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# Ferns diversity in sacred groves of Kodagu: Central Western Ghat

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**Abstract**
A present study on the fern flora diversity in two different vegetation types of sacred groves of Kodagu was conducted and enumerated for the first time. A total of 36 fern taxa are recorded. Species diversity indices (Species richness, Shannon, Simpson, and Margalef) were more in Semi-evergreen (30, 2.90, 0.07 and 4.06) than moist deciduous (19, 2.43, 0.12, and 2.75). *Tectaria paradoxa* recorded maximum frequency, density, and IVI among the species. Seven species are generalist to both vegetation and three species i.e *Athyrium hohenackerianum*, *Diplazium esculentum*, *Drynaria quercifolia* specialist to moist deciduous vegetation whereas three species i.e *Arachnoides sledge*, *Asplenium formosum*, *Angiopteris helferiana* are specialist to semi evergreen vegetation. Overall among the two vegetation, semi-evergreen is the best site for ferns. This study gives an understanding of the diversity of ferns in sacred groves which would help in the conservation and management of the species.

**Keywords:** Ferns, pteridophytes, diversity, sacred groves

## Introduction
Ferns are cosmopolitan and mostly grow in humid tropical areas. The distribution of pteridophytes range from humid tropics to the Arctic Circle but are most abundant in tropical rain forests, moist meadows, alongside streets and rivers [1]. Though ferns are represented by less than 10,000 extant species, they are considered to be necessary because of their size and particular characteristics. The total number of ferns and fern allies found in the world is 13,600 species [2], 1200 species in India [3, 4], 233 species in South Western Ghats [5] and 91 species in Karnataka [6]. The Western Ghats is dominated by fern families such as Aspleniaceae, Polypodiaceae, Thelypteridaceae, Selaginellaceae and Pteridaceae [7]. Traditionally ferns are used for curing many diseases as well as for food and ornamental purpose *viz*. *Drynaria quercifolia* against Jaundice, *Diplazium esculentum* and *Tectaria polymorpha* for food and *Nephrolepis exaltata* and *Nephrolepis undulata* for ornamental [8]. However, the diversity of ferns of Western Ghats is under continuous threat to several natural as well as man-made disasters like forest fire, deforestation, flood and landslides *etc*.
Habitat destruction by man and natural calamities also affects the species richness and evenness. Therefore, for maintaining the ecological harmony, *in-situ* conservation of fern is the need of the hour. Conservation of the forest will not only help the conservation of plants but it will also help the people who depend primarily on the forest products for their food, medicine and other needs. Ferns receive less attention compared to that of other plant groups because society considers them unbeneficial. However, it is not true because, Theophrastus (327-287 BC) and Dioscorides (50 AD) had referred to the economical and the medicinal attributes of certain ferns [9]. The ferns had an essential role in folklore. These plants have been successfully used in Ayurvedic, Unani, Homeopathic, and other systems of medicines.
In India, sacred groves are found all over the country and are known by various vernacular names [10]. Kodagu is one of the densely forested districts in India, with 75 percent of landscape under tree cover. The total geographical area of Kodagu district is 4104 sq. km, of which coffee plantations cover 29 percent of the area and natural forest occupies around 46 percent of the geographical area. About 16 percent of the forested area is found outside the reserve forest which are in central part of the district, which are both under government (Sacred groves, Revenue land, *etc*.) as well as in private holdings (bane lands) [11]. Total Forest area in Kodagu district is of 4,35,694.80 ha in that Devarakadus (sacred groves) comprises 2,550.45 ha of forest area. Since these groves are distributed throughout the landscape, they represent diverse microclimatic conditions and associated biodiversity [12].

Sacred groves are a prime attraction since ancient times in Kodagu and associated with unique Kodava culture, which is the most eco-friendly practice and of nature worship. This umbilical linkage between humans and nature was passed on from one generation to another. This is one of the methods of conserving nature, which is in vogue in India from time immemorial. According to the Karnataka Forest Department survey, Kodagu district has 1,214 scared groves and there is one sacred grove for every 300 hectares of land, and this density could be one of the highest in the world. Kodagu is the only region in India where groves are owned by the forest department and declared as Protected Forest, but are managed by local communities as common property resources. Every village in the district has at least one scared grove and 24 villages have ten or more sacred sites. Sacred groves are one of the least studied but the important forest ecosystems of this region. No studies have been reported so far on ferns present in sacred groves in this ecosystem and also the Flora of Kodagu has no mention and descriptions on pteridophytes.

**Study sites:** A cluster of four villages in each semi evergreen and moist deciduous vegetation types were selected for study based on preliminary study [13]. The details of the study sites are provided in Table 1, Fig.1 & Plate1.

