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Taxonomic Enumeration of Subaerial Cyanobacterial Flora of Similipal Biosphere Reserve, Odisha, India

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ABSTRACT

The Similipal biosphere is located in the Mayurbhanj district of Odisha, India, and is 2,750 km^2 (1,060 sq mi) in size. The purpose of this research is to document the cyanobacteria collected from tree bark and rock surfaces at various collection sites of Similipal Biosphere Reserve. In the present study, a total of 25 cyanobacterial species under 15 genera, 12 families and 05 orders under division Cyanophyta was reported from different sites of Similipal biosphere reserve, Odisha. Out of 25 cyanobacterial species, 21 are first time recorded from the Similipal biosphere reserve such as *Anabaena subcylindrical*, *Aphanothece microscopica*, *Calothrix clavatoides*, *Chroococcus minor*, *Chroococcus minutus*, *Chroococcidiopsiska shayi*, *Gloeocapsa punctata*, *Gloeothece palea*, *Hapalosiphon hibernicus*, *Nostoc piscinale*, *Oscillatoria subbrevis*, *Phormidium ambiguum*, *Phormidium aerugineo-caeruleum*, *Phormidium bulgaricum*, *Phormidium kolkwitzii*, *Phormidium retzii*, *Planktothrixclathrata*, *Planktothrix isothrix*, *Scytonema javanicum*, *Scytonema stuposum*, *Tolypothrix rechingeri.*

Key words : *Cyanobacteria, Similipal biosphere reserve, Subaerial*

Introduction

The majority of photosynthetic microorganisms found in terrestrial and subaerial habitats is Cyanobacteria. Land-based algae are commonly found on stable, exposed surfaces above the soil. In India, subaerial cyanobacteria grow, giving most tree barks, structures, and rocks a golden or reddish orange tint (Neustupa and Škaloud, 2010). Terrestrial cyanobacteria have evolved to thrive in a wide range of microhabitats, including wet soil and all exposed places above the soil surface. Soil and subaerial cyanobacteria are two types of non-aquatic cyanobacterial species that have emerged on land as a result (aerophytic cyanobacteria) (Neustupa and Škaloud, 2010). The cyanobacterial substrates in these habitats include trees, massive rocks, unpainted compound walls, old wood works, metals, exposed pieces of old buildings, tree bark and leaves, stone monuments, and other man-made structures (Lopez-Bautista *et al*., 2007). They can be epiphytic (living on plants), epiphyllous (living on leaves), corticolous (living on tree bark, stems, or trunks), epizoic (living on animals), lithophilous (living on stones, brick, or cement), epixylous (living on dead wood such as poles, posts, or doors), or epimetallous (living on metal) (inhabiting on metals) (Lopez-Bautista *et al.*, 2007). Cyanobacteria (blue-green algae) are photosynthetic prokaryotic microorganisms that may live on exposed rock surfaces,

scorching deserts, dry locations, and tree bark, among other places (Adhikary and Sahu, 2000; Büdel, 2002; Pattanaik and Adhikary, 2005). On exposed surfaces such as rocks, leaves, and tree bark, sub-aerial cyanobacteria have been shown to grow (Neustupa and Škaloud, 2008).

Cyanobacteria are among the oldest fossils known, and they played an important role in the creation of life on Earth as some of the first invaders (Schopf, 2012). Unfortunately, they are also among the least well-studied and catalogued creatures, owing in part to a common misconception among traditional monographers (Desikachary, 1959). Despite being some of the most extensively spread and pervasive creatures on the planet, cyanobacteria have been historically understudied. They are the species that have the best chance of surviving in a variety of subaerial settings. Cyanobacteria are one of the most common and numerous algae lineages with subaerial members, and they play a significant role in community succession (Gerrath *et al.,* 2000). Researchers have been researching subaerial cyanobacteria in various situations since the 19th century. They are the most frequent algal group, but also the least well-known and ignored. Our knowledge of the variety and distribution of algae in subaerial environments is scant and far behind that of freshwater and marine algae (Adhikary and Sahu, 2000; Büdel, 2002; Pattanaik and Adhikary, 2005). Several workers have reported seeing a huge number of cyanobacteria with morphometric records in various locations of Odisha (Dey and Bastia, 2008; Dey *et al*., 2010). However, several researchers have reported on the taxonomy of some corticolous cyanobacteria on tree bark (Bhakta *et al*., 2014; Neustupa and Škaloud, 2010), also reported some algae from soil crust (Bhakta *et al.*, 2015), from rock surface (Barkatullah *et al.,* 2013). Subaerial cyanobacteria have been studied by a small number of people. A review of the literature finds that, with the exception of a few studies, no major attempt has been made to research the subaerial cyanobacterial variety of the Similipal Biosphere Reserve (Bhakta *et al.,* 2015; Bhakta *et al*., 2014). On study exposed surfaces such as rocks, leaves, and tree bark, sub-aerial cyanobacteria have been shown to grow (Singh *et al*., 2017). Corticolous cyanobacteria from the genera *Gloeocapsa, Aphanocapsa, Phormidium, Stigonema, Tolypothrix, Fischerella, Lyngbya, Nostoc, Porphyrosiphon, Hapalosiphon, Lyptolyngbya,* and others have been found on tree bark by several studies (Bhakta *et al*., 2015; Bhakta *et al*., 2014; Neustupa and Škaloud, 2010). However, because to problems in using morphological features to identify species and a lack of specialists exploring new settings, cyanobacterial diversity is still underreported. As a result, subaerial habitats represent a cyanobacterial biodiversity treasure trove that has yet to be discovered.

Apart from this, cyanobacterium have the ability to produce both primary and secondary metabolites. They are cosmopolitan in nature, occurring in both filamentous and coccoid forms, and prefer tropical climates to temperate climates. These autotropic organisms can grow on exposed walls of building facades, temples, and monuments because they can endure tough and extreme conditions such as excessive temperature, drought, UV radiation, and so on.

In this context, the Similipal Biosphere Reserve in Odisha is a new ecosystem that has to be explored for subaerial habitat like dirt, rock, and tree bark. As the drainage systems cut across its area in which anthropogenic activities are less, so the diversity of cyanobacterial forms may be unique in the region. The fluctuating ecosystem of Similipal in various seasons may favor the growth and evolution of many cyanobacterial species. So, the study of diversity of cyanobacteria is indispensable. Keeping all these in view, this investigation aims to document the cyanobacterial flora of Similipal Biosphere Reserve, Odisha is the unique region.

