

# DIVERSITY OF OSCILLATORIA FROM AQUATIC HABITATS OF BILLAWAR, DISTRICT KATHUA, JAMMU & KASHMIR, INDIA

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**Abstract:** The genus *Oscillatoria* Vaucher is one of the most dominant species belonging to non-heterocystous filamentous form of Cyanobacteria. It is distributed in various aquatic habitats of Billawar, district Kathua. The present paper represents 38 taxa of blue-green algae belonging to genus *Oscillatoria* Vaucher were collected during May 2016 to March 2017 in different seasons i.e., summer, rainy and winter.

**Keywords:** *Oscillatoria*, Cyanophyceae, Diversity, Aquatic, Billawar.

## I. INTRODUCTION

Cyanobacteria are diverse group of Gram negative, oxygenic photosynthetic prokaryotes that distributed in all possible aquatic habitats of the world. The genus *Oscillatoria* is a filamentous form which does not bear heterocyst. They may be epilithic, planktonic, epiphytic, endophytic, and terrestrial or epipellic and are capable to thrive in extreme environments such as rocky stones, hot springs, drought, desiccation, salinity and UV stresses.

*Oscillatoria* Vaucher is a commonly occurring Cyanophycean alga of family Oscillatoriaceae. A very few studies have been made from Kathua district for taxonomic point of view as well as its occurrence but no detailed taxonomic investigation has been made so far. The area of Kathua district is unexplored in regard to Cyanophyceae. So, our knowledge regarding the occurrence of Cyanobacteria in Billawar is still inadequate. The present investigation is a step to identify and document the diversity of *Oscillatoria* in different areas of Billawar belonging to Kathua district.

Desikachary (1959), Anand (1976a, 1979), Sarma *et al.* (1979), Kumar (1985), Susella and Goyal (1995), Ahmad *et al.* (1999), Habib (2001), Nayak *et al.* (2001), Kumar (2002, 2009, 2010), Digambar *et al.* (2008), Khare *et al.* (2009), Khare & Kumar (2009, 2010), Selvi & Shivkumar (2011), Bhushan and Kumar (2013), Sebastian & Joseph (2013), Sikdar and Keshri (2014), Barman *et al.* (2015), Kensa (2017) are the various Cyanotaxonomists who have worked a lot to identify the various species of Cyanobacteria.

## II. Materials and Methods

### Study Area

Billawar is a historical place situated in District Kathua of Jammu and Kashmir. It is a town situated in the lap of Shiwalik hills between the banks of Naaz and Bheeni rivulets. It lies at latitude of 32.62° N and longitude of 75.62° E with an average elevation of 844 m (2,769 ft.). The area falling in Billawar experiences wide ranges of altitudinal variation and due to this reason it is rich in floristic diversity. The summer temperature rises as high as 46°C in the plain areas and winter temperature in upper hilly areas touches sub-zero. Most of the higher areas experiences snowfalls for most part of the year. The hilly area receives more rainfall than the plains. Hilly areas have abundant fresh water spring which provides a possible environment for the growth of cyanobacteria (blue-green algae). The sites selected to collect samples were Bhaddu, Mandli, Phinter, Dadwara, Dingi Simbli, Sukrala, Parnala, Kishanpur, Nearuah and Billawar. The samples were collected from different habitats like ditches, streams, springs, rivers, rivulets, etc.

The samples were collected in different seasons of the year 2016 from various sites of Billawar. The samples were cleaned with distilled water and preserved in 4% formalin on returning to the laboratory. The identification of samples is based on monographic account of Desikachary (1959).

### Systematic Enumeration

In the present study altogether 38 species belonging to genus *Oscillatoria* have been identified during the present investigation from various aquatic ecologies of Billawar, district Kathua. All the species of *Oscillatoria* have been described below with their morphological microscopic characters along with their habitat.

#### 1. *Oscillatoria margaritifera* (Kütz.) Gomont

Desikachary, Cyanophyta, 202, pl. 42, fig. 8, 1959.

Trichome light-green, 17.3-20.2µ broad; straight, constricted at the cross-walls, apices slightly bent, slightly attenuated; cells 3.4-5.3µ long, end-cell capitate with slightly convex calyptra.

