Abstract of thesis entitled

Systematics and Molecular Studies on Diversity of Pteridophyte and Gymnosperm of Gujarat

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By

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Research Background

The word pteridophyta is derived from Greek words "*pteron*" means "feather" and "*phytes*" means "plants" (*i.e*. feather like plants). They are spore bearing, seedless vascular cryptogams characterized by the self-regulating heteromorphic alternation of generation. They grow luxuriously in different habitat during rainy season due to the presence of high humidity, moisture content in the atmosphere and enough shade due to less penetration of sunlight. They stands at second position in terms of species richness while, their diversity and distribution ranks next to the angiosperms in plant kingdom. It is estimated that, about 11,916 species representing 337 genera in 51 families showing cosmopolitan distribution in different biogeographic zones of the world (PPG-I 2016). A cosmopolitan distribution of pteridophytes in India comprises about 1,138 species and 114 subspecies belonging to the 125 genera, of 34 families (Fraser-Jenkins *et al*. 2017, 2018a, 2020; Fraser-Jenkins 2020). From which, 47 species of 20 genera belonging to 15 families of pteridophytes are endemic to the country (Fraser-Jenkins 2008a; Fraser-Jenkins *et al*. 2017, 2018a, 2020; Fraser-Jenkins 2020).

The term gymnosperm is attaining from a Greek "*gymnospermos*" means "naked seeds" (*i.e*. seeds not encircled with cotyledons). Gymnosperm is the group of tracheophyta where, ovules are is not encircled in carpel, unlike angiosperms (Singh & Srivastava 2013). In contrast to other group of plant, living gymnosperms are very fewer in number; they comprise *ca*. 1,106 species under four major lineages *viz*., *Ginkgo*, Gnetophytes, Cycads and Conifers (Calonje *et al*. 2020; WCSP 2020). In India, extant gymnosperms diversity is estimated about 149 species and 8 varieties (indigenous/introduced) belonging to 46 under belonging to 12 families (Singh & Srivastava 2013; Sharma & Singh 2015; Akhtar *et al*. 2019).

As compared to other groups of plant, angiosperms have received great attention for its diversity and distribution in the state. Similar studies on pteridophytes are not being reflected in botanical literature due to the lack of enumeration/excursion studies. Few species are known from state usually has information only from a few localities and no detailed studies are carried out on this group of plants in Gujarat state due to aforesaid reasons. In similar case for gymnosperm diversity and only *Ephedra foliata* L. is documented from few places of Saurashtra and Kachchh. However, I feel that there is an existence of more than one species of *Ephedra* from the Gujarat state. Therefore, in the present study aimed to explore the diversity and distribution of pteridophytes and gymnosperms occurring in different biogeographic zones and regions of Gujarat state and their molecular identification using DNA barcoding techniques is undertaken.

Work Flow:

Field visits in different parts of the state and for collections of pteridophytes and gymnosperm flora. Further, processing of collected specimens for microscopic observations and molecular studies was done. The identification, confirmation and nomenclature of the collected specimens were done by referring standard literature, state and national floras, monographs and books. Further, experts in the field of pteridophytes and gymnosperms were consulted for confirmation and authentication of specimens. In the present comprehensive research work, classification proposed by PPG-I (2016) and Singh & Srivastava (2013) has been followed for family and genus level status of pteridophytes and gymnosperms respectively. For molecular identification, specimens processed for DNA isolation, amplification and purification. Purified products were sent for the sequencing and generated sequences were subjected for nucleotide BLAST analysis on the GenBank database (blast.ncbi.nlm.nih.gov) for identification of the species. The sequences which showed significant match in with NCBI Database were submitted to the BOLD Systems (http://www.boldsystems.org/) and NCBI (National Center for Biotechnology Information) by using BankIt (https://www.ncbi.nlm.nih.gov/WebSub/). deposited in different herbaria *viz*., BARO (Department of Botany, The M. S. University of Baroda, Vadodara, Gujarat), BSJO (BSI, Arid and Semi-arid regional center, Jodhpur, Rajasthan), BSI (BSI, Western Regional Centre, Pune, Maharashtra), BLAT (Blatter's Herbarium, Mumbai, Maharashtra) and CAL (Central National Herbarium, Kolkata, West Bengal).

Results:

The present study resulted in the collection and identification of 47 taxa (6 lycophytes and 39 ferns) belonging to the broader category in the pteridophytes, 21 genera under 13 families in the wild from the state (table1). On the other side, two species of gymnosperms belonging to one genus (*i.e. Ephedra*) and one family were documented in the wild from the state (table 1). All the biotypes, morphotypes, synonymy and ecologically variable species were merged to the universally accepted taxon.

Table 1: Pteridophytes and gymnosperms occurring in wild from Gujarat state.