**Table 1:** Details of the selected study sites

| Vegetation type | Sl. No | Name of the grove | Village name | Altitude (m) | Area of grove (ha)* |
|---|---|---|---|---|---|
| Semi evergreen | 1 | Kovale Aiyappa | Mythadi | 886 | 3.3 |
| | 2 | Aiyappa | Kadanur | 897 | 9.3 |
| | 3 | Kakottu Aiyappa | Muggula | 1025 | 8.7 |
| | 4 | Uttarat Aiyappa | Bilagunda | 924 | 2.3 |
| | 5 | Mandath Chamundi | Mythadi | 910 | 1.27 |
| | 6 | Bhagavathi | Kadanur | 912 | 1.42 |
| | 7 | Parel Aiyappa | Muggula | 931 | 0.51 |
| | 8 | Kirlakad Aiyappa | Bilagunda | 940 | 0.60 |
| Moist deciduous | 9 | Bhadrakali | Besaguru | 876 | 4.5 |
| | 10 | Aiyappa | Nalluru | 849 | 3.45 |
| | 11 | Kuttichathan | Kiraguru | 870 | 4.4 |
| | 12 | Bhagavathi | Mugutageri | 862 | 18 |
| | 13 | Bhadrakali | Besaguru | 848 | 0.75 |
| | 14 | Betaguru aiyappa | Nalluru | 840 | 0.7 |
| | 15 | Bhadrakali | Kiraguru | 885 | 1.7 |
| | 16 | Kuttchathana | Mugatageri | 851 | 1.4 |

*The area of the sacred grove has been obtained by the records maintained by the Karnataka Forest Department.

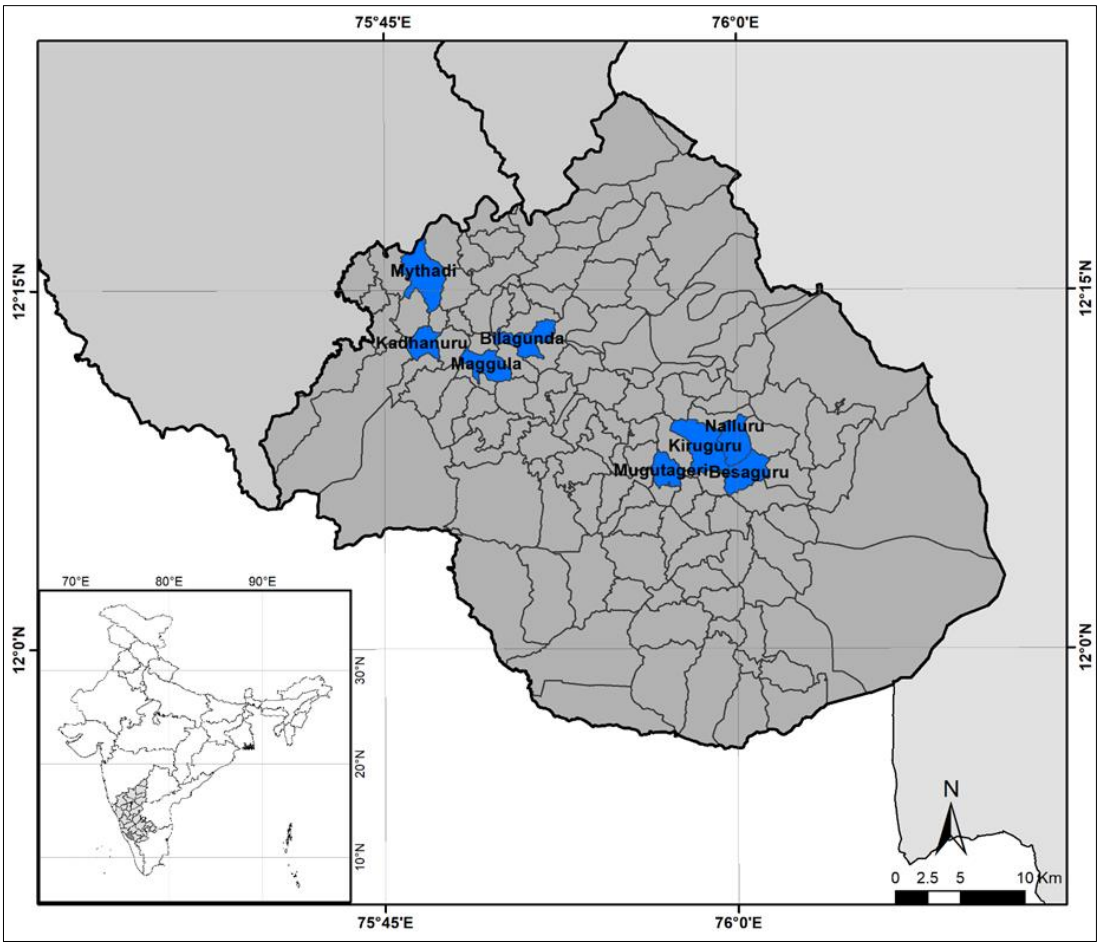


**Fig 1:** Map showing geographic location of the villages under study area


**Plate 1:** Deities of sacred groves. A) Mandath Chamundi, Mythadi. B) Bhatamakki Aiyappa, Mythadi. C) Kakottu Aiyappa, Muggala. D) Bhagavathi, Mugatageri. E) Mallamatti Aiyappa, Mythadi. F) Parle Aiyappa, Muggala. G) Uttarat Aiyappa, Bilagunda. H) Aiyappa, Rudrabedu. I) Bhadrakali, Kiraguru. J) Bhadrakali, Besaguru. K) Kuttichathana, Mugatageri. L) Aiyappa, Nalluru.

