



Ecology of fern wealth (Pteridophyta) of Dehradun district, Uttarakhand, India

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Received for publication: April 11, 2013; **Accepted:** June 25, 2013.

Abstract: The present paper is the outcome of field studies and examination of herbarium sheets housed in different herbaria. Ecologically the ferns of the area are divided into four major categories, which are again subdivided into the subcategories depending upon their growth, habit and habitat they occupy. The maximum no of species are found growing in terrestrial habitat whereas the epiphytic members are comparatively less in numbers.

Keywords: Fern flora, Ecological observations, Dehradun

Introduction

Pteridophytes are the group of plants of the division tracheophyta which do not have seeds or flowers either; instead they also reproduce via spores. Ecological study of any area gives the idea of its flora and its interaction with different components of environment. Ecological study of flora of particular area is an important aspect as it forms baseline information for the distribution of plant species or communities and their relation with physical environment (Bir *et al.*, 2000). Species are in balance with their environment as long as the environment is stable. The field of fern ecology has advanced from simple observation of characteristics of fern habitat to long term complex role in nutrient cycling and successional dynamics of natural ecosystems. Ferns play a significant role as they form an important component of the vegetation of particular area. Whereas ferns in general may be thought of largely being specialists in marginal habitats, often succeeding to grow in places where various environmental factors limit the success of flowering plants.

The ecological distributional survey of the ferns and fern allies of Dehradun district holds an considerable importance to the district with respect to its diversity and conservation which has attracted number of workers both in past and present which includes Beddome (1865-70, 1876, 1883, 1892), Clarke (1880), Blanford (1888), Hope & Trotter (1890), Stewart (1942), Dhir & Sood (1981), Bir *et.al* (1983), Khullar (1994, 2000), Stracheyi (1892), Fraser-Jenkins (1997), Pande & Pande (2002, 2002a, 2002b)

etc. Checklist of ferns of Garhwal Himalaya was published by Khullar *et al.*, (1987).

The ferns are affected by change in its microclimate thus it has own preferences for temperature; humidity; soil type, moisture and pH; light levels etc. The different niche in environments are very clearly marked by the types of fern that grow there. Thus turning them into good ecological indicator of environmental health. The difference in fern diversity in the different areas of the district is due to sharp difference in climatic condition. This could serve as an important ecological tool to study the different aspects of environment which affect the distribution of the ferns of the district and identifying the distribution in various habitats. Ferns are very good indicators of their immediate environment, conducting surveys of fern flora in such area provides valuable ecological tool to measure environments to the micro level.

They forms an important part of world's vegetation found dwelling in a diverse habitats, from remote mountain elevations, to dry desert rock faces, to bodies of water or in open grassfields. Some of the ferns are growing as world's most serious weed species such as the mosquito fern, bracken both species forming large aggressively spreading colonies, in British highlands and tropical lakes. Many ferns, mosses and both are indicators of different types of soils and forests. Some ferns are used in ornamental horticulture in greenhouses.

An important aspect of study of ecology is mapping and describing plant

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communities by vegetation surveys. It documents environmental patterns in the landscape, as shown by different assemblages of plant species. Such studies provide baseline information for further research into the dynamics and distribution of plant species or communities and how they relate to the physical environment (Bir *et al.*, 1991).

To study the diversity of the pteridophyte a survey of the district was undertaken. The present paper is the outcome of field studies and examination of herbarium sheets housed in different herbaria. Ecologically the ferns of the area they inhabit are divided into four major categories, which are again subdivided into the subcategories depending upon their growth, habit and habitat they occupy. The maximum no of species are found growing in terrestrial habitat whereas the epiphytic members are comparatively less in numbers. Ecologically, the ferns are most common plants of shaded damp forests. Some fern species grow equally well on soil and upon rocks; others are confined strictly to rocky habitats, where they occur in fissures and crevices of cliff faces, boulders, may grow as epiphytes (Bir & Vasudeva, 1972).

Geographical location:

Dehradun district lies between the west Himalayan mountain ranges in the north and the Shiwalik range in the south. In the west, it is bordered by the Yamuna River and in the east by the Ganga and Tons rivers. The district lies between 30.33° N 78.06° E with total geographical area of 300 km². Out of the total area covered 43% of the area is covered by forest. The major species of the district is *Shorea robusta*. Dehradun is surrounded by Uttarkashi district in the north, Saharanpur district in the south, Tehri Garhwal & Pauri Garhwal districts in the east, and state of Himachal Pradesh in the west. The variation in latitude, longitude, altitude, Topography and unique geographical location has endowed it with remarkable wealth of biodiversity.

Ecological observations:

Ferns play a significant role as they form an important component of the vegetation of particular area. Environment surrounding a fern consists of the type of soil in which the roots grow and receive nutrition, the light, that shines on its leaves utilizing for photosynthesis and other chemical reactions,

the rain, a source of water, the wind, a source of oxygen and other gases, temperature variations and growth of other vegetation including plants in the surrounding area etc. These are the parameters of environment which affect the growth and distribution of the fern in any area.

Their presence is confined to shady places away from direct exposure to the scorching rays of the sun. However some pteridophytes are adapted to harsh environment as well. Those which can survive under specific conditions possess a narrow range of adaptability. The type of soil, water and atmospheric humidity are the primary factors controlling the distribution of ferns. The wind, temperature, soil, pH drainage of soil and exposure to wind are other factors that may restrict their distribution. The field of fern ecology has advanced from simple observation of characteristics of fern habitat to long term complex roles in nutrient cycling and succession dynamics of natural ecosystems.

In many cases ferns are more specific indicator of the condition they need than flowering plants (Nicholas & Nicholas 1999-2000). This association of species with soil and microclimate clearly indicates the favorable environmental conditions necessary for the growth of ferns as some of the ferns were once classified with the primitive horsetails and club mosses. The ecological distributional survey of the ferns and fern allies of Dehradun district stand considerable importance from phytogeographical and diversity view point.

Thus Ecologically the Pteridophytic flora inhabiting the area may be classified into the following depending upon their growth, habit and habitat they occupy which is as follows,

- Terrestrial
- Epiphytic
- Lithophytes
- Aquatic

Terrestrial ferns: Of the total fern flora occupying the areas of district, 56% of the ferns fall under the category of terrestrial ferns which are found in varied habitat. Mostly the terrestrially grown fronds are short, triangular, and sterile. Terrestrial fern found mostly in well drained soil abundant in well sloped terrain. High steep slopes

support large fern vegetation due to shaded moist condition in presence of canopy of dense forest. The terrestrial species always grow on the ground and often located in the very wet places and/or on river/or stream banks, or sometimes along trekking paths. Some of the characteristics of the terrestrial ferns are hard tissues and thick texture; the surface cells, or epidermis with a very thick cuticle (a waxy layer) and abundant hairs or scales on the leaves and stem surfaces. These can be further classified into the following sub-classes

1. Classification based on altitudinal zones:

- a. Species found at low altitude i.e. up to 1200m
- b. Species found at medium altitude i.e. 1200-2500m
- c. Species found at high altitude i.e. 2500-2950m

2. Classification based on inhabitation in the forest:

- a. Fern species growing in exposed (to direct sun rays) forest on hill slopes.
- b. Fern species growing in shaded forest on hill slopes.
- c. Fern species growing in moist and shaded forest on hill slopes
- d. Fern species growing in moist and shaded forest slopes near water streams
- e. Fern species growing in moist and shaded forest on hill slopes along roadsides
- f. Fern species growing in the interior of the forest
- g. Fern species growing in the fringes of the forest

3. Classification based on the types of soil:

- a. Fern species growing in humus rich soil.
- b. Fern species growing in calcium rich soil.

4. Classification based on special habitat:

- a. Fern species of ravines swamp and gorges
- b. Fern species growing in burnt areas
- c. Climbing ferns
- d. Walking ferns
- e. Ferns met with grassy areas

5. Evergreen ferns:

Classification based on altitudinal zones:

The studies of diversity patterns have the potential to play an important role in understanding the processes behind their diversity patterns. The elevation does not

directly influence plants distribution (Kroner 2000, 2007). Rather certain factors such as air pressure, temperature are directly related to elevation.) or that have complex relationship with elevation (available surface area, precipitation etc.) that affect plants growing at different elevations. The upper limit of a species distribution is generally thought to be determined by low temperature, quantity of snowfall, length of growing period, and wind intensity, whereas at the lower end the range limit may be determined by a combination of climatic and biotic factors (MacArthur, 1972). Thus altitude plays an important role in distribution of the ferns species and shows marked varied types of ferns at different altitudinal zones which are as follows:

a. Species found at low altitude (upto 1200m):

