

The genus *Oscillatoria* Vaucher (Cyanoprokaryota) from India.

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Abstract

The genus *Oscillatoria* Vaucher Oscillatoriales, Cyanoprokaryota is known to be represented by 208 taxa from India. Our collections from various localities of Uttar Pradesh, revealed the occurrence of 30 species. For identification we have followed the diagnosis of *Oscillatoria* as conceived by Komarek and Anagnostidis (2005). The present communication includes a key of all the species, brief description, figures and photomicrographs. Attempts have been made to bring out clearly the distinguish features in description and in line diagrams for easy identification.

Key words: Oscillatoriales, *Oscillatoria*, India.

Introduction

For the last over 150 years, Cyanobacteria have been named on the basis of morpho-taxonomical features. However, in preparing ecological and floristic accounts, the morpho-taxonomy is the only alternative for identification of living organisms. Molecular or biochemical characterization may not be possible each time and for all the specimens. Morpho-taxonomy facilitates many workers to contribute more in the knowledge of these organisms without much sophisticated facilities. However, if one happened to get some remarkable organism from the view point of structural, ecological, biochemical or biotechnological usefulness, it has to be investigated compulsorily by polyphasic approach including all available techniques and parameters to understand the organism and to fully utilize their capabilities. It is well realized that molecular approach can serve better to resolve some specific problem that cannot be settled by morphological parameters.

There are many taxonomic accounts based on morphological parameters on Oscillatoriales of India including Geitler (1932), Desikachary (1959), Tiwari (1975), Anand (1989), Adhikary (2007) and many other floristic papers. However, exclusive details on Oscillatoriales have been given recently by Komarek and Anagnostidis (2005) and McGregor (2007). Most Indian accounts are based on criteria of classical description and classification. The concept of classification of Oscillatoriales by Komarek and Anagnostidis (2005) is an exhaustive study and various taxa are arranged in a single order, 6 families and 12 sub-families. In recent years Komarek and Anagnostidis (2005) reinvestigated the taxa and several new genera have been segregated and they are *Geitlerinema*, *Pseudanabaena*, *Leptolyngbya*, *Tychonema*, *Jaaginema*, *Komvophon*, *Limnothrix*, *Planktothrix*, *Planktothricoides*, *Phormidium* and *Trichodesmium* etc. Our survey of literature on Oscillatoriales revealed that according to classical concept 128 species of *Oscillatoria* have been reported from India (Tiwari *et al.* 2007).

Materials and Methods

During the last over one decade (2003-2013), we have been collecting cyanobacteria from natural habitats of various localities of Uttar Pradesh (Allahabad, Varanasi, Jaunpur, Pratapgarh, Mirzapur, Chitrakoot, Raebareli, Fatehpur and Kaushambi) and collected total 30 species of *Oscillatoria*. We also surveyed the literative reporting species of *Oscillatoria*. During the selection of 30 species of India, attempts were made to recognize the salient features of morphology of each species and to prepare a key for all the species.

Salient feature of the genus *Oscillatoria* Vaucher

Trichomes without sheath, straight or slightly irregularly undulating, cylindrical sometimes screw like coiled at ends, mostly present in mats rarely solitary, 4-50µm wide. Cells are always shorter than wide and disc like. Cells are blue-green, olive or almost blackish, yellow-green or greenish-blue in colour. Sheath usually absent, although they may occur under suboptimal conditions. Trichomes exhibits gliding motility by left or right handed rotations, rates of movement range from 1 to 11µm/s. Division occur in a rapid sequence transversely to the trichomes axis. Trichomes are disintegrated into short motile hormogonia and separate with the help of necridic cells (Desikachary, 1959, Komarek & Anagnostidis 2005).

List of collected thirty Indian species of *Oscillatoria* Vaucher

1. *O. anguina* (Bory) Gomont : **Rao, 1937**
2. *O. annae* van Goor : **Gupta, 1956**
3. *O. bharadwajae* : **Kamat, 1963**
4. *O. bonnemaisonii* Crouan : **Prasad & Srivastava, 1985**
5. *O. chilkensis* : **Biswas, 1932**
6. *O. corakiana* Playfair : **Kamat, 1963**
7. *O. curviceps* Ag. ex Gomont : **Vashishta, 1965**
8. *O. fracta* Carlson : **Venkataraman, 1957**
9. *O. jenensis* Schmidle : **Kamat, 1963**
10. *O. koettlitzii* Fritsch : **Chadha & Pandey, 1983**
11. *O. limosa* Ag. ex Gomont : **Martens, 1870**
12. *O. lutea* Ag. ex Gomont : **Anand, 1989**
13. *O. maharashtrensis* : **Kamat, 1962**
14. *O. margaritifera* (Kutz.) Gomont : **Barhate & Tarar, 1983**
15. *O. miniata* (Zanard.) Hayck. : **Srinivasan, 1965**
16. *O. mitrae* : **Kamat, 1963**
17. *O. nigro-viridis* Thwaites ex Gomont : **Rao, 1938**
18. *O. obtusa* Gardner : **Laloraya & Mitra, 1973**
19. *O. ornata* Kutz. ex Gomont : **Rao, 1938**
20. *O. perornata* Skuja : **Vashishta, 1968**
21. *O. princeps* Vauch. ex Gomont : **Desikachary, 1959**
22. *O. proboscidea* Gomont : **Singh, R.N., 1939**
23. *O. rupicola* Hansg. : **Thomas & Gonz., 1965**
24. *O. sancta* (Kutz.) Gomont : **Schmidle, 1900**
25. *O. simplicissima* Gomont : **Biswas, 1926**
26. *O. subbrevis* Schmidle : **Singh, V.P., 1941**
27. *O. subproboscidea* West, W. & G.S. West : **Parukutty, 1940**
28. *O. tenuis* Ag. ex Gomont : **Martens, 1870**
29. *O. vizagapatensis* : **Rao, 1938**
30. *O. yamadae* : **Kamat, 1963**

