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REVIEW ARTICLE

A systematic review on distribution and morphological characterization of genus *Trentepohlia* Mart. (Chlorophyta) in India

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Abstract

Trentepohlia Mart. is a subaerial green alga, it resides in the division Chlorophyta, class Ulvophyceae, order Trentepohliales, and family Trentepohliaceae which grows freely on tree bark, wood, leaves, rock, concrete walls, and several other artificial substrata by forming yellow, orange and red patches. *Trentepohlia* is widely distributed in tropical, subtropical, and temperate climates and is present in almost all continents. These *Trentepohlia* species are identified on the basis of their morphology, taxonomy, phylogeny, distribution, and reproduction, but molecular studies of this order are still rare. As per the review, 29 species and 2 varieties of *Trentepohlia* have been described in India from the states of Kerala, West Bengal, Karnataka, Tamil Nadu, Meghalaya, Assam and Maharashtra. Hence, it shows the work done in India is meagre, yet there may be species that need to be identified from the other states of India in future. Hence, further research is needed to make availability of good data on species as it has economic importance and potential to have a positive impact on human health. This review highlights the need for a valid document to understand distribution of genus *Trentepohlia* species in India.

Keywords: Chlorophyta; Morphology; Subaerial algae; *Trentepohlia*; Ulvophyceae

1. Introduction

***Etymology*:** Johann Friedrich Trentepohl was a German clergyman and botanist who made significant contributions to the field of botany. He worked as a tutor and pastor in various smaller places in the Weser-Marsch region. Initially, he focused on collecting land vegetation, but later, his interest shifted towards algae. Trentepohl created two herbaria and wrote about the Oldenburg Flora, specifically the Phanerogamen group of plants, although his manuscripts were published posthumously (Burkhardt, 2022).

In honour of Johann Friedrich Trentepohl, Carl Friedrich Philipp von Martius named a particular type of algae as *Trentepohlia* in 1817 (Burkhardt, 2022). This subaerial green algae genus *Trentepohlia* was initially described by Linnaeus as *Byssus aurea* L. in his work "*Species Plantarum*" (Linnaeus, 1753). However, it is widely accepted as *Trentepohlia* Mart. as there is no authentication to suggest that Linnaeus actually observed this species and the term "*Byssus aurea*" was based on the concept of "*Byssus capillacea pulverulenta*" (Guiry and Guiry, 2024).

The unique distinguishing features of Order Trentepohliales are, the presence of β-carotene and haematochrome (yellow, orange, or red colour thallus), transverse cell walls with plasmodesmata, absence of pyrenoids in the chloroplast, a unique flagella apparatus, and the sporangiate lateral (a unique reproductive structure) (Tamal et al., 2012). The most important characteristics for the identification of genus *Trentepohlia* at the species and variety level are the shape and size of vegetative cells, the presence of hair-like cells, branching pattern, position and morphology of reproductive structures (Liu et al., 2012; Sanctuary and Saraphol, 2020). Based on the two main features (Thompson and Wujek, 1992) distinguished the two genera *Printzina* and *Trentepohlia*. Firstly, the extent of the prostrate system relative to the erect system (well developed in *Printzina*, limited in *Trentepohlia*) and secondly, the shape of the zoosporangia (globular to reniform in *Printzina*, ovoid in *Trentepohlia*) (Rindi and Bautista, 2007).

The genus *Trentepohlia* is widely distributed in tropical, subtropical, and temperate environments (Liu et al., 2012; Satpati and Pal, 2016). The sensitivity to cold damage increases the wealth of trentepohliaceous photobionts in tropical and subtropical floras (Nash et al., 1987), they arise in temperate environments and in almost all continents (Sarma, 1986). The phylogenetic point of view, gives the impression of being closely related to marine species and recently it has been moved to the class Ulvophyceae (Chapman et al., 1995). Based on rRNA gene sequence data, the only algal group to make headway straight from the marine to terrestrial habitats (Aboal et al., 2002). These *Trentepohlia* are known as microchlorophytes, distinctive among the other green algae by their blended morphological and ultrastructural characters, they possess a unique characteristic appearance i.e., macrochlorophytes as the species forms irregular red vertical streaks. Hence, the yellow, orange, red or green coloured patches growing on different surfaces produced by the accumulation of beta carotene and hematochrome helps to recognize them easily (Kharkongor and Ramanujam, 2015). It is a dominant subaerial green alga, spread abundantly, and furnishes yellow, red, and orange colors to the tree barks, rocks, walls, and electric poles (Kharkongor and Ramanujam, 2015; Satpati and Pal, 2016).

The basic structure of genus Trentepohlia Mart. (1817)

The *Trentepohlia* thallus is filamentous, sparsely to profusely branched. The thallus is heterotrichous, differentiated into erect system and prostrate system depending on the climatic conditions the development of prostrate and erect parts differs among species or within the same species. Absence of specialized rhizoids but in some species, presence of colourless unicellular hair-like, protuberances on the vegetative cells. Presence of gametangia at lateral terminal, or intercalary on the erect axis and in some species gametangia are borne on prostrate filaments. The gametangia is globular or ovoid in shape and which produce number of biflagellate gametes. The gametes release out through a circular ostiole or an elongated beak and fuse by isogamy. The solitary sporangiate laterals are borne at the top of the erect filaments or short lateral branches, in some species, sporangiate laterals are assembled in groups of 2–8 on enlarged apical cells at the apices of the erect filaments. The life history is believed to consist of an alternation of two generations with similar morphology, a haploid gametophyte reproducing sexually by gametes, and a diploid sporophyte reproducing asexually by zoospores. Fusion of gametes is rare, the gametes behave as spores and reproduce new thalli without sexual fusion has been recorded for several species (Guiry and Guiry, 2024).

2. Methods of data collection

The present data is based on the information collected from the following sources:

- The literature and studies related to Genus *Trentepohlia* collected from monographs and books (Linnaeus, 1753; Cribb, 1958 and 1970; Printz, 1920 and 1939; Krishnamurthy, 2000), research articles and AlgaeBase.
- The description of each species is given by comparing the same books, monographs and research articles.
- The Indian data is provided based on the species reported in research articles, Krishnamurthy book and AlgaeBase.

