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Phylogenetic diversity of *Lycopsids* (*Selaginella*) species in Tropical region - A Review

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Abstract

Selaginella, a prehistoric plant, exists on the earth since 440 mya or the early carboniferous period without significant morphological changes. It successfully continue to exist through natural selection and grow in all biome types (mostly humid and warm climatic regions) except Antarctica. Many of the selaginella species are considered potent medicinal plants. *Selaginella bryopteris* commonly known a Sanjiwani is a widely used herbal medicine in India. From an evolutionary view point selaginella which differ from one another in eco geographical distribution and molecular and morphological features. Phylogenetic diversity is a promising measure of biodiversity sciences, leading to preserving the diversity with natural history. A series of extensive field survey has been conducted by Indian researchers that pioneered the systematic of Indian *selaginella*. Among the Indian species of *selaginella* about 30 are reported to occur in Eastern Himalaya. The Western Ghat another biodiversity hotspot rich in selaginella 18 species as described in earlier reporters.

Key words : Phylogenetic. Diversity, *Selaginella,* Tropical region.

Pteridophytes are relatively a small but highly diverse group of extant and extinct forms of early (=primitive) vascular plants (=tracheophytes), which contrary to the more recent groups *i.e.* the Lignophytes and spermatophytes (gymnosperms and angiosperms), lack flowers & seeds and reproduce mainly by means of spores. These plants are broadly primary in their anatomical structures. They are mostly herbs, twiners and shrubs rather a few with arborescent habit. As compared to gymnosperms and angiosperms, their economical potential is neither thoroughly explored nor fully exploited. In the nineteenth century produced commendable works on the taxonomy of ferns of Indian subcontinent. A major boost to fern studies in India came with the establishment of the Indian Fern Society in 1983. This organization has helped to bring together the pteridologists of the country, and is promoting interest in the study of ferns through meetings and through its publications. With the start of Indian Fern Journal in 1984, a channel has been created for communication with international groups of pteridologists. Bir wrote an account of "Pteridology in India" giving details of work

done in various fields. Foreign scientists did lot of work on Indian Pteridophytes. Of which R.H. Beddome, C.B. Clarke and C.W. Hope are the pioneers, worked upto the end of 19th century. Beddome's Handbook of the ferns of British India", Ceylon and Malay Peninsula" is the only authentic useful work even to-day. Regional flora on Nagaland[5] Meghalaya, (Baishya & Rao), Tirap (Singh, S. and G. Panigrahi (2005). (Arunachal Pradesh) and North-West Himalayas have already been published. Checklist on pteridophytes of North-East India; Darjeeling and Sikkim Himalayas, Western Himalayas, Mount Abu in Rajasthan and other places viz., Pachmarhi, Tamiya and Patalkot in Madhya Pradesh, Kambab; Shevroy and Pachaku-Tattachi hills and Bombay, Mahabaleshwar, Mather and Kanara etc. in western Ghats have been published. Dixit[2] published "A census of Indian pteridophytes" and "Dictionary of Pteridophytes of India" respectively. There are various places in India where thorough collections of pteridophytes have not yet been made till to date, *i.e*. North-East India, Andaman and Nicobar Island, South Indian Hills and several species will be added if extensive collections are made from these areas in near future. In view of variable climatic and altitudinal variations the Indian sub-continent represents Himalayas, Gangetic plains and Thar Desert as bio-diversity centers. Maximum number of diversity of Pteridophytes observed in Himalayas, Eastern and Western Ghats. Except Panchmarhi and Parasnath hills; gangetic plains and Aravalli hills or towards North-west Hindu-Kush much pteridophytes do not occur. The lesser rainfall from Eastern Himalayas to Western hills is responsible for a decrease in Pteridophytic vegetation. There are about 12,000 species of pteridophytes occur in the world flora, of which 1,000 species into 70 families and 192 genera occur in the different parts of the present Indian political boundary. Keeping in view of large area of the country the present number of diversity is quite less. Region-wise studies reveals that maximum number of 700 species (*i.e*. 58% of Pterido-phytes) occur in Eastern Himalayas and adjoining states. Thus, Eastern Himalayas may be termed as one of the Hot Spots diversity centre for pteridophytes. In other regions viz., 400 species in Southern India, 300 species in North-West India and 100 species in Central India and 125 species in Andaman and Nicobar Islands. *Selaginella* is word-wide in distribution and comprises of about 700 species. Majority of the species are tropical and grow in rain forests. Some of the species are found in temperate regions. Some species are xerophytic which grow upon barren rocks and dry soils. The xerophytic species may survive for months together in the conditions of desiccation. Some of the species are moist loving and found in the shady places on the hills. In India, majority of the species of *Selaginella* are common in the Himalayas and the hills of South India. Some of the xerophytic species, like *S. lepidophylla* and *S. rupestris* remain folded or ball-like in dry conditions, but as soon as they come in contact of water they become unfolded and normal, such plants are called 'resurrection plants'. Some of the species are epiphytic, and found growing upon other plants. *S. oregana* grows upon the trunks and branches of the trees covered with moss plants. About 58 species of *Selaginella* have been reported from different parts of India. Some of the most important Indian species are- *S. kraussiana, S. chrysocaulos, S. chrysro-rhizos, S. sanguinolenta, S. pallidissima* etc., and many others.

