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Blue-Green Algal Diversity from Central Bihar, India

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ABSTRACT

Present study deals with morphotaxonomic study of 21 taxa belonging to the class Cyanophyceae (Blue-green algae). These taxa were collected from fourteen freshwater habitats of four districts viz. Patna, Nalanda, Vaishali and Samastipur from central Bihar. These recorded taxa belonging to 11 genera, 21 species of 10 families; viz. *Microcystis* (4 sp.), *Merismopedia* (2sp.), *Sphaerocystis* (1 sp.), *Synechococcus* (1 sp.), *Coelosphaerium* (1 sp.), *Oscillatoria* (4 sp.), *Phormidium* (3 sp.), *Leptolyngbya* (1 sp.), *Planktothrix* (1 sp.), *Gloeotrichia* (1 sp.), *Spirulina* (2 sp.).

INTRODUCTION

Algae, a primary producer, commonly occur in all possible habitats where moisture and light are available. Blue-green algae or Cyanobacterial algae are one of the most primitive groups of organisms, first photosynthetic prokaryotes. They are the connecting link between bacteria, eukaryotic algae, and higher plants. They resemble bacteria (Feldgarden and Cohn 2003) with a photosynthetic system like that of eukaryotic algae and green plants (Castenholz and Waterbury 1989). They are considered as an important group of microorganisms capable of fixing atmospheric nitrogen. Gomont (1892) has published the first monographs 'des-Oscillariees'. Crow (1923) has described morpho-taxonomical variation of the genus *Microcystis* Kuetz. from Ceylon. Bittencourt-Oliveira (2000) described developmental stage of *Microcystis aeruginosa* Kuetz. Pentacost (2003) reported taxonomic identity, ecology and distribution of the calcite deposition of Cyanobacterium *Phormidium incrustatum* (Naeg.) Gomont. Recently, Komarek et al. (2014) gave revised taxonomic classification of Cyanoprokaryotes using a polyphasic approach.

In India, various workers have studied the freshwater Cynophycean algal flora viz; Ghose (1933); Biswas (1934); Iyenger (1957); Prasad and Mehrotra (1977) and Desikacharya (1959). The major work on the blue-green algae has been done by Ghose (1927); Rao (1937, 1938, 1940); Prasad and Srivastava (1992); Mishra et al. (2005). Cynophycean algal flora from different region of India has been worked out by many algologists viz; Patil and Nandan (2011), Sethi et al. (2012), Hazarika (2013), Sikdar and Keshri (2014), Singh et al. (2014), Das and Maurya (2015), Halder and Sinha (2015), Kesarwani et al. (2015), Tandon et al. (2016), Rani et al. (2016), Gupta (2017, 2019), Roy et al. (2017), Pradhan et al (2018), Reddy and Chaturvedi (2018), Ghadage and Karande (2019) Mohan and Kumar (2019), and Pandkar et al. (2020).

MATERIALS AND METHODS

The samples have been collected by random sampling technique from the different habitats and localities of Patna, Nalanda, Vaishali and Samastipur from central Bihar during October to November 2017. The localities have been marked on the map (Figure 1). All samples have been fixed in 3-4% formalin instantly in the field, and collection number, name, date, and longitude- latitude of sites have also been marked on site. Temporary slides have been prepared in glycerin mount and stained with 1% aqueous methylene blue. Photo-micrographs are taken by Leica DM 500 with 63X and Nicon-500 with 60X camera (Phycology Laboratory, CSIR-NBRI, Lucknow). The measuring scale given for algal photographs is equal to 10 µm. Morphological characterization and identifications of species have been done with the help of monographs by Prescott (1951), Desikachary (1959), Philipose (1967), Prasad, and Srivastava (1992), Komárek et al. (1998, 2005). The taxa are arranged according to the classification of Komárek et al. (2014)