Family	**Genus**	**Taxa**
List of pteridophytes occurring in wild from Gujarat state		
Isoetaceae	*Isoetes*	*Isoetes coromandeliana* subsp. *coromandeliana*
		Isoetes coromandeliana subsp. *thanensis*
Selaginellaceae	*Selaginella*	*Selaginella ciliaris*

		Selaginella delicatula
		Selaginella repanda
		Selaginella reticulata
Equisetaceae	*Equisetum*	*Equisetum ramosissimum*
Ophioglossaceae	*Ophioglossum*	*Ophioglossum costatum*
		Ophioglossum gramineum
		Ophioglossum gujaratense
		Ophioglossum indicum
		Ophioglossum jaykrishnae
		Ophioglossum lancifolium
		Ophioglossum lusitanicum
		Ophioglossum nudicaule
		Ophioglossum parvifolium
		Ophioglossum reticulatum
		Ophioglossum rubellum
		Ophioglossum thermale
Lygodiaceae	*Lygodium*	*Lygodium flexuosum*
Salviniaceae	*Azolla*	*Azolla pinnata* subsp. *asiatica*
	Salvinia	*Salvinia molesta*
Marsileaceae	*Marsilea*	*Marsilea minuta*
Pteridaceae	*Ceratopteris*	*Ceratopteris thalictroides* subsp. *thalictroides*
		Ceratopteris thalictroides subsp. *gaudichaudii*
	Actiniopteris	*Actiniopteris radiata*
	Anogramma	*Anogramma reichsteinii*
	Pteris	*Pteris vittata* subsp. *vittata*
	Adiantum	*Adiantum capillus-veneris*
		Adiantum incisum
		Adiantum philippense subsp. *philippense*
	Aleuritopteris	*Aleuritopteris albomarginata*
		Aleuritopteris anceps
		Aleuritopteris bicolor
		Aleuritopteris formosana

	Cheilanthes	*Cheilanthes tenuifolia*
Athyriaceae	*Athyrium*	*Athyrium falcatum*
		Athyrium hohenackerianum
		Athyrium micropterum
		Athyrium parasnathense
		Athyrium schimperi subsp. *biserrulatum*
Thelypteridaceae	*Thelypteris*	*Thelypteris dentata*
		Thelypteris prolifera
Hypodematiaceae	*Hypodematium*	*Hypodematium crenatum* subsp. *crenatum*
Tectariaceae	*Tectaria*	*Tectaria coadunata*
Polypodiaceae	*Lepisorus*	*Lepisorus nudus*
	Microsorum	*Microsorum membranaceum*
List of gymnosperms occurring in wild from Gujarat state		
Ephedraceae	*Ephedra*	*Ephedra foliata*
		Ephedra karumanchiana

Gujarat is divided into six bio-geographical zones *viz*., 1) Desert; 2) Semi-Arid; 3) the Western Ghats (Malabar Plains); 4) the Western Ghats (Western Mountains); 5) Deccan Peninsula and 6) Coasts. The most pteridophyte species-rich bio-geographical zone of the state is Semi-Arid region represents 41 species and the least species rich regions are Deccan Peninsula and Coastal areas of the state which shows, two taxa. Gujarat is divided into five regions *viz*., North, Central, South, Saurashtra and Kachchh. The most pteridophytic species-rich region of the state is central Gujarat and the least species rich is Kachchh encompassing 35 and 9 species respectively. *E. foliata* is mainly distributed in Kachchh and Saurashtra regions, whereas, *E. karumanchiana* occurs only in the north Gujarat.

Conclusion:

The purpose of the present study was to explore the pteridophytes and gymnosperms diversity in Gujarat and to provide authentic data for the determination of taxonomical evaluation as well as their molecular identification using DNA barcoding techniques. It revealed 47 taxa, 21 genera under 13 families in the wild pteridophytes and two taxa of gymnosperms were reported.

In the present study, the morphologically complex taxon was analysed for molecular identification, and a total of 37 DNA barcodes of 20 taxa were generated and submitted to BOLD Systems and/or NCBI. The IUCN status of each taxon was evaluated. Analysis reveals

that a total of 44 taxa of pteridophytes occurring in the state, 25 taxon falls under Least Concern, whereas, 19 taxa categorised under Data Deficient.

Important Findings of Present Investigation:

During the course of time, certain taxa were added new to the world, nation and for the state. A new species *i.e.*, *Ophioglossum gujaratense* SM Patil, RN Kachhiyapatel, R Patel & KS Rajput and *Ephedra karumanchiana* SK Patel, SM Patil, RS Patel, RN Kachhiyapatel & KS Rajput, are described Gujarat. *Anogramma reichsteinii* Fraser-Jenk. is documented for the first time in western Peninsular India and the northern Western Ghats in Gujarat. The species *viz*., *Selaginella ciliaris* (Retz.) Spring, *S. delicatula* (Desv. ex Poir.) Alston, *S. repanda* (Desv. ex Poir.) Spring, *Ophioglossum parvifolium* Grev. & Hook, *O. thermale* Kom., *Lygodium flexuosum* (L.) Sw., *Salvinia molesta* D.S. Mitch., *Actiniopteris radiata* (Sw.) Link, *Pteris vittata* L., *Adiantum capillus-veneris* L., *A. incisum* Forssk., *Aleuritopteris anceps* (Blanf.) Panigrahi, *A. bicolor* (Roxb.) Fraser-Jenk., *A. formosana* (Hayata) Tagawa, *Athyrium falcatum* Bedd., *A. hohenackerianum* T. Moore, *A. parasnathense* (C.B. Clarke) Ching ex Mehra & Bir, *Thelypteris dentata* (Forssk.) E.P. St. John, *T. prolifera* (Retz.) C.F. Reed, *Hypodematium crenatum* (Forssk.) Kuhn. subsp. *crenatum*, *Tectaria coadunata* (J. Sm.) C. Chr., *Lepisorus nudus* (Hook.) Ching and *Microsorum membranaceum* (D. Don) Ching., are added as a new record for the state. *Ophioglossum gramineum* Willd was relocated from the forest area of the Jambughoda wildlife sanctuary, Gujarat. Lecto-typification of *Ophioglossum parvifolium* was done from the state.