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Research Article

# Diversity and distribution of Pteridophytes from Satara District, Maharashtra (India)

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## Abstract

The diversity and distribution along different ecological gradients of eighty six species of pteridophytes from the Satara district were studied. Amongst these species most common species were viz., *Adiantum philippense*, *Aleuritopteris bicolor*, *Azolla pinnata subsp. asiatica*, *Marsilea minuta*, *Pityrogramma calomelanos*, *Pteridium revolutum*, *Pteris vittata*, *Selaginella ciliris* and *Tectaria coadunata*.

## Keywords

Altitude; Rainfall; Sahyadri; Western Ghats

## Introduction

Pteridophytes are an ancient group of species, characterized as a significant plant group in biogeography as they are with a large number of relict and endemic taxa. They provide us a lot of information about the evolution of plants, their components and on evolutionary aspects of biogeography (Tryon and Tryon, 1982). Generally, the pteridophytes are distributed along a latitudinal gradient, with the highest diversity in the tropics (mainly in mountainous areas) (Kornas, 1993). The most common environmental variables related to floristic composition from local to regional scales are soil characteristics (nutrients content and texture), topography, (Vormisto and Svenning, 2004), moisture availability and the length of the dry period (Engelbrecht et al., 2005; Zuquimet et al., 2009).

The diversity and distribution of pteridophytes from different biogeographical regions of India had been carried out by various pteridologists, viz., Punetha (1989), Bir et al. (1991), Joshi et al. (1999), Chaudhary and Dulawat (2006), Joshi and Pande (2006). Recently, diversity and distribution of pteridophytes from northern Western Ghats were studied by Patil et al. (2012).

However, there is no such report on the diversity and distributional studies of Pteridophytes from Satara district (Maharashtra). This emphasizes to study the diversity and distribution of the pteridophytes along with a different altitudinal zones. The maximum diversity was observed at the high altitude zone, high rainfall zone, high atmospheric humidity and low temperature zone.

## Material and Methods

The study of spatial distribution of pteridophytes along the environmental gradients viz., altitude, temperature, rainfall and atmospheric humidity were carried out from Satara district (Map 1). The altitude range was measured by using GPS (Garmin GPSmap 60CSx). However, the categorization of pteridophytes based on rainfall, temperature and humidity is constructed on the basis of data available in the meteorological center (Table 1).

## Results and Discussion

Each species of fern has its own preferences of micro habitat depending on the temperature, humidity, soil type, moisture, pH, light intensity, etc., and in many cases are very specific indicators of the conditions they need. It is well observed and noted that most species of ferns succeed under high humidity and shade conditions unless they are species that prefer more xeric conditions and are more heliophilous (Dudani *et al.*, 2014). The change in diversity and distribution along the ecological gradients and potential mechanism were studied.

During the present investigation diversity and distribution of 86 species of pteridophytes along the various ecological gradients viz., elevation gradient, rainfall zones, temperature and atmospheric humidity in Satara district were studied and grouped under respective categories.

### Diversity and distribution of pteridophytes along altitudinal ranges

The altitudinal gradient is a complex one and varied in climate, edaphic and biotic factors. With increasing elevation, there is a decrease in temperature and an increase in precipitation, relative humidity and increases soil moisture. The maximum height of Satara district is 1500 m. Based on the altitude range pteridophytes were categorized into three zones viz., Foothill zone (below 600 m), Middle hill zone (above 600 and below 1000 m) and high elevation zone (above 1000 m).

**1) Foothills zone pteridophytes:** The zone below the 600 m is considered as foothills zone. The zone is occupied by following pteridophytes:

*Adiantum philippense* L., *Aleuritopteris anceps* Blanf., *A. bicolor* (Roxb.) Fraser-Jenk., *Asplenium yoshinagae* Makino, *Athyrium hohenackerianum* (Kunze) T. Moore, *Azolla pinnata* subsp. *asiatica* R.M.K. Saunders and K. Fowler., *Ceratopteris thalictroides* (L.) Brongn, *Cheilanthes tenuifolia* (Burm. f.) Sw., *Christella dentata* (Forssk.) Brownsey and Jermy, *Christella parasitica* (L.) Holttum., *Isoetes dixitii* Shende, *I. coromandeliana* L.f., *Lepisorus nudus* (Hook) Ching., *Lindsaea ensifolia* Sw., *Lygodium flexuosum*

(L.) Sw., *Marsilea minuta* L., *Microsorium membranaceum* (D. Don) Ching., *Nephrolepis undulate* (Afzel.) J.Sm., *Selaginella delicatula* (Desv.ex Poir.) Alston., *S. ciliaris* (Ritz.) Spring, *S. tenera* (Hook and Grev.) Spring., *Ophioglossum costatum* R. Br., *O. gramineum* Willd., *O. lusitanicum* L., *O. nudicaule* L., *O. petiolatum* Hook., *Pityrogramma calomelanos* (L.) Link, *Pteris biaurita* L., *P. pellucida* C. Presl., *P. vittata* L., *Pyrrosia lanceolata* (Wall.) Farw, *Salvinia molesta* D. Mitch., *Tectaria coadunata* (Wall. ex Hook. and Grev.) C. Chr.