**Habitat and Locality:** Epilithic- on moist stones near the spring at Nearuah, Phinter.

#### 2. *Oscillatoria annae* van Goor

Desikachary, Cyanophyta, 203, pl. 38, fig. 13, 1959.

Trichomes straight, dull blue-green, slightly constricted at the cross walls, 7.6-8.2µ broad in the middle, 7.3-7.8µ at the end; mostly attenuated at the ends and bent; cell length 3.3-4.2µ, not granulated at the cross-walls; end-cell rounded, calyptra absent.

**Habitat and Localities:** Epilithic- on moist stones, Sukrala; Epiphytic- on grasses as well as soil in running water near Dhunari river, Naruah, Phinter

3. *Oscillatoria sancta* (Kütz.) Gomont

Desikachary, Cyanophyta, 203, pl. 42, fig.10, 1959.

Thallus blue-green; trichome straight, 14.3-16.8  $\mu$  broad, distinctly constricted at the cross-walls; ends briefly attenuated, , 3.0-4.8  $\mu$  broad, granulated at the cross-walls, end-cell flattened, hemispherical, with a thickened membrane.

**Habitat and Locality:** Epilithic- on the moist cemented walls of a water tank, Bhaddu.

4. *Oscillatoria vizagapatensis* Rao C. B.

Desikachary, Cyanophyta, 205, pl. 39, fig. 18, 1959.

Thallus blue-green, trichomes straight, uniformly broad except at the extreme apex, 3.1-4 $\mu$ ; without constrictions at the cross-walls; cells 0.9-1.2  $\mu$ ; cells much shorter than broad, contents granular, end cell broadly rounded forming a cap with a slightly thickened outer wall.

**Habitat and Localities:** Terrestrial- on moist soil, Parnala and Epilithic- on moist cemented walls of a water tank, Bhaddu.

5. *Oscillatoria perornata* Skuja

Desikachary, Cyanophyta, 205, pl. 41, fig. 14, 1959.

Trichomes erect and flexuous, 16.8-17.1 $\mu$  broad; apices briefly attenuated and bent or curved, well constricted at the cross-walls; cells 3.3-3.6 $\mu$  long, contents finely granular, septa less granulated, end cell depressed hemispherical, calyptra absent.

**Habitat and Locality:** Epilithic- on the moist stone walls of a spring at Gurunal, Billawar.

6. *Oscillatoria limosa* Ag. ex Gomont

Desikachary, Cyanophyta, 206, pl. 42, fig. 11, 1959.

Thallus dark blue-green to brown; trichomes more or less straight, 9.8-14.2  $\mu$  broad, not constricted at the cross-walls, cells 1.3-2.3 $\mu$  long, cross-walls frequently granulated; end-cell flatly rounded with slightly thickened membrane.

**Habitat and Locality:** Epilithic-On moist walls of a tank near cricket ground, Bhaddu.

7. *Oscillatoria subbrevis* Schmidle

Desikachary, Cyanophyta, 207, pl. 40, fig. 1, 1959.

Trichomes single, nearly straight, not attenuated at the apices, not constricted at the cross-walls; cells not granulated at the cross-walls, cell length 1.5-3.1 $\mu$ , breadth 6.5-7.1  $\mu$ ; end-cell rounded, calyptra absent.

**Habitat and Localities:** Terrestrial and Epilithic- on moist soil and on moist stones near Nearuah, Phinter.

8. *Oscillatoria curviceps* Ag. ex Gomont

Desikachary, Cyanophyta, 209, pl. 3, fig. 2, 1959.

Thallus light blue-green; trichome breadth 11.1- 16.8 $\mu$ , more or less straight, bent at the end or spirally coiled, not attenuated or very little attenuated, not constricted at the cross-walls; cell length 2.7- 5.1 $\mu$ , cross-walls sometimes granulated; end-cells flat rounded, not capitate.

**Habitat and Localities:** Epilithic- on moist wall of natural spring, Nearuah; Terrestrial- on moist soil in rice field, Nearuah, Phinter; Epiphytic- on the bark of a broken branch submerged in water in a pond near Forest Department Park, Phinter.