## Methodology

In order to assess the fern diversity, stratified random sampling technique was followed in moist deciduous and semi evergreen vegetation types. In each vegetation type, belt transect of 5 meter width and 100 meter length was laid. Sampling intensity was one percent of total area. In order to assess the host taxa preference, all trees enumerated in belt transect were observed for vascular epiphytes occurring on host tree. Each sampled tree was schematically divided into 5 horizons for sampling [14].

Identification of specimen's was done referring literature, pteridophytes floras [15-17] and consulting fern's scientist like Gopal Krisna Bhat, Rajgopal. Estimation of fern diversity was done using standard indices like Shannon[18], Simpson and Margalef. Similarity between sacred groves and between vegetation's was done using Sorenson's similarity index and Importance value index (IVI) [19] was also calculated for the ferns.

## Results and Discussion

### Species richness

In the study area 36 ferns belonging 17 families and 28 genera were recorded (Plate 2-4). Of them 29 are terrestrial and 7 species are epiphytic ferns. Dominant family was Polypodiaceae (7 spp.) followed by Pteridaceae (4 spp.). Polypodiaceae family is found to be dominant because all ferns in this family exhibit certain characteristics considered to be evolutionarily advanced—i.e., long-stalked, spore-producing structures (sporangia) characterized by the presence of an incomplete, vertically arranged band of thick-walled cells (annulus). Also, the dominance of this family members is akin to have established niche in the sacred groves where it effectively utilizes the partitioned resources well than other family species. Similar observations were recorded by Vidhyashree, 2018 [20] from the study conducted in Mudigere region of Karnataka where Polypodiaceae with eight species was the dominant family recorded in addition to 34 fern species belonging to 18 families, of which 29 species were terrestrial and five epiphytic and this was followed by Pteridaceae (5 spp.). This establishes the reason that this Polypodiaceae family prefers the specific microclimate that supports its population across wider landscape. Marked difference in level of diversity and composition was found across vegetation. Semi evergreen had highest of 30 species while moist deciduous had lowest of 19 species. A total 16625 individuals /ha (semi evergreen-9130, moist deciduous-7495) were sampled in which *Tectaria paradoxa* was most prominent one (semi evergreen n=1228, moist deciduous n=1499); *Adiantum philippense* was the second predominantly found species (semi evergreen n=942, moist deciduous n=455) (Table 2 & 3). Interestingly, irrespective of the vegetation *Tectaria paradoxa* and *Adiantum philippense* were the top two ferns in study area.

In the present study, *Lygodium flexuosum* and *Stenochlaena palustris* are the only climbing ferns commonly seen growing on trees. The reason for presence of only few climbing ferns could be due to the presence of host species with particular bark characteristics where bark pattern is important morphological feature to support many epiphytic species. Such rare species with climbing habit need to be given attention for conservation and the associated host also need to be taken into consideration for conservation as host species play an important role to support the fern species with climbing habit. Similar observations reported by Deepa *et al.*

2013b [21] in Madhuguni state forest where *Lygodium flexuosum* was only one climbing fern. *Bolbitis semicordata* is endemic fern as reported by Rajgopal and Bhat, 1999 [6]. Most of the other fern species were found abundantly distributed in different localities *viz.* partially shaded roadsides, moist habitats with low light intensities, along shaded stream banks, on partially and fully exposed grassy slopes on the forest edge. Similar observations were recorded by Vidhyashree, 2018 [20] in Mudigere region.

In moist deciduous vegetation type, the highest fern density was found in *Tectaria paradoxa* with 1499 individuals per ha and lowest was found in *Cyathea gigantea* and *Pyrrosia porosa* with nine individuals per ha. In semi evergreen vegetation type, highest fern density was found in *Tectaria paradoxa* with 1228 individuals per ha and lowest was found in *Lygodium microphyllum* with three individuals per ha. This variation in density might be due to the reason that, each fern species has its own preference for temperature, humidity, soil type, moisture. Combined with these parameters, another important ecological factor that influences the density and abundance of the species is the canopy dynamics which regulates solar flux that reaches forest floor to enhance the edaphic role in supporting higher density and abundance of the species.

Species richness is the easy way to describe community and regional diversity [22] and this varying number of species forms the basis of many ecological models of community structure [23]. Both anthropogenic and natural factors can influence the species richness and diversity [24]. Variation in species richness in different location could be due to variation in topographic factors like altitude, latitude, longitude, slope and biotic factors like past and present management activities and anthropogenic pressure. The estimated species richness value of different vegetation types are presented in the (Table 4.). The results in the present study revealed the considerable variation in species richness between different vegetation types. Among two vegetation types, substantially highest species richness was recorded in semi evergreen vegetation (30) and lowest in moist deciduous vegetation (19). Maximum number of fern species in semi evergreen is mainly due to biotic and abiotic factors such as edaphic factors such as acidic soil, litter accumulation along streams and water bodies and among biotic factors, shade bearing trees, host tree branching patterns and soil macro fungus such as mushrooms which supports fern survival. Lower number of fern species in moist deciduous is due to disturbance level, open canopy which leads obnoxious weed growth like *Lantana camara*, grazing which ultimately decrease ferns growth and development. These results are in accordance with the findings of Deepa *et al*., 2013a, 2013b [25, 21] where the highest number of fern species was seen in semi evergreen Kigga forest (31) followed by moist deciduous Kemmanagundi forest (23). Variation in composition of fern species across vegetation type could be due to vegetation structure and disturbance level.

