

## Cyanobacteria and micro-algae in biological crusts on soil and sub-aerial habitats of eastern and north eastern region of India

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### Abstract

Twenty four species of Cyanobacteria and six species of micro-algae were recorded in biological crusts from different sub-aerial habitats e.g. cemented building facades, tree trunks, soil surface of barren land and rice fields in certain locations of eastern region of India. These belong to seventeen genera e.g. *Gloeocapsa* (1), *Aphanocapsa* (1), *Oscillatoria* (4), *Phormidium* (5), *Calothrix* (1), *Anabaena* (2), *Nostoc* (5), *Cylindrospermum* (2), *Scytonema* (1), *Fischerella* (1), *Westiellopsis* (1), *Chlorococcum* (1), *Chlorella* (1), *Microspora* (1), *Pandorina* (1), *Volvox* (1), *Closterium* (1). All these taxa were described with illustrations and the habitats in which they occur is presented. The brownish coloured crusts on soil contained sheathed cyanobacteria species where as the greenish-brown crusts on rice field soils harboured green algae and cyanobacteria. The cemented building facades and tree trunks were colonized by filamentous cyanobacteria species. The green algal forms occurred in the crust only during the rainy season.

Key Words: Cyanobacteria, eastern India, micro-algae, soil crust, sub-aerial habitat

### Introduction

Biological crusts are generally formed by microorganisms, e.g. algae, cyanobacteria, fungi, lichen and sometimes bryophytes, which are closely associated with the substratum forming mat like structures (Belnap *et al.*, 2001; Pattanaik and Adhikary, 2005). Such crusts occur on a variety of substrata ranging from exposed rock to hot deserts, arid areas, forest soils and rice fields (Adhikary and sahu, 2000; johansen and shubert, 2001; büdel, 2002). In soil crusts, activity of these organisms results in stabilization of the surfaces, reduction in erosion and retaining moisture thus providing suitable habitat for growth of higher plants (johansen, 1993). Little information is available on the composition of cyanobacteria and algae communities in the biological soil crusts, especially in the Indian subcontinent (marathe and kushaldas, 1997; venkatraman *et al.*, 1974; Tirkey and Adhikary, 2006). Due to arid and semi-arid climatic condition in eastern region of India during most part of the year, blackish brown crusts are usually found in the upper millimeter of soil and on sub-aerial habitats. A systematic account of the cyanobacteria and micro-algal forms which form these crusts in different locations of the region is reported.

### Materials and Methods

Crusts samples were collected from upper surfaces of soil as well as various sub-aerial habitats from different locations of Orissa state, in the eastern region of India. These samples were stored in pre-sterilized screw cap bottles and transported to the laboratory for analysis. The crusts sample were wetted with sterile water and examined under light microscope. Within few hour of wetting, living filament could be visualized; however, morphological features were not distinct basing on which identification could be made. So a pinch of crust materials were transferred to BG-11 medium with or without combined nitrogen (rippka *et al.*, 1979) and to agar plates (1% w/v agar-agar in the same medium) and incubated at 25±1°C under continuous light from fluorescent tube in the

intensity 7.5 W/m<sup>2</sup> up to 60 days. The organisms appeared in the enriched culture were morphometrically analyzed and identified following anagnostidis and komárek (1988, 1990), Cronberg and Komárek (2004); desikachary (1959); iyengar and desikachary (1981); komárek (2005); komárek and anagnostidis (1986, 1989); komárek and fott (1983); kant and gupta (1998) and ramanathan (1964). Microphotographs were taken in a MEIJI ML-TH-05 trinocular research microscope using Nikon 4500 coolpix camera. Voucher number was assigned to each sample together with date of collection and deposited at the Department of Botany, Utkal University. Nomenclature and taxonomy of each taxa was authenticated following algae BASE.

### Results

Greenish biological crusts were distinctly visible on the embankment of rice fields and on moist soil surfaces during the rainy season. The crusts on barren fields, forest floor and tree barks occur during winter season showing brownish-green colouration (Plate -1, Fig. a-d). The cemented surface of building facades also appeared blackish-green to brownish-green due to crusts during all the three seasons. To the contrary only brownish crusts showed visible appearance where ever they occur during summer months (Plate -1, Fig. a and b). Details of the appearance of the biological crusts during different seasons on the substratum of several localities is given in Table 1. These crusts harbour principally cyanobacteria and unicellular green algal species which live there-in in hibernating state in form of spores, cysts or few vegetative cells enclosed by a sheath or slime matrix. Hence the crusts were cultured in defined medium under fluorescent light and the organisms appeared in the culture were identified. The systematic account of these algal and cyanobacterial taxa is presented below.