9. *Oscillatoria princeps* Vaucher ex Gomont

Desikachary, Cyanophyta, 210, pl. 37, fig. 1, 1959.

Trichomes blue-green, mostly straight, not constricted at the cross-walls, slightly or briefly attenuated at the apices and bent, trichome breadth 27.3-35.7  $\mu$ ; cell length 2.7-6.3  $\mu$ , cross-walls not granulated; end-cells flatly rounded, slightly capitate without thickened membrane.

**Habitat and Localities:** Terrestrial-on the soil of paddy field, Nearuah, Phinter and on moist rocks, Parnala.

10. *Oscillatoria proboscidea* Gomont

Desikachary, Cyanophyta, 211, pl. 38, fig. 9, 1959.

Thallus dark blue-green; trichomes more or less straight, not constricted at the cross-walls, at the ends distinctly attenuated, slightly curved, brightly blue-green; cells 12.4-15.1  $\mu$  broad; cells 2.0-4.1  $\mu$  long, not granulated at the cross-walls; end-cells flatly rounded, capitate, with slightly thickened membrane.

**Habitat and Localities:** Terrestrial- on moist soil in paddy fields, Kishanpur; Epilithic-on the moist stones under seeping water at Nearuah, Phinter

11. *Oscillatoria anguina* (Bory) Gomont

Desikachary, Cyanophyta, 210, pl. 38, fig. 11, 1959.

Thallus gelatinous, trichomes straight, breadth 5.3-6.4 $\mu$ , at the ends spirally coiled and distinctly attenuated, not constricted at the cross walls, cell length 1.4-2.1  $\mu$ , , end cells capitate with a slightly thickened membrane.

**Habitat and Locality:** Terrestrial- on moist soil near Gurunal, Billawar

12. *Oscillatoria laete-virens* (Crouan) Gomont

Desikachary, Cyanophyta, 213, 1959.

Thallus gelatinous, trichome straight, breadth 3.1-4  $\mu$ , slightly constricted at the cross-walls, apices attenuated, 2.7-3.3  $\mu$  long; end-cells not capitate, more or less obtuse or conical, without calyptra.

**Habitat and Localities:** Epilithic- on the moist stones at Sukrala; Terrestrial: on moist soil near natural spring (Bowli), Bhaddu.

13. *Oscillatoria subtilissima* Kütz.

Desikachary, Cyanophyta, 215, 1959.

Trichome single, cells 1.1-1.6  $\mu$  broad and 1.5-2.2  $\mu$  long, straight or curved, septa indistinct, without gas-vacuoles.

**Habitat and Locality:** Epilithic- on the stone walls of a polluted drain with soil layer, Sukrala road, Billawar

14. *Oscillatoria chilkensis* Biswas

Desikachary, Cyanophyta, 215, pl. 39, fig. 1, 1959.

Thallus gelatinous, trichome somewhat curved, 3.1-5.2  $\mu$  broad, slightly constricted at joints, apex of the trichome very shortly tapering, cell length 2.3-3.1  $\mu$ , apical cell obtusely rounded, not pointed or capitate, transverse wall not granulated, cell contents homogeneous.

**Habitat and Localities:** Terrestrial- on moist soil in a paddy field, Dadwara; Epilithic- on the sandy soil in a drain, Sukrala road, Billawar; Epiphytic- on the bark of a broken branch submerged in a pond near Forest Department Park, Phinter

15. *Oscillatoria chlorina* Kütz. ex Gomont

Desikachary, Cyanophyta, 215, pl. 40, fig. 4, 1959.

Thallus very thin, yellowish green; trichome straight, 3.1-6.2  $\mu$  broad, unconstricted or slightly constricted at the cross-walls, cells 1.6-8.1  $\mu$  long, calyptra absent.

**Habitat and Locality:** Epilithic- on the moist cemented wall of a water tank, Sukrala.

16. *Oscillatoria grunowiana* Gomont

Desikachary, Cyanophyta, 216, 1959.

Thallus gelatinous, thallus mostly very lightly spirally coiled, trichome breadth 3.4-5.7  $\mu$ , apices not attenuated, or slightly capitate, cells 1.4-3.2  $\mu$  long, often granulated at the cross walls, end cells rounded without a calyptra.

