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## Research Article

# Mycorrhizal Association in Pteridophytes Species from Marathwada Region of Deccan Plateau Zone of India

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## Abstract

**Background and Objectives:** Marathwada region shows vertisols type soil and classified as deep black soils, medium black soils and coarse shallow soils. This paper describes the status of pteridophytes and association of arbuscular mycorrhizal fungi (AMF) from Marathwada region of Deccan Plateau Zone of India. **Materials and Methods:** Pteridophytic plant species were collected from Nanded, Hingoli, Latur, Parbhani, Jalna, Aurangabad, Beed and Osmanabad area during July, 2014 to September, 2016 and assessed the AM fungal infection. Pteridophytic plants were surveyed, recorded, photographed and identified with the help of different flora. The rhizosphere soil and root samples were collected and analyzed AMF (%) root colonization and types. **Results:** Pteridophytic 10 plants species belonging to 5 different families were surveyed viz., *Actinopteris radiata* (Pteridaceae), *Adiantum caudatum* (Pteridaceae), *Adiantum lunulatum* (Pteridaceae), *Adiantum capillus-veneri* L. (Pteridaceae), *Cheilanthes farinosa* (Forssk.) Kaulf (Pteridaceae), *Equisetum hyemale* L. (Equisetaceae), *Marsilea quadrifolia* (L.) (Marsileaceae), *Nephrolepis exaltata* (L.) (Lomariopsidaceae), *Ophioglossum vulgatum* L. (Ophioglossaceae) and *Pteris vittata* L. (Pteridaceae) from 8 different district. Present results were varied in Root Colonization (RC) from 06.25-50%, root length colonization (RLC) was ranged from 1.56-14.28% and types of root colonization were hyphal (H), vesicles (V), Arbuscle (A) and Dark septate endophytes (DSE). **Conclusion:** Study concluded that, among studied species; *Nephrolepis exaltata* and *Marsilea quadrifolia* were found dominant AMF root colonization was found in all collected plant species and AMF infection was observed more in *O. vulgatum* while less in *P. vittata*.

**Key words:** Marathwada region, deccan plateau zone, pteridophytes, mycorrhizal fungi, root colonization

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**Data Availability:** All relevant data are within the paper and its supporting information files.

## INTRODUCTION

Pteridophytes are vascular cryptogams, forming neglected group of plants in biodiversity. All over the earth's surface, it forms a conspicuous element of vegetation. They occupy an important and a crucial general position, although they have been replaced by the spermatophytes in the modern day flora. This group of plants grows more in Himalaya and hilly regions of Central and South. India shows about 110 genera and 600 species are the only authentic taxonomic work on this group plants<sup>1-4</sup>. Western Ghats shows most of southern Indian Pteridophytes, which has been explored by Nampy and Madusoodanan<sup>5</sup>.

A similar message is given in another contribution, which explores the distinct pteridophyte flora of the east African Biodiversity hotspot<sup>6</sup>. This latter study was enabled by the outstanding contributions of many pteridologists who explored Africa, culminating in the work<sup>7</sup>. A somewhat more local perspective is provided by focusing on the pteridophyte diversity of Hawaii<sup>8</sup>. Oceanic islands are known to have exceptionally high proportions of pteridophyte diversity<sup>9</sup>. A final contribution to this issue is provided an important look to the current threats to pteridophyte diversity, as assessed using IUCN Red List criteria<sup>10</sup>. At the family level almost all 48 pteridophyte families are represented in the data pool except for 3 species-poor leptosporangiate fern families (Matoniaceae, Thyrsopteridaceae, Rhachidosoraceae)<sup>11</sup>. *Psilotum vittata* has a chlorophyllous gametophyte of limited growth, the most vulnerable phase of the life cycle<sup>12</sup>.

Mycorrhiza has an excellent fossil record of symbiosis in early land plants from Rhynie chert in Scotland showing typical AM fungal structures such as arbuscules and spores which were already present 400 million years ago<sup>13,14</sup>. The AMF and plants have a complex coexistence and multilateral connection with one another and positive approach of AMF, in some plants, roots are colonized with arbuscular mycorrhizal fungi along with Dark Septate Endophytes (DSE) and most DSE belong to the Ascomycota while few of them to the Basidiomycota<sup>15,16</sup>.

An investigation on the root fungal association in fern sporophytes indicates the widespread occurrence of Arbuscular Mycorrhizal (AM) association<sup>17</sup>. The VAM have been reported in aquatic pteridophytes<sup>18</sup>. Mycorrhizal status of ferns is very much dependent on the type of the substrate on which they grow and their habitat, since aquatic ferns such as *Azolla*, *Marsilea* and *Salvinia* and epiphytes are less likely to be mycorrhizal or even non-mycorrhizal than terrestrial species<sup>19</sup>. There is no similar clear pattern in pteridophytes apart from a likely loss of AM from the lycophytes to the

horsetails, consequence of their recent reassignment to the base of the monilophyte tree and their reacquisition in eusporangiate ferns<sup>20</sup>. This area has paid no attention for this study, therefore the present investigation was made to Mycorrhizal association in pteridophytes species from Marathwada region of Deccan Plateau Zone of India.

