Review of Literature

CHAPTER - II

The ferns and their allies are being the most important and gorgeous group of plants owing to their great variety and fascinating foliage among the vascular plants. They have a wide range of diversity around the world and rank next to the flowering plants. Ecologically, they thrive well in tropical, sub-tropical and temperate zones including various niches of habitat ranging from the tropical rain forest, alpine floristic vegetation to the temperate zones of the world. The maximum diversity of this group of the plant is in tropical and subtropical zones of the world. According to PPG-I (2016), ferns and fern-allies are cosmopolitan in distribution. Taxonomic enumeration of this group has been extensively carried out throughout the world and nearly 11,916 species representing 337 genera in 51 families in different biogeographic zones of the world (PPG-I 2016; Fraser-Jenkins *et al*. 2016). They can survive in different habitat ranging from aquatic to terrestrial condition and as lithophyte to epiphytes life forms.

2.1 Work on Pteridophytes of India:

The history of documentation of the first pteridophyte from India was described in a seminal book, '*Species Plantarum*' by Linnaeus in 1753. Later, Swartz (1801, 1806) gave a comprehensive and detailed account of ferns of India in his important book '*Genera et Species Filicum*'. The subsequent taxonomic work carried out by Sprengel (1827) and Blume (1828). The earliest work on the ferns of South India was done by Kunze (1851), who recorded and described 82 ferns and 12 fern allies from the Nilgiris Hills. Further Bayness (1887) enumerated ferns from India in his book entitled '*Album of Indian Ferns*'.

A prominent, active and incredible pteridologist R. H. Beddome has started the work in the field of ferns and their allies on the present-day Indian subcontinents. Based on field observations and exclusive collections, he published several books and their supplements during 1863-1892 on '*The ferns of Southern India* and *The Ferns of British India, Ceylon and Malay Peninsula*'. He elucidated detailed descriptions and provided illustrations/figures of about 631 species from India; of them, 320 species from South India, 330 species from Trans-Gangetic Peninsula, 405 species in Northern India (Beddome 1863, 1866, 1873, 1876, 1883, 1892). Nowadays, Beddome's effort remains the greatest significant and useful source of literature for the identification of ferns of India. Based on Beddome's work, Nayar & Kaur (1974) and Chandra & Kaur (1987, 1994) produced a nomenclatural guide of ferns. Clarke (1879) covered the entire Himalayas (north India) and listed 363 species of ferns and fern-allies. Subsequently,

Clarke (1880) revised ferns of north India and added 16 new species to the region and enlisted a total of 379 taxa for north-Indian fern diversity. Hope (1899-1904) made a detailed study on the ferns in Northern Western India in various publications and compiled all the research work in 1976. Blatter & d'Almeida (1922) published a book on the ferns of Bombay including some parts of present-day Gujarat.

The remarkable impact of the late Prof. S. S. Bir who is known as the 'Father of Indian Pteridology' has significantly influenced Indian pteridology. His detailed survey studies were concentrated mostly on the pteridophytes of central and north Eastern India along with their cytology, ecology and anatomy (Bir 1963, 1964, 1969, 1987; Bir & Verma 1961, 1963, 2010; Mehra & Bir 1964; Bir & Shukla 1966, 1971; Bir & Trikha 1968a-c, 1972a, b, 1974; Bir & Rani 1986; Bir *et al*. 1974, 1989, 1991; Vasudeva & Bir 1994).

A wide range of work on ferns and their allies, which are naturally occurring in different parts of the country, was carried out by subsequent researchers. Amongst them, Dixit (1984) compiled and reported an enumerated list of about 1000 fern and fern allies belonging to 191 genera from 67 families in the seminal book entitled '*A Census of the Indian pteridophytes'*. Another noteworthy input that provided detailed illustrations and description of ferns and fern-allies of west Himalaya is '*An Illustrated Fern Flora of the West Himalaya*' vol., I & II by Khullar (1994, 2000). Subsequently, Ghosh *et al*. (2004) also published a book on '*The Pteridophytic Flora of Eastern India - I*'.

Chandra (1982) provided a checklist of endemic ferns of India, whereas, Bir (1987) accounted for rare, endangered and conservation status of Indian pteridophytes. Besides documenting and providing the information about species richness, their updated nomenclature as per ICBN/ICN is also important; therefore, Chandra & Kaur (1994) provided the nomenclature notes on Indian ferns. Ghosh & Ghosh (1997) also detailed the floristic diversity and conservation of 1018 species belonging to 194 genera under 58 families of pteridophyte of India while Chandra (2000) excluded a doubtful species and some nomenclature confusions of ferns and fern-allies reported by Dixit (1984).

Chandra *et al*. (2008) summarized total of 414 species of pteridophytes taxa were threatened or rare in India. Subsequently, an important contribution to the pteridophyte flora of the Indian subcontinent is of Fraser-Jenkins (2008b, 2017, 2018, 2020). His studies on the revision and compilation of ferns and fern-allies of India led to the conclusion that only 47 species are endemic to India. Fraser-Jenkins (2008b) revised the census list and reported about 1000 species of pteridophyte from the Indian subcontinent.

'*An Annotated checklist of Indian pteridophytes, Part-I*' listed 572 species plus 32 subspecies representing 59 genera under 23 families whereas his volume *i.e*. '*Part-II'* enlisted nearly 317 species, plus 5 exotic and 45 hybrids belonging to 30 genera under 4 families (Fraser-Jenkins *et al.* 2017, 2018a).

A detailed study on pteridophyte families from India had also been attempted by researcher's *viz*., Aspleniaceae (Bir 1962); Selaginellaceae (Dixit 1992); Ophioglossaceae, Osmundaceae, Marrattiaceae and Gleicheniaceae (Panigrahi & Dixit 1967, 1969a-c, Balmrishnann *et al*. 1980, Bir & Rani 1986); Plagiogyreaceae (Dixit & Das 1981); Polypodiaceae (Bir *et al*. 1982); Oleandraceae (Ghosh 1983); Elaphoglossaceae (Biswas & Ghosh 1984); Adiantaceae (Bir & Rani 1986); Cryptogrammaceae (Bir & Rani 1986); Lycopodiaceae, Selaginellaceae and Cyatheaceae (Dixit 1987, 1992, 1998); Gleicheniaceae (Punetha & Kaur 1990); Thelypteridaceae (Dixit & Bala 1990); Loxogrammaceae (Das & Dixit 1996); Cheilanthoid (Fraser-Jenkins & Dulawat 2009, Sen & Mukhopadhyay 2016) and Vittariaceae (Bhandari & Mukhopadhya 2009).