Morphology of Trentepohlia species found in India

1. Trentepohlia aurea (Linnaeus) C Martius (1817)

Thallus heterotrichous, pseudoparenchymatous, (Krishnamurthy, 2000; Sanctuary and Saraphol, 2020) 987.80-1.5 mm tall (Rindi and Bautista, 2008; Sanctuary and Saraphol, 2020). Filaments are long, straight, slightly curved, more or less branched. Cells cylindric or slightly inflated, 7-30 µm broad, 1-4 times long as broad or Cell length 10-60 µm (Printz, 1920; Krishnamurthy, 2000; Tiwari et al., 2011; Satpati and Pal, 2015; Singh and Singh, 2017; Sanctuary and Saraphol, 2020). The cells of the main axis are cylindrical (Binoy et al., 2019; Sanctuary and Saraphol, 2020) and lateral branches have either cylindrical or barrel-shaped cells. Cell length ranges from 2–50 µm and width ranges from 8–20 µm (Sau, 2011; Binoy et al., 2019; Sanctuary and Saraphol, 2020). Cells of basal filaments are cylindrical or swollen, erect filaments cylindrical, parallel or irregular, richly branched; branches obtuse, sometimes tapering. Cells 11-17 µm wide, 1.5 to three times longer than wide (Uyenco, 1965; Rindi and Bautista, 2008). The apical cells obtuse with pectic cap (Krishnamurthy, 2000; Sanctuary and Saraphol, 2020) and are variable in shape with blunt tips but occasionally pointed. Presumptive gametangia globular, sub globular, or flask-shaped or slightly ellipsoid or ovoid, 15–35 µm wide (Printz, 1920; Rindi and Bautista, 2008; Sau, 2011; Allali et al., 2013; Sanctuary and Saraphol, 2020), 32.05-36.63 µm long (Sanctuary and Saraphol, 2020). The membrane is thin and glabrous or crenulate. Two gametangia may arise from one vegetative cell (Printz, 1920). 10.05-30 µm wide, 49.40 - 52.23 µm long, (half to three times as long) (Tiwari et al., 2011; Sanctuary and Saraphol, 2020). Zoosporangia oval, elliptical, or ovoid 11-17.5 µm in diameter, attached to suffultory cell (Uyenco, 1965; Rindi and Bautista, 2008). Sporangia sessile, spherical, lateral and terminal 10 – 70 µm in diameter (Panikkar and Sindhu, 1993; Sau, 2011; Tiwari et al., 2011; Satpati and Pal, 2015; Krishnamurthy, 2000). Sporangia occurs in pairs by series of cells (Krishnamurthy, 2000).

Distribution: Kerala, Assam, West Bengal, and Karnataka.

Trentepohlia aurea* var. *tenuior P. Brühl and K. Biswas (1923)

The cells, cylindrical, elongated, and constricted at the cross walls, often slightly or irregularly swollen in middle 4 -12.1 µm broad and 12-34.8 µm long (Panikkar and Sindhu, 1993; Krishnamurthy, 2000). Sporangia lateral as well as terminal, spherical about 16 µm in diameter or obovoid 12-20 µm long and 9-16 µm broad (Krishnamurthy, 2000).

Distribution: Kerala and West Bengal.

2. Trentepohlia jolithus (L) Wallorth (1833)

The thallus is a slight differentiation between prostrate and erect filaments. The basal parts gradually die. Branching is irregular, unilateral, and more profuse in apical parts as branches emerge from the apical part of the main filament cell and remain parallel to it. Cells cylindrical, slightly constricted, 30-50 X 10-32.5 µm. Apical cells, blunt with mucilage caps. Cell wall, thick, lamellated with rough divergent layers. Zoosporangia solitary or in couples and globose, 18.4 – 25 X 10.4 – 22.5 µm. Presumptive gametangia sessile, globose or subglobose, 25 – 40 X 28.5 – 32.5 µm or bottle-like 50 – 105 X 30 - 55 µm (Aboal et al., 2002).

Cells of the prostrate system are fusiform or slightly swollen and those on the erect system cylindrical, 24-50 µm long and 14-30 µm broad (Krishnamurthy, 2000; Tiwari et al., 2011). Apical cells bluntly rounded. Cell wall is thick with a rough surface (Krishnamurthy, 2000). Sporangia stalked globose, terminal or lateral, 20-50 µm in diameter (Krishnamurthy, 2000; Tiwari et al., 2011).

Distribution: Kerala.

3. Trentepohlia umbrina (Kutzing) Bornet (1873)

Thallus heterotrichous (Sanctuary and Saraphol, 2020), pseudoparenchymatous (Rindi et al., 2008). Cells globular, cylindrical, elliptical or less swollen, or barrel-shaped, or rounded, 8–25 µm in diameter (Rindi et al., 2005, 2006 and 2008; Allali et al., 2013; Singh and Singh, 2017) and 25.35-29.60 µm long or 1–2.5 times as long as wide (Uyenco, 1965; Rindi et al., 2005; Rindi and Bautista, 2008; Sanctuary and Saraphol, 2020). Cells rounded, spherical, ellipsoid or ovoid, 3-4 times as long as broad, 15-25 µm (up to 35 µm) (Printz, 1920). Apical cells with pectic cap (Sanctuary and Saraphol, 2020). Zoosporangia and gametangia were not observed (Rindi et al. 2005; Rindi and Bautista 2008; Allali et al., 2013; Sanctuary and Saraphol, 2020). Presumptive gametangia were similar to the vegetative cells, with a short neck (Printz, 1920; Uyenco, 1965) or gametangia sub-globular, globular or flask-shaped, 10-26 µm in diameter, with a short neck (Rindi et al., 2006 and 2008). Zoosporangia globose, single, 15 µm in diameter, zoospores quadriflagellated (Uyenco, 1965). Sporangia stalked, terminal on poorly developed erect filaments (Krishnamurthy, 2000).