## MATERIALS AND METHODS

**Sample collection:** Randomly, pteridophytic plants were collected from Nanded, Hingoli, Latur, Parbhani, Jalna, Aurangabad, Beed and Osmanabad area during July, 2014 to September, 2016, for AM fungal association. Pteridophytic plants were surveyed viz. *Actinopteris radiata* (Pteridaceae), *Adiantum caudatum* (Pteridaceae), *Adiantum lunulatum* (Pteridaceae), *Adiantum capillus-veneri* L. (Pteridaceae), *Cheilanthes farinosa* (Forssk.) Kaulf (Pteridaceae), *Equisetum hyemale* L. (Equisetaceae), *Marsilea quadrifolia* (L.), (Marsileaceae), *Nephrolepis exaltata* (L.) (Lomariopsidaceae), *Ophioglossum vulgatum* L. (Ophioglossaceae) and *Pteris vittata* L. (Pteridaceae). To remove adherent soil debris, on uprooting primary and secondary fine roots of plants were washed in water and then preserved in Formalin-Acetic-Alcohol (FAA) (Ethyl alcohol 50 mL, Glacial acetic acid 5 mL, Formaldehyde (37-40%) 10 mL and Distilled water 35 mL) (50:5:10:35) in specimen bottles. Also, make herbarium each in consecutive order, the collection numbers have been given in collected plant specimens like ASCNB1. ASCNB10 and deposited at Department of Botany, Arts, Science and Commerce College Naldurg, Tq. Tuljapur, District Osmanabad, India.

**Identification of pteridophytes:** The plant species were recorded, photographed and identified with the help of different flora<sup>21-23</sup>.

### Mycorrhizal root colonization

**Clearing root:** Preserved roots of *A. radiata*, *A. caudatum*, *A. lunulatum*, *A. capillus-veneri*, *C. farinosa*, *E. hyemale*, *M. quadrifolia*, *N. exaltata*, *O. vulgatum* were washed in water to remove traces of FAA [Formaldehyde Alcohol Acetic Acid (50:5:10:35)], at the time of root colonization assessment. In 25 mL beaker half filled with 10% KOH, nearly 40-50 root segments of 1-2 cm length were added to facilitate stain penetration in cortex tissue. For 2 h at 70°C, beaker was placed in oven. Till de-pigmentation roots were heated. For KOH treatment, in some cases microwave oven (30 sec) was also used.

**Rinsing and acidification of root tissues:** The roots are diluted in KOH residue and the root segments were rinsed 5-6 times in water and then immersed in 5 mL of hydrochloric acid (HCL) (5%) for 2 min at room temperature to improve the root staining efficiency.

**Root staining:** Acidified roots were washed in water for 5-6 times and for overnight period, immersed in trypan blue (0.05%). It was remove the excess stain from root tissues, destaining was done using water.

**Slide mounting:** In polyvinyl lactic acid glycerol (PVLG) [(Polyvinyl alcohol 8.33 g, distilled water 50 mL, lactic acid 5 mL, glycerin 5 mL)] were stained 48 root segments each species and mounted on microscopic slides. At 60°C to dissolve it, a dry powder polyvinyl alcohol was added to the water in beaker and kept in oven lactic acid and glycerine was then added. Solution was used<sup>24,25</sup> after 24 h. Roots were observed under the binocular microscope (LOBAMED Vision 2000) and photographed with a Sony digital camera (DSC-W310/BC E37). When arbuscules, vesicles, hyphae and alone or in any combination of these were present, a root colonization was considered mycorrhizal and root colonization (%) was measured using the following equation<sup>26</sup> and mycorrhizal root length colonization was quantitatively calculated<sup>27,28</sup>:

$$\text{Root colonization (\%)} = \frac{\text{No. of colonized segments}}{\text{Total No. of segments examined}} \times 100$$

**Statistical analysis:** Each experimental data was subjected to analysis statistically by variance (ANOVA) means were separated using at 5% level of significance<sup>29</sup>.

## RESULTS

**Survey of pteridophytes:** Surveys were conducted for pteridophytic plants and collected roots from different localities of Marathwada region, Aurangabad district represented 06 spesies which was dominant habitat of pteridophytes i.e., *Adiantum capillus-veneri* (L.), *Adiantum caudatum* (Klotzsch), *Adiantum lunulatum* (Burm.f), *Cheilanthes farinosa* (Forssk.) Kaulf, *Ophioglossum vulgatum* (L.) and *Pteris vittata* (L.) followed by Osmanabad district i.e., *Equisetum hyemale* (L.), *Marsilea quadrifolia* (L.) and *Nephrolepis exaltata* (L.). Nanded district

had very poor habitat of pteridophytes i.e., *Actiniopteris radiata* (J. Koenig ex Sw.) Link. Among all observed species, *Nephrolepis exaltata* and *Marsilea quadrifolia* were observed from all district of Marathwada region. Overall, Aurangabad district was found dominant habitat of pteridophytes due to hilly climatic condition than other districts. Nanded, Latur, Hingoli, Jalna, Parbhani and Beed district were observed very poor occurrence of pteridophytic plants.