Key to the thirty Indian species of *Oscillatoria* Vaucher

1. Trichome 4-10 µm broad-----2
1. Trichome 11-18 µm broad-----14
1. Trichome 19-50 µm broad-----22
 2. Trichome 4-6 µm broad-----3
 2. Trichome 6-11 µm broad-----4
 3. Trichome somewhat curved, apex shortly tapering-----*O. chilkensis*
 3. Trichome straight with straight end-----*O. rupicola*
4. End cell with calyptra-----5
4. End cell without calyptra-----6
 5. Trichome spirally coiled, apical cell button like capitate with slightly thickened membrane-----*O. anguina*
 5. Trichome straight or slightly curved, apical cell hyaline, flattened-rounded and oval -----*O. koettlitzii*
6. Cells constricted and granulated at the cross wall-----7
6. Cells not or slightly constricted at the end-----8
 7. Trichome 7-11 µm, ± straight and slightly arcuated at the end-----*O. nigro-viridis*
 7. Trichome 8-11 µm, ± straight and screw like coiled towards end-----*O. ornata*
 8. Trichome end attenuated and hooked; apical cell short, blunt and convex with thickened membrane-----*O. subproboscidea*
 8. Trichome end not hooked, apical cell rounded or flat rounded-----9
 9. Trichome straight, slightly constricted, free floating-----*O. annae*

9. Trichome not constricted, not free floating-----10
10. Trichome straight to slightly curved at the end-----11
10. Trichome not curved at the end-----12
11. Thallus forming flat mats, apical cell rounded-----*O. tenuis*
11. Thallus not forming mats, apical cell flattened-rounded-----*O. fracta*
12. Trichome 5-8 μm broad-----*O. subbrevis*
12. Trichome 6-10 μm broad-----13
13. Trichome 6-10, end cell rounded with thickened wall-----*O. lutea*
13. Trichome 8-10, end cell rounded without thickened wall-----*O. simplissima*
14. Trichome upto 4-12 μm broad-----15
14. Trichome over 12 μm broad-----17
15. Thallus pale or greyish green, apical cell rounded without calyptra-----*O. corakiana*
15. Thallus blue-green, apical cell broadly rounded forming cap or calyptra-----16
16. Trichome straight, uniformly broad except at the extreme apex,
apical cell with cap-----*O. vizagapatensis*
16. Trichome straight, long, slightly tapering towards the apices,
apical cell capitate with calyptra-----*O. yamadae*
17. Distinctly constricted and granulated at the cross wall-----18
17. Distinctly not constricted and slightly granulated at the cross wall-----19
18. Thallus pale blue green, apical cell humilis depressed, calyptra absent-----*O. perornata*
18. Thallus dark brownish, apical cell hemispherical or flat with thick calyptra-----*O. sancta*
19. Trichome straight, not attenuated-----*O. limosa*
19. Trichome \pm straight or curved, attenuated at the apex-----20
20. Thallus olive green, trichome tapering towards end-----*O. mitrae*
20. Thallus blue green, trichome screw like coiled at the end-----21
21. Trichome 12-15 μm , apical cell slightly capitate, without calyptra-----*O. proboscidea*
21. Trichome 10-18 μm , apical cell with thickened wall, not capitate-----*O. curviceps*
22. Thallus dirty or dark red, trichome 16-23 μm broad-----*O. miniata*
22. Thallus olive green, blue green or brownish to black-----23
23. Trichome 15-22 μm , straight, constricted at the cross wall, apical cell capitate with
convex calyptra-----*O. margaritifera*
23. Trichome slightly tapering towards end, not or slightly constricted-----24
24. Trichome screw like coiled, apical cell without thick wall or
calyptra-----*O. bonnemaisonii*
24. Trichome not screw like coiled-----25
25. Trichome 19-25 μm broad-----26
25. Trichome 20-50 μm broad-----28
26. Thallus olive green, apical cell not capitate-----*O. maharashtrensis*
26. Thallus blue green to brown, apical cell with thickened outer wall -----27
27. Trichome end narrowed, long, bent with yellowish terminal cell-----*O. jenensis*
27. Trichome \pm straight or arcuated, cylindrical -----*O. obtusa*
28. Trichome 34-37 μm , long, apical cell rounded with narrow calyptra-----*O. bharadwajae*
28. Trichome 20-50 μm , apical cell flatly rounded, slightly capitate, truncate-----*O. princeps*