### Systematic account

Cyanophyta (Cyanobacteria/ Cyanoprokaryota)

1. *Gloeocapsa aeruginosa* kützing

Cells spherical, surrounded by colourless mucilaginous envelope, more or less spherical, blue - green; many sub-colonies assemble to form amorphous colonies; cell 2–3 µm in diameter, with sheath 9–12 µm diameters.

Collection site: Soil crust from rice field, Surada, Ganjam, Orissa (Voucher no. 312, Date: 29-05-2003); Pl. 2, fig. 11.

2. *Aphanocapsa biformis* a. brown

Cells yellowish-green, spherical, 4 - 7 µm diameter, loosely arranged, 2-4 together.

Collection site: Soil crust from rice field, Sorisibilli, Surada, Ganjam, Orissa (Voucher no. 1192, Date: 29-05-2003); Pl. 2, fig. 12.

3. *Phormidium acutum* (Brühl and Biswas) anagnostidis and Komárek

[Synonym: *Oscillatoria acuta* Brühl & Biswas ex. Geitler 1932]

Trichome solitary, almost straight, not constricted at the cross wall, 4 - 7 µm broad, slightly attenuated toward sub-obtuse apex which is bent aside; cells 3.0-4.5 µm long.

Collection site: Crust on tree trunk, Biswanathpur, Cuttack, Orissa (Voucher no. 81, Date: 29 - 01 - 2004); Pl. 2, fig. 1.

4. *Phormidium animale* (Agardh ex. Gomont) anagnostidis and Komárek

[Synonym: *Oscillatoria animalis* C. Agardh 1827]

Thallus dark blue green; trichome straight, not constricted at the cross wall; end briefly

attenuated, slightly bent; cell 3 - 4 µm broad, 1.6-4.0 µm long; pointed, conical.

Collection site: Soil crust from rice field, Surada, Ganjam, Orissa (Voucher no. 1181, Date: 15 - 08-2007); Pl. 2, fig. 2.

5. *Phormidium limosum* (Dillwyn) Silva

[Synonym: *Oscillatoria limosa* (Dillwyn) C. Agardh 1812]

(Basionym: *Conferva limosa* Dillwyn)

Thallus deep green; filamentous, without sheath, granulated, showing typical oscillatory movement; end cell with thick outer membrane, cells broader than long, length 2.5–4.0 µm and breadth 12.5-16.6 µm.

Collection site: Soil crust, bank of Rushikullya river, Ganjam, Orissa (Voucher no. 395, Date: 25- 09 - 2004); Pl. 2, fig. 3.

6. *Oscillatoria vizagapatensis* Rao

Thallus blue green, trichomes straight, uniformly broad except at the extreme apex, without constriction at the cross wall, cell shorter than broad, 8 - 10 µm broad, 1.5-2.0 µm long, end cell rounded forming a cap.

Collection site: Soil crust from rice field, Surada, Ganjam, Orissa (Voucher no. 1190, Date: 15 - 08-2007); Pl. 2, fig. 4.

7. *Lyngbya anomala* (Rao) Umezaki and Watanabe

[Synonym: *Phormidium anomalum* C. B. Rao 1937]

Thallus expanded, deep blue green; trichome without constriction at the cross walls; sheath thin; colourless; cells disc-shaped, 9 - 10 µm broad, 1.2–2.0 µm long, end cell rounded.

Collection site: Soil crust from rice field, Asurabandha, Ganjam, Orissa (Voucher no. 312,

Date: 29-05-2003); Pl. 2, fig. 5.

8. *Phormidium ambiguum* Gomont

[Synonym: *Amphithrix amoena* Kützinger 1843]

Thallus expanded, bright blue- green; filament flexuous; trichome slightly constricted at the cross walls; sheath thin; cells shorter than broad, 4.0-5.6 µm broad, 1.5-2.7 µm long, rarely granulated at the cross walls; end cell rounded.

Collection site: Soil crust, Patia, Bhubaneswar, Orissa (Voucher no. B-29, Date: 29-01-2004); Pl. 2, fig. 6.

9. *Phormidium autumnale* (Agardh) Trevisan ex. Gomont

[Synonym: *Phormidium autumnale* (Agardh) Gomont 1892]

(Basionym: *Oscillatoria autumnalis* C. Agardh)

Thallus expanded, dark blue green or brownish green, sometimes yellowish; filament straight, rarely flexuous, variously entangled; sheath firm; trichomes not constricted at the cross wall, 4.8–5.0 µm broad, ends attenuated, straight or curved, prominently capitate; cell 5 - 6 µm long; end cell with a rounded or truncated conical calyptra.

Collection site: Soil crust from Rice field, Asurabandha, Surada, Ganjam Orissa (Voucher no. 1193, Date; 15-08-2007); Pl. 2, fig. 7.

