : Fern-insect interaction; *Azolla pinnata*; *Elophila obliteralis*; paddy field; waterproof microclimate.

INTRODUCTION

Fern-insect interaction is creating more attention to the interaction biologist after the discovery of different mode of interaction of fern with other organisms from different corners of the world. Seedless vascular plants develop coexistence with mycorrhizal fungi since Devonian and with insects during Carboniferous (Kevan *et al.* 1975, Smith *et al.,* 2006, Mehltreter, 2010). Ferns are less preferred to the phytophagus insects because of the absence of colorful flowers and aroma that is present in angiosperms. Some deterrent chemicals like tannin, alkaloid, thiaminase, cyanogenic glycosides and more amounts of

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fibres in the tissue make them unpalatable or less preferable to the herbivores. Though ferns had developed an array of interaction like neutralism, antagonism and mutualism and the insects are mainly from the order Coleoptera, Hemiptera and Lepidoptera (Hendrix, 1977, Balick, 1978, Somvanshi, 1980, Kramer, 1995, Bera *et al*., 2003, Patra *et al.,* 2010, Santos *et al*., 2019). Ferns can be considered important for biodiversity, because there are specialist insects that can only survive on ferns. Without the ferns, those insects would not exist as evidenced by Lecanopteris-ant association (Camus *et al.* 1991).

Azolla is used as green manure in the paddy field since long especially in the agriculture based developing country like India and other Asian countries. Interaction of *Azolla* with the insect is very rare. Surveys of *Azolla*–insect pest in the Philippines and Asian countries revealed two major insect genera *i.e., Elophila* (caseworm) and *Ephestiopsis* (spinning worm) causing yield loss of 13-57% in field grown *Azolla pinnata* (Watanabe *et al.,* 1986).

The interaction between economically important fern *Azolla* with a Lepidopteran insect in the paddy fields has been studied. The insect was *Elophila obliteralis* Walker belonging to the family Crambidae: Acentropinae. The insect depends on the fern for its food and shelter and completed its life cycle in the paddy field before the paddy harvested. A tritrophic relationship was established among the insect-fern and the rice plant.

MATERIAL AND METHODS

Materials was collected from three different districts of West Bengal through the period 2014-2019. Geographical details and abundance of the leaf balls collected from different sites are provided in Table 1.

TABLE 1 : Geographical details, time and availability of the fern-insect association during field collections.

Collection sites	Sl. No.	Altitude	Latitude-Longitude	Time of field visit	Frequency of leaf ball in the field
Burdwan University Farm, Burdwan	Site 1	40m	22^{0}56’ to 23^{0}53’N, 86^{0}48’ to 88^{0}25’E	July-October, 2014 and 2015 March, 2019	10-15 balls / sq.ft
Arambag, Hooghly	Site 2	15m	22.88° N, 87.70° E	July-October, December-February 2014, 2017	2-3 balls / sq.-ft
Kalyani, Nadia	Site 3	11m	22.98° N, 88.44° E	April-October 2017-2019	4-5 balls / sq.ft

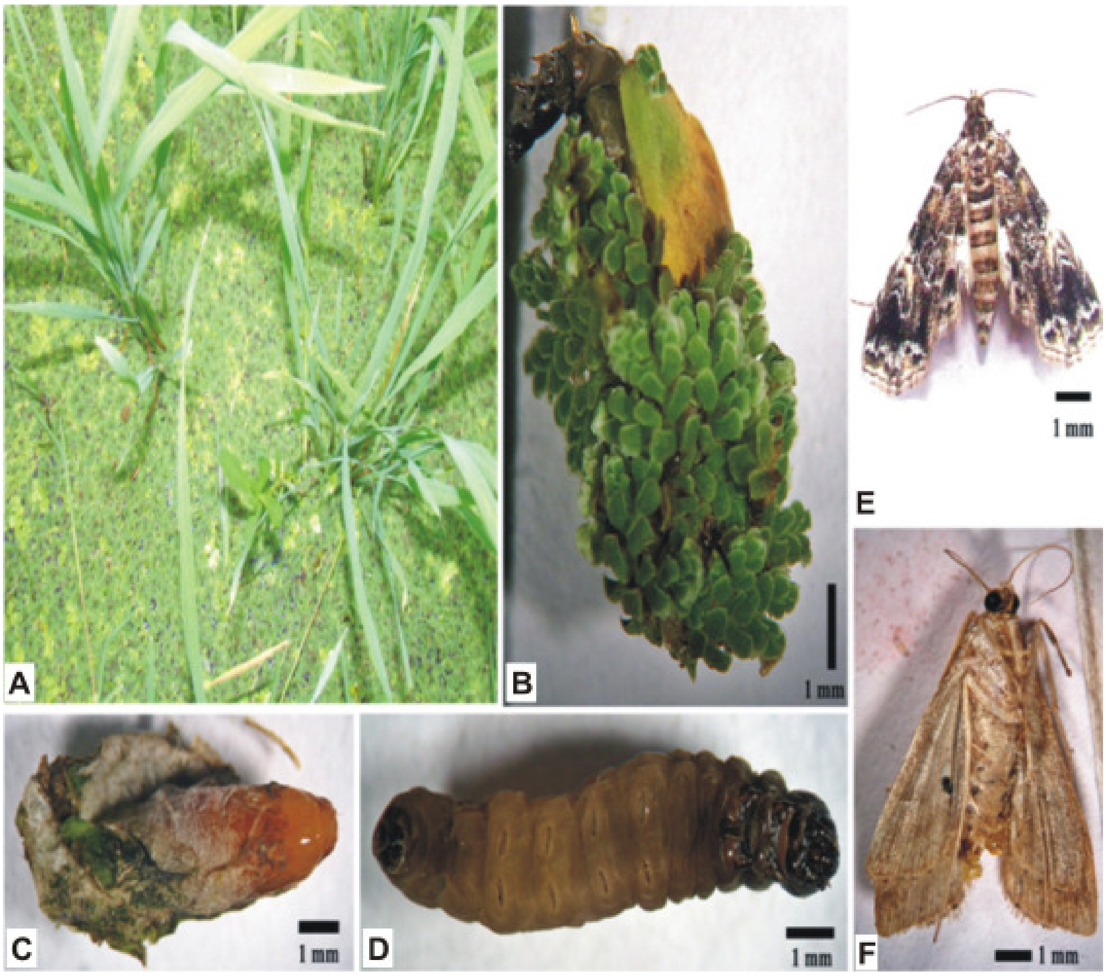

Plate I : Field photographs **(A)** and the life cycle stages of the insect *Elophila* (**B-F**). **A.** *Elophila-Azolla* interaction in the rice field. **B**. Leaf case with larvae inside (magnified view). **C.** Pupa, **D.** Larva, **E**. Adult-dorsal view, **F.** Adult-ventral view.

The metamorphosis and host–insect relationship was studied by regular field visit. The leaf balls were collected in plastic container by simple hand picking and carried to the laboratory to see the feeding behavior and the metamorphosis of the larva. The feeding preference and mechanism of feeding were studied in laboratory conditions by placing the larval case collected from field in a well aerated container. Single or mixed feed in different combinations were supplied to study the feeding preference of larvae. Combinations of the plants include *Azolla*, rice leaves and the other weeds like *Marsilea*, *Lemna etc.* present in the rice field. Feeding time and phase changes of larval instars were recorded to get the complete picture of the life cycle. Detailed measurements of larval case, larvae, pupa and

TABLE 2 : Metamorphosis and life cycle stages of *Elophila obliteralis* with its feeding preferences.

Life cycle stages of the insect	Where found	Brief morphology of each stage	Feeding preference
Egg	On the underside of *Azolla* leaves	White, small oval structure like opium seeds	—
Larvae (Fig.1D)	Inside the leaf case (Fig. 1B) made by *Azolla* primarily and secondarily with *Marsilea, Lemna* or other weeds, 17.1±4.5mm in length and 15.3±4.1mm in width, larval time span 5 days.	Length 8.30±1.34mm, dia 0.84± 0.13mm, cylindrical without tracheal gills (fifth instar larva) case size increases as the larva goes to advanced instars	Vigorous feeding on Azolla leaves, secondarily feed on *Marsilea* or *Lemna* leaves
Pupa (Fig.1C)	Floating on the water	Length16.30±4.32mm, width 4.20 ±1.01mm, oval, covered with white membranous covering attached with some substratum	—
Adult (Fig.1E, F)	Came out within 5-7 days after pupation.	1cm in length.	—

adult sizes were recorded (Table 2). Larval faecal matter was studied in intact condition and analyzed by treating with 5% KOH solution and then photographed under Zeiss AXIOSKOP 40 microscope.

RESULT AND DISCUSSION

An extensive field survey was carried out in three different districts of West Bengal through the period 2014-2019. It revealed the presence of the insect with *Azolla* in the paddy field. The association was observed as the floating balls in the paddy field (Fig.1A). Detail of the field survey and geographical information of the localities are mentioned in Table 1. Regular field visits were carried out to see the behavior of the insects in the field and several leaf balls (Fig.1B) were collected in the plastic container to observe the same in the laboratory condition. An interesting play was observed in the field. The insect laid eggs on the underside of the *Azolla* leaves and in its larval phases (Fig.1D) make case by the help of field grown *Azolla* leaves. The case was woven with the mouthparts of the larvae with the mucilaginous secretions. The insect left its previous case in each instars. During larval stage excessive feeding was observed on the *Azolla* leaves. Also the secondary preference of food and making leaf case was observed as other weeds like *Marsilea* and *Lemna* were present in the paddy field. Always the leaf balls were found in floating condition. The muddy part of the field having less water did not contain any leaf balls. After larval stage the insect underwent pupation. Pupa stages (Fig.1C) were covered with thin white membranous structure found to be floating in the field and within a few days the adult (Fig 1 E, F) came out. Detail of the metamorphosis and life cycle stages of the insect is given in Table-2 including the morphology and association of each stage of the insect with the fern in the field. The insect completed many cycles between July to October before the paddy was harvested. During post harvest time bare field were left or sometimes other crops like mustard and potato farming were done. One important observation during this time was that the *Azolla* populations were grown in full bloom (*i.e.* with sporocarp) in the nearby canals or ditches showing no infestations. Only exception was noticed in site 2 that the leaf balls were found in winter time *(i.e.* in December to February) in the adjacent swampy land of paddy field during post-harvest time. The leaf balls were very large (about double of other two sites) in size and the metamorphosis did not occur as in the pre-harvest time.

From the present survey an array of information regarding the interaction of insect life cycle was gathered. First, the floating niche established by the insect using *Azolla* or other weeds of paddy field is a unique type of interaction.. The insect used *Azolla* plant for feeding, dwelling and oviposition. Second, the lepidopteran life cycle traits and their evolutionary trend in the field of insect-plant interaction is also found. Though the trichopteran larvae live in leaf-made cases and habituated in under-water life, the lepidopterans rarely acquire such adaptive trait in their life-cycle unlike *Elophila obliteralis*. The *E. obliteralis* larvae do not have an aquatic life with gill like respiratory structures instead they have prominent tracheal terrestrial respiratory system. The case made by the *Azolla* leaves or occasionally made by other aquatic plant leaves seem to render a moist waterproof microclimate in order to enable the larvae to carry out terrestrial mode of respiration. Another unique trait to be mentioned from this study that the larvae mostly feed on the leaves of same host plants which provide their leaf case materials. From the present study, it may be tenable to predict that both life cycle traits may be treated as pre-conditions or pre-adaptive traits paving towards the evolution of leaf mining lepidopterans like plutellid in *Podocarpus* (Bera and Ghorai, 1997).

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REFERENCES

BALICK M J, FURTH D G, COOPER-DRIVER G 1978 Biochemical and evolutionary aspects of arthropod predation on ferns *Oecologia* (Berlin), **35** : 55-89

BERA S, GHORAI N 1997 On the interaction between Podocarpus spp and Plutellid leaf miner from Darjeeling(West Bengal) and their possible co-evolution *Sci & Cult* **63(9-10) :** 239-241

BERA S, PATRA B & GHORAI N 2003 Animal interaction with pteridophytes with emphasis on Indian records, in Chandra S, and Srivastava M (Eds) *Pteridology in the New Millennium*

Kluwer Academic Press, London, pp 383-395

CAMUS J M, JERMY A C & THOMAS B A 1991 *A World of Ferns* Nat Hist Mus London Publication

HENDRIX S D 1977 The resistance of *Pteridium aquilinum* (L) Kuhn. to insect attack by *Trichoplusa ni* (Hubn) *Oecologia* **26 :** 347-361

KEVAN P G, CHALONER W G & SAVILE D B O 1975 Interrelationship of early terrestrial arthropods and plants *Paleontology* **18** : 391-427

KRAMER K U, SCHNELLER J J & WOLLENWEBER E 1995 Farne and Farnverwandte Georg Thieme Verlag Stuttgart : Germany

MEHLTRETER K 2010 Interactions of ferns with fungi and animals In : Mehltreter K, Walker L R and Sharpe J M (Eds) *Fern Ecology* Cambridge University Press, U K, pp 220-254

PATRA B, BERA S AND MEHLTRETER K 2010 Structure, biochemistry and ecology of entomogenous galls in *Selaginella* Pal Beauv (Selaginellaceae) from India *Journal of Plant Interaction* **5(1) :** 29-36

SANTOS M G, PORTO G F, LANCELLOTTI I R & FEITOSA R M 2019 Ant fauna associated with Microgramma squamulosa (Kaulf) de la sota (Polypodiaceae) fern galls *Revista Brasilia de Entomologia*

SMITH A R, PRYER K M, SCHUETPELZ E, KORALL P, SCHNEIDER H, PAUL G & WOLF H A 2006 Classification for extant ferns *Taxon* **55(3) :** 705-731

SOMVANSHI R, LAUREN D R, SMITH B L, DAWRA R K, SHARMA O P, SHARMA V K, SINGH A K & GANGWAR N K 2006 Estimation of the fern toxin, ptaquiloside, in certain Indian ferns other than bracken *Current Science* **91(11) :** 1547-1552

WATANABE I, ROGER P A & LADHA J K 1986 Problems in application of biological dinitrogen fixation in wetland rice. INSFFER Planning Meeting-Workshop in Hangzhou, China

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FLORISTIC STUDIES ON FERNS AND LYCOPHYTES OF NEYYATTINKARA MUNCIPALITY, THIRUVANANTHAPURAM DISTRICT

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ABSTRACT

Pteridophytes are the first vascular plants (originated from Silurian period and dominated the Devonian period) that played an important role in establishing the early land flora. They are economically important and are used as medicines, ornamentals, bio-fertilizer and food and are easily vulnerable to anthropogenic interactions owing to their susceptibility and lack of addictiveness to the environmental perturbations. Field studies at Neyyattinkara Municipality resulted in the documentation of 37 species of Ferns and Lycophytes under 26 genera belongs to 16 families.

Key Words : Pteridophytes, Ferns, Lycophytes, Neyyattinkara

INTRODUCTION

Pteridophytes, the seedless vascular plants are characterized with independent heteromorphic alternation of generation with a primitive vasculature and having roots, stem and leaves. The stem is usually rhizome, slender and elongated with scattered leaves or may be short and compact with clustered leaves. As growth proceeds, more rapid elongation of the cells of inner side of the leaf causes the tip to uncurl slowly. This unfolding of the fern is one of the features which distinguish mostly from other kinds of vascular plants.

Being a dominant vegetation of the earth about 280-230 million years ago Pteridophytes were the pioneer colonizers on land. They are the non-flowering dominant group of plants next to the angiosperms mainly distributed to the tropical, subtropical and warm temperate regions of the world representing a wide spectrum of ecological types which in turn provides a lot of information about the evolution of plants (Patil *et al.*, 2016). Carboniferous period is considered as the 'Golden age of ferns'. There are about 12000 species of Pteridophytes reported from all over the world. The distribution and abundance of Pteridophytes in India is fairly over 1200 species (Dixit, 1984). Of which 200 taxa are endemic to India. In India maximum diversity of Pteridophytes is observed in the Eastern Himalaya, Eastern and Western Ghats (Dixit, 2000). More than 300 Species of fern and fern allies are reported from the Western Ghats (Manickam & Irudayaraj, 1988), among this more than 250 species from Kerala (Nair *et al.*, 1988, 1992 a & b, 1994). Though the fern diversity of Kerala is rich and diverse, it is not yet fully explored and understood among the scientific community. In this scenario, this study aimed for the collection, identification and documentation of the Ferns and Lycophytes from Neyyattinkara Municipality of Thiruvananthapuram District.

MATERIALS AND METHODS

The collections were made between March 2017-June 2018 from all the localities of Neyyattinkara Municipality. The information about the collection such as habit, habitat, locality and date of collection were recorded in the field book. Herbarium specimens collected were processed using standard methods (Forman & Bridson, 1989) and deposited at the Herbarium of Tropical Botanic Garden and Research Institute, Thiruvananthapuram (TBGT). The collected specimens were critically studied and identified with the help of authentic taxonomic literatures such as *The Ferns of Southern India* (Beddome, 1864); *Pteridophyte Flora of the Western Ghats, South India* (Manickam & Irudayraj, 1992); *Fern Flora of Malabar* (Nayar & Geevarghese, 1993) and Fern *Flora of South India* (Nampy & Madhusoodanan, 1998) and the identification authenticated by third author.

RESULTS AND DISCUSSION

The classification of Smith *et al.* (2006) with certain modification has been followed. Thirty seven species have been collected from Neyyattinkara Muncipality among them thirty species were wild type and seven cultivated varieties. Alphabetical order is followed in the genera within the families, and species within the genera.

ENUMERATION OF SPECIES

SELAGINELLACEAE

Selaginella delicatula (Desv. ex Poir.) Alston, J. Bot. **70:** 282; 1932.

Stems suberect, thick, fleshy. Rhizophores many, thick, long, restricted to basal one-third. Leaves dimorphic, pale green, membranous, distant on main stem but contiguous on the branches. Strobili single at the apex of lateral branchlets. Sporophylls unimorphic, broadly ovate.

Species collected from: Punnakkadu. *LIJA 021.*

Ecology: Terrestrial, found along road cuttings and earth banks.

Selaginella vogelii Spring , Mem. Acad. Sci. Belg. **24:** 170, 111; 1850.

Plants large, firm, erect. Leaves on main stem unimorphic, broadly ovate, apex acute to acuminate, peltate, margin distinctly fimbriate. Leaves on branches dimorphic, entire, shining green, iridescent to metallic blue. Sporophylls unimorphic, broadly ovate at base, acuminate at apex, margin entire.

Species collected from: Vlangamuri. *LIJA 036.*

Cultivated species.

PSILOTACEAE

Psilotum nudum (L.) P. Beauv., Prod. Fam. Aetheog. **106:** 112; 1805.

Rhizome short, creeping, branched, dark-brown, densely covered by dark brown, slender, unicellular, tubular, deciduous hairs; roots absent. True leaves absent; stem dark

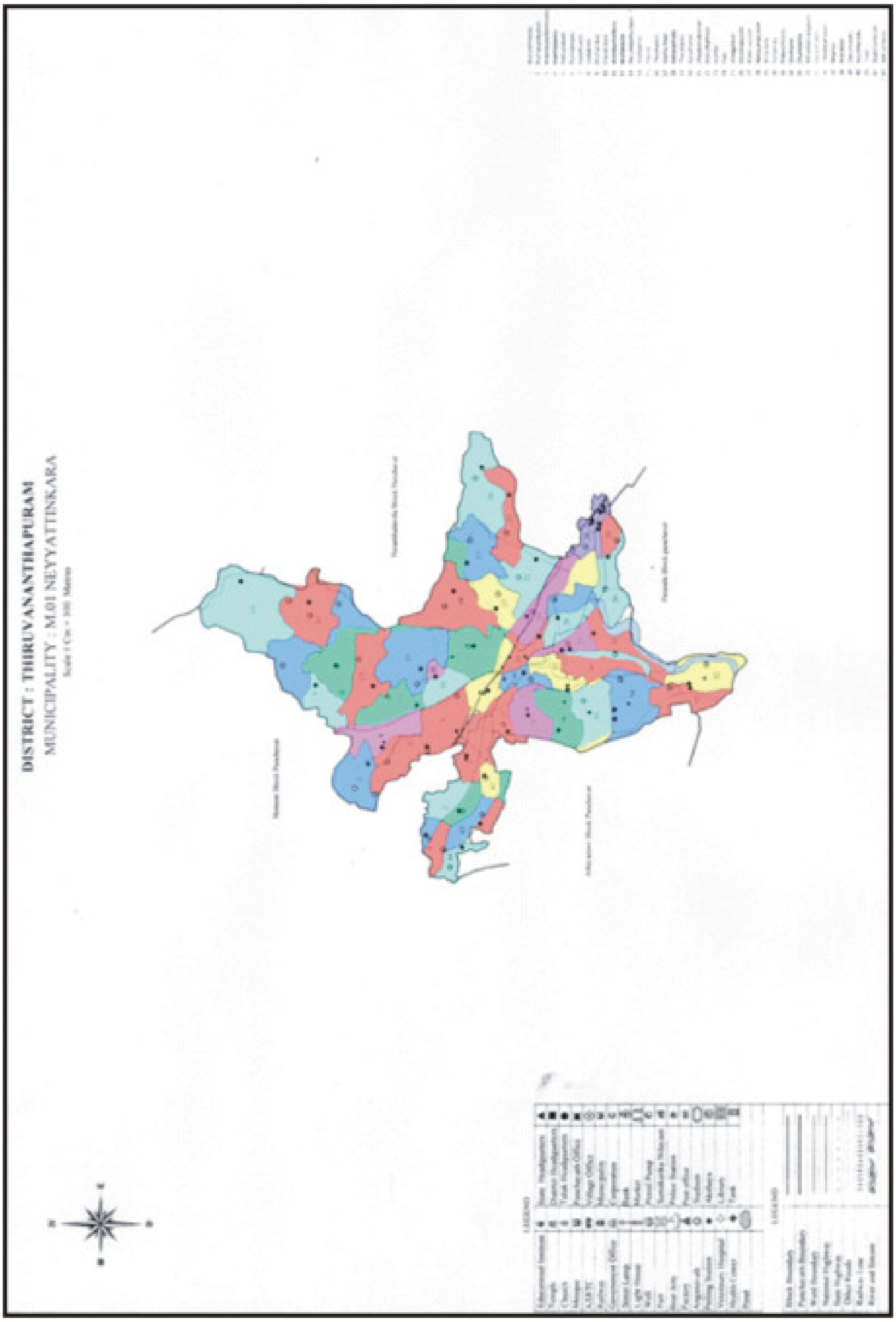

Figure 1 : Study Area - Neyyattinkara Municipality

green, glabrous. Sporangia trilocular, synangia borne at the axis of scale leaves.

Species collected from: Aralummoodu. *LIJA 032.*

Ecology: Very rare species as epiphyte*s* on base of coconut trees along stream banks.

GLEICHENIACEAE

Dicranopteris linearis (Burm. f.) Underw., Bull. Torrey Bot. Club**. 34:** 249; 1907.

Rhizome long creeping. Lamina decompounds; veins forked two or three times, free, reaching the margin. Sori submedian on the veinlets.

Species collected from: Moonnukalinmoodu. *LIJA 027.*

Ecology: It is a large terrestrial scrambling ferns form dense thickets on earth banks and road cuttings.

SCHIZAEACEAE

Lygodium flexuosum (L.) Sw. Schrad. J. Bot. **1800 (2):** 106; 1801.