**Identified pteridophytic plant species:** A survey it become conducted from July, 2014 to September, 2016. In this study some pteridophytes viz. *Actiniopteris radiata* (J. Koenig ex Sw.) Link (Pteridaceae), *Adiantum capillus veneri* (L.) (Pteridaceae), *Adiantum caudatum* Klotzsch (Pteridaceae), *Adiantum lunulatum* Burm.f. (Pteridaceae), *Cheilanthes farinosa* (Forssk.) Kaulf (Pteridaceae), *Equisetum hyemale* (L.) (Equisetaceae), *Marsilea quadrifolia* (L.) (Marsileaceae), *Nephrolepis exaltata* (L.) (Lomariopsidaceae), *Ophioglossum vulgatum* (L.) (Ophioglossaceae), (Pteridaceae) and *Pteris vittata* (L.) were observed from natural habitat. The following morphological and habitat details are observed and discussed (Table 1, Fig. 1).

***Actiniopteris radiata* (J. Koenig ex Sw.) Link:** *Actiniopteris radiata* is member of family Pteridaceae, this species is found in hot, dry habitats, growing at the base of rocks and in crevices but also on deep soil in shady places. It is common in deciduous woodland with perennially high temperatures and low rainfall, ranging from 500-1300 m. The distinctive fronds issue from a prostrate rhizome and is somewhat dimorphic. The laminae are 15-45 mm long and fan-shaped with a spread of some 180°, the tip of each segment bearing 2-5 teeth. This species was collected from Nanded area with the location of N-19°09' Latitude and E-77°27' Longitude.

***Adiantum capillus-veneris* (L.):** *Adiantum capillus-veneris* member of family Pteridaceae, grows from 6-12 inch (15-30 cm) in height, its fronds arising in clusters from creeping rhizomes 8-27.5 inch (20-70 cm) tall, with very delicate, light green fronds much sub-divided into pinnae 0.2-0.4 inch (5-10 mm) long and broad, the frond rachis is black and wiry. Dimorphism between sterile and fertile fronds is generally delicate and many species are especially known for growing on rock walls around waterfalls and water leakage areas. This species was