**2) Middle hill zone pteridophytes:** The zone in between 600 – 1100 m. The zone occupied by the following pteridophytes:

*Actiniopteris radiata* (Sw.) Link., *Adiantum caudatum* L., *A. capillus-veneris* L., *A. incisum* Forssk., *A. philippense* L., *A. raddianum* C. Presl., *Aleuritopteris albomarginata* (C.B. Clarke) Ching., *A. anceps* Blanf., *A. bicolor* (Roxb.) Fraser-Jenk., *Angiopteris helferiana* C. Presl., *Araiostegia pulchra* (D. Don) Copel, *Asplenium yoshinagae* Makino, *Athyrium hohenackerianum* (Kunze) T. Moore, *A. micropterum* Bedd., *Azolla pinnata* subsp. *asiatica* R.M.K. Saunders and K. Fowler., *Blechnum orientale* L., *Bolbitis angustipinna* (Hayata) H. Ito, *B. appendiculata* var. *asplenifolia* (Bory) Sledge, *B. preseliana* (Fee) Ching., *B. prolifera* (Bory) C. Chr. & Tardieu-Blot, *B. subcrenatoides* Frazer Jenkins, *B. virens* (Wall. ex Hook. and Grev.) Schott, *Ceratopteris thalictroides* (L.) Brongn, *Cheilanthes tenuifolia* (Burm. f.) Sw, *Christella dentata* (Forssk.) Brownsey and Jermy., *C. parasitica* (L.) Holttum., *Crepidoman eslatealatum* (Bosch) Copel., *Diplazium esculentum* (Retz.) Sw., *Dryopteris cochleata* (Buch.Ham.ex D. Don) C. Chr., *Equisetum ramosissimum* Desf., *Huperzia hamiltonii* (Spreng. ex Grev. and Hook.) Trevis., *Hypodematium crenatum* subsp. *crenatum*, *Isoetes coromandeliana* L.f., *Isoetes dixitii* Shende, *Lepisorus nudus* (Hook) Ching., *Lindsaea ensifolia* Sw., *L. heterophylla* Dryand., *Lygodium flexuosum* (Linn.) Sw., *Marsilea minuta* L., *Microlepis speluncae* (L.) T. Moore, *Microsorium membranaceum* (D. Don) Ching., *Ophioglossum costatum* R. Br., *O. gramineum* Wild., *O. lusitanicum* L., *O. nudicaule* L., *O. parvifolium* Grev. and Hook, *O. petiolatum* Hook., *O. reticulatum* L., *Osmunda huegeliana* C. Presl., *Pityrogramma calomelanos* (L.) Link, *Pteris biaurita* L., *P. blumeana* J. Agardh, *P. pellucid* C. Presl., *P. heteromorpha* Fee., *P. venusta* Kunze, *P. vittata* L., *Pyrrosia lanceolata* (Wall.) Farw., *Selaginella ciliaris* (Ritz.) Spring, *S. delicatula* (Desv. ex Poir.) Alston., *S. tenera* (Hook and Grev.) Spring., *Salvinia molesta* D. Mitch., *Tectaria coadunata* (Wall. ex Hook. and Grev.) C. Chr., *T. paradoxa* (Fee) Sledge etc.

**3) High elevation zone pteridophytes:** The zone above 1100 m is considered here as higher elevation zone. This is the most favourable zone



**Map 1. A map showing tehsils in Satara district**

for the growth of pteridophytes due to cool climate, high atmospheric moisture and high soil moisture that help pteridophytes to proliferate extensively. Maximum number of pteridophytes were found from this zone, they are:

*Actiniopteris radiata* (Sw.) Link., *Adiantum caudatum* L., *A. capillus-veneris* L., *A. incisum* Forssk., *A. philippense* L., *A. poiretii* Wikstr., *A. raddianum* C. Presl., *Aleuritopteris albomarginata* (C.B. Clarke) Ching., *A. anceps* Blanford., *A. bicolor* (Roxb.) Fraser-Jenk., *A. rufa* (D. Don) Ching., *Angiopteris helferiana* C. Presl., *Anogramma leptophylla* (L.) Link., *Araiostegia pulchra* (D. Don) Copel., *Asplenium decrescens* Kunze., *A. inaequilaterale* Willd., *A. polyodon* G. Forst. *A. yoshinagae* Makino, *Athyrium falcatum* Bedd., *A. hohenackerianum* (Kunze) T. Moore, *A. parasnathense* (Kunze) T. Moore, *A. pectinatum* (Wall. ex Mett.) T. Moore, *Azolla pinnata* subsp. *asiatica* R.M.K. Saunders and K. Fowler., *Blechnum orientale* L., *Bolbitis angustipinna* (Hayata) H. Ito, *B. appendiculata* var. *asplenifolia* (Bory) Sledge, *B.*

*presliana* (Fee) Ching., *B. prolifera* (Bory) C. Chr. and Tardieu-Blot, *B. subcrenatooides* Frazer Jenkins, *B. virens* (Wall. ex Hook. and Grev.) Schott., *Botrychium lanuginosum* Wallich ex Hooker and Greville, *Ceratopteris thalictroides* (L.) Brongn., *Cheilanthes tenuifolia* (Burm. f.) Sw., *Christella dentata* (Forssk.) Brownsey and Jermy., *C. parasitica* (L.) Holttum., *Crepidomanes latealatum* (Bosch) Copel., *Deparia petersenii* (Kunze) M. Kato, *Diplazium esculentum* (Retz.) Sw., *Dryopteris cochleata* (Buch.Ham.ex D. Don) C. Chr., *D. sparsa* (Buch. Ham. ex D. Don) Kuntze, *Huperzia hamiltonii* (Spreng. ex Grev. and Hook.) Trevis., *Hypodematium crenatum* (Forssk.) Kuhn. subsp. *crenatum*, *Isoetes coromandeliana* L. f., *I. dixitii* Shende, *I. panchganiensis* Srivastava and Pant., *I. sahyadrensis* Mahabale, *Lepisorus nudus* (Hook) Ching., *Leptochilus decurrens* Blume., *Leucostegia truncata* Frazer Jenkins, *Lindsaea heterophylla* Dryand., *Marsilea minuta* L., *Microlepia speluncaea* (L.) T. Moore, *Microsorium membranaceum* (D. Don) Ching., *Ophioglossum costatum* R. Br.,