Materials and Methods

The study sites: The Similipal Biosphere Reserve (SBR), an unique ecosystem, is situated in the heart of Mayurbhanj district of Odisha. The Biosphere Reserve being an assemblage of number of ecosystems is rich in floristic and faunal accounts, has the potential to serve as an untapped reservoir of natural resources like freshwater, trees rock surfaces.The Similipal Biosphere Reserve, an unexplored storehouse of various algal resources, is located in the centre region of Odisha's Mayurbhanj district, between 21° 28" and 22° 08" north latitude and 86° 04" and 86° 37" east longitude(Bhakta *et al.,* 2014; Jena *et al.,* 2006). The name Similipal comes from the 'Simul' (silk cotton) tree. In 1956, it was formally declared as a tiger reserve, and in 1973, it was placed under Project Tiger. In June of 1994, the Indian government designated it as a biosphere reserve. Since 2009, it has been a member of the

UNESCO World Network of Biosphere Reserves. It is part of the Mayurbhanj Elephant Reserve, which contains three protected areas: Similipal Tiger Reserve, Hadagarh Wildlife Sanctuary, and Kuldiha Wildlife Sanctuary. It is located in the Mayurbhanj district of Odisha, in the northwestern region of the state. It is situated at the eastern end of the eastern ghat (Ray, 2014). The biosphere covers 4,374 square kilometres and includes 845 square kilometres of core forest (tiger reserve), 2,129 square kilometres of buffer land, and 1,400 square kilometres of transition space. Similipal is home to 1,076 blooming plants including 96 orchid species. Tropical semi-evergreen woods, tropical moist deciduous forests, dry deciduous hill forests, high level sal forests, and expansive meadows are all found there. The ErengaKharias and the Mankirdias are two tribes who live in the reserve's forests and engage in traditional agricultural pursuits (the collection of seeds and timber) (Upadhyay *et al.*, 2012). Similipal is home to a diverse assortment of wild creatures, including tigers and elephants, as well as 304 bird species, 20 amphibian species, and 62 reptile species (Dash and Behera, 2012). Samples were gathered in the Mayurbhanj area of Odisha's Similipal Biosphere Reserve. Samples of algae were taken in April 2021, December 2022. Samples are taken from a variety of sourcesand Figure 1 depicts the map of collection sites of Similipal Biosphere Reserve, Odisha.

Sampling: A total of 55 samples were collected in sterile tarson centrifuge tubes/plastic jars. The visual prevalence of cyanobacteria in the Similipal biosphere reserve, such as epilithic, and epiphytic cyanobacteria, was gathered using forceps, needles, polythene bags, brush, petri dishes, scalpel, and brushes.

Sample preservation: The samples were dried and kept in a cool, dark location. Each sample was assigned a unique voucher number and placed in the Maharaja Sriram Chandra Bhanja Deo University's Department of Botany in Baripada.

Sample processing: Due to the crust or dense connection with the tree bark, samples are particularly difficult to identify in their natural state. As a result, these were inundated in distilled water in petri plates and cultured for 24 hours under white light before being examined under a microscope.

Microscopy and microphotography: After each filament, colony, or consortium had grown, it was microphotographed. A phase contrast microscope was used to analyse two to three slides from each sample, with the features enumerated. The gathered samples were examined using a phase-contrast mi-

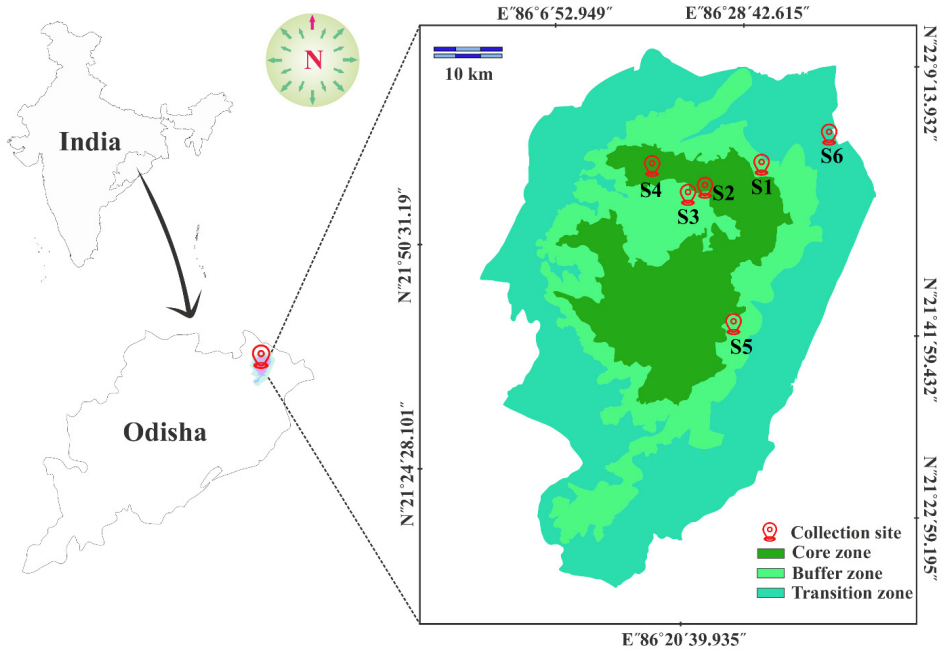

Fig. 1. Map showing the sample collection sites of Similipal biosphere reserve, Odisha. S1: Bhajam, S2: Joranda, S3: Barehipani, S4: Chahala, S5: Devkund, and S6: Machhakandana.

croscope (Olympus, Model no. BX53). A phase-contrast microscope and a digital camera were used to take microphotographs of each species (Olympus SC180).

Morphological identification: By the following existing literature, the morphological traits of specimens of cyanobacterial species were identified and enumerated (Behera *et al.,* 2020; Behera *et al*., 2021; Bhakta *et al.*, 2015; Bhakta *et al.*, 2014; Das and Adhikary, 2014; Dash *et al*., 2020; Dash *et al.,* 2021; Desikachary, 1959; Hanna *et al.,* 2022; Hindák, 1977; Jena *et al*., 2006; Khaybullina *et al.,* 2010; Kim and Lee, 2014; Komárek, 2005; Komárek and Anagnostidis, 1999; Komárek *et al*., 1983; Komárek and Johansen, 2015; Komárek *et al*., 2011; Komárek *et al.,* 2013; Komárková *et al*., 2010; Lopez-Bautista *et al.,* 2007; Loza *et al.,* 2013; Maharana *et al.*, 2019; Mahendra Perumal and Anand, 2009; Nakano and Isagi, 1987; Neustupa and Škaloud, 2008, 2010; Pradhan *et al.,* 2021a; Pradhan *et al*., 2021b; Stace *et al.* 2005; Vijayan and Ray, 2015; West *et al*., 1912).