The evenness measures a value between 0 and 1 which being complete evenness [22]. In the present study, evenness indices ranged between 0.61 and 0.60 for semi evergreen and moist deciduous vegetation types respectively (Table 4). These values indicating the good equitable distribution of the fern species which opines that almost all species represent in the sacred groves with equal number of individuals contributes to higher diversity. This could be due to each fern species has its own preference for temperature, humidity, soil type, moisture etc. Any kind of variation in these microclimatic conditions can hinder the growth and evolutionary processes occurring naturally in these plants thereby, leading to decline in their evenness. Species were found to be distributed evenly in semi evergreen than moist deciduous vegetation. The higher evenness in semi evergreen vegetation type results in the equal sharing of resource available among the species. Similar observations reported by Raghavendra, 2003 [13] where evenness was ranged between 0.71 and 0.75 for tree species in sacred groves under semi evergreen and moist deciduous vegetation in Virajpet taluk.

**Table 2:** Population status of wild ferns in sacred groves of moist deciduous vegetation type

| Sl. No | Fern name | Fern density in different sacred groves (No. of individuals/ha) | | | | | | | | Individuals (per ha) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Mugatageri | | Nalloor | | Kiraguru | | Besaguru | | |
| | | Bhagavati | Kuttachatana | Bhattamakki Aiyappa | Betaguru Aiyappa | Kuttichathan | Bhadrakali | Bhadrakali | Bhadrakali | |
| 1 | *Adiantum capillus veneris* | 50 | 0 | 261 | 4286 | 0 | 235 | 0 | 800 | 704 |
| 2 | *Adiantum philippense* | 233 | 0 | 493 | 7143 | 0 | 412 | 1489 | 1867 | 1455 |
| 3 | *Angiopteris helferiana* | 39 | 0 | 87 | 0 | 45 | 0 | 0 | 0 | 21 |
| 4 | *Athyrium hohenackerianum* | 356 | 2643 | 0 | 0 | 0 | 0 | 0 | 0 | 375 |
| 5 | *Cyathea gigantean* | 0 | 0 | 0 | 0 | 68 | 0 | 0 | 0 | 9 |
| 6 | *Dicranopteris linearis* | 133 | 143 | 145 | 2857 | 136 | 412 | 156 | 0 | 498 |
| 7 | *Diplazium esculentum* | 206 | 357 | 0 | 0 | 0 | 48 | 44 | 0 | 82 |
| 8 | *Drynaria quercifolia* | 83 | 3071 | 464 | 1429 | 114 | 0 | 711 | 0 | 734 |
| 9 | *Vittaria elongate* | 0 | 0 | 0 | 0 | 45 | 118 | 0 | 0 | 20 |
| 10 | *Lygodium microphyllum* | 0 | 0 | 0 | 0 | 0 | 0 | 111 | 0 | 14 |
| 11 | *Microsorum membranaceum* | 0 | 143 | 0 | 0 | 68 | 294 | 67 | 0 | 72 |
| 12 | *Nephrolepis exaltata* | 72 | 0 | 0 | 0 | 250 | 0 | 0 | 933 | 157 |
| 13 | *Nephrolepis undulata* | 0 | 1929 | 0 | 0 | 0 | 0 | 0 | 0 | 241 |
| 14 | *Pteris biaurita* | 0 | 0 | 87 | 0 | 0 | 176 | 111 | 0 | 47 |
| 15 | *Pyrrosia porosa* | 0 | 71 | 0 | 0 | 0 | 0 | 0 | 0 | 9 |
| 16 | *Tectaria paradoxa* | 72 | 0 | 0 | 11429 | 23 | 0 | 200 | 267 | 1499 |
| 17 | *Tectaria polymorpha* | 0 | 0 | 203 | 0 | 0 | 0 | 0 | 0 | 25 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 18 | *Thelypteris dentata* | 117 | 0 | 116 | 2857 | 80 | 0 | 0 | 0 | 396 |
| 19 | *Thelypteris parasitica* | 89 | 0 | 435 | 8571 | 0 | 0 | 0 | 0 | 1137 |
| | Total number of individuals | 1450 | 8357 | 2291 | 38572 | 829 | 1695 | 2889 | 3867 | -- |
| | Shannon Diversity index (H') | 2.19 | 1.38 | 2.01 | 1.76 | 1.99 | 1.69 | 1.43 | 1.37 | --- |
| | Simpson Diversity index (D) | 0.13 | 0.28 | 0.14 | 0.83 | 0.14 | 0.17 | 0.33 | 0.30 | --- |