Distribution: Karnataka, Kerala and Meghalaya.

4. Trentepohlia odorata (F. H. Wiggers) Wittrock Fionia (1880)

Thallus heterotrichous. Branched filaments, Cells cylindrical, in erect filament, 10-42 µm long and 5-18 µm broad. Apical cells with pectose caps (Krishnamurthy, 2000; Tiwari et al., 2011). The Cells are subglobose to ellipsoid in basal filaments and are usually sub-cylindric to cask-shaped in erect filaments, and generally about as long as broad, or a little longer or shorter, 17-25 x 14-24 µ. Cell walls are thin and smooth in basal filaments, and thicker in erect filaments, 2-4-(7) µ, and often roughened and shaggy-scaly (Cribb, 1958). Presumptive gametangia nearly spherical to elliptic, lateral, terminal, or intercalary; zoosporangia similar in shape, 13 µ in diameter (Uyenco, 1965). Sporangia, globose to subglobose, lateral/terminal, sessile and stalked, 10-30 µ diameter (Cribb, 1958; Krishnamurthy, 2000; Tiwari et al., 2011).

Distribution: Kerala.

5. Trentepohlia abietina (Flotow ex Kützing) Hansgirg (1886)

Thallus heterotrichous, pseudoparenchymatous (Krishnamurthy, 2000; Sanctuary and Saraphol, 2020). The thallus consisted of erect axes, 195.45 - 600 µm tall, arising from a limited prostrate system (Rindi et al., 2005, 2006 and 2008; Rindi and Bautista 2008; Allali et al., 2013; Binoy et al., 2019; Sanctuary and Saraphol, 2020).Cell length 10-55 µm, Cell breadth10-20 µm (Krishnamurthy, 2000; Satpati and Pal, 2015).Cells of the erect axes are cylindrical, occasionally swollen or barrel-shaped 4–12 µm in diameter (rarely up to 12, mostly 7–8) and 1–6 times as long as wide (mostly 3–4, 15 – 20 µm) (Rindi et al., 2005, 2006 and 2008; Rindi and Bautista, 2008; Tiwari et al., 2011; Allali et al., 2013; Sanctuary and Saraphol, 2020). Cells of the prostrate filaments are globular, elliptical or cylindrical, or barrel-shaped, 4 –12 µm in diameter and 1–3 times as long as wide (6–20 µm in length) (Rindi et al., 2005, 2006 and 2008; Binoy et al. 2019; Sanctuary and Saraphol, 2020). Sporangia rare, cylindrical, diameter of sporangia 10-35 µm (Satpati and Pal, 2015). Apical cell 10 – 45 µm long and 10 – 25 µm broad without a cap (Krishnamurthy, 2000). Presumptive gametangia globular or ovoid, 10–25 µm in diameter (Uyenco, 1965; Rindi et al., 2005, 2006 and 2008; Rindi and Bautista 2008; Allali et al., 2013). Suffultory cell straight or slightly curved neck 12–14 µm wide, zoosporangia globular, 14–20 µm in diameter (Rindi et al., 2005; Allali et al., 2013). Apical cell with pectic cap (Rindi et al., 2006 and 2008; Rindi and Bautista 2008; Allali et al., 2013; Binoy et al., 2019).

Distribution: Kerala, West Bengal, Tamil Nadu and Meghalaya.

6. Trentepohlia flava (W.J.Hooker and Arnott) De Toni ex De Wildeman (1888)

The thallus is up to 200 - 800 µm tall (Rindi et al., 2005 and 2006; Tamal et al., 2012). Erect filaments are rigid, mainly straight, branching, commonly with 20 or more cells. Erect cells are cylindrical or slightly inflated, 8.5-20 µm in diameter (mostly 25), and 1.5-4.5 diameter long or 1.5 –10 times as long as wide (mostly 5–6) (Cribb, 1970; Rindi et al., 2005 and 2006; Tamal et al., 2012). Prostrate filaments subtorulose, isodiametric, up to 26 µm in diameter (Cribb, 1970). The prostrate cells, globular to elliptical, 12–16 µm in diameter (Rindi et al., 2005 and 2006; Rindi et al., 2018). Apical cells with pectic cap (Rindi et al., 2005 and 2006; Rindi et al., 2018) and cells with irregular caps, up to 36 µm long (Cribb, 1970). Presumptive gametangia globular, sub globular, egg-shaped, urn-shaped, or flask-shaped, with a short neck, 14–36 µm in diameter (Rindi et al., 2005 and 2006; Rindi et al. 2018). Biflagellate elliptical swarmers, 8–10 µm long and 5–8 µm wide (Rindi et al., 2005). The zoosporangia globular or sub globular, 20-30 µm in diameter. The neck of the suffultory cell bent (Rindi et al., 2006). Sporangia globose or subglobose, intercalary, lateral and sessile (Cribb, 1970).

Distribution: West Bengal.

7. Trentepohlia torulosa De Wildeman (1888)

Vegetative filaments are torulose and branched. Cells elliptical sometimes subspherical constricted at the cross wall. The cells are 14-20 µm in diameter and 16-36 µm long. The cell wall is thin 1-1.5 µm in thickness, usually smooth (Krishnamurthy, 2000; Tiwari et al., 2011). Sporangia spherical, sessile, lateral or terminal, rarely intercalary, 14 – 24 µm in diameter (Krishnamurthy, 2000).

Distribution: West Bengal.

