# CONSERVATION OF PTERIDOPHYTES TO MAINTAIN VITAL LINK BETWEEN LOWER AND HIGHER GROUP OF PLANTS

**Sumesh N. Dudani, M. D. Subhash Chandran and T. V. Ramachandra**

**Energy and Wetlands Research Group, Centre for Ecological Sciences,**

**Indian Institute of Science, Bangalore – 560 012**

**Email – sumesh@ces.iisc.ernet.in, mds@ces.iisc.ernet.in, cestvr@ces.iisc.ernet.in**

---

Pteridophyta (*pteron* = feather, *phyton* = plants) are the most primitive vascular plants and are also known as 'vascular cryptogams'. They are vascular, spore bearing plants and include ferns and fern-allies. They were the first vascular plants to grow on the surface of earth and began their life period from leafless and rootless individuals (with photosynthetic stem and rhizoids performing the function of roots) in the Silurian and Devonian periods. The pteridophytes are a paraphyletic group of seed plants and consist of four groups: Lycopods, *Equisetum*, Psilotaceae and Ferns (Qiu & Palmer, 1999). They played an important role in establishing the early land flora as they emerged shortly after the evolution of land plants and are much larger than bryophytes (Kenrick & Crane, 1997). They spread rapidly along the shores and river banks and due to the absence of any kind of disturbance in the new habitats along with having a simple genetic makeup, a very rapid evolution was stimulated and witnessed among these land invaders. With this rapid rate of evolution, by the approach of carboniferous period most of the forests of the earth's surface were dominated by members of pteridophytes mainly including large sized trees with secondary growth. However, with the upheavals in the evolutionary period majority of this arboreal vegetation including many tall trees representing several genera and species had perished and in the modern period form the major carboniferous coal reserves of the world. The pteridophytic ancestors of the present day vegetation of ferns and fern allies are the plants which evolved the seed habitat and passed on this characteristic to the present day vegetation and hence, the pteridophytes could be genuinely considered as the forefathers of the present day vegetation.

The word ‘cryptogams’ is formed from two Greek words namely ‘kruptos’ meaning **hidden** and ‘gamos’ meaning **wedded**. The cryptogams form the lower group of plants including all those plants which reproduce by the means of spores and do not produce seeds including algae, fungi, bryophytes and pteridophytes. The term spermatophyte is also derived from Greek words ‘spermatos’ meaning **seed** and ‘phyton’ meaning **plant** and it refers to the higher group of seed producing plants including Gymnosperms and Angiosperms. The lower cryptogams, i.e. algae, fungi and bryophytes do not possess a well developed conducting system whereas the spermatophytes or phanerogams possess a well developed and differentiated vascular system for conduction of water and nutrients in the plant body. The pteridophytes were the first group of cryptogams to be showing the presence of a well developed conducting system with xylem (mainly composed of tracheids) and phloem. Hence, they are regarded as ‘Vascular cryptogams’ which can be referred to an assemblage of seedless vascular plants which have successfully invaded the land and reproduce by the means of spores. As they show the evolution of vascular system and reflect the emergence of seed habitat in the plant, they are considered to be a vital link between the lower cryptogam group of plants and higher spermatophyte group of plants. Hence are placed between bryophytes and higher vascular plants i.e., gymnosperms and angiosperms in the hierarchical plant classification system. They are connected to the bryophytes as they show the ‘Heteromorphic life cycle’ with alternation of generations and they are also connected with the gymnosperms and angiosperms by showing the presence of vascular system for conduction.

Pteridophytes grow luxuriantly in moist tropical forests and temperate forests and their occurrence in different eco-geographically threatened regions from sea level to the highest mountains are of much interest (Dixit, 2000). Though they have been largely replaced by the spermatophytes in the modern day flora, they continue to occupy an important and crucial position in the evolutionary history of the plant kingdom. India has a rich and varied pteridophytic flora due to its diversified topography, variable climatic conditions and its geographical position with several migration-flows of species of different phytogeographical elements meeting in different parts of the Country. They occur in a variety of habitats like terrestrial (*Equisetum*, *Selaginella*), aquatic (*Azolla*, *Marsilea*), epiphytic (*Lepisorus*, *Drynaria*) and lithophytic (*Psilotum*, *Adiantum*).