Climber. Rhizome short creeping densely covered by dark brown, multicellular, uniseriate and tubular hairs. Stipes closely arranged up to 34 cm long it containing dark brown and densely hairy at the base. Lamina oblong-lanceolate, tripinnate. Sporangia arranged adaxially on 2.5 x 1 mm, finger like sporophores along the margin of the pinnules.

Species collected from: Panagatukari. *LIJA 010.*

Ecology: Terrestrial along fully or partially exposed places.

Lygodium microphyllum (Cav.) R. Br., Prod. Fl. N. Holl. 162; 1810.

Climber. Rhizome long creeping. Frond 2-3 m long; pinnules pale green; veins distinct above and below, raised on lower surface. Sporangia borne on the surface of the sporophores along the margin of the pinnules; spores are trilete, exine densely verrucate.

Species collected from: Plavilamoola. *LIJA 011.*

Ecology: It is found in marshy area.

MARSILEACEAE

Marsilea minuta L., Mant. 308; 1771.

Rhizome long creeping, green in aquatic plants, pale or dark brown in terrestrials. Roots borne usually on nodes rarely on internodes. Sporocarps borne at the nodes in clusters alternately. Microsporangia and megasporangia enclosed in the same sporocarp.

Species collected from: Krishnapuramgramam. *LIJA 023.*

Ecology: Found in aquatic or semi aquatic ponds, paddy fields and marshy places.

SALVINIACEAE

Azolla pinnata R. Br., Prodr. Fl. Nov. Holl.167; 1810.

Stem horizontal, profusely branched, zig-zag, bearing roots which are densely covered by about 2 mm long hairs. Leaves alternate, more or less rectangular.

Megasporocarp smaller than the microsporocarp.

Species collected from: Krishnapuramgramam. *LIJA* 026.

Ecology: A free floating aquatic fern

Salvinia molesta Mitch., Br. Fern Gaz. **10:** 251; 1973.

Aquatic free floating, stem spongy. Normal leaves borne at the nodes in two opposite pairs. Sporocarp borne in clusters on submerged leaves; micropsorangia borne on the branched receptacle in cluster in microsporocarps; megasporangia borne in megasporocarp.

Species collected from: Raveli. *LIJA 005.*

Ecology: It is commonly found in fully exposed ponds.

LINDSAEACEAE

Lindsaea ensifolia Sw., Schrad. J. Bot. **1800 (2):** 77; 1801;

Rhizome short creeping branched. Lamina simply pinnate; veins slightly distinct above and below. Sori marginal, linear; spores dark brown, exine with finely reticulate thickenings.

Species collected from: Elavanikara. *LIJA 019.*

Ecology: Terrestrial on road cuttings.

PTERIDACEAE

Acrostichum aureum L., Sp. Pl. **2:** 1068; 1753.

Rhizome erect, 5 cm thick densely covered by scales all over. Fronds simply pinnate, oblong. Sori acrostichoid, spores trilete, 50 × 40 µm, pale brown.

Species collected from: Pullamala. *LIJA O24.*

Ecology: Present in tidal backwaters exposed places.

Ceratopteris thallictroides (L.) Brongn., Bull. Soc. Philom. 186; 1821.

Aquatic plants. Rhizome erect, bearing thick fibrous or fleshy roots densely on the abaxial side. Fronds dimorphic; spore strilete, pale green in colour.

Species collected from: Pirayummoodu. *LIJA 004.*

Ecology: Found in Paddy fields.

Mickelopteris cordata (Roxb. ex Hook. & Grev.) Fraser-Jenk., Annotated Checklist Indian Pteridophytes Part-1 (Lycopodiaceae to Thelypteridaceae); p 247; 2017.

Parahemionitis cordata (Hook. & Grev.) Fraser-Jenk., New Sp. Syndr. 187; 1997.

Rhizome short, creeping, densely covered by scales. Fronds dimorphic; veins obscure, anastomosing. Sori continuous along the veins filling the entire surface of the lamina when mature, intermixed with hairs and scales; spores trilete, spherical; exine with minute reticulations.

Species collected from: Olathanni. *LIJA 014.*

Ecology: As lithophytes on dry rock.

Pityrogramma calomelanos (L.) Link, Handb. Erken. Gewasche **3:** 20; 1883.

Rhizome densely scaly at the apex; scales lanceolate. Lamina bipinnate, lanceolate, dark-green; pinnae up to 18 pairs, 2-11 x 0.7-2.5 cm, opposite or subopposite; pinnules up to 16 pairs, up to 1 x 0.3 cm, acute at apex, margin entire; veins obscure. Sori along the veins coverd by entire surface when mature; spores trilete, honey coloured, exine densely, minutely pappilose.

Species collected from: Perumbazhuthoor. *LIJA 006.*

Ecology: Usually terrestrials, rarely lithophytic, along the roadsides in fully exposed dry places.

Pteris ensiformis Burm. *f.,* Fl. Ind. 230; 1768.

Rhizome short creeping. Fronds dimorphic, pinnate to bipinnate, dark green above. Sori marginal, spores trilete, tetrahedral, dark brown, surfaces tuberculate, perispore thick and unfolded.

Species collected from: Mullaravilla. *LIJA 012.*

Ecology: Terrestrials along the road cuttings in open places.

Pteris multifida Poiret, in Lam., Encycl. Meth. Bot.**5:** 714; 1804.

Rhizome small, short, decumbent or erect usually branched, the margins often glandular. Fronds are glabrous, slightly dimorphic; stipes slender, grooved adaxially, straw-coloured; fertile divisions narrower (mostly 4 mm broad or less), very long attenuate at the apex and with entire margins; veins simple or 1-2 forked, tissue thin–herbaceous, light green, indusium 0.4 -0.5mm wide, whitish and entire.

Species collected from: Nilamel. *LIJA 009.*

Ecology: Found on old shady walls and masonry around cemeteries.

Pteris praetermissa T. G. Walker, Kew Bull. **14** (3): 327; 1960.

Rhizome erect, scaly at the apex. Lamina 26-48 x 23.5-30 cm, broadly ovate, bipinnate, pale green, subcoriaceous; pinnae upto 9 pairs, up to 14.5 x 2.7 cm, oblong-lanceolate; veins slightly raised above and below, free, forked ones. Sori marginal, linear, indusiate; spores are trilete and tetrahedral.

Species collected from: Muttakkad. *LIJA 013.*

Ecology: Terrestrials along the road cuttings.

Pteris vittata L., Sp. Pl. **2:** 1074; 1753.

Rhizome suberect, 6 cm thick, covered by scales at the apex; margin entire. Stipes tufted, 20 cm long, 8 mm thick, abaxially rounded, adaxially grooved. Lamina simply pinnate, lanceolate. Sori all along the margin upto the base except at the apex. Spores yellowish–green with tangled thread like thickenings.

Species collected from : Nilamel. *LIJA 008.*

Ecology: It grows along fully exposed roadside on stone crevices.

ADIANTACEAE

Adiantum caudatum L., Mant. 308; 1771.

Rhizome erect, densely covered by scales all over. Fronds oblong-lanceolate; pinnae upto 34 pairs, alternate, sessile, basal pairs slightly distinct, dichotomously branched reaching the margin. Sori reniform, indusia sparsely hairy.

Species collected from: Kavalakulam. *LIJA 017.*

Ecology: Grown as terrestrial or lithophytes along the road slopes.

Adiantum incisum Forssk., Fl. Aeg.-Arab. 187; 1775.

Rhizome erect, densely covered by scales all over; stipes tufted upto 43 cm long. Lamina oblong-lanceolate, simply pinnate. Sori marginal, oblong or reniform, indusiate; indusia dark brown, margin entire.

Species collected from: Amaravila. *LIJA 018.*

Ecology: Grown as terrestrial plant or lithopytes along the road cuttings.

Adiantum latifolium Lam., Encycl. **1:** 43; 1783.

Rhizome long creeping, branched, densely scaly all over; scales lanceolate, pale brown, acuminate at apex, margin sparsely fimbriate. Lamina broadly ovate, bipinnate. Sori along the upper margin, oblong and indusiate.

Species collected from: Marapalam. *LIJA* 002.

Ecology: Terrestrial, found along the stream banks and road cuttings.

Adiantum philippense L., Fl. Ind. 235; 1768.

Rhizome suberect, scales ovate-lanceolate, acuminate at apex, margin entire. Lamina lanceolate; pinnae upto 14 pairs, alternate, stalked, fan shape; veins distinct. Sori continuous along the edge of the lobe, crescent shaped.

Species collected from: Alampotta. *LIJA 031.*

Ecology: Terrestrial habitat along fully or partially exposed road cuttings.

ASPLENIACEAE

Asplenium nidus L., Sp. Pl. **2:** 1079; 1753.

Rhizome erect or suberect. Lamina simple elliptic to lanceolate. Sori usually distributed towards the distal one - third to three -fourth part of the frond, spores ellipsoid, plano- convex or reniform.

Species collected from: Alummoodu. *LIJA 029.*

Cultivated.

THELYPTERIDACEAE

Thelypteris dentata (Forsk.) E. P. St. John, Amer. Fern J.**:26**(2) 44; 1936.

Rhizome creeping, sparsely scaly; scales lanceolate. Stipes upto 20 cm long, pale brown, scaly at base. Lamina oblong-lanceolate. Sori median on veins, round, indusiate; indusia with short hairs; spores monolete.

Species collected from: Kavalakulam. *LIJA 025.*

Ecology: Terrestrial, found along the road cuttings and stream banks.

Thelypteris parasitica (L.) Tardieu, Notul. Syst. Paris 7: 75; 1938.

Rhizome short creeping, scaly at the apex; scales upto 8 x 1.5 mm, linear-lanceolate. Stipes upto 30 com long. Lamina deltoid, 25-40 x 16-22 cm. Sori round, submarginal, indusiate; spores monolete, exine irregularly granulose.

Species collected from: Raveli. *LIJA 003.*

Ecology: Found in road cuttings.

Thelypteris interrupta (Willd.) K. Iwats., J. Jap. Bot. 38(10): 314; 1963.

Rhizome long creeping branched, scaly at the apex. Lamina 33-40 x 19-24 cm, oblong-lanceolate; pinnae upto 25 pairs, 6-13 x 0.5-1 cm, subopposite or alternate; veins distinct below, indistinct above, upto 7 pairs. Sori median on the veins, indusiate; indusia hairy; sporangia stalk bearing capitates hairs; spores are monolete, ellipsoid, pale brown, exine spinulose.

Species collected from: Koottappana. *LIJA 001.*

Ecology: Terrestrial in paddy fields.

BLECHNACEAE

Blechnum orientale L. Sp. Pl. **2:** 1077; 1753.

Rhizome erect, densely scaly all over. Stipes reddish brown at base. Lamina ovate; pinnae oblong-linear-lanceolate. Sori linear along the either side of the costa. Spores yellowish brown.

Species collected from: Mambazhakkara. *LIJA* 015.

Ecology: Terrestrial, found along the stream banks.

Stenochlaena palustris (Burm.*f.*) Bedd., Ferns Brit. India Suppl. 26**;** 1876.

Rhizome long creeping. Stipes scattered, dark green when fresh. Lamina dimorphic; sterile lamina ovate or oblong-lanceolate. Sori born all over the lower surface of the fertile lamina, protected by indusia; spores monolete, pale green.

Species collected from: Elavanikara. *LIJA 028.*

Ecology: Terrestrial, found in marshy places.

TECTARIACEAE

Tectaria incisa Cav., Descr. Pl. 249. 1802. *Polypodium expansum* Poiret. in Lam., Encycl. Meth.Bot.5:523.1804.

Rhizome erect, woody, densely clothed with scales. Fronds clustered; stipes yellowish, grooved, about equaling the lamina; lamina oblong to ovate-oblong; pinnae oblique, the basal pair excavate on the basiscopic side at the base and deeply 2-lobate; veins reticulate, areoles often with a free included veinlets. Sori round, indusiate; indusia round-reniform.

Species collected from: Thozhukkal. *LIJA 034.*

Cultivated.

OLEANDRACEAE

Nephrolepis brownii (Desv.) Hovenkamp & Miyam., Blumea **50** (2): 293; 2005.

Rhizome erect, bearing stolons which branched and producing daughter plants. Lamina oblong-lanceolante, simply pinnate; pinnae upto 45 pairs; veins well distinct in younger fronds, obscure in mature fronds. Sori submarginal at the vein end, reniform; spores monolete, reniform, exine granulose.

Species collected from: Nilamel. *LIJA 007.*

Ecology: Terrestrial, found on road cuttings.

Nephrolepis cordifolia (L.) C. Presl, Tent. Pterid. 79; 1836.

Rhizome erect, bearing stolons which producing fleshy, spherical tubers. Lamina linear-oblong-lanceolate, simply pinnate. Sori submarginal seated on the acroscopic veinlets, reniform; spores monolete, reniform or plano-convex.

Species collected from: Ooruttukala. *LIJA 030.*

Cultivated.

DAVALLIACEAE

Davallia fejeensis Hook**.** Sp. Fil. **1**: 166, t. 55 D. (1845).

Rhizome thick, long creeping. Fronds triangular, quadripinnate, texture leathery; pinnules narrowly ovate; veins simple, not reaching the margin. Sori half cylindrical.

Species collected from: Manaloor. *LIJA 016.*

Cultivated.

POLYPODIACEAE

Drynaria quercifolia (L.) J. Sm., J. Bot. **3:** 398; 1841.

Rhizome short creeping, densely clothed by scales. Lamina dimorphic. Sori numerous, usually two per each primary areoles, round; spores monolete and golden brown.

Species collected from: Koottappana. *LIJA 020.*

Ecology: It grows as epiphytes on large trees.

Microsorum punctatum (L.) Copel. Univ. Calif. Publ. Bot. **16:** 111; 1929.

Rhizome short creeping, densely scaly at the apex. Lamina 64-118 x 6-8 cm, simple oblanceolate; costa raised on both surfaces and rounded; veins indistinct, anastomosing with included veinlets. Sori numerous; spores monolete, bilateral, hyaline or yellowish, exine smooth.

Species collected from: Alummoodu. *LIJA 035.*

Cultivated.

Phymatosorus scolopendria (N. L. Burm.) Pic.Serm.,Webbia **28:** 460. 1973

Rhizome long creeping, grayish-green. Fertile fronds longer than the sterile fronds. Sori usually in two (rarely more) irregular rows on either side of the midrib, circular to ovate. Spores 27 × 19 µm, monolete, bilateral, light–yellow and exine smooth.

Species collected from: Vazhimukku. *LIJA 037.*

Cultivated.

Pyrrosia heterophylla (L.) M. G. Price, Kalikasan **3:** 177; 1973.

Rhizome long creeping, wiry, slender. Fronds dimorphic, scattered; bearing stellate hairs densely on abaxial surface when young; fertile fronds 20-50 x 3-5 mm, simple, oblong to linear-lanceolate; veins indistinct above and below, anastomosing to form larger costal areoles and smaller marginal areoles. Sori acrostichoid, intermingled with stellate hairs.

Speies collected from: Rameswaram. *LIJA 022.*

Ecology: Commonly grow as epiphytes on trees.

Pyrrosia lanceolata (L.) Farw., Amer. Midl. Nat. **12**: 245; 1930.

Rhizome long creeping, slender, densely scaly at the apex. Fronds simple, lanceolate. Sori irregularly distributed mainly in the distal part of the lamina, orbicular, dark brown; spores monolete, bilateral, light yellow, exine with few prominent tubercles.

Species collected from: Mullaravilla**.** *LIJA 033.*

Ecology: Epiphyte or lithophyte in exposed places.

CONCLUSION

The present floristic studies document the Ferns and Lycophytes of Neyyattinkara Muncipality, Thiruvananthapuram District. These have never been attempted before. The present study provides information on the diversity and distribution pattern of ferns and lycophytes in this area. Therefore the study and documentation of ferns is an appropriate strategy for the conservation and management of the species for their economic utility.

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REFERENCES

BEDDOME R H 1864 *The Ferns Southern India* Madras

DIXIT R D 1984 *A Census of the Indian Pteridophytes* Bot Surv India, Howrah

DIXIT R D 1984 *Two new species of Selaginellafrom India* Bull Bot Surv India **26(1) :** 104-107

DIXIT R D 2000 Conspectus of Pteridophytic diversity in India *Indian Fern J* **17 :** 77-91

FRASER-JENKINS C R, GANDHI K N, KHOLIA B S & BENNIAMIN A 2017 *An Annotated Checklist* *of Indian Pteridophytes Part-1 (Lycopodiaceae to Thelypteridaceae)* Bishen Singh Mahendra Pal Singh, Dehra Dun

FRASER-JENKINS C R, GANDHI K N & KHOLIA B S 2018 *An Annotated Checklist of Indian Pteridophytes Part-2 (Woodsiaceae to Dryopteridaceae)* Bishen Singh Mahendra Pal Singh, Dehra Dun

MADHUSOODANAN P V 2015 Handbook on Ferns and Fern Allies of Kerala Malabar Bot Gard Inst Pl Sci, Kozihikode, Kerala

NAIR N C, GHOSH S R & BHARGAVAN P 1988 Fern-allies and ferns of Kerala - Part I *J Econ Tax Bot* **12(1)** : 171-209

NAIR N C, GHOSH S R & BHARGAVAN P 1992a Fern allies and ferns of Kerala - Part II *J Econ Tax Bot* **16(2)** : 251-282

NAIR N C, GHOSH S R & BHARGAVAN P 1992b Fern allies and ferns of Kerala - Part III *J Econ Tax Bot* **16(3)** : 501-549

NAIR N C, GHOSH S R & BHARGAVAN P 1994 Fern allies and ferns of Kerala - Part IV *J Econ Tax Bot* **18(2)** : 449-476

NAMPY S & MADHUSOODANAN P V 1998 *Fern Flora of South India* Diya Publishing House, New Delhi

NAYAR B K & GEEVARGHESE K K 1993 *Fern Flora of Malabar* New Delhi

MANICKAM V S & IRUDAYARAJ V 1992 *Pteridophytic Flora of the Western Ghats - South India* B I Publications, New Delhi

MANICKAM V S & IRUDAYARAJ V 1988 *Cytology of Ferns of the Western Ghats – South India* Today and Tomorrow's Printers & Publishers, New Delhi

PATIL S, LAVATE L, RAWAT R & DONGARE M 2016 Diversity and distribution of Pteridophytes from Satara District, Maharashtra (India) *Plant Science Today* **3(2)** : 149-156

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ABNORMALITY IN *OPHIOGLOSSUM THERMALE* KOM., FROM GUJARAT

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Ophioglossum L., is a very intricate and a challenging genus showing great morphological variations within species. Therefore, many species have biotypes; and as a result several of them have been misidentified or misreported from India. The genus *Ophioglossum* L., belongs to the most primitive family Ophioglossaceae and has a great importance in the plant kingdom. It has a very high chromosome base-number of (x=720). About 40 species of the genus have been reported worldwide, of which 18 species are documented from India (Patil 2014, Patil *et al*., 2014 and Patil *et al*., 2018). Fraser-Jenkins (2016) list 12 species from India. Amongst these, nearly 10 species are documented from Gujarat (Kachhiyapatel *et al*., 2018).

As far as Gujarat is concerned, few records are found in the literature *viz*., Phatak *et al*. (1953), Chavan and Mehta (1956), Inamdar and Shah (1967), Panighrahi and Dixit (1969), Inamdar (1970) and Dixit (1984). These studies listed six species *viz*., *Ophioglossum costatum* R. Br*.*, *O. gramineum* Willd*.*, *O. nudicaule* L. *f.*, *O. reticulatum* L*.*, *O. vulgatum* L. and an unidentified species. Studies on pteridophytes of Gujarat state was carried out by Rajput *et al.* (2016a, b), and confirmed five species here *viz*., *Ophioglossum costatum* R. Br*.*, *O. gramineum* Willd*.*, *O. parvifolium* Grev. & Hook., *O. nudicaule* L. *f*., and *O. reticulatum* L., of the genus *Ophioglossum* L., (excluding dubious species *viz*.,*O. fibrosum* Schum. and *O. vulgatum* L.) occurring in the Gujarat state. Further,three more species *viz*., *O. gujaratense* S.M. Patil, R.N. Kachiya, R.S. Patel & K.S. Rajput, *O. thermal* Kom. and *O. lucitanicum* L., were added to the flora of Gujarat.

While working on the genus *Ophioglossum*, we have collected an *Ophioglossum thermal* from Jambughoda Wildlife Sanctuary, Gujarat (**Fig.1**). which shows interesting character like branched or forked sporangiophore (fertile stalk). The number of branches varies from 1-4 (-rarely 5). We also studied the spores from all the forked branches and they were found to be normal and without any unusual features. A population of > 500 individuals per Km^2 was collected from open grassy wetland of Lafni and moist shady places of Dhanpuri camp site, which falls under Jambughoda Tehsil of Panchamahal District, Central Gujarat. The area of occupancy (AOO) is 50 Km^2. Other forested areas of the state are yet to be explored completely. Additionally, we assume that the species might be distributed in similar ecological conditions. The herbarium specimens were deposited in the Herbarium Department of Botany, M S University of Baroda, Vadodara [BARO]. The herbarium accession number is BARO12345700131 (SMPKSR3038).

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Fig. 1. *Ophioglossum thermale* Kom., Repert. Spec. Nov. Regni Veg. **13** : 85 (1914).

Earlier such types of abnormalities were reported in *O. petiolatum* (Goswami, 2007), *O. gramineum* and *O. nudicaule* (Rajput *et al*., 2016a).The genus *Ophioglossum*is known in literature for having maximum number of chromosomes. Therefore, it appears thata few characters are not yet stabilised. Thus, authors assumed that forked sporangiophore (fertile stalk) may be an adaptive feature for the genus.

REFERENCES

CHAVAN A R & MEHTA A R 1956 Occurrence of *Ophioglossum gramineum* Willd in Gujarat *Science and Culture* **21** : 538-540

DIXIT R D 1984 *A census of the Indian Pteridophytes. Flora of India*, Ser 4 Botanical Survey of India, Howrah (Calcutta) India

FRASER-JENKINS C R, GANDHI K N, KHOLIA B S & BENNIAMIN A 2016 *An Annotated Checklist of Indian Pteridophytes*. Part-1 Bishen Singh Mahendra Pal Singh, Dehra Dun

GOSWAMI H K 2007 Biology of *Ophioglossum*. *Bionature* **27(1&2)** : 1-73

INAMDAR J A & SHAH J J 1967 Occurrence of *Ophioglossum nudicaule* L f and *Ophioglossum nudicaule* var *macrorrhizum* (Kze) Clausen in Dharampur Forest *Indian Forester* **93(2)** : 95-97

INAMDAR J A 1970 Development of stomata in some Ophioglossum species *Annals of Botany* **34** : 975-981

PANIGRAHI G & DIXIT R D 1969 Studies in Indian Pteridophytes-IV The family Ophioglossaceae India, *Proc Natl Acad Sciences, India* **35B** : 230-266

PHATAK V G, GAEKWAD L K, DESHMUKH Y S (1953) *Ophioglossum* from Baroda and teratology *J M S University of Baroda* **2(2)** : 135-141

RAJPUT K S, KANCHHIYAPATEL R N, RAOLE V M & SINGH A P 2016a Relocation of *Ophioglossum gramineum* Willd (Ophioglossaceae) *Current Science* **111(2)** : 243

RAJPUT K S, KACHHIYAPATEL R N, PATEL S K & RAOLE V M 2016b Study on Pteridophyte diversity of Gujarat state, Western India, *Plant Science Today* **3(4)** : 327-338

PATIL S 2014 Systematic studies on pteridophytes of Satara districts (Maharashtra) Ph D Thesis Shivaji University, Kolhapur (Maharashtra State, India)

PATIL S & DONGARE M 2014 The genus *Ophioglossum* from Western Ghats of India *Indian Fern Journal* **31** : 17-24

PATIL S M, KACHHIYAPATEL R N, PATEL R S & RAJPUT K S 2018 *Ophioglossum gujaratense* a new species from Gujarat State, India. Phytotaxa **351(4)** : 273-280

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CLASSIFICATION OF EXTANT PTERIDOPHYTES : A NEW APPROACH

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ABSTRACT

The present paper deals with classification of extant Pteridophytes on the basis of their morphological features after brief reviewing of various systems of classification of the Pteridophytes. Accordingly, the authors planned to make the systematics of Pteridophytes easier and proposed the present classification with new concept including the following skeletal categorization i.e. division, class, subclass, order and family. The present proposal of Pteridophyte classification is the incorporation of all the species of extant Pteridophytes into 04 divisions, 06 classes, 13 subclass, 22 orders and 29 families. Lycopodiophyta divided in 01 class and 03 subclass, orders, families. Equisetophyta and Psilotophyta have single class, subclass, order and family. Filicophyta divided in 03 classes, 08 subclasses, 17 orders and 24 families. Accordingly, this is new approach for resolving the taxonomic problem amongst taxonomists throughout the world.