10. *Leptolyngbya fragilis* (Gomont) Anagnostidis and Komárek

[Synonym: *Phormidium fragile* (Meneghini) Gomont 1892]

Thallus mucilaginous, dark blue green; sheath gelatinous, fibrous, diffuent into mucus; trichome 1.2–2.3 µm in diameter, more or less flexuous, entangled or some what parallel to each other, constricted at the joints; apical cell acute conical; cells 1.2–2.3 µm broad, 1.2–3.0 µm long.

Collection site: Soil crust from rice field, Gobindapur, Surada, Ganjam, Orissa (Voucher no. 1189, Date; 15-08-2007); Pl. 2, fig. 8.

11. *Leptolyngbya tenuis* (Gomont) Anagnostidis and Komárek

[Synonym: *Phormidium tenue* (Meneghini) Gomont 1892]

(Basionym: *Anabaena tenuis* Meneghini)

Thallus pale blue green, thin; trichome straight or slightly bent; attenuated at the end, 1–2.0 µm broad, cell up to 3 times longer than broad, 2.5–5.0 µm long, end cell acute-conical.

Collection site: Soil crust from rice field, Jeypur, Koraput, Orissa (Voucher no. 312, Date: 29 - 05-2003); Pl. 2, fig. 9.

12. *Nostoc commune* (Vaucher) ex. Bornet and Flahault

[Synonym: *Nostocella communis* (Vaucher) Gaillon; *Tremella nostoc* Linnaeus 1753;

*Nostoc commune* Vaucher 1803; *Nostoc kurzianum* Zeller 1873]

Thallus brownish; filament coiled, densely entangled; cells 2.5-3.7 µm broad, 3.7–6.4 µm long; heterocyst at two different ends, sub-spherical to spherical, 5 - 7 µm diameter. Collection site: Crust on cemented wall, Maniakati, Ganjam, Orissa (Voucher no. 273, Date: 08-05-2004); Pl. 2, fig. 14.

13. *Nostoc carneum* Agardh ex. Bornet and Flahault

[Synonym: *Nostoc carneum* (C. Agardh) 1824]

Thallus globose, leathery, gelatinous, olive green, filament loosely contracted, trichome 3.5-4.0 µm broad; cells oblong cylindrical; heterocyst yellowish, both terminal and intercalary, 4.0 - 5.6 µm broad, 4.5-5.3 µm long.

Collection site: Soil crust from rice field, Surada, Ganjam, Orissa. (Voucher no. 1194, Date: 20-09-2007); Pl. 2, fig. 13.

14. *Nostoc muscorum* agardh ex. bornet and Flahault  
[Synonym: *Nostoc muscorum* C. Agardh 1812]  
Thallus gelatinous, membranous, irregularly expanded;  
trichome, dark brown, 4.5–5.9  $\mu\text{m}$  broad; heterocyst  
spherical, 6.0–7.2  $\mu\text{m}$  broad.  
Collection site: Soil crust from rice field, Asurabandha,  
Surada, Ganjam, Orissa (Voucher no. 1195, Date: 20-09-  
2007); Pl. 2, fig. 15.

15. *Nostoc punctiforme* (kützing) hariot  
[Synonym: *Nostoc hederulae* Meneghini 1849]  
Filament flexuous densely entangled; sheath delicate;  
trichome 3 – 4  $\mu\text{m}$  broad, cells short, barrel shaped, bluish-  
green heterocyst 3.3-4.4  $\mu\text{m}$  broad, spores sub- spherical,  
5.0-6.5  $\mu\text{m}$  broad.  
Collection site: Crust on cemented wall, Maniakati,  
Ganjam, Orissa (Voucher no. 273, Date: 09-06-2004); Pl.  
2, fig. 16.

16. *Anabaena recta* geitler et. ruttner  
Trichome straight and solitary, clearly visible; trichome  
5.0-7.5  $\mu\text{m}$  broad; cell barrel shaped, heterocyst nearly  
spherical, 6.6-8.3  $\mu\text{m}$  broad, spores not seen.  
Collection site: Soil crust from rice field, Jeypur, Koraput,  
Orissa (Voucher no. 312, Date: 25 – 09 - 2004); Pl. 2, fig.  
17.

17. *Anabaena circinalis* (rabenhorst) ex. bornet et. flahault  
[Synonym: *Anabaena hassallii* (Kützing) Wittrock 1882]  
Trichome single, spirally coiled; without sheath; 4.4-5.5  
 $\mu\text{m}$  broad, cells barrel shaped; heterocyst sub-spherical,  
6.6-8.0  $\mu\text{m}$  broad; end cell rounded.  
Collection site: Crust on cemented wall, Jeypur, Koraput,  
Orissa (Voucher no. 313, Date: 25-09-2004); Pl. 3, fig. 18.