*Ophioglossum gramineum* Willd., *O. lusitanicum* L., *O. nudicaule* L., *O. parvifolium* Grev. and Hook, *O. petiolatum* Hook., *O. reticulatum* L., *Osmunda huegeliana* C. Presl., *Pityrogramma calomelanos* (L.) Link, *Pteridium revolutum* (Blume) Nakai, *Pteris biaurita* L., *P. blumeana* J. Agardh, *P. liniaris* Poir., *P. pellucida* C. Presl., *P. vittata* L., *Pyrrosia lanceolata* (Wall.) Farw., *Salvinia molesta* D. Mitch., *Selaginella ciliaris* (Ritz.) Spring., *S. crassipes* Spring., *S. delicatula* (Desv. ex Poir.) Alston., *S. repanda* (Desv. ex Poir.) Spring., *S. tenera* (Hook and Grev.) Spring., *Tectaria coadunata* (Wall. ex Hook. and Grev.) C. Chr., *Tectaria paradoxa* (Fee) Sledge.

### Diversity and distribution of pteridophytes on the basis of rainfall

It is one of the important climatic factors that restrict the distribution of pteridophytes because pteridophytes are water loving plants, grow well where the water content high in the atmosphere and soil. The average rainfall of Satara district is 1450 mm per year. Eastern part of the district like Man tehsils, part of Phaltan and Khatav experiences very low rain (443 mm per year) while, the Western part of a district like Mahabaleshwar, Patan, Jaoli is having high rainfall (6000 mm per year) and rest of having moderate rainfall (2000–3000 mm per year). On this basis pteridophytes of Satara district were categorized into three categories viz., high rainfall zone (above 3000 mm), Moderate rainfall zone (below 3000 mm and above 1000 mm) and low rainfall zone (below 1000). The observed pteridophytes at various rainfalls are given in fig. 2. Maximum diversity was observed as high rainfall zone (75 species) whereas minimum diversity was observed at low rainfall zone (12 species).

**a. High Rainfall Pteridophytes:** The zone where rainfall is more than 3000 mm per annum. Maximum numbers of pteridophytes were collected from this region. They are as follows:

*Adiantum capillus-veneris* L., *Adiantum caudatum* L., *Adiantum incisum* Forssk., *Adiantum philippense* L., *Adiantum poiretii* Wikstr., *Adiantum raddianum* C. Presl., *Aleuritopteris albomarginata* (C.B. Clarke) Ching., *Aleuritopteris anceps* Blanf., *Aleuritopteris bicolor* (Roxb.) Fraser-Jenk., *Aleuritopteris rufa* (D. Don) Ching., *Angiopteris helferiana* C. Presl., *Anogramma leptophylla* (L.) Link., *Araiostegia pulchra* (D. Don) Copel., *Asplenium decrescens* Kunze., *Asplenium inaequilaterale* Willd., *Asplenium polyodon* G. Forst., *Asplenium yoshinagae* Makino, *Athyrium falcatum* Bedd., *Athyrium hohenackerianum* (Kunze) T. Moore, *Athyrium micropterum* Bedd., *Athyrium parasnathense* (Kunze) T. Moore, *Athyrium pectinatum* (Wall. ex Mett.) T. Moore, *Azolla pinnata* subsp. *asiatica* R.M.K. Saunders and K. Fowler., *Blechnum orientale* L., *Bolbitis*