Key Words : Classification, Extant, Ferns & Fern-Allies, Pteridophytes.

INTRODUCTION

Pteridophytes (Gr. *pteron* = wing; phyton = *plants*) are vascular cryptogams, which have well developed vascular systems and reproduce by spores. They are also called as 'reptiles of plant kingdom'. The Pteridophytes include lycophytes, horsetails and ferns. As per Christenhusz & Byng (2016), the lycopods have 03 families, 05 genera and 1,290 species while ferns include 21 families, 215 genera and 10,560 species. Smith (1793) recognized 20 genera based on characters of the shape of the sorus and also the first classification to be presented as a natural system. Swartz (1806) in his book *Synopsis Filicum* treated 33 genera and ca. 700 species. Desvaux (1827) recognized 66 genera of Filicales, on the basis of characters of the indusium and of the disposition of the sporangia. Presl (1836) recognized 117 genera on the basis of habit, of the rhizome, position of the leaves, number of vascular bundles in the petiole, nature of the indusium and added 59 more in his later publications (Presl, 1843, 1845, 1852). Smith (1841-1843) recognized 138 genera of Filicales as per characters described by Presl. Hooker (1844-1864) accepted many of John Smith's and Presl's genera in his *'Genera Filicum'* (Hooker & Bauer, 1838-1842)

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and recognized only 63 genera and based them on the classical characters of sorus and indusium. The Hooker's system was dominated in pteridology for the next half-century and not effectively opposed until nearly the 20th century. Fee (1850-1852) in his *Genera Filicum* recognized 181 genera with an additional seven of doubtful status. Christ (1897) recognized only 92 genera in his *Die Farnkrauter der Erde while* Diels (1898-1900) recognized 130 genera in *Natirlichen Pflanzenfamilien.* Adolf Engler (1903) has given a detail classification of plant kingdom including Pteridophytes in *Syllabus der Pflanzenfamilien*. Bower (1923-1928) give first phyletic classification on a broad basis of anatomical, morphological, and developmental characters. He recognized 12 families of Filicales and 06 lines of evolution in family Polypodiaceae. Copeland (1929, 1947) was the first systematist to deal with the problem of recognizing the polyphyletic origin of Polypodiaceae in a formal classification. His Polypodiaceae includes the *Plagiogyriaceae*, *Cyatheaceae*, *Dicksoniaceae*, *Matoniaceae* and *Dipteridaceae* (1929). In *Genera Filicum* (1947), Copeland classified Filicales in 19 families. Based on a wide variety of characters Christensen (1938) published the first complete taxonomic synopsis of Filicales. He recognized 12 families of Filicales and about 230 genera. Ching (1940) divided the Polypodiaceae into 32 families which were grouped into seven distinct lines of evolution. Holttum (1947) revised classification of Polypodiaceae. He recognizes five families (Polypodiaceae, Grammitidaceae, Thelypteridaceae, Dennstaedtiaceae containing 11 sub-families and Adiantaceae). Ching (1940), Copeland (1947), Holttum (1947) incorporated major changes into fern classifications. Pichi Sermolli (1953, 1970, 1981, 1982, 1986, 1993) also listed and discussed all published Pteridophyte families and genera, and with his great knowledge of nomenclature and his careful application of the ICBN to historical literature (Fraser-Jenkins, 2009). Taxonomic review of family Hymenophyllaceae has been recently been revised by Ebihara *et al.* (2006). The number of families, genera and species were rapidly increased due to arrival of phylogenetics and molecular phylogenetics. Mehra (1961a, b, 1975) made attempt in categorising Himalayan ferns and its phylogenetic interrelationship on the basis of chromosome number. Nayar (1970) divided homosporous ferns into 03 subclasses Ophioglossidae, Marattidae and Filicidae which in turn were divided into 06 orders out of which Ophioglossales with 01 family, Marrattiales 04, Osmundales 02, Schizeales 08, Cyatheales 04, Gleicheniales with 06 families. Families Dryopteridaceae and Filicaceae have been divided into 04 and 05 sub-families respectively. Pichi Sermolli (1977) divides Pteridophyta into four subdivisions as Lycophytina, Sphenophytina, Psilophytina and Filicophytina. They include 443 genera of extant Pteridophyta, subdivided into 64 families. Kramer & Green (1990) divides Pteridophytes in to 04 divisions as Psilotatae with 01 living family, Lycopodiatae with 03 living families, Equisetatae with 01 monogeneric family and Filicatae with 33 families. Hasebe *et al.* (1994, 1995), Pryer *et al.* (2001, 2004), Schneider *et al.* (2004), Schuettpelz *et al.* (2006), Schuettpelz & Pryer (2007) studied phylogenetic analysis of DNA sequence data while Schneider (1996), Stevenson & Loconte (1996), Schneider *et al.* (2009) studied morphological data alone and combined analysis of molecular and morphological evidence have been conducted by Pryer *et al.* (1995, 2001), Schneider (2007), Lehtonen *et al.* (2010). Smith *et al.* (2006) given a classification for extant ferns on the basis of phylogenetic hypothesis based on both morphological and molecular data. They recognized 04 monophyletic classes, 11 monophyletic orders and 37 families, 32 of which are strongly supported as monophyletic. He also described 01 new family Cibotiaceae. Fraser-Jenkins (2009) has presented a brief account of comparison of various fern classification based on Indian fern species and incorporated all Pteridophytes into 36 families. He has critically examined the characters as well as positioning based on morphology and molecular characters. Christenhusz *et al.* (2011) expressed the linear sequence of extant families and genera of lycophytes and ferns. They recognized 03 families under lycophytes with 05 genera and under ferns 45 families with about 280 genera. In 2016 the phylogenetic classification of Pteridophytes came in existence as Pteridophyte Phylogeny Group (PPG). This classification includes 11916 species in 337 genera, 51 families, 14 orders and 02 classes.

Total 101 families are taken for consideration for new proposed classification given by different taxonomist at regular intervals and Pteridophyte Phylogeny Group (2016). The number of division, classes, subclass, order, suborders and families are variable in each classification and revised from time to time. So complexity has been created to know the current position of taxa in every system. It creates problems in field collection and identification of plants as well as the herbarium arrangement. The new proposed classification resolves the difficulties occurring for plant positioning and their identification based on morphological characters. The Table 1 is intended as a help in recognizing the similarities and differences among the major contemporary system of Pteridophyte classification. The basis of classification has been the stem and sporangia/cone (Psilopsida, Lycopsida, Equisetopsida), rhizome (Filicopsida) shape and positionings. Second criteria considered was the frond, shape of frond, pinnati section of fronds (single laminate or pinnate), position of sori on frond or pinnule i.e. marginal (Pteridaceae, Schizaeaceae, with delicate moist membranous frond Hymenophyllaceae), submarginal (Marrattiaceae), abaxial surface adjascent to midveins (Blechnaceae), secondary and tertiary veins (Thelypteridaceae, Aspleniaceae, Dicranopteridaceae), forming spikes (Osmundaceae), shape and distribution i.e. dense/ sporadic, etc.

The families Ophioglossaceae Botrychiaceae and Helminthostachyaceae were treated as separate families under Ophioglossales by Engler (1903), Copeland (1947), Kramer & Green (1990), Smith *et al.* (2006), Christenhusz *et al.* (2011) and in PPG (2016). In PPG (2016) Ophiglossaceae was divided in 04 subfamilies (Helminthostachyoideae C. Presl, Mankyuoideae J. R. Grant & B. Dauphin, Ophioglossoideae C. Presl, Botrychioideae C. Presl) with 10 genera and an estimated 112 species, whereas most of the characters does not support the creation of separate families and being considered under family Ophioglossaceae treated as single family.

Separation of Angiopteridaceae, Christenseniaceae, Danaeaceae by Pichi Sermolli (1977) from Marattiaceae is not having sufficient ground and earlier family by Engler (1903), Copeland (1947) and later Kramer & Green (1990), Christenhusz *et al.* (2011) and in PPG (2016) supports to keep all in Marattiaceae as single family. Schizaeaceae, Anemiaceae and Lygodiaceae considered as separate families by Pichi Sermolli (1977), Smith *et al.* (2006), Christenhusz *et al.* (2011) and in PPG (2016), whereas, as per morphological characters, we recognized single family Schizaeaceae as considered by Copeland (1947).

Family Pteridaceae comprising of 63 genera with similar major characters to define family instead of generic 19 families described by Pichi sermoli and others have been put under Pteridaceae inclusive of 1000 species (Hassler & Swale, 2003). Family Ceratopteridaceae had been included into Pteridaceae by Kramer & Green (1990), Smith *et al.* (2006), Christenhusz *et al.* (2011) and in PPG (2016) however, we propose it to keep as separate family following the description by Engler (1903), Copeland (1947), Pichi Sermolli (1977). Maxon's (1926) concept of keeping *Ceratopteris* and *Parkeria* under Parkeriaceae could not be accepted longer and Ceratopteridaceae has been accepted. Having no any resemblance of *Vittaria, Plagiogyrea, Matonia* R. Br. ex Wall. and Copel. with any other family characters both the genera are being considered under separate families Vittariaceae, Plagiogyriaceae and Matoniaceae (Matonia and Phanerosorus) (Copeland, 1947; Pichi Sermolli, 1977; Kato & Setoguchi, 1998; Smith *et al.*, 2006; Christenhusz *et al.*, 2011; PPG, 2016). Large subsessile, sporangia provided with a transverse or oblique annulus not interrupted by the stalk, opening by a vertical slit and much like those of *Stromatopteris* (Pichi Sermolli, 1977; Copeland, 1947). *Gleichenia* and *Dicranopteris* both have similar morphological and reproductive features therefore, we consider *Gleicheniaceae* as separate family including *Dicranopteridaceae*.

Dipteris and *Cheiropleuria* being very much different from the members of Polypodiaceae kept in separate family Dipteridaceae following the views of Pichi Sermolli (1977) and Smith *et al.* (2006). 60 genera kept under family Polypodiaceae by Copeland, 1947; Janssen & Schneider, 2005; Otto *et al.*, 2009; Parris, 2007; Ranker *et al.*, 2004; Smith *et al.*, 2006; Christenhusz *et al.*, 2011; PPG, 2016. After consideration of *Hymenophyllum* and *Trichomanes* as synonyms by Copeland (1947) and Pichi Sermolli (1977), the Hymenophyllaceae based on similarity amongst 42 genera, we agree in including 42 genera under the family *Hymenophyllaceae*. Genus *Hymenophyllopsis* being kept under family Hymenophyllopsidaceae has not much resemblance with the members of Cyatheaceae as considered by Smith *et al.* (2006), Christenhusz *et al.* (2011) and in PPG (2016) and being kept under separate family.

02 genera (*Loxsoma* from New Zealand and *Loxsomopsis* from Central and Southern America) with ca. 04 species (Bower, 1923; Copeland, 1947; Pichi Sermolli, 1977; Lehnert *et al.*, 2001; Christenhusz *et al.*, 2011). Seeking out difference in morphological characters of the members of Aspleniaceae and Aspidiaceae and the resemblance of morphological characters of *Aspidium* and other members with the members of *Dryopteris* and other associated genera, Aspidiaceous members have been considered under family Dryopteridaceae with the prominent genera *Aspidium, Onoclea, Dryopteris, Thelypteris Lomariopsis* and *Athyrium*. Genus *Aspidium* itself being an illegitimate genus does not support the existence of family Aspidiaceae and the family Dryopteridaceae has been considered in support of Pichi Sermolli (1977).

Inclusion of Psilotales and Equisetales with their genera (scally leaves, primitive sporangia or cone) under Filicophyta by Christenhusz *et al.* (2011) having well developed single lobed or pinnate fronds with eusporangiate and leptosporangiate sori, placed on abaxial surface does not support the basis of morphological characters which are the basic criteria of field collection and systemic arrangement in Herbaria. Any morphological character does not resemble with Filicopsida to keep them together and morphological expression by the genetic material is must for any type of classification. Though these both groups have long been put separately from ferns by the scientists in past either on the basis of morphology or other phylogenetic characters like anatomy and cytology (Ching, 1940; Copeland, 1947; Holtum, 1947; Pichi Sermoli, 1953, 1970, 1981, 1982, 1986, 1993; Nayar, 1970).

Maxon (1926) suggested the name *Ceratopteridaceae* for this family as the genus name *Parkeria* was no longer in use, hence, we considered *Ceratopteridaceae* in place of *Parkeriaceae* as accepted family. *Dicksonia* being placed in Cyatheaceae from Pteridaceae shows tree habit and other similar features to the members of family Cyatheaceae have been shifted to Cyatheaceae. *Parkeria* being an unresolved name need not to support as type genus for family Parkeriaceae and being considered with Ceratopteridaceae. Dipteridaceae has been separated from Polypodiaceae due to non resemblences of morphological characters of *Dipteris* with the members of Polypodiaceae.

Families Davalliaceae and Blechnaceae with 10-12 genera in each family were kept as such in support of Copeland, 1947; Pichi Sermolli, 1977, Smith *et al.*, 2006.

In support of Copeland, 1947; Smith *et al.*, 2006; Nagalingum *et al.*, 2008; Christenhusz *et al.*, 2011; PPG, 2016, 03 genera (*Marsilea* L., *Pilularia* L., *Regnellidium* Lindm.) and ca. 65 species have been considered under family Marsiliaceae. Further, consideration of *Azolla* and *Salvinia* in a single family Salviniaceae is fully justified on the basis of morphology as well as molecular ground.

Present classification expresses the extant Pteridophytes divided into 04 divisions, 06 classes, 13 subclass, 22 orders and 29 families. Following templets of the Pteridophytes, are hierarchial arrangement in descending order of division (-*phyta*), class (-*opsida*), subclass (-*idae*), orders (-*ales*) and families (-*aceae*). For example:

Division: Psilotophyta
Class: Psilotopsida
Subclass: Psilotidae
Order: Psilotales
Family: Psilotaceae

CLASSIFICATION OF EXTANT LYCOPHYTES AND FERNS

1. **Division: Psilotophyta** B. Boivin ex Reveal in Phytologia 79(2): 70. 1995.

Class: Psilotopsida D.H. Scott, Stud. Foss. Bot. (ed. 2) 616, 631-632. 1909.

Subclass: Psilotidae Reveal in Phytologia 79(2): 70. 1996.

Order: Psilotales Prant, Lehrb. Bot., ed.5. 183. 1884.

Family: Psilotaceae J.W. Griff. & Henfr., Microgr. Dict. 540. 1855. Type: *Psilotum* Sw., J. Bot. (Schrader)1800(2): 8, 109. 1801. (*Psilotum triquetrum* Sw.)

Tmesipteridaceae Nakai, Chosakuronbun Mokuroku 206. 1943. Type: *Tmesipteris* Bernh., J. Bot. (Schrader)1800(2) 131. 1801 [*Tmesipteris tannensis* (Spreng.) Bernh. = (*Lycopodium tannense* Spreng.)]

Two genera (*Psilotum* Sw., *Tmesipteris* Bernh.) and ca. 18 species (2 in *Psilotum* Sw.) (Copeland, 1947; Smith *et al.*, 2006; PPG, 2016).

Note: Pichi Sermolli (1977) treated *Psilotaceae* J.W. Griff. & Henfr. and *Tmesipteridaceae* Nakai as separate families but Engler (1903), Kramer & Green (1990), Smith *et al.* (2006), Christenhusz*et al.* (2011) and in PPG (2016) includes *Tmesipteridaceae* in *Psilotaceae*. A re-examination of characters does not support the creation of *Tmesipteridaceae* as a seperate family. This view is in support with Bierhorst's opinion (1971) that the two genera certainty do not represent two separate families.

2. **Division: Lycopodiophyta** D.H. Scott, Stud. Foss. Bot. 13, 500-501. 1900.

Class: Lycopodiopsida Bartl., Ord. Nat. Pl. 14, 19. 1830.

A. Subclass: Lycopodiidae Bek., Kurs Bot. 1: 115. 1863.

Order: Lycopodiales DC. ex Bercht. & J. Presl, Prir. Rostlin 272. 1820.

Family: Lycopodiaceae P. Beauv. ex Mirb., Hist. Nat. Vég. 4: 293. 1802. Type: *Lycopodium* L., Sp. Pl. 2: 1100. 1753. (*L. clavatum* L.)

Phylloglossaceae Kunze in Bot. Zeitung (Berlin) 1: 722. 1843. Type: *Phylloglossum* Kunze, Bot. Zeitung (Berlin) 1: 721. 1843. (*P. drummondii* Kunze)

Huperziaceae Rothm. in Feddes Repert. Spec. Nov. Regni Veg. 66: 236. 1962. Type: *Huperzia* Bernh., J. Bot. (Schrader) 1800(2): 126. 1801. [*H. selago* (L.) Bernh. ex Schrank & Mart. = (*Lycopodium selago* L.)].

Three genera (*Huperzia* Bernh., *Lycopodiella* Holub, *Lycopodium* L.) and ca. 410 species.

Note: Engler (1903), Pichi Sermolli (1977), Kramer & Green (1990), Christenhusz *et al.* (2011) and in PPG (2016) treated *Lycopodiaceae* P. Beauv. ex Mirb. as an accepted family including *Phylloglossaceae* Kunze and *Huperziaceae* Rothm. In PPG (2016) *Lycopodiaceae* includes 03 subfamilies, 16 genera and ca. 388 species, while Pichi Sermolli (1977) includes 07 genera in *Lycopodiaceae*. But as a result of a study of morphological characters, *Phlegmariurus* (Herter) Holub goes under *Huperzia*, *Phylloglossum* Kunzeunder *Huperzia* (Wikström & Kenrick, 1997), *Diphasium* Presl ex Rothmaler under *Lycopodium* and *Diphasiastrum* Holub under *Lycopodium*.

B. Subclass: Isoetidae Reveal in Phytologia 79: 70. 1996.

Order: Isoëtales Prantl, Lehrb. Bot. 116, 125. 1874.

Family: Isoëtaceae Dumort., Anal. Pl. 67. 1829. Type: *Isoetes* L., Sp. Pl. 2: 1100. 1753. (*I. lacustris* L.)

A single genus (*Isoetes*) and about 186 species (Rydin & Wikström, 2002; Christenhusz *et al.*, 2011; PPG, 2016).

C. Subclass: Selaginellidae Knobl. in J.E.B.Warming, Handb. Syst. Bot. 157. 1890.

Order: Selaginellales Prantl, Lehrb. Bot. 116, 124. 1874.

Family: Selaginellaceae Willk., Anleit. Stud. Bot. 2: 163. 1854. Type: *Selaginella* P. Beauv., Mag. Encycl. 9(5): 478. 1804. (*S. spinosa* P. Beauv.)

Note: Engler (1903), Pichi Sermolli (1977), Kramer & Green (1990), Christenhusz *et al.* (2011) and in PPG (2016) also treated *Selaginellaceae* as monotypic family.

A single genus (*Selaginella*) and about 716 species (Plants of the World Online, 2019).

3. Division: Equisetophyta D.H. Scott, Stud. Foss. Pl.: 13, 489, 492, 493. 1900.

Class: Equisetopsida C. Agardh, Cl. Pl. 1: 7. 1825.

Subclass: Equisetidae Warm., Osnov. Bot. 221. 1883.

Order: Equisetales DC. ex Bercht. & J. Presl, Prir. Rostlin 271. 1820.

Family: Equisetaceae Michx. ex DC., Essai Propr. Méd. Pl. 49. 1804. Type: *Equisetum* L., Sp. Pl. 2: 1061. 1753. (*E. fluviatile* L.)

A single genus (*Equisetum*) and about 18 species (Plants of the World Online, 2019).

Note: Engler (1903), Pichi Sermolli (1977), Kramer & Green (1990), Christenhusz *et al.* (2011), Pteridophyte Phylogeny Group (2016) also treated *Equisetaceae* as monotypic family.

4. Division: Filicophyta J. Mackay, Fl. Hiber. 336. 1836.

A. Class: Ophioglossopsida Thomé, Lehrb. Bot., ed. 4: 205. 1874.

Subclass: Ophioglossidae Klinge, Fl. Est-Liv-Churland 1: 94. 1882.

Order: Ophioglossales Link, Hort. Berol. 2: 151. 1833.

Family: Ophioglossaceae Martinov, Tekhno-Bot. Slovar. 438. 1820. Type: *Ophioglossum* L., Sp. Pl. 2: 1062. 1753. (*O. vulgatum* L.)

Botrychiaceae Horan., Char. Ess. Fam. 15. 1847. Type: *Botrychium* Sw., J. Bot. (Schrader)1800(2): 8, 110. 1801. [*B. lunaria* (L.) Sw. = (*Osmunda lunaria* L.)]

Helminthostachyaceae Ching, Bull. Fan Mem. Inst. Biol., Bot. 10: 235. 1941. Type: *Helminthostachys* Kaulf., Enum. Filic. 28. 1824. (*H. dulcis* Kaulf.)

Four genera (*Botrychium* Sw., *Helminthostachys* Kaulf., *Mankyua* B.Y. Sun, M.H. Kim & C.H. Kim, *Ophioglossum* L.) with ca.107 species. *Helminthostachys* and *Mankyua* are monotypic genera. *Botrychium* (incl. *Sceptridium*, *Botrypus*, *Japanobotrychium*) and *Ophioglossum* (incl. *Cheiroglossa*, *Ophioderma*, *Rhizoglossum*) (Wagner & Wagner, 1983; Kato, 1988; Hauk *et al.*, 2003)

Note: Engler (1903), Copeland (1947), Kramer & Green (1990), Smith *et al.* (2006), Christenhusz *et al.* (2011) and in PPG (2016) *Ophioglossaceae* treated as single family including *Botrychiaceae* and *Helminthostachyaceae*, while Pichi Sermolli (1977) and Ching (1978) treated *Botrychiaceae* and *Helminthostachyaceae* as separate family under *Ophioglossales*. Nishida (1952, 1957, 1959) adopts three families and eight genera with the *Ophioglossaceae* as the most primitive and *Helminthostachyaceae* in an intermediate position. In PPG (2016) *Ophioglossaceae* divided into 04 subfamilies (*Helminthostachyoideae* C. Presl, *Mankyuoideae* J.R. Grant & B. Dauphin, *Ophioglossoideae* C. Presl, *Botrychioideae* C. Presl) with 10 genera and an estimated 112 species. While cross examination of characters, creation of *Botrychiaceae* and *Helminthostachyaceae* as new family could not support for the creation of separate families and member kept as such in family *Ophioglossaceae.*

B. Class: Marattiopsida Doweld, Tent. Syst. Pl. Vasc. vii. 2001.

Subclass: Marattidae Klinge, Fl. Est-Liv-Churland 1: 93. 1882.