Several workers have attempted their work on monographs and revisionary studies on certain genera of pteridophytes specifically from India. *Ophioglossum* (Mahabale 1937, 1962, Chakravarty 1951, Balakrishnan *et al*. 1960); *Selaginella* (Alston 1945, Panigrahi & Dixit 1968); *Lygodium* (Alston & Holttum 1959); *Adiantum* (Vasudeva *et al.* 1991); *Cheilanthes* (Nayar 1962); *Isoetes* (Srivastava *et al*. 1993, Shukla *et al*. 2002, Patil & Rajput 2017); *Adiantum* (Nayar 1961) and *Tectaria* (Patil *et al*. 2019).

India is a much-diversified country in terms of pteridophyte diversity. In the present study, we followed the classification of India into ten major biotic zones as provided by Rodgers *et al*. (2000). Biogeographically, the country has been divided into ten major biotic zones *viz*., Trans-Himalaya (Ladakh and north Sikkim); Himalaya (Jammu and Kashmir, Himachal Pradesh, Uttarakhand, south Sikkim and Arunachal Pradesh); Desert (Rajasthan, Gujarat [Kachchh]); Semi-Arid (Rajasthan, north-eastern Madhya Pradesh, Gujarat); the Western Ghats (southern Gujarat, western Maharashtra, Goa, Karnataka, Kerala); Deccan Peninsula (eastern and central Tamil Nadu, Andhra Pradesh, Telangana, Odisha, Chhattisgarh, Jharkhand, Madhya Pradesh, eastern Maharashtra, parts of eastern Karnataka); Gangetic Plains (West Bengal, Uttar Pradesh, Bihar); Coasts (Peninsular Indian's coasts); North-East (Assam, Meghalaya, Tripura,

Mizoram, Manipur, Nagaland) and Island (Andaman & Nicobar and Lakshadweep) (fig. 1).

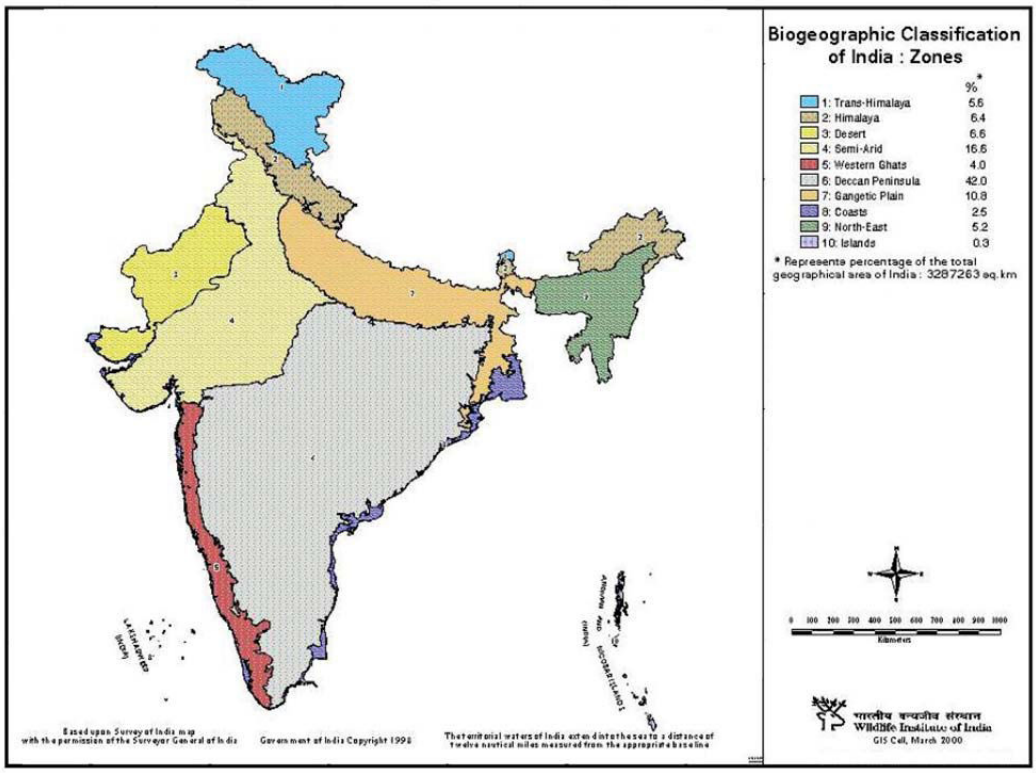

Figure 1: Biogeographical zones of India (Rodgers *et al*. 2000).

2.1.1 Trans-Himalaya*:* This biogeographic region includes Ladakh and northern parts of Sikkim.

The first monumental work on pteridophytes of the Ladakh was carried out by Stewart (1916) and reported *Cystopteris fragilis* (L.) Bernh., and *Equisetum arvense* L. Further inputs on the ferns of Gilgit, Baltistan and Ladakh were done by Stewart (1944), who enumerated 32 ferns and fern-allies. Later, *Athyrium mackinnoni* (Hope) C. Chr. was reported from Trans Indus to Trans Sikkim by Stewart (1945). Furthermore, Dixit & Ghosh (1985) recorded an endemic fern from the northern part of Sikkim. Thereafter, Kholia (2011) surveyed and enlisted ferns from Trans-Himalaya and recorded 14 species from 9 genera. Kholia (2012, 2013, 2014a) also reported three endemic and rare ferns from north Sikkim.

2.1.2 Himalaya: This area of the Indian region extended from the north *i.e.* Jammu and Kashmir to Himachal Pradesh, encompassing Uttarakhand, west, central and eastern Sikkim and Arunachal Pradesh.