**Habitat and Localities:** Epilithic- on moist stones, Dhunari river, Nearuah, Phinter, on the moist cemented wall of drain, Bus Stand, Billawar and on moist stones near the spring (Bowli), Bhaddu.

17. *Oscillatoria willei* Gardner em Drouet

Desikachary, Cyanophyta, 217, pl. 38, figs. 4, 5 & pl. 40, fig. 5, 1959.

Trichomes 3.3-4.1  $\mu$  broad, bent at the ends or screw-like, unconstricted at the cross-walls, ends not attenuated, not capitate; cells 2.6-4.2  $\mu$  long, nearly as long as broad, not granulated at the cross-walls, end cell rounded without a thickened membrane.

**Habitat and Locality:** Epilithic-on moist stones with seeping water, near Ujh river, Phinter.

18. *Oscillatoria terebriformis* Ag. ex Gomont

Desikachary, Cyanophyta, 217, pl. 38, fig. 16, 1959.

Thallus dull blue; trichomes 3.3-7.1  $\mu$  broad, end bent in a screw-like manner, and slightly attenuated, unconstricted at the cross-walls; cell length 1.8-5.7  $\mu$  long, end cell rounded, not capitate, calyptra absent.

**Habitat and Localities:** Epilithic-on cemented tank, cricket ground, Bhaddu; Terrestrial- on moist soil in a paddy field, Dadwara.

19. *Oscillatoria boryana* Bory ex Gomont

Desikachary, Cyanophyta, 218, pl. 38, fig. 12, 1959.

Trichomes 7.9-10.3  $\mu$  broad, coiled screw-like either fully or only at the apices, sometimes straight, constricted at the cross-walls, apex slightly attenuated; end cells rounded, not capitate; calyptra absent.

**Habitat and Localities:** Epilithic- on moist cemented wall of water tank, Mandli and Planktonic- free-floating on stagnant water in paddy fields, Dadwara.

20. *Oscillatoria foreaui* Ffemy

Desikachary, Cyanophyta, 219, pl. 40, fig. 18, 1959.

Trichomes 2.6-3.1  $\mu$  broad, bent or suberect, apex gently curved, distinctly constricted at the cross-walls, apex not attenuated not capitate; cells 1.3-1.8  $\mu$  long, protoplasm granular, apical cell obtuse conical, calyptra absent.

**Habitat and Localities:** Epiphytic- on moist bark of Mango tree, Bhaddu and on moist bark of *Toona haxandra*, Sukrala.

21. *Oscillatoria proteus* Skuja

Desikachary, Cyanophyta, 221, pl. 41, fig. 15, 16, 1959.

Trichomes more or less straight, sometimes curved, apices briefly attenuated and slightly bent or curved, 6.3- 7.7 $\mu$  broad, well constricted at the cross-walls, slightly granulated; cells 2- 5.1 $\mu$  long, apical cell hemispherical.

**Habitat and Localities:** Epilithic- on moist rocks with seeping water, near Dhunari river, Nearuah, Phinter.

22. *Oscillatoria jasorvensis* Vouk.

Desikachary, Cyanophyta, 221, 1959.

Thallus pale blue-green; trichomes 3.4-4.1 $\mu$  broad, straight, bent at the ends, not attenuated, not capitate; cells 1.8-2.2 $\mu$  long; end cells rounded, without calyptra.

**Habitat and Localities:** Terrestrial- on moist soil in a paddy field, Dadwara and Nearuah.

23. *Oscillatoria tenuis* Ag. ex Gomont

Desikachary, Cyanophyta, 222, pl. 42, fig. 15, 1959.

Thallus thin; trichome 6.3-12.4 $\mu$  broad, straight, slightly constricted at the cross-walls, sometimes bent at the ends, not attenuated at the apices, not capitate; cells 2.5-6.3 $\mu$  long, end cell more or less hemispherical with thickened outer membrane.

**Habitat and Locality:** Epilithic- on the moist stones near the natural spring, Bhaddu.

24. *Oscillatoria raoi* De Toni, J.

Desikachary, Cyanophyta, 223, pl. 42, fig. 18, 1959.