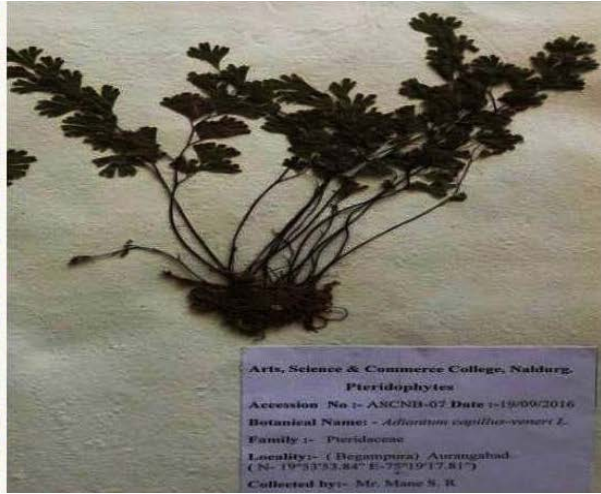
*Actiniopteris radiata*



*Actiniopteris radiata*



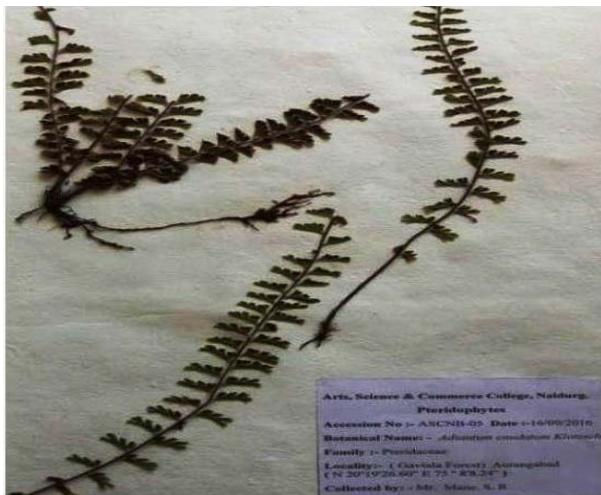
*Adiantum capillus-veneris*



*Adiantum capillus-veneris*



*Adiantum caudatum*



*Adiantum caudatum*

Fig. 1: Continue



*Adiantum lunulatum*



*Adiantum lunulatum*



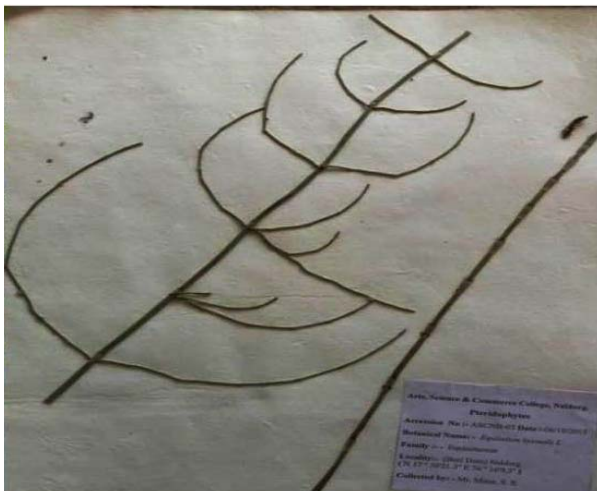
*Cheilanthes farinose*



*Cheilanthes farinose*

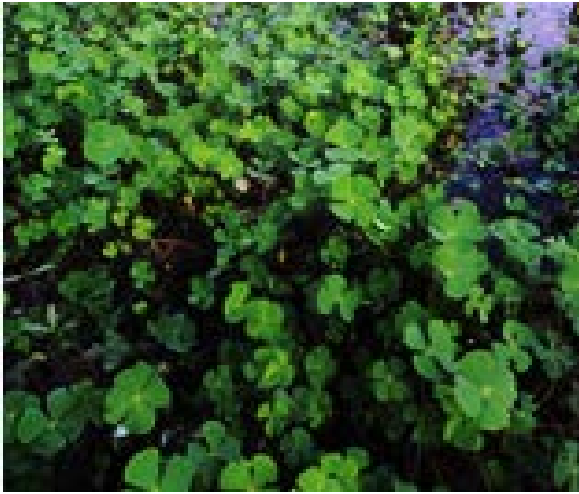


*Equisetum hyemale*



*Equisetum hyemale*

Fig. 1: Continue



*Marsilea quadrifolia*



*Marsilea quadrifolia*



*Nephrolepis exaltata*



*Nephrolepis exaltata*



*Ophioglossum vulgatum*



*Ophioglossum vulgatum*

Fig. 1: Continue



*Pteris vittata*

*Pteris vittata*

Fig. 1: Pteridophytic plant species habitat from study area and its herbarium

Table 1: Common pteridophytes of Marathwada region of Maharashtra, India

Name of pteridophytes	Family	Place	Location	Latitude	Longitude
<i>Actiniopteris radiata</i> (J. Koenig ex Sw.) Link	Pteridaceae	Nanded	Nanded	N-19°09'N	E-77°27'
<i>Adiantum capillus-veneri</i> (L.)	Pteridaceae	Aurangabad	Begampura	N-19°53'53.84"	E-75°19'17.81"
<i>Adiantum caudatum</i> (Klotzsch)	Pteridaceae	Aurangabad	Gavtala Forest	N-20°19'26.60"	E-75°8'8.24"
<i>Adiantum lunulatum</i> (Burm.f.)	Pteridaceae	Aurangabad	Gavtala Forest	N-20°19'26.60"	E-75°8'8.24"
<i>Cheilanthes farinosa</i> (Forssk.) Kaulf.	Pteridaceae	Aurangabad	Gavtala Forest	N-20°19'26.60"	E-75°8'8.24"
<i>Equisetum hyemale</i> (L.)	Equisetaceae	Naldurg	Bori Dam	N-17°50'21.3"	E-76°16'9.3"
<i>Marsilea quadrifolia</i> (L.)	Marsileaceae	Naldurg	BSNL office	N-17°49'14.1"	E-76°15'38.1"
<i>Nephrolepis exaltata</i> (L.)	Lomariopsidaceae	Osmanabad	Sai Nursery	N-18°08'	E-76°06'
<i>Ophioglossum vulgatum</i> (L.)	Ophioglossaceae	Aurangabad	Dr. BAMU Campus A, bad	N-19°54'12.68"	E-75°18'25.22"
<i>Pteris vittata</i> (L.)	Pteridaceae	Aurangabad	Aurangpura	N-19°52'58.90"	E-75°19'37.11"

collected from Aurangabad (Begampura) area with the location of N-19°53'53.84" Latitude and E-5°19'17.81" Longitude.

***Adiantum caudatum* Klotzsch:** *A. caudatum* is characteristic in presence with dark, often black stripes and rachises and bright green. The sori are borne on submarginally and it covered by reflexed flaps of leaf tissue which resemble indusial. It grows on rich humus, moist, well drained sites ranging from bottomland to vertical rock walls soils. This fern in the genus *Adiantum* belongs to the family Pteridaceae. This species was collected from Aurangabad (Gavtala Forest) area with the location of N-20°19'26.60" Latitude and E-75°8'8.24" Longitude.

***Adiantum lunulatum* Burm.F:** It is named after its half-moon shaped pinnae. *A. lunulatum* belonging to family Pteridaceae grows in a creeping or semi-erect position. Its fronds are arched and tufted. It is very glabrous and smooth. It grows on stream banks, often on rocks in forests and woodland. This species was collected from Aurangabad (Gavtala Forest) area with the location of N-20°19'26.60" Latitude and E-75°8'8.24" Longitude.

***Cheilanthes farinose* (Forssk.) Kaulf:** *Cheilanthes farinose* belong to family Pteridaceae rhizome short, erect, up to 10 mm in diameter, rhizome scales dark-brown, entire up to 7 mm in length, margins pale. Fronds tufted, erect, arching, herbaceous or thinly coriaceous, up to 40 cm long, stipe black to castaneous shiny with scattered brown scales up to 7 mm



long. Lamina lanceolate to narrowly ovate in outline up to 390×180 mm, 2-3-pinnatifid; pinnae glabrous, dark matt green above, covered with a white or sometimes pale, yellow powder beneath. Lower pinnae larger than the ones above and more or less basiscopically developed upper pinnae oblong decurrent ultimate lobes oblong, rounded and minutely toothed. Rachis costae, costules, shiny black and glabrous, sori small, marginal, in discrete or continuous clusters indusium small, semi-transparent, variously lacerate. This species was collected from Aurangabad (Gavtala Forest) area with the location of N-20°19'26.60" Latitude and E-75°8'8.24" Longitude.