18. *Anabaena torulosa* lagerheim ex. bornet and Flahault  
Thallus mucilaginous, thin; trichome 4.2–5.0  $\mu\text{m}$  broad,  
apical cell acutely conical, cells barrel-shaped; heterocyst  
sub-spherical, spores on both side of the heterocyst, 6.0  $\mu\text{m}$   
broad and 6.0 – 10.0  $\mu\text{m}$  long.  
Collection site: Soil crust from rice field, Jeypur, Koraput,  
Orissa (Voucher no. 329, Date: 25 - 09 -2004); Pl. 2, fig.  
10.

19. *Cylindrospermum doryphorum* brühl and biswas  
Trichomes straight, cell constricted at cross walls, barrel  
shaped, 3.2  $\mu\text{m}$  broad; heterocyst spherical or oblong, 4.5-  
4.8  $\mu\text{m}$  broad, 6.5-8.0  $\mu\text{m}$  long; spores oblong, solitary,  
6.4-14.4  $\mu\text{m}$  broad, 16.5-19.2  $\mu\text{m}$  long.  
Collection site: Soil crust from rice field, Sorissibili,  
Surada, Ganjam, Orissa (Voucher no. 1190, Date: 15-08-  
2007); Pl. 3, fig. 19.

20. *Cylindrospermum michailovskoense* Elenkin  
Thallus blue green, mostly bent, sometimes straight, cell  
quadrate or cylindrical, constricted at the cross walls, 3 -5  
 $\mu\text{m}$  broad, 4 -7  $\mu\text{m}$  long; heterocyst oblong or spherical,  
5.0-5.5  $\mu\text{m}$  broad, 6 –8  $\mu\text{m}$  long, spores single, ellipsoidal  
or oblong, 8 –10  $\mu\text{m}$  broad, 15 –17  $\mu\text{m}$  long.  
Collection site: Wet soil from rice field, Maniakati,  
Ganjam, Orissa (Voucher no. 1195, Date: 20-09-2007); Pl.  
3, fig. 20.

21. *Scytonema stuposum* (kützing) bornet and Flahault  
Thallus broadly expanded, greenish; filament 4 -10  $\mu\text{m}$   
long, false branched; sheath thick, gelatinous; trichome  
olive violet, when dry greenish, 12 -18  $\mu\text{m}$  broad; cell 1/2-  
1/3 shorter than broad, sub-quadrate; heterocyst 9.9-11.6  
 $\mu\text{m}$  broad, 11.8-13.2  $\mu\text{m}$  long.

Collection site: Soil crust, Nandapur, Koraput, Orissa  
(Voucher no. 334, Date: 26-01-2004); Pl. 3, fig. 21.

22. *Calothrix clavata* West  
Filament single, slightly bent; sheath close to trichome,  
very thin, colourless; trichome slightly constricted at the  
cross walls, 5.0-5.5  $\mu\text{m}$  broad at the base, in the middle 2 -5  
 $\mu\text{m}$  broad; heterocyst basal, single, hemispherical.  
Collection site: Soil crust from field, Maniakati, Ganjam,  
Orissa (Voucher no.99, Date: 04-04-2003); Pl. 3, fig. 22.

23. *Fischerella tenuis* (martens) forti  
Thallus greenish, spongy, branched, branching on one side,  
heterocystous, cells quadrate to  
rectangular, 4.6-7.5  $\mu\text{m}$  broad, 5.2-6.5  $\mu\text{m}$  long; heterocyst  
oval or cylindrical, 4.0-4.5  $\mu\text{m}$   
broad, 5.2-7.5  $\mu\text{m}$  long.  
Collection site: Crust on cemented wall, Maniakati,  
Ganjam, Orissa (Voucher no. 273, Date:  
08-05-2004); Pl. 3, fig. 23.

24. *Westiellopsis prolifica* Janet  
Thallus bluish green, spongy; filamentous, heterocystous,  
branched, lateral filaments thinner  
than main branch, end with sporulated cells, 5.9-7.2  $\mu\text{m}$   
broad, 9 -12  $\mu\text{m}$  long; heterocyst  
intercalary, light yellow, cubical, cylindrical or oval, 5.0-  
5.9  $\mu\text{m}$  broad, 9.5-10.9  $\mu\text{m}$  long.  
Collection site: Soil crust from rice field, Budhipada,  
Cuttack, Orissa (Voucher no. 78, Date:  
29- 01-2004); Pl. 3, fig. 24.