Results

A total of 25 cyanobacterial species under divisions such as Cyanoprokaryotawere recorded from Similipal biosphere reserve, Odisha. These species belonged to 5 orders and 12 families. Further, these cyanobacterial species belonged to 15 genera such as *Anabaena, Aphanocapsa, Aphanothece, Calothrix, Chroococcus, Chroococcidiopsis, Gloeocapsa, Gloeothece, Hapalosiphon, Nostoc, Oscillatoria, Phormidium, Planktothrix, Scytonema* and *Tolypothrix.* The microphotographs identified algal species were shown Figs. 2 & 3. The details of the systematic accounts and all the algal species were described below.

Systematic accounts and taxonomic enumeration of algal species

Cyanophyta

Order: Nostocales; **Family**: Nostocaceae; **Genus**: *Anabaena*

1. *Anabaena subcylindrical* Borge, 1921 (Plate 1, Fig. 1)
Komárek *et al*., 2013, p. 805, Figs. 1008 g-h
Trichomes solitary, straight, sometimes irregularly flexuous, slightly attenuated, cross-walls slightly constricted, cells cylindrical, longer than broad, end cells bluntly conical, heterocyst intercalry and cylindrical, akinetes long-cylindrical with rounded or bluntly rounded ends, 100 µm long and 4 µm broad, heterocyst 5 µm long, 2.5 µm broad.

Habitat: on tree bark; Voucher no: 861, Place of collection: Devkund, Date: 30th April 2021.

Order: Synechococcales; **Family**: Merismopediaceae; **Genus**: *Aphanocapsa*

2. ***Aphanocapsa testacea*** (A.Braun ex Kützing) Nägeli 1849 (Plate 1, Fig. 2)
[Synonym: *Microcystis testacea* (Nägeli) Elenkin]
Komárek and Anagnostidis 1999, p. 423, Fig. 553
Colony oval to irregular, 5.3 µm in diameter.

Habitat: on tree bark surface; Voucher Number: 912; Place of collection: Bhajam, Similipal; Date of collection: 30th April 2021.

Order: Chroococcales; **Family**: Chroococcaceae; **Genus**: *Aphanothece*

3. ***Aphanothece microscopica*** Naegeli, 1849 (Plate 1, Fig. 3)
Komárek *et al*., 2011, p. 322, Fig. 5 (a)
Each cells oval in shape, subaerophytic, structured mucilage, cells with structured envelopes 16.5 µm long, 10.56 µm broad.

Habitat- black patches on soil crust; Voucher no:021; place of collection: Barehipani, Similipal; Date: 11th December 2021.

Order: Nostocales; **Family**: Calothricaceae **Genus**: *Calothrix*

4. ***Calothrix clavatoides*** Ghose 1927(plate 1, Fig.4)
Komárek *et al*., 2013, P. 256, Figure 274
Thallus bluish green; filament heterocystous, unbranched, heterocyst basal, hemispherical, unipolar, trichome solitary, not constricted, gradually attenuated to an acute apex; basal 2-4 cells are broader, cells of intermediate to apices longer than broad, cell content finely granulated, 2.8 to 3.64 m long, 1.56 to 9.36 m broad.

Habitat: soil crust, brown patches; Voucher no: 024; Place of collection: Barehipani, Date: 11th December 2021

Order: Chroococcales; **Family**: Chroococcaceae; **Genus**: *Chroococcus*

5. ***Chroococcus minor*** (Kützing) Nägeli 1849 (Plate 1, Fig. 5)
Komárková *et al.,* 2010, p. 76, Fig. Cl2a, b, c
Spherical cells, cells are slightly attached to each other and enveloped in a rounded gelatinous mass, 8.52 µm in diameter.

Habitat: on tree bark surface; Voucher Number: 854; Place of collection: Devkund, Similipal; Date of collection: 30th April 2021.

6. *Chroococcusminutus* (Kützing) Nägeli 1849 (Plate 1, Fig. 6)

