



Oedocladium sahyadricum (Chlorophyceae), a new species from Western Ghats, India

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ABSTRACT: A new edaphic green alga, *Oedocladium sahyadricum* sp. nov was identified from a natural forest in Kerala, India. In the present study, the new species is described and compared with its related species. The primary distinguishing characteristics of *O. sahyadricum* include its dioecious and terrestrial nature, superior operculum, ellipsoid oogonium, and oospore. The study highlights the presence of *Oedocladium* in Kerala and emphasize the need for exploration of soil algae to further understand the diversity of this genus.

KEY WORDS: Green algae, *Oedocladium terrestre*, *Oedogonium*, Sahyadri, soil algae.

INTRODUCTION

Chlorophycean algae exhibit remarkable diversity within tropical forest soils, where they dominate the algal flora specifically in acidic soil environments (Hoffmann, 1989). It has become essential to investigate novel and uncommon species of green algae for prospective utilisation. Not only for the value-added product (Uma *et al.*, 2023) but also for the comparison of biodiversity shifts between environments (Richards and Bass, 2005). *Oedocladium* belongs to the order Oedogoniales under the division Chlorophyta. This genus was established by Stahl (1891) and is now represented by 17 species according to the algal database. This genus is easily recognisable by the presence of terminal conical cells. Among the collected species, all are terrestrial except *Oedocladium hazenii* I.F Lewis (Tiffany, 1930). Moist or humid climate is necessary for their enumerate growth (Whitford, 1938; Halder, 2015). Research on this alga is limited due to its infrequent occurrence. Remarkably, *O. carolinianum* Beane & Hoffman stands out as the sole filamentous green algae capable of producing astaxanthin (Wang *et al.*, 2022). In another study, addition of *O. carolinianum* as a feed ingredient improves the flesh quality and increased the immunity of gibel carp (Chen *et al.*, 2019). Therefore, it is imperative to taxonomically identify the species of *Oedocladium*, not solely for the enrichment of biodiversity records but also for their potential practical applications in fields such as medicine, agriculture, and industry.

This genus is so far recorded in north America (Collins, 1918; Tiffany, 1930; Whitford, 1938), Europe (Hirn, 1900), Australia (Cribb, 1956) and Pakistan (Nurul, 1962). In India, first recorded species of *Oedocladium* was *O. terrestre* Biswas (Biswas, 1936) subsequently

several species has been reported from various parts of India (Randhawa, 1941; Kamat, 1962; Kushwah and Agarker, 1993). Most of the collected species are from the northern and central part of India. The occurrence of members of this genus has not yet been documented in the region of Kerala. The geological structure and climatic characters of Western Ghats play an important role in vegetation and biodiversity. Green algal vegetation of Western Ghats has been previously reported (Suresh *et al.*, 2012; Binoy *et al.*, 2019). During the field studies in southern Western Ghats of Kerala, a remarkable species of *Oedocladium* was noticed with attributes differ from already described species. The detailed investigation on the specimen revealed that this taxon is hitherto unknown to science, and is described and illustrated here as a new species.

MATERIALS AND METHODS

Collection and identification of algal sample

The samples were collected during monsoon season from the natural forest in Kollam district, Kerala (9°05'02.6"N, 77°10'22.0"E). The top soil samples (5–10 cm) along with algae were collected using a spatula and transferred into a polythene bag. The specimens were washed properly and mounted on a glass slide to examine directly under the microscope and photomicrographs of algae were taken using camera (Cmos Cam 3.0m 105 pixels) attached to Olympus CX41 microscope. Isolation and culturing of the alga was done in Bold's Basal Media (BBM) but it was not successful. The taxonomic classification was based on Smith (1950) and identification was based on algal flora (John and Rindi, 2014), scientific literatures (Nurul, 1962; Taft and Ross, 1980) and monographs (Tiffany, 1930).



Fig.1. Microphotographs of *Oedocladium sahyadricum* sp.nov. **A.** vegetative filament **B.** filament with conical apex **C.** a part of filament with oogonium **D.** ruptured oogonium with oospore