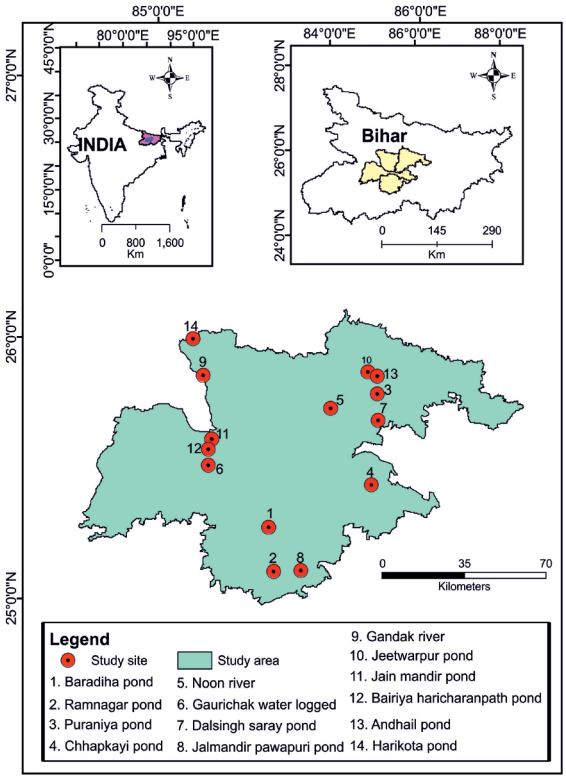

Figure 1: Showing map of Bihar and collection sites.

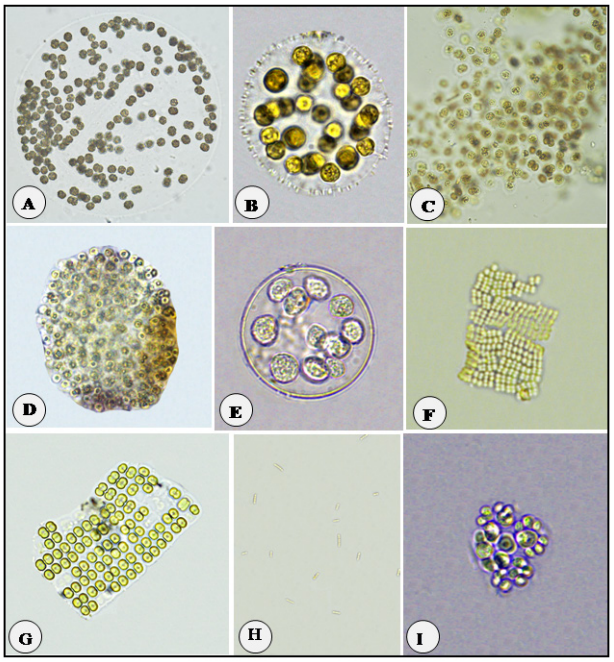

Figure 2 (A-I): A. *Microcystis smithii*, B. *Microcystis botrys*, C. *Microcystis aeruginosa*, D. *Microcystis flosaquae*, E. *Sphaerocystis schroeteri*, F. *Merismopedia glauca*, G. *Merismopedia elegans*, H. *Synechococcus elongatus*, I. *Coelosphaerium dubium*.

OBSERVATIONS / RESULTS

Class: Cyanophyceae

Order: Chroococcales

Family: Microcystaceae Elenkin

1. *Microcystis aeruginosa* (Kuetzing) Kuetzing (Figure 2C)

Desikachary, 1959, p. 93, pl.17, Figure 1, 2, 6; pl.18, Figure 10.

Colonies mucilaginous, spherical to elongate or clathrate in various shapes; mucilage colourless, diffluent not well defined; cells numerous densely packed, spherical or hemispherical after division, 3.5-4.5 µm in diameter with conspicuous aerotopes.

Collection number: Nalanda-13

Date of collection: 03.11.2017

Longitude- latitude: 85.4151° E-25.2613° N

2. *Microcystis botrys* Teiling (Figure 2B)

Komárek & Anagnostidis, 1998, p. 228, Figure 298.

Colonies mucilaginous, essentially spherical, with irregularly and densely aggregated cells; mucilage thick, wide, colourless, 63 µm in diameter, semiglobose or tubular gelatinous projections, radially arranged. Cells spherical, with aerotopes, 6-10.8 µm in diameter.

Collection number: Nalanda-9

Date of collection: 03.11.2017

Longitude- latitude: 85.4336° E-25.0915° N

3. *Microcystis flosaquae* (Wittrock) Kirchner (Figure 2D)

Desikachary 1959, p.94, pl. 17, Figure 11.

Colonies light blue green, spherical and clathrate with colourless mucilaginous sheath. Cells 2.35 µm in diameter.