#### Chlorophyta

25. *Chlorococcum infusionum* (Schrank) Meneghini  
[Synonym: *Chlorococcum humicola* (Nägeli) Rabenhorst  
1868]  
(Basionym: *Cystococcus humicola* Nägeli)  
Cells spherical, light green in color, solitary or a number of  
cells crowded together to form a  
stratum; chloroplast with a hallow sphere with a lateral  
notch; cells 6.6–20.0  $\mu\text{m}$  in diameter.  
Collection site: Soil crust from rice field, Surada, Ganjam,  
Orissa (Voucher no. 1190, Date: 15-  
08-2007); Pl. 3, fig. 25.

26. *Chlorella vulgaris* Beijerinck  
[Synonym: *Chlorella pyrenoidosa* var. *duplex* (Kützing)  
West; *Pleurococcus beijerinckii*  
Artari 1892; *Chlorella communis* Artari 1906; *Chlorella*  
*vulgaris* var. *viridis* Chodat 1913;  
*Chlorella terricola* Gollerbach 1936; *Chlorella Candida*  
Shihira & Krauss 1965]  
Cell spherical; single parietal and cup-shaped chloroplast  
with one pyrenoid; cells 7.5-10.0  $\mu\text{m}$   
in diameter.  
Collection site: Soil crust from rice field, Gazalbadi,  
Surada, Ganjam, Orissa (Voucher no. 1191, Date: 25-08-  
2007); Pl. 3, fig. 27.

27. *Pandorina morum* (Müll.) Bory de Saint-Vincent  
[Synonym: *Volvox morum* O. F. Müller]  
(Basionym: *Volvox morum* O. F. Müller)  
Colonies spherical or ellipsoidal, both end broadly rounded,  
8 -16  $\mu\text{m}$  celled, embedded in a  
common gelatinous matrix, 24 -36  $\mu\text{m}$  in diameter; cell  
obovate or wedge shaped, broad side

turned toward the outside, narrower and rounded posteriorly, closely packed, 8.4-10  $\mu\text{m}$  broad, 8 -17  $\mu\text{m}$  long; chloroplast massive, cup-shaped, one basal pyrenoid.

Collection site: Soil crust from rice field, Gobindapur, Surada, Ganjam, Orissa (Voucher no. 1193, Date: 20-08-2007); Pl. 3, fig. 28.

28. *Volvox carteri* Stein

Colonies globose 450-480  $\mu\text{m}$  broad; cell ovoid, round in surface view, no protoplasmic interconnection discernible, thick sheath, gelatinous; gonidia 3- 4, 4-6 per colony 48 -53  $\mu\text{m}$  in diameter.

Collection site: Soil crust from rice field, Padaraisuni, Surada, Ganjam, Orissa (Voucher no. 1194, Date: 15-08-2007); Pl. 3, fig. 29.

29. *Microspora willeana* Lagerheim

Filament cylindrical slightly constricted at cross wall; cell wall thin, H piece scarcely visible in vegetative cell;

chloroplast variable, cell 12.5-15.0  $\mu\text{m}$  broad, 11/2 time as long as broad.

Collection site: Soil crust from rice field, Asurabandha, Surada, Ganjam, Orissa (Voucher no. 1195, Date: 25-09-2007); Pl. 3, fig. 26.

30. *Closterium lunula* Nitzsch ex. Ralfs

[Synonym: *Closterium lunula* var. *giganteum* (C. Bernard) Playfair; *Echinella radiosa* Acharius; *Closterium turgidum* var. *giganteum* (Nordstedt) De Toni 1889]

Cells solitary, elongated, attenuated towards the end; chloroplast with longitudinal linear ridge, separated at the middle, many pyrenoids; at each end one reddish nodule is present; cells 450-666  $\mu\text{m}$  long and 40-112  $\mu\text{m}$  broad.

Collection site: Soil crust, rice field, Gobindapur, Surada, Ganjam, Orissa (Voucher no. 1189, Date: 15-08-2007); Pl. 3, fig. 30.

