Research Article

Atlas of *Cyathodium Kunze* Species from India

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ABSTRACT

It has been shown that India is one of the mega-biodiversity nations in the world. Incredible floral variety may be attributed to India's many biogeographic regions, each of which has its distinct geographical zones and physico-climatic characteristics. Miniature amphibians most closely represent the three bryophyte lineages: mosses, hornworts, and liverworts. Mosses are classified as their category and make up the most diverse and extensive group. The purpose of the present research is to compile a list of all of India's known *Cyathodium* species utilizing data gathered from herbaria owned by a variety of organizations as well as any publications that are pertinent to the topic. Eight different species of *Cyathodium* were discovered by a group of Indian bryologists. A great number of species share characteristics and looks that might be confusing. It is necessary to revise *Cyathodium* in order to get rid of the overlapping and convoluted linked groupings that exist between the specified species.

Keywords: *Cyathodium*, Characters, Distribution, India, Species diversity.

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INTRODUCTION

After flowering plants, bryophytes constitute the second-highest diverse category of terrestrial vegetation, and they can be found all over the globe. Bryophytes, in general, are photoautotrophic cryptogams that display a generational heterology characterized by a predominance of the gametophytic stage. The haploid gametophyte is free-living and essential to the development of the sporophyte, which includes the foot, seta, as well as a capsule. The "Amphibians of the Plant Kingdom" get their name because, despite their terrestrial habitat, sexual reproduction needs access to water. These plants are also known as "resurrection plants" because of their remarkable capacity to absorb water and revive themselves in a matter of minutes.[1] There are three separate families within this group: mosses (music), liverworts (hepaticae), and hornworts (anthocerotae). The majority of mosses and liverworts have leaves and stalks but no roots. All hornworts and certain liverworts develop as undifferentiated thalli, or ribbons, rather than leaves and stems. Bryophytes don't have roots; thus, they must get all of their moisture via other means.[2]

About 14 different species belong to the genus *Cyathodium*. Only two of these species, *C. cavernarum* Kunze and *C. foetidissimum,* are found across the whole pantropical region. The other species are either exclusive to the Neotropics, Palaeotropics, or Asia.[3-8] *Cyathodium* used to be classified as a member of the subfamily Cyathodioideae under the Targioniaceae family; however, the most current analysis points to its position as a member of a new family called the Cyathodiaceae.[9,10] The genus Cyathodium Kunze is found all over the globe, and there are 11 species that have been formally recognized as belonging to it. The Indian subcontinent is where the most species diversity can be found. The vast majority of the species are only found in this one location. *Cyathodium aureonitens* (Griff.) Mitt. from the state of Assam is one example of them.[11] Dehradun, Bombay and Calcutta[12] *C. smaragdinum* Schiffn., found on the western ghats between Bombay and Khandala,[13,14] *C. tuberosum* Kash. (= syn. *C. penicillatum St., C. pectinatum*,[15] from the

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Western Himalayas (Mussoorie) and the Punjab plains, *C. pectinatum* is a species of *C. penicillatum*.[16] *C. cavernarum* Kunze, which is synonymous with *C. barodae Chavan* and *C. africanum* Mitt., Baroda.[17] in addition to Africa,[18] *C. indicum* Udaret Singh from the Western Himalayas: Nainital;[7] *C. tuberculatum* Udar et Singh;[7] *C. denticulatum* Udar et Sri vast. from Darjeeling;[19] *C. mehranum* Singh from Assam;[14] *C. foetidissimum* Schiffn. from Java;[20] and *C. steerei* Hassel from Argentina.[21] Due to a lack of valid type specimens, it was not possible to determine the current state of *C. flabellatum* Mehra from Punjab[22,23] and *C. acrotrichum* Schiffn. from Kurseong.[13,14] As a result, these two species have been removed from this study.