These flourish well during the rainy season and are at their best from July to September. The fern species of the area are: *Adiantum capillus-veneris* L., *Adiantum edgeworthii* Hook., *Adiantum incisum* Forssk., *Adiantum lunulatum* Burm. *Ampelopteris prolifera* (Retz.) Copel., *Athyrium pectinatum* (Wall. ex Mett.), *Blechnum orientale* L., *Christella arida* (D. Don) Holtt., *Christella appendiculata* (C. Presl) Holtt., *Christella dentata* (Forssk.) Brown., *Christella papilo* (Hope) Holtt., *Christella parasitica* (L.) Leve., *Colysis elliptica* (Thunb.) Ching., *Deparia petersenii* (Kunze) M. Kato., *Diplazium esculentum* (Retz.) Sw., *Diplazium spectabile* (Wall. ex Mett.) Ching., *Dryopteris cochleata* (Ham. ex D. Don) C. Chr., *Dryopteris stenolepis* (Baker) C. Chr., *Hypodematum crenatum* (Forssk.) Kuhn. ssp. *crenatum*, *Lygodium flexosum* (L.) Sw., *Lygodium japonicum* (Thunb.) Sw., *Microlepia speluncae* (L.) T. Moore., *Marsilea minuta* L., *Nephrolepis auriculata* (L.) Trimen., *Onychium siliculosum* (Desv.) C. Chr., *Ophioglossum reticulatum* L., *Pseudocyclosorus canus* (Baker) Holtt., *Pteris biaurita* L., *Pteris multifida* Poir., *Pteris vittata* L., *Tectaria coadunata* (J. Smith) C. Chr.

b. Species found at medium altitude (1200-2500m):

The diversity of fern species increases along with the altitude. Certain parameters such as humidity, temperature in high altitude are low as compared to the low altitude area, which help them flourish well in the area. The altitudinal variation results into varied ferns species and

this altitude covers the area of Mussoorie region. The species includes: *Adiantum capillus-veneris* L., *Adiantum edgeworthii* Hook, *Adiantum incisum* Forssk, *Adiantum lunulatum* Burm, *Adiantum venustum* D. Don, *Amplopteris prolifera* (Retz.) Copel, *Anogramma reichtenii* Fraser-Jenk., *Asplenium adiantum-nigrum* L., *Asplenium dalhousiae* Hook, *Asplenium enisforme* Wall.ex Hook. et Grev, *Asplenium indicum* Sledge, *Asplenium laciniatum* D. Don, *Asplenium tenuifolium* D. Don, *Asplenium trichomanes* subsp *quadrivalens* D. E. Meyer, *Asplenium unilaterale* Lamk., *Asplenium yunnanense* Franch., *Athyrium anisopterum* H.Christ., *Athyrium attenuatum* (Wall. ex C. B. Clarke) Tagawa, *Athyrium falcatum* Bedd., *Athyrium foliolosum* (Wall.) T. Moore ex Sim, *Athyrium pectinatum* (Wall. ex Mett.) T. Moore, *Athyrium rupicola* (Edegw. ex Hope) C. Chr, *Athyrium schimperii* Moug. ex fee', *Athyrium setiferum* C. Chr, *Athyrium strigillosum* (T. Moore ex E. J. Lowe) T. Moore ex Salom, *Botrychium lunaria* (L.) Sw., *Botrychium lanuginosus* (Wall. ex Hook. et Grev.) Holub., *Botrychium multifidum* (Gmelin) Rupr, *Botrychium ternatum* (Thunb.) Sw., *Crepidomanes insigne*, *Christella arida* (D. Don) Holtt., *Christella appendiculata* (C. Presl) Holtt., *Christella dentate* (Forssk.) Brown., *Christella papilio* (Hope) Holtt, *Christella parasitica* (L.) Leve, *Coniogramme intermedia* Heiron, *Coniogramme fraxinea* (D. Don) Fee ex Diels, *Coniogramme serrulata* (Bl.) Fee, *Cyclogramma auriculata*, (J. Smith) Ching, *Cyrtomium caryotideum* (Wall. ex Hook. et Grev.) C. Presl., *Deparia allantodioides* (Bedd.) M. Kato, *Deparia boryana* (Willd.) M. Kato, *Deparia japonica* (Thunb. ex Murr.) M. Kato, *Deparia petersenii* (Kunze) M. Kato, *Dennstaedtia scabra* Wall. ex T. Moore, *Diplazium esculentum* (Retz.) Sw., *Diplazium longifolium* T. Moore, *Diplazium maximum* (D. Don) C. Chr, *Diplazium spectabile* (Wall. ex Mett) Ching, *Drynaria propinqua* (Wall. ex Mett.) Smith, *Drynaria mollis* (H.Christ) C. Chr, *Dryopteris cochelata* (Ham. ex D. Don) C. Chr, *Dryopteris juxtaopposita* H. Christ, *Dryopteris nigropalaceae* (Fraser- Jenk.) Fraser- Jenk., *Dryopteris ramosa* (Hope) C. Chr, *Dryopteris redactopinnata*, *Dryopteris stewartii* Fraser-Jenk., *Dryopteris wallichiana* (Spreng.) Hyland, *Dryopteris xathomelas* (H. Christ) C. Chr, *Glaphyopteridopsis erubescens* (Wall. ex Hook.) Ching, *Gymnopteris vestita* (Wall. ex T. Moore) Underw., *Hypodematium crenatum* (Forssk) Kuhn ssp. *crenatum*, *Hypolepis*

polypodiodes (Bl.) Hook, *Lepisorus loriformis* (Wall. ex. Mett.) Ching, *Lepisorus nudus* (Hook.) Ching, *Lepisorus oligolepidus* (Baker) Ching, *Lepisorus pseudonudus* Ching, *Lepisorus sesquipedalis* (J.Smith) Fraser-Jenk., *Lepisorus ussuriensis* (Regel et Maack) Ching, *Leucostegia immersa* Wall. ex C.Presl., *Loxogramma involuta* (D. Don) C. Presl., *Lygodium flexosum* (L.) Sw, *Lygodium japonicum* (Thunb.)Sw., *Microsorium membranecum* (D. Don) Ching, *Onychium cryptogrammoides* H. Christ, *Onychium japonicum* (Thunb.)Kunze., *Onychium siliculosum* (Desv.) C. Chr, *Oleandra wallichii* (Hook.) C. Presl., *Ophioglossum petiolatum* Hook., *Ophioglossum reticulatum* L., *Peranema cyatheoides* D. Don, *Pellaea nitidula* (Wall. ex Hook.) Baker, *Pichisermollia ebenipes* (Hook.) Pic.Serm., *Pichisermollia malacodon* (Hook.) Pic.Serm., *Pichisermollia stewartii* (Bedd.), *Pichisermollia quasidivarticata* (Hayata) Fraser-Jenk., *Selliguea oxyloba* (Wall. ex Kunze) Fraser-Jenk., *Polypodiastrium argutum* (Wall. ex Hook.) Ching, *Polypodiodes amonea* (Wall. ex Mett.)Ching, *Polypodiodes lachnopus* (Wall. ex Hook.) Ching, *Polypodiodes microrrhizoma* (C. B. Clarke ex Baker) Ching, *Polypodiodes subamonea* (C. B. Clarke) Ching, *Polystichum discretum* (D.Don) J. Smith, *Polystichum lentum* (D. Don) T. Moore, *Polystichum longipaleatum* H. Christ, *Polystichum mehrae* Fraser- Jenk.& Khullar, *Polystichum obliquum* (D. Don) T. Moore, *Polystichum piceo-paleaceum* Tagawa, *Polystichum squarrosus* (D. Don) Fee *Polystichum stimulans* (Kunze ex Mett.) Bedd., *Polystichum thomsonii* (Hook f.) Bedd., *Pronephrium nudatum* (Roxb.) Holtt, *Pronephrium penangianum* (Hook.) Holtt, *Pseudocyclosorus canus* (Baker) Holtt, *Pseudocyclosorus tyloses* (Kunze) Ching, *Pseudophegopteris levingei* (C. B. Clarke) Ching, *Pseudophegopteris pyrrhorhacis* (Kunze) Ching subsp. *pyrrhorhacis*., *Pseudophegopteris pyrrhorhacis* subsp *distans* Fraser- Jenk., *Pteridium revolutum* (Bl.) Nakai, *Pteris aspercularis* Wall. ex J. Agardh, *Pteris biaurita* L, *Pteris cretica* L, *Pteris dactylina* Hook, *Pteris excelsa* Gaud., *Pteris multifida* Poirer, *Pteris stenophylla* Wall. ex Hook, *Pteris vittata* L, *Pyrrosia costata* (Wall. ex C.Presl) Tagawa et K. Bedd., *Dryopteris blanfordii* (Hope) C. Chr, *Dryopteris caroli-hopei* Fraser- Jenk., *Dryopteris chrysocoma* (H.Christ.)C.Chr, *Pyrrosia flocculosa* (D. Don) Ching, *Pyrrosia lanceolata* (L.) Farwell, *Pyrrosia porosa* (C. Presl.) Hovenkamp., *Sphenomeris chinensis*

(L.) Maxon, *Stenogramma mollisma* (Kunze) Fraser- Jenk., *Tectaria coadunata* (J. Smith) C. Chr, *Vittaria flexuosa* Fee, *Woodwardia ungiemmata* C. Presl.

c. Species found at high altitude (2500-2950m):