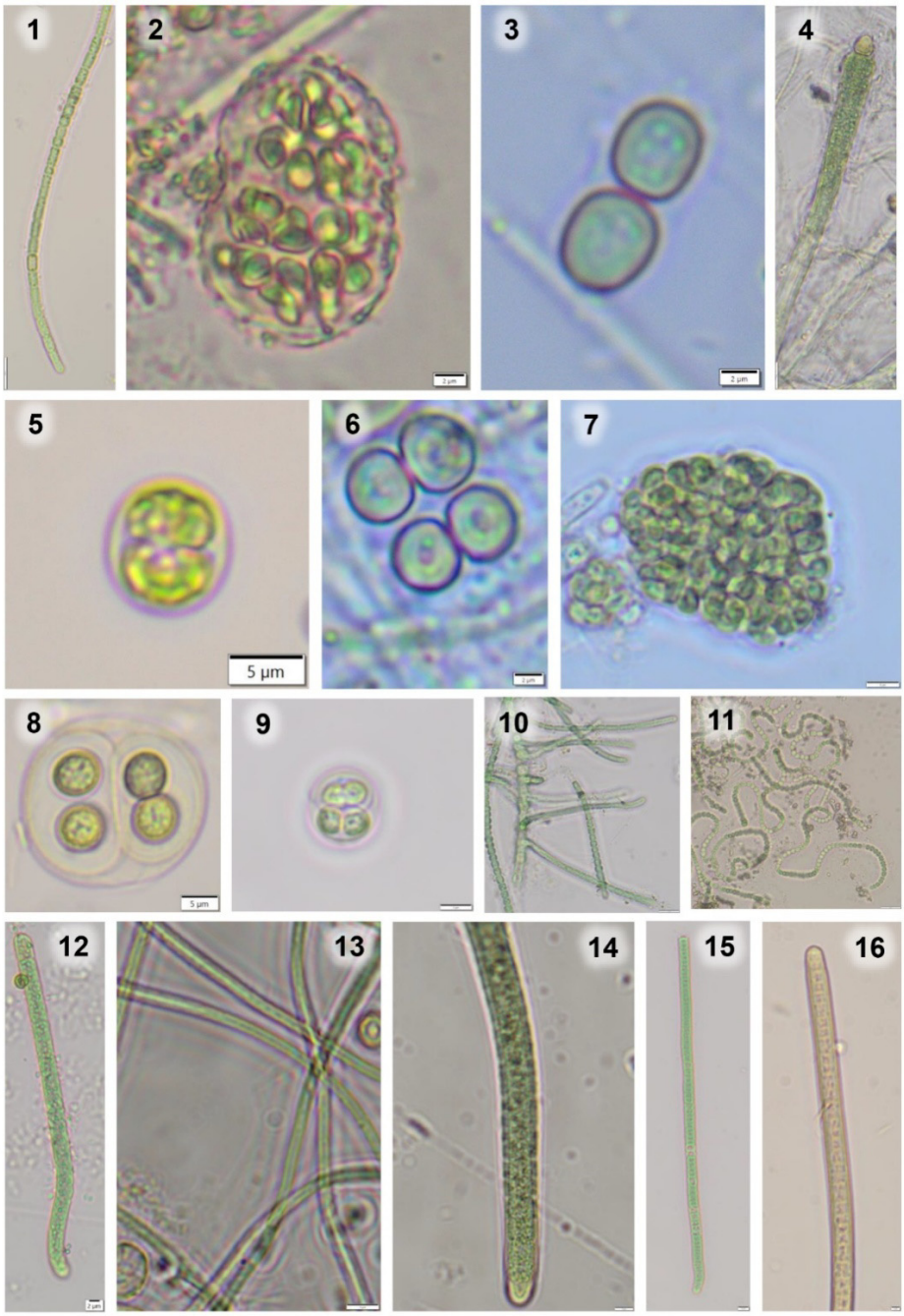

Plate 1. (1-14): Microphotographs of algal species, (1)*Anabaena subcylindrical* Borge, (2) *Aphanocapsatestacea* (A.Braun ex Kützing) Nägeli, (3) *Aphanothecemicroscopica* Naegeli, (4) *Calothrix clavatoides* S.L.Ghose, (5) *Chroococcus minor* (Kützing) Nägeli, (6) *Chroococcusminutus* (Kützing) Nägeli, (7) *Chroococcidiopsiskashayi* Friedmann, (8) *Gloeocapsa punctata* Nägeli, (9) *Gloeothece palea* (Kützing) Nägeli, (10) *Hapalosiphonhibernicus* Nägeli ex Bornet and Flahault, (11) *Nostoc piscinale* Kützing ex Bornet and Flahault, (12) *Oscillatoria subbrevis* Schmidle, (13) *Phormidiumambiguum* Gomont, (14) *Phormidiumaerugineo-caeruleum* (Gomont) Anagnostidis and Komárek, (15) *Phormidiumbulgaricum* (Komárek) Anagnostidis and Komárek, (16) *Phormidiumkolkwitzii* Komárek.

[Basionym- *Protococcusminutus* Kutzing]

[Synonym-*Protococcusminutus* Kutzing, *Gloeocapsaminuta* (Kutzing) Hollerbach]

Komárek and Anagnostidis, 1998, p. 296, Fig. 391

Four celled colonies, cells embedded in homogenous gelatinous mass, cells spherical or oval, pale blue green in color, 4 – 6 µm in diameter.

Habitat: black patches on rock surface; voucher no: 589; Place of collection: Machhakandana; Date: 30th April 2021.

Order: Chroococcidiopsidales; **Family**: Chroococcidiopsidaceae; **Genus**: *Chroococcidiopsis*

7. *Chroococcidiopsiskashayi* Friedmann 1961 (plate 1, Fig. 7)

Komárek and Anagnostidis, 1998, p. 423, Fig. 553

Cells in a group, more or less spherical, colony spherical, enveloped by sheath, cells 3 µm broad, 4 µm long, colony 21 µm in diameter.

Habitat: black patches on rock surface, Voucher no. 589, place: Machhakandana, date-30th April 2021

Order: Chroococcales; **Family**: Microcystaceae; **Genus**: *Gloeocapsa*

8. ***Gloeocapsa punctata*** Nägeli 1849 (Plate 1, Fig. 8)

Komárek and Anagnostidis, 1998, p. 239, Fig. 309

Thallus bluish green, colonial, colony four celled, mucilaginous, mucilage hyaline, stratified, cell content homogenous with individual sheath, cells 6-8 µm in diameter, colony 20 - 22 µm diameter.

Habitat: black patches on soil crust; Voucher no:025; Place of collection: Barehipani, Date: 11th December 2021

Order: Chroococcales; **Family**: Aphanothecaceae; **Genus**: *Gloeothece*

9. ***Gloeothece palea*** (Kützing) Nägeli, 1849 (Plate 1, Fig. 9)

[Basionym- *Gloeocapsa palea* Kutzing]

[Synonym- *Gloeocapsa palea* Kutzing]

Komárek and Anagnostidis, 1998, p. 96, Fig. 93

Four celled colony, cells cylindrical, pale blue green in colour, with homogenous content, 7.2-8.5µm long and 3 - 4 µm broad, envelopes around the cells distinct, with 1- 2 layers.

Habitat: black patches on soil crust; Voucher no-021; Place of collection: Barehipani, Similipal, Date: 11th December 2021

Order: Nostocales; **Family**: Hapalosiphonaceae; **Genus**: *Hapalosiphon*

10. *Hapalosiphonhibernicus* Nägeli ex Bornet and Flahault 1886 (plate 1, Fig. 10)

[Synonym: *Hapalosiphon fontinalis* var. *hibernicus* (West & G.S.West) Elenkin null]

Komárek and Johansen, 2015, p. 201, Fig. 34 A (b)

Thallus is filamentous, composed of free, coiled filamentous clusters, initially attached to the substratum, later floating free in the metaphyton. Filaments are irregularly curved with uniseriate trichomes. True branching is usually lateral (T-type), no morphological differentiation in the main and lateral trichomes, or with branches rarely slightly narrower. Sheaths are colorless, thin, firm, rarely indistinctly lamellated, heterocyst are intercalary, trichome branches, 5.68 µm in long, 7.1 µm in broad.

Habitat: on tree bark; voucher no. 870, place of collection, Devkund, Date: 30th April 2021

Order: Nostocales; **Family**: Nostocaceae; **Genus**: *Nostoc*

11. *Nostoc piscinale* Kützing ex Bornet & Flahault 1886 (plate 1, Fig. 11)

[Synonym: *Nostoc piscinale* Kutzing 1843]

Desikachary, 1959, p. 377, pl. 69, Fig.3

Thallus with a firm mucilaginous layer, trichomes densely coiled, clearly visible, trichome 2-5 ìm broad, cells barrel shaped, homogenous.

Habitat: on tree bark; Voucher no: 870; Place of collection: Devkund; Date: 30th April 2021.