*angustipinna* (Hayata) H. Ito, *B. appendiculata* var. *asplenifolia* (Bory) Sledge, *B. presliana* (Fee) Ching., *B. subcrenatooides* Frazer Jenkins, *B. virens* (Wall. ex Hook. and Grev.) Schott., *B. prolifera* (Bory) C. Chr. and Tardieu-Blot, *Botrychium lanuginosum* Wallich ex Hooker and Greville, *Ceratopteris thalictroides* (L.) Brongn., *Cheilanthes tenuifolia* (Burm. f.) Sw., *Christella dentata* (Forssk.) Brownsey and Jermy., *Christella parasitica* (L.) Holttum., *Crepidomanes latealatum* (Bosch) Copel., *Deparia petersenii* (Kunze) M. Kato, *Diplazium esculentum* (Retz.) Sw., *Dryopteris cochleata* (Buch. Ham. ex D. Don) C. Chr., *Dryopteris sparsa* (Buch. Ham. ex D. Don) Kuntze, *Huperzia hamiltonii* (Spreng. ex Grev. and Hook.) Trevis., *Hypodematum crenatum* (Forssk.) Kuhn. subsp. *crenatum*, *Isoetes coromandeliana* L. f., *Isoetes dixitii* Shende, *Isoetes panchganiensis* Srivastava and Pant., *Isoetes sahyadrensis* Mahabale, *Lepisorus nudus* (Hook) Ching., *Leptochilus decurrens* Blume., *Leucostegia truncata* Frazer Jenkins, *Lindsaea ensifolia* Sw., *Lindsaea heterophylla* Dryand., *Lygodium flexuosum* (Linn.) Sw., *Marsilea minuta* L., *Microlepis speluncae* (L.) T. Moore, *Microsorium membranaceum* (D. Don) Ching., *Microsorium punctata* (L.) Copel., *Nephrolepis cordifolia* (L.) Presl., *Nephrolepis exaltata* (L.) Schott., *Nephrolepis undulata* (Afzel.) J. Sm., *Ophioglossum costatum* R. Br., *Ophioglossum gramineum* Willd., *Ophioglossum lusitanicum* L., *Ophioglossum nudicaule* L., *Ophioglossum parvifolium* Grev. and Hook, *Ophioglossum petiolatum* Hook, *Ophioglossum reticulatum* L., *Osmunda huegeliana* C. Presl., *Pityrogramma calomelanos* (L.) Link, *Pteridium revolutum* (Blume) Nakai, *Pteris biaurita* L., *P. blumeana* J. Agardh, *P. heteromorpha* Fee, *P. liniaris* Poir., *P. pellucida* C. Presl., *P. venusta* Kunze, *P. vittata* L., *Pyrrosia lanceolata* (Wall.) Farw., *Salvinia molesta* D. Mitch., *Selaginella ciliaris* (Ritz.) Spring., *S. crassipes* Spring., *S. delicatula* (Desv. ex Poir.) Alston., *S. repanda* (Desv. ex Poir.) Spring., *S. tenera* (Hook and Grev.) Spring., *Tectaria coadunata* (Wall. ex Hook. and Grev.) C. Chr., *T. paradoxa* (Fee) Sledge.

**b. Moderate rainfall Pteridophytes:** The zone where rainfall is above 1000 mm but below 3000 mm per annum. The pteridophytes growing in this zone are as follows:

*Actiniopteris radiata* (Sw.) Link., *Adiantum capillus-veneris* L., *A. caudatum* L., *A. incisum* Forssk., *A. philippense* L., *Aleuritopteris albomarginata* (C.B. Clarke) Ching., *A. anceps* Blanf., *A. bicolor* (Roxb.) Fraser-Jenk., *Asplenium yoshinagae* Makino, *Athyrium hohenackerianum* (Kunze) T. Moore, *Azolla pinnata* subsp. *asiatica* R.M.K. Saunders and K. Fowler., *Christella dentata* (Forssk.) Brownsey and Jermy., *Christella parasitica* (L.) Holttum., *Diplazium esculentum* (Retz.) Sw., *Equisetum ramosissimum* Desf., *Hypodematum crenatum* (Forssk.) Kuhn. subsp.

**Table 1.** Tehsilwise average Meteorological data of Satara District (2008 – 2013)

Name of tehsils / Parameters	Altitudinal range (m)	Temperature (°C)	Rainfall (mm)	Relative humidity (%)
Mahabaleshwar	1000 – 1450	13 – 34	3000 – 1500	50 - 95
Jaoli	0900 – 1200	15 – 35	2500 – 4000	45 – 90
Patan	0900 – 1200	12 – 34	3000 – 4500	55 – 95
Wai	0800 – 1400	15 – 35	2000 – 3000	45 – 85
Khandala	0800 – 1000	15 – 38	1500 – 2000	40 – 75
Satara	0600 – 1000	14 – 38	1500 – 3000	45 – 80
Karad	0500 – 0800	16 – 38	1000 – 2000	40 – 70
Koregoan	0400 – 0600	18 – 38	1000 – 1100	40 – 60
Phaltan	0300 – 0550	18 – 40	1000 – 1200	25 – 60
Khatav	0300 – 0500	18 – 40	0600 – 0800	20 – 55
Man	0300 – 0500	18 – 42	0400 – 0600	10 – 50

*crenatum*, *Isoetes coromandeliana* L. f., *I. dixitii* Shende, *Lepisorus nudus* (Hook) Ching., *Marsilea minuta* L., *Ophioglossum costatum* R. Br., *O. gramineum* Willd., *O. lusitanicum* L., *O. nudicaule* L., *O. parvifolium* Grev. and Hook, *O. petiolatum* Hook., *O. reticulatum* L., *O. smunda huegeliana* C. Presl., *Pityrogramma calomelanos* (L.) Link, *Pteridium revolutum* (Blume) Nakai, *Pteris biaurita* L., *P. blumeana* J. Agardh, *P. heteromorpha* Fee, *P. liniaris* Poir., *P. pellucida* C. Presl., *P. venusta* Kunze, *P. vittata* L., *Pyrrosia lanceolata* (Wall.) Farw., *Salvinia molesta* D. Mitch., *Selaginella ciliaris* (Ritz.) Spring., *S. crassipes* Spring., *S. delicatula* (Desv. ex Poir.) Alston., *S. repanda* (Desv. ex Poir.) Spring., *S. tenera* (Hook and Grev.) Spring., and *Tectaria coadunata* (Wall. ex Hook. and Grev.) C. Chr.