Order: Marattiales Link, Hort. Berol. 2: 148. 1833.

Christenseniales Doweld, Tent. Syst. Pl. Vasc. (Tracheophyta) 7. 2001.

Family: Marattiaceae Kaulf., Enum. Filic. 31. 1824. Type: *Marattia* Sw., Prodr. 128. 1788. (*M. alata* Sw.)

Angiopteridaceae Fée ex J. Bommer, Bull. Soc. Roy. Bot. Belgique 5: 345. 1867. Type: Commentat. Soc. Regiae Sci. Gott. 12(Cl. Phys.): 29. 1796. [*A. evecta* (G. Forst.) Hoffm. =(*Polypodium evectum* G. Forst.)]

Christenseniaceae Ching, Bull. Fan Mem. Inst. Biol. Bot. 10: 227. 1940. Type: *Christensenia* Maxon., Proc. Biol. Soc. Washington 18(50): 239. 1905. [*C. aesculifolia* (Blume) Maxon. = (*Aspidium aesculifolium* Blume)]

Danaeaceae C. Agardh, Aphor. Bot. 117. 1822. Type: *Danaea* Sm., Mém. Acad. Roy. Sci. (Turin) 5(1790-1791): 420, t. 9, f. 11. 1793. [*D. nodosa* (L.) Sm. = (*Acrostichum nodosum* L.)]

Kaulfussiaceae Campb., Evol. Land Pl. 333. 1940; *nom. illeg.* (Art. 18.3). Type: *Kaulfussia* Blume., Enum. Pl. Javae 2: 260. 1828. [*K. aesculifolia* (Blume) Blume. =

(*Aspidium aesculifolium* Blume)]

Six genera (*Angiopteris* Hoffm., *Christensenia* Maxon, *Danaea* Sm., *Eupodium* J. Sm., *Marattia* Sw., *Ptisana* Murdock) and ca. 126 species (Smith *et al.*, 2006; Christenhusz *et al.*, 2011; PPG, 2016).

Note: Smith *et al.* (2006) treated *Kaulfussiaceae* as a separate family under *Marattiales*. Smith *et al.* (2006), Engler (1903), Copeland (1947), Kramer & Green (1990), Christenhusz *et al.* (2011) and in PPG (2016) all included under *Marattiaceae*. While Pichi Sermolli (1977) treated *Angiopteridaceae*, *Christenseniaceae*, *Danaeaceae* as separate families. Christensen (1938) and Bierhorst (1971) prefer to classify these ferns into two families but as per morphological characters, we recognized single family *Marattiaceae*, as given by Copeland (1947).

C. Class: Filicopsida Pic. Serm. in Webbia 31(2): 355. 1977.

1. Subclass: Osmundidae Pic. Serm. in Webbia 31(2): 356. 1977.

Plagiogyriidae Doweld, Tent. Syst. Pl. Vasc. xii. 2001.

i. Order: Osmundales Link, Hort. Berol. 2: 138. 1833.

Family: Osmundaceae Martinov, Tekhno-Bot. Slovar. 445. 1820. Type: *Osmunda* L., Sp. Pl. 2: 1063. 1753. (*O. regalis* L.)

Four genera (*Leptopteris* C. Presl; *Osmunda* L. [incl. *Plenasium* C. Presl, *Claytosmunda* (Y. Yatabe, N. Murak. & K. Iwats.) Metzgar & Rouhan]; *Osmundastrum* C. Presl; *Todea* Willd. and ca. 24 species (Plants of the World Online, 2019).

ii. Order: Plagiogyriales Pic. Serm. ex Reveal in Phytologia 74: 176. 1993.

Family: Plagiogyriaceae Bower in Ann. Bot. (London) 40: 484. 1926. Type: *Plagiogyria* (Kunze) Mett., Abh. Senckenberg. Naturf. Ges. 2: 1, 268. 1858. [*P. euphlebia* (Kunze) Mett. = (*Lomaria euphlebia* Kunze)]

Note: A single genus (*Plagiogyria*) and ca. 12-15 species (Copeland, 1947; Smith *et al.*, 2006; PPG, 2016). Mehra (1961) considered *Plagiogyriaceae* and *Osmundaceae* both having a common origin with a common chromosome base number 11.

2. Subclass: Schizaeidae Pic. Serm. in Webbia 31(2): 382. 1977.

i. Order: Schizaeales Schimp., Traité Paléont. Vég. 1: 674. 1869.

Family: Schizaeaceae Kaulf., Wesen Farrenkr.119. 1827. Type: *Schizaea* Sm., Mém. Acad. Roy. Sci. (Turin) 5: 419, pl. 9, f. 9. 1793. [*S. dichotoma* (L.) J. Sm. = (*Acrostichum dichotomum* L.)]

Anemiaceae Link, Fil. Spec. 23. 1841. Type: *Anemia* Sw., Syn. Fil. 6, 155. 1806. [*A. phyllitidis* (L.) Sw. = (*Osmunda phyllitidis* L.)]

Lygodiaceae M. Roem., Handb. Allg. Bot. 3: 520. 1840. Type: *Lygodium* Sw., J. Bot. (Schrader)1800(2): 7, 106. 1801. [*L. scandens* (L.) Sw. = (*Ophioglossum scandens* L.)]

Mohriaceae C.F. Reed in Bol. Soc. Broter., ser. 2, 21: 168. 1948. Type: *Mohria* Sw. Syn. Fil. 6, 159. 1806. (*M. thurifraga* Sw.)

Four genera (*Actinostachys* Wall.; *Anemia* Sw.; *Lygodium* Sw.; *Schizaea* Sm.) and ca. 200 species (Plants of the World Online, 2019).

Pichi Sermolli (1977), Smith *et al.* (2006), Christenhusz *et al.* (2011) and in PPG (2016) *Schizaeaceae*, *Anemiaceae* and *Lygodiaceae* considered as separate families, while Engler (1903), Copeland (1947) and Kramer & Green (1990) considered *Schizaeaceae* as accepted family including *Anemiaceae* and *Lygodiaceae*. This is an ancient family, of which Jurassic and probably Carboniferous fossils are known. The genera *Lygodium* and *Schizaea* are pantropic, *Anemia* only American and *Mohria* in South Africa (Holttum, 1949). *Mohria* is now merged in *Anemia* (Wikström *et al.*, 2002). Main branching of frond dichotomous in *Schizaea*, unequally so in *Lygodium*, pinnate in *Anemia* and *Mohria*. One way of evolution of superficial from marginal sporangia is important characters of this family. As per morphological characters, we recognized single family *Schizaeaceae* as considered by Copeland (1947). Also by Christenhuz & Chase (2014) who further divided this family into 03 sub-families which is just based on generic characters only and need not to be given the status of sub-family.

ii. Order: Pteridales Doweld, Tent. Syst. Pl. Vasc. xi. 2001.

Dennstaedtiales Doweld, Tent. Syst. Pl. Vasc. (Tracheophyta) 10. 2001.

Lindsaeales Doweld, New Syllabus 353. 2006.

Parkeriales A.B. Frank in J. Leunis, Syn. Pflanzenk., ed. 2, 3: 1452. 1877.

a. Family: Pteridaceae E.D.M. Kirchn., Schul-Bot. 109. 1831. Type: *Pteris* L., Sp. Pl. 2: 1074. 1753. (*P. longifolia* L.)

The sporangia distributed along the veins on the underside of the leaf, often in marginal coenosori. More rarely, the sporangia may be attached to the false indusium itself (*Adiantum*) or spread evenly across the under surface of the leaf (*Acrostichum*).

Acrostichaceae Mett. ex A.B. Frank in J. Leunis, Syn. Pflanzenk., ed. 2, 3: 1453, 1458. 1877. Type: *Acrostichum* L., Sp. Pl. 2: 1067. 1753. (*A. aureum* L.)

Actiniopteridaceae Pic. Serm. in Webbia 17: 5. 1962. Type: *Actiniopteris* Link., Fil. Spec.79. 1841. [*A. radiata* (Sw.) Link. = (*Asplenium radiatum* Sw.)]

Adiantaceae Newman, Hist. Brit. Ferns: 5. 1840. Type: *Adiantum* L., Sp. Pl. 2: 1094. 1753. (*A. capillus-veneris* L.)

Anopteridaceae Doweld, Tent. Syst. Pl. Vasc. (Tracheophyta): 2 (2001). Type: *Anopteris* Prantl ex Diels in Engl. & Prantl, Nat. Pflanzenfam. 1(4): 288. f. 153(A, B). 1899. [*A. heterophylla* (L.) Prantl ex Diels = (*Pteris heterophylla* L.)]

Cheilanthaceae B.K. Nayar in Taxon 19: 233. 1970. Type: *Cheilanthes* Sw., Syn. Fil. 5, 126. 1806. (*C. micropteris* Sw.)

Cryptogrammaceae Pic. Serm. in Webbia 17: 299. 1963. Type: *Cryptogramma* R. Br., Narr. Journey Polar Sea 767. 1823. (*C. acrostichoides* R. Br.)

Cystodiaceae J.R. Croft in Kew Bull. 41: 797. 1986. Type: *Cystodium* J. Sm., Gen. Fil. (Hooker) t. 96. 1841. [*C. sorbifolium* (Sm.) J. Sm. = (*Dicksonia sorbifolia* Sm.)]

Dennstaedtiaceae Lotsy, Vortr. Bot. Stammesgesch. 2: 655. 1909. Type: *Dennstaedtia*

Bernh., J. Bot. (Schrader)1800(2): 124. 1800. [*D. flaccida* (J.R. Forst.) Bernh. = (*Trichomanes flaccidum* J.R. Forst.)]

Hemionitidaceae Pic. Serm. in Webbia 21: 487. 1966. Type: *Hemionitis* L., Sp. Pl. 2: 1077. 1753. (*H. palmata* L.)

Hypolepidaceae Pic. Serm. in Webbia 24(2): 705. 1970. Type: *Hypolepis* Bernh., Neues J. Bot. 1(2): 34. 1805. [*H. tenuifolia* (G. Forst.) Bernh. = (*Lonchitis tenuifolia* G. Forst.)]

Lindsaeaceae C. Presl ex M.R. Schomb., Reis. Br.-Guiana 2: 883. 1848. Type: *Lindsaea* Dryand. ex Sm., Mém. Acad. Roy. Sci. (Turin) 5: 413, pl. 9, f. 4. 1793. [*L. guianensis* (Aubl.) Dryand. = (*Adiantum guianense* Aubl.)]

Lonchitidaceae C. Presl ex M.R. Schomb, Reis. Br.-Guiana (Ri. Schomburgk) 2: 1047. 1848. Type: *Lonchitis* L., Sp. Pl. 2: 1078. 1753. (*L. hirsuta* L.)

Monachosoraceae Ching in Acta Phytotax. Sin. 16(4): 17. 1978. Type: *Monachosorum* Kunze, Bot. Zeitung (Berlin) 6: 119-120. 1848. (*M. davallioides* Kunze.)

Pleurisoriopsidaceae Kurita & Ikebe ex Ching in Acta Phytotax. Sin. 16. 1978. Type: *Pleurosoriopsis* Fomin, Izv. Kievsk. Bot. Sada 11: 8. 1930. [*P. makinoi* (Maxim. ex Makino) Fomin =(*Gymnogramma makinoi* Maxim. ex Makino)]

Pteridiaceae Ching in Acta Phytotax. Sin. 13(1): 96. 1975. Type: *Pteridium* Gled. ex Scop., Fl. Carniol. 169. 1760, *nom. cons.*, [*P. aquilinum* (L.) Kuhn = (*Pteris aquilina* L.)]

Saccolomataceae Doweld in A. Doweld & J.L. Reveal in Phytologia 90: 417. 2008. Type: *Saccoloma* Kaulf., Berlin. Jahrb. Pharm. Verbundenen Wiss. 21: 51. 1820. (*S. elegans* Kaulf.)

Sinopteridaceae Koidz. in Acta Phytotax. Geobot. 3: 50. 1934, *nom. rej.* Type: *Sinopteris* C. Chr. & Ching, Bull. Fan Mem. Inst. Biol. 4(10): 359. 1933. [*S. grevilleoides* (Christ) C. Chr. & Ching. = (*C. grevilleoides* Christ)]

Taenitidaceae Pic. Serm. in Webbia 29: 1. 1975. Type: *Taenitis* Willd. ex Schkuhr, Kl. Linn. Pfl. -Syst. 1: 20. 1804. 1: 21. 1805. [*T. pteroides* Willd. ex Schkuhr., *nom. illeg.* (=*Pteris blechnoides* Willd.)]

ca. 59 genera (*Acrostichum* L.; *Actiniopteris* Link.; *Adiantum* L.; *Anopteris* Prantl ex Diels; *Cheilanthes* Sw.; *Coniogramme* Fée; *Cryptogramma* R. Br.; *Cystodium* J. Sm.; *Dennstaedtia* Bernh.; *Hemionitis* L.; *Hypolepis* Bernh.; *Lindsaea* Dryand. ex Sm.; *Lonchitis* L.; *Monachosorum* Kunze; *Onychium* Kaulf.; *Pleurosoriopsis* Fomin; *Pteris* L.; *Pteridium* Gled. ex Scop.; *Saccoloma* Kaulf.; *Sinopteris* C. Chr. & Ching; *Taenitis* Willd. ex Schkuhr, etc.) and more than 1000 species (Hassler & Swale, 2003).

b. Family: Ceratopteridaceae Underw., Our Native Ferns, ed. 6: 65, 78. 1900. Type: *Ceratopteris* Brongn., Bull. Sci. Soc. Philom. Paris 1821: 186. 1822. [*C. thalictroides* (L.) Brongn. = (*A. thalictroides* L.)]

Parkeriaceae Hook., Exot. Fl. 2: 147. 1825, *nom. rej.* Type: *Parkeria* Hook., Exot.

Fl. 2: 147. 1825. (*P. pteridoides* Hook.)

01 genus (*Ceratopteris*) and ca. 5 species (Plants of the World Online, 2019).

Note: Kramer & Green (1990), Smith *et al.* (2006), Christenhusz *et al.* (2011) and in PPG (2016) *Ceratopteridaceae* includes in *Pteridaceae* while many taxonomists have placed it in its own family, *Parkeriaceae* [Engler (1903), Copeland (1947), Pichi Sermolli (1977)]. It is a monotypic family consists of single genus *Ceratopteris*, an aquatic,annual, homosporous, dimorphic fern with large, globose, subsessile, solitary sporangia. According to Hooker (1825) *Parkeria* has the sporangial wall without annulus. Later it was found that the annulus of these ferns is quite variable (Thompson, 1918) and that on the same frond are sometimes found sporangia with a well-developed annulus and others without any annulus at all.

c. Family: Vittariaceae Ching in Sunyatsenia 5: 210, 232. 1940. Type: *Vittaria* Sm., Mém. Acad. Roy. Sci. (Turin) 5: 413, pl. 9, f. 5. 1793. [*V. lineata* (L.) Sm. = (*Pteris lineata* L.)]

Antrophyaceae Ching in Acta Phytotax. Sin. 16(3): 11. 1978. Type: *Antrophyum* Kaulf., Enum. Filic. 197, 282. 1824. (*A. plantagineum* Kaulf.)

9-10 genera (*Ananthacorus* Underw. & Maxon ex Maxon; *Antrophyum* Kaulf.; *Hecistopteris* J. Sm., *Monogramma* Comm. ex Schkuhr; *Scoliosorus* T. Moore; *Vittaria* Sm.) and ca. 150 species.

According to Pichi Sermolli (1977), *Vittariaceae* has no morphological resemblance to any of the remaining families of the *Pteridineae*, but some remarkable features viz. the chromosome number and the arrangement of the sporangia, denounce an origin from a source common to the other families of the suborder. We consider *Vittariaceae*ae as a separate family following Pichi Sermolli (1977) and Copeland (1947).

3. Subclass: Gleicheniidae Pic. Serm. in Webbia 31(2): 358. 1977.

i. Order: Matoniales Pic. Serm. ex Reveal in Phytologia 74: 175. 1993.

Family: Matoniaceae C. Presl, Gefässbündel Farrn 32. 1847. Type: *Matonia* R. Br. ex Wall., Pl. Asiat. Rar. 1(1): 16. 1829. (*M. pectinata* R. Br.)

02 genera (*Matonia* R. Br. ex Wall.; *Phanerosorus* Copel.) and an estimated 04 species (Copeland, 1947; Pichi Sermolli, 1977; Kato & Setoguchi, 1998; Smith *et al.*, 2006; Christenhusz *et al.*, 2011; PPG, 2016).

ii. Order: Gleicheniales Schimp., Traité Paléont. Vég. 1: 669. 1869.

Platyzomatales Pic. Serm. ex Reveal in Phytologia 74: 176. 1993.

Stromatoperidales Pic. Serm. ex Reveal in Phytologia 74: 176. 1993.

Family: Gleicheniaceae C. Presl, Reliq. Haenk. 1: 70. 1825. Type: *Gleichenia* Sm., Mém. Acad. Roy. Sci. (Turin) 5: 419, t. 9, f. 10. 1793. [*G. polypodioides* (L.) Sm. = (*Onoclea polypodioides* L.)

Dicranopteridaceae Ching ex Doweld, Tent. Syst. Pl. Vasc. x. 2001. Type:

Dicranopteris Bernh., Neues J. Bot. 1(2): 38-39. 1805. [*D. dichotoma* (Thunb.) Bernh. = (*Polypodium dichotomum* Thunb.)]

Platyzomataceae Nakai in Bull. Natl. Sci. Mus. Tokyo 29: 4. 1950. Type: Platyzoma R. Br., Prodr. 160. 1810. (*P. microphyllum* R. Br.)

Stromatopteridaceae Bierh. in Phytomorphology 18(2): 263. 1968. Type: *Stromatopteris* Mett., Ann. Sci. Nat., Bot., sér. 4, 15: 84. 1861. (*S. moniliformis* Mett.)

This family display's several important distinctive characteristics in morphology and growth-habit (Holttum 1958). Sporangia large, subsessile, provided with a transverse or oblique annulus not interrupted by the stalk and opening by a vertical slit and much like those of *Stromatopteris* (Pichi Sermolli, 1977; Copeland, 1947).

iii. Order: Polypodiales Link, Hort. Berol. 2: 5. 1833.

Dipteridales Doweld, Tent. Syst. Pl. Vasc. (Tracheophyta) 10. 2001.

a. Family: Dipteridaceae Seward & E. Dale in Philos. Trans., ser. B, 194: 487, 499, 502. 1901. Type: *Dipteris* Reinw., Syll. Pl. Nov. 2: 3. 1825. (*D. conjugata* Reinw.)

Cheiropleuriaceae Nakai in Bot. Mag. (Tokyo) 42: 210. 1928. Type: *Cheiropleuria* C. Presl., Epimel. Bot. 189. 1851. [*C. bicuspis* (Blume) C. Presl. = (*Polypodium bicuspe* Blume)]

Two genera (*Cheiropleuria* C. Presl.; *Dipteris* Reinw.) and ca.11 species (Kato *et al.*, 2001; *Smith et al.*, 2006; Christenhusz *et al.*, 2011).

Copeland (1947) includes *Dipteridaceae* in *Polypodiaceae* which is different from each other due to presence of large fronds. We agree with Pichi Sermolli (1977) and Smith *et al.* (2006) and consider *Dipteridaceae* as a separate family.

b. Family: Polypodiaceae J. Presl & C. Presl, Delic. Prag. 159. 1822. Type: *Polypodium* L., Sp. Pl. 2: 1082. 1753. (*P. vulgare* L.)

Drynariaceae Ching in Acta Phytotax. Sin. 16(4): 19-21. 1978. Type: *Drynaria* (Bory) J. Sm., J. Bot. (Hooker) 4: 60. 1842. [*D. quercifolia* (L.) J. Sm. =(*Polypodium quercifolium* L.)]

Grammitidaceae Newm., Hist. Brit. Ferns 7. 1840. Type: *Grammitis* Sw., J. Bot. (Schrader) 2: 3, 17. 1800. [*G. marginella* (Sw.) Sw. = (*Polypodium marginellum* Sw.)]

Loxogrammaceae Ching ex Pic. Serm. in Webbia 29: 11. 1975. Type: *Loxogramme* (Blume) C. Presl., Tent. Pterid. 214-215, pl. 9, f. 8. 1836. [*L. lanceolata* (Sw.) C. Presl. = (*Grammitis lanceolata* Sw.)]

Platyceriaceae Ching in Acta Phytotax. Sin. 16(3): 18. 1978. Type: *Platycerium* Desv., Mém. Soc. Linn. Paris 6(3): 213. 1827. (*P. alcicorne* Desv.)

The number of genera in *Polypodiaceae* adopted in different classifications is extremely variable, from a few only to more than 60 like *Acrosorus* Copel., *Arthromeris* (T. Moore) J. Sm., *Polypodium* L., *Drynaria* (Bory) J. Sm., *Grammitis* Sw., *Leptochilus* Kaulf., *Loxogramme* (Blume) C. Presl., *Platycerium* Desv., *Polypodiopsis* Copel., *Pyrrosia* Mirbel, *Selliguea* Bory, etc. with ca. 1600 species (Copeland, 1947; Janssen & Schneider, 2005; Otto *et al.*, 2009; Parris, 2007; Ranker*et al.*, 2004; Smith *et al.*, 2006; Christenhusz *et al.*, 2011; PPG, 2016).

4. Subclass: Hymenophyllidae Schmakov in Turczaninowia 12(3/4): 95. 2009.

i. Order: Cyatheales A.B. Frank in J. Leunis, Syn. Pflanzenk., ed. 2, 3: 1452. 1877.

Dicksoniales Pic. Serm. ex Reveal in Phytologia 74: 175. 1993.

Metaxyales Doweld, Tent. Syst. Pl. Vasc. (Tracheophyta): 12. 2001.

a. Family: Cyatheaceae Kaulf., Wesen Farrenkr. 119. 1827. Type: *Cyathea* Sm., Mém. Acad. Roy. Sci. (Turin) 5: 416. 1793. [*C. arborea* (L.) Sm. =(*Polypodium arboreum* L.)]

Alsophilaceae C. Presl, Gefässbündel Farrn 22. 1847. Type: *Alsophila* R. Br., Prodr. 158. 1810. (*A. australis* R. Br.)

Cibotiaceae Korall in Taxon 55(3): 712. 2006. Type: *Cibotium* Kaulf., Berlin. Jahrb. Pharm. Verbundenen Wiss. 21: 53. 1820. (*C. chamissoi* Kaulf.)

Lophosoriaceae Pic. Serm. (Webbia 24(2): 700. 1970). Type: *Lophosoria* C. Presl, Gefässbündel Farrn 36. 1847. (*L. pruinata* C. Presl.)

Metaxyaceae Pic.Serm. in Webbia 24(2): 701-702. 1970. Type: *Metaxya* C. Presl., Tent. Pterid. 59. 1836. [*M. rostrata* (Humb. & Bonpl. ex Willd.) C. Presl. = (*Polypodium rostratum* Humb. & Bonpl. ex Willd.)]