There are a total of 13 species in the genus *Cyathodium Kunze (Cyathodiaceae K.* Mull.), among which only 8 are considered to be properly recognized.[3] Authors[8] have recorded the presence of eight in the country of India. The genus Cyathodium can be found on the Indian subcontinent by nine different taxa.[8,24] These taxa consist of *C. mehranum* Singh, *C. tuberculatum* Udar et Singh, *C. tuberosum* Kash., *C. smaragdinum* Schiffn., *C. aureonitens* (Griff.) Mitt., *C. cavernarum* Kunze, *C. indicum* Udar et Singh, However, *C. cavernarum* Kunze may be found all over the place, but the bulk of its species are endemic.[24] The vital role of an ecosystem is significantly impacted by bryophytes, notably in the regulation of water flow and the protection of the substrate from erosion.[25] In conventional Chinese, North American, European, as well as Indian treatment, bryophytes are considered to be plants with medicinal value that may be used to treat fractures, seizures scalds, uropathy, respiratory infections, and neurasthenia. They can also heal cuts, burns, exterior wounds, bacteriosis, pulmonary TB, bacteriosis, and external injury.[26]

MATERIALS AND METHODS

Methods for conducting the investigation included a review of relevant previous research on the species, observations of plants in their natural environments, and examination of herbarium records.

Primary data collection

Field research conducted in several areas throughout Kerala and Tamil Nadu yielded information pertaining to the species of *Cyathodium*.

Secondary data collection

An analysis of the Cyathodium-related research that is currently accessible, both in print and online. In addition, reference was made to a variety of resources, some of which were the ENVIS Hub: Kerala, the India Biodiversity Portal, and the British Bryological Society, amongst others. In a similar manner, the herbarium collections that could be accessed in the southern areas of India were investigated in order to validate the species name that was reported.

RESULTS

1. *Cyathodium aureonitens* (Griff.) Mitt

   The Thallus is light green to green, growing in irregular rosettes, densely overlapping, measuring 5 to 10 mm × 4 to 10 mm, regularly branching, and fan-shaped with entire margins. Air chamber and dorsal pore outline on the dorsal surface. The dorsal epidermis is single-layered, has cell-thin walls, is polygonal, measures 50-90 μm × 40-63 μm, is chlorophyllose, and contains scattered chloroplasts. Cells with thin walls, polygonally elongated dimensions of 85–203 μm × 46–66 μm, chlorophyllose, and dispersed chloroplasts characterise the ventral epidermis. The ventral pore is absent. Rhizoids are numerous, hyaline, smooth-walled, 14–17 μm broad, with walls thick to thin and are either straight or undulating. Tuberculate rhizoids are absent. Ventral scales are filamentous, uni-biseriate, 4–6 cells long, and lack a terminal mucilage papilla. Female thalli can range from being sparsely to heavily fertile, with 3 to 5 or even up to 12 involucres (in larger plants) emerging anteriorly below the sinus notch between the apical lobes of the thalli. The surface of the involucre is covered in thick-walled, uniformly spaced hairs up to 1 mm long. Typically, each involucre contains one (rarely two) sporogoniums. A small, rounded parenchymatous foot, a short seta, and an oval to sub-globose, dark-coloured capsule measuring 0.5–0.8 mm by 0.5–0.9 mm make up the sporophyte (Table 1). Wherever it is single-layered, the capsule wall has a two-tiered apical lid or operculum. Non-dehiscent, cells thin-walled, rectangular to isodiametric, chlorophyllose, 22–60 μm x 19–32 μm capsule walls. Spores are globose to sub-globose, isopolar, 43-51 μm x 41-53 μm, spinate, with spines that are 4–6 μm long by 2–3 μm wide at the base and that are either straight or slightly bent apically.[27]
2. *Cyathodium cavernarum* Kunze

   Sometimes appearing fan-shaped, dichotomously branching thallus Plant 2-10 mm in length and width, with dorsal epidermal cells that are thin-walled and chlorophyllose and lower epidermal cells that are bigger and chlorophyllose. This species is endemic to caves, mildly wet locations, or open

Table 1: Distinguishing characteristics among the species of *Cyathodium* in India.[29]