8. Trentepohlia monilia De Wildemann (1888)

Thallus heterotrichous, pseudoparenchymatous, consisting of separation between dense prostrate parts and erect parts (Panikkar and Sindhu, 1993; Krishnamurthy, 2000; Tiwari et al., 2011; Sanctuary and Saraphol, 2020). The erect axes are up to 197.31-313.39 µm tall. Cells of the prostrate part are elliptic or globular, 16-31 µm wide, 16-30 µm long (Krishnamurthy, 2000; Tiwari et al., 2011; Sanctuary and Saraphol, 2020), 4 -7 µm broad at joints (Krishnamurthy, 2000). Cells of the creeping system globular or ellipsoidal (Singh and Singh, 2017), elongate and deeply constricted at the cross walls, 15.5 – 20 µm broad, and 23 – 45.4 µm long (Panikkar and Sindhu, 1993; Krishnamurthy, 2000; Tiwari et al., 2011; Sanctuary and Saraphol, 2020), 10 – 13 µm broad at joints (Krishnamurthy, 2000). Apical cell, globular (Sanctuary and Saraphol, 2020). Sporangia stalked, 17-27 µm in diameter (Krishnamurthy, 2000; Tiwari et al., 2011).

Distribution: Kerala, Karnataka and Tamil Nadu.

Trentepohlia monilia De Wildemann var. ***subspherica*** V.Krishnamurthy (2000)

The filaments irregularly branched, cells smaller in size than in the species, almost spherical, constricted at septum, 10 – 25 µm long and 15 – 25 µm broad, the septum is 5 – 10 µm in diameter. Sporangia not well developed (Krishnamurthy, 2000).

Distribution: Tamil Nadu.

9. Trentepohlia rigidula (J. Müller) Hariot (1889)

Thallus heterotrichous, pseudoparenchymatous (Sanctuary and Saraphol, 2020) and has moniliform (Cribb, 1970) and uniseriate filaments (Satpati and Pal, 2016; Sanctuary and Saraphol, 2020). Erect axes 255.04-328.99 µm tall (Sanctuary and Saraphol, 2020). Cells are elliptical, barrel-shaped, globular, sub globular or almost cylindrical, 10-33 µm wide (Cribb, 1970; Rindi et al., 2008; Allali et al., 2013; Satpati and Pal, 2016; Binoy et al., 2019) and 12-60 µm in length or 1–3 times as long as wide (Allali et al., 2013; Satpati and Pal, 2016; Binoy et al., 2019). Cells of the prostrate part are globular, sub-globular, barrel-shaped, 12-15 µm wide, 12-18 µm long. Cells of the erect filaments were globular, sub-globular, barrel-shaped, 4.04-7.58 µm wide, 21.00-28.87 µm long (Cribb, 1970). Sporangium varied from globular, orbicular, or dome-shaped (Satpati and Pal, 2016; Binoy et al., 2019) with a 15-30 µm diameter (Satpati and Pal, 2016). The apical cells with pectic cap. Septum is usually 5-10 times the diameter of the cell. No reproductive structures were observed (Cribb, 1970). Presumptive gametangia abundant, globular, ovoid or dome-shaped, 20-26 µm in diameter (Rindi et al., 2008).

Distribution: Kerala, West Bengal.

10. Trentepohlia arborum (C. Agardh) Hariot (1889)

Thallus heterotrichous (Cribb, 1970). The erect axes with limited branching and are 5µm - 2 cm tall (Uyenco, 1965; Rindi et al., 2005; Rindi and Bautista, 2008; Rindi et al., 2008; Allali et al., 2013). Prostrate filaments with cylindrical or subcylindrical cells. Erect filaments sometimes non-tapering, apical cell subcylindrical with rounded apex. More commonly tapering apex, 3.5 µm in diameter (Cribb, 1970). Cells cylindrical, 10–35 µm wide and 34 – 114 µm long or 1.5–6 times as long as wide (Uyenco, 1965; Panikkar and Sindhu, 1993; Krishnamurthy, 2000; Rindi et al., 2005; Rindi and Bautista, 2008; Rindi et al., 2008; Tiwari et al., 2011; Allali et al., 2013; Binoy et al., 2019). Cell wall smooth, sometimes rough 2-4 µm thick (Cribb, 1970; Krishnamurthy, 2000). The apical cells are blunt and devoid of pectic caps (Rindi and Bautista, 2008; Rindi et al., 2008; Allali et al., 2013; Binoy et al., 2019). Zoosporangia elliptical, kidney-shaped, ovoid or globose, 18–25 - 25–40 µm. Gametangia globular, sub globular, ovoid, or elliptic, 25–40 µm in diameter (Uyenco, 1965; Rindi et al., 2005; Rindi and Bautista, 2008; Rindi et al., 2008; Allali et al., 2013). Sporangia terminal sometimes lateral which is sessile, terminal ones stalked and appear either singly or in groups of two or more on swollen subterminal cells, pedicellate, spherical, globose to ellipsoid, globose or subglobose, 19-50 µm in broad (Cribb, 1970; Panikkar and Sindhu, 1993; Krishnamurthy, 2000) and 26 – 38 µm long, stalk twice as long as sporangia (Krishnamurthy, 2000). Ostiole lateral (Cribb, 1970).

Distribution: Kerala, Meghalaya and West Bengal.

11. Trentepohlia dialepta (Nylander) Hariot (1889)

The thallus with distinct prostrate and erect branches tapering towards the end (Salleh and Milow, 1999; Thomas et al., 2017; Binoy et al., 2019). The thallus, richly branched and branches are nearly always opposite and in pairs (Krishnamurthy, 2000; Tiwari et al., 2011). Cells cylindrical / barrel shaped or terete 8–15 µm wide and 4.8– 69.3 µm long (Salleh and Milow, 1999; Krishnamurthy,

2000; Tiwari et al., 2011; Thomas et al., 2017; Binoy et al., 2019). Gametangia globose (Printz, 1920), spherical, lateral or terminal, solitary, and 12–28 µm in diameter. Sporangia ovoid, 16.8 - 19 µm wide and 13.8–21 µm long (Printz, 1939). Stalk cells are bottle-shaped, often bent at the neck, 6.3 - 26 µm wide and 13–21 µm long (Printz, 1939; Salleh and Milow, 1999; Thomas et al., 2017; Binoy et al., 2019). Stalk cells of paired sporangia are borne on cuneate head cells which are not more than 14.7 µm wide and 16.8–21.0 µm long (Salleh and Milow, 1999).