**Table 3:** Population status of wild ferns in sacred groves of semi evergreen vegetation type

| Sl. No | Fern Name | Fern density in different sacred groves (No. of individuals/ha) | | | | | | | | No. of Individuals (per ha) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Bilagunda | | Kadanuru | | Maggula | | Mythadi | | |
| | | Uttarat aiyappa | Aiyappa | Bhattamakki ayyappa | Kakottu ayyappa | Kirlakad aiyappa | Bhagavati | Chamundi | Parel ayyappa | |
| 1 | *Adiantum capillus veneris* | 1609 | 0 | 97 | 352 | 175 | 1339 | 333 | 1373 | 660 |
| 2 | *Adiantum incisum forssk* | 478 | 1500 | 0 | 0 | 0 | 0 | 103 | 0 | 260 |
| 3 | *Adiantum philippense* | 1043 | 667 | 183 | 986 | 636 | 0 | 299 | 3725 | 942 |
| 4 | *Angiopteris helferiana* | 0 | 0 | 32 | 493 | 91 | 630 | 0 | 588 | 229 |
| 5 | *Arachnoides sledge* | 2435 | 500 | 0 | 704 | 0 | 394 | 425 | 0 | 557 |
| 6 | *Asplenium formosum* | 0 | 2333 | 0 | 845 | 333 | 0 | 0 | 2157 | 709 |
| 7 | *Asplenium yoshinaga* | 0 | 0 | 0 | 0 | 394 | 0 | 0 | 2549 | 368 |
| 8 | *Blechnum orientale* | 174 | 0 | 0 | 0 | 91 | 0 | 0 | 0 | 33 |
| 9 | *Bolbitis subcrenata* | 0 | 233 | 0 | 0 | 0 | 0 | 0 | 0 | 29 |
| 10 | *Cyathea gigantea* | 0 | 0 | 0 | 0 | 182 | 0 | 0 | 1176 | 170 |
| 11 | *Dicranopteris linearis* | 0 | 0 | 54 | 1620 | 0 | 315 | 0 | 0 | 249 |
| 12 | *Diplazium esculentum* | 348 | 0 | 0 | 0 | 0 | 0 | 46 | 0 | 49 |
| 13 | *Drymoglossum heterophyllum* | 0 | 0 | 43 | 0 | 0 | 0 | 0 | 0 | 5 |
| 14 | *Drynaria quercifolia* | 0 | 0 | 172 | 0 | 242 | 0 | 0 | 1569 | 248 |
| 15 | *Dryopteris cochleata* | 0 | 0 | 0 | 0 | 0 | 866 | 103 | 0 | 121 |
| 16 | *Lygodium flexuosum* | 0 | 0 | 0 | 0 | 0 | 1339 | 0 | 0 | 167 |
| 17 | *Lygodium microphyllum* | 0 | 0 | 22 | 0 | 0 | 0 | 0 | 0 | 3 |
| 18 | *Microsorum membranaceum* | 3391 | 0 | 0 | 0 | 0 | 0 | 310 | 0 | 463 |
| 19 | *Odontosoria tenuifolia* | 0 | 0 | 0 | 0 | 0 | 0 | 218 | 0 | 27 |
| 20 | *Lycopodium cernuum* | 0 | 0 | 33 | 0 | 0 | 0 | 0 | 0 | 4 |
| 21 | *Parahemionitis cordata* | 0 | 0 | 0 | 282 | 0 | 0 | 0 | 0 | 35 |
| 22 | *Pityrogramma calomelanos* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3725 | 466 |
| 23 | *Pleopeltis polylepis* | 0 | 0 | 0 | 0 | 212 | 0 | 0 | 1373 | 198 |
| 24 | *Pteridium revolutum* | 0 | 0 | 0 | 0 | 212 | 1024 | 0 | 0 | 155 |
| 25 | *Pteris biaurita* | 304 | 0 | 32 | 141 | 0 | 0 | 80 | 0 | 70 |
| 26 | *Pteris pellucida* | 174 | 0 | 0 | 0 | 0 | 157 | 46 | 0 | 47 |
| 27 | *Tectaria paradoxa* | 2261 | 1667 | 0 | 211 | 23 | 0 | 956 | 4706 | 1228 |
| 28 | *Tectaria polymorpha* | 0 | 0 | 75 | 0 | 0 | 1496 | 0 | 0 | 196 |
| 29 | *Thelypteris dentata* | 2391 | 3167 | 43 | 0 | 0 | 1811 | 34 | 0 | 931 |
| 30 | *Thelypteris parasitica* | 1000 | 0 | 161 | 986 | 0 | 1339 | 600 | 0 | 511 |
| | Total individuals | 15608 | 10067 | 947 | 6620 | 2591 | 10710 | 3553 | 22941 | |
| | Shannon Diversity index (H') | 2.15 | 2.16 | 2.28 | 2.36 | 1.72 | 2.09 | 2.24 | 2.15 | --- |
| | Simpson diversity index (1-D) | 0.13 | 0.14 | 0.12 | 0.11 | 0.21 | 0.14 | 0.12 | 0.14 | --- |