Great diversity of fern species was recorded due to altitudinal variation coupled with rainfall (Arora, 1993). Chakrata, Deoban region of district falls within this altitude range where wide fern diversity was recorded. This zone is characterized by coniferous trees like *Abies pindrow* Royle, *A. spectabilis* (D. Don) Spach, *Cedrus deodara* (Roxb. ex La.) G. Don The fern species composition of this area are : *Adiantum capillus-veneris* L, *Adiantum edgeworthii* Hook, *Adiantum incisum* Forssk, *Adiantum venustum* D.Don, *Ampelopteris prolifera* (Retz.) Copel, *Araoistegia beddomei* (Hope) Ching, *Araoistegia hookeri* (T. Moore ex Bedd.) Ching, *Arthromeris wallichiana* (Spreng.) Ching, *Asplenium adiantum-nigrum* L., *Asplenium ceterach* L, *Asplenium dalhousiae* Hook, *Asplenium enisforme* Wall.ex Hook.et Grev, *Asplenium indicum* Sledge, *Asplenium laciniatum* D.Don, , *Asplenium trichomanes subsp quadrivalens* D.E. Meyer, *Asplenium unilaterale* Lamk., *Athyrium anisopterum* H. Christ., *Athyrium attenuatum* (Wall. ex C. B. Clarke) Tagawa, , *Athyrium rupicola* (Edegw. ex Hope) C.Chr, *Athyrium schimperi* Moug. ex fee', *Athyrium setiferum* C.Chr , *Athyrium atkinsoni* Bedd., *Athyrium fimbriatum* T. Moore., *Athyrium mackinnonionrum* (Hope) C. Chr, *Athyrium micropterum* Fraser-Jenk., *Athyrium pectinatum* (Wall.ex Mett.) T. Moore, *Botrychium lunaria* (L.) Sw., *Botrychium lanuginosus* (Wall.ex Hook. et Grev.) Holub., *Aleuritopteris anceps* (Blanford) Panigrahi, *Aleuritopteris bicolor* (Roxb.) Fraser- Jenk., *Aleuritopteris formosana* (Hayata) Tagwa, *Aleuritopteris leptolepis* (Fraser- Jenk.), *Aleuritopteris rufa* (D. Don) Ching, *Aleuritopteris subvillosa* (Hook.) Ching *Crepidomanes insigne*, *Christella appendiculata* (C.Presl) Holtt, *Christella dentate* (Forssk.) Brown., *Christella papilio* (Hope) Holtt ,*Coniogramme affinis* Wall. ex Heiron, *Coniogramme fraxinea* (D.Don) Fee ex Diels, *Coniogramme serrulata* (Bl.) Fee *Coniogramme pubescens* Heiron., *Cyclogramma auriculata*, (J.Smith) Ching, *Cyrtomium caryotideum* (Wall.ex Hook.et Grev.) C.Presl., *Cystopteris dickieana* Sim., *Deparia petersenii* (Kunze) M. Kato, *Diplazium longifolium* T.Moore, *Diplazium maximum*

(D.Don) C.Chr, *Drynaria mollis* Bedd, *Dryopteris barbigera* (T. Moore ex Hook.) Kuntze, *Dryopteris blanfordii* (Hope) C.Chr, *Dryopteris caroli-hopei* Fraser- Jenk., *Dryopteris chrysocoma* (H.Christ) C.Chr, *Dryopteris cochelata* (Ham.ex D.Don) C.Chr, *Dryopteris juxtaposita*H. Christ, *Dryopteris nigropalaceae* (Fraser- Jenk.) Fraser- Jenk., *Dryopteris ramosa* (Hope) C.Chr, *Dryopteris lepidopoda* Hayata, *Dryopteris redactopinnata.*, *Dryopteris sparsa* (Ham. ex D.Don) Kuntze, *Dryopteris stewartii* Fraser- Jenk, *Dryopteris wallichiana* (Spreng.) Hyland, *Dryopteris xathomelas* (H. Christ) C.Chr, *Glaphyopteridopsis erubescens* (Wall.ex Hook.) Ching., *Hypodematum crenatum*(Forssk) Kuhn ssp. *crenatum*, *Hypolepis polypodioides* (Bl.) Hook, *Lepisorus pseudonudus* Ching, *Lepisorus sesquipedalis* (J.Smith) Fraser- Jenk., *Lepisorus ussuriensis* (Regel et Maack) Ching, *Lygodium japonicum* (Thunb.) Sw, *Matteuccia orientalis* (Hook.) Tév., *Microsorium membranecum* (D.Don) Ching, *Nephrolepis auriculata* (L.) Trimen, *Onychium cryptogrammoides* H.Christ, *Onychium siliculosum* (Desv.) C. Chr, *Ophioglossum reticulatum* L, *Osmunda claytonia* L., *Osmunda regalis* L, *Pellaea hastate* (Thunb.) Prantl., *Pellaea nitidula* (Wall. ex Hook.) Baker, *Pichisermollia ebenipes* (Hook.) Pic.Serm., *Pichisermollia malacodon* (Hook.) Pic.Serm., *Selliguea oxyloba*, (Wall. et Kuntze) Pic. Serm., *Polypodioides amonea* (Wall. ex Mett.) Ching, *Polypodioides lachnopus* (Wall. ex Hook.) Ching, *Polypodioides, microrrhizoma* (C.B.Clarke ex Baker) Ching, *Polypodioides subamonea* (C.B.Clarke) Ching, *Polystichum discretum* (D.Don) J. Smith, *Polystichum lentum* (D.Don) T. Moore, *Polystichum longipaleatum*H. Christ, *Polystichum mehrae* Fraser Jenk. et Khullar, *Polystichum obliquum* (D.Don) Moore, *Polystichum piceo-paleaceum* Tagawa, *Polystichum squarrosus* (D.Don) Fee, *Polystichum stimulans* (Kunze ex Mett.) Bedd., *Polystichum thomsonii* (Hook f.) Bedd., *Polystichum neolobatum* Nakai., *Polystichum nepalense* (Spreng.) C.Chr, *Polystichum yunnanense* H. Christ, *Pronephrium nudatum* (Roxb.)Holtt, *Pronephrium penangianum* (Hook.) Holtt, *Pseudocyclosorus canus* (Baker) Holtt, *Pseudophegopteris levingei* (C.B.Clarke) Ching, *Pseudophegopteris pyrrhorhacis* (Kunze) Ching subsp. *pyrrhorhacis.*, *Pseudophegopteris pyrrhorhacis subsp distans* Fraser- Jenk., *Pteridium revolutum* (Bl.) Nakai, *Pteris aspercularis* Wall. ex J.

Agardh, *Pteris biaurita* L., *Pteris cretica* L., *Pteris dactylina* Hook., *Pteris excelsa* Gaud., *Pteris multifida* Poiret, *Pteris stenophylla* Wall. ex Hook, *Pteris vittata* L., *Pyrrosia costata* (Wall. ex C.Presl) Tagawa et K.Iwats., *Pyrrosia flocculosa* (D.Don) Ching, *Pyrrosia lanceolata* (L.) Farwell, *Pyrrosia porosa* (C. Presl.) Hovenkamp., *Sphenomeris chinensis* (L.) Maxon, *Stenogramma mollisma* (Kunze) Fraser- Jenk., *Tectaria coadunata* (J. Smith) C.Chr, *Vittaria flexuosa* Fee, *Woodwardia ungiemmata* C. Presl., *Woodsia elongata* Hook.,

Classification based on inhabitation in the forest:

Vegetation within forest is affected by variation in the microclimate aspect and altitude (Pande et al., 1996). Ferns usually cannot tolerate the excessive sunlight. So, understory of forests including the forest floor plays an important role. The combination of densely shaded slopes, cool and moist microclimates produces conditions that are conducive for the growth of many fern species.

a. Fern species growing in exposed forest on hill slopes: The forest area with scanty vegetation gets exposed to sun light. This reduces relative humidity of air thereby raises rate of transpiration from tender leaves. These leaves have insufficient protection against cuticular water loss and as a result of which little or no ferns are found as understory of trees. Thus scanty rainfall results into decrease in moisture and humidity etc.

The fern species which thrive best in the sun exposed areas of forests are: *Adiantum capillus-veneris* L., *Anogramma reitchesii* Fraser-Jenk., *Onychium cryptogrammoides* H.Christ, *Onychium siliculosum* (Desv.) C. Chr, *Aleuritopteris anceps* (Blanford) Panigrahi, *Aleuritopteris rufa* (D. Don) Ching, *Pronephrium nudatum* (Roxb.) Holtt, *Pteris biaurita* L., *Pteris cretica* L., *Pteris dactylina* Hook., *Pteris excelsa* Gaud, *Hypodematium crenatum* (Forssk) Kuhn ssp. *Crenatum*, *Hypolepis polypodioides* (Bl.) Hook., *Pteridium revolutum* (Bl.) Nakai, *Polystichum discretum* (D.Don) J. Smith, *Polystichum mehrae* Fraser- Jenk. et Khullar, *Polystichum squarrosus* (D. Don) Fee, *Polystichum prescottianum* (found to occur on open, exposed, forest floor in dense patches) *Lygodium flexuosum* (L.) Sw., *Osmunda*

regalis L., *Sphenomeris chiensis* (L.) Maxon, *Tectaria coadunata* (J. Smith) C.Chr, *Woodwardia ungiemmata* C.Presl.

b. Fern species growing in shaded forest slopes:

The ever-flowing streams, deep shade and the cool climatic conditions, are most congenial and best suited for the luxuriant growth of a large variety of ferns. The shadow of the trees on forest floor reduces the incident solar radiation and lowers the temperatures of both the soil and the air. These impacts affect the diversity of plant communities and the associated ferns. Ferns growing in shade have thinner fronds, the fertile fronds are longer than sterile fronds, and their blades are arrowed and the broader sterile fronds spreading out around them. (<http://www.britannica>). The ferns species are mostly found in shaded forest thus represents rich fern flora in particular area and their composition differs as per the condition which are.