***Equisetum hyemale* (L.):** *Equisetum hyemale* belonging to family Equisetaceae has vertical jointed reed-like stalks of medium to dark green. The stems are found up to 3 feet (0.91 m) in height. The stems are not branched. The stems have conspicuous ridges and deposition of silica. This makes the ridges feel rough and harsh. The scaly leaves are grouped together around the stem and forming a narrow band or sheath at every joint. Like other ferns and their relatives, the plant reproduces by spores and does not produce flowers or seeds. The *E. hyemale*, commonly known as rough horsetail and scouring rush. This species was collected from Naldurg (Bori Dam) area with the location of N-17°50'21.3" Latitude and E-76°16'9.3" Longitude.

***Marsilea quadrifolia* (L.):** *Marsilea quadrifolia* is a aquatic fern from family Marsileaceae, bearing 4 parted leaf resembling '4-leaf clover' (Trifolium). Leaves are floating in deep or erect in shallow water or on land. Leaflets obdeltoid, to 3/4" long, glaucous, petioles to 8" long, Sporocarp (ferns) ellipsoid, to 3/16" long, dark brown, on stalks to 3/4" long, attached to base of petioles. It is a herbaceous plant found naturally during rainy season. This species was collected from Naldurg (BSNL office) area with the location of N-17°49'14.1" Latitude and E-76°15'38.1" Longitude.

***Nephrolepis exaltata* (L.):** The sword fern is a species of fern in the family Lomariopsidaceae (sometimes treated in the families Davalliaceae or Oleandraceae or in its own family, Nephrolepidaceae), native to tropical regions throughout the world. The branches of *N. exaltata* are 50-250 cm long and 6-15 cm broad, with alternate pinnae and each pinna being 2-8 cm long and compound. The edges appear slightly serrate. This species was collected from Osmanabad (Sai Nursery) area with the location of N-18°08' Latitude and E-76°06' Longitude.

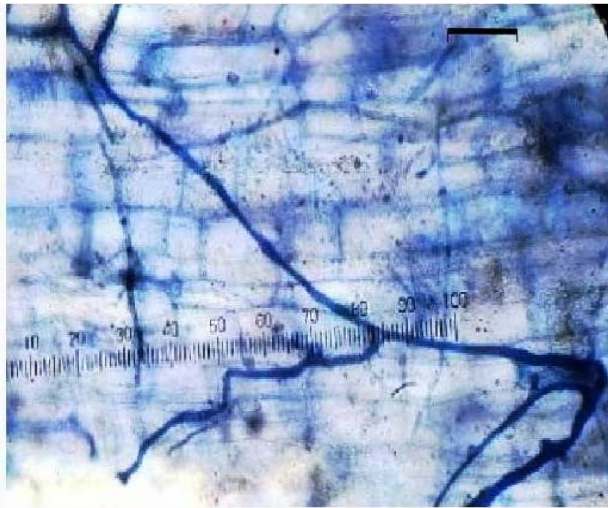
***Ophioglossum vulgatum* (L.):** *Ophioglossum vulgatum* from family Ophioglossaceae grows from a rhizome base to 10-20 cm tall (rarely to 30 cm). It consists of spore-bearing spike and has around 10-40 segments on each side. It reproduces by means of spores. This species was collected from Aurangabad (Dr. BAMU Campus) area with the location of N-9°54'12.68" Latitude and E-75°18'25.22" Longitude.

***Pteris vittata* (L.):** *Pteris vittata* is a perennial and evergreen fern, native to tropical regions and naturalized throughout much of the world. It has pinnate fronds tufted or closely spaced, herbaceous to slightly coriaceous. It has 0.3-0.5 m height. Roots habits are strong creeping rhizome with very abundant and thin rhizoids and maximum root-system depth upto 30 cm. Leaf is tufted fronds, arching, leathery, pinnate, with an elliptic shape. Reproductive structure is fertile fronds bear sporangia (spore producing structures) on the underside of fronds. This species was collected from Aurangabad (Aurangpura) area with the location of N-19°52'58.90" Latitude and E-75°19'37.11" Longitude.

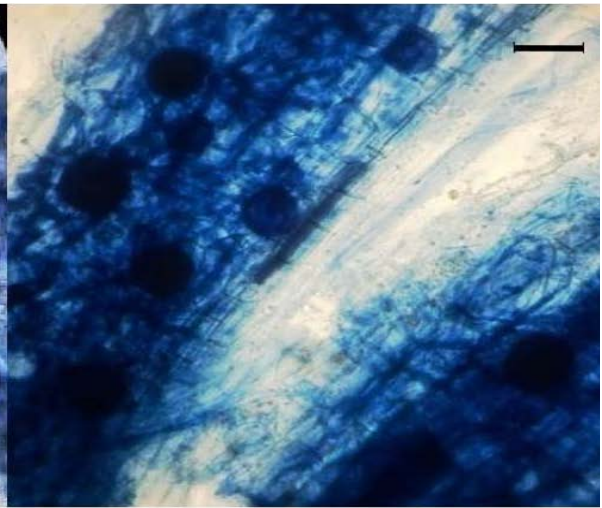
#### Assessments of AMF root colonization

**Root colonization:** Ten pteridophytic plants were studied of mycorrhizal colonization with respect to percentage (%) of Root Colonization (RC), percentage (%) of root length colonization (RLC) and types of root colonization were studied. Total 48 root segments were studied in each individual species.