Trichomes 5.4-6.3 $\mu$  broad, straight, without constrictions at the joints, septa indistinct, but with distinct granules closely arranged on either side; cells 4.2-5.1 $\mu$  long, with homogeneous contents; end cells rounded, not capitate, without any calyptra.

**Habitat and Locality:** Epilithic- on moist walls of a water tank, near Billawar Tehsil.

25. *Oscillatoria simplicissima* Gomont

Desikachary, Cyanophyta, 224, 1959.

Thallus dark blue-green; trichome 6.9-8.2 $\mu$  broad, straight, not constricted at the cross-walls, not attenuated at the apices, not capitate; cells 2.1-4.1 $\mu$  long, septa not granulated; end cells hemispherical, with a slightly thickened membrane.

**Habitat and Locality:** Epilithic-on the moist cemented floor with seeping water at Shiv temple, Billawar

26. *Oscillatoria amphigranulata* van Goor

Desikachary, Cyanophyta, 226, Pl. 37, figs. 4, 1959.

Trichomes straight or bent, constricted at the cross-walls, 2.2-3.2  $\mu$  broad, slightly attenuated, cells 4.0-6.1  $\mu$  long septa with one or two gas vacuoles on either side, end cell broadly conical.

**Habitats and Localities:** Terrestrial: in the paddy fields , Nearuah, Phinter and Dadwara.

27. *Oscillatoria pseudogeminata* G. Schmid

Desikachary, Cyanophyta, 228, pl. 41, fig. 10, 1959.

Thallus pale or dirty blue-green; trichomes 1.9-3.2 $\mu$  broad, coiled, ends not attenuated; cells 2.6-3.2  $\mu$  long or as long as broad or somewhat longer or shorter than broad, not constricted at the cross-walls, cross-walls thick, end cell rounded, calyptra absent.

**Habitat and Localities:** Epilithic- on moist rocks and on cemented wall of a tank, Sukrala; Epipellic- on moist sand in a drain, Billawar.

28. *Oscillatoria amoena* (Kütz.) Gomont

Desikachary, Cyanophyta, 230, pl. 40, fig. 12, 1959.

Thallus more or less blue-green; trichomes 2.7-4.1 $\mu$  broad, straight, slightly constricted at the cross-walls, ends gradually attenuated, cells 2.1-4.1 $\mu$  long, septa granulated; end cells capitate, broadly conical with calyptra.

**Habitat and Localities:** Epilithic- on moist rocks, Sukrala; Epiphytic- on the bark of *Cedrella toona*, Bhaddu

29. *Oscillatoria formosa* Bory ex Gomont

Desikachary, Cyanophyta, 232, pl. 40, fig. 15, 1959.

Thallus blue-green; trichome 2.7-4.1 $\mu$  broad, straight, slightly constricted at the cross-walls, attenuated at the ends and bent; cells 2.3-5.2 $\mu$ , nearly quadrate, septa not granulated; end-cells nearly obtuse, calyptra absent, not capitate.

**Habitat and Localities:** Epilithic-on the cemented wall of a pond, Bhaddu, on moist stones, Sukrala, on moist cemented wall of a drain, Bus Stand, Billawar; Planktonic- free-floating on water in a ditch, Parnala.

30. *Oscillatoria prolifica* (Grev.) Gomont

Desikachary, Cyanophyta, 234, 1959.

Thallus blue-green, trichomes 3.0-3.8  $\mu$  broad, not constricted at the cross walls, generally attenuated, cells 0.9-1.2 $\mu$  long, septa often granulated, gas vacuoles present, end cells capitate with calyptras.

**Habitat and Localities:** Epilithic- on the moist stones in Naaj river, Billawar; Planktonic- free-floating on water in a ditch, Parnala.

**31. *Oscillatoria agardhii* Gomont**

Desikachary, Cyanophyta, 235, 1959.

Thallus light green; trichomes straight not constricted at the cross-walls, 3.2-5.2  $\mu$  broad, at the ends gradually tapering, cells 1.5-2.3  $\mu$  long, granulated at the septa, with gas vacuoles; end-cells convex, convex calyptras, seldom capitate.**Habitat and Localities:** Epilithic- on moist stones, Nearuah, Phinter; Terrestrial- on soil in paddy field, Dadwara and Nearuah.**32. *Oscillatoria deflexa* W. et G. S. West**

Desikachary, Cyanophyta, 236, 1959.