Characters	1. *C. aureonitens*	2. *C. cavernarum*	3. *C. smaragdinum*	4. *C. indicum*
Thallus	Thallus green midrib absent	Thallus green midrib absent	Thallus green midrib absent	Thallus green midrib absent
Sexuality	Dioecious	Monoecious	Monoecious	Dioecious
Antheridium	Stalked	Sessile	Sessile	Sessile
Involucure	Hairy	Smooth	Smooth	Smooth
Spores	Spinate isopolar. oval blackish brown	Black spores isopolar, Baculate, spinate	Black, Deep brown, Granulate 36-52m	Baculate, blackish brown, apopolar, 56-64 m
Elateres	Blackish brown 8-15 per capsule tri spirate, large	Reddish brown, Bispiral 8-11 per cell 245- 480m	Bispiral and trispiral in the same capsule, 4-8 per Capsule	8-12 per capsule elongate trispiral
Distribution		Eastern Himalaya Western Ghats Bombay, Malabar hill, central India, Gujrat Gangetic, plains, java, Africa America.	Malabar hills, garh Khandala, Pratap	Endemic to N. E. Himalaya, Nainitaal

Characters	5. *C. tuberculatum*	6. *C. mehranum*	7. *C. tuberosum*	8. *C. denticulatum*
Thallus	Thallus green to fluorescence midrib absent	Thallus dark green and storage zone air chambers present	Thallus green midrib absent oil cells present with one layer air chamber	Thallus dark green, midrib, storage zone with air chambers present
Sexuality	Monoecious/ Dioecious	Dioecious	Dioecious	Dioecious
Antheridium	Sessile	Sessile	Stalked	Stalked
Involucure	Hairy	Hairy	Hairy	Denticulate
Spores	Oval spores Tuberculate.	Baculate apolar, muricate	Spinate isopolar double sculpture, dark brown	Verrucose, blakish brown
Elateres	Reddish brown elongated tri-, tetra spiral except from the tips	Reddish brown trispiral 640-900m	15-50 per capsule 280-360m tri- spiral	Reddish brown 8-10 per capsule760- 800m elongated tri spiral
Distribution	Endemic to eastern Himalayas	Eastern Himalays Arunachal Pradesh	Eastern Himalaya-Darjeeling, Sikkim, Western Himalaya, Western Ghats, Poona (karle caves) Gangetic plains	Darjeeling

moist protected places. Pores on the dorsal surface are surrounded by 2-3 concentric rings of 4-6 cells each; air chambers are typically arranged in a single row; the partition between air chambers is 1–2 cells high and is lined with chloroplasts; chloroplasts are scarce and big. The ventral scales of rhizoids are small, simple, filamentous, and covered in mucilage papillae, and the rhizoid itself has a smooth wall. Monoecious, with male receptacles that are disc- or cushion-shaped and located laterally to the terminal;cells with semi-annular or annular thickening bands in upper portion but without thickenings in lower section; operculum two tiers, outer tier of 4-6 cells and inner tier of 8-10 cells; spores 41-70 µm in diameter, brownish-black, isopolar, spiny, spines 3-4 µm high; elaters 8-12 in a capsule, 225-450 µm long, 2-3 spirals, reddish brown.[28]

3. *Cyathodium smaragdinum* Schiffn

   The plant exhibits a light green coloration and lacks a midrib while possessing monoecious sexuality. Its antheridium is sessile, and the involucre appears smooth. The spores are granulated and range in colour from black to deep brown, measuring 36-52 µm in size. Additionally, the plant's capsules contain both bispiral and trispiral elateres, with 4-8 elateres present in each capsule.[29]

4. *Cyathodium indicum* Udar and D.K. Singh

   plants with a pale green color, an indistinguishable midrib, polygonal dorsal dermal cells alongside narrow walls ranging from 37.6-128 µm in length, and 37.6-75.2 µm, than width, presence of chlorophyll inside walls that a little protrude