In pteridophytes, AMF root colonization was found in all collected plant species. Root Colonization (RC) was observed additional in *O. vulgatum* i.e., 50% from the Dr. Babasaheb Ambedkar Marathwada University Campus Aurangabad followed by *N. exaltata* (45.45%) from Sai nursery Osmanabad while less in *P. vittata* i.e., 6.25% from Aurangpura, Aurangabad. Percentage of (%) root length colonization (RLC) also found more in *O. vulgatum* i.e., 14.28% and less in *P. vittata* i.e., 1.56%. Types of root colonization was observed i.e., arbuscular (A), hyphal (H) vesicular (V) and dark septate endophyte (DSE), in different pteridophytic plant observed but hyphal type of root colonization was found significant as compared to other types. Arbuscles are found in *C. farinosa* and *O. vulgatum* only and vesicle are found in *A. capillus-veneri*, *A. caudatum* and *N. exaltata*. Extra-radical spore of AMF was found in *A. caudatum* (Table 2, Fig. 2).



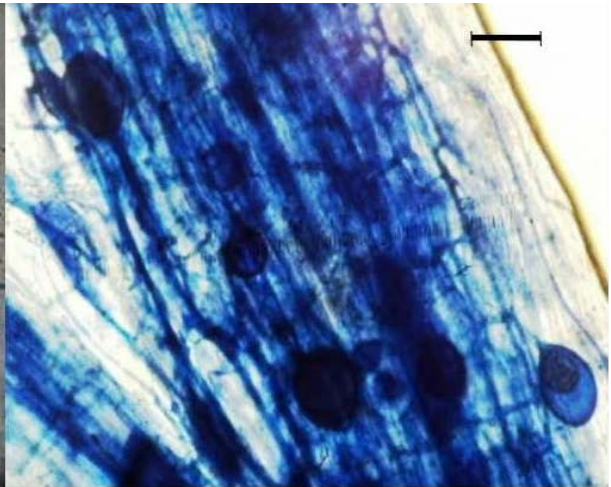
Vesicle (*Equisetum hyemale*)



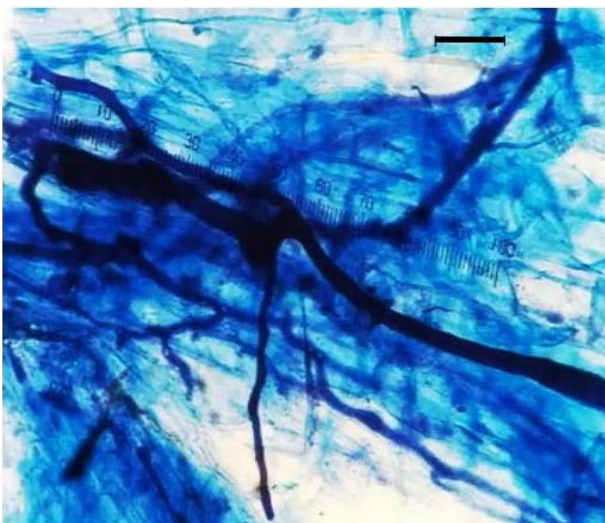
Hyphal (*Equisetum hyemale*)



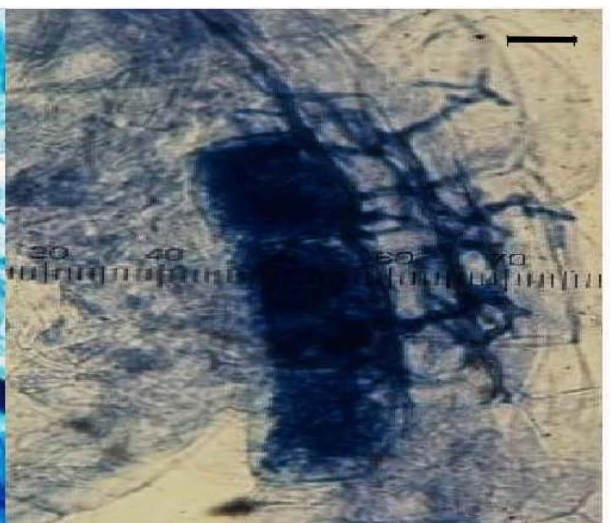
DSE (*Marsilea quadrifolia*)



Swelling (*Marsilea quadrifolia*)



DSE (*Adiantum lunulatum*)



Hyphal (*Pteris vittata*)