**c. Low rainfall Pteridophytes:** It is the zone where rainfall is very little, i.e. below 1000 mm per annum. Very few species were adapted to this region they are,

*Actinopteris radiata* (Sw.) Link., *Adiantum philippense* L., *Aleuritopteris bicolor* (Roxb.) Fraser-Jenk., *Azolla pinnata* subsp. *asiatica* R.M.K. Saunders and K. Fowler., *Marsilea minuta* L., *Ophioglossum petiolatum* Hook., *Pityrogramma calomelanos* (L.) Link., *Pteridium revolutum* (Blume) Nakai, *Pteris biaurita* L., *P. vittata* L., *Salvinia molesta* D. Mitch., *Selaginella ciliaris* (Ritz.) Spring., *Tectaria coadunata* (Wall. ex Hook. and Grev.) C. Chr., etc

### Diversity and distribution of pteridophytes based on atmospheric humidity

Pteridophytes are very sensitive to the change in atmospheric humidity. On this basis pteridophytes are grouped into 3 perspective categories, viz., high humidity zone (where the atmospheric

humidity is above 70%), moderate humidity zone (where the atmospheric humidity is in between 35-70%) and low humidity zone (where the humidity is below 35%). The maximum diversity was observed at the high humidity zone, whereas low was observed at low humid zone.

**a. High Humidity zone:** In this zone the atmospheric humidity is above 70% and the pteridophytes which grow in this zone are as given below:

*Adiantum capillus-veneris* L., *A. caudatum* L., *A. incisum* Forssk., *A. philippense* L., *A. poiretii* Wikstr., *A. raddianum* C. Presl., *Aleuritopteris albomarginata* (C.B. Clarke) Ching., *A. anceps* Blanford., *A. bicolor* (Roxb.) Fraser-Jenk., *A. rufa* (D. Don) Ching., *Angiopteris helferiana* C. Presl., *Anogramma leptophylla* (L.) Link. *Araiostegia pulchra* (D. Don) Copel., *Asplenium decrescens* Kunze., *A. inaequilaterale* Willd., *A. polyodon* G. Forst., *A. yoshinagae* Makino, *Athyrium falcatum* Bedd., *A. hohenackerianum* (Kunze) T. Moore, *A. micropterum* Bedd., *A. parasnathense* (Kunze) T. Moore, *A. pectinatum* (Wall. ex Mett.) T. Moore, *Azolla pinnata* subsp. *asiatica* R.M.K. Saunders and K. Fowler., *Blechnum orientale* L., *Bolbitis angustipinna* (Hayata) H. Ito, *Bolbitis appendiculata* var. *asplenifolia* (Bory) Sledge, *Bolbitis presliana* (Fee) Ching., *Bolbitis subcrenatooides* Frazer Jenkins, *Bolbitisvirens* (Wall. ex Hook. and Grev.) Schott., *Bolbitis X prolifera* (Bory) C. Chr. and Tardieu-Blot, *Botrychium lanuginosum* Wallich ex Hooker and Greville, *Ceratopteris thalictroides* (L.) Brongn., *Cheilanthes tenuifolia* (Burm. f.) Sw., *Christella dentata* (Forssk.) Brownsey and Jermy., *Christella parasitica* (L.) Holttum., *Crepidomanes latealatum* (Bosch) Copel., *Deparia petersenii* (Kunze) M. Kato, *Diplazium esculentum* (Retz.) Sw., *Dryopteris cochleata* (Buch.Ham. ex D. Don) C. Chr., *D. sparsa* (Buch.

Ham.ex D. Don) Kuntze, *Huperzia hamiltonii* (Spreng. ex Grev. and Hook.) Trevis., *Hypodematium crenatum* (Forssk.) Kuhn. subsp. *crenatum*, *Isoetes coromandeliana* L. f., *Isoetes dixitii* Shende, *Isoetes panchganiensis* Srivastava and Pant., *Isoetes sahyadrensis* Mahabale, *Lepisorus nudus* (Hook) Ching., *Leptochilus decurrens* Blume., *Leucostegia truncata* Frazer Jenkins, *Lindsaea ensifolia* Sw., *Lindsaea heterophylla* Dryand., *Lygodium flexuosum* (Linn.) Sw., *Marsilea minuta* L., *Microlepidia spelunca* (L.) T. Moore, *Microsorium membranaceum* (D. Don) Ching., *Microsorium punctata* (L.) Copel., *Nephrolepis cordifolia* (L.) Presl., *Nephrolepis exaltata* (L.) Schott., *Nephrolepis undulata* (Afzel.) J.Sm., *Ophioglossum costatum* R. Br., *Ophioglossum gramineum* Willd., *Ophioglossum lusitanicum* L., *Ophioglossum nudicaule* L., *Ophioglossum parvifolium* Grev. and Hook, *Ophioglossum petiolatum* Hook., *Ophioglossum reticulatum* L., *Osmunda huegeliana* C. Presl., *Pityrogramma calomelanos* (L.) Link, *Pteridium revolutum* (Blume) Nakai, *Pteris biaurita* L., *P. blumeana* J. Agardh, *P. heteromorpha* Fee, *P. liniaris* Poir., *P. pellucida* C. Presl., *P. venusta* Kunze, *P. vittata* L., *Pyrrosia lanceolata* (Wall.) Farw., *Salvinia molesta* D. Mitch., *Selaginella ciliaris* (Ritz.) Spring., *S. crassipes* Spring., *S. delicatula* (Desv. ex Poir.) Alston., *S. repanda* (Desv. ex Poir.) Spring., *S. tenera* (Hook and Grev.) Spring., *Tectaria coadunata* (Wall. ex Hook. and Grev.) C. Chr., *Tectaria paradoxa* (Fee) Sledge