The enormous report on the ferns of Kashmir was done by Stewart (1945), who listed 113 taxa belonging to 33 genera under 7 families. Khullar *et al*. (1988) also carried

out studies in this region and listed 75 species of ferns from the Jammu division. Subsequently, Singh *et al*. (1999) enumerated 168 ferns from Jammu and Kashmir. Kirn (2000) enlisted pteridophytic flora of Poonch and enlisted 94 ferns. On a similar line, Singh & Pande (2002) and Shagufta & Pant (2017) took the opportunity and revised the pteridophytic work from Jammu and Kashmir. Dar *et al.* (2002) enlisted 90 species of pteridophytes occurring Kashmir. Wani *et al*. (2012) updated the ferns of Kashmir and enlisted 113 taxa under 38 genera from 23 families. Ecological studies on pteridophytes of Jammu and Kashmir were carried out by Anjum *et al*. (2014). Recently, Kumar *et al*. (2020) provided a comprehensive and an updated list of ferns from Jammu and Kashmir by enumerated 200 species (189 ferns and 11 ferns-allies) belonging to 44 genera under 19 families.

The foremost record on ferns diversity of Himachal Pradesh was reported by Stewart (1869) and listed two ferns with their economic value. Ecological observations of 70 fern species from Kangra and Kullu (Himalaya) was done by Scheple (1954). Cytotaxonomy of Western Himalayan ferns (Polypodiaceae) was carried out by Khullar & Mehra (1972). Khullar & Gupta (1980) and Khullar & Sharma (1980) worked on systematics of the genus *Polystichum* and *Onychium* from the Himalayas respectively. Pteridophyte diversity on Kangra district (Himachal Pradesh) was done by Khullar *et al*. (2008) and enlisted nearly 265 taxa. Kumari *et al*. (2013, 2014) enumerated 90 species of pteridophytes (85 ferns and 5 ferns-allies) belonging to 31 genera and 14 families from Barot, Mandi, Himachal Pradesh with few additions. Mazumdar (2018) reported *Adiantum breviserratum* as an addition to Western Himalaya.

Pioneering work on pteridophytes of Kumaon and adjacent area of Garhwal including Tibet was carried out by Duthie (1906) and reported 185 taxa. Contemporarily, Mehra (1939) and Dhir & Sood (1981) enriched the diversity of ferns from Mussoorie. Singh (1931), Verma & Khullar (1980) and Khullar *et al*. (1991) accounted diversity of ferns from Nainital. Subsequently, 69 species of ferns from Dharmshala Hills were studied by Dhir & Datta (1976, 1977). Khullar *et al*. (1982) described 72 ferns from Chakrata hills. Khullar (1984) also worked on the Western Himalayas and enlisted 357 species including a few additions, corrections and annotation of ferns of this area. An updated checklist of ferns of Garhwal was framed by Khullar *et al*. (1987) and documented nearly 258 taxa. At the same time, Khullar & Sharma (1987) enumerated 245 ferns and fern-allies from Western Himalaya excluding Uttarakhand.

An updated list of pteridophytic flora of Kumaun (Himalaya) enlisting 267 species was carried out by Pangtey & Punetha (1987). Punetha & Kholia (1988, 1989a) reported *Vittaria himalayensis* Ching and *Polystichum makinoi* (Tag.) Tag., from Pithoragarh as a new record for the Western Himalaya. Khullar *et al*. (1989) listed 188 species of ferns from Shimla Hills. Pteridophytes of Pithoragarh were further revised with some additions and enlisted 206 species by Punetha & Kholia (1989b). Pande (1990) listed 322 ferns from Kumaon (Himalaya). Intensive work on the West Himalaya illustrated 172 species, 4 varieties and 10 hybrids belonging to 28 families (Vol. I) and 164 species and 14 hybrids representing 16 families of ferns have been described in the books '*An Illustrated Fern Flora of West Himalaya, Vol I and II*' by Khullar (1994, 2000). Pande & Pande (2002, 2003) described 581 species of pteridophytes from Kumaon Himalaya. Punetha *et al*. (2004) revised the pteridophyte diversity of Kumaon (Himalaya). Samant *et al*. (2005) revised pteridophytes of Nanda Devi Biosphere Reserve and listed 172 species. A floristic account of 320 fern species encompassing 88 genera from Uttarakhand has been listed by Punetha & Kholia (2010). An extensive taxonomic account of the genus *Lepisorus* from central India has been carried out by Kholia *et al*. (2012). Kholia *et al*. (2013) and added *Cyathea spinulosa* Wall. Ex Hook. and Rai *et al*. (2015) added *Aleuritopteris chrysophylla* (Hook.) Ching for the first time from Himalayan ranges of Uttarakhand. Punetha *et al*. (2013) recorded 146 lithophytic ferns and fern-allies of a total of 304 species from Kumaon. Joshi *et al*. (2018) enlisted 14 species ferns and fern-allies of Tarai west forest division, Uttarakhand.

The Himalayan ranges in Sikkim cover west, central and east Sikkim. Gammie (1893) reviewed and provided notes on *Alsophila ornata* J. Scott from Sikkim. Ching (1931) studied the genus *Vittaria* from China and Sikkim. Monumental work on pteridophytes of Sikkim and Darjeeling was carried out by Mehra & Bir (1964) and enlisted 362 ferns and fern-allies. Kalyani (2009) reported 362 species of ferns from Sikkim. Admirable work published in the two volumes of pictorial handbooks entitles '*Ferns and Fern-allies of Sikkim - A Pictorial Handbook, Part-I and II*' reported by Kholia (2010a, 2014b). Later, Kholia (2010b) described a note on silver brake fern (*Pteris subquinata*) from Gangtok, Sikkim. Kholia (2011) accounted for 500 taxa of pteridophytes from Sikkim Himalaya. Furthermore, Kholia (2012) identified 5 tree ferns species from Sikkim. A rare epiphytic species *Ophioglossum pendulum* L. was rediscovered by Kholia & Fraser-Jenkins (2014) from Sikkim Himalaya.