Fig. 2: Continue

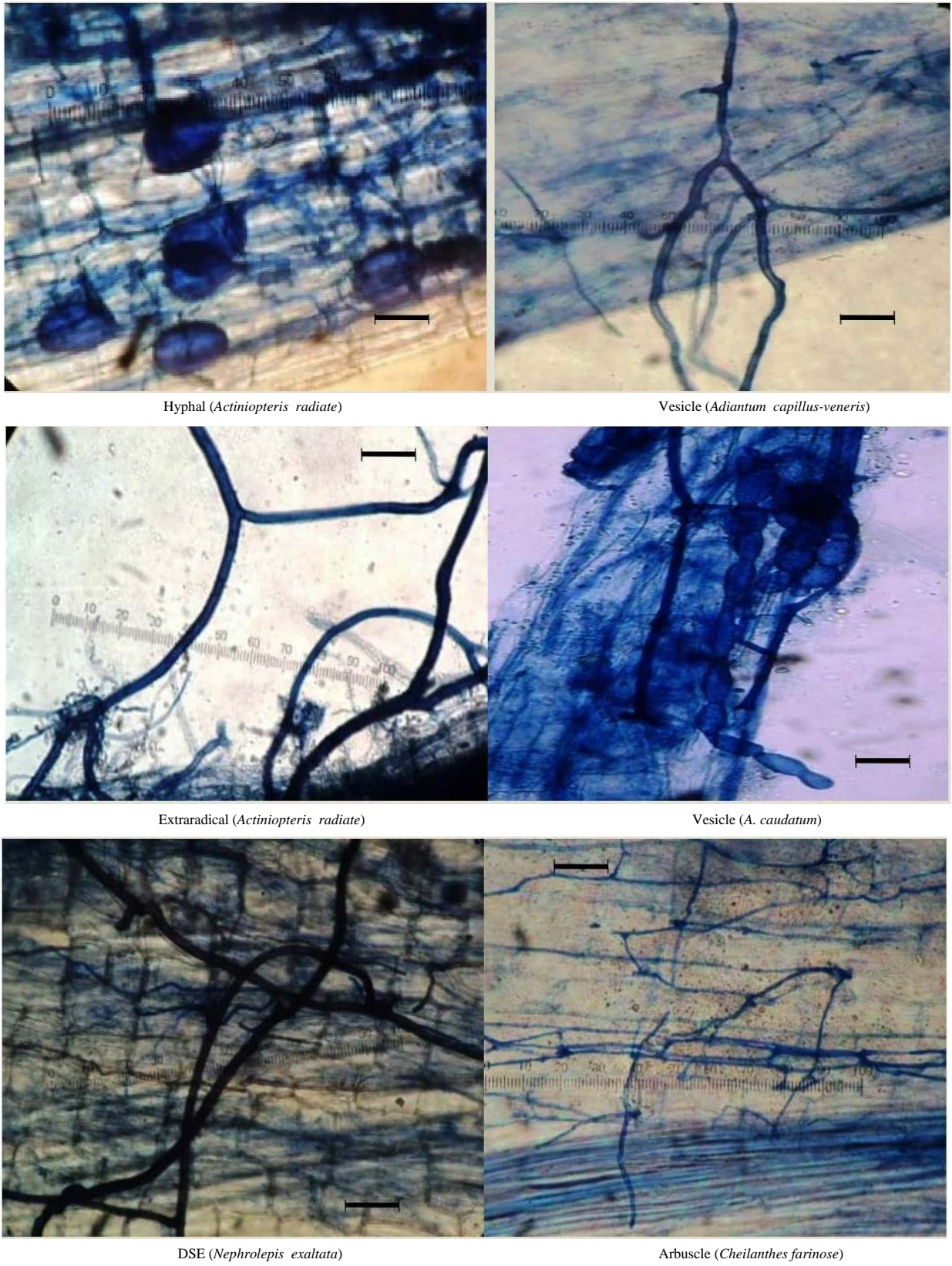


Fig. 2: Types of root colonization on pteridophytes  
Scale bars = 50 µm

Table 2: Assessments of AMF root colonization of pteridophytic plant species from different district of Marathwada region (n\* = 48)

Pteridophytes	Location (District)	Rc (%)	Rlc (%)	Types of Rc
<i>Actiniopteris radiata</i>	Nanded	39.28±2.11	11.60 ± 3.99	H
<i>Adiantum capillus-veneri</i>	Begampura (Aurangabad)	33.33±1.44	9.89 ± 2.77	HV
<i>Adiantum caudatum</i>	Gautala Forest (Aurangabad)	27.08 ± 5.11	8.33±2.11	HV, DSE, Er.
<i>Adiantum lunulatum</i>	Gautala Forest (Aurangabad)	18.75 ± 2.33	5.72±0.69	H
<i>Cheilanthes farinosa</i>	Gautala Forest (Aurangabad)	22.91±6.11	5.72±2.44	HA
<i>Equisetum hyemale</i>	Bori Dam (Naldurg, Osmanabad)	32.14±4.66	8.3±4.11	H
<i>Marsilea quadrifolia</i>	BSNL office (Naldurg, Osmanabad)	42.85±6.99	10.93±1.77	H, DSE
<i>Nephrolepis exaltata</i>	Sai Nursery (Osmanabad)	45.45±3.22	11.93 ± 2.11	HV, DSE
<i>Ophioglossum vulgatum</i>	Dr. BAMU Campus A, bad	50 ± 7.88	14.28±3.01	HA
<i>Pteris vittata</i>	Aurangapura (Aurangabad)	6.25±0.71	1.56±0.19	H
SE±		4.25	1.18	
CD at 5%		9.60	2.67	

Rc: Root colonization, Rlc: Root length colonization, AM: Arbuscular mycorrhizal, H: Hyphal, V: Vesicular, A: Arbuscular, DSE: Dark septate endophytes, Er: Extra radical spore, n\*: Number of root segments, value after ± indicates standard deviation

## DISCUSSION

This results are discussed that, it was varied in Root Colonization (RC) from 06.25-50%, root length colonization (Rlc) is ranged from 1.56-14.28% and types of root colonization are hypal (H), vesicles (V), arbuscle (A) and dark septate endophyte (DSE) belonging from 10 different pteridophytes and found very less AMF colonization.