**b. Moderate humidity zone:** The pteridophytes growing in this zone are as follows:

*Actiniopteris radiata* (Sw.) Link., *Adiantum capillus-veneris* L., *Adiantum caudatum* L., *Adiantum incisum* Forssk., *Adiantum philippense* L., *Aleuritopteris albomarginata* (C.B.Clarke) Ching., *A. anceps* Blanf., *A. bicolor* (Roxb.) Fraser-Jenk., *Asplenium yoshinagae* Makino, *Athyrium hohenackerianum* (Kunze) T. Moore, *Azolla pinnata* subsp. *asiatica* R.M.K. Saunders and K. Fowler., *Christella dentata* (Forssk.) Brownsey and Jermy., *Christella parasitica* (L.) Holttum., *Diplazium esculentum* (Retz.) Sw., *Equisetum ramosissimum* Desf., *Hypodematium crenatum* (Forssk.) Kuhn. subsp. *crenatum*, *Isoetes coromandeliana* L. f., *Isoetes dixitii* Shende, *Lepisorus nudus* (Hook) Ching., *Marsilea minuta* L., *Ophioglossum costatum* R. Br., *Ophioglossum gramineum* Willd., *Ophioglossum lusitanicum* L., *Ophioglossum nudicaule* L., *Ophioglossum parvifolium* Grev. and Hook, *Ophioglossum petiolatum* Hook., *Ophioglossum reticulatum* L., *Osmunda huegeliana* C. Presl., *Pityrogramma calomelanos* (L.) Link, *Pteridium revolutum* (Blume) Nakai, *Pteris biaurita* L., *P. blumeana* J. Agardh, *P. heteromorpha* Fee, *P. liniaris* Poir., *P. pellucida* C. Presl., *P. venusta* Kunze, *P. vittata* L., *Pyrrosia lanceolata* (Wall.) Farw., *Salvinia molesta* D. Mitch., *Selaginella ciliaris* (Ritz.) Spring., *S.*

*crassipes* Spring., *S. delicatula* (Desv. ex Poir.) Alston., *S. repanda* (Desv. ex Poir.) Spring., *S. tenera* (Hook and Grev.) Spring., *Tectaria coadunata* (Wall. ex Hook. and Grev.) C. Chr., etc.

**c. Low humid zone:** The zone where humidity is below 25 %, very few species were adapted to this region. They are *Actiniopteris radiata* (Sw.) Link., *Adiantum philippense* L., *Aleuritopteris bicolor* (Roxb.) Fraser-Jenk., *Azolla pinnata* subsp. *asiatica* R.M.K. Saunders and K. Fowler., *Marsilea minuta* L., *Ophioglossum petiolatum* Hook., *Pityrogramma calomelanos*, *Pteridium revolutum* (Blume) Nakai, *P. biaurita* L., *P. vittata* L., *Salvinia molesta* D. Mitch., *Selaginella ciliaris* (Ritz.) Spring, and *Tectaria coadunata* (Wall. ex Hook. and Grev.) C. Chr.

### Diversity and distribution of pteridophytes based on Temperature

It is one of the important climatic factors on which distribution of pteridophytes depends. A very little change in temperature affects the diversity of pteridophytes. During the present investigation pteridophytes were grouped into three different categories based on the temperature as given below:

**a. Low temperature zone:** In this zone pteridophytes grow below 18° C. They are as follows:

*Adiantum capillus-veneris* L., *A. caudatum* L., *A. incisum* Forssk., *A. philippense* L., *A. poiretii* Wikstr., *A. raddianum* C. Presl., *Aleuritopteris albomarginata* (C.B.Clarke) Ching., *A. anceps* Blanf., *A. bicolor* (Roxb.) Fraser-Jenk., *A. rufa* (D.Don) Ching., *Angiopteris helferiana* C. Presl., *Anogramma leptophylla* (L.) Link., *Araiostegia pulchra* (D. Don) Copel., *Asplenium decrescens* Kunze., *A. inaequilaterale* Willd., *A. polyodon* G. Forst., *A. yoshinagae* Makino, *Athyrium falcatum* Bedd., *A. hohenackerianum* (Kunze) T. Moore, *A. micropterum* Bedd., *A. parasnathense* (Kunze) T. Moore, *A. pectinatum* (Wall. ex Mett.) T. Moore, *Azolla pinnata* subsp. *asiatica* R.M.K. Saunders and K. Fowler., *Blechnum orientale* L., *Bolbitis angustipinna* (Hayata) H. Ito, *B. appendiculata* var. *asplenifolia* (Bory) Sledge, *B. presliana* (Fee) Ching., *B. subcrenatoides* Frazer Jenkins, *B. virens* (Wall. ex Hook. and Grev.) Schott., *B. prolifera* (Bory) C. chr. and Tardieu-Blot, *Botrychium lanuginosum* Wallich ex Hooker and Greville, *Ceratopteris thalictroides* (L.) Brongn., *Cheilanthes tenuifolia* (Burm. f.) Sw., *Christella dentata* (Forssk.) Brownsey and Jermy., *Christella parasitica* (L.) Holttum., *Crepidomanes latealatum* (Bosch) Copel., *Deparia petersenii* (Kunze) M. Kato, *Diplazium esculentum* (Retz.) Sw., *Dryopteris cochleata* (Buch.Ham.ex D. Don) C. Chr., *Dryopteris sparsa* (Buch. Ham. ex D. Don) Kuntze, *Huperzia hamiltonii* (Spreng. ex Grev.