Five genera (*Cyathea* Sm., *Alsophila* R. Br., *Cibotium* Kaulf., *Lophosoria* C. Presl, *Metaxya* C. Presl.) and ca. 590 species (Plants of the World Online, 2019).

b. Family: Dicksoniaceae M.R. Schomb., Reis. Br.-Guiana (Ri. Schomburgk) 2: 1047. 1848. Type: *Dicksonia* L'Hér., Sert. Angl. 30. 1789. (*D. arborescens* L'Hér.)

Culcitaceae Pic. Serm. in Webbia 24(2): 702. 1970. Type: *Culcita* C. Presl, Tent. Pterid. 135, t. 5, f. 5. 1836. (*C. macrocarpa* C. Presl.)

Thyrsopteridaceae C. Presl, Gefässbündel Farrn 22, 38. 1847, as '*Thyrsopterideae'*. Type: *Thyrsopteris* Kunze, Linnaea 9: 507. 1835. (*T. elegans* Kunze.)

Three genera (*Dicksonia* L'Hér., *Culcita* C. Presl, *Thyrsopteris* Kunze) with ca. 28 species (Plants of the World Online, 2019).

ii. Order: Hymenophyllales A.B. Frank in J. Leunis, Syn. Pflanzenk., ed. 2, 3: 1452. 1877.

Family: Hymenophyllaceae Mart., Consp. Regni Veg. 3. 1835. Type: *Hymenophyllum* Sm., Mém. Acad. Roy. Sci. (Turin) 5: 418, pl. 9, f. 8. 1793. [*H. tunbrigense* (L.) Sm. = (*Trichomanes tunbrigense* L.)]

Trichomanaceae Burmeist., Handb. Naturgesch. 196. 1836. Type: *Trichomanes* L., Sp. Pl. 1097. 1753, *nom. cons.* (*T. crispum* L.)

Two genera (*Hymenophyllum* Sm., *Trichomanes* L.) and ca. 565 species (Plants of the World Online, 2019).

Note: Pteridologists disagree about the classification of the genera of

Hymenophyllaceae. Some recognize only a few genera, whereas several others consider many genera. Copeland (1947) included 34 genera in *Hymenophyllaceae*. Morton (1968) adopted only 06 genera, subdividing them into many subgenera, sections and subsections and Pichi Sermolli (1977) included 42 genera in this family. Presently as per molecular study all genera of *Hymenophyllaceae* mentioned in Copeland (1947) and Pichi Sermolli (1977) treated as synonyms of *Hymenophyllum* and *Trichomanes*. Smith (2006) and Christenhuz *et al.* (2011) included 08 monophyletic groups that are regarded here as genera: *Abrodictym, Callistopteris, Cephalomanes*, C*repidomanes*, *Didymoglossum*, *Pogenera* as well as *Hymenophyllum* and *Trichmanes* with ca. 600 species under Genus *Trichomanes*. Division of Hymenophyllaceae into two subfamilies i.e. Trichomanoidae and Hymenophylloidae by PPG is just the creation of complexity.

iii. Order: Hymenophyllopsidales Pic. Serm. ex Reveal in Phytologia 74: 175 (1993).

Family: Hymenophyllopsidaceae Pic. Serm. in Webbia 24(2): 712-713. 1970. Type: *Hymenophyllopsis* K.I. Goebel., Flora 124(1): 3, f. 21. 1929. [*H. dejecta* (Bak.) Goebel = (*Hymenophyllum dejectum* Bak.)]

Monotypic family with single genus *Hymenophyllopsis* K.I. Goebel.

Note: Copeland (1947), Pichi Sermolli (1977) and Kramer & Green (1990) included *Hymenophyllopsis* in family *Hymenophyllopsidaceae* while Smith *et al.* (2006), Christenhusz *et al.* (2011) and in PPG (2016) included Hymenophyllopsis in *Cyatheaceae*. White & Turner (2017) based on comparative anatomy of *Hymenophyllopsis* and *Cyathea,* due to *Hymenophyllopsis* sp. having simple stem anatomy and *Cyathea* sp. with complex stelar anatomy as well as morphological features, these authors considered *Hymenophyllopsis* in the family *Hymenophyllopsidaceae*.

iv. Order: Loxsomatales Pic. Serm. ex Reveal in Phytologia 74: 175. 1993.

Family: Loxsomataceae C. Presl, Gefässbündel Farrn 31. 1847 as *Loxsomaceae*. Type: *Loxsoma* R. Br. ex A. Cunn., Companion Bot. Mag. 2: 366. 1837. (*L. cunninghamii* R. Br. ex A. Cunn.)

Two genera (*Loxsoma* from New Zealand and *Loxsomopsis* from Central and Southern America) with ca. 04 species (Bower, 1923; Copeland, 1947; Pichi Sermolli, 1977; Lehnert *et al.*, 2001; Christenhusz *et al.*, 2011)

v. Order: Dryopteridales Schmakov in Turczaninowia 4: 66. 2001.

Aspidiales Pic. Serm. in Webbia 31(2): 436. 1977.

Athyriales Schmakov, Turczaninowia 4: 55. 2001.

Thelypteridales Doweld, Tent. Syst. Pl. Vasc. (Tracheophyta) 11. 2001.

a. Family: Aspleniaceae Newman, Hist. Brit. Ferns 6. 1840. Type: *Asplenium* L., Sp. Pl. 2: 1078. 1753. (*A. marinum* L.)

Two to twenty genera and ca.750 species (Copeland, 1947; Pichi Sermolli, 1977; Schneider*et al.*, 2004, 2005; Smith *et al.*, 2006; PPG, 2016).

TABLE 1 : Compearative statements of different classifications of Pteridophytes

S. No.	**Christenhusz *et al.* (2011)**	**Smith *et al.* (2006)**	**Pteridophyte Phylogeny Group (2016)**	**Engler (1903)**	**Kramer & Green (1990)**	**Rodolfo E. G. Pichi Sermolli (1977)**	**Copeland (1947)**
1.	**Lycophytes**						
	Subclass Lycopodiidae Bek.						
	Order Lycopodiales DC. ex Bercht. & J.Presl						
	Lycopodiaceae P. Beauv. ex Mirb.	**	Lycopodiaceae (Lycopodiales)	Lycopodiaceae (Lycopodiales Eligulatae)	Lycopodiaceae (Lycopodiatae)	Lycopodiaceae (Lycopodiales)	**
	Phylloglossaceae Kunze	**	in Lycopodiaceae (Lycopodiales)	in Lycopodiaceae (Lycopodiales Eligulatae)	in Lycopodiaceae (Lycopodiatae)	in Lycopodiaceae (Lycopodiales)	**
	Huperziaceae Rothm.	**	in Lycopodiaceae (Lycopodiales)	**	in Lycopodiaceae (Lycopodiatae)	in Lycopodiaceae (Lycopodiales)	**
	Order Isoëtales Prantl						
	Isoetaceae Reichenb.	**	Isoëtaceae (Isoëtales)	Isoëtaceae (Lycopodiales Ligulatae)	Isoëtaceae (Lycopodiatae)	Isoëtaceae (Isoëtales)	**
	Order Selaginellales Prantl						
	Selaginellaceae Willk.	**	Selaginellaceae (Selaginellales)	Selaginellaceae (Lycopodiales Ligulatae)	Selaginellaceae (Lycopodiatae)	Selaginellaceae (Selaginellales)	**
2.	**Ferns**						
	Subclass : II Equisetidae Warm.						
	Order Equisetales DC. ex Bercht. & J.Presl						
	Equisetaceae Michx. ex DC.	Equisetaceae (Equisetales)	Equisetaceae (Equisetales)	Equisetaceae (Equisetales)	Equisetaceae (Equisetatae)	Equisetaceae (Equisetales)	**
	Subclass : III Ophioglossidae Klinge						
	Order Ophioglossales Link						
	Ophioglossaceae Martinov	Ophioglossaceae (Ophioglossales)	Ophioglossaceae (Ophioglossales)	Ophioglossaceae (Ophioglossales)	Ophioglossaceae (Psilotatae)	Ophioglossaceae (Ophioglossales)	Ophioglossaceae (Ophioglossales)

	Botrychiaceae Horan.	in Ophioglossaceae (Ophioglossales)	in Ophioglossaceae (Ophioglossales)	in Ophioglossaceae (Ophioglossales)	in Ophioglossaceae (Psilotatae)	Botrychiaceae (Ophioglossales)	in Ophioglossaceae (Ophioglossales)
	Helminthostachyaceae Ching	in Ophioglossaceae (Ophioglossales)	in Ophioglossaceae (Ophioglossales)	in Ophioglossaceae (Ophioglossales)	in Ophioglossaceae (Psilotatae)	Helminthostachyaceae (Ophioglossales)	in Ophioglossaceae (Ophioglossales)
	Order Psilotales Prantl						
	Psilotaceae J.W. Griff. & Henfr.	Psilotaceae (Psilotales)	Psilotaceae (Psilotales)	Psilotaceae (Lycopodiales Eligulatae)	Psilotaceae (Psilotatae)	Psilotaceae (Psilotales)	**
	Tmesipteridaceae Nakai	in Psilotaceae (Psilotales)	in Psilotaceae (Psilotales)	in Psilotaceae (Lycopodiales Eligulatae)	in Psilotaceae (Psilotatae)	Tmesipteridaceae (Psilotales)	**
	Subclass: IV Marattiidae Klinge						
	Order Marattiales Link						
	Marattiaceae Kaulf.	Marattiaceae (Marattiales)	Marattiaceae (Marattiales)	Marattiaceae (Marattiales)	Marattiaceae (Psilotatae)	Marattiaceae (Marattiales)	Marattiaceae (Marattiales)
	Danaeaceae C.Agardh	in Marattiaceae (Marattiales)	in Marattiaceae (Marattiales)	in Marattiaceae (Marattiales)	in Marattiaceae (Psilotatae)	Danaeaceae (Marattiales)	in Marattiaceae (Marattiales)
	in Marattiaceae (Marattiales)	*Kaulfussiaceae Campb. (Marattiales)*	in Marattiaceae (Marattiales)	in Marattiaceae (Marattiales)	**	**	in Marattiaceae (Marattiales)
	Angiopteridaceae Fée ex J.Bommer	in Marattiaceae (Marattiales)	in Marattiaceae (Marattiales)	in Marattiaceae (Marattiales)	in Marattiaceae (Psilotatae)	Angiopteridaceae (Marattiales)	in Marattiaceae (Marattiales)
	Christenseniaceae Ching	in Marattiaceae (Marattiales)	in Marattiaceae (Marattiales)	**	in Marattiaceae (Psilotatae)	Christenseniaceae (Marattiales)	in Marattiaceae (Marattiales)
	Subclass : V Polypodiidae Cronquist, Takht. & Zimmerm.						
	Order Osmundales Link						
	Osmundaceae Martinov	Osmundaceae (Osmundales)	Osmundaceae (Osmundales)	Osmundaceae (Filicales)	Osmundaceae (Filicatae)	Osmundaceae (Osmundales)	Osmundaceae (Filicales)

	Order Hymenophyllales A.B. Frank in J.Leunis						
	Hymenophyllaceae Mart.	Hymenophyllaceae (Hymenophyllales)	Hymenophyllaceae (Hymenophyllales)	Hymenophyllaceae (Filiclaes)	Hymenophyllaceae (Filicatae)	Hymenophyllaceae (Hymenophyllales)	Hymenophyllaceae (Filicales)
	Trichomanaceae Burmeist.	in Hymenophyllaceae (Hymenophyllales)	in Hymenophyllaceae (Hymenophyllales)	in Hymenophyllaceae (Filicatae)	in Hymenophyllaceae (Hymenophyllales)	in Hymenophyllaceae (Filicales)	in Hymenophyllaceae (Filiclaes)
	Order Gleicheniales Schimp.						
	Gleicheniaceae C. Presl	Gleicheniaceae (Gleicheniales)	Gleicheniaceae (Gleicheniales)	Gleicheniaceae (Filicales)	Gleicheniaceae (Filicatae)	Gleicheniaceae (Gleicheniales)	Gleicheniaceae (Filicales)
	in Gleicheniaceae (Gleicheniales)	*Dicranopteridaceae Ching ex Doweld*	in Gleicheniaceae (Gleicheniales)	**	in Gleicheniaceae (Filicatae)	in Gleicheniaceae (Gleicheniales)	in Gleicheniaceae (Filicales)
	Stromatopteridaceae Bierh.	in Gleicheniaceae (Gleicheniales)	in Gleicheniaceae (Gleicheniales)	**	in Gleicheniaceae (Filicatae)	Stromatopteridaceae (Stromatopteridales)	in Gleicheniaceae (Filicales)
	Dipteridaceae Seward & E. Dale	Dipteridaceae (Gleicheniales)	Dipteridaceae (Gleicheniales)	**	Dipteridaceae (Filicatae)	Dipteridaceae (Polypodiales)	in Polypodiaceae (Filicales)
	Cheiropleuriaceae Nakai	in Dipteridaceae (Gleicheniales)	in Dipteridaceae (Gleicheniales)	**	Cheiropleuriaceae (Filicatae)	Cheiropleuriaceae (Polypodiales)	in Polypodiaceae (Filicales)
	Matoniaceae C. Presl	Matoniaceae (Gleicheniales)	Matoniaceae (Gleicheniales)	Matoniaceae (Filicales)	Matoniaceae (Filicatae)	Matoniaceae (Matoniales)	Matoniaceae (Filicales)
	Order Schizaeales Schimp.						
	Lygodiaceae M. Roem.	Lygodiaceae (Schizaeales)	Lygodiaceae (Schizaeales)	in Schizaeaceae (Filicales)	in Schizaeaceae (Filicatae)	Lygodiaceae (Schizaeales)	in Schizaeaceae (Filicales)
	Schizaeaceae Kaulf.	Schizaeaceae (Schizaeales)	Schizaeaceae (Schizaeales)	Schizaeaceae (Filicales)	Schizaeaceae (Filicatae)	Schizaeaceae (Schizaeales)	Schizaeaceae (Filicales)
	Anemiaceae Link	Anemiaceae (Schizaeales)	Anemiaceae (Schizaeales)	in Schizaeaceae (Filicales)	in Schizaeaceae (Filicatae)	Anemiaceae (Schizaeales)	in Schizaeaceae (Filicales)
	in Anemiaceae (Schizaeales)	*Mohriaceae C.F. Reed*	in Anemiaceae (Schizaeales)	in Schizaeaceae (Filicales)	in Schizaeaceae (Filicatae)	in Anemiaceae (Schizaeales)	in Schizaeaceae (Filicales)
	Order Salviniales Bartl. in Mart.						
	Marsileaceae Mirb.	Marsileaceae (Salviniales)	Marsileaceae (Salviniales)	Marsileaceae (Filicales)	Marsileaceae (Filicatae)	Marsileaceae (Marsileales)	Marsileaceae (Filicales)

	Pilulariaceae Mirb. ex DC.	in Marsileaceae (Salviniales)	in Marsileaceae (Salviniales)	in Marsileaceae (Filicales)	in Marsileaceae (Filicatae)	in Marsileaceae (Marsileales)	in Marsileaceae (Filicales)
	Salviniaceae Martinov	Salviniaceae (Salviniales)	Salviniaceae (Salviniales)	Salviniaceae (Filicales)	Salviniaceae (Filicatae)	Salviniaceae (Salviniales)	Salviniaceae (Filicales)
	Azollaceae Wettst.	in Salviniaceae (Salviniales)	in Salviniaceae (Salviniales)	in Salviniaceae (Filicales)	Azollaceae (Filicatae)	Azollaceae (Salviniales)	in Salviniaceae (Filicales)
	Order Cyatheales A.B. Frank						
	Thyrsopteridaceae C. Presl	Thyrsopteridaceae (Cyatheales)	Thyrsopteridaceae (Cyatheales)	in Cyatheaceae (Filicales)	in Dicksoniaceae (Filicatae)	Thyrsopteridaceae (Dicksoniales)	in Pteridaceae (Filicales)
	Loxsomataceae C. Presl	Loxomataceae (Cyatheales)	Loxomataceae (Cyatheales)	**	Loxomataceae (Filicatae)	Loxomataceae (Loxsomales)	Loxomataceae (Filicales)
	Culcitaceae Pic. Serm.	Culcitaceae (Cyatheales)	Culcitaceae (Cyatheales)	**	in Dicksoniaceae (Filicatae)	Culcitaceae (Dicksoniales)	in Pteridaceae (Filicales)
	Plagiogyriaceae Bower	Plagiogyriaceae (Cyatheales)	Plagiogyriaceae (Cyatheales)	**	Plagiogyriaceae (Filicatae)	Plagiogyriaceae (Plagiogyriales)	Plagiogyriaceae (Filicales)
	Cibotiaceae Korall	Cibotiaceae (Cyatheales)	Cibotiaceae (Cyatheales)	in Cyatheaceae (Filicales)	in Dicksoniaceae (Filicatae)	in Dicksoniaceae (Dicksoniales)	in Pteridaceae (Filicales)
	Cyatheaceae Kaulf.	Cyatheaceae (Cyatheales)	Cyatheaceae (Cyatheales)	Cyatheaceae (Filicales)	Cyatheaceae (Filicatae)	Cyatheaceae (Dicksoniales)	Cyatheaceae (Filicales)
	Alsophilaceae C. Presl	in Cyatheaceae (Cyatheales)	in Cyatheaceae (Cyatheales)	in Cyatheaceae (Filicales)	in Cyatheaceae (Filicatae)	in Cyatheaceae (Dicksoniales)	in Cyatheaceae (Filicales)
	Hymenophyllopsidaceae Pic. Serm.	in Cyatheaceae (Cyatheales)	in Cyatheaceae (Cyatheales)	**	Hymenophyllopsidaceae (Filicatae)	Hymenophyllopsidaceae (Hymenophyllopsidales)	Hymenophyllopsidaceae (Filicales)
	Dicksoniaceae M.R. Schomb.	Dicksoniaceae (Cyatheales)	Dicksoniaceae (Cyatheales)	in Cyatheaceae (Filicales)	Dicksoniaceae (Filicatae)	Dicksoniaceae (Dicksoniales)	in Pteridaceae (Filicales)
	Lophosoriaceae Pic. Serm.	in Dicksoniaceae (Cyatheales)	in Dicksoniaceae (Cyatheales)	**	Lophosoriaceae (Filicatae)	Lophosoriaceae (Dicksoniales)	in Cyatheaceae (Filicales)
	Metaxyaceae Pic. Serm.	Metaxyaceae (Cyatheales)	Metaxyaceae (Cyatheales)	**	Metaxyaceae (Filicatae)	Metaxyaceae (Dicksoniales)	in Cyatheaceae (Filicales)

	Order Polypodiales Link						
	Lonchitidaceae C. Presl ex M.R. Schomb	in Lindsaeaceae (Polypodiales)	Lonchitidaceae (Polypodiales)	in Polypodiaceae (Filicales)	in Dennstaedtiaceae (Filicatae)	in Hypolepidaceae (Dennstaedtiales)	in Pteridaceae (Filicales)
	Saccolomataceae Doweld	Saccolomataceae (Polypodiales)	Saccolomataceae (Polypodiales)	**	in Dennstaedtiaceae (Filicatae)	in Dennstaedtiaceae (Dennstaedtiales)	in Pteridaceae (Filicales)
	Cystodiaceae J.R. Croft	in Lindsaeaceae (Polypodiales)	Cystodiaceae (Polypodiales)	**	in Dicksoniaceae (Filicatae)	in Dicksoniaceae (Dicksoniales)	in Pteridaceae (Filicales)
	Lindsaeaceae C. Presl ex M.R. Schomb.	Lindsaeaceae (Polypodiales)	Lindsaeaceae (Polypodiales)	in Polypodiaceae (Filicales)	in Dennstaedtiaceae (Filicatae)	Lindsaeaceae (Dennstaedtiales)	in Pteridaceae (Filicales)
	Dennstaedtiaceae Lotsy	Dennstaedtiaceae (Polypodiales)	Dennstaedtiaceae (Polypodiales)	**	Dennstaedtiaceae (Filicatae)	Dennstaedtiaceae (Dennstaedtiales)	in Pteridaceae (Filicales)
	Hypolepidaceae Pic. Serm.	in Dennstaedtiaceae (Polypodiales)	in Dennstaedtiaceae (Polypodiales)	**	in Dennstaedtiaceae (Filicatae)	Hypolepidaceae (Dennstaedtiales)	in Pteridaceae (Filicales)
	in Dennstaedtiaceae (Polypodiales)	*Monachosoraceae Ching*	in Dennstaedtiaceae (Polypodiales)	**	Monachosoraceae (Filicatae)	in Dennstaedtiaceae (Dennstaedtiales)	in Pteridaceae (Filicales)
	Pteridiaceae Ching	in Dennstaedtiaceae (Polypodiales)	in Dennstaedtiaceae (Polypodiales)	in Polypodiaceae (Filicales)	in Dennstaedtiaceae (Filicatae)	in Hypolepidaceae (Dennstaedtiales)	in Pteridaceae (Filicales)
	Pteridaceae E.D.M. Kirchn.	Pteridaceae (Polypodiales)	Pteridaceae (Polypodiales)	in Polypodiaceae (Filicales)	Pteridaceae (Filicatae)	Pteridaceae (Pteridales)	Pteridaceae (Filicales)
	Parkeriaceae Hook.	in Pteridaceae (Polypodiales)	in Pteridaceae (Polypodiales)	Parkeriaceae (Filicales)	in Pteridaceae (Filicatae)	Parkeriaceae (Pteridales)	Parkeriaceae (Filicales)
	Adiantaceae Newman	in Pteridaceae (Polypodiales)	in Pteridaceae (Polypodiales)	in Polypodiaceae (Filicales)	in Pteridaceae (Filicatae)	Adiantaceae (Pteridales)	in Pteridaceae (Filicales)
	Acrostichaceae Mett. ex A.B. Frank	in Pteridaceae (Polypodiales)	in Pteridaceae (Polypodiales)	in Polypodiaceae (Filicales)	in Pteridaceae (Filicatae)	in Pteridaceae (Pteridales)	in Pteridaceae (Filicales)
	Ceratopteridaceae Underw.	in Pteridaceae (Polypodiales)	in Pteridaceae (Polypodiales)	in Parkeriaceae (Filicales)	in Pteridaceae (Filicatae)	in Parkeriaceae (Pteridales)	in Parkeriaceae (Filicales)
	Sinopteridaceae Koidz.	in Pteridaceae (Polypodiales)	in Pteridaceae (Polypodiales)	**	in Pteridaceae (Filicatae)	Sinopteridaceae (Pteridales)	in Pteridaceae (Filicales)
	Vittariaceae Ching	in Pteridaceae (Polypodiales)	in Pteridaceae (Polypodiales)	in Polypodiaceae (Filicales)	Vittariaceae (Filicatae)	Vittariaceae (Pteridales)	Vittariaceae (Filicales)