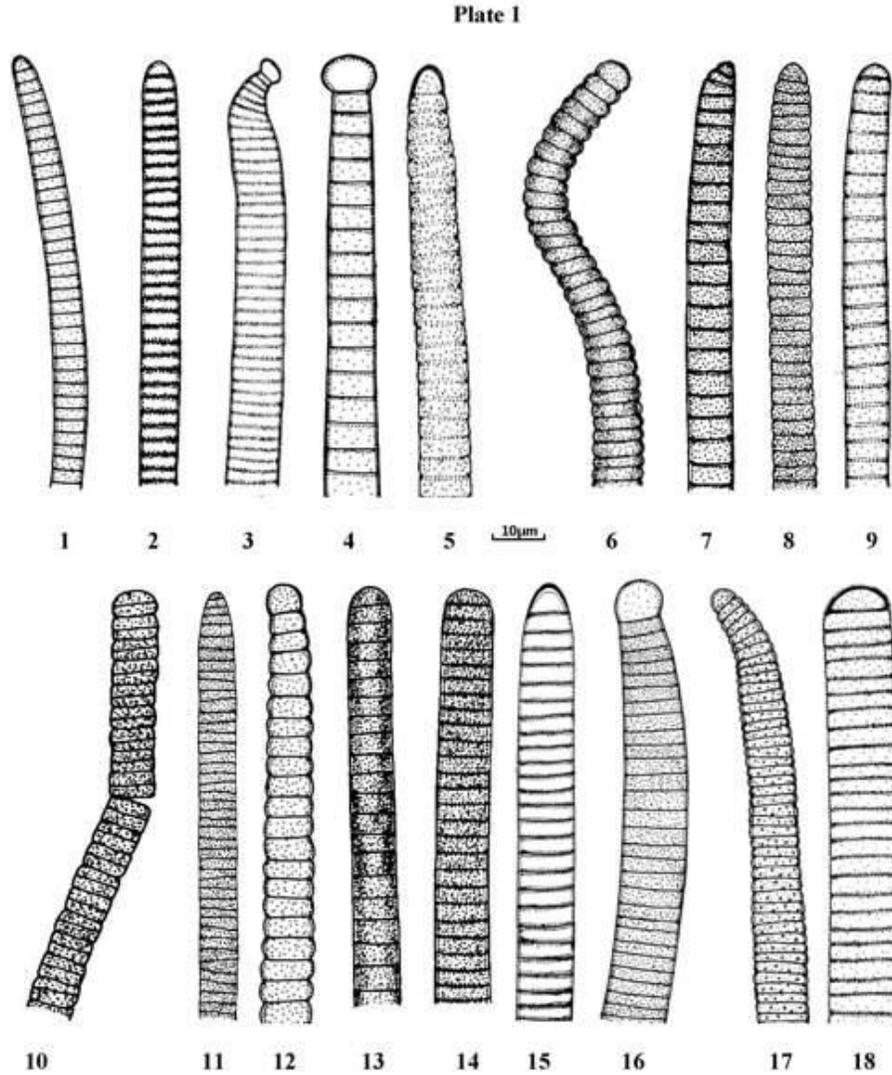


Plate 1 Explanation of Figures 1-18 *Oscillatoria* Vaucher. 1: *O. chilkinsis*. 2: *O. rupicola*. 3: *O. anguina*. 4: *O. koettlützi*. 5: *O. nigro-viridis*. 6: *O. ornata*. 7: *O. subproboscidea*. 8: *O. annae*. 9: *O. tenuis*. 10: *O. fracta*. 11: *O. subbrevis*. 12: *O. lutea*. 13: *O. simplicissima*. 14: *O. corakiana*. 15: *O. vizagapatensis*. 16: *O. yamadae*. 17: *O. perornata*. 18: *O. sancta*
Scale 10µm