c. Fern species growing in moist and shaded forest slopes:

When the forests are very thick and the requisite amount of moisture is available for the ground growing fern species, such forest floor and forest margins represent the mesophytic conditions. The lofty forest trees provide shade and prevent rapid movements of air to a considerable extent. The fern flora is thus protected from direct sun or wind. The diurnal fluctuations in the climatic conditions are not as evident as in directly exposed places along the roadsides. Under these conditions, a large number of fern species grow. The fern species compositions in moist and shaded forest are: *Amplopterus prolifera* (Retz.) Copel, *Coniogramme intermedia* Hieron., *Pteris vittata* L., *Pteris cretica* L., *Dryopteris sparsa* (Ham. ex D.Don) Kuntze, *Asplenium dalhousiae* Hook., *Botrypus langinosus* (Wall. ex Hook. et Grev.) Holub., *Cyrtomium caryotideum* (Wall. ex Hook. et Grev.) C.Presl., *Athyrium schimperi* Moug. ex Fee', *Athyrium pectinatum* (Wall. ex Mett.) T. Moore, *Deparia boryana* (Willd.) M. Kato, *Diplazium esculentum* (Retz.) Sw, *Diplazium maximum* (D.Don) C.Chr, *Diplazium longifolium* T.Moore, *Dryopteris lepidopoda* Hayata, *Polystichum neolobatum* Nakai., *Cyclogramma auriculata* (J.Smith) Ching, *Onychium siliculosum* (Desv.) C. Chr.

Those species found in partially shaded places are *Microsorium membranecum* (D.Don) Ching, *Pteris biaurita* L., *Pteris*

aspercularis Wall. ex J. Agardh, *Onychium cryptogrammoides* H.Christ, *Christella arida* (D.Don) Holtt., *Christella dentata* (Forssk.) Brown, *Glaphyopteridopsis erubescens* (Wall.ex Hook.) Ching, *Pronephrium nudatum* (Roxb.) Holtt., *Pronephrium penangianum* (Hook.) Holtt., *Pseudocyclosorus canus* (Hook.) Holtt., *Pseudocyclosorus tylodes* (Kunze) Ching, *Hypodematium crenatum* (Forssk) Kuhn ssp. *crenatum*, *Dryopteris cochelata* (Ham.ex D.Don) C.Chr, *Dryopteris juxtaposita* H.Christ, , *Dryopteris ramosa* (Hope) C.Chr, *Dryopteris lepidopoda* Hayata, *Dryopteris sparsa* (Ham. ex D.Don) Kuntze, *Polystichum discretum* (D.Don) J. Smith, *Polystichum lentum* (D.Don) T. Moore, *Polystichum squarrosus* (D.Don) Fee, *Polystichum stimulans* (Kunze ex Mett.) Bedd, *Tectaria coadunata* (J. Smith) C.Chr, *Woodwardia unigemmata* C.Presl.

d. Ferns species growing in moist and shaded forest slopes near the water streams:

These forests are mostly found in Mussoorie and Chakrata region where the forests have mostly closed canopy and besides streams providing continuous moisture and humidity as raw material for the ferns to flourish. In such forests 'terrestrial' species are occasionally found on the base of trunks or on emerged tree roots, and more often on fallen and/or rotten logs. Most commonly occurring species in such areas are: *Athyrium mackinnonirum* (Hope) C. Chr, *Athyrium atkinsonii* Bedd., *Athyrium foliosum* (Wall.) T. Moore ex Sim, *Coniogramme pubescens* Heiron., *Cyrtomium caryotideum* (Wall.ex Hook.et Grev.) C. Presl., *Cyclogramma auriculata* (J.Smith) Ching., *Glaphyopteridopsis erubescens*, (Wall.ex Hook.) Ching, *Pseudocyclosorus canus* (Baker) Holtt, *Pseudocyclosorus tylodes* (Kunze) Ching, *Dennstaedtia scabra* Wall.ex T. Moore, *Dryopteris ramosa* (Hope) C.Chr, *Pteris stenophylla* Wall.ex Hook., *Pronephrium penangianum* (Hook.) Holtt.

e. Ferns species growing in moist and shaded forest slopes along roadsides:

The forest which flourishes mostly during the rainy season retains water for some period. Thus the fern species in the area appear during rainy season or which could withstand some of the sun rays. The fern species growing in such areas are *Pteris dactylina* Hook, *Pteris biaurita* L., *Hypolepis polypodioides* (Bl.) Hook, *Athyrium pectinatum* (Wall.ex Mett.) T. Moore.,

Lygodium flexuosum(L.) Sw., *Lygodium japonicum* (Thunb.) Sw., *Adiantum lunulatum* Burm, *Asplenium dalhousiae* Hook., *Cheilanthes dalhousiae* Hook., *Dryopteris cochleata* (Ham.ex D.Don) C.Chr, *Hypodematium crenatum* (Forssk) Kuhn ssp. *crenatum*, *Onychium cryptogrammoides* H.Christ,, *Pteris vittata* L., *Pteris cretica* L., *Polystichum squarrosus*(D.Don) Fee, *Ophioglossum reticulatum* L., *Tectaria coadunata* (J. Smith) C.Chr.

f. Ferns species growing in interior of forest:

Forest interior habitat is a remnant natural environment, they are rich in vegetation with little disturbance. The common fern species are – *Christella papilio* (Hope) Holtt, *Christella parasitica* (L.) Leve, *Athyrium fimbriatum* T. Moore., *Athyrium schimperi* Moug.ex fee', *Dryopteris chrysocoma* (H.Christ) C.Chr, *Pteris excelsa* Gaud., *Christella dentata* (Forssk.) Brown., *Dryopteris caroli-hopei* Fraser- Jenk., *Polystichum discretum* (D.Don) J. Smith, *Psedophegopteris levengii* (C.B.Clarke) Ching., *Arthromeris wallichiana* (Spreng.) Ching.

g. Ferns species growing in fringes of forest:

Forest edges are also more exposed to blow down, noise pollution, motorized vehicles, vegetation clearing and urban development, thus species able to cope with change in condition are found in such habitat. The species commonly met are: *Athyrium pectinatum* (Wall.ex Mett.) T. Moore., *Athyrium setiferum* C.Chr, *Athyrium schimperi* Moug. ex fee', *Athyrium atkinsonii* Bedd. *Coniogramma pubescens* Heiron., *Dryopteris juxtaposita* H.Christ, *Hypolepis polypodioides* (Bl.) Hook, *Ophioglossum reticulatum*L.

Classification based on the type of soil:

The soil composition, profile does play an important role in distribution of the ferns. The soil characteristics also vary at short distances the variation may occur due to the presence of fresh litter on the floor of the forest make the soil humus rich thus forming it a fern rich areas whereas the exposed areas remain devoid of humus.

a. Fern species growing in humus rich soil:

The Chakrata region and some of areas of Mussoorie area falling in area which is mostly mountainous area the vegetation is affected by several factors of which altitude

aspect, slope, position on hill slope, soil depth are predominant.

Since mountainous regions of Chakrata and Mussoorie receive plenty of rainfall thus enriches the soil with the essential nutrient. Such fertile and nutrient rich soil supports the extensive growth of ferns in the area. The common fern species of these areas are:

Athyrium schimperi Moug.ex fee'(along the forest margin in damp), *Athyrium fimbriatum* T. Moore. (Dense forest), *Amelopteris prolifera* (Retz.) Copel., *Botrychium ternatum* (Thunb.) Sw., *Botrychium lanuginosum* (Wall.ex Hook. et Grev.) Holub., *Christella arida* (D.Don) Holtt., *Christella dentate* (Forssk.) Brown, *Cyclogramma auriculata* (J.Smith) Ching, *Coniogramma affinis* Wall.ex Heiron, *Deparia allantodiodes* (Bedd.) M. Kato, *Deparia boryana* (Willd.) M. Kato, *Dryopteris chrysocoma* (H.Christ) C.Chr, *Glaphyopteridopsis erubescens* (Wall.ex Hook.) Ching, *Ophioglossum reticulatum* L., *Osmunda claytonia* L., *Onychium cyrtogrammoides* H.Christ, *Polypodiodes amonea* (Wall. ex Mett.) Ching, *Polypodiodes lachnopus* (Wall. ex. Hook.) Ching, *Polypodiodes microrhizoma* (C.B.Clarke ex Baker), *Polystichum nepalensis* (Spreng.) C.Chr, *Polystichum neolobatum* Nakai., *Polystichum squarrosuum* (D.Don) Fee, *Pronephrium nudatum* (Roxb.) Holtt, *Pronephrium penangianum* (Hook.) Holtt, *Pteris aspercularis* Wall. ex J. Agardh.

b. Fern species growing in calcium rich soil: calcareous fens are wetlands that receive continuous groundwater discharge that is calcium enriched through contact with carbonate-containing bedrock or glacial deposits and is sufficient to maintain soil saturation. These fens are subtype of extremely rich fern, which are important because of their rarity, their distinctive water chemistry; The distribution of the ferns in calcium rich soil depends on the root system such as in shallow root system the top soil is freely drained and getting dry from time to time whereas those areas nearby streams get continuous drainage keeping it moist.