	Platyzomataceae Nakai	in Pteridaceae (Polypodiales)	in Pteridaceae (Polypodiales)	**	in Pteridaceae (Filicatae)	Platyzomataceae (Platyzomatales)	in Gleicheniaceae (Filicales)
	Actiniopteridaceae Pic. Serm.	in Pteridaceae (Polypodiales)	in Pteridaceae (Polypodiales)	in Polypodiaceae (Filicales)	in Pteridaceae (Filicatae)	Actiniopteridaceae (Pteridales)	in Pteridaceae (Filicales)
	Cryptogrammaceae Pic. Serm.	in Pteridaceae (Polypodiales)	in Pteridaceae (Polypodiales)	in Polypodiaceae (Filicales)	in Pteridaceae (Filicatae)	Cryptogrammaceae (Pteridales)	in Pteridaceae (Filicales)
	Hemionitidaceae Pic. Serm.	in Pteridaceae (Polypodiales)	in Pteridaceae (Polypodiales)	in Polypodiaceae (Filicales)	in Pteridaceae (Filicatae)	Hemionitidaceae (Pteridales)	in Pteridaceae (Filicales)
	Cheilanthaceae B.K. Nayar	in Pteridaceae (Polypodiales)	in Pteridaceae (Polypodiales)	in Polypodiaceae (Filicales)	in Pteridaceae (Filicatae)	in Sinopteridaceae (Pteridales)	in Pteridaceae (Filicales)
	Taenitidaceae Pic. Serm.	in Pteridaceae (Polypodiales)	in Pteridaceae (Polypodiales)	in Polypodiaceae (Filicales)	in Pteridaceae (Filicatae)	Taenitidaceae (Pteridales)	in Pteridaceae (Filicales)
	Antrophyaceae Ching	in Pteridaceae (Polypodiales)	in Pteridaceae (Polypodiales)	in Polypodiaceae (Filicales)	in Vittariaceae (Filicatae)	in Vittariaceae (Pteridales)	in Vittariaceae (Filicales)
	Anopteridaceae Doweld	in Pteridaceae (Polypodiales)	in Pteridaceae (Polypodiales)	**	in Pteridaceae (Filicatae)	in Pteridaceae (Pteridales)	in Pteridaceae (Filicales)
	Cystopteridaceae Schmakov	in Woodsiaceae (Polypodiales)	Cystopteridaceae (Polypodiales)	in Polypodiaceae (Filicales)	in Dryopteridaceae (Filicatae)	in Athyriaceae (Aspidiales)	in Aspidiaceae (Filicales)
	Aspleniaceae Newman	Aspleniaceae (Polypodiales)	Aspleniaceae (Polypodiales)	in Polypodiaceae (Filicales)	Aspleniaceae (Filicatae)	Aspleniaceae (Aspidiales)	Aspleniaceae (Filicales)
	Diplaziopsidaceae X.C. Zhang & Christenh.	in Woodsiaceae (Polypodiales)	Diplaziopsidaceae (Polypodiales)	**	in Dryopteridaceae (Filicatae)	in Athyriaceae (Aspidiales)	in Aspidiaceae (Filicales)
	in Diplaziopsidaceae	in Woodsiaceae (Polypodiales)	*Hemidictyaceae Christenh. & H. Schneid. (Polypodiales)*	**	in Dryopteridaceae (Filicatae)	in Athyriaceae (Aspidiales)	in Aspidiaceae (Filicales)
	Thelypteridaceae Pic. Serm.	Thelypteridaceae (Polypodiales)	Thelypteridaceae (Polypodiales)	**	Thelypteridaceae (Filicatae)	Thelypteridaceae (Aspidiales)	in Aspidiaceae (Filicales)
	in Thelypteridaceae (Polypodiales)	*Sphaerostephanaceae Ching (Polypodiales)*	in Thelypteridaceae (Polypodiales)	**	in Thelypteridaceae (Filicatae)	in Thelypteridaceae (Aspidiales)	in Aspidiaceae (Filicales)

	Woodsiaceae Herter	Woodsiaceae (Polypodiales)	Woodsiaceae (Polypodiales)	in Polypodiaceae (Filicales)	in Dryopteridaceae (Filicatae)	Woodsiaceae (Aspidiales)	in Aspidiaceae (Filicales)
	Rhachidosoraceae X.C. Zhang	in Woodsiaceae (Polypodiales)	Rhachidosoraceae (Polypodiales)	**	in Dryopteridaceae (Filicatae)	in Athyriaceae (Aspidiales)	**
	Onocleaceae Pic. Serm.	Onocleaceae (Polypodiales)	Onocleaceae (Polypodiales)	in Polypodiaceae (Filicales)	in Dryopteridaceae (Filicatae)	Onocleaceae (Aspidiales)	in Aspidiaceae (Filicales)
	Blechnaceae Newman	Blechnaceae (Polypodiales)	Blechnaceae (Polypodiales)	in Polypodiaceae (Filicales)	Blechnaceae (Filicatae)	Blechnaceae (Blechnales)	Blechnaceae (Filicales)
	**	**	*Desmophlebiaceae Mynssen (Polypodiales)*	**	**	**	**
	Stenochlaenaceae Ching	Stenochlaenaceae (Polypodiales)	in Blechnaceae (Polypodiales)	**	in Blechnaceae (Filicatae)	in Blechnaceae (Blechnales)	in Blechnaceae (Filicales)
	Athyriaceae Alston	in Woodsiaceae (Polypodiales)	in Woodsiaceae (Polypodiales)	in Polypodiaceae (Filicales)	in Dryopteridaceae (Filicatae)	Athyriaceae (Aspidiales)	in Aspidiaceae (Filicales)
	Hypodematiaceae Ching	in Dryopteridaceae (Polypodiales)	Hypodematiaceae (Polypodiales)	**	in Dryopteridaceae (Filicatae)	in Athyriaceae (Aspidiales)	in Aspidiaceae (Filicales)
	in Hypodematiaceae	in Dryopteridaceae (Polypodiales)	*Didymochlaenaceae Ching ex Li Bing Zhang & Liang Zhang (Polypodiales)*	**	in Dryopteridaceae (Filicatae)	in Aspidiaceae (Aspidiales)	in Aspidiaceae (Filicales)
	Dryopteridaceae Herter	Dryopteridaceae (Polypodiales)	Dryopteridaceae (Polypodiales)	**	Dryopteridaceae (Filicatae)	in Aspidiaceae (Aspidiales)	in Aspidiaceae (Filicales)
	Aspidiaceae Mett. ex A.B. Frank	in Dryopteridaceae (Polypodiales)	in Tectariaceae (Polypodiales)	in Polypodiaceae (Filicales)	in Dryopteridaceae (Filicatae)	Aspidiaceae (Aspidiales)	Aspidiaceae (Filicales)
	Filicaceae Juss.	**	**	**	**	**	**
	Peranemataceae Ching	in Dryopteridaceae (Polypodiales)	in Dryopteridaceae (Polypodiales)	**	in Dryopteridaceae (Filicatae)	in Aspidiaceae (Aspidiales)	in Aspidiaceae (Filicales)
	Elaphoglossaceae Pic. Serm.	in Dryopteridaceae (Polypodiales)	in Dryopteridaceae (Polypodiales)	in Polypodiaceae (Filicales)	in Lomariopsidaceae (Filicatae)	Elaphoglossaceae (Aspidiales)	in Aspidiaceae (Filicales)
	Bolbitidaceae Ching	in Dryopteridaceae (Polypodiales)	in Dryopteridaceae	** (Polypodiales)	in Lomariopsidaceae (Filicatae)	in Lomariopsidaceae (Aspidiales)	in Aspidiaceae (Filicales)

	Lomariopsidaceae Alston	Lomariopsidaceae (Polypodiales)	Lomariopsidaceae (Polypodiales)	**	Lomariopsidaceae (Filicatae)	Lomariopsidaceae (Aspidiales)	in Aspidiaceae (Filicales)
	Nephrolepidaceae Pic. Serm.	in Lomariopsidaceae (Polypodiales)	in Lomariopsidaceae (Polypodiales)	in Polypodiaceae (Filicales)	Nephrolepidaceae (Filicatae)	Nephrolepidaceae (Aspidiales)	in Davalliaceae (Filicales)
	Tectariaceae Panigrahi	Tectariaceae (Polypodiales)	Tectariaceae (Polypodiales)	**	in Dryopteridaceae (Filicatae)	in Aspidiaceae (Aspidiales)	in Aspidiaceae (Filicales)
	Dictyoxiphiaceae Ching	in Tectariaceae (Polypodiales)	in Tectariaceae (Polypodiales)	**	in Dryopteridaceae (Filicatae)	in Aspidiaceae (Aspidiales)	in Aspidiaceae (Filicales)
	Hypoderriaceae Ching	in Tectariaceae (Polypodiales)	in Tectariaceae (Polypodiales)	**	in Dryopteridaceae (Filicatae)	in Aspidiaceae (Aspidiales)	in Aspidiaceae (Filicales)
	Oleandraceae Ching ex Pic. Serm.	Oleandraceae (Polypodiales)	Oleandraceae (Polypodiales)	in Polypodiaceae (Filicales)	Oleandraceae (Filicatae)	Oleandraceae (Aspidiales)	in Davalliaceae (Filicales)
	Davalliaceae M.R. Schomb.	Davalliaceae (Polypodiales)	Davalliaceae (Polypodiales)	in Polypodiaceae (Filicales)	Davalliaceae (Filicatae)	Davalliaceae (Aspidiales)	Davalliaceae (Filicales)
	Polypodiaceae J.Presl & C. Presl	Polypodiaceae (Polypodiales)	Polypodiaceae (Polypodiales)	Polypodiaceae (Filicales)	Polypodiaceae (Filicatae)	Polypodiaceae (Polypodiales)	Polypodiaceae (Filicales)
	Grammitidaceae Newm.	in Polypodiaceae (Polypodiales)	in Polypodiaceae (Polypodiales)	**	Grammitidaceae (Filicatae)	Grammitidaceae (Polypodiales)	in Polypodiaceae (Filicales)
	Gymnogrammitidaceae Ching	in Polypodiaceae (Polypodiales)	in Polypodiaceae (Polypodiales)	in Polypodiaceae (Filicales)	in Davalliaceae (Filicatae)	in Davalliaceae (Aspidiales)	in Davalliaceae (Filicales)
	Loxogrammaceae Ching ex Pic. Serm.	in Polypodiaceae (Polypodiales)	in Polypodiaceae (Polypodiales)	**	in Polypodiaceae (Filicatae)	Loxogrammaceae (Polypodiales)	in Polypodiaceae (Filicales)
	Drynariaceae Ching	in Polypodiaceae (Polypodiales)	in Polypodiaceae (Polypodiales)	in Polypodiaceae (Filicales)	in Polypodiaceae (Filicatae)	in Polypodiaceae (Polypodiales)	in Polypodiaceae (Filicales)
	Platyceriaceae Ching	in Polypodiaceae (Polypodiales)	in Polypodiaceae (Polypodiales)	in Polypodiaceae (Filicales)	in Polypodiaceae (Filicatae)	in Polypodiaceae (Polypodiales)	in Polypodiaceae (Filicales)
	Pleurisoriopsidaceae Kurita & Ikebe ex Ching	in Polypodiaceae (Polypodiales)	**	**	**	**	in Pteridaceae (Filicales)

(Note : Newly created families by authors in text has been shown in italics)

Note: Copeland (1947) included 09 genera in *Aspleniaceae* while Pichi Sermolli (1977) included 17 genera in this family. As per PPG-I (2016) these genera are treated as synonyms of *Asplenium* (*Antigramma* C. Presl; *Camptosorus* Link; *Ceterach* Willd.; *Ceterachopsis* (J. Sm.) Ching; *Diellia* Brack.; *Diplora* Baker; *Holodictyum* Maxon; *Loxoscaphe* T. Moore; *Phyllitis* Hill; *Pleurosorus* Fee; *Schaffneria* Fee ex T. Moore) and *Hymenasplenium* Hayata (Smith *et al.*, 2006; Christenhusz *et al.*, 2011; PPG, 2016). According to Pichi Sermolli (1977) *Aspleniaceae* is sharply distinct from the rest of the *Aspidiales* and cannot be united to any other family of this order. Copeland (1947) also considered *Aspleniaceae* as separate family with the plants of terrestrial and epiphytic, creeping or suberect rhizome, dictyostelic, petiole having two vascular bundles at base merging in the middle or at the end of the petiolar region, fronds simple or compound pinnate, sori elongated along the veinlets with inducium of similar shape and bilateral spores.

b. Family: Thelypteridaceae Ching ex Pic. Serm. in Webbia 24(2): 709. 1970. Type: *Thelypteris* Schmidel, Icon. Pl. 3: 45-48, pl. 11, 13. 1763. [*T. palustris* Schott = (*Acrostichum thelypteris* L.).

Athyriaceae Alston in Taxon 5: 25. 1956. Type: *Athyrium* Roth., Tent. Fl. Germ. 3(1): 31, 58-59. 1800. [*A. filix-femina* (L.) Roth. = (*Polypodium filix-femina* L.)]

Hemidictyaceae Christenh. & H. Schneid. in Phytotaxa 28: 51. 2011. Type: *Hemidictyum* C. Presl, Tent. Pterid. 110, t. 3, f. 24-26. 1836. [*H. marginatum* (L.) C. Presl = (*Asplenium marginatum* L.]

Hypoderriaceae Ching in Sunyatsenia 5: 209, 245. 1940. Type: *Hypoderris* R. Br. ex Hook., Gen. Fil. t. 1. 1838. (*H. brownii* J. Sm. ex Hook.)

Rhachidosoraceae X.C. Zhang in Phytotaxa 19: 16. 2011. Type: *Rhachidosorus* Ching in Acta Phytotax. Sin. 9(1): 73. 1964. [*R. mesosorus* (Makino) Ching = (*Asplenium mesosorum* Makino)].

Onocleaceae Pic. Serm. in Webbia 24(2): 708. 1970. Type: *Onoclea* L., Sp. Pl. 2: 1062. 1753. (*O. sensibilis* L.)

Diplaziopsidaceae X.C. Zhang & Christenh. in Phytotaxa 19: 15. 2011. Type: *Diplaziopsis* C. Chr., Index Filic. 227. 1905. [*D. brunoniana* (Wall.) W.M. Chu = (*Allantodia brunoniana* Wall.)].

Sphaerostephanaceae Ching in Sunyatsenia 5: 240. 1940; *nom. nud.*, without Latin description. Type: *Sphaerostephanos* J. Sm., Gen. Fil. (Hooker): pl. 24. 1840. (*S. asplenioides* J. Sm.)

ca. 5-30 genera, depending on taxonomic viewpoint.

c. Family: Dryopteridaceae Herter, Revista Sudamer. Bot. 9(1): 15. 1949. Type: *Dryopteris* Adans., Fam. Pl. 2: 20. 1763. [*D. flix-mas* (L.) Schott (*Polypodium flix-mas* L.)]

Aspidiaceae Mett. ex A.B. Frank, Syn. Pflanzenk. (ed. 2) 3: 1469. 1877. Type:

Aspidium Sw. in J. Bot. (Schrader) 1800(2): 4, 29. 1801. [*A. trifoliatum* (L.) Sw.= (*Polypodium trifoliatum* L.)]

Bolbitidaceae Ching, Acta Phytotax. Sin. 16(4): 15. 1978. Type: *Bolbitis* Schott, Gen. Fil. pl. 14. 1834. [*B. serratifolia* (Mert. ex Kaulf.) Schott. = (*Acrostichum serratifolium* Mert. ex Kaulf.)]

Cystopteridaceae Schmakov in Turczaninowia 4(1-2): 60. 2001. Type: *Cystopteris* Bernh., Neues J. Bot. 1(2): 26. 1805. [*C. fragilis* (L.) Bernh. = (*Polypodium fragile* L.)]

Desmophlebiaceae Mynssen, A. Vasco, Sylvestre, R.C. Moran & Rouhan, Taxon 65(1): 19. 2016. Type: *Desmophlebium* Mynssen, A. Vasco, Sylvestre, R.C. Moran & Rouhan, Taxon 65(1): 27, f. 5. 2016. [*D. lechleri* (Mett.) Mynssen, A. Vasco, Sylvestre, R.C. Moran & Rouhan = (*Asplenium lechleri* Mett.)]

Dictyoxiphiaceae Ching in Sunyatsenia 5: 205, 218. 1940. Type: *Dictyoxiphium* Hook., Gen. Fil. (Hooker) t. 62. 1840. (*D. panamense* Hook.)

Didymochlaenaceae Ching ex Li Bing Zhang & Liang Zhang, Taxon 64(1): 34. 2015. Type: *Didymochlaena* Desv., Mag. Neuesten Entdeck. Gesammten Naturk. Ges. Naturf. Freunde Berlin 5: 303. 1811. (*Didymochlaenasinuosa* Desv.)

Elaphoglossaceae Pic. Serm. in Webbia 23: 209-210. 1968. Type: *Elaphoglossum* Schott ex J. Sm., J. Bot. (Hooker) 4: 148. 1842. [*E. conforme* (Sw.) J.Sm. = (*Acrostichum conforme* Sw.)]

Hypodematiaceae Ching in Acta Phytotax. Sin. 13(1): 96. 1975. Type: *Hypodematium* Kunze in Flora 16(2): 690. 1833. (*H. onustum* Kunze)

Lomariopsidaceae Alston in Taxon 5(2): 25. 1956. Type: *Lomariopsis* Fee, Mem. Foug., 2. Hist. Acrostich. 10. 1845. [*L. sorbifolia* (L.) Fee = (*Acrostichum sorbifolium* L.)

Peranemataceae Ching in Sunyatsenia 5: 208. 1940. Type: *Peranema* D. Don, Prodr. Fl. Nepal. 12. 1825. (*P. cyathoides* D. Don)

Tectariaceae Panigrahi in J. Orissa Bot. Soc. 8: 41. 1986. Type: *Tectaria* Cav., Anales Hist. Nat. 1(2): 115. 1799. [*T. trifoliata* (L.) Cav. = (*Polypodium trifoliatum* L.)

Woodsiaceae Herter in Revista Sudamer. Bot. 9: 14. 1949. Type: *Woodsia* R. Br., Prodr. 158, Obs. 4. 1810. [*W. ilvensis* (L.) R. Br. (*Acrostichum ilvense* L.)]

ca. 30-35 genera, depending on taxonomic viewpoint.

d. Family: Davalliaceae M.R. Schomb., Reis. Br.-Guiana 3: 883. 1848. Type: *Davallia* Sm., Mem. Acad. Roy. Sci. (Turin) 5: 414, pl. 9, f. 6. 1793. [*D. canariensis* (L.) Sm. (*Trichomanes canariense* L.)]

Oleandraceae Ching ex Pic. Serm in Webbia 20(2): 745. 1965. Type: *Oleandra* Cav., Anales Hist. Nat. 1(2): 115. 1799. (*O. neriiformis* Cav.)

Gymnogrammitidaceae Ching in Acta Phytotax. Sin. 11: 12. 1966. Often misspelled *Gymnogrammaceae*. Type: *Gymnogrammitis* Griff., Icon. Pl. Asiat. 2: t. 129, f.1. 1849. [*G. dareiformis* (Hook.) Ching ex Tardieu & C. Chr. = (*Polypodium dareiforme* Hook.)]

Nephrolepidaceae Pic. Serm. in Webbia 29(1): 8-11. 1975. Type: *Nephrolepis*

Schott, Gen. Fil. 1, pl. 3. 1834. [*N. exaltata* (L.) Schott = (*Polypodium exaltatum* L.). 12 genera by Copeland (1947) 9 by Pichi Sermolli (1977) viz. *Ariostegia, Arthropteris, Davallia, Davallodes, Humata, Nephrolepis, Pammeosorus, Parasorus etc.*

vi. Order: Blechnales Pic. Serm. ex Reveal in Phytologia 74: 175. 1993.

Family: Blechnaceae Newman, Hist. Brit. Ferns, ed. 2: 8. 1844. Type: *Blechnum* L., Sp. Pl. 2: 1077. 1753. (*B. occidentale* L.)

Stenochlaenaceae Ching in Acta Phytotax. Sin. 16: 18.1978. Type: *Stenochlaena* J.Sm., J. Bot. (Hooker) 4: 149 (1841). (*S. scandens* J. Sm.)

10-12 genera (*Anchistea* C. Presl; *Blechnum* L.; *Brainea* J.Sm.; *Doodia* R. Br.; *Lorinseria* C. Presl; *Stenochlaena* J.Sm.; *Woodwardia* Sm.) with ca. 200 species (Copeland, 1947; Pichi Sermolli, 1977; Smith *et al.*, 2006).

5. Subclass: Marsileidae Doweld, Tent. Syst. Pl. Vasc. x. 2001.

Order: Marsileales Mart., Consp. Regn. Veg. 4. 1835.

Pilulariales Bercht. & C. Presl, Prir. Rostlin 272. 1820.

Family: Marsileaceae Mirb. in Lam. & Mirb., Hist. Nat. Vég. 5: 126. 1802. Type: *Marsilea* L., Sp. Pl. 2: 1099. 1753. (*M. quadrifolia* L.)

Pilulariaceae Mirb. ex DC., Essai Propr. Méd. Pl. 48. 1804. Type: *Pilularia* L., Sp. Pl. 2: 1100. 1753. (*P. globulifera* L.)

Note: 03 genera (*Marsilea* L., *Pilularia* L., *Regnellidium* Lindm.) and ca. 65 species (Copeland, 1947; Smith *et al.*, 2006; Nagalingum *et al.*, 2008, Christenhusz *et al.*, 2011; PPG, 2016).

6. Subclass: Salviniidae Pic. Serm. ex Reveal in Phytologia 79: 70. 1996.

Order: Salviniales Link, Hort. Berol. 3: 155. 1833.

Family: Salviniaceae Martinov, Tekhno-Bot. Slovar 559. 1820. Type: *Salvinia* Seg., Pl. Veron. 3: 52. 1754. [*S. natans* (L.) All. = (*Marsilea natans* L.)]

Azollaceae Wettst., Handb. Syst. Bot. 2: 77. 1903. Type: *Azolla* Lam., Encycl. 1(1): 343. 1783. (*A. fliculoides* Lam.)

02 genera (*Salvinia* Seg.; *Azolla* Lam.) and an estimated 21 species (Copeland, 1947; Smith *et al.*, 2006; PPG, 2016).

Note: Some authors considered *Salvinia* and *Azolla* into two families (Christensen, 1938; Bonnet, 1957; Pichi Sermolli, 1977; Schneller in Kubitzki, 1990) whereas, Copeland (1947), Smith *et al.* (2006) and in PPG (2016) *Azolla* is included in Salviniaceae. Both genera have same reproductive characters: sporangia are produced in globose or ovoid bodies which are called sporocarps; accordingly, *Salvinia* and *Azolla* are kept under Salviniaceae. Hope that the arrangement of all this information in this clarifying and easily accessible form will be helpful in understanding the classification for the student of fern taxonomy and scientists.

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REFERENCES

BIERHORST D W 1971 *Morphology of vascular plants* New York (Macmillan)

BONNET A L M 1957 Contribution a l'etude des Hydropteridees IV - Commentaires et conclusions generales Naturalia Monsp ser Bot **8** : 37-104 f 1-12

BOWER F O 1923 Studies in phylogeny of the Filicales VIII On Loxsoma and Loxsomopsis Annals of Botany **37** : 349-354

BOWER F O 1923-1928 *The Ferns* 3 vols Cambridge

CANTINO P D, DOYLE J A, GRAHAM S W, JUDD W S, OLMSTEAD R G, SOLTIS D E, SOLTIS P S & DONOGHUE M J 2007 Towards a Phylogenetic Nomenclature of Tracheophyta Taxon **56(3)** : 822-846

CHASE M W & REVEAL J L 2009 A phylogenetic classification of the land plants to accompany APG III *Botanical Journal of the Linnean Society* **161** : 122-127

CHING R C 1940 On natural classification of the family "Polypodiaceae" *Sunyatsenia* **5** : 201-268

CHING R C 1978 The Chinese fern families and genera: systematic arrangement and historical origin Acta Phytotaxonomica Sinica, **16(3)** : 1-19; **16(4)** : 16-37

CHRIST H 1897 Die Farnkrauter der Erde Jena

CHRISTENHUSZ M J M & BYNG J W 2016 The number of known plant species in the world and its annual increase Phytotaxa **261(3)** : 201-217

CHRISTENHUSZ, M.J.M & CHASE, M.W 2014 Trends and concepts in fern classification Annals of Botany **113** : 571-594

CHRISTENHUSZ M J M & SCHNEIDER H 2011 Corrections to Phytotaxa 19: linear sequence of lycophytes and ferns Phytotaxa **28** : 50-52

CHRISTENHUSZ M J M, CHASE M W & FAY M F 2011 Preface to "Linear sequence, classification, synonymy, and bibliography of vascular plants: Lycophytes, Ferns, Gymnosperms and Angiosperms Phytotaxa **19** : 4-6.