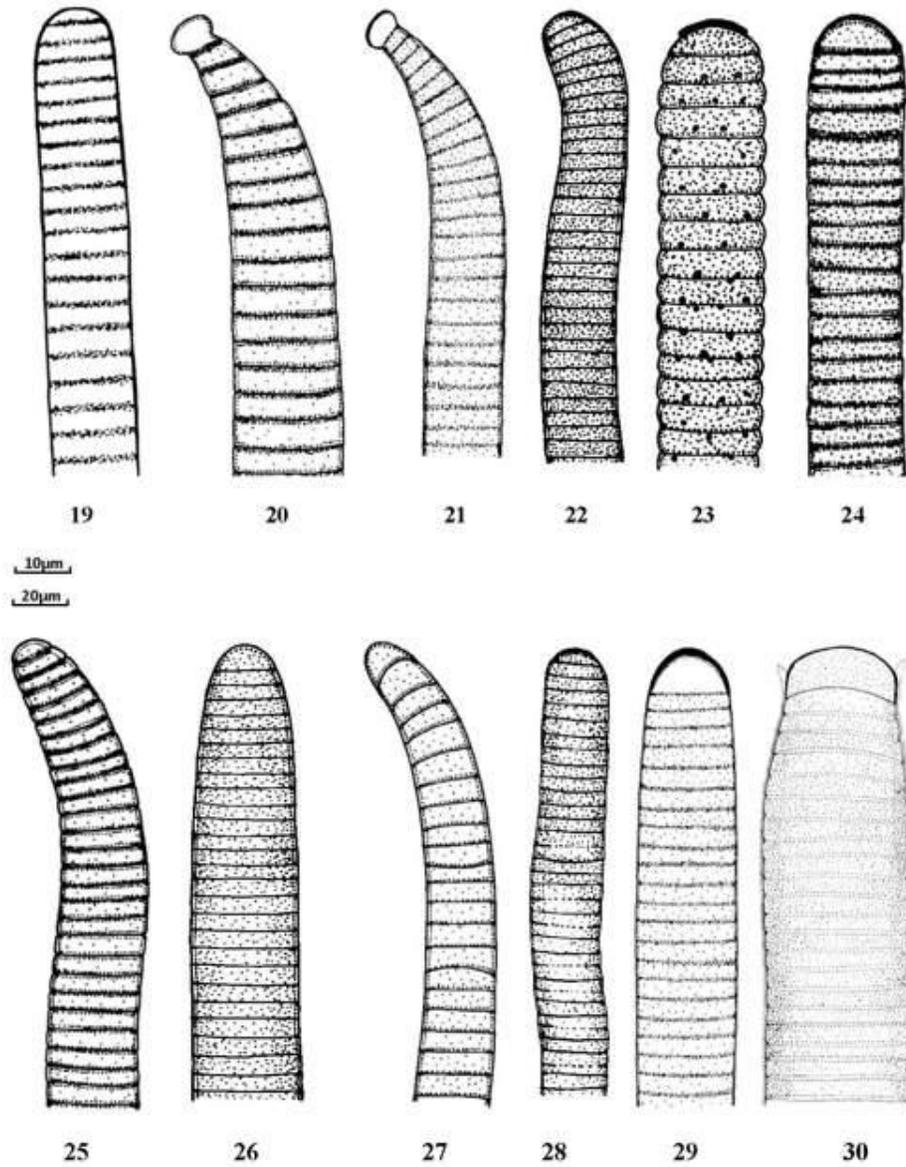


Plate 2 Explanation of Figures 19-30 *Oscillatoria* Vaucher. 19: *O. limosa*. 20: *O. mitrae*. 21: *O. proboscidea*. 22: *O. curviceps*. 23: *O. miniata*. 24: *O. margaritifera*. 25: *O. bonnemaisonii*. 26: *O. maharashtrensis*. 27: *O. jenensis*. 28: *O. obtusa*. 29: *O. bharadwajae*. 30: *O. Princeps*
Scale 10µm for figs. 19-25; Scale 20µm for figs. 26-30.