In northeast India, Arunachal Pradesh encompasses the Himalayan ranges. The first monumental work was carried out by Bir *et al*. (1990) and documented ferns of northeast India including some ferns from Arunachal Pradesh. Extensive work on ferns and fern-allies of Arunachal Pradesh was carried out by Singh & Panigrahi (2005) and published their work in two volumes of books '*Ferns and Fern-Allies of Arunachal Pradesh*' vol. 1 & 2. Thereafter, Rawat *et al*. (2005) gave a brief account of the pteridophytes from Maheo Wildlife Sanctuary, Arunachal Pradesh. Later, Benniamin (2010a) reported some important ferns for the first time from Arunachal Pradesh. Later, Benniamin (2010b) enlisted 122 taxa under 56 genera and 32 families from Itanagar Wildlife Sanctuary, Arunachal Pradesh. Later, Fraser-Jenkins *et al*. (2018b) outlined a checklist of fern-allies (750 species) of Arunachal Pradesh.

2.1.3 Semi-Arid: This region encompassing Punjab, Haryana, Delhi, Rajasthan, Madhya Pradesh (some north-eastern regions) and Gujarat (north, central and Saurashtra region).

Lyell (1870) reported 3 ferns from the Punjab region. Sharma *et al*. (2006) enlisted pteridophytic flora from Punjab and Shivaliks. Manhas *et al*. (2010) enumerated 4 ferns from the Kandi region of Punjab. Balkrishna *et al*. (2018) listed 16 species of ferns and fern-allies from Morni Hills, Panchkula, Haryana.

Bir & Verma (1963) enumerated 19 ferns from Mount Abu, followed by this work. Sharma & Bhardwaja (1976) recorded *Selaginella repanda* from Rajasthan. *Selaginella rajasthanensis* was described from Kundakhoh, Rajasthan by Gena (1979). Sharma & Vyas (1985) and Sharma (2002) studied ethnobotanical properties of ferns and fern-allies from Rajasthan. Bhardwaja *et al*. (1987) accounted for the endangered 36 species of pteridophytes from Rajasthan. Sharma & Sharma (1988) studied the spore morphology of 38 fern species from Rajasthan. Chaudhary *et al*. (2006) and Meena & Yadav (2016) supplemented the fern flora of Kumbhalgarh Wildlife Sanctuary and Sita Mata Wildlife Sanctuary, Rajasthan. Yadav & Meena (2009) accounted for ferns and fern-allies of the Bundi and Kota districts of Rajasthan. Further, Yadav & Goswami (2010) and Yadav *et al*. (2011) described *Ophioglossum indicum* from Mainal and *Selaginella reticulata* from Rajasthan.

2.1.4 The Western Ghats: This region extended from Gujarat (south Gujarat) in the north and ending in the south by Tamil Nadu (Kanyakumari). The Western Ghats covers Maharashtra, Goa, Karnataka, Kerala and Tamil Nadu.

The earliest noteworthy work on ferns of southern India was done by Beddome (1863, 1866, 1873, 1876). Blatter & d'Almeida (1922) worked extensively on the ferns

of the Bombay presidency (including some part of present-day Gujarat). Later, Chandra & Kaur (1987) provided a nomenclatural guide to Beddome's work on ferns of South India and ferns of British India. Manickam & Irudayaraj (1990, 1991) accounted for Thelypteridaceae and Pteridaceae from the Western Ghats, South India. Manickam & Rajkumar (1991) described polymorphic ferns of the Western Ghats, South India. An intensive work on '*Pteridophytes Flora of the Western Ghats of South India*' describing 252 species was carried out by Manickam & Irudayaraj (1992). Manickam (1995) and Benniamin *et al*. (2008) accounted for rare and endangered ferns of the Western Ghats. Dudani *et al*. (2011, 2012) detailed the diversity of 320 ferns and fern-allies from the Western Ghats while Patil *et al*. (2014a) revised genus *Ophioglossum* (8 species) from the Western Ghats of India.

Ewbani (1932) reported the ferns of Mahabaleshwar. *Marsilea poonensis* was described from Pune by Kolhatkar (1957) in error for *M. minuta*. Later, Patil & Dongare (2011) enumerated ferns from the Kolhapur district. Subsequently, Mahamuni & Dongare (2008) reported important ferns from Maharashtra. The diversity of ferns was recorded from the northern Western Ghats by Patil *et al*. (2012). Further inputs were made by Shaikh *et al*. (2012) for the ferns of Maharashtra. Patil *et al*. (2013) revised the genus *Adiantum* from Maharashtra. Dudani *et al*. (2014a) recorded a threatened tree fern. Patil & Dongare (2014, 2017) and Patil *et al*. (2014b, c, 2016) further affected the ferns of northern Western Ghats. Moreover, Patil *et al*. (2016) enriched ferns and fern-allies from Satara. Further exertions were made by Shaikh *et al*. (2018) and Das *et al*. (2019) to the ferns from the northern Western Ghats.

The monumental list on ferns of Goa was done by Irudayaraj & Bir (1997) and Mandar *et al*. (2010). Manickam *et al*. (2004) added 51 species of pteridophytes to the Goa. *Adiantum tenerum* was added new to India collected from Goa by Patil & Dongare (2013).

Rajagopal & Bhat (1998) enumerated ferns from Karnataka. Shukla *et al*. (2005) described two new species of *Isoetes* from Udupi & Lonawala. Further, Dudani *et al*. (2010, 2013, 2014b), Deepa *et al*. (2011, 2013), Mallayya *et al*. (2014) and Parashurama *et al*. (2016) enriched the diversity of ferns and fern-allies form different forest areas of Western Ghats. Patil *et al*. (2013, 2014, 2018) and Jesubalan *et al.* (2020) collected and reported an exclusive fern from the Western Ghats. Rajagopal & Bhat (2016) updated the account of pteridophytes of Karnataka. On a similar line, Tripathi *et al*. (2017)

enumerated 34 species of medicinally important pteridophytes from Kudremukh National Park of Karnataka state.