Distribution: Kerala, West Bengal, Tamil Nadu.

12. Trentepohlia jucunda (Cesati) Hariot (1889)

Filaments are cushion-forming, and consist of loose interwoven radiating filaments. Filaments are made up of long cylindrical cells. Usually, cells initiate in the unilateral branches at a right angle to their own. The filaments have slightly attenuated terminal cells and the cells are 12-20 µm in diameter and 30-60 µm in length (Tiwari et al., 2011).

Distribution: West Bengal.

13. Trentepohlia tenuis (Zell.) De Toni (1889)

The filaments are straight or flexuous. Cells constricted at the cross walls. Cells elongate ellipsoidal often asymmetric. The cells of primary and secondary filaments, 8-14 µm long and 6-8 µm in breadth. The cell wall is 1-1.5 µm thick very rough on the outer surface. Sporangia spherical, terminal, or lateral not clustered and sessile (Krishnamurthy, 2000; Tiwari et al., 2011).

Distribution: Kerala, West Bengal.

14. Trentepohlia bossei de Wildeman (1890)

The filaments are pseudo-dichotomously branched and consist of elongated cylindrical cells that may be slightly constricted at the cross walls. Cells measure 12-18 µm in width and 32-35 µm in length. Sporangia terminal or lateral, spherical or ovoid, 22-28 µm in diameter, and stalk cells 9-20 µm in width and 15-30 µm in length. The terminal cells of the filaments are slightly tapering (Tiwari et al., 2011). De Wildeman gives cell dimensions of this species as 9-12 µ broad and 2-3 diameter long (Printz, 1939) gives dimensions of 9-19 µ (Cribb, 1958).

Distribution: Kerala.

15. Trentepohlia dusenii Hariot Bonge (1893)

The thallus was distinctly separated into a prostrate part and an erect part. The erect axes, 300 - 350 µm tall (Rindi et al., 2007 and 2008), irregularly branched (Tiwari et al., 2011). The cells are cylindrical or barrel-shaped to globular or elliptical and were 5–9 µm wide and 10-14 µm in length (Rindi et al., 2007 and 2008; Tiwari et al., 2011) or 1–4 times as long as wide, mainly 1.5 and 2–4 times as long as wide, mainly 2.5–3 times (Rindi et al., 2007; Allali et al., 2013). Gametophyte generation has thinner axes 3.5–7.5 µm wide (mainly 5.5–6), and Sporophyte generation has thicker axes, 7–11 µm wide (Rindi et al., 2007 and 2008). The apical cells are slightly pointed and bullet-shaped to blunt with no pectic caps (Rindi et al., 2007; Rindi and Bautista 2008), in some devoid of pectic caps (Allali et al., 2013). Presumptive gametangia globular or ovoid, 10–15 µm in diameter (Rindi et al., 2007 and 2008). The suffultory cell is long, and slightly enlarged, with a neck bent at approximately a 90-degree angle. The zoosporangium is elliptical, 10–13 to 14– 16 µm in size (Rindi et al., 2007; Rindi and Bautista, 2008; Allali et al., 2013) and globular zoosporangium is 12-15 µm in diameter (Rindi et al., 2008). Sporangia spherical in shape, 10-18 µm in diameter (Tiwari et al., 2011).

Distribution: West Bengal.

16. Trentepohlia cucullata De Wildeman (1896)

Thallus differentiated into prostrate and erect systems. Erect axes 1-1.5 mm tall. Cells are cylindrical, 8-14 µm wide, and 2-3 times as long as wide (mainly 10-12 µm). Apical cells blunt with brownish cap. Gametangia globular, 25-40 µm in diameter (Rindi and Bautista, 2008).

Distribution: Assam.

17. Trentepohlia treubiana De Wildeman (1896)

The thallus is light green to yellowish in colour (Tiwari et al., 2011). Thallus consisting of erect axes poorly branched (Rindi et al., 2008; Tiwari et al., 2011), up to 350 µm tall, arising from a limited prostrate system (Rindi et al., 2008). Cells are cylindrical, slightly inflated, 6-12 µm wide (mainly 7.5-9.0 µm) and 19-25 µm long (Rindi et al., 2008; Tiwari et al., 2011) or 1-2 times as long as wide. Apical cells are blunt and devoid of pectic caps. New branches arise from either the corners or the central parts of the cells. Gametangia abundant, globular or subglobular, 18-25 µm in diameter (Rindi et al., 2008). Sporangia are spherical in shape mostly found 2-6 in series and may be up to 22 µm in diameter (Tiwari et al., 2011).

Distribution: West Bengal.

18. Trentepohlia minima Schmidle (1897)

Thallus with a clear separation between erect and prostrate parts (Rindi et al., 2008; Singh and Singh, 2017). Erect axes, up to 100 µm tall (Allali et al., 2013), they are 3–4 µm wide, 3–8 times as long as wide (Rindi et al., 2008; Allali et al., 2013) and 3–5 times as long as wide in the prostrate axes (Rindi et al., 2008). Erect filament thin, 13.8-15.3 X 3-4.5µ wide, cells cylindrical and swollen. Prostrate wider than erect one, 8.4µ wide. Cells are globular or ellipsoidal more or less spherical (Singh and Singh, 2017) has pointed tip and tapered towards apices (Rindi et al., 2008; Allali et al., 2013), Gametangia globular or elliptical, spherical, ellipsoidal or oval sometimes with a short beak, 5–13 µm in diameter (Rindi et al., 2008; Allali et al., 2013; Singh and Singh., 2017). Gametangia in rows or spirally arranged, 7.6-9.2 µ in diameter (Singh and Singh, 2017).

Distribution: Karnataka.