CHRISTENHUSZ M J M, JONES M & LEHTONEN S 2013 Phylogenetic placement of the enigmatic fern genus *Dracoglossum* American Fern Journal **103** : 131-138

CHRISTENHUSZ M J M, TUOMISTO H, METZGAR J S & PRYER K M 2008 Evolutionary relationships within the neotropical, eusporangiate fern genus *Danaea* (Marattiaceae) Molecular Phylogenetics and Evolution **46** : 34-48

CHRISTENHUSZ M J M, ZHANG X-C & SCHNEIDER H 2011 A linear sequence of extant families and genera of Lycophytes and Ferns Phytotaxa **19** : 7-54

CHRISTENSEN C 1938 Filicinae In Verdoorn's Manual of Pteridology The Hague.

COPELAND E B 1929 Pteridophyta Novae Caledoniae University of California Publications in Botany **14** : 353-369

COPELAND E B 1929 The oriental genera of Polypodiaceae Univ Cal Publ Bot **16** : 45-128

COPELAND E B 1947 Genera Filicum Chronica Botanica, Waltham, Massachusetts

CRONQUIST A, TAKHTAJAN A & ZIMMERMANN W 1966 On the Higher Taxa of Embryobionta Taxon **15(4)** : 129-134

DESVAUX N A 1827 Prodrome de la famille des fougeres Mem Soc Linn Paris **6** : 171-337

DIELS L 1898-1900 In Engler und Prantl's Die Natfirlichen Pflanzenfamilien 14 Liepzig

Ebihara A, Dubuisson J Y, Iwatsuki K & Eto M 2006 A Taxonomic Revision of Hymenophyllaceae Blumea **51(2)** : 221-280

FEE A L A 1850-1852 Genera Filicum (Memoire sur la famille des Fougeres, V) Paris & Strasbourg

FRASER JENKINS C R 2018 Should we follow cladononomic or taxonomic classification, or draw a happy medium? Pteridology Today: Challenges and Opportunities pp 76-79 Proceedings of the Symposium held at BSI, WRC, Pune

FRASER-JENKINS C R 2009 A brief comparison of modern Pteridophyte classification (Families and Genera in India) *Indian Fern J* **26** : 107-126

HASEBE M, OMORI T, NAKAZAWA M, SANO T, KATO M & IWATSUKI K 1994 rbcL gene sequences provide evidence for the evolutionary lineages of leptosporangiate ferns Proceedings of the National Academy of Sciences of the United States of America **91** : 5730-5734

HASEBE M, WOLF P G, PRYER K M, UEDA K, Ito M, SANO R, GASTONY G J, YOKOYAMA J, MANHART J R, MURAKAMI M, CRANE E H, HAUFLER C H & HAUK W D 1995 Fern phylogeny based on rbcL nucleotide sequences *American Fern Journal* **85** : 134-181

HASSLER M & SWALE B 2003 Checklist of World Ferns

HAUK W D, PARKS C R & CHASE M W 2003 Phylogenetic studies of Ophioglossaceae: Evidence from rbcL and trnLF plastid DNA sequences and morphology Molecular Phylogenetics and Evolution **28** : 131-151

HOLTTUM R E 1947 A revised classification of Leptosporangiate ferns Botanical Journal of the Linnean Society **53(350)** : 123-158

HOLTTUM R E 1949 The Classification of Ferns Biological Review **24(3)** : 267-296.

HOLTTUM R E 1958 Morphology, growth-habit, and classification in the family Gleicheniaceae Phytomorphology **7** : 168-184 f 1-6 1958

HOOKER W J & BAUER F 1838-1842 Genera Filicum London

HOOKER W J 1825 Exotic Flora Vol 2

HOOKER W J 1844-1864 Species Filicum 5 vols London

JANSSEN T & SCHNEIDER H 2005 Exploring the evolution of humus collecting leaves in drynarioid ferns (Polypodiaceae, Polypodiidae) Plant Systematics and Evolution **252** : 175-197

KATO M & SETOGUCHI H 1998 An rbcL-based phylogeny and heteroblastic leaf morphology of Matoniaceae Systematic Botany **23** : 391-400

KATO M 1983 Classification of major groups of pteridophytes J Fac Sci Uni Tokyo III **13**: 263-283.

KATO M 1988 The phylogenetic relationship of Ophioglossaceae Taxon **37**: 381-386.

KATO M, YATABE Y, SAHASHI N & MURAKAMI N 2001 Taxonomic studies of *Cheiropleuria* (Dipteridaceae) Blumea **46** : 513-525

KENRICK P & CRANE P R 1997 The origin and early evolution of plants on land Nature **389** : 33-39.

KORALL P, PRYER K M, METZGAR J S, SCHNEIDER H & CONANT D S 2006 Tree ferns : monophyletic groups and their relationships as revealed by four protein-coding plastid loci Molec Phylog Evol **39** : 830-845

KRAMER K U & GREEN P S (eds) 1990 Pteridophytes and Gymnosperms In: Kubitzki K ed The families and genera of vascular plants Berlin: Springer-Verlag I : 1-404

LEHNERT M, MÖNNICH M, PLEINES T, SCHMIDT-LEBUHN A & KESSLER M 2001 The relictual fern genus Loxsomopsis American Fern Journal **91** : 13-24

LEHTONEN S, TUOMISTO H, ROUHAN G & CHRISTENHUSZ M J M 2010 Phylogenetics and classification of the pantropical fern family Lindsaeaceae Botanical Journal of the Linnean

Society **163** : 305-359

LIU H-M 2016 Embracing the Pteridophyte classi?cation of Ren-Chang Ching using a generic phylogeny of Chinese ferns and Lycophytes Journal of Systematics and Evolution **54(4)** : 307-335

MAXON W R 1926 Pteridophyta of Porto Rice and the Virgin Islands Survey of Porto Rice and Virgin Islands **6** : 379-380

MEHRA P N 1961a Chromosome numbers in Himalayan ferns Res Bull Punjab Univ (N S) **12** : Parts I-II, 139-164

MEHRA P N 1961b Cytological evolution of ferns with particular reference to Himalayan Ferns [Presidential Address, Section Botany], Proc 48th Ind Sci Congr, Part II, 130-53

MEHRA P N 1975 Some aspects of differentiation in cryptogams Res Bull Panjab Univ (Chandigarh, India) **23** : 221-242

MORTON C V 1968 The genera, subgenera, and sections of the *Hymenophyllaceae* Contr U S Nation Herb **38** : 153-214

MYNSSEN C M, VASCO A, MORAN R C, SYLVESTRE L S & ROUHAN G 2016 Desmophlebiaceae and *Desmophlebium* : A new family and genus of Eupolypod II ferns Taxon **65(1)** : 19-34

NAGALINGUM N S, NOWAK M D & PRYER K M 2008 Assessing phylogenetic relationships in extant heterosporous ferns (Salviniales), with a focus on *Pilularia* and Salvinia Botanical Journal of the Linnean Society **157** : 673-685

NAYAR B K 1970 A Phylogenetic Classification of the Homosporous Ferns Taxon, **19(2)** : 229

NISHIDA M 1952 A new system of Ophioglossales (Studies on the systematic position and constitution of Pteridophyta - 3) J Jap Bot **27** : 271-278

NISHIDA M 1957 Studies on the systematic position and constitution of Pteridophyta 10 A further investigation on the vascular dichotomy in the phyllomophore of Ophioglossales, with special reference to phylogeny J Colleg Arts Sc Chiba Univ **2** : 179-211 f 1-18 t 1-7

NISHIDA M 1959 Studies on the systematic position and constitution of Pteridophyta No 11 *Ophioglossales* with special reference to Japanese species Bull Nation Sc Mus (Tokyo) **44** : 325-335 t 49-54

NOPUN P, TRAIPERM P, BOONKERD T & JENJITTIKUL T 2016 Systematic importance of rhizome stelar anatomy in selected *Monilophytes* from Thailand Taiwania **61(3)** : 175-184

OTTO E M, JANßEN T, KREIER H-P & SCHNEIDER H 2009 New insights into the phylogeny of Pleopeltis and related Neotropical genera (Polypodiaceae, Polypodiopsida) Molecular Phylogenetics and Evolution **53** : 190-201

PARRIS B S 2007 Five new genera and three new species of Grammitidaceae (Filicales) and the re-establishment of Oreogrammitis *The Gardens' Bulletin Singapore* **58** : 233-274

PICHI SERMOLLI R E G 1946 Negripteridaceae e Negripteris, nuova famiglia e nuovo genere delle Filicales Nuov Giorn Bot Ital ser 2 **53** : 129-169 f 1-4 t 14-16

PICHI SERMOLLI R E G 1953 The nomenclature of some fern-genera Webbia **9(2)** : 387-454

PICHI SERMOLLI R E G 1970 A provisional catalogue of the family names of living Pteridophytes Webbia **25(1)** : 219-297

PICHI SERMOLLI R E G 1977 Tentamen pteridophytorum genera in taxonomicum ordinem redigendi Webbia **31(2)** : 313-512

PICHI SERMOLLI R E G 1981 Report of the Subcommittee for family names of Pteridophyta Taxon **30** : 163-168

PICHI SERMOLLI R E G 1982 A further contribution to the nomenclature of the families of Pteridophyta Webbia **35** : 223-237

PICHI SERMOLLI R E G 1986 Report of the Subcommittee for family names of Pteridophyta Taxon **35** : 686-691

PICHI SERMOLLI R E G 1993 New studies on some family names of Pteridophyta Webbia **47** : 121-143

PRESL C B 1836 Tentamen pteridographiae Pragae 1836 Abh B6hm Ges; Wiss n ser; **53** : 1-290 1837

PRESL C B 1843 Hymenophyllaceae Tentamen pteridographiae V, **3** : 93-162 (Reprint pp 1-70 Prag 1843)

PRESL C B 1845 Supplementum tentaminis pteridographiae Tentamen pteridographiae V, **4** : 261-380 (Reprint pp 1-120 Pragae 1845)

PRESL C B 1852 Epimeliae botanicae Tentamen pteridographiae **6** : 361-624 (1851, acc to Roy Soc Cat Sci Papers; Reprint pp 1-264 Pragae 1852)

PRYER K M, SCHNEIDER H, SMITH A R, CRANFILL R, WOLF P G, HUNT J S & SIPES S D 2001 Horsetails and ferns are a monophyletic group and the closest living relatives to seed plants Nature **409** : 618-622

PRYER K M, SCHUETTPELZ E, WOLF P G, SCHNEIDER H, SMITH A R & CRAN?LL R 2004 Phylogeny and evolution of ferns (monilophytes) with a focus on the early leptosporangiate divergences American Journal of Botany **91**: 1582-1598

PRYER K M, SMITH A R & SKOG J E 1995 Phylogenetic relationships of extant pteridophytes based on evidence from morphology and rbcL sequences American Fern Journal **85**: 205-282

RANKER T A, SMITH A R, PARRIS B S, GEIGER J M O, HAUFLER C H, STRAUB S C K & SCHNEIDER, H 2004 Phylogeny and evolution of grammitid ferns (Grammitidaceae): a case of rampant morphological homoplasy Taxon **53**: 415-428

ROTHFELS C J, SUNDUE M A, KUO L-Y, LARSSON A, KATO M, SCHUETTPELZ E & PRYER K M 2012 A revised family-level classification for eupolypod II ferns (Polypodiidae: Polypodiales) Taxon **61**: 515-533

RYDIN C & WIKSTRÖM N 2002 Phylogeny of *Isoëtes* (Lycopsida): resolving basal relationships using rbcL sequences Taxon **51**: 83-89

SCHNEIDER H & SCHUETTPELZ E 2016 Systematics and evolution of lycophytes and ferns J Syst Evol **54(6)**: 561-562

SCHNEIDER H 1996 Vergleichende Wurzelanatomie der Farne.Shaker-Verlag, Aachen.

SCHNEIDER H 2007 Plant morphology as the cornerstone to the integration of fossils and extant taxa in phylogenetic systematics Species, Phylogeny and Evolution **1**: 65-74

SCHNEIDER H, RANKER T A, RUSSELL S J, CRANFILL R, GEIGER J M O, AGURAIUJA R, WOOD K R, GRUNDMANN M, KLOBERDANZ K & VOGEL J C 2005 Origin of the endemic fern genus Diellia coincides with the renewal of Hawaiian terrestrial life in the Miocene Proceedings of the Royal Society B: Biological Sciences **272**: 455-460

SCHNEIDER H, RUSSELL S J, COX C J, BAKKER F, HENDERSON S, GIBBY M & VOGEL J C 2004 Chloroplast phylogeny of asplenioid ferns based on rbcL and trnL-F spacer sequences (Polypodiidae, Aspleniaceae) and its implications for biogeography Systematic Botany **29**: 260-274

SCHNEIDER H, SMITH A R & PRYER K M 2009 Is morphology really at odds with molecules in estimating fern phylogeny? Systematic Botany **34**: 455-475

SCHNEIDER H, SMITH A R, CRANFILL R, HILDEBRAND T, HAUFLER C H & RANKER T A 2004 Unraveling the phylogeny of the polygrammoid ferns (Polypodiaceae and Grammitidaceae): Exploring aspects of the diversification of epiphytic plants Molecular Phylogenetics and Evolution **31**: 1041-1063

SCHUETTPELZ E & PRYER K M 2007 Fern phylogeny inferred from 400 leptosporangiate species and three plastid genes Taxon **56**: 1037-1050

SCHUETTPELZ E, KORALL P & PRYER K M 2006 Plastid atpA data provide improved support for deep relationships among ferns Taxon **55**: 987-906

SMITH A R, PRYER K M, SCHUETTPELZ E, KORALL P, SCHNEIDER H & WOLF P G 2006 A classification for extant ferns Taxon **55**: 705-731

SMITH J 1841-1843 An arrangement and definition of the genera of ferns Jour Bot **4**(1842): 38-70, 147-198 1841; London Jour Bot 1:419-438, 659-668 1843; 2:378-394 1843 (Reprint pp 1-131)

SMITH J E 1793 Tentamen botanicum de filicum generibus dorsiferarum Mem Roy Acad Sci Turin 5:401-422 (Republished in Roemer, Arch Bot **12** : 47-59, 1797, and in Usteri, Ann Bot **23** (Neue Ann 17): 91-109, 1799; English transl in J E Smith, Tracts relating to natural history 217-263, London, 1798)

STEVENSON D W & LOCONTE H 1996 Ordinal and familial relationships of pteridophyte genera, in: Camus, J.M, Johns, R.J & Gibby, M (eds.) Pteridology in perspective Royal Botanic Gardens, Kew, pp 435-467

SWARTZ O 1806 Synopsis Filicum Kiliae

THE PTERIDOPHYTE PHYLOGENY GROUP 2016 A community-derived classification for extant lycophytes and ferns Journal of Systematics and Evolution **54(6)**: 563-603

THOMPSON J M'Lean 1918 The anatomy and affinity of certain rare and primitive ferns Trans Roy Sco Edin **52**: pl.7 363-397

TRYON R M Jr 1952 A sketch of the history of fern classification Annals of the Missouri Botanical Garden **39(4)** : 255-262

VERMA S C 2018 Opportunities and challenges of exploring ferns and Lycophytes in the genomics age : a brief overview of Some issues Pteridology Today: Challenges and Opportunities pp 8-32 Proceedings of the Symposium held at BSI, WRC, Pune

WAGNER W H Jr & WAGNER F S 1983 Genus communities as a systematic tool in the study of New World Botrychium (Ophioglossaceae) Taxon **32** : 51-63

WHITE R A & TURNER M D 2017 The Comparative Anatomy of Hymenophyllopsis and Cyathea (Cyatheaceae): a Striking Case of Heterochrony in Fern Evolution American Fern Journal **107(1)**: 30-57

WIKSTRÖM N & KENRICK P 1997 Phylogeny of Lycopodiaceae (Lycopsida) and the relationships of *Phylloglossum drummondii* Kunze based on *rbcL* sequences International Journal of Plant Sciences **158**: 862-871

WIKSTRÖM N, KENRICK P & VOGEL J C 2002 Schizeaceae : a phylogenetic approach *Review of Palaeobotany and Palynology* **119** : 35-50

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BOOK REVIEW

FERNS AND FERN-ALLIES OF NEPAL

Volume 2 (2019), Pp. 446 [Aspleniaceae to Dryopteridaceae]

by C. R. FRASER-JENKINS & D. R. KANDEL

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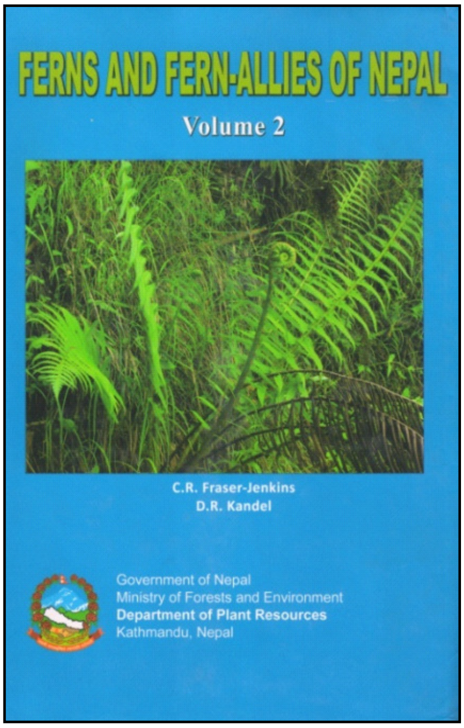

The volume 1 of "Ferns and Fern-Allies of Nepal" was published in 2015 and contained detailed taxonomical accounts of: Fern-Allies, Ophioglossaceae, Marattiaceae, Osmundaceae, Plagiogyriaceae, Lygodiaceae, Marsileaceae, Salviniaceae, Gleicheniaceae, Dipteridaceae, Hymenophyllaceae, Cyarheaceae, Dennstaedtiaceae, Lindsaeaceae, Pteridaceae, and Vittariaceae. (Total species from number 1 to 210. These are the serial numbers of Fraser-Jenkins).

The second volume is a continuation of volume 1 (species number 211-484) and contains detailed taxonomical accounts of families Aspleniaceae, Thelypteridaceae, Woodsiaceae, Onocleaceae, Blechnaceae, and Dryopteridaceae. For all the taxa included therein, detailed distribution in Nepal is provided, besides mention is also made of Himalayan Distribution, and distribution in other parts of the world. Over the years, it has become known to pteridologists in India, that Fraser-Jenkins, because of his wide experience, is ever-ready to update taxonomic identities of taxa and thereby keeps changing names or describe new species or sub-species. They also identify natural hybrids, that are supposed to serve as problems for further analyses. Below are mentioned some such cases for Nepal ferns..

In Aspleniaceae, 33 species + 17 sub-species are discussed with very brief descriptions. Fourteen of these fifty taxa bear the name, Fraser-Jenkins, as one of the authorities. In addition seven hybrids are also included.

For family Thelypteridaceae, only a single genus *Thelypteris* is recognized, a very sensible and workable idea. In this family 37 species are discussed, and nine of these have Fraser-Jenkinss' name associated as an authority. Six hybrids are also described.

Family Woodsiaceae, contains accounts of the genera *Acystopteris* (a single species), *Athyrium* (33 species; two of these are described by Fraser-Jenkins, besides providing a new name for a single species and also segregating a sub-species). Six hybrids are also described), *Cornopteris* (four species), *Cystopteris* (3 species + 4 sub-species + I hybrid; a lone sub-species is described by Fraser-Jenkins); *Deparia* 7 species and 3 sub-species; of these 3 taxa have Fraser-Jenkins name associated); *Diplazium* (18 specie + three hybrids); *Gymnocarpium* (2 species), *Woodsia* (6 species) and *Onoclea* (1 species).

Family Blechnaceae includes the genera *Blechnum*, *Stenochlaena* and *Woodwardia* (each with a single species).

Family Dryopteridaceae includes *Arachniodes* (8 species, two of these owe corrections in nomenclature to Fraser-Jenkins), *Cyrtomium* (3 species), *Dryopsis* (4 species), *Dryopteris* (36 species + 9 sub-species; Fraser-Jenkins is involved in providing his name to seven species and 5 sub-species); *Hypodematium* (1 species and three sub-species; all three sub-species were segregated by Fraser-Jenkins); *Nothoperanema* (2 species), *Peranema* (3 species), *Pleocnemia* (1 species), *Poyltstichum* (36 species; 4 described by Fraser-Jenkins) + 7 hybrids) and *Tectaria* (5 species).

The book is obviously very valuable wherein nomenclatural changes and new subspecies have been segregated by the authors, all principally bearing the signature of Fraser-Jenkins' authority on the taxonomy of ferns and fern-allies of the Nepal and the Himalaya. The book is indeed well illustrated with 172 beautiful colour pictures. However, many of these are too small in size to enable a beginner to identify taxa from these; hence some of these may not be of much use (e.g. Figs.5, 12, 13, 14, 16, and a few more). One wishes that the photographs of species could be full page illustrations.

We would like to congratulate the authors, Mr. Christopher Roy Fraser-Jenkins and Dr. Dhan Raj Kandel for this very valuable contribution to the Ferns and Fern-allies of Nepal, which would also benefit all those interested in the Ferns and Fern-allies of the Himalaya. The Volume 2, like the Volume 1, is not priced, but can be obtained from the Director General, Department of Plant Resources, Kathmandu, Nepal [E-mail : info@dpr.gov.np]. This will ensure its wider use by active pteridologists engaged in taxonomy of Ferns and Fern-allies of Nepal and the Himalaya.

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(Besides all the co-authors)

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THE INDIAN FERN SOCIETY

[Registered under, the Societies Registration Act of 1860 as amended by Punjab Amendment Act 1957]

Head Office : House No. 1633 Sector 7-C, CHANDIGARH

BANK DETAILS

FOR DIRECT BANK TRANSFER OF FUNDS

1. Name of the Account Holder : INDIAN FERN SOCIETY.
2. Complete postal address : 1633 SECTOR 7-C, CHANDIGARH -160019
3. Name of the Bank : **STATE BANK OF INDIA (03246)**
   SECTOR 7-C, MADHYA MARG,
   CHANDIGARH-160019.
4. Branch Code : 0003246
5. Account No. : 65055644880
6. Type of Account (Saving/Current) : SAVINGS
7. MICR Code : 160002116
8. IFSC Code : SBIN0003246
9. SWIFT Code :
9. S.W.F.T. Code :

Prof S P Khullar
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Indian Fern Society
1633, Sector 7-C,
CHANDIGARH-160019 India
sp.khullar@gmail.com
Phone : 0172-2794484
Mobile : 098555-51633

GUIDELINES FOR THE AWARDS OF THE INDIAN FERN SOCIETY

For any award of the Indian Fern Society, the applicant should be a LIFE MEMBER of the Indian Fern Society and fulfill the following conditions :

CERTIFICATE OF MERIT

1. Age : Not more than 36 years on January 1, of the year of award.
2. At least **one** publications in the **Indian Fern Journal**.
3. Attended at least one symposium and presented a paper in the symposium organized by the Indian Fern Society.