Nair & Ghosh (1973) and Madhusoodanan (1991) reported rare ferns from Kerala. Nayar & Geevarghese (1993) enlisted 178 taxa of ferns from Malabar. Madhusoodanan & Nampy (1994), Madhusoodanan & Hameed (1999), Antony *et al*. (2007) and Nisha *et al.* (2010) described some new species from Kerala. Antony *et al*. (2000), Mini *et al*. (2013), Kavitha *et al*. (2015), Vijisha & Rajesh (2016) and Rekha & Krishnan (2017) accounted diversity of pteridophytes of Kerala. Antony *et al*. (2000) listed rare, endangered and threatened ferns from Chemunji Hills, Kerala.

d'Almeida (1926) reported ferns of the High wavy Mountains of Tamil Nadu. Manickam (1986) enumerated ferns from Palni hills. Later, Manickam & Irudayaraj (2003), Sukumaran *et al*. (2006), Jeeva *et al*. (2012), Antony (2013), Benniamin & Sundari (2017) and Pounraj & Suresh (2017) listed pteridophyte flora from different conserved forest areas of Tamil Nadu.

2.1.5 Deccan Peninsula: This biogeographic region extended from central and eastern Tamil Nadu, Andhra Pradesh, Telangana, Odisha, Chhattisgarh, Jharkhand, Madhya Pradesh, central, parts of eastern Karnataka and eastern part of Maharashtra).

Gardner (1847) initiated work on pteridophytes of Nilgiri hills and described a new species of *Anemia*. Later, Beddome (1909) provided a detailed sketch of the ferns of the Nilgiri. Subramanyam *et al*. (1961) and Ghatak (1965) enlisted ferns and fern-allies from Cumbum Valley and Pachakumatchi Hills of Madurai. Manickam & Ninan (1976) enumerated ferns of Palni Hills. Viswanathan (1996), Manickam *et al*. (2004) and Parthipan *et al*. (2013) added ferns from various hills, valleys and forests of south India. Study on Koli Hills was carried out by several workers such as Sathish & Vijayakanth (2016), Vijayakanth & Sathish (2016), Vijayakanth *et al*. (2016, 2017, 2018a, b, 2019) and Sureshkumar *et al*. (2019) enriched the list of pteridophytes occurring in this area.

Noteworthy work on the pteridophyte diversity was added by Raju *et al.* (1964) who enumerated 30 species in 22 genera. Pullaiah *et al*. (2003) enlisted the diversity in the form of book '*Pteridophytes in Andhra Pradesh, India*', while, Rao *et al.* (2007) further studied ethnomedicinal important ferns species from Andhra Pradesh. Later, monumental work on diversity and conservation of ferns were carried out by Padal *et al*. (2009). Murty *et al*. (2011) recorded 13 species from Punyagiri hill. Narasimha & Lohitasyudu (2012) provided distribution of 20 species of ferns and Narasimha (2014) gave a preliminary report on ferns from Razole Mandal, Andhra Pradesh.

Significant work on ferns and fern-allies of Telangana was carried out by Odelu (2016) who reported aquatic and semi-aquatic species from Karimnagar, Ragan *et al*. (2017) recorded *Ophioglossum reticulatum* from Lankapalli, Sadasivaiah *et al*. (2018) accounted diversity of 21 species from Irumalaiah Gutta sacred grove, Wanaparthy. Mirashi & Paradkar (1961) enlisted 9 species representing 7 genera under 6 families of pteridophytes from Nagpur.

Extensive work on Pachmarhi was listed by Graham (1915). Tiwari (1964) accounted ferns of Madhya Pradesh. Likewise, Panigrahi & Dixit (1966) recorded some new records of ferns for Madhya Pradesh. Das & Datta (1980) reported 7 new records Bastar. Later, a critical study on the ecology of ferns of Madhya Pradesh was carried out by Dixit (1989) and Khare (1989) surveyed threatened and ethnomedicinal important ferns in Amarkantak hills. Vasudeva & Bir (1994) listed pteridophytic flora of Pachmarhi, Tamia & Patalkote in Pachmarhi. Further, pteridophytes of Chhindwara were studied by Omkar (2010). Pathak *et al*. (2011) detailed 15 species of ethnomedicinal uses of pteridophytes of Vindhyan Region.

A detailed list on pteridophytes of Chhattisgarh was reported by Ganguli *et al*. (2002). Jha *et al*. (2003) enlisted 32 species medicinally important pteridophytes of Bastar. Nonhare (2004) reported tree ferns from Galli Nala. Singh (2010) enumerated pteridophytic diversity of Kanger Valley National Park and Sharma & Roy (2018) listed 13 species of pteridophytes from Ambikapur Surguja, Chhattisgarh.

Noteworthy work on the ferns of Panchmarhi particular to the Mahendragiri, Odisha was carried out by Gamble (1892). Enormous works enumerating 150 species of pteridophytes were documented from the Eastern Ghats including Odisha, Bihar and Assam by Panigrahi (1960). A significant contribution to the botany of Orissa was accounted by Panigrahi *et al*. (1964), Das *et al*. (1989) listed ferns of Koraput and this work revised by Dixit (1996) and Panigrahi (1998) reported 141 ferns from Odisha.

Panda & Patnaik (2001) accounted for 36 ferns and 5 fern-allies from Puri District. Rout *et al.* (2009) studied 33 species of ethnomedicinal important pteridophytes of Similipal biosphere reserve. Further contributing to the Mahendragiri hills was done by Sahu *et al*. (2013).

A pioneer work on ferns and fern-allies of Jharkhand was initiated by Kumari & Srivastava (2008). Later, Singh & Sahu (2015) revised the pteridophyte flora of the Ranchi district.

2.1.6 Gangetic Plains: This region is extended in the north form Uttar Pradesh to the south-east side of Bihar and West Bengal.