Order: Oscillatoriales; **Family**: Oscillatoriaceae; **Genus**: *Oscillatoria*

12. *Oscillatoria subbrevis* Schmidle 1901 (Plate 1, Fig. 12)

[Synonym: *Oscillatoria subbrevis* f. major West]

Komárek and Anagnostidis, 2005, p. 587, Fig. 877

Trichome usually solitary, blue green, straight with oscillating movement of the apex, cell content slightly granulated at cross walls, sheath absent, cell wall not constricted, cells slightly broader than long, 1.6 µm long, 3.5 µm broad.

Habitat: Black patches on soil crust; Voucher no: 025; Place of collection: Chahala, Similipal; Date: 11th December 2021.

Order: Oscillatoriales; **Family**: Oscillatoriaceae; **Genus**: *Phormidium*

13. *Phormidiumambiguum* Gomont 1892 (Plate 1, Fig. 13)

[Synonym:*Amphithrixamoena* Kütz., 1843, *Lyngbyabourrellyana* Compère, 1974]

Hanna *et al.*, 2022, p. 05, Fig-c, d

Filaments usually in expanded thallus, form clusters, without any branching, long filament with thin sheath,tip slightly rounded,cells are bead like, 1.86 µm long and 1.86 µm broad, trichome not narrow, slightly rounded tip, non- heterocystous, blue-green in color.

Habitat: Black patches on rock surface; Voucher no: 019; Place of collection: Chahala, Similipal; Date: 11th December 2021

14. *Phormidiumaerugineo-caeruleum* (Gomont) Anagnostidis and Komárek, 1988 (Plate 1, Fig. 14)

[Basionym: *Lyngbyaaerugineo-coerulea* Gomont 1892, *Potamolinea aerugineocaerulea* (Gomont, 1892) Martins and Branco, 2016]

Desikachary, 1959, p. 315, pl. 48, Fig. 9

Loza *et al*., 2013, p. 240, Fig-17, 18

Filaments flexuous, single or forming dark blue green aggregates, sheath thin, trichomes pale blue green, 3.6-6.8 µm broad, not constricted at the cross walls, end cell slightly rounded.

Habitat: Black patches on rock surface, Voucher no: 019, Place of collection: Barehipani, Similipal,

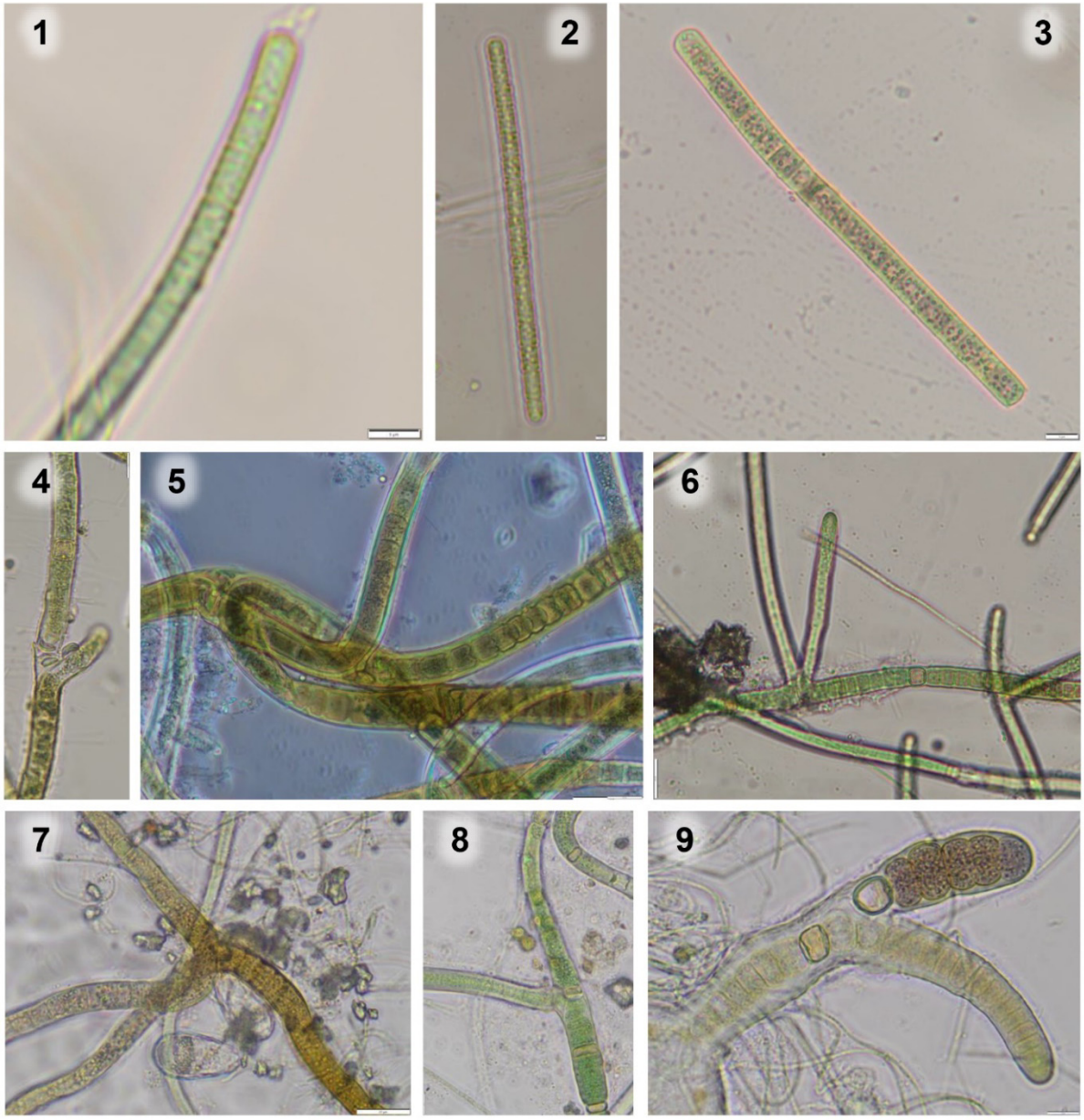

Plate 2. (1-14): Microphotographs of algal species, (1) *Phormidiumretzii*Kützing ex Gomont, (2) *Planktothrixclathrata* (Skuja) Anagnostidis and Komárek, (3) *Planktothrixisothrix* (Skuja) Komárek and Komárková, (4) *Scytonemaburmanicum* Skuja, (5) *Scytonemajavanicum* (Kütz.) Bornet, (6) *Scytonemaschmidtii* Gomont, (7) *Scytonemastuposum* f. nanyohense C.-C.Jao, (8) *Tolypothrixrechingeri* (Wille) Geitler, and (9) *Tolypothrixscytonematoides* (N.L.Gardner) Geitler.