According to the survey reports and available information, *Psilotum nudum* has been found in Myanmar, Malaysia and India. In India *P. nudum* is found in the Western Ghats, central India and eastern India<sup>30</sup>. The seven *Huperzia* and *Lycopodium* species sampled are extant members of two Lycopodiaceae genera whose ancestors diverged approx 350 million years<sup>31</sup>. Fungi are obligate and ubiquitous in the earlier lineages but their incidence become far more capricious in polypod ferns. This trend is very clearly contrary to species richness, whereas the polypodiales number thousands of species, the numbers of species are much lower for earlier groups; *Ophioglossum* 25-30, *Botrychium* 50-60, Marattiales 135, Osmundales 25 and Schizaeales 190 was reported by Christenhusz and Byng<sup>32</sup>. It was reported that 256 species of pteridophytes surveyed, out of these 20 species were fern-allies, 12 species were eusporangiates and 224 were leptosporangiates from south west China<sup>33</sup>. Furthermore, pteridophytes boast a high percentage of epiphytes (24% of ca. 12,000 species vs. 9% of ca. 275,000 species of angiosperms)<sup>34</sup>. The world flora consists of approximately 12,000 species of pteridophytes of which around 1000 species distributed in 70 families and 192 genera are likely to occur in India and Aspleniaceae family comprising of 27 species followed by Polypodiaceae (25 spp), Athyriaceae (24 spp), Lypteridaceae (23 spp), Selaginellaceae

(20 spp), Pteridaceae (17 spp.), Aspidaceae (13 spp.), etc and maximum diversity was observed in the genera *Selaginella* (20 spp), *Pteris* (17 spp) and *Diplazium* (7 spp) were recorded by Dixit<sup>35</sup> and Dixit<sup>36</sup>.

It was reported the AM morphology conformed to the intermediate type with intracellular hyphal coils, arbusculate coils and intercellular hyphae and no AM fungal spores could be retrieved from the soil on which gametophytes and young sporophytes were growing. In ferns, root colonization ranged from 15% (*Lygodium flexuosum*) to 30% (*Adiantum philippense*)<sup>37</sup>. It was reported pteridophytes showed maximum VAM colonization during spring with gradual reduction in other season<sup>38</sup>.

It was reported intracellular, aseptate glomeromycotean fungi resembling the Paris-type of arbuscular mycorrhizas in the parenchymatous cortical cells of rhizomes and gametophytes of *Psilotum nudum*<sup>39</sup>. The abundance of AMF in the roots varied with the species and ranged from 7% (*Polypodium lepidotrichum*) to 88% (*Marattia* sp.) and root solonization was not observed in *Asplenium praemorsum*, *A. miradoreense* and *Pecluma dispersa* and Paris-type of AMF morphology was dominant, 72%, while 8% were found to be of the Arum-type and 8% of the intermediate-type. The AMF colonization was accompanied by DSF in 10 species (40%) and the mean% colonisation intensity was just over 40% of root segments examined<sup>40</sup>. In pteridophytes AMF root colonization were reported from Dujiangyan, China ranged from *Parathelypteris nipponica* (0%)-*Botrychium lonuginacum* (50%)<sup>41</sup>. It was reported both AM fungi with vesicles and dark septate hyphae in old roots of 6 species of *Equisetum* from different habitats, viz., *E. arvense*, *E. fluviatile*, *E. giganteum*, *E. hyemale*, *E. telmateia* and *E. variegatum*<sup>42</sup>. In a recent study, more

than 90% of field-collected gametophytes were colonized by AM fungi in *Angiopteris lygodiiifolia* (Marattiaceae) and *Osmunda japonica* (Osmundaceae)<sup>43</sup>.

Study area is comes under the drought prone region of Maharashtra but also found some species of pteridophytes. Generally, pteridophytes are grown in shady, wet and moist places and such availability are suited from eastern and western Himalaya and south hill region of India. During study period, it was found very fewer rain but also observed different 10 types of species and studied its myorrhizal association. Mycorrhizal fungi are used as biofertilizers, biological control and bioreceptors. Hence this investigation was observed the infection of AMF and isolated AMF species and mass multiplied by using indigenous plant species for further study. Therefore this study recommended to restore the pteridophytes and its associated AMF species for enhancing the crop plant growth productivity.

### CONCLUSION

Study concluded that, total 10 species of pteridophytes were observed due to fewer rain and especially this area comes under drought prone. Aurangabad district represented 06 species which was dominant habitat of pteridophytes Nanded district had very poor habitat of pteridophytes. Species number would be increased when falls sufficient rain. Among species, *Nephrolepis exaltata* and *Marsilea quadrifolia* were observed almost in all district of Marathwada regions. Overall, Aurangabad district was found dominant habitat of pteridophytes due to hilly climatic condition than other districts. The AMF root colonization was found in all collected plant species. Mycorrhizal infection was observed more in *O. vulgatum* while less in *P. vittata*. There is need to be study and conservation of some pteridophytes due to its medicinal properties. Some dominant Indigenous mycorrhizal species were isolated and mass multiplied and used for further study.

### SIGNIFICANCE STATEMENT

Pteridophytic plants species belonging to 5 different families were surveyed and studied its richness. *Nephrolepis exaltata* and *Marsilea quadrifolia* were found dominant and AMF root colonization was found in all collected plant species but AMF infection was observed additional in *O. vulgatum* while less in *P. vittata*. Some dominant Indigenous AMF species were isolated and mass

multiplied by using restoring plant species and used as biofertilizer for enhancement of growth and productivity in further study.

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