Study Site : India is one of the richest regions of the world in Lycopsids diversity due to great variation in geo topography and climate. There are 3 living genera 1000 species are present in India, of which many are endemic to India *i.e*. occurring in political boundaries of India Phyto-geographically the Western region North India and Central region is the hot spots of India (Himanchal Pradesh, Uttarakhand-Dehradun, Hamalaya region-Jammu & Kashmir) and richest region of the Lycopsids diversity. Which includes mountains George, valley and plane makes the tropical belt of the country? The Western Ghats in Peninsular India is one among the two well recognized 'hot spot' of biodiversity in India. All the Indian species of *Selaginella* generally grow in identical climate of population. These are most widely distributed in entire country of forestry area. The number of species found at any particular locality ranges from 1 to 4. Single species populations are frequent while mixed populations of four species are occasional. Almost all populations consist of single of double species at lower altitudes but at higher altitudes, their number may be 2-4. The diversity centres in India are mentioned in Table-1 This listing of diversity centres is intended to provide precise information in support of conservation strategies for Indian quillworts, which include populations of all the presently known species in India.

Table-1 List of taxa along with collecting locations and their voucher number

S.no.	Taxa	Province	Provenance
1	*S. tenera*	Kerala	Pokkod lake, Wayanad, Kerala
2	*S. delicatula*	Karnataka	Someshawara Wild Life Sanctuary, Agumbe, Karnataka
3	*S. delicatula*	Maharashtra	Pratapgarh Road, Mahabaleshwar, Maharashtra
4	*S. delicatula*	Karnataka	Udupi, Karnataka
5	*S. delicatula*	Karnataka	Thirthalli, Karnataka
6	*S. delicatula*	Maharashtra	Tilarinagar
7	*S. ganguliana*	Kerala	New by Pass Idumuni, Calicut, Kerala
8	*S. miniatospora*	Goa	Mangesi Temple, Old Goa, Goa
9	*S. miniatospora*	Goa	Kanti Nagar, Old Goa, Goa
10	*S. miniatospora*	Goa	Mahalasa Temple, Old Goa, Goa
11	*S. miniatospora*	Goa	Mangesi Temple, Old Goa, Goa
12	*S. panchghaniana*	Maharashtra	Monkey Point, Old Mahabaleshwar, Maharashtra
13	*S. crassipes*	Maharashtra	Pratapgarh Road, Mahabaleshwar, Maharashtra

Biodiversity Determination :

Biodiversity is the variation of life forms within a given ecosystem, biome or for entire earth. The term, biodiversity itself may have been coined by W.G. Rosen (1985). Biodiversity is all life on earth, the number, variety & variability of all living organisms. The most straightforward definition of biodiversity is "Variation of life at all levels of biological organisms". In other words it is a measure of relative density among organisms present in different ecosystems. The term in this case includes diversity within a species & among species & comparative diversity among ecosystems.