**General account and Life-Cycle of Pteridophytes**

Pteridophytes form a major part of the flora next to the angiosperms in the species diversity rich region like India. Their life cycle shows alteration of generations with sporophyte being the dominant phase. The sporophyte of pteridophytes is generally differentiated into root, stem and leaves. The primary root is short lived and is usually replaced by adventitious roots. The stem is usually branched and the branches do not arise in the axil of the leaves. The leafy branch of the fern is called a 'frond' and the small leaflets that make up the whole frond are termed as 'pinnae'. The leaves may be simple (*Equisetum*), simple and sessile (*Selaginella, Lycopodium*) or large and pinnately compound (*Dryopteris, Adiantum*). The vascular system consists of xylem (composed of tracheids, true fibres and vessels absent) and phloem (consisting of only sieve tubes). They have an affinity for the sheltered places under the forest canopy along creeks and streams and other sources of permanent moisture.

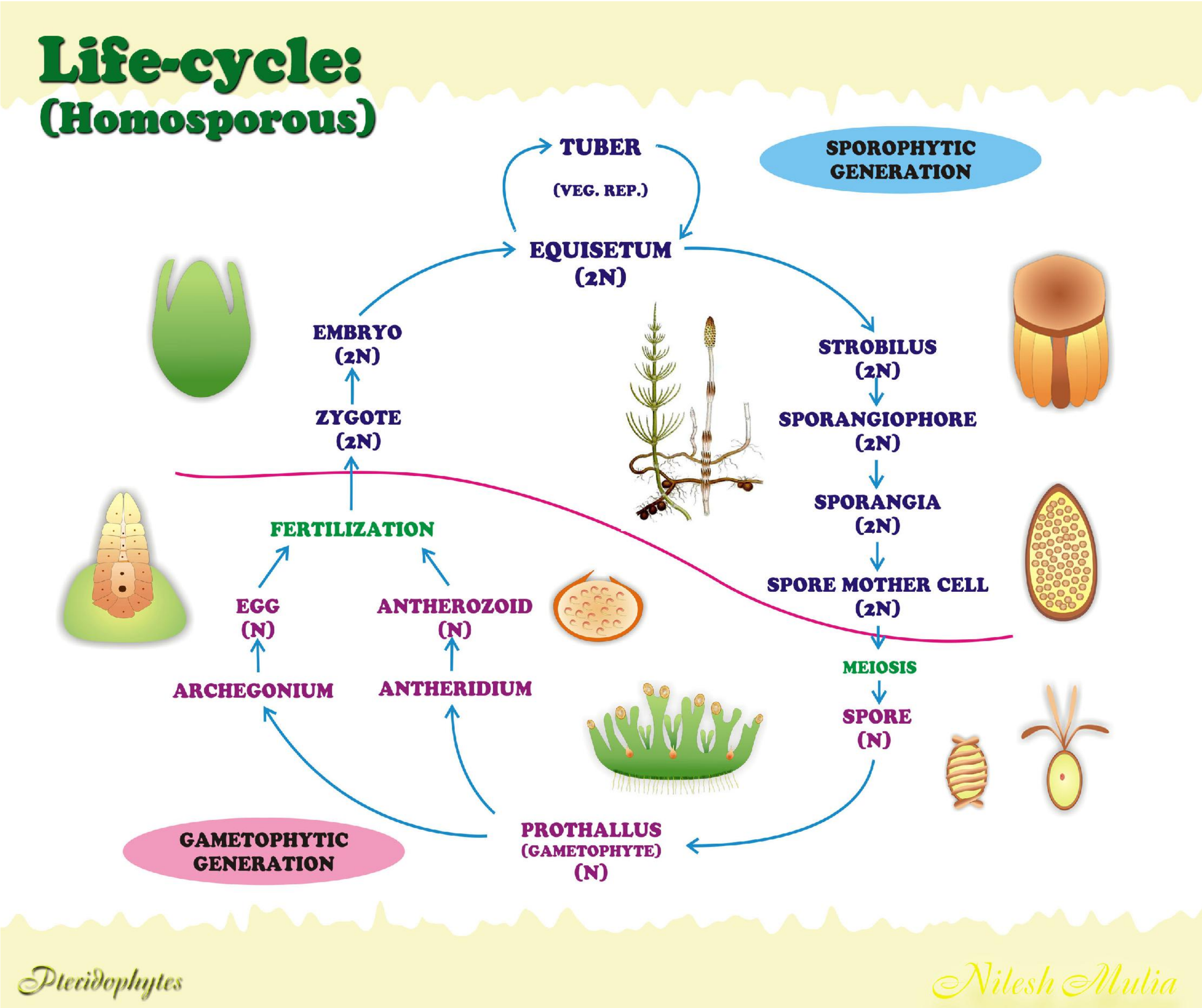
The life cycle of the fern differs from both higher plants (Gymnosperm, Angiosperm) and Bryophytes. In bryophytes the gametophytic generation is the dominant phase in the life cycle and the sporophyte phase is dependent upon it whereas in angiosperms, the sporophyte is the dominant phase and the gametophyte is dependent upon it. However, in pteridophytes, both the sporophytic phase and gametophytic phase in the life cycle are independent of each other. The reproduction in pteridophytes takes place with the help of spores. Some pteridophytes give rise to two different types of spores – large, female spores called as megaspores and small, male spores called as microspores. Such pteridophytes are referred to as 'Heterosporous' pteridophytes. The living species of Heterosporous pteridophytes are small herbaceous perennials usually not more than a few inches high and fall into six genera namely *Azolla*, *Salvinia*, *Marsilea*, *Pilularia*, *Isoetes*, and *Selaginella* (Schaffner, 1905). Those pteridophytes which possess only one kind of non-sexual reproductive spores are referred to as 'Homosporous' pteridophytes. These pteridophytes possess true fibro-vascular system, true roots and leaves and fall naturally into three distinct classes – Ferns or Filices, Horsetails or Equisetaceae and Lycopods or Lycopodiaceae (Schaffner, 1906).