The first report from this precise region was recorded by Anderson (1859) from Lucknow, Uttar Pradesh. Subsequent work was carried out by Chowdhury & Raizada (1954) reported 57 ferns and fern-allies from the Upper Gangetic Plain. Subsequently, Raizada & Chowdhury (1961) accounted fern-allies of the Upper Gangetic Plain. Bhattacharya (1963) worked on ferns of Mirzapur. Chowdhury (1973) enlisted 72 pteridophytes from the Upper Gangetic Plains. Extensive work was detailed in the book by Ghosh *et al*. (2004) in '*The Pteridophytic Flora of Eastern India - I*'. Ecological studies on ferns and fern-allies from Sonbhadra were studied by Khare *et al*. (2005). Singh & Singh (2011) enlisted 17 species of pteridophytes from Varansi. Singh *et al*. (2015) enumerated ferns of Dudhwa National Park. A monumental work on ferns and fern-allies of Uttar Pradesh was carried out by Singh *et al*. (2017), who listed 59 species of them 49 species reported for the very first time for Uttar Pradesh.

The foremost work on pteridophytes, listing 56 species from Bihar was carried out by Haines (1922). Mehta (1956) enumerated ferns of Parasnath (Bihar). Pravesh & Singh (2001) studied the distribution and ecology of *Ophioglossum* from the Chhota Nagpur plateau.

Panigrahi & Patnaik (1961) worked on diverse forest areas of Eastern Ghats and enlisted 79 species of Polypodiaceae. A preliminary sketch of 5 fern-allies and 48 ferns were enumerated by Sikdar *et al*. (1983). Sen *et al*. (2010) worked on biodiversity of pteridophytes of Sundarbans. Fortythree taxa of fern and fern allies have been listed by Sarkar *et al*. (2012). Mukherjee & Mitra (2013) evaluated ethnobotanical property of north Bengal 23 species of pteridophytes. Revision on ferns of Hooghly was carried out by Ghosh & Mazumdar (2018).

2.1.7 Coasts: Indian coast are engaged in the areas of Diu and Daman, Goa, Pondicherry. Gopal (1968) described a new species *Marsilea maheshwarii* from a coastal area of Pondicherry.

2.1.8 North-East India: This biogeographic zone encompassing Assam, Meghalaya, Tripura, Mizoram, Manipur and Nagaland.

Bir *et al*. (1989, 1991) and Vasudeva *et al*. (1990) studied '*Pteridophytic Flora of North-Eastern India I-V*' (Families: Huperziaceae-Sinopteridaceae; Cryptogrammaceae-Thelypteridaceae; Aspleniaceae-Oleandraceae; Davalliaceae-Salviniaceae and ecological, distributional and phytogeographic account). Rawat & Benniamin (2018)

revised family Polypodiaceae in northeast India including Arunachal Pradesh, Assam, Manipur, Sikkim, Mizoram, Meghalaya, Tripura and Nagaland. Further, Rawat *et al*. (2018) studied the diversity, distribution and ecology of 9 species under the genus *Arthromeris* in north-east India.

An immense work on ferns of Assam was conducted by Hope (1890), Kachroo (1975) and enlisted 89 ferns from Assam, Sikkim and Nepal. Subsequently, Handique & Konger (1986) listed ferns and fern-allies of greater Guwahati. Borthakur *et al*. (2001) published a book on '*Illustrated Manual of Ferns of Assam*' accounted 221 species. Later, Nath & Sharma (2008) enumerated pteridophytes of Laokhowa Wildlife Sanctuary. Bhattacharya (2009) listed some threatened ferns of Barak Valley. Dey *et al*. (2011) revised the ferns of Barak Valley and listed 159 species, 1 subsp. and 2 varieties. Consequently, an ethnobotanical study was carried out by Sen & Ghosh (2011) from Assam. Rathoure (2017) listed 16 ferns from Nagaon, Assam.

Ferns and Fern-allies of Meghalaya state and *The Ferns of Nagaland* were published by Baishya & Rao (1982) and Jamir & Rao (1988). Later, Singh *et al*. (2012) enlisted 98 ferns and 15 fern-allies from Nokrek Biosphere Reserve of them, 25 species were added to the Meghalaya. Joshi *et al*. (2015) reported *Adiantum hispidulum* from Senapati and *Cheilanthes tenuifolia* from Manipur.

Chandra & Chandra (1983) contributed to the ferns of Mizoram. Later, Benniamin (2012) studied the diversity of pteridophytes from Murlen National park, Mizoram. Moreover, rare ferns were reported for the very first time from Mizoram by Sharma *et al*. (2013, 2018). Barbhuiya & Singh (2014) enlisted 36 ferns from Thorangtlang Wildlife Sanctuary, Mizoram. Das & Sen (1991) reported fern flora of Tripura State.

2.1.9 Islands: This area encircling Andaman and Nicobar, Lakshadweep.

Nayar & Srivastava (1962) provided a initial record on the *Fern Flora of the Great Andaman Island*. *Lindsaea parasitica* was reported as new to India collected from Nicobar Island by Dixit & Ghosh (1978). Ellis (1987) listed the pteridophytic flora of the Andaman and Nicobar Islands. Another significant work was done by Dixit & Sinha (2001) in the book '*Pteridophytes of Andaman and Nicobar Islands*'. Future contribution in pteridophytes of south Andaman was carried out by Singh & Medhi (2006) reported a total of 50 species. Singh *et al*. (2011, 2016) reported *Thelypteris polycarpa* and *Diplazium proliferum* from Little Andaman and added new to India and an Andaman and

Nicobar Island respectively. Singh *et al*. (2016) gave detailed notes on the occurrence and distribution of two filmy ferns from the Andaman and Nicobar Islands.

2.2 Work on Gymnosperms of India:

A notable enlisted report on five gymnosperms occurring in Punjab and Sindh area was done by Aitchison (1869). Later, Stewart (1869) recorded 9 taxa from Punjab and Himachal Pradesh. Subsequently, Watt (1889-1893) recorded *Abies smithiana* (Wall.) Lindl., and *Ephedra vulgaris* Rich., from the Himalayan region. Thiselton-Dyer (1883) described *Cycas beddomei* from southern India.