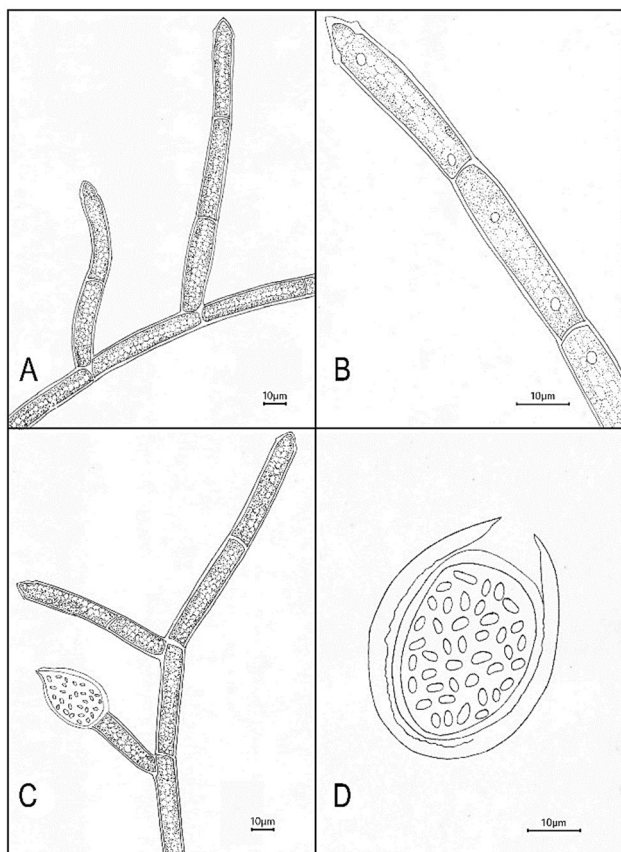


Fig.2. Line drawings of *Oedocladium sahyadricum* sp.nov. **A.** vegetative filament **B.** filament with conical apex **C.** a part of filament with oogonium **D.** ruptured oogonium with oospore

TAXONOMIC TREATMENT

Oedocladium sahyadricum G.J. Merin, V.P.Thomas & T.T. Binoy, *sp. nov.* **Figs. 1,2 A-D**

Type: INDIA, Kerala, Kollam District, Kumbhavuruttu, natural forest (9°05'02.6"N, 77°10'22.0"E), 27 August 2022, *Merin GJ 2050* (Holotype, CAPH! Isotype, CATH!).

Diagnosis: The new species is similar to *Oedocladium terrestre* Biswas in having dioecious habit, terminal solitary oogonia, oospore almost filling the oogonia and superior oogonial opening, differs in having longer cells (58–65µm), oogonium opening by operculum, ellipsoidal oogonium and ellipsoid oospore.

Description: Thallus dioecious, terrestrial, profusely branched; branches bilateral and arise just below the septum, filaments dichotomous towards the end. Vegetative cells are cylindrical and cells in prostrate filament is slightly elongate than those of erect branches (1.5 times). Terminal cells with conical apex and a whitish sheath. Colourless rhizoids are present; cells long and narrow. Chloroplast is reticulate with starch granules, containing two pyrenoids with starch sheath. In later stage peripheral movement of chloroplast is seen. Oogonia solitary, terminal, ellipsoidal and operculum superior.

Oospores are ellipsoid and nearly filled the oogonium. Antheridium was not observed both in post and pre-monsoon. Vegetative cells 9–11 µm broad and 58–65 µm long; oogonia 23–28µm broad and 29–39 µm long; rhizoidal cells 2–5 µm broad and 63–86 µm long.

Phenology: July to October

Ecology: The alga was found like filmy mat of elongated strands on damp soil. It resembles moss protonema and are velvety green in colour but in later stage it becomes yellowish green. Algal occurrence in this area was very rare. But during the season of monsoon and summer it was collected. The diversity of species is also very meagre.

Habitat: Habitat of the species was loamy, acidic in nature and moisture was determined as 15.7%.

Etymology: The specific epithet '*sahyadricum*' indicates Sahyadri (Western Ghats), place of collection, abundant in its floristic diversity and offers salubrious conditions for luxuriant growth of terrestrial microalgae.

Notes: *Oedocladium sahyadricum* is closely related to *O. terrestre* and also shows affinity with *O. tiffanyanum* A.B. Cribb, *O. carolinianum* Beaney & Hoffman and *O. cirratum* Beaney & Hoffman (Table 1).

DISCUSSION

The present study investigated the taxonomy of *Oedocladium* sp. found on damp soil in a reserve forest of Kerala, part of southern Western Ghats. Rainy weather is probably necessary for the abundant growth of this alga. The presence and position of sex organs, the position of operculum, nature of oospore wall is usually considered for the identification of species. The vegetative characters also serve as identification features but are not critical. The description of present species is based on first two characters but vegetative characters also considered. The present study suggests that Kerala, part of Western Ghats is still a sparsely studied area for soil green filamentous algae. Since it was failed to develop cultures of this species, possibly this will respond differently from the natural environment. However, in a previous study the cultures of *O. carolinianum* and *O. cirratum* has been successfully developed. (Beaney and Hoffman, 1968).

The new specimen should be compared with *O. terrestre*, *O. tiffanyanum*, *O. carolinianum* and *O. cirratum*. It differs from *O. terrestre* in having superior operculum, ellipsoidal oogonium and oospore. It resembles *O. carolinianum* and *O. cirratum* in its dioecies plant body and terrestrial habitat and differs from that in superior operculum rather than inferior operculum, all layers of spore wall are smooth, oogonium and oospore shape is ellipsoidal. It differs from *O. tiffanyanum* in having superior operculum, all layers of spore wall are smooth, ellipsoidal oogonium and oospore while *O. tiffanyanum* have globose to sub globose shape.