19. Trentepohlia annulata, F. Brand, Germany (1902)

Thallus is formed by erect axes and without branched, arising from the prostrate axes which are poorly developed (Rindi and Bautista, 2008; Binoy et al., 2019). Cells are cylindrical 18-45 µm length and width range from 7-14 µm (Rindi and Bautista, 2008; Bast et al. 2015; Binoy et al., 2019) or 2-3 times as long as wide (Binoy et al., 2019; Rindi and Bautista, 2008). The barrel-shaped or globular cells are 32-38 × 12-16 µm or 35 × 26 µm in size (Bast et al., 2015). Gametangia globular, 25-35 µm in diameter (Rindi and Bautista, 2008; Bast et al., 2015). Zoosporangium elliptical or flask-shaped 20 – 33 µm in diameter supported by suffultory cell (Rindi and Bautista, 2008).

Distribution: Kerala.

20. Trentepohlia gracilis Iyengar in Bruhl and Biswas (1923)

Thallus is heterotrichous with prostrate and erect systems (Panikkar and Sindhu, 1993; Krishnamurthy, 2000). The Prostrate system has sub-globose, ellipsoidal, or oval cells constricted at the joints. Cells of the Prostrate system are 9 – 15 µm broad, 12 -18.18 µm long (Panikkar and Sindhu, 1993; Krishnamurthy, 2000; Tiwari et al., 2011). Erect filaments have ellipsoidal or pear-shaped cells. The filaments are elongated and branched. Cells of the erect system subglobose, 4 - 8 µm broad, 9-15 µm long (Panikkar and Sindhu, 1993; Krishnamurthy, 2000; Tiwari et al., 2011). Sporangia were not seen (Krishnamurthy, 2000).

Distribution: Kerala, West Bengal.

21. Trentepohlia pathanamthittaensis M. V. N. Panikkar and P. Sindhu (1993)

Cells cylindrical 10-12.1 µm broad and 18-30.3 µm long, sporangia intercalary or lateral, sessile, 25-30.3 µm in diameter (Panikkar and Sindhu, 1993; Krishnamurthy, 2000; Tiwari et al., 2011).

Distribution: Kerala.

22. Trentepohlia angadickalensis, M. V. N. Panikkar and P. Sindhu (1993)

Thalli are highly branched. Cells of prostrate filaments 18-22.7 µm long and 4-10µm broad, cells of erect filament 9-15 µm long and 4.5-8 µm broad. Sporangia sessile, clustered on the surface of cells, 9-15.1 µm in diameter (Panikkar and Sindhu, 1993; Krishnamurthy, 2000; Tiwari et al., 2011).

Distribution: Kerala.

23. Trentepohlia thevalliensis M. V. N. Panikkar and P. Sindhu (1993)

Thalli saxicolous, forming small dark brown cushions (Krishnamurthy, 2000; Tiwari et al., 2011). Filaments are long, bearing primary and secondary branches. Cells of primary branches are large, 18-23 µm long and 10-12.12 µm broad, cells of secondary branches are 10-15.2 µm long and 4-6 µm broad. Sporangia sessile, produced on both primary and secondary branches, sporangia of primary branches lateral, terminal, or intercalary, 12-18.1 µm in diameter, sporangia of secondary branches lateral, 7-9 µm in diameter (Panikkar and Sindhu, 1993; Krishnamurthy, 2000; Tiwari et al., 2011).

Distribution: Kerala.

24. Trentepohlia chapmanii Rindi and López-Bautista (2007)

Thallus heterotrichous, prostrate part spreading, pseudoparenchymatous (Rindi et al., 2007 and 2008; Rindi and Bautista, 2008; Sanctuary and Saraphol, 2020) 10–50 µm thick. Erect filaments arising from the prostrate parts, 50– 200 µm tall (Rindi et al., 2007 and 2008; Rindi and Bautista, 2008). Cells of the prostrate part are elliptic or globular, 7–10 µm wide 8- 10 µm long (Rindi et al., 2007 and 2008; Rindi and Bautista, 2008; Sanctuary and Saraphol, 2020). Cells are usually polygonal and 16–25 µm wide (Binoy et al., 2019), globular cells are 10–20 µm (Allali et al., 2013). Cells of the erect filaments cylindrical, 3.5– 8 µm wide (Rindi et al., 2007; Rindi and Bautista, 2008; Allali et al., 2013), and 3-8 times as long as wide (Rindi and Bautista, 2008; Rindi et al., 2008), 3.14-3.63 µm wide, 6.98-10.27 µm long (Sanctuary and Saraphol, 2020). Zoosporangia globular, 10–15 µm wide (9.45-12.36 µm wide), 9.87- 16.20 µm long (Sanctuary and Saraphol, 2020). Gametangia globular, 10-12.15 µm wide, 9.87-13.65 µm long (Sanctuary and Saraphol, 2020), lateral or apical on erect filaments. The apical cells are flattened or pointed and usually bear a pectic cap (Allali et al., 2013; Sanctuary and Saraphol, 2020; Rindi and Bautista, 2008; Rindi et al., 2008). The suffultory cell is straight or slightly curved, flask-shaped 10-16 µm wide, and 10-15 µm in diameter (Sanctuary and Saraphol, 2020).

Distribution: Kerala.

25. Trentepohlia sundarbanensis G. G. Satpati and R. Pal (2015)

The thallus heterotrichous is differentiated into a clear prostrate and upright system. Erect axes up to 37.54-60.38 µm tall, Cells cylindrical, swollen or inflated, vegetative cells 30-40 µm wide and 50-80 µm long. The terminal and lateral Sporangia varies in shape from spherical to conical and bilobed, and both are sessile and stalked ranges 50-80 µm in diameter (Satpati and Pal, 2015). Sanctuary and Saraphol (2020) has reported much variation in measurements of the same species as, cells of prostrate part elliptic or globular, 5-8 µm wide, 6-10 µm long and cells of the erect axes cylindrical with 6.01-7.80 µm wide, 11.03-13.46 µm long. Apical cells with pectic cap. Gametangia globular lateral on erect filaments, 3.86-5.68 µm wide, 5.39-9.78 µm long.

Distribution: West Bengal.