Later, Gammie (1898) enumerated 10 species of gymnosperms from the Himalayan region. Collelt (1902) enlisted 11 taxa from Shimla. Bamber (1916) enlisted 6 taxa from Kashmir Himalaya, Punjab and Himachal Pradesh. The Conifers of India was revised by Biswas (1933) reported and reported 29 wild taxa. Furthermore, Puri & Gupta (1951) studied the ecology of Himalayan conifers in detail. Later, Raizada & Sahni (1960) enlisted 40 species belonging to Cycadales, Ginkgoales and Coniferales occurring in India and adjacent countries. Dogra (1964) published a monograph on Chilgoza pine (*Pinus gerardiana* Wall.) which includes 17 taxa. Subsequently, Shabnam (1964) detailed medicinal uses of 8 species of gymnosperms from Himachal Pradesh, while, Gupta (1971) recorded 6 commercially important medicinal gymnosperms from the Himalaya. Furthermore, Chowdhury (1974) detailed a monograph on *Abies* and *Picea*. Murti & Uniyal (1985) revised gymnosperms from Himachal Pradesh and recorded 24 taxa. Mehra (1988) studied morphology, cytology and phylogeny of Indian Conifers and Gnetophytes. A magnificent work was carried out by Sahni (1990), who published a book on gymnosperms of India and adjacent countries. Later, Srivastava (1993) provided a brief taxonomic account of 24 species in 18 genera belonging to 10 families of gymnosperms found in Sikkim. Kaushal (1994) detailed two trees species and three shrubs of *Juniperus* from the Western Himalayas. Samant *et al*. (1998) studied 12 medicinally important gymnosperms of the Indian Himalaya. Uniyal & Anjali (2000) enlisted 18 wild and 22 introduced taxa of gymnosperms from Uttar Pradesh. Dar & Christensen (2003) worked on gymnosperms of the Western Himalaya. Subsequently, Seth (2006) listed planted/naturally occurring 147 taxa of gymnosperms in India. Srivastava (2006) carried out detailed studies on the diversity and economic importance of 101 species, 4 varieties and one forma of living gymnosperms from India. Lindstrom & Hill (2007) studied the genus *Cycas* in India and reported 8 taxa. Singh (2007) studied the economic importance of living gymnosperms in India. Pandey & Diwakar (2008)

updated the checklist on gymnosperms of Andaman and Nicobar Islands. Sharma & Uniyal (2008) described *Ephedra sumlingensis* from Himachal Pradesh. Singh & Radha (2008) described *Cycas swamyi* from Karnataka. Later, Tripathi *et al*. (2009) enumerated 15 species belonging to 14 genera of gymnosperms from Nainital. Subsequently, Sharma *et al*. (2010) described *Ephedra kardangensis* and *Ephedra khurikensis* from Lahaul and Spiti Districts of Himachal Pradesh. The diversity of 31 taxa of gymnosperms from Uttarakhand was carried out by Tewari *et al*. (2010). Das & Yadav (2011) accounted distribution of *Gnetum montanum* Markgraf in Terai and Duars of West Bengal. Kandi *et al*. (2011) reported 2 gymnosperms from Sunabeda wildlife sanctuary, Odisha. Jeevith *et al*. (2014) enriched the gymnosperms of Nilgiris District, Tamil Nadu and listed 43 species belonging to 20 genera under 10 families including wild and exotic species. Further, Khuraijam & Singh (2015) and Khuraijam & Mujumdar (2019) revised gymnosperms from Northeast India and western Himalaya. Prasad *et al*. (2015) described *Cycas andamanica* from the Andaman Islands. Sharma & Singh (2015) described *Ephedra pangiensis* from Himachal Pradesh. *Ephedra yangthangensis* was described from Himachal Pradesh by Sharma & Singh (2016). Srivastava (2017) provided a note on indigenous pines of India. Moreover, Singh *et al*. (2018a) revised studies on gymnosperms diversity of the Himalaya Biodiversity Hotspot. Singh *et al*. (2018b) reported *Juniperus chinensis* L. new to South Asia. Later, Khuraijam *et al*. (2020) revised the genus *Gnetum* from India.

2.3 Pteridophytic Studies and reports from Gujarat State:

The first and foremost report from the state was recorded in '*Plants of Northern Gujarat*' by Saxton and Sedgwik (1918) and reported *Ceratopteris thalictroides* from the river bed of Watrak. Later, Mahabale (1948) studied the prothalli of *Ceratopteris thalictroides* collected from the Sabarmati river bed. Furthermore, Phatak *et al*. (1953) enumerated four species of *Ophioglossum viz*., *Ophioglossum fibrosum, O. vulgatum, O. reticulatum* and *O. nudicaule* from Harni pond, Baroda (Vadodara) and reported for the first time for Baroda, Bombay Precedency. Gaekwad & Deshmukh (1954) collected *Isoetes* from Baroda, Bombay state and reported as unidentified species and further in 1956 was reported with confirmed identification *i.e*. *I. coromandeliana*, from the Director, Royal Botanical Garden, Kew. The occurrence of *Ophioglossum gramineum* was reported the first time from Harni, Baroda (Vadodara) by Chavan & Mehta (1956). *Marsilea quadrifolia* and *Azolla* sp. were recorded by Chavan & Padate (1960) from Savli Taluka. Further, Chavan & Sabnis (1961) enumerated *Isoetes coromandeliana*,