and Hook.) Trevis., *Hypodematium crenatum* (Forssk.) Kuhn. subsp. *crenatum*, *Isoetes coromandeliana* L. f., *Isoetes dixitii* Shende, *Isoetes panchganiensis* Srivastava and Pant., *Isoetes sahyadrensis* Mahabale, *Lepisorus nudus* (Hook) Ching., *Leptochilus decurrens* Blume., *Leucostegia truncata* Frazer Jenkins, *Lindsaea ensifolia* Sw., *Lindsaea heterophylla* Dryand., *Lygodium flexuosum* (Linn.) Sw., *Marsilea minuta* L., *Microlepia speluncae* (L.) T. Moore, *Microsorium membranaceum* (D. Don) Ching., *Microsorium punctata* (L.) Copel., *Nephrolepis cordifolia* (L.) Presl., *N. exaltata* (L.) Schott., *N. undulata* (Afzel.) J.Sm., *Ophioglossum costatum* R. Br., *O. gramineum* Willd., *O. lusitanicum* L., *O. nudicaule* L., *O. parvifolium* Grev. and Hook, *O. petiolatum* Hook., *O. reticulatum* L., *Osmunda huegeliana* C. Presl., *Pityrogramma calomelanos* (L.) Link, *Pteridium revolutum* (Blume) Nakai, *Pteris biaurita* L., *P. blumeana* J. Agardh, *P. heteromorpha* Fee, *P. liniaris* Poir., *P. pellucida* C. Presl., *P. venusta* Kunze, *P. vittata* L., *Pyrrosia lanceolata* (Wall.) Farw., *Salvinia molesta* D. Mitch., *Selaginella ciliaris* (Ritz.) Spring., *S. crassipes* Spring., *S. delicatula* (Desv. ex Poir.) Alston., *S. repanda* (Desv. ex Poir.) Spring., *S. tenera* (Hook and Grev.) Spring., *Tectaria coadunata* (Wall. ex Hook. and Grev.) C. Chr., *Tectaria paradoxa* (Fee) Sledge.

**b. Moderate temperature zone:** It is the zone where the temperature is above 18°C but below 25°C. The pteridophytes growing in this zone are as follows:

*Actiniopteris radiata* (Sw.) Link., *Adiantum capillus-veneris* L., *A. caudatum* L., *A. incisum* Forssk., *A. philippense* L., *Aleuritopteris albomarginata* (C.B. Clarke) Ching., *A. anceps* Blanf., *A. bicolor* (Roxb.) Fraser-Jenk., *Asplenium yoshinagae* Makino, *Athyrium hohenackerianum* (Kunze) T. Moore, *Azolla pinnata* subsp. *asiatica* R.M.K. Saunders and K. Fowler., *Christella dentata* (Forssk.) Brownsey and Jermy., *Christella parasitica* (L.) Holttum., *Diplazium esculentum* (Retz.) Sw., *Equisetum ramosissimum* Desf., *Hypodematium crenatum* (Forssk.) Kuhn. subsp. *crenatum*, *Isoetes coromandeliana* L. f., *I. dixitii* Shende, *Lepisorus nudus* (Hook) Ching., *Marsilea minuta* L., *Ophioglossum costatum* R. Br., *O. gramineum* Willd., *O. lusitanicum* L., *O. nudicaule* L., *O. parvifolium* Grev. and Hook, *O. petiolatum* Hook., *O. reticulatum* L., *Osmunda huegeliana* C. Presl., *Pityrogramma calomelanos* (L.) Link, *Pteridium revolutum* (Blume) Nakai, *Pteris biaurita* L., *P. blumeana* J. Agardh, *P. heteromorpha* Fee, *P. liniaris* Poir., *P. pellucida* C. Presl., *P. venusta* Kunze, *P. vittata* L., *Pyrrosia lanceolata* (Wall.) Farw., *Salvinia molesta* D. Mitch., *Selaginella ciliaris* (Ritz.) Spring., *S. crassipes* Spring., *S. delicatula* (Desv. ex Poir.) Alston., *S. repanda* (Desv. ex Poir.) Spring., *S. tenera* (Hook and Grev.) Spring., *Tectaria coadunata* (Wall. ex Hook. and Grev.) C. Chr., etc.

**c. High temperature zone:** In this zone temperature is above 25°C, very few species were adapted to this region. They are *Actiniopteris radiata* (Sw.) Link., *Adiantum philippense* L., *Aleuritopteris bicolor* (Roxb.) Fraser-Jenk., *Azolla pinnata* subsp. *asiatica* R.M.K. Saunders and K. Fowler., *Marsilea minuta* L., *Ophioglossum petiolatum* Hook., *Pityrogramma calomelanos*, *Pteridium revolutum* (Blume) Nakai, *Pteris biaurita* L., *P. vittata* L., *Salvinia molesta* D. Mitch., *Selaginella ciliaris* (Ritz.) Spring., *Tectaria coadunata* (Wall. ex Hook. and Grev.) C. Chr., etc.