The sporophyte of the pteridophyte produces spores inside the sporangia after meiosis. The sporangia develop either on the ventral surface of leaves (as in case of ferns) or in the axil of stem and leaves (*Lycopodium, Selaginella*). The sporangia bearing leaves are called as 'sporophylls'. The development of the pteridophytes is of two different types:

1. Eusporangiate development – wherein the sporangium develops from a group of superficial cells. Examples – *Lycopodium, Selaginella, Equisetum*
2. Leptosporangiate development – wherein the sporangium develops from a single initial cell. Examples – *Pteris, Polypodium*

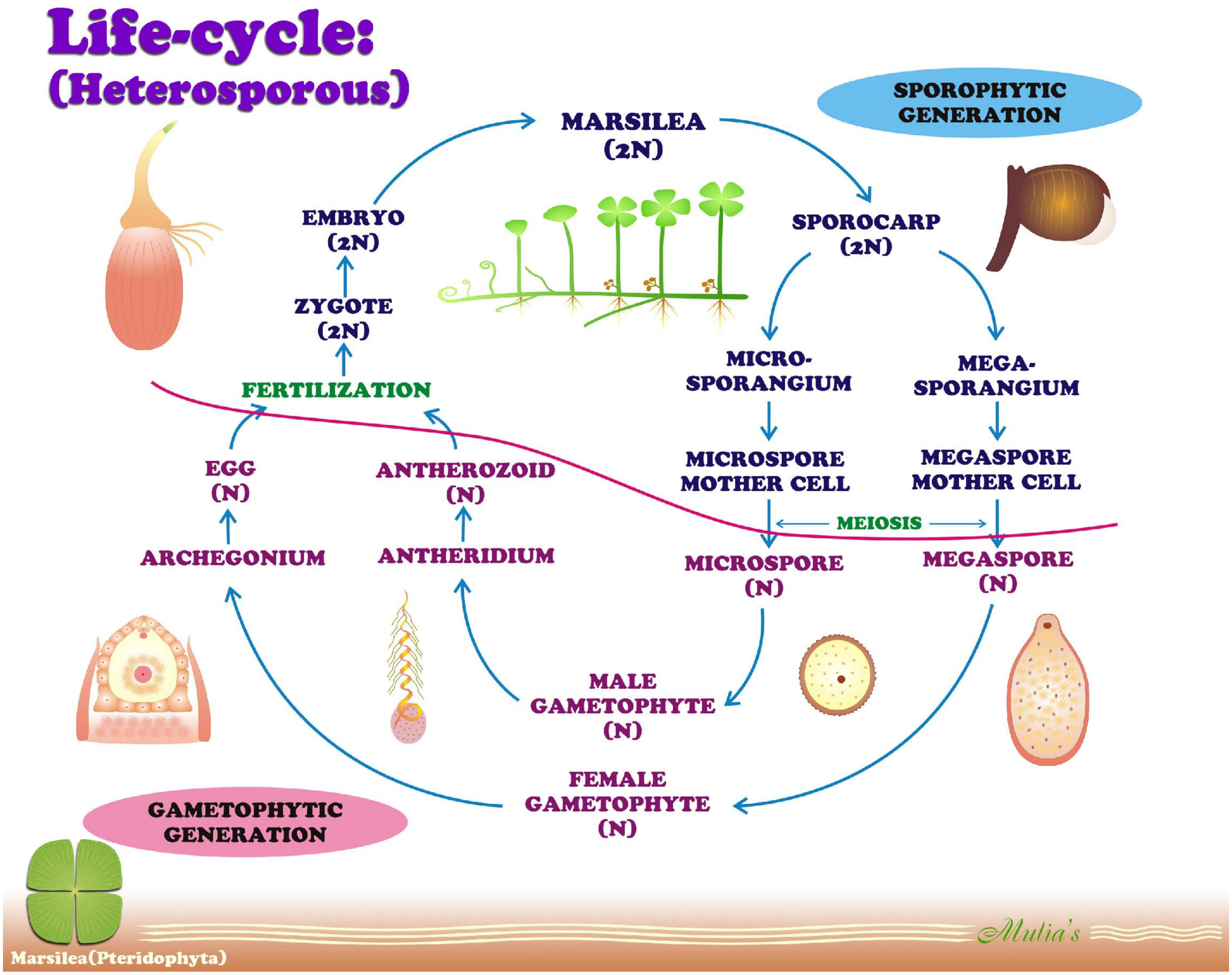
The spores germinate to give rise to the gametophyte known as prothallus which is green and bears sex organs – antheridia and archegonia. The homosporous pteridophytes form monoecious prothallus whereas the heterosporous pteridophytes form the dioecious prothallus. The antheridium gives rise to numerous antherozoids which are ciliated. Water is essential for the fertilization process as the antherozoids travel to the archegonia in the presence of water. The fertilization between the male and female gametes results in the formation of zygote which gives rise to the sporophyte.