Thallus non-gelatinous, trichomes 0.3-1.2 $\mu$  broad, single, at the apices gradually attenuated and slightly curved, not constricted at the cross walls, contents blue green, cells 2.2-2.9 $\mu$  long, end cell tapering, without calyptra.**Habitat and Localities:** Epilithic- on moist stones at Shiv Temple, Billawar; Epiphytic- on the moist bark of *Toona ciliata*, Bhaddu.**33. *Oscillatoria earlei* Gardner**

Desikachary, Cyanophyta, 238, pl. 38, fig. 15, 1959.

Thallus dark green, trichome short, 0.9-1.3 $\mu$  broad, straight curved or bent at the ends, ends attenuated, not constricted at the cross walls, 1.5-2.0 $\mu$  long, end cells prominently pointed.**Habitat and Localities:** Epilithic- on moist walls of cemented wall of water tank, Parnala and on moist stones, Nearuah, Phinter.**34. *Oscillatoria salina* Biswas**

Desikachary, Cyanophyta, 239, 1959.

Trichome 3.1-3.4 $\mu$  broad, straight, elongate, scarcely curved, not at all constricted at the joints, apices of trichomes straight, not capitate, apical cells mucronate, hyaline, calyptra absent, cells 1.5-1.8 $\mu$  long, cell contents finely uniform granular, almost homogeneous.**Habitat and Localities:** Terrestrial- on moist soil in paddy field, Parnala, Nearuah and Dadwara.**35. *Oscillatoria animalis* Ag. ex Gomont**

Desikachary, Cyanophyta, 239, pl. 40, fig. 14, 1959.

Thallus dark green, trichome 3.1-5.2 $\mu$  broad, straight, not constricted at the cross walls, briefly attenuated at the ends and slightly bent, cells 1.6-3.6 $\mu$  long, not granulated at the cross walls, end cell pointed, acute, no calyptra, not capitate.**Habitat and Localities:** Epilithic- on moist walls of cemented water tank, Parnala, Mandli and Sukrala; Terrestrial- on moist soil in the paddy fields, Dadwara.**36. *Oscillatoria acuminata* Gomont**

Desikachary, Cyanophyta, 240, pl. 38, fig. 7, 1959.

Thallus non-gelatinous, blue-green to brown, trichomes 5.4-6.1 $\mu$  broad, slightly constricted at cross walls, at the ends sharply pointed, bent, cells 6.2-6.9 $\mu$  long, sometimes granulated at the cross walls, end cell mucronate, without calyptra.**Habitat and Locality:** Epilithic-on moist walls of a tank and drain, Bus stand, Billawar**37. *Oscillatoria cruenta* Grun.**

Desikachary, Cyanophyta, 241, 1959.

Thallus light green, trichomes 4.4-6.2 $\mu$  broad, cells 2.4-3.1 $\mu$  long, transverse wall granulated, apex obtuse, straight.**Habitat and Locality:** Epilithic- on moist cemented walls of a drain near Bus Stand, Billawar.**38. *Oscillatoria brevis* (Kütz.) Gomont**

Desikachary, Cyanophyta, 241, 1959.

Thallus blue-green, trichomes 3.2-6.2 $\mu$  broad, straight, not constricted at the cross walls, ends briefly attenuated, more or less bent, non-capitate, cells 1.5-3.1 $\mu$  long, end cell rounded, conical, calyptra absent.**Habitat and Localities:** Epilithic- on moist cemented walls of a tank, Parnala and on moist cemented walls of a drain, Mandli and Billawar; terrestrial- on moist soil at village Bhaddu.**III. RESULTS AND DISCUSSION**

The investigation conducted on the cyanobacterial samples collected from different sites of Billawar represent 38 species belonging genus *Oscillatoria*. The occurrence of epilithic species is followed by terrestrial, epiphytic, epipellic and planktonic habitats. The dominance sequence of the distribution of *Oscillatoria* species at Billawar on the basis of habitat diversity is as follows:

Epilithic &gt; Terrestrial &gt; Epiphytic &gt; Epipellic &gt; Planktonic habitats

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