With its branching structure and terrestrial environment,

**Table 1.** Comparison of diagnostic characters with *O. tiffanyanum*, *O. terrestre*, *O. carolinianum*, *O. cirratum* and *O. protonema*.

Features	<i>O. sahyadricum</i>	<i>O. tiffanyanum</i>	<i>O. terrestre</i>	<i>O. carolinianum</i>	<i>O. cirratum</i>	<i>O. protonema</i> (Type sp.)
Plant body	Dioecious	Dioecious	Dioecious	Dioecious	Dioecious	Monoecious
Habitat	Terrestrial	Terrestrial	Terrestrial	Terrestrial	Terrestrial	Terrestrial
Vegetative cell (b x l)	9–11 µm x 58–65 µm	14–30 µm x 40–130 µm	12–14 µm x 35–45 µm	8–26 µm x 34–186 µm	8–17 µm x 68–272 µm	7 µm x 20 µm
Oogonium opening	Superior operculum	Inferior pore	Superior pore	Inferior operculum	Inferior operculum	Median pore
Oospore wall	All layers smooth	Outer and inner layers smooth, middle layer angulate	All layers smooth	Outer and inner layers smooth, middle layer angulate	Outer and inner layers smooth, middle layer angulate	All layers smooth
Oospore shape	Ellipsoid	Globose to sub globose	Globose or oval	Globose to sub globose	Globose to sub globose	Globose or sub globose
Oogonium shape	Ellipsoid	Globose or sub globose	Sub globose	Globose	Globose	Sub globose
Oogonium size (b x l)	23–28 µm x 29–39 µm	52–67 µm x 35–63 µm	26–36 µm x 40–50 µm	49–62 µm x 44–57 µm	48–73 µm x 54–80–97 µm	50–76 µm x 58–76 µm

Oedocladium is considered as the most evolved member of the Oedogoniales (Randhawa, 1941). In addition, it has been believed that this genus evolved from *Oedogonium* via a *Bulbochaete* stage (Biswas, 1936). In a previous study, it has been found that the top cell of *Oedocladium prescottii* A.K Islam possesses an asymmetric anterior weakening site, postulated to function as an adaptive mechanism for growth in soil (Luo *et al.*, 2003). Similarly, the study of *Oedocladium terrestre* in West Bengal highlighted ecological adaptations like downward bending mature oogonia and narrower rhizoids for terrestrial habitats (Halder, 2015). So far 15 species of *Oedocladium* have been described and majority of them from outside India. To date, only a limited number of molecular studies have been done in this genus and most of the data is of two species viz. *O. carolinianum* and *O. prescoti* (Xiong *et al.*, 2021). Understanding the chloroplast genome evolution in *Oedocladium*, compared to *Oedogonium*, reveals slower gene rearrangement and intron proliferation dynamics (Brouard *et al.*, 2016). These findings emphasize the importance of detailed morphological and genetic analyses in identifying and describing new *Oedocladium* species, contributing to the taxonomic richness and ecological understanding of this genus.

The following new key is helpful in identifying the existing *Oedocladium* spp.

- 1a. Plants monoecious 2
- 1b. Plants dioecious 11
- 2a. Oogonium ellipsoid to ovoid 3
- 2b. Oogonium globose to sub globose 6
- 3a. Antheridium borne below the oogonium on the same filament 4
- 3b. Antheridium borne terminal on separate filament *O. indicum*
- 4a. Outer wall of oospore smooth 5
- 4b. Outer wall of oospore papillose *O. eriense*
- 5a. Middle layer of oospore scrobiculate *O. operculatum*
- 5b. Middle layer of oospore smooth *O. prescottii*
- 6a. Oogonium opening inferior or inframedian 7
- 6b. Oogonium opening middle 10
- 7a. Oogonium c. 90 µm long; middle layer of oospore wall scrobiculate; *O. albermalense*
- 7b. Oogonium ≤ 70µm long; middle layer not scrobiculate; 8

- 8a. All layers of oospore wall smooth *O. himalayense*
- 8b. Middle layer angulate or with markings 9
- 9a. Antheridia up to 9 cells in a series *O. lewisii*
- 9b. Antheridia up to 15 cells in a series *O. wetsteinii*
- 10a. Oospore completely filling the oogonium *O. protonema*
- 10b. Oospore not completely filling the oogonium *O. media*
- 11a. Terrestrial 12
- 11b. Aquatic *O. hazenii*
- 12a. Oospore ellipsoid *O. sahyadricum*
- 12b. Oospore globose/sub globose/oval 13
- 13a. Oospore wall with middle layer smooth *O. terrestre*
- 13b. Oospore wall with middle layer angulate 14
- 14a. Oogonium open by pore *O. tiffanyanum*
- 14b. Oogonium open by operculum 15
- 15a. Androsporangial branch is coiled *O. cirratum*
- 15b. Androsporangial branch is not coiled *O. carolinianum*

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