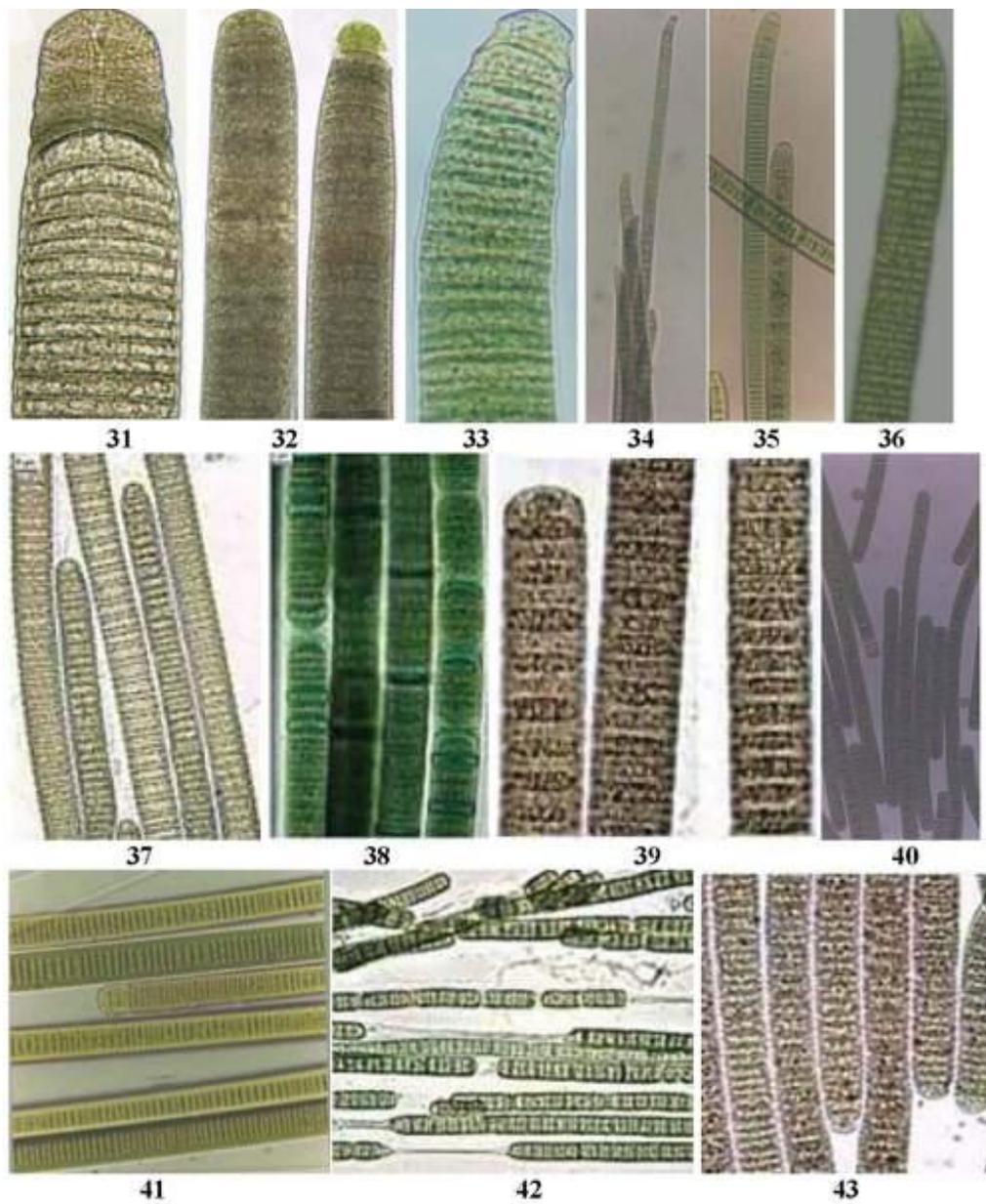


Plate 3 Explanation of Figures 31-43 *Oscillatoria* Vaucher. 31-33: *O. princeps*. 34: *O. anguina*. 35: *O. vizagapatensis*. 36: *O. proboscidea*. 37: *O. nigro-viridis*. 38: *O. limosa*. 39: *O. margaritifera*. 40: *O. subbrevis*. 41: *O. tenuis*. 42: *O. rupicola*. 43: *O. sancta*



Plate 4 Explanation of Figures 44-49 *Oscillatoria* Vaucher. 44: *O. sancta*. 45: *O. nigro-viridis*. 46: *O. vizagapatensis*. 47: *O. limosa*. 48: *O. subbrevis*. 49: *O. princeps*

Brief description of species of *Oscillatoria* Vaucher recorded in the present study

1. *O. chilkinsis* Biswas (Pl. 1, Fig. 1)

Thallus pale blue-green; trichome somewhat curved, apex shortly tapering; cells 4-6 μm x 2 μm (width x length), slightly constricted at the cross walls; apical cell obtusely rounded without calyptra.

Habitat and Occurrence: It was found in ponds, cemented tanks and ditches; Allahabad, Mirzapur, Chitrakoot, Kaushambi and Fatehpur.

2. *O. rupicola* Hansg. (Pl. 1, Fig. 2; Pl. 3, Fig. 42)

Thallus small clusters, mats olive green, blue green; trichome straight or slightly curved, rarely with fine sheath; cells 4-6(8) μm x 1.5-3 μm , granules are prominent at the cross wall; apical cell widely rounded, without calyptra or thickened wall.

Habitat and Occurrence: It grows in mixed population of other *Oscillatoria* species but frequently with *O. anguina*, *O. margartifera* and other genera of Oscillatoriales; Allahabad, Mirzapur, Chitrakoot, Kaushambi and Fatehpur.

3. *O. anguina* (Bory) Gomont (Pl. 1, Fig. 3; Pl. 3, Fig. 34)

Thallus thin, mucilaginous, dark blue-green; trichome straight, at the end spirally coiled and distinctly attenuated; cells 6-8 μm x 1.3-2.6 μm , cross wall sometimes granulated; apical cell button like capitate with slightly thickened membrane.

Habitat and Occurrence: It was found growing in irrigation channels mixed with other species of *Oscillatoria* and other algae; Allahabad, Jaunpur, Mirzapur and Kaushambi.

4. *O. koettlitzii* Fritsch (Pl. 1, Fig. 4)

Thallus dark violet; trichome straight or slightly curved, solitary; cells 7- 9 μm ; apical cell hyaline, flattened- spherical ends in mature trichomes.

Habitat and Occurrence: It was found in stagnant waters; Pratapgarh, Mirzapur, Raebareli and Kaushambi.

5. *O. nigro-viridis* Thwaites ex Gomont (Pl. 1, Fig. 5; Pl. 3, Fig. 37; Pl. 4, Fig. 45)

Thallus prostrate, blackish green or olive green; trichome \pm straight or wavy, narrowed and slightly arcuated at the end; cells 7-11 μm x 2-4 μm , constricted and granulated at cross walls; apical cell conical rounded with slightly thickened wall.

Habitat and Occurrence: Frequently observed in aquatic as well as in moist soils. It grows in slow flowing channels or building walls during rains and usarland rice fields; Kaushambi, Allahabad, Chitrakoot and Pratapgarh.