**Fig.1 – Life cycle of a Homosporous Pteridophyte (eg: *Equisetum*)**




**Contributed by: Prof. Nilesh Mulia, Department of Botany, M.G. Science Institute, Ahmedabad**

**Fig.2 – Life cycle of a Heterosporous Pteridophyte (eg: *Marsilea*)**




**Contributed by: Prof. Nilesh Mulia, Department of Botany, M.G. Science Institute, Ahmedabad**

## Different habits and habitats of ferns

Due to availability of favourable climatic conditions and suitable habitats for growth, the pteridophytes are widely distributed in Indian continent, even becoming abundant and conspicuous at some parts. However, they need proper microclimatic conditions for their survival and any disturbance in these conditions may lead to their extinction. Each fern species has its own preferences for temperature, humidity, soil type, moisture, etc. and in many cases are very specific indicators for the conditions they need (Shaikh & Dongare, 2009). Though some studies have been done taking different habits and habitats of pteridophytes into account, in-depth ecological studies have not been done on the Indian pteridophytes. The pteridophytes grow in different habitats like moist or dry rocks and boulders, on tree trunks, as hydrophytes in lakes, ponds, etc., on forest floors and edges, along perennial streams and deep ravines, grasslands, tea and coffee estates, inside dark Georges, etc. Ecologically various members of ferns and fern allies inhabiting a region can be classified into different categories depending upon their growth habits and various habitats they occupy.

Some pteridophytes grow as epiphytes on the stem and branches of the trees in moist and shady evergreen forests. The barks or branches covered with moss and humus form ideal base for their growth. Some of the epiphytic pteridophyte species are *Drynaria quercifolia, Lepisorus nudus, Microsorum punctatum, Asplenium nidus, Huperzia squarrosum,* etc. Most of these epiphytic species prefer trees like *Ficus sp.* and *Mangifera* sp. At high altitudes, the stems and branches of trees are usually covered with moist mossy surface and leafy liverworts which provide an ideal condition for the growth of pteridophytes. The ferns and fern allies like *Hymenophyllum javanicum, Araiostegia pulchra, Vittaria elongata, Didymoglossum insignis, Ctenopteris subfulcata,* etc. occur at such places.