Another definition of biodiversity often used by ecologists is the, "totality of genes, species & ecosystem of a region". For geneticists biodiversity is the diversity of genes & organisms. The ecologists use following three indices to measure special level biodiversity:

i) Alpha Diversity (α-Diversity)
ii) Beta Diversity (β-Diversity)
iii) Gamma Diversity (γ-Diversity)

i) ***Alpha Diversity (α-Diversity) :*** It refers to diversity within a particular area, community or ecosystem & is measured by counting the number of taxa within the ecosystem (usually species).

Simpson index : Simpson's diversity index (also known as Species diversity index) is a measure of diversity. In ecology, it is often used to quantify the biodiversity of a habitat. It takes into account the number of species present, as well as the relative abundance of each species. The Simpson index was first proposed by the British statistician Edward H. Simpson in a paper in *Nature* in 1949.

ii) ***Beta Diversity (β-Diversity) :*** It is species diversity between ecosystems. This involves comparing the number of taxa that are unique to each of the ecosystems or along environmental gradients. It is the rate of change in species composition across habitats or among communities. It gives a quantitative measure of diversity of communities that experience changing environments.

iii) ***Gamma Diversity (γ-Diversity) :*** It is the measure of overall diversity for different ecosystem within a region. It refers to the total species richness over a large area or region. It is the product of the α diversity of component ecosystems and the β diversity between component ecosystems. According to Whittaker (1972), gamma diversity is the richness in species of a range of habitats in a geographic area (*e.g.*, a landscape, an island) and it is consequent on the alpha diversity of the individual communities and the range of differentiation or beta diversity among them. Like alpha diversity, it is a quality which simply has magnitude, not direction and can be represented by a single number.

Biodiversity Aspects : Biodiversity is not uniformly distributed on the surface of the planet earth & is dependent on altitude & latitude etc. It provides humankind enormous direct benefits & indirect essential service through natural ecosystem function & stability. India with a highly variable climate has a rich pteridophytic flora. Ferns & Fern-allies flourish well in tropical, sub-

tropical & temperature forests. Ferns & their allies are found all over the world. These occur through an extra ordinary range of habitats from sea level to high mountains. Survey of ferns & their allies is highly warranted since some of the taxa like *Lycopodium* Linn. *Cheilanthes* & *Pteris* are being used as Homeopathic medicine.

Genetic diversity :

Genetic biodiversity within a population of the same species involves individuals and their unique combination of genes & chromosomes. Indeed the very fabric of all other aspects of biodiversity, genetic diversity provides populations with enough variability that they should be able to survive changing environmental conditions because some variants would possess the unique genes that enable them to survive.

Different species of club-mosses show a great diversity. The chromosome number of about 70 species has been reported. Baranov (1925) was first to report chromosome number in *L. japonicum*.

Sampling status: Plants from their natural habitats have been collected from randomly selected three spots per population, per species, per area. The plants have been removed gently from the habitats soil and kept in polythene bags and the bag mouth was closed with rubber band after labeling. A portion of collected plants have been preserved separately in FAA and labeled. The habitat details have been noted out on the spot. These samples were brought to the laboratory for the further observations.

Identification of taxa : The specific status of plants have been identified by the well known signatures on the genus *Lycopodium, Selaginella* and *Isoetes,* Advance study centre, Botany Faculty of Science, BHU, Varanasi with the help of published literature.