Collection number: Samastipur-9

Date of collection: 22.10.2017

Longitude- latitude: 85.8300° E-25.7706° N

4. *Microcystis smithii* Komárek et Anagnostidis (Figure 2A)

Komárek & Anagnostidis, 1998, pg. 228, Figure 299.

Colonies free-floating, spherical or slightly irregular, mucilage fine, colourless, more or less distinctly delimited or diffuse; cells loosely arranged throughout the colony, single or in pairs after division, spherical with several brownish aerotopes in each cell, 4.72-5.9 µm in diameter.

Collection number: Nalanda-13

Date of collection: 03.11.2017

Longitude- latitude: 85.4151° E-25.2613° N

5. *Sphaerocystis schroeteri* Chodat (Figure 2E)

Prescott 1951, p. 83, pl. 3, Figure 6, 7.

Colony spherical, 31.54 µm diameter, 4-8 celled, arranged periphery in hyaline envelop; cells spherical, 3.8-6.84 µm in diameter.

Collection number: Patna-3

Date of collection: 02.11.2017

Longitude- latitude: 85.1841° E-25.49700° N

Order: Synechococcales

Family: Merismopediaceae Elenkin

6. *Merismopedia elegans* A.Braun ex Kuetzing (Figure 2G)

Desikachary 1959, 156, 29: 9.

Colonies small, free floating with 8-16 cells, cells oblong, closely arranged, cell wall thick and smooth. Cells 1.58-2.17 µm in diameter.

Collection number: Samastipur-15

Date of collection: 22.10.2017

Longitude- latitude: 85.6521° E-25.7142° N

7. *Merismopedia glauca* (Ehrenberg) Kuetzing (Figure 2F)

Desikachary 1959, p. 155, pl. 29, Figure 5.

Colonies light blue green; cells arranged in rectangular colony with slightly sinuate margin; hemispherical cells, 3.52-5.29 µm in diameter.

Collection number: Samastipur-13

Date of collection: 22.10.2017

Longitude- latitude: 85.8075° E-25.4210° N

Family: Synechococcaceae Anagnostidis et Komárek

8. *Synechococcus elongatus* (Nägeli) Nägeli (Figure 2H)

Desikachary, T.V., 1959, pg. 126, pl. 25, figs. 7&8.

Cells cylindrical, 1.76 µm broad, 3.52 µm, single or 2-4 cells together; cell content homogenous and light blue-green.

Collection number: Nalanda-13

Date of collection: 03.11.2017

Longitude- latitude: 85.4151° E-25.2613° N

Family: Coelosphaeriaceae Elenkin

9. *Coelosphaerium dubium* Grunow (Figure 2I)

Huber-Pestalozzi 1938, pg. 155, Figure 47.

Colonies spherical, irregularly shaped often 3-4 colonies together in a common, up to 100 µm broad; gelatinous sheath, jelly coat tight, not stratified, spherical; densely stored cells with gas vacuoles, 1.14-3.04 µm in diameter.

Collection number: Patna-3

Date of collection: 02.11.2017

Longitude- latitude: 85.1841° E-25.49700° N

Order: Oscillatoriales

Family: Oscillatoriaceae Kirchner.

10. *Oscillatoria agardhii* Gomont (Figure 3M)

Prescott (1951), p.484, pl. 109, figs. 2&4.

Trichome straight, not constricted at the cross walls, end cell gradually attenuated. Cells quadrate 3.66 µm