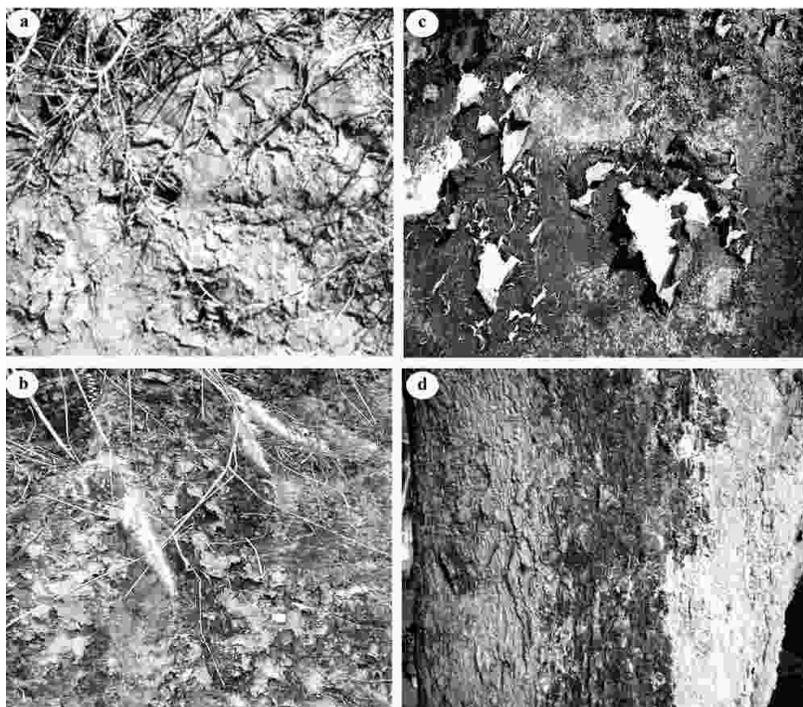


Plate 1. (Figs 1-4) The crusts on 1. barren field, 2. lime washed wall, 3. forest floor and 4. Tree bark occur during winter season.

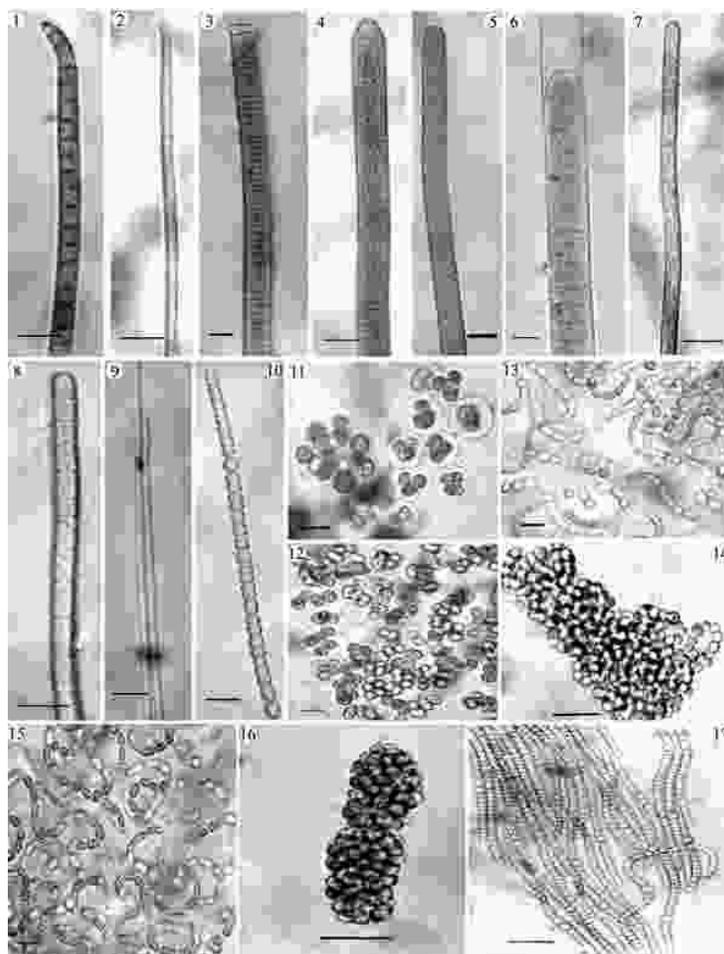


Plate. 2, Figs. 1 – 17: *Phormidium acutum* (Brühl and Biswas) Anagnostidis and Komárek, 2. *Phormidium animale* (Agardh ex. Gomont) Anagnostidis and Komárek, 3. *Phormidium limosum* (Dillwyn) Silva, 4. *Oscillatoria vizagapatensis* Rao, 5. *Lyngbya anoma* (Rao) Umezaki and Watanabe, 6. *Phormidium ambiguum* Gomont, 7. *Phormidium autumnale* (Agardh) Trevisan ex Gomont, 8. *Leptolyngbya fragilis* (Gomont) Anagnostidis and Komárek, 9. *Leptolyngbya tenuis* (Gomont) Anagnostidis and Komárek, 10. *Anabaena torulosa* Lagerheim ex. Bornet and Flahault, 11. *Gloeocapsa aeruginosa* Kützing, 12. *Aphanocapsa biformis* A. Brown, 13. *Nostoc carneum* Agardh ex. Bornet and Flahault, 14. *Nostoc commune* (Vaucher) Bornet and Flahault, 15. *Nostoc muscorum* (Agardh) ex. Bornet and Flahault, 16. *Nostoc punctiforme* (Kützing) Hariot, 17. *Anabaena recta* Geitler.  
Scale bar = 10  $\mu$ m.