Date: 11/12/2021

15. ***Phormidiumbulgaricum*** (Komárek) Anagnostidis and Komárek 1988 (Plate 1, Fig. 15)

Komárek, 2005, p. 442, Fig. 642.

Filaments usually without sheaths, bluish green; trichomes among other cyanobacteria in mats, straight or slightly curved, very slightly constricted at cross-walls; cells cylindrical, 1-5 ìm long, with pale blue-green, homogenous content, usually granulated, no granulation at cross walls, apical cells widely-rounded.

Habitat: Black patches on soil crust; Voucher no. 021; Place of collection: Barehipani, Similipal, Date: 11th December 2021

16. *Phormidiumkolkwitzii* Komárek 2001 (Plate 1, Fig. 16)

Komárek, 2005, p. 409, Fig. 576.

Thallus membranous, blue green, or solitary trichomes, 5-6 µm broad, not constricted and not granulated at cross walls, attenuated towards ends, generally curved, sheaths not found or very fine cells are wider than long, apical cell without calyptra and rounded in shape.

Habitat: on tree bark; Voucher no:864; Place of collection: Devkund, Similipal; Date: 30th April 2021.

17. *Phormidiumretzii* Kützing ex Gomont, 1892 (Plate 2, Fig. 1)

[Synonims: *Oscillatoria retzi, Phormidiumretzii* (C. Agardh) Gomont]

Behera *er al*., 2021, p. 113, Plate 2, Fig. m

Thallus bluish-green color, slightly curve, without constriction at cell-cell junction, 4.62 µm in broad, granules present along septum, tip and bottom oval in shape.

Habitat: on tree bark; Voucher no: 915: Place of collection: Bhajam, Similipal; Date: 30th April 2021.

Order: Oscillatoriales; **Family**: Microcoleaceae; **Genus**: *Planktothrix*

18. *Planktothrixclathrata* (Skuja) Anagnostidis and Komárek 1988 (Plate 2, Fig. 2)

[Basionym: *Oscillatoria mougeotii* var. clathrata Skuja]

[Synonym: *Oscillatoria mougeotii* var. clathrata Skuja, *Oscillatoria mougeotii* f. clathrata Skuja ex Starmach]

Komárek 2005, p. 358, Fig. 457

Filaments free floating, slightly constricted at the cross walls, gradually attenuated towards the apex, cells 4.5 – 5 µm broad and 1.6 – 2 µm long, with aerotopes, apical cell widely rounded.

Habitat: Brown patches on soil crust; Voucher no: 017; Place of collection: Chahala, Similipal; Date: 11th December 2021

19. *Planktothrixisothrix* (Skuja) Komárek and Komárková 2004 (Plate 2, Fig. 3)

[Basionym: *Oscillatoria agardhii* var. isothrix Skuja]

[Synonym: *Oscillatoria agardhii* var. isothrix Skuja]

Komárek, 2005, p. 356, Fig. 495

Trichomes usually straight, blue green or grey green, not or very slightly constricted at the usually inconspicuous cross walls, 4.5-6 µm broad, cylindrical and not attenuated ends, cells slightly shorter than broad, 1.8-2.5 µm long, with plenty of irregular aerotopes causing the characteristic brown color, apical cells cylindrical and widely rounded or flat rounded, without calyptra or thickened outer cell wall.

Habitat: on tree bark; Voucher no: 912; Place of collection; Bhajam, Similipal; Date: 30th April 2021.

Order: Nostocales; **Family**: Scytonemataceae; **Genus**: *Scytonema*

20. *Scytonemaburmanicum* Skuja 1949 (plate 2, Fig. 4) Desikachary 1959, p. 460, Plate 97, Figs. 1-9

Thallus brownish, sheathed, sheath lamellated, brownish to clear, thick 4.3 µm, broad, filament pseudo branched, trichome slightly constricted at cross walls, heterocyst intercalary, rectangular to compressed, cells barrel shaped to compressed, broader than long, 8.6 µm long, 7.2 µm to 10 µm broad, cell content granular.

Habitat: on bark surface; Voucher no: 861; Place of collection: Devkund, Similipal; Date: 30th April 2021.

21. *Scytonemajavanicum* ***(Kütz.)*** Bornet 1887 (Plate 2, Fig. 5)

Komárek *et al.*, 2013, Plate 178, Fig. 3 (d)

Filaments 12–15, trichomes 6–10 (14) µm broad, sheaths colorless to yellow, bases of branches usually shortly parallel, trichomes usually compact, hormogonia separate, solitary, cells mostly isodiametric, sheath mostly smooth from the outsides.

Habitat: on rock surface; Voucher no: 011; Place of collection: Joranda, Similipal; Date: 11th December 2021.

22. *Scytonemaschmidtii* Gomont 1901 (Plate 2, Fig. 6) Komárek *et al*., 2013, Plate. 186, Fig. 10 (a-k)

Filaments cylindrical, binary branches, filaments and branches straight, slightly curved or rarely slightly flexuous, intercalary Heterocyst, usually barrel–shaped, 7.5 µm in long, 10 µm in broad.

Habitat: black patches on rock surface; Voucher

no: 019; Place of collection: Bohreipani, Similipal, Date: 11th December 2021.

23. *Scytonemastuposum* f. nanyohense C.-C.Jao 1939 (plate 2, Fig. 7)

Behera *et al.,* 2020, Plate 211, Fig. 2 (j)

Thallus blackish violet to reddish, false branched, thick sheath, gelatinous, 3.33 µm broad, cell 12-15 µm broad and 3-5 µm long, cell sub quadrate, heterocyst 14-16 µm broad and 6-6.6 µm long, filament 18-21 µm broad.

Habitat: on soil crust; Voucher no: 017; Place of collection: Barehipani, Similipal; Date: 11th December 2021.

Order: Nostocales; **Family**: Tolypothrichaceae; **Genus**: *Tolypothrix*

24. ***Tolypothrixrechingeri*** (Wille) Geitler 1925 (Plate 2, Fig. 8)

Keshari and Adhikary, 2014, Plate 47, Fig-2 (x)

Long filaments bearing spherical, heterocyst arises at which false branching arises, heterocyst is intercalary,4 µm long, 12 µm broad, sheath is thin and not constant, cell cylindrical.

Habitat: black patches on rock surface; Voucher no: 019; Place of collection: Barehipani, Similipal; Date: 11th December 2021.

25. *Tolypothrixscytonematoides* (N.L.Gardner) Geitler 1932 (Plate 2, Fig. 9)

Keshari and Adhikary, 2014, Fig. 2 (c), pg-47

Habitat: Black patches on soil crust; Voucher no: 021; Place of collection: Barehipani, Similipal; Date: 11th December 2021.