The Doon valley and the areas of Mussoorie are rich in calcium soil thus following fern species flourish well in these areas: *Christella papilio* (Hope) Holtt (moist

and shaded), *Glaphyopteridopsis erubescens* (Wall.ex Hook.) Ching (Along streamlet), *Pseudocyclosorus canus* (Baker) Holtt, *Pseudophegopteris pyrrhorhacis* (Kunze) Ching subsp. *pyrrhorhacis* (Found in damp, exposed sunny slopes along water), *Pseudophegopteris levingei* (C.B.Clarke) Ching., (Shaded and humus rich), *Lygodium flexuosum* (L.) Sw.

Classification based on special habitat:

Ferns are found in varied habitat but sometimes they are found in unusual habitat which could be further categorized as follows,

a. Fern species of ravines swamp and gorges: The ravine and gorges are popularly known as "fern centers". This is due to the fact that in contrast to the forest floor, forest borders, and open places, ravines are far more humid with low temperature. In such areas temperature fluctuation is very less. Thus fluctuations in temperature and humidity, prevailing in the exposed situations during the day with the change in weather conditions, are not marked in the ravines. Such climatic conditions of ravines provide the most congenial atmosphere for the hydrophytic ferns to flourish. The ferns with large fronds or those with delicate fronds inhabit such situations.

Wetlands, which are neither aquatic nor terrestrial, but are transitional zones supports its unique fern flora. Swamps lie in the palustrine system of wetland. These are marshy areas with typical habitats where water oozes out in perennial streams at constant level throughout the year. They support characteristic vegetation on account of specialized edaphic conditions, as influenced by free water accumulation. The vegetation and botanical value of swamps were first observed by Kanjilal (1901).

The Mothronwala swamp of study area is a well known as "Hot Spot" of biodiversity due to topographic and edaphic variations. The vegetation of Golatappar and Manu swamp of study area i.e. Doon valley were also studied by Deva (1974), Srivastava (1978) and Ghildiyal (1989).

The fern species of such areas include- *Ampelopteris prolifera* (Retz.) Copel., *Christella arida* (D.Don) Holtt., *Christella dentate* (Forssk.) Brown., *Coniogramma fraxinea* (D.Don) Fee ex Diels (moist habitats),

Cyclogramma auriculata (J.Smith) Ching, *Glaphyopteridopsis erubescens* (Wall.ex Hook.) Ching, *Dryopteris cochleata* (Ham.ex D.Don) C.Chr., *Dryopteris sparsa* (Ham.ex.D.Don) Kuntze, *Pseudocyclosorus canus* (Baker) Holtt., *Pseudocyclosorus tylodes* (Kunze) Ching, *Pseudophegopteris levengii* (C.B.Clarke) Ching., *Pteris cretica* L., *Polystichum lentum* (D.Don) T. Moore, *Polystichum luctuosum* (Kuntze) T. Moore, *Polystichum obliquum* (D.Don) T. Moore, *Tectaria coadunata* (J. Smith) C.Chr., *Woodwardia ungiemmata* C.Presl. (Shady ravines along water side).

The other large sized ravine ferns, which are confined to certain specific localities, are *Microlepia speluncae* (L.) T. Moore, *Diplazium esculentum* (Retz.) Sw. whereas *Anogramma reichsteinii* Fraser-Jenk. found in densely shaded gorges.

b. Fern species growing in burnt areas: The ferns are not common in the forest areas which are burnt either due to forest fire or human activity. But some of the fern species are found in Pine forest which is prone to the forest fire but the rhizomes of fern of such areas are mostly subterranean, hence the fire events generally have little effect and plants re-grow rapidly. Fern species of burnt areas are *Pteridium revolutum* (Bl.) Nakai., *Polystichum squarrosus* (D.Don) Fee, *Dryopteris sp.*

c. Climbing ferns: Certain fern species bear widely creeping and underground rhizomes which helps them to cover a vast area individually. For securing optimum light conditions, the plants grow up the adjacent shrubs and branches of neighboring trees by the help of its stiff, wiry, and twining rachises. The lower pinnae of such ferns are larger and always sterile, whereas the upper smaller one is fertile. The climbing ferns of the area are- *Amelopteris prolifera* (Retz.) Copel., *Lygodium flexosum* (L.) Sw. and *Lygodium japonicum* (Thunb.) Sw.

d. Walking ferns: The ferns where rooting occurs by apical buds which may occur on either rachis or pinnae and due to its proliferous nature are called as Walking ferns and thus it covers vast areas. Such ferns of the area are *Adiantum lunulatum* Burm., *Adiantum incisum* Forssk., *Amelopteris prolifera* (Retz.) Copel., *Asplenium yunnanense*

Franch., *Athyrium strigillosum* (T. Moore ex E. J. Lowe) T. Moore ex Salom, *Polystichum lentum* (D.Don) T. Moore, *Polystichum obliquum* (D. Don) T. Moore, *Woodwardia ungiemmata* C.Presl.

e. Ferns met with grassy areas:

Certain species of ferns grow mixed with the grasses/sedges. Such individuals are small sized and rather inconspicuous. These are usually over-shadowed by grass. It flourishes well during the rainy season every year. *O. reticulatum* L. also in grasslands in sunny or shady situations. These are some fern species usually over- shadowed by grass: *Lygodium flexosum* (L.) Sw., *Amelopteris prolifera* (Retz.) Copel., *Onychium cryptogrammoides* H.Christ, *Athyrium pectinatum* (Wall. ex Mett.) T. Moore., *Adiantum lunulatum* Burm.

Evergreen ferns:

The ferns that are perennial and found in every season are called evergreen. As they are found in every season so to avoid high temperature during summers some internal adaptation are present in plant such as the leaflets are covered in a thick waxy epidermis with strong water-repellent properties. Evergreen ferns are not really ever-green. They hold their leaves well during the winter, but once the mild weather comes and the new young fronds start to push up from the middle, the over-wintered leaves begin to look very tatty. The evergreen ferns present in the study are as follows:

a. Evergreen at low-altitude: They will grow in dry shade under trees, and moisture rich soil helps them to survive in sun. Fronds of these ferns are tough and not too lacy. The fern species thriving at low altitude include; *Adiantum edgeworthii* Hook., *Adiantum incisum* Forssk., *Amelopteris prolifera* (Retz.) Copel., *Asplenium dalhousiae* Hook., *Diplazium esculentum* (Retz.) Sw., *Diplazium maximum* (D.Don) C.Chr., *Christella dentata* (Forssk.) Brown., *Tectaria coadunata* (J. Smith) C.Chr., *Woodwardia ungiemmata* C.Presl .

b. Evergreen at high-altitude: Some of the fern species thriving perennially at high altitude in spite of cold weather which include: *Athyrium schimperi* Mougl. ex fee, *Cyrtomium caryotideum* (Wall.ex Hook.et Grev.) C.Presl., *Dryopteris nigropalaceae* (Fraser- Jenk.) Fraser- Jenk., *Dryopteris barbigera* (T. Moore ex Hook.) Kuntze,

Dryopteris chrysocoma (H.Christ) C.Chr,
Polystichum squarrosus (D.Don) Fee,
Pteridium revolutum (Bl.) Nakai.

Epiphytic ferns:

The ferns found symbiotically living on other plants for obtaining nutrients and moisture are called epiphytic ferns. They are found growing on wet branches and trunks of trees and other plants attached via rhizomes and adventitious roots. Some even grow on the surface of living leaves (Richards 1996). The epiphyte's roots grow around the host (phorophyte) stem or branches, give anchorage and contact with the stem and branch. Kress (1986) estimated that about 29 per cent of fern make the epiphytic fern vegetation of the world. They play a crucial role as they provide the chief and in sometimes the only habitat for a rich fauna and flora which play an important role in the forest ecosystem (Ursula et al. 1995). Epiphytic ferns collect masses of humus, which provide nesting sites for many species of arboreal ants and other invertebrates. Dissolved chemicals in the rainfall water are trapped by the roots as water runs down the bark of the host.

Ferns and fern allies inhabiting the region may be classified into the different categories depending upon their growth habits and various habitats they occupy, receive a high rainfall, the epiphytic vegetation is very high which are as follows-

1. Classification based on altitudinal zonation:

- Species found at low altitude i.e upto 1200m
- Species found at medium altitude i.e 1200-2500m
- Species found at medium altitude i.e 2500-2950m

2. Classification based on light requirement:

- Epiphytic fern species growing in dense shade
- Epiphytic fern species growing in exposed conditions

3. Classification based on occurrence on host parts:

- Epiphytic species on moss laden branches
- Epiphytic species on tree trunks
- Epiphytic species at upper canopy.

Classification based on altitudinal zonation:

The change in altitude affects to great extent in distribution of epiphytic fern species as there occurs change in temperature, rainfall, humidity and moisture content and fern respond to change in microclimate as elevation increased; the percent epiphyte cover and the percent soil moisture increased but water temperature, conductivity, and dissolved oxygen decreased

a. Species found at low altitude i.e upto 1200m: fern found are: *Lepisorus intermedus* Ching, *Lepisorus nudus* (Hook.) Ching, *Microsorium membranecum* (D.Don) Ching, *Pyrrosia flocculosa* (D.Don) Ching.

b. Species found at medium altitude i.e 1200-2500m: *Cedrus deodara* and some other gymnosperms make dense vegetation in this altitudinal range and the epiphytic species flourish well on the host plants. The altitude shows marked variation in the epiphytic fern flora.