Azolla sp. and *Marsilea quadrifolia* from Baroda and environs. *Ophioglossum fibrosum*, *O. vulgatum*, *Adiantum* sp. and *Marsilea quadrifolia* was listed by Chavan *et al*. (1961) from Devgadh hills and adjoining area, Devgadh Baria. Chavan & Padate (1962) enlisted *Ceratopteris thalictroides, Azolla pinnata, Marsilea minuta, M. quadrifolia, Equisetum debile* from Savali Taluka. Chavan & Padate (1963) revised the occurrence and distribution of *Ceratopteris thalictroides* in Gujarat and recorded from four places *viz*., Savali (Savli, Javala and Karcia); Rajpipla (Rajpipla-Laldarwaja road along the bank of river Karjan and Bharambha forest); Ratanmahal (hill tracts); Khedbramha (Savalia Tank at Derol Jagir) and Junagadh (foot of the Girnar hills). The cultural behaviour of prothalli of *Ceratopteris thalictroides* was carried out by Mahabale (1963) collected from the Sabarmati river bed. Shah & Vaidya (1964) reported the occurrence of *Ophioglossum reticulatum* for the first time in Dangs forests. Nayar & Devi (1964) carried out spore morphology of *Athyrium solenopteris* and *Tectaria cicutaria* collected from Girnar, Saurashtra. Inamdar & Shah (1967) reported new localities of *Ophioglossum nudicaule* var. *macrorrhizum* and *O. nudicaule* from Dharampur, of them; *O*. *nudicaule* var. *macrorrizum* was recorded as new for the state. Padate (1969) revised the flora of Savli taluka and enlisted *Ceratopteris thalictroides* and *Equisetum debile*. Contribution on the development of stomata in *Ophioglossum nudicaule, O*. *nudicaule* var. *macrorrhizum* and *O*. *costatum* collected from Dharampur forest was done by Inamdar (1970). Later, Thaker *et al*. (1971) enumerated five species of pteridophytes *viz*., *Actiniopteris austrialis, Adiantum lunulantum, Marsilea quadrifolia, Ophioglossum fibrosum* and *Selaginella* sp. from Chhotaudepur ranges. A study for the presence of antibacterial substances of a total of 13 ferns was carried out by Kshirsagar & Mehta (1973); this study includes collection from Gujarat and some species from Mount Abu, Rajasthan *viz*., *Adiantum incisum, A. lunulatum*, *A. trapiziforme*, *Aleuritopteris farinosa, Athyrium falcatum, A. filix-femina*, *Nephrolepis cordifolia, N. exaltata*, *Nephrolepis* sp., *Dryopteris crenata, Pteris vittata, Tectaria macrodanta* and *Actiniopteris austrialis*. Gandhi *et al*. (1976) reported *Ophioglossum fibrosum* for the first time from Girnar hills (Junagadh) and the Saurashtra region. A compilation of all reported ferns and fern-allies of Gujarat was done by Gujarat Ecological Commission (1996) and enumerated 16 species representing 13 genera in the wild and 26 species belonging to 9 genera under cultivation. Nagar & Pandya (2003) also listed four species of pteridophytes *viz*., *Adiantum* sp., *Actiniopteris australis, Ophioglossum fibrosum* and *Marsilea quadrifolia* from Barda hills and their surroundings. Parmar (2008) enumerated *Actiniopteris radiata*

(Taranga Hills and Taranmata) and *Adiantum lunulantum* (Taranga Hills) from the Mehsana district. Patel *et al*. (2010) recorded *Marsilea minuta* and *Nephrolepis* sp. from the campus of Arts, Commerce and Science college of Borsad. Dabgar (2012) listed *Azolla pinnata* and *Marsilea* sp. from Wadhvana wetland, Dabhoi. Parmar (2012) listed *Azolla africana* from Vijaynagar, Sabarkantha district. Later, Modi & Dudani (2013) enlisted *Azolla pinnata*, *Marsilea minuta* and *Nephrolepis* sp. from Gujarat University Campus, Ahmedabad. Parikh *et al*. (2015) studied aquatic weeds in Harni and Gotri ponds of Vadodara and recorded *Azolla pinnata* var. *imbricata* and *Marsilea quadrifolia*. Dudani & Gavali (2016) reported *Thelypteris prolifera* collected from Mahuva, Surat as a new fern record for Gujarat state; which is a duplication of the recorded ferns of Gujarat. This fern was already reported earlier by Kachhiyapatel *et al*. (2016) and additional distribution record for *Ceratopteris thalictroides* collected from Veraval, Gir-Somnath.

Fraser Jenkins *et al*. (2018) documented *Ceratopteris thalictroides* (L.) Brogn. subsp. *gaudichaudii* (Brongn.) Fraser-Jenk. & Pariyar in his book on "*Checklist of Indian Pteridophytes Part 2*". As a source of information, he has cited reference of Rajput *et al*. (2016a), however, in that article it is mentioned as *C. thalictroides* and there is no mention about the *C. thalictroides* subsp. *gaudichaudii*. Similarly, Fraser-Jenkins *et al*. (2018a) has also reported *Diplazium esculentum* (Retz.) Sw. from Gujarat state.

Patel & Reddy (2018a) described a new species *i.e. Ophioglossum malviae* Mitesh Patel & Mandadi Narsimha Reddy, based on the size of the plant, spore morphology and molecular identification. Further, Patel & Reddy (2018b) added some mistaken identification of previously reported pteridophytes from the state. Moreover, Patel & Reddy (2018c) reported *Equisetum ramosissimum* Desf. subsp. *debile* from the Mayadevi Temple, Dangs district, Gujarat. Morecover, Patel & Reddy (2018d) recorded *Cheilanthes tenuifolia* from near Zand Hanuman. Patel *et al*. (2018e) and Patel & Reddy (2018) described two new taxa *i.e. Ophioglossum aletum* Patel, Reddy & Goswami and *Ophioglossum hitkishorei* M. Patel & M. N. Reddy from Baripada, and Kodmal, Dang district respectively.

2.4 Studies on Gymnosperms of Gujarat State:

A sporadic work on gymnosperms, that occur naturally or exotic species occurring in different parts of the state were carried out by various researchers. The first report on the occurrence of exotic species *i.e. Thuja occidentalis* was recorded by Bharti (1959) from Visnagar. Thereafter, Inamdar & Bhatt (1972) worked on epidermal

structure and ontogeny of stomata of *Ephedra* sp., collected from Bet Dwarka. Subsequently, Joshi *et al*. (2006), Joshua *et al*. (2008), Joshi (2009), Patel *et al*. (2012); Joshi *et al*. (2013) recorded rare and endangered plant species (*i.e*. *Ephedra foliata*) near Bhuj, Kachchh district and its surrounding. Afterwards, Pandey *et al*. (2009) studied the phytodiversity of *E. foliata* from Narayan Sarovar Wildlife Sanctuary, Kachchh. Patel *et al*. (2010) recorded three ornamental gymnosperms from the campus of Arts, Commerce & Science College, Borsad. Modi and Dudani (2013) enlisted two ornamental gymnosperms from the campus of Gujarat University, Ahmedabad. Subsequently, Khokhariya *et al*. (2014) collected *E. foliata* from the island of Bet Dwarka. Meena (2014) listed one species of gymnosperm from Bhavnagar.