Discussion

The finding of our present study represented those 25 subaerial cyanobacteria reported. It is important to note that out of these 25 cyanobacteria species 21 subaerial cyanobacterial species were first time recorded from Similipal biosphere reserve, Odisha such as *Anabaena subcylindrical* Borge, *Aphanothece microscopica* Naegeli, *Calothrix clavatoides* S.L. Ghose, *Chroococcus minor* (Kützing) Nägeli, *Chroococcusminutus* (Kützing) Nägeli, *Chroococcidiopsis kashayi* Friedmann, *Gloeocapsa punctata* Nägeli, *Gloeothece palea* (Kützing) Nägeli, *Hapalosiphonhibernicus* Nägeli ex Bornet and Flahault, *Nostoc piscinale*Kützing ex Bornet and Flahault, *Oscillatoria subbrevis*Schmidle, *Phormidium ambiguum* Gomont, *Phormidium aerugineo-caeruleum* (Gomont) Anagnostidis and Komárek, *Phormidium bulgaricum* (Komárek) Anagnostidis and Komárek, *Phormidium kolkwitzii* Komárek, *Phormidium retzii* Kützing ex Gomont, *Planktothrix clathrata* (Skuja) Anagnostidis and Komárek, *Planktothrix isothrix* (Skuja) Komárek and Komárková, *Scytonema javanicum* (Kütz.) Bornet, *Scytonema stuposum* f. nanyohense C.-C.Jao, *Tolypothrix rechingeri* (Wille) Geitler. Furthermore, it is found that among these 25 cyanobacterial species 4 species are previously reported such as Similipal biosphere reserve, Odisha (Bhakta *et al.,* 2015; Bhakta *et al.,* 2014; Jena *et al.,* 2006). Our findings of present investigations and the occurrence of the cyanobacterial species were quite similar to the previous reports on subaerial cyanobacterial diversity from several subaerial parts of India (Bhakta *et al*., 2015; Bhakta *et al*., 2014; Keshari and Adhikary, 2014). Similar research was done on the dynamics of species richness of bark algae and cyanobacteria in South-East Asian rain forest mountainous settings (Neustupa and Škaloud, 2010).Many sub aerial cyanobacteria colonising tree bark under the names *Nostoc, Phormidium, Scytonema,* and *Stigonema* (Bhakta *et al*., 2015; Bhakta *et al.*, 2014). Furthermore, cyanobacteria indicated that ecological niches have a substantial impact on species composition. Cyanobacteria are found abundantly in samples taken from the subaerial portion (Mikhailyuk *et al*., 2001). These findings suggest that micro habitat factors, particularly humidity and illumination, may be important in shaping the diversity and species composition of subtropical bark-growing cyanobacterial assemblages. The distribution may be due to the subtropical climate of the Similipal Biosphere Reserve which is comparable with similar works carried out by (Bhakta *et al.*, 2015; Bhakta *et al.*, 2014). Furthermore, it is found that Similipal biosphere reserve, Odisha. are an important habitat of bio-resources in terms of the presence of important microalgal species which are having many uses in aquaculture and biotechnological applications.

Conclusion

In the present field investigation, a total of 25 cyanobacterial species had been identified and documented from 50 samples. Furthermore, taxonomic enumeration of all the subaerial cyanobacterial species were characterised. Among them, 21 species are first time recorded from the Similipal biosphere reserve Odisha, India. Similipal Biosphere Reserve in Odisha is an unique habitat for

cyanobacterial diversity. The identified cyanobacteria can be used in different biotechnological applications in future.

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References

Adhikary, S. and Sahu, J. 2000. Survival strategies of cyanobacteria occurring as crust in the rice fields under drought conditions. *Indian Journal of Microbiology.* 40: 53-56.

Barkatullah, F.H., Ali, N. and Ahmad, I. 2013. Rock algae of Batkhela district Malakand, Pakistan. *Pak. J. Bot.* 45: 329-340.

Behera, C., Dash, S.R., Pradhan, B., Jena, M. and Adhikary, S.P. 2020. Algal diversity of Ansupa lake, Odisha, India. *Nelumbo.* 62 : 207-220.

Behera, C., Pradhan, B., Panda, R., Nayak, R., Nayak, S. and Jena, M. 2021. Algal diversity of Saltpans, Huma (Ganjam), India. *J Indian Bot Soc*. 101 : 107-120.

Bhakta, S., Dutta, P., Sahu, E. and Bastia, A. 2015. Soil crust algae of Similipal Biosphere Reserve (SBR), Odisha. *J Adv Microbiol.* 2 : 54-63.

Bhakta, S., Pattanaik, L., Dutta, P., Sahu, E. and Bastia, A. 2014. Diversity of corticolous algae from Similipal Biosphere reserve, Mayurbhanj, Odisha. Personal Communication.

Büdel, B. 2002. Diversity and ecology of biological crusts. *Progress in Botany.* 386-404.

Das, S.K. and Adhikary, S.P. 2014. *Freshwater Algae of Eastern India.* Daya Publishing House.

Dash, M. and Behera, B. 2012. Management of similipal biosphere reserve forest: Issues and challenges. *Advances in Forestry Letter (AFL)*. 1:7-15.

Dash, S., Pradhan, B. and Behera, C. 2020. Algal Diversity of Kanjiahata Lake, Nandankanan, Odisha, India. *J Indian Bot Soc*. 99 : 11-24.

Dash, S., Pradhan, B., Behera, C., Nayak, R. and Jena, M. 2021. Algal Flora of Tampara Lake, Chhatrapur, Odisha, India. *J Indian Bot Soc.* 101 : 1-15.

Desikachary, T.V. 1959. Cyanophyta. *Indian Council of Agricultural Research*, New Delhi.

Dey, H. and Bastia, A. 2008. Cyanobacterial Flora from rice growing areas of Mayurbhanj. *Plant. Sc. Res*. 30: 22-26.

Dey, H., Tayung, K. and Bastia, A. 2010. Occurrence of nitrogen-fixing cyanobacteria in local rice fields of Orissa, India. *Ecoprint: An International Journal of Ecology.* 17 : 77-85.

Gerrath, J., Gerrath, J., Matthes, U. and Larson, D. 2000. Endolithic algae and cyanobacteria from cliffs of the Niagara Escarpment, Ontario, Canada. *Canadian Journal of Botany*. 78: 807-815.