Common species are: *Araoistegia pseudocystopteris* (Kunze) Copel., *Arthromeris wallichiana* (Spreng.) Ching, *Asplenium enisforme* Wall.ex Hook.et Grev, *Asplenium indicum* Sledge, *Asplenium unilaterale* Lamk., *Asplenium yunnanense* Franch., *Drynaria propinqua* (Wall. ex Mett.) J. Smith, *Drynaria mollis* Bedd., *Lepisorus loriformis* (Wall. ex. Mett.) Ching, *Lepisorus mehrae* Fraser-Jenk., *Lepisorus nudus* (Hook.) Ching, *Lepisorus oligolepidus* (Baker) Ching, *Lepisorus pseudonudus* Ching, *Lepisorus sesquipedalis* (J.Smith) Fraser-Jenk., *Lepisorus ussuriensis* (Regel et Maack) Ching, *Loxogramma involuta* (D.Don) C.Presl., *Microsorium membranecum* (D.Don) Ching, *Oleandra wallichii* (Hook.) C. Presl., *Pichisermollia ebenipes* (Hook.) Pic.Serm., *Pichisermollia malacodon* (Hook.) Pic.Serm., *Phymatopteris oxyloba*, (Wall. et Kuntze) Pic. Serm., *Pichisermollia stewartii* (Bedd.), *Pichisermollia quasidivarticata* (Hayata), *Selliguea oxyloba* (Wall. ex Kunze), *Polypodiastrium argutum* (Wall. ex. Hook.) Ching, *Polypodiodes amonea* (Wall. ex Mett.) Ching, *Polypodiodes lachnopus* (Wall. ex. Hook.) Ching, *Polypodiodes microrrhizoma* (C. B. Clarke ex Baker) Ching, *Polypodiodes subamonea* (C. B. Clarke) Ching

c. Species found at medium altitude i.e 2500-2950m: The epiphytes

flourishes well during rainy seasons as they receive good amount of rainfall, optimum temperature and high humidity. These factors help them to proliferate in large area. The epiphytic vegetation decreases considerably with the altitude. *Quercus semicarpifolia* is a good host for some ferns at higher elevations, in Uttarakhand (Kumar, 2008).

The fern found in this altitude are- *Araoistegia beddomei* (Hope) Ching, *Arthromeris wallichiana* (Spreng.) Ching, *Asplenium enisforme* Wall. ex Hook. et Grev., *Asplenium indicum* Sledge, *Asplenium unilaterale* Lamk., *Drynaria mollis* Bedd., *Matteuccia orientalis* (Hook.) Tuv., *Microsorium membranecum* (D. Don) Ching, *Lepisorus mehrae* Fraser-Jenk., *Lepisorus pseudonudus* Ching, *Lepisorus sesquipedalis* (J. Smith) Fraser-Jenk., *Nephrolepis auriculata* (L.) Trimen, *Pyrrosia costata* (Wall. ex C. Presl) Tagawa et K. Iwats., *Pyrrosia flocculosa* (D. Don) Ching, *Pyrrosia lanceolata* (L.) Farwell, *Pichisermollia ebenipes* (Hook.), *Pichisermollia malacodon* (Hook.), *Selliguea oxyloba* (Wall. ex Kunze), *Polypodiodes amonea* (Wall. ex Mett.) Ching, *Polypodiodes lachnopus* (Wall. ex. Hook.) Ching, *Polypodiodes microrrhizoma* (C.B. Clarke ex Baker) Ching, *Selliguea oxyloba* (Wall. ex Kunze), *Woodsia elongate* Hook., *Vittaria flexuosa* Fee.

Classifications based on light requirement:

The favorable sites for epiphytes offer a nice balance between sun and shade, drought and drawing and provide shelter from wind and nearly all direct solar radiation. Since the epiphytic fern trail on the host plant for optimum light and nutrient so on this basis they can be further categorized into-

a. Epiphytic fern species growing in dense shade: These ferns found in moist and shady places have fleshy rhizomes covered by delicate scales which avoid total desiccation of the whole plant during the dry season by drooping of fronds, thus reducing transpiration.

The species found in dense shade are: *Araoistegia beddomei* (Hope) Ching, *Asplenium enisforme* Wall. ex Hook. et Grev., *Asplenium lacinatedum* D. Don, *Arthromeris wallichiana* (Spreng.) Ching, *Leucostegia immerse* Wall. ex C. Presl., *Microsorium membranecum* (D. Don) Ching, *Nephrolepis*

auriculata, (L.) Trimen, *Pichisermollia ebenipes* (Hook.) Fraser-Jenk., *Selliguea oxyloba* (Wall. ex Kunze), *Polypodiastrium argutum* (Wall. ex. Hook.) Ching, *Polypodiodes amonea* (Wall. ex Mett.) Ching, *Polypodiodes lachnopus* (Wall. ex. Hook.) Ching, *Polypodiodes microrrhizoma* (C.B. Clarke ex Baker) Ching, *Polypodiodes subamonea* (C.B. Clarke) Ching, *Pyrrosia lanceolata* (L.) Farwell, *Oleandra wallichii* (Hook.) C. Presl. In some moist and shady places, such as near waterfalls or streamlets, there are small or medium-sized epiphytes on shrubs or small trees such as *Loxogramme involuta* (D. Don) C. Presl, *Crepidomanes insigne* (v.d. Bosch) Fu.

b. Epiphytic fern species growing in exposed conditions-

The ferns species are found enormously in the areas exposed to high sun-light and high temperature. These types of epiphytic species are well adapted for open and exposed conditions due to their thick leathery, hairy and sterile winter fronds and presence of fleshy leaves. In these species spongy mass of roots and debris store plenty of water. The common species of such habitat are *Drynaria propinqua* (Wall. ex Mett.) J. Smith, *Drynaria mollis* Bedd., *Lepisorus nudus* (Hook.) Ching, *Lepisorus oligolepidus* (Baker) Ching, *Lepisorus pseudonudus* Ching, *Lepisorus sesquipedalis* (J. Smith) Fraser-Jenk., *Lepisorus loriformis* (Wall. ex. Mett.) Ching, *Oleandra wallichii* (Hook.) C. Presl., *Pyrrosia costata* (Wall. ex C. Presl) Tagawa et K. Iwats., *Pyrrosia porosa* (C. Presl.) Hovenkamp., *Gymnopteris vestita* (Wall. ex T. Moore) Underw., *Vittaria flexuosa* Fee.

Classification based on occurrence of host parts:

The majority of epiphytes grow above the ground where relatively strong illumination compensates for lack of soil but some may be found growing on twigs and tree bases where the light is more favorable than on the ground as per the requirement of the plant. So on the basis of their occurrence on the host they can be further classified into-

a. Epiphytic species on moss laden Branches/Tree trunk: Epiphytic ferns collect masses of humus, from the mosses found on the branches. The trunk of trees bear the highest number the fern clumps may be due to the fact that tree trunk has higher water flow on it than on the branches.

The fern species that occur on the moss laden branches of host trees such as *Magnifera*, *Delonix*, *Emblia*, *Bauhinia* etc it includes *Arthromeris wallichiana* (Spreng.) Ching, *Araoistegia beddomei* (Hope) Ching (Tree trunk), *Asplenium enisforme* Wall.ex Hook.et Grev, *Araoistegia pseudocystopteris* (Kunze) Copel., *Drynaria mollis* Bedd., *Lepisorus loriformis* (Wall. ex. Mett.) Ching, *Lepisorus nudus* (Hook.) Ching, *Loxogrammae involuta* (D.Don) C. Presl, *Oleandra wallichii* (Hook.) C.Presl, *Pichisermollia ebenipes* (Hook.) Fraser-Jenk., *Selliguea oxyloba* (Wall. ex Kunze) Fraser-Jenk., *Polypodiodes amonea* (Wall. ex Mett.) Ching, *Polypodiodes lachnopus* (Wall. ex. Hook.) Ching, *Polypodiodes microrhizoma* (C.B.Clarke ex Baker) Ching, *Pyrrosia costata* (Wall. ex C.Presl) Tagawa & K.Iwats, *Pyrrosia flocculosa* (D.Don) Ching, *Pyrrosia lanceolata* (L.) Farwell, *Vittaria flexuosa* Fee.

b. Epiphytic species on tree trunk:

such epiphytic species found on tree trunk are -*Arthromeris wallichiana* (Spreng.) Ching, *Drynaria propinqua* (Wall. ex Mett.) Smith, *Lepisorus nudus* (Hook.) Ching, *Leucostegia immersa* Wall. ex C. Presl, *Microsorium membranaceum* (D.Don) Ching, *Pichisermollia ebenipes* (Hook.) Fraser-Jenk., *Selliguea oxyloba* (Wall. ex Kunze) Fraser-Jenk., *Pichisermollia malacodon* (Hook.) Pic.Serm., *Polypodiodes amonea* (Wall. ex Mett.) Ching, *Polypodiodes lachnopus* (Wall.ex. Hook.) Ching, *Pyrrosia flocculosa* (D.Don) Ching, *Pyrrosia lanceolata* (L.) Farwell, *Vittaria flexuosa* Fee. Some terrestrial ferns like *Nephrolepis* sp. are growing as epiphytes on tree trunks. This is due to the high humidity of the area.

c. Epiphytic species at upper canopy: The epiphytic species that are found in maximum exposure of light are placed under this category are; *Arthromeris wallichiana* (Spreng.) Ching, *Araoistegia beddomei* (Hope) Ching (Tree trunk), *Asplenium enisforme* Wall.ex Hook.et Grev, *Araoistegia pseudocystopteris* (Kunze) Copel., *Asplenium unilaterale* Lamk., *Drynaria mollis* Bedd., *Leucostegia immersa* Wall.ex C. Presl, *Oleandra wallichii* (Hook.) C. Presl, *Pyrrosia* sp, *Pichisermollia ebenipes* (Hook.) Fraser-Jenk., *Vittaria flexuosa* Fee.