1. *Adiantum capillus veneris*
2. *Adiantum incisum* Forrsk
3. *Adiantum philippense*
4. *Angiopteris helferiana*
5. *Arachnoides sledge*
6. *Asplenium formosum*
7. *Asplenium yoshinaga*
8. *Athyrium hohenackerianum*
9. *Blechnum orientale*
10. *Bolbitis subcrenata*
11. *Cyathea gigantea*
12. *Dicranopteris linearis*

**Plate 2:** Fern species in sacred groves of Virajpet taluk

13. *Diplazium esculentum*
14. *Drymoglossum heterophyllum*
15. *Drynaria quercifolia*
16. *Dryopteris cochleata*
17. *Vittaria elongata*
18. *Lycopodium cernuum*
19. *Lygodium flexuosum*
20. *Lygodium microphyllum*
21. *Microsorum membranaceum*
22. *Nephrolepis exaltata*
23. *Nephrolepis undulata*
24. *Odontosoria tenuifolia*

**Plate 3:** Fern species in sacred groves of Virajpet taluk

25. *Parahemionitis cordata*
26. *Pityrogramma calomelanos*
27. *Pleopeltis polylepis*
28. *Pteridium revolutum*
29. *Pteris biaurita*
30. *Pteris pellucida*
31. *Pyrrosia porosa*
32. *Tectaria paradoxa*
33. *Tectaria polymorpha*
34. *Thelypteris dentate*
35. *Thelypteris parasitica*
36. *Stenochlaena palustris*

**Plate 4:** Fern species in sacred groves of Virajpet taluk

**Diversity indices**

Shannon's diversity index and Simpson's index computed for fern species differed across vegetations and sacred groves. Among the vegetations, Shannon's diversity index (2.90) was highest for semi evergreen and lowest for moist deciduous (2.43). Pooled over all sacred groves, Shannon's diversity index (2.36) for Kakottu Aiyappa and lowest for Bhadrakali sacred grove. While the Simpson's dominance index was highest for Bhadrakali and lowest for Kakottu Aiyappa sacred grove. Overall sacred groves of semi evergreen have highest diversity index than moist deciduous (Table 4 & 5).

In the present study, diversity indices differed across the sacred groves and ranged from 2.36 to 1.37. The highest Shannon's diversity index was observed for Kakkotu Ayyappa sacred grove of Maggula village (2.36) located at interior inaccessible area compared to other sacred groves due to this disturbance level is very low so maximum fern diversity is present. While, the lowest Shannon's diversity index observed in Bhadrakali sacred grove of Besaguru village (1.37) this may be because this sacred grove located near the vicinity of village and experiences human disturbance, animal grazing and vehicular movement, contributing to low diversity.

The combined Shannon's diversity index of both vegetation type is (2.99) and Semi-evergreen sacred groves recorded highest Shannon's diversity index (2.90) whereas moist deciduous sacred groves recorded lowest Shannon's diversity index (2.43). This is because semi evergreen sacred groves have evergreen tree species like *Mangifera indica*, *Artocarpus heterophyllus* which provide shade on ferns all through the year. These variations might be because of difference in

species richness and evenness between sacred groves. Similar observations reported by Raghavendra, 2003 [13] where Shannon's diversity index was 3.58 and 3.46 for tree species in sacred groves under semi evergreen and moist deciduous vegetation respectively in Virajpet taluk. Generally, area and environmental heterogeneity have strong effects on species diversity[26]. High values of Shannon's diversity index indicate the presence of a greater number of species sharing more or less equally. Lower diversity index could be due to dominance of few species[27]. Similar study by Vidhyashree, 2018 [20] reported that Shannon diversity index (H') was highest in Mudigere region (2.97) whereas, lowest value (1.79) was recorded for Banajalaya forest [28].

The highest Simpson's dominance index was observed for moist deciduous vegetation with D (0.12) whereas semi evergreen recorded Simpson's dominance index (0.07). This indicates that moist deciduous vegetation type has higher number of individuals of ferns with fewer fern species and semi evergreen has lesser individuals of ferns with higher fern species.

*Tectaria paradoxa* reported with higher importance value index (24.04), followed by *Adiantum philippense* (23.45), *Adiantum capillus veneris* (15.84), *Thelypteris parasitica* (15.47), *Thelypteris dentata* (14.23), *Drynaria quercifolia* (12.16), *Dicranopteris linearis* (11.43), *Microsorum membranaceum* (7.38), *Angiopteris helferiana* (7.06) and *Asplenium formosum* (7.04). Among the two vegetation types, highest importance value index was recorded by *Adiantum philippense* (29.09) in moist deciduous vegetation type whereas *T*ectaria paradoxa (20.43) in semi evergreen vegetation type (Table 6 & 7). Seven species are generalist to both vegetation and three species i.e *Athyrium hohenackerianum*, *Diplazium esculentum*, *Drynaria quercifolia* specialist to moist deciduous vegetation whereas three species i.e *Arachnoides sledge*, *Asplenium formosum*, *Angiopteris helferiana* are specialist to semi evergreen vegetation.