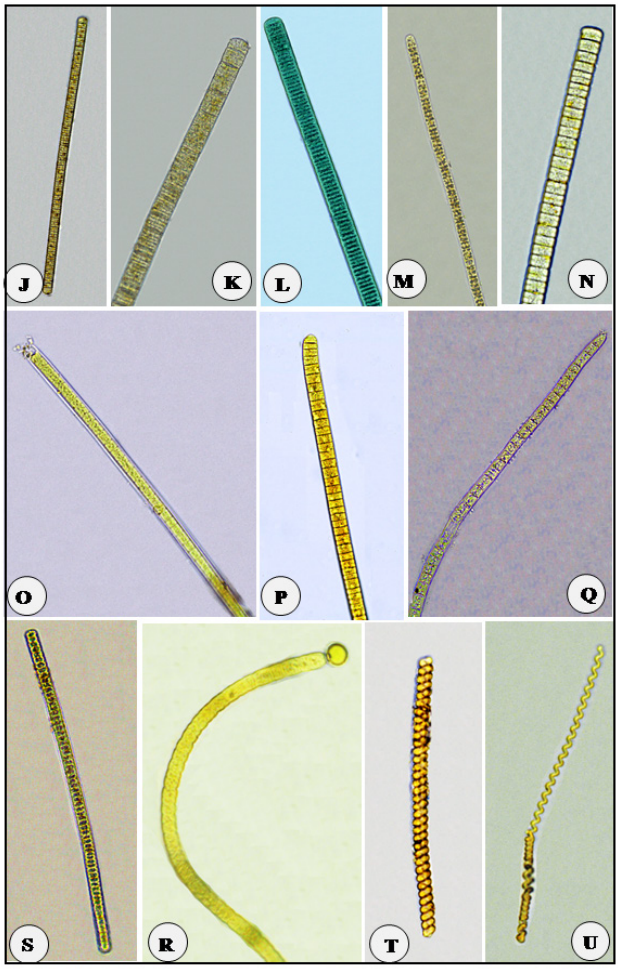

Figure 3 (J-U): J. *Oscillatoria tenuis*, K. *Oscillatoria limosa*, L. *Oscillatoria subbrevis*. M. *Oscillatoria agardhii*, N. *Phormidium nigrum*, O. *Phormidium aerugineo-caeruleum*, P. *Phormidium simplicissimum*, Q. *Leptolyngbya weissii*, R. *Planktothrix cryptovaginata*, S. *Gloeotrichia echinulata*, T. *Spirulina labyrinthiformis*, U. *Spirulina major.*

wide and 1.83-2.44 µm long granulated at septa, end cell convex without calyptra.

Collection number: Nalanda-12

Date of collection: 04.11.2017

Longitude- latitude: 85.5392° E-25.0934° N

11. *Oscillatoria limosa* C.Agardh ex Gomont (Figure 3K)

Komárek 2005, pg. 595, Figure 886.

Trichome, straight, cells 15.3 µm wide, 1.8-3.6 µm long. Apical cell flat-rounded, not capitate, convex, without calyptra.

Collection number: Nalanda-9

Date of collection: 03.11.2017

Longitude- latitude: 85.4336° E-25.0915° N

12. *Oscillatoria subbrevis* Schmidle (Figure 3L)

Kesarwani, Tandon, and Tiwari 2015, Pl. 3, Figure 41.

Trichome single, straight, slightly tapering at the end. Cell 13.35 µm wide and 1.78-2.67 µm long; apical cell rounded, not capitate, without calyptra.

Collection number: Samastipur-12

Date of collection: 22.10.2017

Longitude- latitude: 85.8358° E-25.6696° N

13. *Oscillatoria tenuis* C. Agardh ex Gomont (Figure 3J)

Komárek 2005, pg. 588, Figure 878e.

Trichome straight, not tapering, without granulation at cross-walls, not attenuated, well-developed. Cells always shorter than wide, 5.88 µm wide and 2.94 µm long. Apical cell rounded, not capitate.

Collection number: Nalanda-9

Date of collection: 03.11.2017

Longitude- latitude: 85.4336° E-25.0915° N

Family: Phormidiaceae Anagnostidis & Komárek

14. *Phormidium aerugineo-caeruleum* (Gomont) Anagnostidis et Komárek. (Figure 3O)

Komárek (2005), pg. 445, Figure 649.

Thallus mucilaginous, greenish. Trichome, straight. Cells 8.82 µm wide and 3.15 µm long sheath facultive, thin, firm or up to 1 µm thick, or lamellated, colourless. Apical cells obtusely-conical or rounded, with slightly thickened outer cell wall.

Collection number: Vaishali-13

Date of collection: 11.11.2017

Longitude- latitude: 85.85.1640° E-25.842° N

15. *Phormidium nigrum* (Vaucher ex Gomont) Anagnostidis et Komárek (Figure 3N)

Komárek (2005), pg. 448, Figure 658.

Trichome blue-green, straight, sheath occur rarely, thin, colourless. Cells 10.58 µm wide and 2.28-5.88 µm long. Apical cells rounded-truncate or widened-conical, some time with thickened outer cell wall.

Collection number: Nalanda-12

Date of collection: 04.11.2017

Longitude- latitude: 85.5392° E-25.0934° N

16. *Phormidium simplicissimum* (Gomont) Anagnostidis et Komárek. (Figure 3P)

Komárek (2005), pg. 448, Figure 658.