6. *O. ornata* Kuetz. ex Gomont (Pl. 1, Fig. 6)

Thallus forming blackish blue- green mats; trichome \pm straight or wavy, screw like coiled towards end; cells 8-11 μm x 2-6 μm , distinctly constricted and granulated at the cross wall; apical cell rounded, without thickened wall or calyptra.

Habitat and Occurrence: Plankton in ponds and ditches; Mirzapur, Jaunpur and Chitrakoot.

7. *O. subproboscidea* West, W. & G.S. West (Pl. 1, Fig. 7)

Trichome metaphytic, olive to blue green, single, straight or slightly bent, ends attenuated; cells 8-9 μm x 3-4 μm ; apical cell short, conical with slightly thickened membrane.

Habitat and Occurrence: Planktonic in ponds and ditches; Raebareli and Mirzapur.

8. *O. annae* Van Goor (Pl. 1, Fig. 8)

Trichome straight, in mats or clusters or free-floating; dull blue-green; cells 7-9 μm x 2-3 μm , constricted at the cross walls; apical cell rounded, calyptra absent.

Habitat and Occurrence: It was found attached to leaves along with other algae; Allahabad, Jaunpur, Kaushambi, Fatehpur, Raebareli and Mirzapur.

**O. annae* and *O. subbrevis* can also compared but we distinguished them as independent species on the basis of trichome width, colour of thallus and presence of constriction in *O. annae*.

9. *O. tenuis* Ag. ex Gomont (Pl. 1, Fig. 9; Pl. 3, Fig. 40)

Thallus forming flat mats, blue green or olive green; trichome straight or slightly curved; cells 6-11 μm x 2-3 μm ; apical cell rounded with slightly thickened wall.

Habitat and Occurrence: It was growing on cemented wall of buildings or water tanks where water leaks and also in ponds and ditches; Varanasi, Pratapgarh, Raebareli, and Chitrakoot.

*In *O. tenuis* and *O. koeltitzii* cells are not much shorter than wide, but in *O. koeltitzii* distinct hyaline, flattened spherical apical cell in mature trichome.

10. *O. fracta* Carlson (Pl. 1, Fig. 10)

Thallus blue green; trichome \pm straight to slightly curved; cells short 7-11 μm x 2-2.8 μm , discoid; apical cell flattened rounded.

Habitat and Occurrence: In small ditches and stagnant water bodies; Varanasi, Raebareli and Kaushambi.

11. *O. subbrevis* Schmidle (Pl. 1, Fig. 11; Pl. 3, Fig. 41; Pl. 4, Fig. 48)

Thallus yellow grey to green- yellowish; trichome single, straight, slightly tapering at the end; cells 5-8 μm x 1-2 μm ; apical cell rounded, without calyptra.

Habitat and Occurrence: Common on moist soils with other Oscillatoriales during rains. Frequently observed in rice-fields; Allahabad, Jaunpur, Raebareli, Kaushambi and Fatehpur.

12. *O. lutea* Ag. ex Gomont (Pl. 1, Fig. 12)

Trichome, pale blue green or yellowish; \pm straight, solitary or in small clusters; cells 6-10 μm , constricted at the cross wall; apical cell rounded with slightly thickened wall.

Habitat and Occurrence: In metaphyton among plants and mosses; Jaunpur, Fatehpur, Chitrakoot and Allahabad.

13. *O. simplicissima* Gomont (Pl. 1, Fig. 13)

Thallus flat in mats, blackish blue green, trichome straight or flexuous, straight at the end; cells 8-10 μm x 2-4 μm , homogeneously granulated; apical cell rounded, without thickened wall or calyptra.

Habitat and Occurrence: Planktonic in ponds and lakes; Varanasi, Jaunpur, Pratapgarh and Fatehpur.

14. *O. corakiana* Playfair (Pl. 1, Fig. 14)

Thallus pale or greyish green, trichome straight; cells 9-12 μm x 2.6-3 μm , discoid; apical cell flat rounded without calyptra.

Habitat and Occurrence: It was found in river Yamuna and in filter tanks and also in ponds; Allahabad, Chitrakoot and Kaushambi.

**O. corakiana* appears comparable to *O. simplicissima* but the most distinction lies in the broader diameter of the former and different colour of the thalli.

15. *O. vizagapatensis* Rao (Pl. 1, Fig. 15; Pl. 3, Fig. 35; Pl. 4, Fig. 46)

Thallus blue green; trichome straight or slightly bent, uniformly broad except at the extreme apex; cells 9-12 μm x 1-3 μm ; apical cell broadly rounded, forming a cap with slightly thickened outer wall.

Habitat and Occurrence: Frequently observed around shores or attached to side walls of small ditches, ponds and lakes. Often mixed other genera of Oscillatoriales found in rice fields; Varanasi, Jaunpur, Fatehpur and Raebareli.

16. *O. yamadae* Kamat (Pl. 1, Fig. 16)

Thallus blue green; trichome long, slightly tapering towards the apices; cells 10-12 μm x 2.5-3 μm ; apical cell capitate with calyptra.