Hanna, A.L., Hamouda, H.M., Goda, H.A., Sadik, M.W., Moghanm, F.S., Ghoneim, A.M., Alenezi, M.A., Alnomasy, S.F., Alam, P. and Elsayed, T.R. 2022. Biosynthesis and Characterization of Silver Nanoparticles Produced by *Phormidium ambiguum* and *Desertifilum tharense* Cyanobacteria. *Bioinorganic Chemistry and Applications.* 2022 : 9072508.

Hindák, F. 1977. Studies on the Chlorococcal Algae (Chlorophyceae). I. Slovak Academy of Sciences. VEDA publishing house, Bratislava, Slovakia, 189pp.

Jena, M., Ratha, S. and PAdhikary, S. 2006. Algal diversity of Similipal biosphere reserve, Orissa.

Keshari, N. and Adhikary, S.P. 2014. Diversity of cyanobacteria on stone monuments and building facades of India and their phylogenetic analysis. *International Biodeterioration & Biodegradation.* 90 : 45-51.

Khaybullina, L.S., Gaysina, L.A., Johansen, J.R. and Krautová, M. 2010. Examination of the terrestrial algae of the Great Smoky Mountains National Park, USA. *Fottea*. 10: 201-215.

Kim, J.W. and Lee, O.M. 2014. The distribution and three newly reported species of aerial algae at Mt. Gwanggyo, Korea. *Journal of Ecology and Environment.* 37 : 327-339.

Komárek, J. 2005. Cyanoprokaryota 2. Teil/2nd part: oscillatoriales. *Susswasserflora von Mitteleuropa.* 19: 1-759.

Komárek, J. and Anagnostidis, K. 1999. Cyanoprokaryota 1. Teil: Chroococcales. Süßwasserflora von Mitteleuropa 19/1. Stuttgart: Fisher.

Komárek, J., Fott, B. and Huber-Pestalozzi, G. 1983. Das Phytoplankton des Süßwassers. Systematik und Biologie-Teil 7 : 1. Hälfte.

Komárek, J. and Johansen, J.R. 2015. *Filamentous cyanobacteria, Freshwater Algae of North America*. Elsevier, pp. 135-235.

Komárek, J., Kaštovský, J. and Jezberová, J. 2011. Phylogenetic and taxonomic delimitation of the cyanobacterial genus Aphanothece and description of Anathece gen. nov. *European Journal of Phycology*. 46: 315-326.

Komárek, J., Sant'Anna, C.L., Bohunicka, M., Mareš, J., Hentschke, G.S., Rigonato, J. and Fiore, M.F. 2013. Phenotype diversity and phylogeny of selected Scytonema-species (Cyanoprokaryota) from SE Brazil. *Fottea*. 13 : 173-200.

Komárková, J., Jezberová, J., Komárek, O. and Zapomìlová, E. 2010. Variability of *Chroococcus* (Cyanobacteria) morphospecies with regard to phylogenetic relationships. *Hydrobiologia*. 639 : 69-83.

Lopez-Bautista, J.M., Rindi, F. and Casamatta, D. 2007. *The Systematics Of Subaerial Algae, Algae And Cyanobacteria In Extreme Environments.* Springer, pp. 599-617.

Loza, V., Perona, E., Carmona, J. and Mateo, P. 2013. Phenotypic and genotypic characteristics of Phormidium-like cyanobacteria inhabiting microbial mats are correlated with the trophic status of running waters. *European Journal of Phycology*. 48: 235-252.

Maharana, S., Pradhan, B., Jena, M. and Misra, M.K. 2019. Diversity of phytoplankton in Chilika lagoon, Odisha, India. *Environ Ecol*. 37.

Mahendra Perumal, G. and Anand, N. 2009. *Manual of Freshwater Algae of Tamil Nadu.* Bishen Singh Mahendra Pal Singh.

Mikhailyuk, T., Tsarenko, P., Nevo, E. and Wasser, S. 2001. Additions to the study of aerophytic eukaryotic algae of Israel. *Int. J. Algae.* 3 : 19-39.

Nakano, T. and Isagi, Y. 1987. *Dictyochloropsis irregularis* sp. nov.(Chlorococcales, Chlorophyceae) isolated from the surface of bark. *Phycologia*. 26 : 222-227.

Neustupa, J. and Škaloud, P. 2008. Diversity of subaerial algae and cyanobacteria on tree bark in tropical mountain habitats. *Biologia*. 63 : 806-812.

Neustupa, J. and Škaloud, P. 2010. Diversity of subaerial algae and cyanobacteria growing on bark and wood in the lowland tropical forests of Singapore. *Plant Ecology and Evolution*. 143 : 51-62.

Pattanaik, B. and Adhikary, S. 2005. Microbial crust and their ecological significance. 180-194. *Microbial Diversity Opportunities and Challenges.* Shree publishers and distributors, New Delhi.

Pradhan, B., Patra, S., Dash, S.R., Nayak, R., Behera, C. and Jena, M. 2021a. Evaluation of the anti-bacterial activity of methanolic extract of *Chlorella vulgaris* Beyerinck [Beijerinck] with special reference to antioxidant modulation. *Futur J Pharmaceut Sci*. 7: 17.

Pradhan, B., Patra, S., Maharana, S., Behera, C., Dash, S.R. and Jena, M. 2021b. Demarcating antioxidant response against aluminum induced oxidative stress in *Westiellopsis prolifica* Janet 1941. *Int. J. of Phytoremediation.* 23 : 238-251.

Ray, S. 2014. People and protected areas: protest dynamics in a conservation project in Odisha. *Sociological Bulletin.* 63 : 59-76.

Schopf, J.W. 2012. *The Fossil Record of Cyanobacteria, Ecology of Cyanobacteria II.* Springer, pp. 15-36.

Singh, A., Tyagi, M.B. and Kumar, A. 2017. Cyanobacteria growing on tree barks possess high amount of sunscreen compound mycosporine-like amino acids (MAAs). *Plant Physiology and Biochemistry.* 119 : 110-120.

Stace, C., Walters, S. and Wurzell, B. ?? Some preliminary observations on algae and associated microorganisms of subaerial habitats, particularly among mosses, near Cambridge. *Published in association with the Cambridge Natural History Society.* 60.

Upadhyay, S., Sahoo, S., Panda, G. and Upadhyay, V. 2012. Linkages between agriculture and forest: case study from three tribal villages located in a biosphere reserve of India. *Geo-Eco-Tropicol.* 36 : 39-48.

Vijayan, D. and Ray, J.G. 2015. Green algae of a unique tropical wetland, Kuttanadu, Kerala, India, in relation to soil regions, seasons, and paddy growth stages. *International Journal of Science, Environment and Technology.* 4 : 770-803.

West, W., West, G. and Carter, N. 1912. A Monograph of the. British Desmid.