26. Trentepohlia gaviensis Binoy T.T., Bhagya M.V. and V.P. Thomas (2019).

Thallus heterotrichous, prostrate and erect system, rudimentary and pseudoparenchymatous prostrate system. Cells 10–22 µm long and 3–4 µm wide. Profuse branching in the main axis, regular branching pattern, oppositely arranged, rarely alternate, lateral branches arranged monopodially, uniseriate axes, 10–14 µm internodal length, apical cells fusiform to blunt, 14–15 µm long, oblong to cylindrical vegetative cell, 10–22 µm long, 3–4 µm wide, thickened cell wall and septum, globular zoosporangium, 3 to 4 µm wide and globular gametangia (Binoy et al., 2019).

Distribution: Kerala.

27. Trentepohlia keralensis G.G. Satpati and R. Pal (2019).

Thallus heterotrichous, differentiated into prostrate and upright systems. Filaments uniseriate, vegetative cells were elliptical, 20-30 µm long and 5-10 µm wide. Sporangia were globose, non-stalked, and arose laterally from vegetative cells. Terminal vegetative cells transformed into globular sporangia, 30-80 µm. A hyaline small hook-like filament on the apical vegetative cells of the uniseriate filaments, 10-30 µm long and 2-8 µm wide (Satpati and Pal, 2019).

Distribution: Kerala.

(*Note:* The description of *Trentepohlia diffracta* and *Trentepohlia radicans* are not covered in this present review due to the unavailability of valid documents/resources.)

3. Result

In the present review, the published work/research records has been made easier to describe and provide data of total 29 species and 2 varieties of *Trentepohlia* from India from a total of 53 species and 28 varities 3 forma of genus *Trentepohlia* from world data recorded. The study also highlights that, there are only 7 states (Figure 1) i.e. Kerala, West Bengal, Karnataka, Tamil Nadu, Meghalaya, Assam and Maharashtra in India which has been recorded with genus *Trentepohlia* and contributed for more than 50% of species from global data. Hence, the distribution indicates India's richness and diversity of genus *Trentepohlia*. Kerala has contributed for the highest number of 20 species towards genus *Trentepohlia* in India when compared to other states like West Bengal (15), Karnataka (4), Tamil Nadu (4), Meghalaya (4), Assam (2) and Maharashtra (1) (Table 1).

4. Discussion

The present review revealed valuable information which describes the species of *Trentepohlia* in detail. Algaebase has mentioned species of *Trentepohlia* and have provided basic structure of *Trentepohlia* i.e. thallus organization, shape and size of cells and gametes which made it easier to describe each species accordingly.

From the handbook (Krishnamurthy, 2000) and research articles (Panikkar and Sindhu, 1993; Tiwari et al., 2011; Tamal et al., 2012; Satpati and Pal, 2013, 2015 and 2016; Bast et al., 2015; Singh and Singh, 2017; Binoy et al., 2019) have further contributed for easier compilation of the data, provided checklist of 29 species and 2 varieties found to be distributed in India.

Further information is also gathered from other international monographs and review articles to describe the *Trentepohlia species, Trentepohlia umbrina, Trentepohlia arborum, Trentepohlia dusenii, Trentepohlia rigidula, Trentepohlia chapmanii, Trentepohlia treubiana, Trentepohlia minima* (Allali et al., 2013 and Rindi et al., 2005, 2006, 2007, 2008 and 2018). *Trentepohlia aurea, Trentepohlia umbrina, Trentepohlia dialepta, Trentepohlia bossie* (Printz, 1920 and 1939). Trentepohlia flava, Trentepohlia rigidula, Trentepohlia arborum, Trentepohlia bossie (Cribb, 1958 and 1970). *Trentepohlia arborum, Trentepohlia dusenii, Trentepohlia cucullata, Trentepohlia annulata, Trentepohlia chapmanii* (Rindi and Bautista, 2008). *Trentepohlia aurea, Trentepohlia umbrina, Trentepohlia arborum* (Uyenco, 1965). *Trentepohlia dialepta* (Salleh and Milow, 1999). *Trentepohlia aurea, Trentepohlia umbrina, Trentepohlia monilia, Trentepohlia chapmanii, Trentepohlia sundarbanensis* (Sanctuary and Saraphol, 2020).

The Indian authors (Krishnamurthy, 2000; Tiwari et al., 2011) has mentioned *Trentepohlia jolithus* as *Trentepohlia iolithus*. Both the species has been considered as same globally. Hence, in the present study the morphological characteristic of *Trentepohlia jolithus* is provided by based on the articles published in India and abroad (Aboal et al., 2002; Krishnamurthy, 2000; Tiwari et al., 2011).

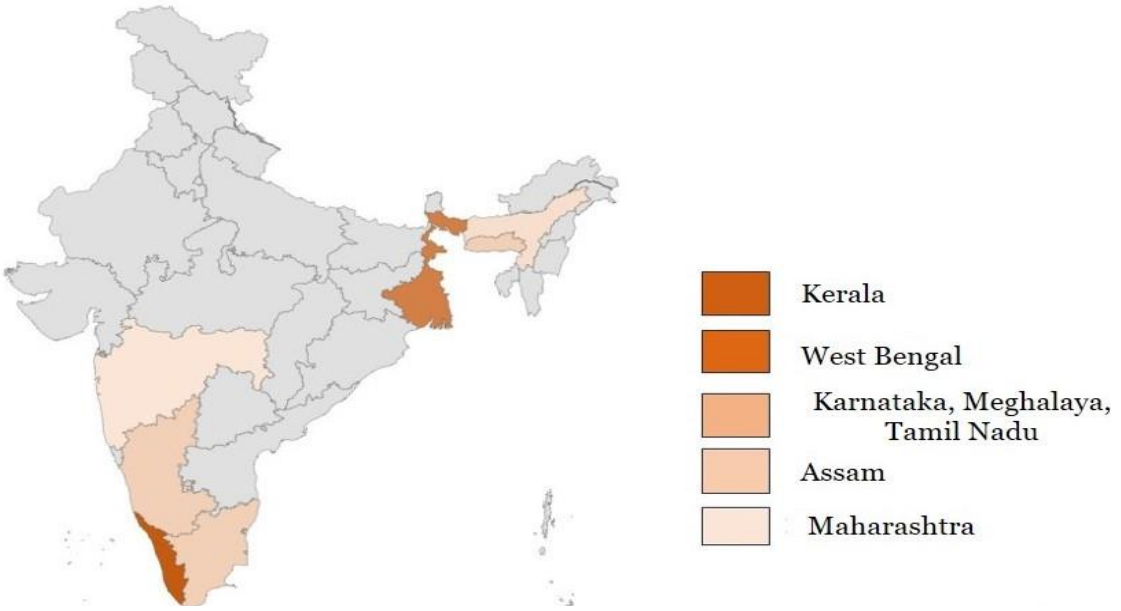

Figure 1. Species of *Trentepohlia* recorded from the states in India.