Habitat and Occurrence: In a puddles; Pratapgarh, Kaushambi and Fatehpur.

17. *O. perornata* Skuja (Pl. 1, Fig. 17)

Trichome, pale blue- green, erect or flexuous, apices briefly attenuated or curved; cells 9-11 μm x 2.5-6.5 μm , distinctly constricted and granulated at the cross wall; apical cell hemispherical without calyptra.

Habitat and Occurrence: Planktonic in lakes and rain water puddles; Mirzapur, Kaushambi, Fatehpur and Jaunpur.

18. *O. sancta* (Kutz.) Gomont (Pl. 1, Fig. 18; Pl. 3, Fig. 43; Pl. 4, Fig. 44)

Thallus thin, dark brownish, shining, gelatinous; trichome straight or slightly curved, ends briefly attenuated; cells 13-15 μm x 3-5 μm , distinctly constricted and granulated at the cross wall; apical cell hemispherical or flat, with thick calyptra.

Habitat and Occurrence: Most common and grows all round the year in open domestic sewage drains. It forms membranous layer on the bottom and side walls of drains. It also grows mixed as metaphytes with other genera of Oscillatoriales in other water bodies; Allahabad, Jaunpur, Pratapgarh, Chitrakoot, Fatehpur and Kaushambi.

19. *O. limosa* Ag. ex Gomont (Pl. 2, Fig. 19; Pl. 3, Fig. 38; Pl. 4, Fig. 47)

Thallus expanded, bright blue-green to brown; trichome \pm straight or rarely curved; cells 12-20 μm x 2-4 μm , cross wall frequently granulated; apical cell flat or obtuse rounded with thickened wall.

Habitat and Occurrence: Common in larger water bodies mixed with other Oscillatoriales and also as a dominant species; found also in low land rice field; Pratapgarh, Allahabad, Fatehpur, Raebareli, Kaushambi and Mirzapur.

20. *O. mitrae* Kamat (Pl. 2, Fig. 20)

Thallus olive green; trichome \pm straight, long, tapering towards the apices; cells 12-24 μm x 4-6 μm , constricted at the granulated cross wall; apical cell capitate, without calyptra.

Habitat and Occurrence: In a puddles and drains; Pratapgarh, Allahabad and Chitrakoot.

**O. mitrae* may appear similar to *O. proboscidea*, and the main distinction lies in the broader dimension of the trichome in the former.

21. *O. proboscidea* Gomont (Pl. 2, Fig. 21; Pl. 3, Fig. 36)

Thallus dull green, dark blue green; trichome straight or curved, solitary, screw like coiled at the end; cells 12-15 μm x 2-4 μm , faintly granulated at the cross wall; apical cell flatly rounded, capitate.

Habitat and Occurrence: It grows mixed with other species of *Oscillatoria*. Often characteristic tips are obscured and identified as other species of *Oscillatoria*; Allahabad, Kaushambi, Chitrakoot, Fatehpur, Raebareli and Varanasi.

22. *O. curviceps* Ag. ex Gomont (Pl. 2, Fig. 22)

Thallus bright blue green or blackish mats; trichome \pm straight, long, hooked or loosely spirally coiled at the end; cells 10-18 μm x 2-6 μm ; apical cell rounded with thickened wall.

Habitat and Occurrence: Planktonic and found in a rice field, ponds and lakes; Kaushambi. Allahabad, Chitrakoot and Pratapgarh.

23. *O. miniata* (Zanard.) Hayck. (Pl. 2, Fig. 23)

Trichome \pm straight, reddish, solitary or in small clusters; cells 16-23 μm x 3-6 μm ; constricted at the cross wall, finely granulated, very short; apical cell flat with thickened outer wall, without calyptra.

Habitat and Occurrence: It was found in stagnant waters; Allahabad, Chitrakoot and Kaushambi.

24. *O. margaritifera* (Kutz.) Gomont (Pl. 2, Fig. 24; Pl. 3, Fig. 39)

Thallus expanded, olive green, brownish to blackish; trichome straight or wavy, cells 15-22 μm x 3-5 μm , distinctly constricted at the granulated cross wall; apical cell capitate, with convex calyptra.

Habitat and Occurrence: It grows in water channels, ditches and ponds forming mucilaginous layers in shady places. It was also found growing on tree trunks during rains with other of Oscillatoriales; Allahabad, Kaushambi, Varanasi, Jaunpur, Mirzapur and Fatehpur.

25. *O. bonnemaisonii* Crouan (Pl. 2, Fig. 25)

Thallus thin, blue-green to blackish; trichome screw like loosely coiled; cells 21-30 μm x 3-6.5 μm , constricted at the ungranulated cross walls, discoid; apical cell convex without thickened membrane or calyptra.

Habitat and Occurrence: It was found on mud, walls and epiphytic on various aquatic plants and other algae; Allahabad, Pratapgarh, Fatehpur, Raebareli, Mirzapur and Kaushambi.