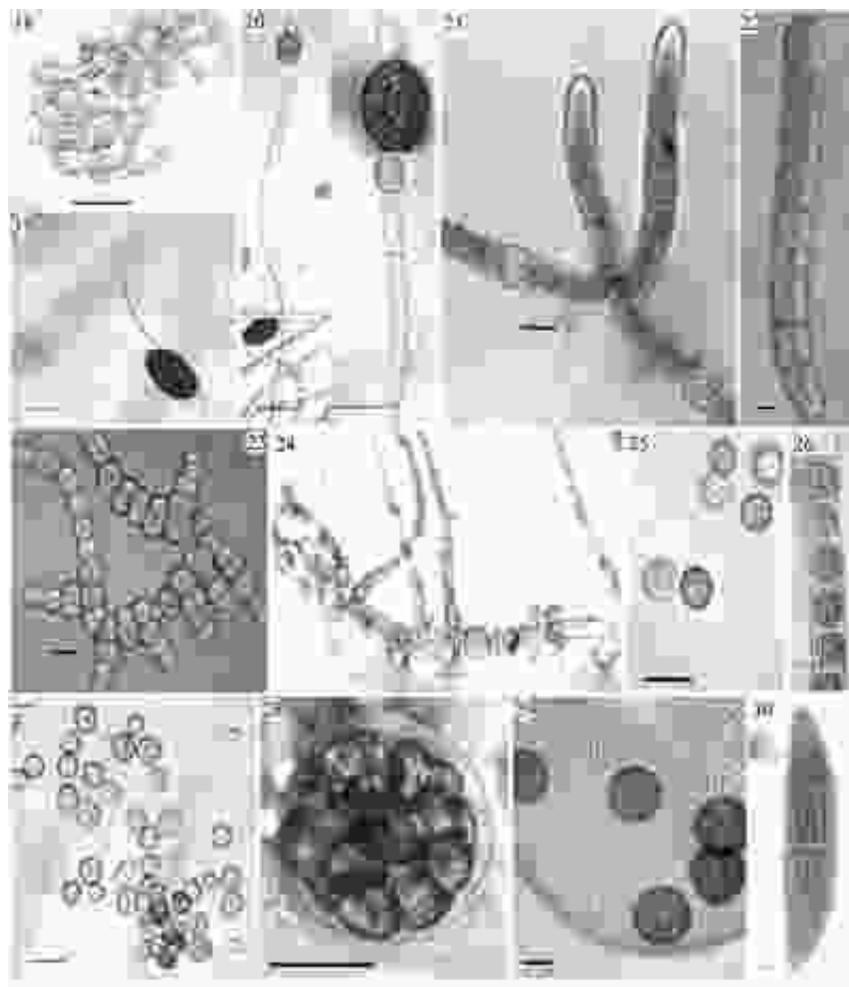


Plate. 3, Figs. 18 – 30: *Anabaena circinalis* (Rabenhorst) Bornet and Flahault, 19. *Cylindrospermum doryphorum* Brühl and Biswas, 20. *Cylindrospermum michailovskoense* Elenkin, 21. *Scytonema stuposum* (Kützing) Bornet and Flahault, 22. *Calothrix clavata* West, 23. *Fischerella tenuis* (Martens) Forti, 24. *Westiellopsis prolifica* Janet, 25. *Chlorococcum infusionum* (Schrank) Meneghini, 26. *Microspora willeana* Lagerheim, 27. *Chlorella vulgaris* Beijerinck, 28. *Pandorina morum* (Müller) Bory de Saint-Vincent, 29. *Volvox carteri* Stein, 30. *Closterium lunula* Nitzsch ex. Ralfs.  
Scale bar = 10 µm

## DISCUSSION

Analysis of these results showed that species composition in the crusts varies with the nature of the substratum and the sampling season. The brownish crust or mat on all types of soils during summer and winter seasons harbour only certain species of cyanobacteria e.g. *Scytonema stuposum*, *Lyngbya anomala*, *Calothrix clavata*, *Leptolyngbya tenuis*, *Gloeocapsa aeruginosa* and *Aphanocapsa biformis*, all of which possess well developed sheath or slime layers around their cells/trichome. In the crust on

building facades with cemented substratum, however, were cyanobacteria species belonging to *Nostoc* and *Anabaena*, and on tree bark the filamentous non-heterocystous *Phormidium acutum* was the principal component. In the rainy season few green algae, e.g. *Microspora willeana*, *Chlorococcum infusionum*, *Chlorella vulgaris*, *Pandorina morum*, *Volvox carteri* and *Closterium lunula* occur in the crusts on rice field soils along with few cyanobacteria of the genera *Nostoc*, *Anabaena*, *Cylindrospermum*, *Fischerella*, *Oscillatoria*, *Phormidium* and *Leptolyngbya* (Table 1).