IVI congregates the values of three parameters to highlight in a way to explain the species that is of more representative in an ecosystem. *Tectaria paradoxa* had highest importance value index of 24.04 while, *Pyrrosia porosa* had lowest importance value index. This variation in the importance value among the fern species is could be due to the fact that Western Ghats form one of the most diverse habitats for pteridophytes with the perennial streams, evergreen forests, grasslands and many other habitats, all supporting different fern and fern allies. Similar results were reported by Vidhyashree, 2018 [20] in Mudigere region where Tectaria paradoxa had highest importance value index of 10.91. *Aleuritopteris anceps* (Blanf.) Panigrahi. Had highest importance value index (25.2) in Kigga forest of Karnataka [25] and *Pteris biaurita* the most densely populated with highest Importance value index (16.5) in Kemmanagundi forest of Karnataka [21]. Seven species are generalist to both vegetation and three species i.e *Athyrium hohenackerianum*, *Diplazium esculentum*, *Drynaria quercifolia* specialist to moist deciduous vegetation whereas three species i.e *Arachnoides sledge*, *Asplenium formosum*, *Angiopteris helferiana* are specialist to semi evergreen vegetation.

**Table 4:** Fern species diversity for two vegetation types of Virajpet taluk

| Sl. No | Diversity indices | Moist deciduous | Semi evergreen |
|---|---|---|---|
| 1 | Species richness | 19 | 30 |
| 2 | Shannon –Weiner diversity index | 2.43 | 2.90 |
| 3 | Simpson index of dominance(D) | 0.12 | 0.07 |
| 4 | Species evenness index(E) | 0.60 | 0.61 |
| 5 | Margalef | 2.754 | 4.064 |

**Table 5:** Fern diversity in different sized sacred groves in Moist deciduous and Semi evergreen vegetation types

| Vegetation | Sacred grove | Shannon Index of Diversity (H') | Simpson's Index of Dominance (D) |
|---|---|---|---|
| Moist deciduous | Bhagavati | 2.18 | 0.13 |
| | Aiyappa | 2.01 | 0.15 |
| | Kutiichatana | 1.99 | 0.16 |
| | Besaguru Bhadrakali | 1.43 | 0.34 |
| | Kuttachatana | 1.38 | 0.29 |
| | Betaguru Aiyappa | 1.76 | 0.20 |
| | Kirguru Bhadrakali | 1.69 | 0.20 |
| | Bhadrakali | 1.37 | 0.30 |
| Semi evergreen | Uttarat Aiyappa | 2.15 | 0.14 |
| | Aiyappa | 2.16 | 0.14 |
| | Bhattamakki Ayyappa | 2.28 | 0.12 |
| | Kakottu Aiyappa | 2.36 | 0.11 |
| | Kiralkad Ayappa | 1.72 | 0.21 |
| | Bhagavati | 2.09 | 0.14 |
| | Mandath Chamundi | 2.24 | 0.12 |
| | Parel Ayyappa | 2.15 | 0.13 |

**Table 6:** Importance Value Index (IVI) of top ten dominant Fern species in Virajpet taluk

| Sl. No | Fern name | Relative density | Relative frequency | IVI |
|---|---|---|---|---|
| 1 | *Tectaria paradoxa* | 16.40 | 7.64 | 24.04 |
| 2 | *Adiantum philippense* | 14.42 | 9.03 | 23.45 |
| 3 | *Adiantum capillus veneris* | 8.20 | 7.64 | 15.84 |
| 4 | *Thelypteris parasitica* | 9.91 | 5.56 | 15.47 |
| 5 | *Thelypteris dentate* | 7.98 | 6.25 | 14.23 |
| 6 | *Drynaria quercifolia* | 5.91 | 6.25 | 12.16 |
| 7 | *Dicranopteris linearis* | 4.49 | 6.94 | 11.43 |
| 8 | *Microsorum membranaceum* | 3.21 | 4.17 | 7.38 |
| 9 | *Angiopteris helferiana* | 1.51 | 5.56 | 7.06 |
| 10 | *Asplenium formosum* | 4.26 | 2.78 | 7.04 |

**Table 7:** Importance Value index (IVI) of top ten dominant fern species of two vegetation type of sacred groves

| Moist deciduous | | | Semi evergreen | | |
|---|---|---|---|---|---|
| **Sl. No** | **Name of species** | **IVI** | **Sl. No** | **Name of species** | **IVI** |
| 1 | *Adiantum philippense* (2) | 29.09 | 1 | *Tectaria paradoxa* (5) | 20.43 |
| 2 | *Drynaria quercifolia* | 28.07 | 2 | *Adiantum philippense* (2) | 18.46 |
| 3 | *Dicranopteris linearis* (10) | 20.01 | 3 | *Adiantum capillus veneris* (8) | 16.01 |
| 4 | *Athyrium hohenackerianum* | 19.47 | 4 | *Thelypteris dentate* (7) | 15.37 |
| 5 | *Tectaria paradoxa* (1) | 17.93 | 5 | *Arachnoides sledge* | 12.41 |
| 6 | *Diplazium esculentum* | 11.74 | 6 | *Thelypteris parasitica* (9) | 11.92 |
| 7 | *Thelypteris dentate* (4) | 11.27 | 7 | *Microsorum membranaceum* | 11.41 |
| 8 | *Adiantum capillus veneris* (2) | 8.23 | 8 | *Asplenium formosum* | 8.33 |
| 9 | *Thelypteris parasitica* (6) | 7.54 | 9 | *Angiopteris helferiana* | 7.39 |
| 10 | *Microsorum membranaceum* (7) | 7.41 | 10 | *Dicranopteris linearis* (3) | 6.36 |