Thallus olive- green color, blue-green, sheath lacking. Trichome straight, sometimes slightly curved, 10.68 µm wide and 3.56 µm long. Apical cell hemispherical, without or with a very slightly thickened cell wall.

The collection number: Samastipur-3

Date of collection: 21.10.2017

Longitude- latitude: 85.7945° E-25.8541° N

Family: Leptolyngbyaceae

17. *Leptolyngbya weissii* (Drouet) Anagnostidis (Figure 3Q)

Komárek (2005), pg. 237, Figure 303.

Thallus blue-green or blackish, mucilaginous, sheath thin later forming gelatinous mass. Filament straight or undulate arranged parallel. Trihomes 2.2- 4 wide µm 4.4-6 long µm, constricted at the granulated and conspicuous cross wall, gradually attenuated at the end. Apical cell acute conical, not capitate, without calyptra.

Collection number: Patna-1

Date of collection: 02.11.2017

Longitude- latitude: 85.1967° E-25.5974° N

Family: Microcoleaceae Komárek et al

18. *Planktothrix cryptovaginata* (Schkorbatov) Anagnostidis et. Komárek (Figure 3R)

Komárek (2005), pg. 355, Figure 493.

Trichomes solitary or in loose clusters, straight or irregularly wavy coiled, not attenuated at the ends. Cells 3.8 µm wide and 1.52 µm long cell contents aerotops. Apical cells widely-rounded.

Collection number: Patna-4

Date of collection: 02.11.2017

Longitude- latitude: 85.1832° E-25.5574° N

Order: Nostocales

Family: Gloeotrichiaceae

19. *Gloeotrichia echinulata* P.G.Richter (Figure 3S)

Desikachary 1959, pg. 556, pl. 116, Figure 9 & 10.

Thallus spherical, laments loose, radial; sheath not lamellated, colourless. Tichome 6.1 µm broad at base, with a long hair; cells cylindrical with gas vacuoles.

Collection number: Samastipur-6

Date of collection: 22.10.2017

Longitude- latitude: 85.8308° E-25.8384° N

Order: Spirulinales

Family: Spirulinaceae (Gomont) Hoffmann, Komarek & Kastovsky

20. *Spirulina labyrinthiformis* Gomont. (Figure 3T)

Komárek (2005), pg. 145, Figure 171.

Trichome very regularly, densely spirally coiled, with right-handed screw-like rotation, about 92.9 µm long. Cells 2.35 µm wide. Coils mostly short and straight, tightly joined one with another. Apices rounded.

Collection number: Vaishali-6

Date of collection: 21.10.2017

Longitude- latitude: 85.1183° E-25.9921° N

21. *Spirulina major* Kuetzing ex Gomont (Figure 3U)

Komárek (2005), pg. 153, Figure 184.

Thallus thin to thick, compact, blue-green. Trichome 1.2-3.1 µm wide, flexible, regular or nearly irregular loosely screw-like coiled, distance between coils 3.78 µm. Apical cell rounded.

Collection number: Vaishali-10

Date of collection: 21.10.2017

Longitude- latitude: 85.1247° E-25.9827° N

DISCUSSION AND CONCLUSIONS:

In India the Cyanophyceae is represented by 1232 taxa belonging to 90 genera (Gupta, 2012). They are distributed widely in all available possible type of habitats. Though, the Cyanophycean algae of the Bihar state have been studied by several algologists. However, few reports are available on the cyanophycean algae from above four districts of Bihar. Hence, the present study on cyanophyceaen taxa is important and fill the gaps of taxonomically unexplored area of Bihar. A total number of 21 species belonging to 11 genera have been reported for first time from various sites of the Patna, Nalanda, Samastipur and Vaishali. *Coelosphaerium dubium* Grunow (from Patna) *Leptolyngbya weissii* (Drouet) Anagnostidis (from Patna) *Planktothrix cryptovaginata* (Schkorbatov) Anagnostidis et. Komárek (from Patna) *Gloeotrichia echinulata* (Smith) Richter (from Samastipur) and *Spirulina major* Kuetzing ex Gomont (from Vaishali) are new record for the Bihar state. From this study it is observed that the districts are rich in algal biodiversity and need further extensive taxonomic studies in different ecological habitats.

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