Table-1: Nature of the substratum of the sampled sites and the species composition from different localities of Orissa state, eastern region of India.

Sl. no.	Nature of Substratum sampled site	Locality in Orissa state, India	Season of collection	Appearance of crust on the substratum	Species composition in the crusts
1.	Rice field	Asurabandha, Ganjam	Summer	Brownish mats on soil	Lyngbya anomala
			Rainy	Greenish mat on moist soil	Phormidium autumnale Nostoc moscorum Microspora willeana
2.	Rice field	Budhipada, Cuttack	Winter	Greenish mat on soil	Westielloopsis prolifica
			Rainy	Greenish mat on moist soil	Chlorococcum infusionum
3.	Rice field	Gazalbadi, Ganjam	Rainy	Greenish crust on soil	Nostoc moscorum Chlorella vulgaris
4.	Rice field	Gobindapur, Surada block, Ganjam	Rainy	Brownish green crust on soil	Leptolyngbya fragilis Pandorina morum Closterium lunula
5.	Rice field	Jeypur, Koraput	Summer	Brownish crust on soil	Leptolyngbya tenuis
			Rainy	Greenish crust on soil	Anabaena recta Anabaena torulosa
6.	Rice field	Maniakati, Surada block, Ganjam	Rainy	Greenish mat on soil	Cylindrospermum michailovskaense Nostoc carneum Chlorococcum infusionum
7.	Rice field	Maniakati, Surada block, Ganjam	Summer	Brownish dried soil crust	Calothrix clavata
			Winter	Bluish soil crust	Scytonema stuposum
8.	Rice field	Padaraisuni, Surada block, Ganjam	Rainy	Greenish crust on soil	Nostoc moscorum Volvox carteri
9.	Rice field	Surada, Ganjam	Summer	Dark green crust on soil	Gloeocapsa aeruginosa
			Rainy	Greenish crust on soil	Oscillatoria vizagapatensis Phormidium animale Nostoc carneum Chlorococcum infusionum
10.	Rice field	Sorisibilli, Surada block, Ganjam	Summer	Brownish mat on moist soil	Aphanocapsa biformis
			Rainy	Greenish mat on wet soil	Cylindrospermum doryphorum Chlorococcum infusionum
11.	Cemented Building facades	Jeypur, Koraput	Winter & Summer	Blackish - Green crust on wall	Anabaena circinalis
			Rainy	Greenish crust on wall	Fischerella tenuis
12.	Cemented pits	Maniakati, Surada block, Ganjam	Winter & Summer	Blackish-green crust on wall	Nostoc punctiforme
			Rainy	Greenish crust on wall	Fischerella tenuis
13.	Forest soil	Nandapur, Koraput	Winter	Blackish brown crust on soil surface	Scytonema stuposum
14.	Barren land	Patia, Bhubaneswar	Winter	Brownish crust on soil surface	Phormidium ambiguum Scytonema stuposum
15.	Moist soil	Rushikullya river bank, Ganjam	Rainy	Greenish mat, attached on moist soil in the bank of river	Phormidium limosum
16.	Tree trunk	Biswanathpur, Cuttack	Winter	Brownish-green crust on tree trunk	Phormidium acutum

Summer (March – May); Rainy (July – September); Winter (December – January).

Occurrence of several species of green algae and cyanobacteria have been reported in the biological crusts on different substrata comprising of building facades, stone monuments, bricks, bark of trees and soil surfaces in temperate and tropical region of the globe (Crispim *et al.*, 2003; 2004; Gaylarde and Gaylarde, 2000; Johansen and Shubert, 2001; Ortega-Morales *et al.*, 2005; Tirkey and Adhikary, 2006; Tripathi *et al.*, 1991; Uher *et al.*, 2005; Tripathy *et al.*, 1999). These results showed that invariably species belong to green algae were the principal components in the crusts from various substratum in cooler regions e.g. Germany (Karsten *et al.*, 2007), Ukraine (Darienko and Hoffmann, 2003), UK (Crispim *et al.*, 2003; Gaylarde and Gaylarde 2005; Rindi *et al.* 2005), France (Barberousse *et al.* 2006, 2007), Spain (Ortega-Calvo *et al.*, 1993; Uher *et al.*, 2005) and Italy (Rindi and López Bautista, 2007; Tomaselli *et al.*, 2000) where as cyanobacteria were the principal species of the crust on similar substratum in warmer region of India (Büdel, 1999; Mishra and Srivastava, 2003; Tripathi *et al.*, 1991). The results of this communication also showed that cyanobacteria were the prominent components in the crust on soil, building facades as well as bark of trees during dry season where as green algal forms occur in the crusts only when sufficient moisture is available in the substratum.

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