## Discussion

The maximum pteridophytes were observed above 1000m (high altitude, 77 species) whereas only 34 species were observed at low altitude (600 m). The most common pteridophyte species viz., *Adiantum philippense* L., *Aleuritopteris anceps* Blanf., *A. bicolor* (Roxb.) Fraser-Jenk., *Asplenium yoshinagae* Makino, *Christella dentata* (Forssk.) Brownsey and Jermy, *Christella parasitica* (L.) Holttum., *Isoetes coromandeliana* L.f., *I. dixitii* Shende, *Lepisorus nudus* (Hook) Ching., *Marsilea minuta* L., *Microsorium membranaceum* (D. Don) Ching., *Selaginella delicatula* (Desv. ex Poir.) Alston., *Selaginella ciliaris* (Ritz.) Spring., *Selaginella tenera* (Hook and Grev.) Spring., *Ophioglossum costatum* R. Br., *O. gramineum* Willd., *O. lusitanicum* L., *O. nudicaule* L., *O. petiolatum* Hook., *O. reticulatum* L., *Pityrogramma calomelanos*, *Pteris biaurita* L., *P. pellucida* C. Presl., *P. vittata* L., *Pyrrosia lanceolata* (Wall.) Farw., *Salvinia molesta* D. Mitch., *Selaginella ciliaris* (Ritz.) Spring., *S. crassipes* Spring., *S. delicatula* (Desv. ex Poir.) Alston., and *Tectaria coadunata* (Wall. ex Hook. and Grev.) C. Chr., were found growing from low to high altitudinal zones. However, the species like *Aleuritopteris rufa* (D. Don) Ching., *Angiopteris helferiana* C. Presl., *Anogramma leptophylla* (L.) Link., *Asplenium polyodon* G. Forst., *Athyrium pectinatum* (Wall. ex Mett.) T. Moore, *Deparia petersenii* (Kunze) M. Kato, *Dryopteris sparsa* (Buch. Ham. ex D. Don) Kuntze, *Isoetes panchganiensis* Srivastava and Pant., and *Isoetes sahyadrensis* Mahabale, are considered as high altitudinal pteridophytes. Biologists have recognized the variations in species richness along the elevation gradients. Lellinger (1985) reported the greatest number of pteridophytes in mountain forests of Panama at 1500 m., a similar result was found by Parris *et al.*, (1992). Hemp (2002) studied the ecology of pteridophytes on the southern slopes of Mt. Kilimanjaro. He found the highest numbers of species were observed between 1200–1800 m a.s.l., similar results were observed during the present investigation on distribution of pteridophytes along altitudinal gradients.

Numerous classifications of vegetation have been proposed based on climatic factors (Troll, 1959; Lauer, 1986). The climatic factors, viz. temperature, atmospheric humidity, rainfall, etc.

influence the species richness along the elevation gradients (Whittaker *et al.*, 1967). During the present investigation maximum diversity (84 species) of pteridophytes were observed in the high rainfall zone, high atmospheric and low temperature whereas low (13 species) were grown at low rainfall, low humidity and high temperature zones. The species like *Adiantum philippense* L., *Aleuritopteris bicolor* (Roxb.) Fraser-Jenk., *Marsilea minuta* L., *Microsorium membranaceum* (D. Don) Ching., *Ophioglossum costatum* R. Br., *O. gramineum* Willd., *O. lucitanicum* L., *O. nudicaule* L., *O. petiolatum* Hook., *Pityrogramma calomelanos*, *Pteris biaurita* L., *Pteris vittata* L., *Selaginella ciliaris* (Ritz.) Spring., *S. delicatula* (Desv. ex Poir.) Alston., and *Tectaria coadunata* (Wall. ex Hook. and Grev.) C. Chr., were found to be common in the zones. However, the species like *Adiantum poiretii* Wikstr., *Aleuritopteris rufa* (D. Don) Ching., *Angiopteris helferiana* C. Presl., *Anogramma leptophylla* (L.) Link., *Asplenium inaequilaterale* Willd., *A. polyodon* G. Forst., *Athyrium pectinatum* (Wall. ex Mett.) T. Moore, *Athyrium micropterum* Bedd., *Botrychium lanuginosum* Wallich ex Hooker and Greville., *Deparia petersenii* (Kunze) M. Kato, *Dryopteris sparsa* (Buch. Ham. ex D. Don) Kuntze, *Isoetes pachyandensis* Srivastava and Pant., *Isoetes sahyadrensis* Mahabale, *Leptochilus decurrens* Blume., *Leucostegia truncata* Frazer Jenkins and *Tectaria paradoxa* (Fee) Sledge., were strictly grow at high rainfall, high atmospheric humidity and low temperature region. Bhattarai and Vetaas (2003) studied the fern species richness along the central Himalayan elevational gradient, Nepal. According to them fern richness has a unimodal response along the energy gradients and a linear response to moisture gradients. They also stated that the importance of moisture on fern distribution as the peak coincide spatially with climatic factors that enhance the moisture level. All the above observations on the distribution of pteridophytes along different climatic factors of Satara district were agreed with investigations of earlier authors in different geographical regions of the globe.

## Conclusion

Species diversity and distribution at different altitudinal zones were diverse based on their withstanding capacity to those conditions. Similarly, pteridophytic flora may be controlled by the environmental factors such as temperature, rainfall and humidity whereas the deep ravines, continuously flowing streams, water channels, thick evergreen forests regulate the canopy of this attractive vegetation.

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