toward the air chambers; lower the epidermal cells with slender walls that are larger, measuring 37.6-213 μm in length, 21.3-64 μm in width; plants that are pale green color; Air compartments in one row, void, uniseriate divisions, 2-3 cells high; rhizoids frequent on the ventral side of the thallus; dorsal pores exceedingly rare, often only one near the site of first dichotomy; simple, without an easily identifiable concentric rim of cells. Lower scales are inconspicuous, single-layered or bi-layered on the dorsal side of the thallus and receptacles, cells either with or without chloroplasts and the mucilage papillae; ventral branches, as well as tubers, are absent; the presence of chloroplast as well as papillae which contain mucilage is not common in the receptacle and thallus surface. compared to male plants, female is, 4-6 mm long, 2-6 mm wide, shows repeated dichotomous branching from an unbranched stage, has a number of ventral involucres ranging, 1-6 per thallus, ovoid, not projecting above the margin of the thallus, wide mouth, somewhat two valved, margin covered with stiff hairs, its base broader tapering towards the tip, branching not present in typical male plants, they are tiny, length ranging 3-4 mm, and 0.5-2 mm wide. The color of the capsule wall may be described as being reddish to brown.[30]

5. *Cyathodium tuberculatum* Udar and D.K. Singh

   Thalli are enormous in size, have the form of a fan, and have a midrib that is not prominent. With the lower epidermis, the cells are bigger, their walls are thinner, and they do not contain chlorophyll; the upper whole surface is covered with dorsal epidermal air pores. Empty air champers are layered and have walls that with 2–4 cells tall. They are located in the upper epidermal cells. These are thin-walled polygonal cells completely filled with chlorophyllated cells. Large male plants measure 10–14 mm in length and 9.14 mm in width, and they have terminal receptacles which are sometimes ventral side stalked, and bisexual. Female plants are lower, 5-9 mm long and 10-14 mm wide, with up to 15 archegonial discs each thallus, elliptical oval in shape, with the mouth generally elliptical and hadn't projecting outside the thallus margin. The exterior face is pubescent, with hairs that are broader at the bottom and directed at the top. Each involucre contains one spore-bearing capsule that is roughly spherical in shape and dark brown to black in color. The apical disc has two layers, the outer layer consisting of four thick-walled cells with strengthening bands on their outer walls, and the layer within consisting of twelve to fourteen thin-walled, smooth cells.[31]

6. *Cyathodium mehranum* D.K. Singh

   The existence of pubescent involucres that have thick-walled and deeply colored marginal cells; the existence of apically fixed elaters; capsule walls are strengthend with annular thickening bands and nodulose radial wall thickenings, in addition to the presence of spiral layers on the capsule wall; and the tubers are exist, which usually occur on both male and female plants.[32]

7. *Cyathodium tuberosum* Kash

   Dioecious, tiny, delicate, pale green or green linear lobes, dichotomously branching, densely overlapping, with a length of 5-10 mm and width of 2–5 mm. Female plants are linear, flat, and normally lack dorsal pores, these characteristics are not common in female plants with developed characters. Male plants show extended anteriorly to posteriorly and rounded at the base, with slender, branching, linear lobes and many, big, simple ventral holes; Without a distinct midrib, thalli bear tubers densely covered with rhizoids; rhizoids on the ventral surface are smooth, shin, or thick-walled, scales of simple cells arranged in rows of 3-6 cells in a row or plate-like. Male plants are often smaller and their receptacles can take a variety of shapes, including a disc, a circle, a fork, or terminal lobes. Sessile, subsessile, and short-stalked male plants are all possible. Involucre ovoid, open by circular or elliptical mouth, borders purplish, involucre with scales and rhizoids; large female plants with multiple involucres with one to four sporogonia each. A capsule that is spherical in shape and has one layer of wall, a seta that has two rows of cells, a foot that has two lobed cells, an operculum that has two layers, the outer layer having four thick walls and the inner layer having up to twelve thin walls; The spores are spherical, dark brown, and spiny, measuring 40-62 μm in diameter; the elaters number 30-45 per capsule and can have two or three spirals up to 500 μm length.[28]

8. *Cyathodium denticulatum* Udar and Srivast

   Widespread midribs on both sides of thalli with a width of 1–2.5 cm and the length of 2.5–3.5 cm. and yellowish green in color. Midrib air chambers, huge rings with a modest elevation, and a straightforward dorsal pore are all present. Rhizoids exhibited filamentous ventral hyaline scales, and the thallus had differentiated into storage and assimilatory zones with two to three layers of chambers. Male

plants are smaller than females (2-4.5 cm vs. 3-5 cm), and the ovoid to elliptical involucre projects beyond the thallus apex. The involucre is in shape, and its border is denticulate. The involucre valves have brown marginal cells with 300-500 μm length dentitions. Each involucre contains a single sporophyte.