Lithophytic ferns:

A large number of fern and fern allies occupy rock crevices, boulders or road embankments in shady or sunny situations, and rocks in shady

- Species found at low altitude i.e upto 1200m
- Species found at medium altitude i.e 1200-2500m
- Species found at medium altitude i.e. 2500-2950m

2. Classification based on light requirement

- Ferns on exposed areas
- Lithophytic species occurring on moist, shaded and humus rich rocks
- Lithophytic species occurring on moist shaded and humus rich rock along the streams.

3. Classification based on type of substratum:

- Fern species on calcium rocks
- Ferns species on moss matted rocks.

4. Xerophytic ferns.

5. True rock ferns.

Classification based on altitudinal zonation:

a. Species found at low altitude i.e upto 1200m: The lithophytic species occurring at this altitude range are- *Adiantum incisum* Forssk., *Asplenium dalhousiae*, Hook., *Aleuritopteris anceps* (Blanford) Panigrahi, *Aleuritopteris bicolor* (Roxb.) Fraser- Jenk, *Aleuritopteris rufa* (D. Don) Ching, *Cystopteris fragilis* (L.) Bernh., *Hypodematum crenatum* (Forssk) Kuhn ssp. *crenatum*

b. Species found at medium altitude i.e 1200-2500m: The species include *Adiantum capillus-veneris* L, *Adiantum edgeworthii* Hook., *Adiantum incisum* Forssk., *Adiantum lunulatum* Burm., *Anogramma reichtenii* Fraser-Jenk, *Athyrium anisopterum* H.Christ., *Asplenium adiantum-nigrum* L, *Asplenium unilaterale* Lamk., *Asplenium tenuifolium* D.Don, *Asplenium trichomanes* L. subsp. *quadrivalens* D.E. Meyer, *Asplenium yunnanense* Franch., *Aleuritopteris anceps* (Blanford) Panigrahi, *Aleuritopteris bicolor* (Roxb.) Fraser- Jenk, *Aleuritopteris formosana* (Hayata) Tagawa, *Aleuritopteris leptolepis* (Fraser- Jenk.), *Aleuritopteris*

grisea (Blanf.) Panigrahi, *Aleuritopteris subvillosa* (Hook.) Ching., *Drynaria propinqua* (Wall. ex Mett.) Smith, *Gymnopteris vestita* (Wall. ex Moore) Underw., *Hypodematium crenatum* (Forssk) Kuhn ssp. *crenatum*, *Leucostegia immersa* Wall.ex C. Presl, *Polystichum stimulans* (Kunze ex Mett.) Bedd., *Polystichum lentum* (D.Don) T. Moore, *Polystichum thomsonii* (Hook f.) Bedd., *Polystichum obliquum* (D.Don) T. Moore, *Pellaea nitidula* (Wall. ex Hook.) Baker, *Sphenomeris chinensis* (L.) Maxon, *Oleandra wallichii* (Hook.) C.Presl, *Woodwardia biserrata* C.Presl.

Species found at medium altitude i.e 2500-2950m: *Adiantum capillus-veneris* L, *Adiantum edgeworthii* Hook., *Adiantum incisum* Forssk, *Adiantum venustum* D.Don, *Arthromeris wallichiana* (Spreng.) Ching, *Araoistegia beddomei* (Hope) Ching, *Athyrium anisopterum* H.Christ., *Asplenium adiantum-nigrum* L, *Asplenium unilaterale* Lamk., *Asplenium trichomanes* L. subsp.*quadrivalens* D.E. Meyer, *Athyrium micropterum* Fraser-Jenk., *Aleuritopteris anceps* (Blanford) Panigrahi, *Aleuritopteris bicolor* (Roxb.) Fraser-Jenk, *Aleuritopteris formosana* (Hayata) Tagawa, *Aleuritopteris leptolepis* (Fraser-Jenk.), *Aleuritopteris rufa* (D. Don) Ching, *Aleuritopteris subvillosa* (Hook.) Ching., *Cystopteris dickieana* Sim, *Hypodematium crenatum* (Forssk) Kuhn ssp. *crenatum*, *Hypolepis polypodiodes* (Bl.) Hook., *Leucostegia immersa* Wall.ex C. Presl, *Polystichum stimulans* (Kunze ex Mett.) Bedd., *Polystichum lentum* (D.Don) T. Moore, *Polystichum obliquum* (D.Don) T. Moore, *Pellaea nitidula* (Wall.ex Hook.) Baker, *Matteuccia orientalis* (Hook.)Tev, *Polystichum mehrae* Fraser-Jenk.et Khullar, *Polystichum yunnanense* H. Christ, *Tectaria coadunata*(Smith) C.Chr, *Woodsia elongata* Hook., *Woodwardia biserrata* C. Presl

Classification based on light requirement:

a. Ferns found in exposed areas:

Some common species of this habitat are *Asplenium trichomanes* L. subsp.*quadrivalens* D.E. Meyer, *Gymnopteris vestita* (Wall. ex T. Moore), *Dryopteris chrysocoma* (H.Christ) C.Chr, *Dryopteris cochleata* (Ham.ex D.Don) C.Chr, *Hypolepis polypodiodes* (Bl.) Hook., *Oleandra wallichii* (Hook.) C.Presl, *Pteris vittata* L., *Pteris cretica* L., *Polystichum stimulans* (Kunze ex Mett.) Bedd, *Pyrrosia*

costata (Wall. ex C.Presl) Tagawa & K.Iwats, *Pyrrosia porosa* (C. Presl.) Hovenkamp., *Polystichum squarrosus* (D.Don) Fee, *Tectaria coadunata* (Smith) C.Chr, *Woodsia elongata* Hook.

b. Lithophytic species occurring on moist shaded and humus rich rocks:

These groups of plants remain firmly attached on the moist and shaded rocks with the help of their creeping rhizomes. These are *Adiantum capillus-veneris* L, *Adiantum edgeworthii* Hook., *Adiantum incisum* Forssk., *Arthromeris wallichiana* (Spreng.) Ching, *Asplenium enisforme* Wall. ex Hook.et Grev, *Araoistegia pseudocystopteris* (Kunze) Copel., *Asplenium unilaterale* Lamk., *Asplenium lacinatedum* D.Don, *Athyrium anisopterum* H.Christ., *Athyrium falcatum* Bedd., *Crepidomanes insigne*(v.d. Bosch) Fu., *Cystopteris fragilis*(L.) Bernh, *Cystopteris dickienia* Sim, *Leucostegia immersa* Wall.ex C. Presl., *Microsorium membranecum* (D.Don) Ching, *Oleandra wallichii* (Hook.) C. Presl.

c. Lithophytic species occurring on moist shaded and humus rich rock along the streams:

In some moist spots where sun-light penetrate to the forest floor, along streamlet banks, *Adiantum philippense* was observed in clumps on moist or humus-rich rocks.

Lithophytes usually occur in high humidity areas such as along stream banks or on muddy rocks in streamlets. Many rocks and boulders near waterfalls have thick velvety covering of liverworts and mosses which serve as a sponge for water absorption and which provide an excellent substratum for various ferns and fern-allies. The fern species found in such areas are *Adiantum lunulatum* Burm., *Araoistegia pseudocystopteris* (Kunze) Copel, *Asplenium capilles*, *Asplenium unilaterale* Lamk., *Polystichum stimulans* (Kunze ex Mett.) Bedd., *Polystichum lentum* (D.Don) T. Moore, *Woodsia elongata* Hook., *Woodwardia ungiemmata* C. Presl

Classification based on type of substratum:

Lithophytic rocks are also found in diverse habitat, apart from moist and humid rocks they are found to occur on special habitat which are;

a. Fern species on calcium rocks:

The common species found on the calcium rocks are *Adiantum edgeworthii* Hook.,

Adiantum incisum Forssk, *Asplenium ceterach* L., *Aleuritopteris bicolor* (Roxb.) Fraser- Jenk, *Aleuritopteris leptolepis* (Fraser- Jenk.), *Aleuritopteris rufa* (D. Don) Ching, *Drynaria mollis* Bedd., *Pteris cretica* L, *Pteris vittata* L, *Polystichum obliquum* (D.Don) T. Moore, *Pyrrosia costata*. (Wall. ex C.Presl) Tagawa et K.Iwats.

b. Ferns species on moss matted

rocks: The common species of these areas are- *Araoistegia pseudocystopteris* (Kunze) Copel *Araoistegia beddomei* (Hope) Ching, *Leucostegia immersa* Wall.ex C. Presl, *Anogramma reichtenii* Fraser-Jenk, *Polystichum thomsonii* (Hook f.) Bedd., *Polypodiumdiastrium argutum* (Wall. ex. Hook.) Ching, *Microsorium membranecum* (D.Don) Ching.