**O. jenensis* is quite comparable to *O. bonnemaisonii* on the basis of trichome width but both the species are separated in having different colour of the thallus, constriction of trichome and characteristic apical cells.

26. *O. maharashtrensis* Kamat (Pl. 2, Fig. 26)

Thallus olive green; trichome \pm straight, long, slightly tapering towards end; cells 19-23 μm x 3-5 μm ; apical cell rounded, not capitate.

Habitat and Occurrence: On moist soil; Kaushambi, Varanasi and Fatehpur.

27. *O. jenensis* Schmidle (Pl. 2, Fig. 27)

Thallus dark brown or dirty blue green mats; trichome end narrowed, long, slightly attenuated and bent with yellowish terminal cell; cells 19-25 μm x 3-6 μm , cross wall distinctly granulated; apical cell conical, without thickened wall.

Habitat and Occurrence: It was found on moist soils, usually found in areas with intense rains and in wetland marshes; Chitrakoot, Fatehpur, Allahabad and Varanasi.

28. *O. obtusa* Gardner (Pl. 2, Fig. 28)

Thallus bright blue- green; trichome \pm straight or arcuated; cells 23-25 μm ; apical cell flattened rounded, with slightly outer thickened wall.

Habitat and Occurrence: In a pool and puddles; Allahabad, Varanasi and Jaunpur.

29. *O. bharadwajae* Kamat (Pl. 2, Fig. 29)

Thallus blue-green; trichome long, slightly tapering at the end; cells 34-37 μm x 3-5 μm , cross wall sometimes granulated, much shorter than broad, apical cell rounded with narrow calyptra.

Habitat and Occurrence: It was found in temporary ponds and puddles; Kaushambi, Fatehpur, Raebareli and Pratapgarh.

**O. bharadwajae* is quite comparable with *O. princeps* in measurement but can be distinguished on the basis of colour and apical cells of trichomes.

30. *O. princeps* Vauch. ex Gomont (Pl. 2, Fig. 30; Pl. 3, Fig. 31,32,33; Pl. 4, Fig. 49)

Thallus expanded, attached, forming mats blue green, brownish or violet; trichome mostly straight, slightly attenuated at the apices, occasionally with thin sheaths; cells 20-50 μm x 3.5-7.5 μm ; apical cell flatly rounded, slightly capitate, truncate, fragmented part containing two horns like structure.

Habitat and Occurrence: It was found growing purely in slow flowing clear water often mixed with aquatic weeds; Mirzapur, Pratapgarh, Raebareli, Kaushambi and Chitrakoot.

Discussion:

On the basis of field observations it could be concluded that the species of *Oscillatoria* grow in all type of freshwater reservoirs, however limited growth was also seen in polluted water bodies. Many species of *Oscillatoria* are planktonic and found in lakes, ponds, puddles, ditches, water leakage areas and irrigation channels. *Oscillatoria sancta* was frequently found in domestic sewage drains where it forms membranous layer on the bottom and side walls of drains. Some species were found spreaded on moist soil. *Oscillatoria subbrevis*, *O. curviceps* were recorded in rice fields. The species of *Oscillatoria* grow luxuriantly in rainy seasons and found in almost all type of habitats. In winter, they are mostly observed in water channels, sewage water. In summer, they show limited growth and found only in perennial drains, water reservoirs or other shady and moist places. Some species of *Oscillatoria* viz., *O. sancta*, *O. nigro-viridis*, *O. subbrevis* are common and grow all around the year. Certain species of *Oscillatoria* viz. *O. lutea*, *O. simplicissima*, *O. perornata* and *O. proboscidea* grow mixed as metaphytes with other genera of Oscilltoriales. *Oscillatoria rupicola*, *O. ornata*, *O. annae* and *O. princeps* may form thin mat on the bottom of slow flowing water channels. *O. subproboscidea* is free floating. The colour of thallus ranges from mainly pale blue-green, olive- green to dark blue-green in different species of *Oscillatoria*, but in *O. miniata*, the thallus may appear dark reddish in colour. In *Oscillatoria sancta* and *O. margaritifera* the colour of thallus were mostly brownish-black. The width and tip of the trichome are the distinguishing features for segregating the different species of *Oscillatoria*. *Oscillatoria princeps* is the broadest species and ranges from 20 to 50 μm in diameter while *Oscillatoria chilkinsis* is the narrowest species in having trichomes 4-6 μm in diameter. *Oscillatoria miniata*, *O. maharashtrensis*, *O. jenensis*, *O. obtusa*, *O. bharadwajae* and *O. bonnemaisonii* are thicker and trichome ranges from 19 to 37 μm in diameter. The end cells of trichome in *Oscillatoria anguina*, *O. proboscidea* and *O. mitrae* are distinctly attenuated. Apical cell with thick calyptra are found in *Oscillatoria vizagapatensis*, *O. sancta*, *O. miniata* and *O. bharadwajae*. Constriction of trichome at the cross wall is another distinctive feature found in *Oscillatoria ornata*, *O. sancta*, *O. perornata*, *O. annae*, *O. lutea*, *O. mitrae*, *O. bonnemaisonii* and *O. margaritifera*.

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