The capsule is dehiscing, oval, dark brown to black in color, and between 0.75 and 1.2 millimetres in diameter; the upper part of the capsule is thick and brown with annular thickenings. Black, isopolar, verrucose spores (70-80 μm in diameter) with Y-shaped verrucae create imperfect reticulations. Reddish-brown elaters (800-900 μm in length, 20-30 μm in width), few in number (15:4 elater to spore ratio), trifid in shapes.[29]

DISCUSSION

There are around 14 species that belong to the genus *Cyathodium*. Only two of these species, *C. cavernarum* Kunze and *C. foetidissimum,* are found throughout the entire pantropical region. The remaining species are either exclusive to the Neotropics, Palaeotropics, or Asia.[3-8] In the past Even though the *Cyathodium* was placed in the subfamily Cyathodioideae within the Targioniaceae, in the past, the recent morphological, anatomical studies, studies of cell arrangements, cell contents and its physical parameters are indicated separate familial status, the Cyathodiaceae.[9,10]

The genus *Cyathodium* Kunze (Cyathodiaceae K. Mull.) comprises 13 species among those 8 are validly recognised in India[3] namely *C. mehranum* Singh, *C. tuberculatum* Udar et Singh, *C. tuberosum* Kash., *C. smaragdinum* Schi ffn., *C. aureonitens* (Griff.) Mitt. *C. cavernarum* kunze, *C. indicum* Udar et Singh, *C. denticulatum* Udar et Srivastava, *C. foetidissimum* schiffn.

In *C. aureonitens*, *C. cavernarum*, *C. smaragdinum*, and *C. indicum* thallus is green and midrib is absent. The midrib is also lacking in *C. tuberculatum*, and the thallus is green to fluorescent in colour. Between *C. mehranum* and *C. denticulatum* storage zone air chambers are present and thallus is dark green in colour (Table 1). In *C. tuberosum*, the thallus is green, the midrib is missing, and oil cells are present. *C. cavernarum* and *C. smaragdinum*, on the other hand, are monoecious. *C. aureonitens*, *C. indicum*, *C. mehranum*, *C. denticulatum*, and *C. tuberosum* are dioecious in nature. *C. tuberculatum* acts both like a monoecious and a dioecious plant. Antheridium has been followed by the *C. aureonitens*, *C. tuberosum*, and *C. denticulatum*. Still, *C. indicum, C. mehranum, C. cavernarum, C. smaragdinum, and C. tuberculatum* all have antheridium that sticks to the plant. *C. aureonitens, C. tuberculatum, C. mehranum*, and *C. tuberosum* all have hairy involucure. *C. denticulatum* has denticulate involucure, while C. indicum, C. cavernarum, and C. smaragdinum have smooth involucure. Spores from *C. aureonitens* are spiny, blackish-brown, oval, and all face the same direction. Spores from *C. cavernarum* are oblong, dark-colored, isopolar, baculate and, spinate., Spores from *C. smaragdinum* are granular and black or dark brown. Tuberculate and oval spores are present in *C. tuberculatum*. Spores are muricate in *C. mehranum*, dark brown, spinate, isopolar double sculpture spores are found in *C. tuberosum* and spores of *C. denticulatum* are verrucose and bluish brown in colour.

CONCLUSION

Bryophtes are ecologically distinct amphibians with a wide range of ecological environments. The genus Cyathodium, which has a wide range of traits, is found in the majority of countries. Several Indian taxonomists identified eight species. However, it looked like numerous species overlapped. Future study using molecular approaches to differentiate the species is required.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

ABBREVIATIONS

***C.*:** *Cyathodium*; ***syn.*:** Synonym; **ENVIS:** Environmental Information System; **mm:** Millimetre; **μm:** Micrometre; **cm:** Centimetre.

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