**Similarity indices**

To find the similarity co-efficient, we used Sorenson's similarity index, which gives the fern species occur in the two vegetation types of sacred groves, than to those are unique to either vegetation type of sacred groves. Result show that 60.00% of similarity in semi evergreen and moist deciduous vegetation types.

The extent of variation present in species composition among the different vegetation types i.e., semi evergreen vs. moist deciduous was computed using β diversity. β diversity is related to the proportion of unshared and shared species in comparing the two sets of species and was measured as similarity and dissimilarity of species composition [29]. To find the similarity, co-efficient we used Sorenson's similarity index, which gives the fern species reoccur in the two vegetation types of sacred groves, than to those are unique to either vegetation type of sacred groves. Result shows that 60% of similarity in two vegetation type of sacred groves. The higher similarity in species composition is perhaps due to protection of ferns by Kodagu people by retaining protected areas like sacred groves and as well as the microclimatic conditions which enhances ferns growth and development. This can be attributed to changes in species composition, changing environmental conditions and the associated relationships that could be explained by the homogeneity and heterogeneity among the geographical areas. Similar observations were reported by Raghavendra, 2003 [13] in sacred groves of Virajpet taluk, where similarity between moist deciduous and semi evergreen vegetation was 58% for RET tree species. Our findings are consistent with earlier findings of Amelia *et al*., 2017 [1] which revealed that each species of fern has its own preference of micro habitat depending on the temperature, high humidity, soil type, moisture, pH and light intensity.

The zone wise distribution of ferns in sacred groves under semi-evergreen vegetation is more distributed in the second zone (99) followed by third zone (37), fourth zone (13), fifth zone (5) (Table 8). The zone wise distribution of ferns in sacred groves moist deciduous vegetation is more distributed in the second zone (96) followed by third zone (38), fourth zone (9), first zone (6), fifth zone (2) (Table 7). Irrespective of vegetation type, epiphytic fern species occupy same zones.

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**Table 8:** Percentage Distribution of epiphytic ferns as per Johansson zone classification in two vegetation types

| Moist deciduous | | | | | | | Semi evergreen | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sl. No** | **Species name** | **Z1** | **Z2** | **Z3** | **Z4** | **Z5** | **Sl. No** | **Species Name** | **Z1** | **Z2** | **Z3** | **Z4** | **Z5** |
| 1 | *Drynaria quercifolia* | 4(6) | 63(84) | 25(33) | 7(9) | 1(2) | 1 | *Drymoglossum heterophyllum* | 0 | 75(3) | 25(1) | 0 | 0 |
| 2 | *Vittaria elongate* | 0 | 100(4) | 0 | 0 | 0 | 2 | *Drynaria quercifolia* | 7(2) | 83(25) | 10(3) | 0 | 0 |
| 3 | *Microsorum membranaceum* | 0 | 62(8) | 38(5) | 0 | 0 | 3 | *Vittaria elongata* | 0 | 24(4) | 76(13) | 0 | 0 |
| | | | | | | | 4 | *Microsorum membranaceum* | 9(9) | 57(60) | 17(18) | 12(13) | 5(5) |
| | | | | | | | 5 | *Pleopeltis polylepis* | 0 | 100(7) | 0 | 0 | 0 |
| | Total | 4(6) | 64(96) | 25(38) | 6(9) | 1(2) | | Total | 7(11) | 60(99) | 22(37) | 8(13) | 3(5) |

**Note:** Z1 – Zone 1, Z2 – Zone 2, Z3 – Zone 3, Z 4 – Zone 4, Z5 – Zone 5.
(*) indicates no. individuals epiphytic ferns in each zone

## Conclusion

In the present study, 36 fern species belonging to 17 families and 28 genera are recorded. Semi evergreen vegetation has the highest species richness (30) and diversity (H':2.901) than moist deciduous vegetation due to the presence of evergreen host tree species that provide shade throughout the year to ferns. Since small sacred groves have small patches of area, they experience encroachment; hence they have less fern diversity than large sacred groves. Microhabitat of most epiphytic ferns appeared on canopy branch and tree trunk, suggesting that zone second and zone third are ideal habitat for epiphytic fern growth. Further, our study indicates that the Kodagu region provides an ideal habitat for the conservation, protection, and preservation for the posterity of wild fern species.

## Conflict of interest

The authors declare that they have no conflict of interest.

## Author contributions

SRH conducted field survey, analyzed and interpreted the data, and wrote the manuscript. MJ edited and approved the final manuscript. SBH and SGB contributed in organizing and revising the manuscript. JMR contributed to the design of the survey.

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