Majority of ferns and fern allies are terrestrial growing and differing in growth and habitat they occupy. Some major terrestrial growing pteridophyte genera are *Pteris, Dryopteris, Athyrium, Diplazium, Thelypteris, Cyclosorus, Alsophila,* etc. Some terrestrial ferns like *Dicranopteris linearis* grow abundantly and form thickets in the forests. Species like *Pteris vittata, Diplazium esculentum, Pronephrium nudatum, Leptochillus axillaries* grow in moist and shady places whereas species like *Asplenium bulbatum, Diplazium esculentum, Pteris semipinnata,* etc. grow in the edge of forests along secondary forests (Dixit, 2000).

The fern genera *Lygodium, Stenochlaena* and *Microsorium* are climbing ferns with underground serpentine rhizomes. For securing favourbale light conditions, the plants grow up the adjacent shrubs and branches of nearby trees with the help of rachis. *Microsorium superfeciable* occurs in the dense evergreen forest while *Lygodium japonicum*, *L. flexuosum* and *L. circinalis* normally occur upto 1000m altitude (Dixit, 2000).

Some ferns are lithophytes and are found in rock crevices and among rock boulders along water channels. Species such as *Adiantum venustum*, *A. capillusveneris* and *Asplenium rutamaria* grow in wall crevices under shade or around falls among rock boulders (Dixit, 2000). Other examples of lithophytic species are *Cheilanthes farinose*, *Pityrogramma calomelanos, Adiantum philipense,* etc.

**Economic importance of pteridophytes**

Man has been dependent upon the plants as an important source of medicine since ancient times. Even today, many tribal communities and rural population is dependent heavily upon the natural resources obtained from the surrounding forest regions for treatment of various ailments and diseases. The Indian traditional medicine is based on different systems such as Ayurveda, Siddha and Unani used by various tribal communities (Gadgil, 1996).Though, lot of studies focusing on the medicinal properties of plants, especially angiosperms, have been taken place, unfortunately limited amount of studies have been done to explore the medicinal potentialities of the pteridophytes. The pteridophytes constitute a significant part of the earth's plant diversity and being the second largest group of vascular plants, they form a dominant component of many plant communities. The medicinal qualities of ferns, real or imaginary, are mentioned as early as 300 B.C. by the Greek philosopher Theophrastus and by his Indian contemporaries Sushrut and Charak. The medicinal uses of some ferns and pteridophytes of India have also been described (Caius, 1935; Nair, 1959). The medicinal uses of 61 different ferns and fern-allies have been well described by (Benjamin & Manickam, 2007). *Adiantum capillus-veneris* and *Marsilea minuta* have been mentioned as of medicinal importance in 'Charak Samhita' and the rhizome of *Polystichum squamosum*, which is known as 'Nirviri' in India is effectively used against scorpion bite and insect bites (Dixit, 2000). The leaf and root decoction of commonly occurring *Adiantum lunulatum* has been found to be very effective in the treatment of chest complaints (Nair, 1959; Rout *et al*, 2009). The leaf extract of *Angiopteris* *evecta* is used in treatment of dysentery whereas the spores are effective in the treatment of leprosy and other skin diseases (Kirtkar *et al*, 1935). *Actiniopteris radiata* possesses the properties like anthelmintic, astringent, sweet, cooling, acrid, febrifuge and is used for treating severe conditions of diarrhea, dysentery, helminthiasis, haemopstysis and fever (Warrier *et al*, 1996).

Another important pteridophyte which plays many important and different roles in the ecosystem is *Azolla* (Family – Azollaceae). It is a genus of small, aquatic, heterosporous, leptosporangiate ferns, commonly found in still or slow moving water ponds, ditches, swamps, lakes, tanks. One important characteristics of *Azolla* is its symbiotic association with nitrogen-fixing, blue-green algae namely – *Anabaena azollae* Strasburger. Due to this property, the agronomic potential of *Azolla* as biofertilizer for rice has been recognized in many countries including India, Philippines, USA, Sri Lanka and Thailand (Ahluwalia *et al*, 2002). It has been also found that by applying *Azolla* the soil fertility is improved by increasing total nitrogen, available organic carbon, phosphorous and potassium (Mandal *et al*, 1999; Sharma *et al*, 1999). *Azolla* has also been used as food supplement in fresh or dried or silage form for aa variety of animals including pigs, cattle, rabbits, ducks, chicken and fish (Ahluwalia *et al*, 2002). *Azolla* can also be used for control of weeds like *Eichornia sp*., *Chara* sp., *Nitella* sp. and *Hygrophila* sp. (Sahoo & Datta, 1999). The remarkable activity of *Azolla* to take up heavy metals from polluted water can be used for treatment of wastewater (Sanyahumbi *et al*, 1998; Vermaat & Hanif, 1998). Its use as traditional medicine for treating cough and sore throat is also known (Wagner, 1997; Usher, 1974). Other uses of *Azolla* include hydrogen production, biogas production, as an ingredient in soap production and to certain extent as human food (Ahluwalia *et al*, 2002).