Table 1: Total number of species recorded from States of India

Sl. No.	Regions	No. of Species and variety recorded	Name of Species and Variety
1.	Kerala	20	*Trentepohlia aurea* (Linn.) Martius (1817), *Trentepohlia jolithus* Wallroth (1833), *Trentepohlia arborum* (Ag.) Hariot, (1886), *Trentepohlia abietina* (Flotow) Hansg (1886), *Trentepohlia umbrina* (Kuetz) Bornet in Wille (1887), *Trentepohlia monila* De Wildeman (1888), *Trentepohlia dialepta* (Nyl.) Hariot (1889), *Trentepohlia rigidula* (J. Müller) Hariot (1889), *Trentepohlia tenuis* (Zell.) De Toni (1989), *Trentepohlia bossei* De Wildeman (1890), *Trentepohlia annulata* F. Brand (1902), *Trentepohlia aurea* var, tenuior Bruhl and Biswas (1923), *Trentepohlia gracilis* Iyengar in Bruhl and Biswas (1923), *Trentepohlia odorata* (Wiggers) Wittrock (1990), *Trentepohlia thevalliensis* Panikkar and Sindhu (1993), *Trentepohlia pathanamthittensis* Panikkar and Sindhu (1993), *Trentepohlia angadickalensis* Panikkar and Sindhu (1993), *Trentepohlia chapmanii* Rindi & López-Bautista (2007), *Trentepohlia gaviensis* Binoy T.T., Bhagya M.V. & V.P. Thomas (2019), *Trentepohlia keralensis* G.G. Satpati & R. Pal (2019).
2.	West Bengal	15	*Trentepohlia aurea* (Linn.) Martius (1817), *Trentepohlia arborum* (Ag.) Hariot, (1886), *Trentepohlia abietina* (Flotow) Hansg (1886), *Trentepohlia torulosa* De Wildeman (1888), *Trentepohlia flava* (W.J.Hooker & Arnott) De Toni ex De Wildeman (1888), *Trentepohlia dialepta* (Nyl.) Hariot (1889), *Trentepohlia jucunda* (Cesati) Hariot (1889), *Trentepohlia rigidula* (J. Müller) Hariot (1889), *Trentepohlia treubiana* De Wildeman (1889), *Trentepohlia dussenii* Hariot (1893), *Trentepohlia gracilis* Iyengar in Bruhl and Biswas (1923), *Trentepohlia aurea* var, tenuior Bruhl & Biswas (1923), *Trentepohlia tenuis* (Zell.) De Toni (1989), *Trentepohlia thevalliensis* Panikkar and Sindhu (1993), *Trentepohlia sundarbanensis* G. G. Satpati & R. Pal (2015),
3.	Karnataka	4	*Trentepohlia aurea* (Linn.) Martius (1817), *Trentepohlia umbrina* (Kuetz) Bornet in Wille (1887), *Trentepohlia monilia* de Wildeman (1888), *Trentepohlia minima* Schmidle (1897).
4.	Meghalaya	4	*Trentepohlia abietina* (Flotow) Hansg (1886), *Trentepohlia arborum* (Ag.) Hariot (1886), *Trentepohlia umbrina* (Kuetz) Bornet in Wille (1887), *Trentepohlia diffracta* (Krempelhüber) Hariot (1889).
5.	Tamil Nadu	4	*Trentepohlia abietina* (Flotow) Hansg (1886), *Trentepohlia monilia* de Wildeman Physolinum monilia (1888), *Trentepohlia dialepta* (Nyl.) Hariot (1889), *Trentepohlia monilia* var. *subsphaerica* V. Krishnamurthy (2000)
6.	Assam	2	*Trentepohlia aurea* (Linn.) Martius (1817), *Trentepohlia cucullata* De Wildeman (1896).
7.	Maharashtra	1	*Trentepohlia radicans* G. Beck (1901)

5. Conclusion

The information presented in this review provides insights into distribution and morphological characterization of *Trentepohlia* species in India. This study also reveals that, there are only 7 states who have contributed for maximum number of species recorded under the genus *Trentepohlia* in India. Hence, focus should be on undertaking research on taxonomic identification of *Trentepohlia* species from other states of India. India has contributed some new taxa *Trentepohlia radicans* G. Beck (1901), *Trentepohlia aurea* var. *tenuior* Bruhl and Biswas (1923), *Trentepohlia angadickalensis* Panikkar and Sindhu (1993), *Trentepohlia thevalliensis* Panikkar and Sindhu (1993), *Trentepohlia sundarbanensis* G. G. Satpati and R. Pal (2015), *Trentepohlia gaviensis* Binoy T.T., Bhagya M.V. and V.P. Thomas (2019), *Trentepohlia keralensis* G.G. Satpati and R. Pal (2019). *Trentepohlia monilia* var. *subsphaerica* V. Krishnamurthy (2000) is a new variety recorded under the genus *Trentepohlia*. Hence, similar attempt may be made in the future to understand richness and representativeness of *Trentepohlia* in India.

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Author's contribution

Research design – Doris M. Singh; Preparation of Manuscript - Seema Jagannath Rajapure.

Conflict of interest

The authors declare no conflict of interest.

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