The Taxa and vouchers : The herbarium specimens as voucher of various species and their populations have been prepared, labeled and numbered, after the treatment with 2% Mercuric Chloride solution. These vouchers have been deposited in the Duthie Herbarium of Botany Department, BHU, Varanasi.

Field photography: Field photographs of plants, in their diverse habitats have been taken from NIKON-F90X SLR field camera.

Selaginella has a wide distribution range in tropical and subtropical regions having more species diversity in rain forests and shady hills sides but some species can thrive in xerophytic conditions[10]. Selaginella are widely distributed in tropics, subtropics and temperature regions. Within the tropics, orchids form an important feature of the vegetation, chiefly as epiphytes. India's epiphytic Selaginella is to be found primarily in the Eastern Himalayas and Western Ghats, while the terrestrial species flourishes in the Western Himalayas. In the state of Uttarakhand, India, Selaginella are typically concentrated along the riverine areas and in pockets of moist forests where there is suitable habitat for their growth, development and regeneration.

It can be concluded that species diversity is being regulated by factors like community stability and evolutionary time as heterogeneity of both micro and macro environment affects

Fig. 1. Diversity of Lycopsids (*Selaginella*) morphological structure

the diversification among different communities. Amongst major factors that influenced vegetation structure are human disturbance, extensive grazing, trampling, invasion of opportunistic species and soil erosion. Human disturbance, extensive grazing has resulted in the formation of highly fragmented vegetation type, which in turn has critical impact on community structure.

As in many pervious classifications[12] we treat Selaginellaceae as a monotypic family with the single genus Selaginella. The type of the genus of Selaginella selaginoides, which means that, based on the phylogenetic relationships found, any division into several genera would lead to the genus Selaginella including only two species; S. selaginoides and S. deflexa. All other species, nearly all described and known in floras under the well-established generic name Selaginella, would have to be transferred to other genera. Besides the large number of recombinations needed, we see two major problems with such a scenario. *Pulvinella* and subgenera *Stachygynandrum* and *Heterostachys* [12]. Species in subg. *Pulviniella* are in gross morphology and growth form very similar to species in these two other subgenera. The megaspores show sculpturing closely similar to those of species referred to as subg. *Heterostachys*. In conclusion, we believe that species are difficult to unequivocally assign to a specific subgenus based on morphology using the classification by Zhou and Zhang[12]. Morphological characters studied were isophylly vs. anisophylly and

phyllotaxy, with respect both to vegetative leaves and sporophylls, presence/absence of articulations, rhizophore position, stellar arrangement and megaspore features. Many of these features were used as diagnostic characters in earlier classifications of *Selaginella*.

The strobilus of S. tenera has been studied, previously by Dixit[3] and Manickam & Irudayaraj[9]. Out of 8 parameters (present study) viz. no. per plants, no. of per branch, position, stalked or sessile, shape, colour, appearance and range, Dixit[3] has mentioned only two characters viz. position and size of cone. Therefore remaining 6 parameters are studied for the first time of this species in India. The comparative assessment shows that Dixit[3] study and present study are similar only in position of cones. However, the size of cone in terms of range is variable between the two studies. Manickam & Irudayaraj[9] also studied the strobilus of this species. They have recorded only one parameter *i.e.* shape. According to them the shape of cone is elongated. Research on diversity of *Selaginella* based on DNA/RNA marker is relatively still limited. Kolukisanoglu *et al*.,[6] indicate that *Selaginella* and Equisetum emerge earlier than *Psilotum* based on phytochrome gene. This result corresponds to chloroplast gene[11]; and supported by ribulose-bisphosphate carboxylase gene (rbcL)[7,8] prove that Rsubgenera *Selaginella* and *Tetragonostachys* are monophyletic, *Satchygynandrum* and *Heterostachys* are polyphyletic; while the nature of *Ericetorum* is still unknown yet. This research is relied on chloroplast gene of *rbcL* from 62 species (± 10%) which selected by morphological, ecological and geographical diversity.

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