The ferns have also shown to be having an important role in bioremediation of wastewater. Ma *et al*. (2001) found the Chinese Bracken fern namely *Pteris vittata* L. to be a hyperaccumulator of the toxic metal Arsenic. Besides producing large biomass, they also found this fern to be efficient in Ar accumulation with the concentrations as high as 2.3% in the aerial portions of the fern. Later on, many researchers provided the reports of the hyperaccumulation properties of *Pteris* as well as many other ferns also. Tu *et al*. (2002)

suggested that *P. vittata* could be an excellent model to study arsenic uptake, translocation, speciation, distribution and detoxification in plants and for phytoremediation of arsenic contaminated soil and water. Researchers like Nichols *et al.*, 2000; Olguín *et al.* 2002; Sun˜e *et al.*, 2007) have shown that several species of *Salvinia* such as *S. herzogii*, *S. minima*, *S. natans*, *S. rotundifolia* possess the potential of removing various contaminants including heavy metals from the wastewater. The non-living biomass of *Salvinia* exhibit equivalently high potential to remove heavy metals (Dhir, 2009). The advantageous features of *Salvinia* such as wide geographical distribution, high productivity, high surface area and carboxylic content, efficiency of pollutant removal throughout different seasons, higher rate of metal removal per surface unit and easy to grow makes it an important species to be used in phytoremediation technologies (Dhir, 2009).

Besides having all these wonderful properties, the pteridophytes are also greatly valued as ornamentals. Prior to the discovery of these benefits obtained from this group of plants, ferns were used to enhance the beauty of the landscape and are continued to be used so till now. *Nephrolepis cordifolia* also commonly known as 'Sword fern' is one of the most commonly used ornamental fern species. Other ferns like *Adiantum capillus-veneris*, *Asplenium sp.*, *Selaginella sp.*, *Lygodium sp.*, *Pteris sp.*, etc. are also grown in the gardens or in the pots. Many nurseries grow these ferns and sell them off for a good price and these ferns are then used as ornamentals either as garden plants or during functions to beautify the place.

**Threats and conservation of pteridophytes**

The pteridophytes are moisture and shade loving plants and dependent upon the microclimatic conditions of the region for their successful survival in that region. Any kind of disturbance in these microclimatic conditions can hinder the growth and evolutionary processes occurring naturally in these plants thereby, leading to decline in their populations. Thus, factors like climate change, increasing urbanization, industrialization, encroachment of forest lands, unplanned developmental activities, over exploitation of natural resources, pose a major threat to the survival of these groups of plants. Due to unplanned felling of trees in the forests the members of epiphytic pteridophytes belonging to the families Polypodiaceae, Davalliaceae, Aspleniaceae, Vittariaceae, have been reduced day-by-day (Dixit, 2000). Large scale collection of ferns from the forests by the visitors and local people for ornamental purpose, medicinal purpose and during excursions also increases the pressure on these plants.

Biodiversity conservation is the need of time and hence, it has become imperative to develop *in situ* and *ex situ* conservation methods for conservation of the diminishing biodiversity. The *in situ* conservation is very beneficial as it allows the evolution of the species to continue within the area of natural occurrence. Hence, the steps for conserving the ferns *in situ* should be focused upon. The *ex situ* conservation includes development of botanical gardens or conservatories, germplasm banks, DNA banks, seed banks and involve the use of techniques such as tissue culture, cryopreservation; incorporation of disease, pest and stress tolerance traits through genetic transformation and ecological restoration of rare plant species and their populations (Kapai *et al*, 2010). The conservation of flowering plants has been achieved to good extent by developing conservatories and botanical gardens which also help in creating awareness among the local people. However, developing a fern conservatory or fern garden is not preferred much and hence, such steps should be considered and implemented for conserving the rare and endangered species. The tissue culture is a very useful technique for the mass multiplication of the plant species in a short time and hence, researches focusing on developing a protocol for *in vitro* regeneration of ferns and fern-allies should be encouraged. Parts of areas rich in abundant pteridophyte diversity can be declared as pteridophyte biosphere reserves or small gene sanctuaries can be established to save the epiphytic pteridophytes.