Xerophytic ferns:

The water holding capacity of rocky soils along the roadside and bridle paths is very poor. Ferns of xerophytic condition are *Asplenium lacinatum* D.Don, *Asplenium trichomanes* L. subsp. *quadrivalens* D.E. Meyer, *Aleuritopteris anceps* (Blanford) Panigrahi, *Hypodematium crenatum* (Forssk) Kuhn ssp. *crenatum*, *Hypolepis polypodiodes* (Bl.) Hook, *Pteris cretica* L., *Woodsia elongata* Hook, *Polystichum stimulans* (Kunze ex Mett.) Bedd, *Oleandra wallichii* (Hook.) C. Presl., *Pyrrosia porosa* (C. Presl.) Hovenkamp., *Gymnopteris vestita* (Wall. ex T. Moore), *Polystichum mehrae* Fraser- Jenk. & Khullar, *Pyrrosia costata* (Wall. ex C.Presl.) Tagawa & K.Iwats.

True rock ferns:

Many rocks and boulders in ravines and near water falls between 700 –1000m altitude have thick velvety covering of liverworts and mosses which serve as a sponge for water absorption and which provide an excellent substratum for various ferns and fern-allies. The polypodiaceous fern *Microsorium membranaceum* (D. Don) Ching with its soft membraceous fronds is seen growing on rock boulders in sunny situations during rainy months (July –September) every year.

Another prominent fern belonging to this category is *Hypodematium crenatum* (Forssk.) Kuhn. Its dorsiventral and creeping rhizome densely covered over by large golden brown scales penetrate the fissures in the bare rocks. This is a true rock fern species

and grows under extremely xerophytic conditions.

Amongst the small sized ferns, which grows in the crevices of dripping rocks near waterfalls or in the ravines include *Adiantum capillus-veneris* L. and *Asplenium cheilosorum* Kunze.ex. Mett. Both of these flourish well in protected places.

Other small sized ferns, which colonize in moist shaded rocks between 900-12000m altitude are *Sphenomeris chinensis* (L.) Maxon, and *Leucostegia immersa* (Wall. ex Hook.) C.Presl. The first are confined to ravines only, where as the last one has an altitude to grow in the open situation near falls or caves. It may also grow along roadsides forming large populations and the pale yellow fronds can be seen drooping from the dripping rocks at the road turning.

Hydrophytic Ferns:

Marsilea minuta L. and *Azolla pinnata* R. Br. are the water ferns in the area, which grows luxuriantly in the local lake, near the town. The individuals are rooted in the mud below their long petiolated leaves (with four leaflets) float on the surface of water to secure favorable light conditions for photosynthetic purposes. Quite often leaves form a thick mat on the surface of lake water because of extensive, widely creeping and spreading nature of the rhizomes of the fern in all directions. The sporocarps generally appear late in the rainy season when water recedes. The individuals that grow wholly in water are long petiolated where as those growing on the edges or banks of the lake are quite interesting to see this water fern at such an altitude (800m).

Acknowledgements

The authors are grateful to Dr. Paramjit Singh, Director, Botanical Survey of India, Kolkata, for facilities and encouragement.

References

1. Atkinson, E.T.(1882) The Himalayan Districts of North-Western Provinces of India(forming vol. X of the Gazetteer, N. W. P., Allahabad), Reprinted in 1973 Cosmo Publication New Delhi under the name The Himalayan Gazetteer,1: 672-923.
2. Awasthi, D.K. & Pande, P.C. (1985) A note on phytogeographical distribution of Ferns and Fern-Allies of Almora (West. Himal.)J. Bomb. Nat. Hist. Soc., 81: 739-741.

3. Awasthi, D.K. & Sharma, M.P. (1980) Ecological and Phytogeographical observation on the Ferns and Fern-Allies of Nagpur Block (Chamoli Garhwal), Western Himalayas Proc. Indian Acad. Sci., 89: 307-312.
4. Awasthi, D.K. and Sharma, M.P. (1980) Ecological and phytogeographical observations on the fern and fern-allies of Nagapur block (Chamoli Garhwal), Western Himalayas Proc. Indian Acad. Sci. (Pl. Sci.) 89: 307-313.
5. Beddome, R.H. (1883) A Handbook to the Ferns of British India, Ceylon and Malaya Peninsula, Supplement. Thacker Spink & Co., Calcutta.
6. Beddome, R.H. (1892) A Handbook to the Ferns of British India, Ceylon and Malaya Peninsula. Thacker Spink & Co., Calcutta.
7. Beddome, R.H. (1965-70) The Ferns of British India. Gantz Brothers Madras, Reprint-Oxford and IBH Publication Co., New Delhi, 1976.
8. Bir, S.S. (1985) Ecological classification and distribution of polypodiaceous ferns of the Himalayas Appendix-I in Aspects of Plant Sciences VIII eds C.K. Satija & S.S.S. Bir Today & Tomorrows Printers and Publishers New Delhi pp. 104-110.
9. Bir, S.S. (1987b) Pteridophytic flora of India: Rare and Endangered elements and their conservation Indian Fern J., 4: 95-101.
10. Bir, S.S., Satija, C.K., Goyal, P. & Vasudeva, S.M. (1979-1980) Further studies on the distribution and taxonomy of *Cystopteris fragilis* (Linn.) Bernh. from the Western Himalayas Phytia, 2&3: 62-66.
11. Bir, S.S. & Vasudeva, S.M. (1972), Ecological & Phytogeographical observation on the Pteridophytic flora of Pachmarhi Hills (Central India). J. Indian Bot. Soc., 15: 297-304.
12. Chowdhury, N. (1959). Observation on the structure and ecology of a xerophytic *Selaginella* from India *S. bryopteris* L. Baker Jap. Jour. Bot. Tokyo 17: 101-119.
13. Dixit, R.D. and Kumar, R. (2002). Pteridophytes of Uttaranchal (A Checklist). Bishen Singh Mahendra Pal Singh, Dehra Dun (India).
14. Fraser-Jenkins, C.R. (1997b) New Species Syndrome in Indian Pteridology and the Ferns of Nepal. International Book Distribution, Dehra Dun (India).
15. Ghildiyal, J.C. and Srivastava, M.M. (1989) The vegetation of Manu swamp: A Tropical fresh water swamp forest. Indian Forester, 15(a):183-191.
16. Hietz, P., and O, Briones. (1998) Correlation between water relations and within-canopy distribution of epiphytic ferns in a Mexican cloud forest. *Oecologia* 114:305-316.
17. Kanjilal, U.N. (1901) Swamp forest in Dehradun, N.W. Province. Indian Forester, 27:228-230.
18. Khullar, S.P. (1994) An illustrated Fern Flora of West Himalaya, Vol I. International Book distributors, Dehra Dun (India).
19. Khullar, S.P. (2000) An illustrated Fern Flora of West Himalaya, Vol II. International Book distributors, Dehra Dun (India).
20. Kramer, K.U. and Green, P.S. Assisted by E. Gotz (1990) Pteridophytes and Gymnosperms Vol I: I-XIII; 1-404. In the families and Genera of Vascular Plants (eds. Kubizil, K.) Springer-Verlag, Berlin, Heidelberg, New York, London, Tokyo, Hong-Kong, Barcelona.
21. Kress, W.J. (1986) The systematic distribution of vascular epiphytes: An update *Selbyana*. 9:2-22.
22. Korner, C. (2000) Why are there global gradients in species richness? Mountains might hold the answer. *Trends in Ecology and Evolution* 15:513-514.
23. Korner, C. (2007) The use of 'altitude' in ecological research. *Trends in Ecology and Evolution* 22:569-57.
24. Kumar, Muktesh, Remesh, M. and Sequeira Stephen, (1998b) Diversity, Systematics, Distribution and Taxonomy of Epiphytic pteridophytes of Kerala Part of Western Ghats, South India, Indian Fern J. 15:106-130.
25. MacArthur (1972) Geographical Ecology New: Harper & Row.
26. Maheswari, J.K. (1982) Some thoughts on the endangered flora of the Himalayas in the vegetational wealth of the Himalayas (Eds.) Paliwala, G.S., Puja Publications, New Delhi. Pp.256-268.
27. Joshi, Pragya and Pande, P.C. (2005) Ecology of the ferns in Context to Chamoli & Rudrapur districts (Garhwal: North-West Himalaya). In National Seminar on Current Perspectives in Environment Health concerns. Sponsored by UGC & ICMR, organised by Department of Botany & Zoology, DAV, P.G. College D. Dun, India, Abs. Pp. 14.
28. Ursula, H., H. Peter and Sergio, G. (1995) Epiphyte vegetation and diversity and remnant trees after forest clearance in Southern Veracruz, Mexico. *Biological Conservation*, 75:103-111.

Source of support: Nil

Conflict of interest: None Declared