GOLD MEDAL IN PTERIDOLOGY

1. Age : Below 50 years on January 1, of the year of award.
2. At least **three** publications in the **Indian Fern Journal**.
3. Attended at least two symposia and presented a paper in the symposium organized by the Indian Fern Society.
4. Gold Medal Awardees will have to deliver a 'Gold Medal Award Lecture'. Applicants wishing to be considered for the IFS Gold Medal, are required to submit a **single-author** manuscript, which will form the substance of the Medal Award Lecture for the successful applicant/s. All such MSS will be taken as duly submitted for Indian Fern Journal.

   The successful applicant will be duly intimated, for preparation of the Medal Award Lecture, form the substance of the Medal Award Lecture, to be delivered at the Symposium, and Medal will be presented after the lecture. The MSS based on the Award Lecture will be published in the Indian Fern Journal.

FELLOW

1. At least four publications in the **Indian Fern Journal,** one of which should be in the immediate last volume of the Journal.
2. Attended at least **two** symposia and presented a paper in the symposium organized by the Indian Fern Society.

LIFE TIME ACHEIVEMENT AWARD

1. A senior well known Pteridologist.
2. At least **five** publications in the **Indian Fern Journal**, one of which should be in the immediate last volume of the Journal.

DONATIONS 2019

1.	PROF. J. SHARPE USA	Rs.7,277/- (Nov. 15, 2019)
2.	PROF. MANISHA KALE JAYSINGPUR (Dist. Kolhapur) Maharashtra	Rs.10,000/- (Dec. 7, 2019).
3.	PROF. K. D. CHAWLA Mumbai	Rs.2,500/- (08/03/2019)
4.	PROF. H. S. KIRN Poonch	Rs.2,000/- (08/03/2019)
5.	PROF. S. P. KHULLAR CHANDIGARH	Rs.3,000/- (15/04/2019)

Total amount donated by Prof. S P Khullar so far : Rs 8000/- (Rs. 5000/- + Rs. 3000/-).

PREVIOUS DONATIONS

Earlier, The Indian Fern Society received the following donations :

1. Prof. B. D. Sharma Rs.11,000/- (2012)
2. Prof. G. Srivastava Rs.20,000/- (2014)
3. Prof. B. L. Yadav Rs.5000/- (Rs.2000/- (2012) + Rs.3000/- (09/02/2018)
4. Prof. S P Khullar Rs.5000/- (Rs.1000/- (2015) + Rs.2000/- (2016) + Rs.2000/- (2017)

Secretary
Indian Fern Society

* * * * *

WEBSITE OF THE INDIAN FERN JOURNAL

The website of the Indian Fern Journal can be accessed at : www indianfernjournal.com

Secretary,
Indian Fern Society

Indian Fern J. **36 :** 348 (2019) ISSN 0970-2741

OBITUARY

DR. SUBHASH CHANDRA
(27.11.1943 to 11.9.2019)

Dr. Subhash Chandra, Former Senior Principal Scientist and Deputy Director CSIR-National Botanical Research Institute (NBRI), Lucknow, left for his heavenly abode on 11th September 2019, due to respiratory tract infection and congestion.

Dr. Chandra was an accomplished well known Pteridologist. His contributions in Pteridology are outstanding, highly appreciated and useful. Dr. Chandra was born on November 27, 1943 at Ghatampur, Kanpur, U.P. where he spent his childhood and early career. His father Late Shree Sarju Prasad Srivastava was a renowned lawyer of Kanpur. After his intermediate study from Kanpur he did B.Sc. and M.Sc. Degree from Agra University in the year 1960 and 1962 respectively. He joined the National Botanical Garden (later renamed as NBRI) as Junior Scientific Assistant in 1963 and continued as Senior Scientific Assistant from 1970 to 1976. In the year 1976 he got an opportunity to work as Research Assistant at the Office for research coordination, University of the Philippines, Diliman Quezon City and further received a fellowship there named **Integrated Foreign Scholarship** till completion of his Ph. D. degree in 1978 on the thesis entitled, **"Morphology and Phylogeny of Drynarioid ferns"** from University of Philippines.

Dr. Chandra returned to India and served CSIR- NBRI, Lucknow till November 2003 (around 25 years). During this period he did rigorous studies on vasculature and its phylogenetic relationships with various groups of ferns. He contributed on the morpho-taxonomy and floristic studies on Pteridophytes in the CSIR-NBRI laboratory. Dr. Subhash Chandra made some monumental contributions like: *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* (Eds. Chandra and Srivastava 2003). He also reviewed “Endemic and threatened Pteridophytes of India”. He published a list of endemic pteridophytes of India as well as an extensive review on threatened pteridophytes.

I greatly value my professional association with him during my short tenure as Research Associate (around 6 months). In this short period I learnt a lot under his able guidance. He kept on guiding me even after his retirement and also had a long personal association with my family. To me he was like a very caring parent, and gave me very useful suggestions and guidance in my career and life. A special quality of Dr. Chandra was his commitment and love for hard work. He also had a hard and critical editorial ability. He was a man of strict principles but at times was a bit short tempered. Dr. Chandra leaves behind his wife, a son and a daughter and also a daughter-in-law, and two grandsons.

Members of the Indian Fern Society express their heartfelt condolences to the bereaved family and pray for peace of the departed soul.

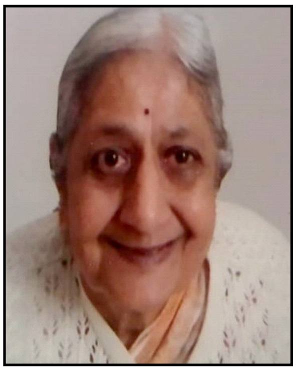
October, 01, 2019

Dr. Alka Kumari
Department of Botany, University of Lucknow,
Lucknow-226 007 U.P.

Indian Fern J. **36 :** 349 (2019) ISSN 0970-2741

OBITUARY

PROF. DR. MAYNAVATHI A. PADHYA
(02 December 1936 - December 10, 2019)



Dr. Maynavathi A. Padhya passed away peacefully at Pune on the night of December 10, 2019, after a well-lived, experience-rich life, deeply loved and respected by her family, friends, colleagues and students up till the end. Dr. Padhya graduated from Fergusson College, Pune and received Ph. D. from The Maharaja Sayajirao University of Baroda. The excellent training and influences formed the template for developing her own skills as a researcher and mentor, which she amplified and passed onto many generations of students throughout her academic career. Dr. Padhya immensely contributed towards to university teaching and research goals in enhancing the capacity of the institution. A multitalented and zealous educator, she taught a wide variety of subjects: phycology, pteridophytes, palaeobotany, plant physiology, tissue culture. Numerous undergraduate and graduate students greatly benefitted from her erudite and generous knowledge, delivered with her unique eloquence, charm and humour. In every interaction with her, students always came away feeling reverent and inspired by the subject she talked enthusiastically. She exercised the same rigor in her research with a dedicated focus on conveying the information effectively and enjoyably. Interspersing her lectures with available literature collected from various sources in her life time. This could make even the most ordinary student and researcher alluring by injecting her unique perspective.

Madam Padhya directed 8 Ph.D. students, published over 60 peer-reviewed research articles. In addition, she mentored research of hundreds of Masters students'. She along with her students worked on a range of topics in plant sciences. She developed the tissue culture of pteridophytes and tree species which formed the basis of research of several other research groups in Pteridophytes and algal biology, and clonal tree propagation, which are least attempted in 1980s, by the plant researchers. She influenced many students to define their career path and her Ph. D students are currently reached to trajectory of their professional goals. Dr. M.A. Padhya was recognized nationally and internationally for her innumerable contributions to plant science in general, and especially in phycology and pteridophytes. She travelled extensively both national and internationally to disseminate the research knowledge to the younger generation and peers. This lifelong commitment to effective scientific communication extended to her scholarly contributions in research and teaching as well. She was passionate about promoting and popularizing science among the masses and making even the most complex information accessible to audience of large number of learning stages. As an academician, she was professionally active till the very end of her tenure in office. After her retired life she was busy with her family and looked after siblings. Despite an exemplary and prolific career, Dr. Padhya was soft spoken and affectionate. She led a life dedicated to education, academic unassuming nature and desire for greater good. She was very fond of music and travelling. We will greatly miss her presence and guidance, but hope her influence inspires us to continue her rich legacy of lifelong learning and popularization of science.

Prof. K. S. Rajput
Maharaja Sayajirao University of Baroda,
Vadodara-390 002

THE INDIAN FERN SOCIETY (NOW AT CHANDIGARH)

Registered under the Societies Registration Act XXI of 1860 as Amended
by Punjab Government Act 1957.

BALANCE SHEET
AS ON 31st MARCH, 2019

Liabilities		**Amount**	**Assets**	**Amount**
		(Rs.)		***(Rs.)***
Capital Account			State Bank of Patiala	9,19,025.00
Opening Balance	11,19,896.83		Cash in Hand	–
Add : Excess of				
Income Over	62,742.44		FDR - 144452	1,00,000.00
Expenditure		11,82,639.27	FDR - 144402	1,00,000.00
			TDS 2014-15	1,849.00
Audit Fees Payable		3,540.00	TDS 2015-16	1,930.00
Legal Fees Payable		1,180.00	TDS 2016-17	1,877.00
			TDS 2017-18	1,510.00
			TDS 2018-19	1561.00
			Interest Accrued	59,607.27
		11,87,359.27		**11,87,359.27**

Auditor's Report

As per our separate report
of even date attached.

For S. K. Bhasin & Associates
Chartered Accountants

S. P. Khullar

Sunil Kumar Bhasin
Partner
M.No. 085976
Date : 27-09-2019
Place : Chandigarh

Secretary-Treasurer
S. P. Khullar

THE INDIAN FERN SOCIETY (NOW AT CHANDIGARH)

Registered under the Societies Registration Act XXI of 1860 as Amended
by Punjab Government Act 1957.

INCOME & EXPENDITURE ACCOUNT
FOR THE YEAR ENDED 31st MARCH, 2019

Particulars	**Amount** *(Rs.)*	**Particulars**	**Amount** *(Rs.)*
To Bank Charges	14.50	By Annual Membership	6,000.00
To Printing Charges	2,18,108.50	By Life Membership Fees	68,575.00
To Symposium Related Expenses	2,000.00	By Subscription - Indian	74,123.00
To Mailing Charges	1,08,000.00	By Collection of Printing & Mailing	209,475.00
To Audit Fees	3,540.00	By Bank Interest	36,391.00
To Website Running Exp.	10,000.00	By Royalty	20,732.00
To Broadband & Telephone Exp.	11,000.00	By FDR Interest	15,608.94
To Life Achievement Award	22,000.00	By Donation	6,500.00
To Excess of Income Over Expenditure	62,742.44		
	4,37,404.94		**4,37,404.94**

Auditor's Report

As per our separate report
of even date attached.

For S. K. Bhasin & Associates
Chartered Accountants

S. P. Khullar

Sunil Kumar Bhasin
Partner
M.No. 085976
Date : 27-09-2019
Place : Chandigarh

Secretary-Treasurer
S. P. Khullar

THE INDIAN FERN SOCIETY (NOW AT CHANDIGARH)

Registered under the Societies Registration Act XXI of 1860 as Amended
by Punjab Government Act 1957

RECEIPTS & PAYMENTS FOR THE YEAR ENDING 31ST MARCH, 2019

Receipts		Total *(Rs.)*	Payments	Total *(Rs.)*
Opening Balance :			Printing Charges (for Vols.34 & 35)	2,26,108.00
State Bank of	6,93,339.00		Mailing Expenses (for Vols.34 & 35)	1,00,000.00
India 0003246			Symposium related Expenses	2,000.00
FDR with SBI 144452	1,00,000		Audit Fees	3,540.00
FDR with SBI 144402	1,00,000	10,71,891.00	Bank Charges	14.50
Cash	–	6,93,339.00	Website Running Exp.	10,000.00
Annual Membership		6,00.00	Broadband & Telephone Expenses	11,000.00
			(For Chief Editor & Secretary Treasury)	
Life Membership Fees		68,575.00	Life Time Achievement Award	22,000.00
Collection of Printing &			Closing Balance :	
Mailing Charges		2,09,475.00	FDR with SBI 144452	1,00,000
Donations		6,500.00	FDR with SBI 144402	1,00,000
Indian Institutions-Subscription		74,123.00	State Bank of India	9,19,025.00
Bank Interest		36,391.00		
Royalty IFJ		20,732.00		
		14,93,687.50		**14,93,687.50**

For S. K. Bhasin & Associates
Chartered Accountants

Sunil Kumar Bhasin
Partner
M.No. 085976
Date : 27-09-2019
Place : Chandigarh

S. P. Khullar
Secretary-Treasurer
(S. P. Khullar)

AUDITOR'S REPORT

We have examined the Receipts & Payments Account, Income & Expenditure Account and Balance Sheet of the Indian Fern Society, Chandigarh (earlier at Patiala) for the year ended 31st March, 2019.

We have obtained all the information & explanations which to the best of our knowledge and belief were necessary for the purpose of the Audit.

In our opinion and to the best of our knowledge and according to the explanations given to us thereto, the said accounts give true & fair view and the payments have been made in accordance with the bye-laws of the society.

For S. K.Bhasin & Associates
Chartered Accountants

Sunil Kumar Bhasin	**Date : 27.09.2019**
Partner	**Place : Chandigarh**
M.No. 085976	

THE INDIAN FERN SOCIETY

(Established 1983)

[Registered under the Societies Registration Act XXI of 1860 as amended by Punjab Amendment Act 1957]

Head Office : **#1633, Sector 7-C, CHANDIGARH-1600 19, INDIA**

[Formerly at the Department of Botany, Punjabi University, Patiala-147002, India]

ENROLLMENT PROFORMA FOR FRESH MEMBERSHIP (INDIA)

I desire to enroll myself as an ordinary/ life member* of the Indian Fern Society. I shall abide by the constitution of the Society, and the decisions taken from time to time.

Name (in BLOCK LETTERS) ....

Place and Date of Birth ....

Qualifications ....

Field /s of Specialisation ....

....

Professional details ....

....

Address for Correspondence ....

....

.... PIN..

Telephone .... (Mobile) ....

Email address ....

The **Annual Subscription** for members in India with effect from January 2019 is Rs. 1500/- Or **Life Membership** is Rs. 7500/- (Rs 5000/- for Students & Research Scholars who do not get any fellowship. However they will have to pay the balance after they get a fellowship/job). Add Rs 500/- if you wish to get the Indian Fern Journal through registered Book Post.

Subscription can be sent as DD/Cheque No................ dated................, made in favour of **'The Secretary / Treasurer, INDIAN FERN SOCIETY', CHANDIGARH, India', payable at CHANDIGARH;** or can be remitted directly to the Bank Account of INDIAN FERN SOCIETY. (Bank details are given separately). Intimation of direct remittance to the Bank Account of Indian Fern Society must be sent to Prof. S. P. KHULLAR, Secretary, The Indian Fern Society, by email : <sp.khullar@gmail.com>.

*Please strike out whatever is not applicable.

Note : The Indian Fern Journal, of the Society, is sent by Registered Post at the given address of all members. However, to Life Members the supply of the Journal by Registered Post is made on onetime payment of **Rs. 500/-** only, which may be added to Life Membership Fee. The completed Membership Form along with the Cheque/DD (payable at Chandigarh) is to be sent to Prof. S. P. Khullar, The Secretary-Treasurer, Indian Fern Society, House No.1633, Sector 7-C, Chandigarh-160019, India.

Place :

Date : Signature

THE INDIAN FERN SOCIETY

(Established 1983)

[Registered under the Societies Registration Act XXI of 1860 as amended by Punjab Amendment Act 1957]

Head Office : 1633, Sector 7-C, CHANDIGARH-160019, INDIA

[Formerly at the Department of Botany, Punjabi University, Patiala-147002, India]

ENROLLMENT PROFORMA FOR FRESH MEMBERSHIP (FOREIGN)

I desire to enroll myself as an ordinary/ life member* of the Indian Fern Society. I shall abide by the constitution of the Society, and the decisions taken from time to time.

Name (in BLOCK LETTERS) ....

Place and Date of Birth ....

Qualifications ....

Field /s of Specialisation ....

....

Professional details ....

....

Address for Correspondence ....

....

.... PIN...

Telephone (Office) .... (Res.) ....

Email address ....

The Annual Subscription* (for members from abroad) of US $ 75 plus US $ 5 as one-time Enrollment Fee, Or Life Membership Subscription* of US $ 600. You may send the amount through bank transfer to the account of the Indian Fern Society *(Bank Account details given separately)*.

Note : The completed Membership Form along with Bank Receipt to 'Treasurer/Secretary, Indian Fern Society, Chandigarh' is to be sent to Prof. S.P. Khullar, The Secretary, Indian fern Society, House No.1633, Sector 7-C, Chandigarh-160019, India.

You may enquire for any other requirement from your local bank for direct remittance. Intimation of direct remittance to the Bank Account of Indian Fern Society must be sent to Prof. S.P. KHULLAR, Secretary, The Indian Fern Society, by email : <sp.khullar@gmail.com>.

Place :

Date : Signature

STATEMENT ABOUT OWNERSHIP AND OTHER PARTICULARS OF INDIAN FERN JOURNAL

Published in accordance with form IV, Rule 8 of the Registration of Newspaper (Central) Rules, 1956

1. Place of Publication : Chandigarh
2. Periodicity of publication : Yearly Volume (May be issued in two numbers)
3. Printers Name : Prof. S. C. Verma, Editor-in-chief
   Whether citizen of India : Citizen of India
   Address : Prof. S. C. Verma
   (Formerly Professor, Department of Botany,
   Panjab University, Chandigarh)
   5452/1, Cat. II, Modern Housing Complex,
   Manimajra, Chandigarh-160 101
4. Publishers Name : The Indian Fern Society (Regd.)
   Whether citizen of India : Citizen of India
   Address : 1633, Sector 7-C, Chandigarh
5. Editor-in-chief's name : Prof. S C Verma
   Whether citizen of India : Citizen of India
   Address : Prof. S. C. Verma
   (Formerly Professor, Department of Botany,
   Panjab University, Chandigarh)
   5452/1, Cat. II, Modern Housing Complex,
   Manimajra, Chandigarh-160 101

6a. Name and Address of Individuals who own the newspaper : The Indian Fern Society (Regd.)

6b Partners or shareholders holding More than one per cent of the Total capital : Not Applicable

I Professor S. C. Verma, hereby declare that the particulars given above are true to the best of my knowledge and belief. (The change in publisher's name has been necessitated due to the demise of Prof. S. S. Bir on August 26, 2015.)

Sd/-
(S. C. Verma)
Signature of Publisher
Editor of Publications

Dated : January 31, 2020

THE INDIAN FERN SOCIETY

GUIDELINES/SUGGESTIONS FOR CONTRIBUTORS

The INDIAN FERN JOURNAL publishes original Research Reviews / Articles dealing with any aspect of study on Pteridophytes. It is mandatory for **all authors to be members** of THE INDIAN FERN SOCIETY. **Authors will have to bear the cost of pagination and illustrations.** There will be no charges for Invited articles.

Format of the Manuscript

Manuscripts should be typed in double space, 'Times New Roman', 12 font size. The electronic version of text and figures should be in MS office, photographs should be in JPG or JPEG format. Original text, figures, line-diagrams and B&W/coloured photographs should be submitted. The photographs and figures should be mounted in a fashion that no space is wasted.

Title of the paper should be short, and in bold CAPITAL LETTERS, font size 14 and centered near the top of the first page.

Author's name/s should be in CAPITAL LETTERS, font size 12. The affiliation/s should be in font size 10. All authors should give their **e-mail address**.

Normally the manuscript should have the following pattern (Typed in bold, CAPITAL LETTERS and arranged in the centre of the page): ABSTRACT (font size 10), INTRODUCTION, MATERIALS & METHODS, OBSERVATIONS, DISCUSSION OR RESULTS, ACKNOWLEDGEMENTS, AND REFERENCES. The Abstract (in font size 10) giving the salient features of the work in about 70-80 words, should precede the text. **Key Words** (3-5, and in bold, font size 10), should follow the abstract. The contributions should follow the style of the latest issue of the Journal. Generic and species names and all words from a language other than English should be in *italics*. Tables should have concise captions and must be on separate pages. Foot-notes be kept to the minimum.

Illustrations : Figures should be numbered consecutively using Arabic numerals. Line diagrams and inscriptions should be legible. Legends of figures should be typed on a separate sheet. These should be brief and self explanatory.

Tables should also be numbered consecutively using Arabic numerals, with a self explanatory title. Abbreviations should be explained in foot notes.

REFERENCES should be arranged in alphabetical order in the following style of IFJ :

Journal :

ALSTON, A.H.G. 1945. An enumeration of the Indian species of *Selaginella Proc National Institute Sci India* **11B :** 211-235

Books :

DIXIT, R. D. 1992. *Selaginellaceae of India* Bishen Singh Mahendra Pal Singh Dehra Dun, India.

FRASER-JENKINS, C.R. 2007. Endemics & Pseudoendemics in relation to the Distribution patterns of *Indian Pteridophytes*. In "Fourth Symposium on Asian Pteridology and Garden Show." Abs. Ed V B Ambrose. Central Mindanao University, Musan, Bukidnon, Philippines.

BANERJEE, R. & MUKHOPADHYAY, R. 2008. Studies in the leaf epidermis and Venation patterns of some Indian species of Tectarioid ferns. In "*Perspectives In Pteridophytes* Eds. S C Verma, S P Khullar & H K Cheema. Publishers : Bishen Singh Mahendra Pal Singh, Dehra Dun, (INDIA). Pp 397-406.

The authors reference in text should be cited as Cronquist *et al.* (1970) or Tryon & Tryon (1973) or (Tryon & Tryon 1973). **Only articles and books referred to in the text should be listed.** The abbreviations of the journals should conform to the latest edition of the *"World List of Scientific Periodicals"* (eds. P Brown & G B Straiton) Butterworths, London.

All papers are reviewed. The comments of the referees/editor will be communicated to the authors for revision and incorporation of suggestions, before the paper is finally accepted by the Editor. The printing charges are as follows : **Ordinary printed pages @ Rs. 500/- per page. Color plates Rs. 1500/- per plate (subject to a minimum of two plates); Black & White Plates @ Rs 1000/- per plate.** Authors will be provided with a pdf of their contribution. The printing cost will be intimated and should be sent in advance after the paper is accepted by the Editor, through crossed Bank Cheque, Bank Demand Draft payable at **Chandigarh** in the name of the **'SECRETARY-TREASURER, INDIAN FERN SOCIETY' (mailed to Prof. S P Khullar, 1633, Sector7-C, Chandigarh- 160047 (U.T.). E-mail: sp.khullar@gmail.com** OR funds can be transfered directly into the account of the Indian Fern Society with information to the Secretary-Treasurer. Bank details are on page 345 of this volume. (There are some changes due to merger of banks).

Book Review : A copy of the book (non-returnable) will have to be submitted to the Secretary/Editor.

Manuscript fully formatted to IFJ style, be submitted as email attachment either to the Editor-in-chief IFJ (Prof. S.C.Verma, **verma1sc@yahoo.co.in**; **scverma1931@gmail.com** or to Prof. S.P. Khullar Editor, IFJ, **sp.khullar@gmail.com**).