

Research Article

A SYSTEMATIC ACCOUNT OF ORDER CHROOCOCCALES FROM RIVER GANGA AT KANPUR, UP, INDIA

***Vinod Rishi¹, Ravindra Singh¹ and A. K. Awasthi²**

¹Department of Botany, M.G.C.G. University, Chitrakoot, Satna, M.P

²Department of Botany, Brahmanand P.G. College, Kanpur, U.P.

*Author for Correspondence

ABSTRACT

The cyanobacteria are an immense group of gram-negative photosynthetic prokaryotes. They are morphologically diverse *i.e.* they may be found as unicellular, colonial and filamentous. Basically, Order Chroococcales represents the unicellular and colonial forms of cyanobacteria. The present study based on the systematic account of Chroococcales found in five sampling stations of river Ganga at Kanpur, between Bithoorghat to Jajmaughat, during the period from February 2013 to January 2014. During the present study 29 species belonging to 9 genera were identified and all these species belongs to single family Chroococcaceae. The observed genera were *Microcystis* (Kuetzing), *Chroococcus* (Naegeli), *Gloeocapsa* (Kuetzing), *Gloeotheca* (Naegeli), *Aphanocapsa* (Naegeli), *Aphanothece* (Naegeli), *Synechococcus* (Naegeli), *Synechocystis* (Sauvageau) and *Merismopedia* (Meyen).

Keywords: *Cyanobacteria, Chroococcales, Ganga*

INTRODUCTION

Cyanobacteria are nature's inimitable souvenir for mankind because they possess several innate properties those make them ideal organisms with potential for versatile biotechnological applications (Bullerjahn and Post, 2014). They are large and morphologically diverse group of unique photosynthetic organisms of great importance because of their very long existence for well over 3.5-3.8 billion years ago (Tomitani, *et al.*, 2006) and cosmopolitan distribution in terrestrial, freshwater and marine habitats (Whitton and Potts, 2000).

The morphology of the cyanobacteria is remarkable. Both unicellular and filamentous forms are known and considerable variations within these morphological types occur. According to Bergey's Manual cyanobacteria has been divided into five morphological groups: unicellular dividing by binary fission, unicellular dividing by multiple fission (colonial), filamentous containing differentiated cells called heterocysts that function is nitrogen fixation, filamentous non heterocystous forms and branched filamentous types.

The first cyanobacteria *Calothrix indica* described by Montagne in 1849 from Assam and Kirtikar (1886) was the first Indian to record any alga. Ghose (1919, 1923, 1926, 1927a, b) published a series of publications and widely contributed to our knowledge on the Indian Blue-green algae. Bhardwaja (1933) began a series of studies on Indian blue-green algae. Bhardwaja (1935) and his students (Singh, 1939a,b; Singh, 1941; Rao, 1936,1937, 1938a,b; Rao, 1939, 1940; Parukutty, 1939, 1940) have further contributed to our knowledge of cyanobacterial flora of India.

Desikachary (1959) was the major contributor of Indian cyanobacteria and he has explored several cyanobacteria from different parts of India. Laxmi Narayana (1965) was made studies on phytoplankton of river Ganges, Varanasi, UP.

During the past few years some relevant literature have also been available on cyanobacterial diversity and ecology from different regions of India (Parikh, *et al.*, 2006; Gupta, *et al.*, 2006; Saha, *et al.*, 2007; Kumar, 2010; Kumar, *et al.*, 2011;Patil *et al.*, 2012).

Some reports also available on algal studies at Kanpur (Ahmad, 1973; Shukla, 1983; Tripathi and Pandey, 1989; Tiwari, *et al.*, 2001; Tiwari and Shukla, 2007, Rishi and Awasthi, 2015).

The present investigation deals the detailed studies on the observed members of Chroococcales from five Ghats of River Ganga at Kanpur. Few taxonomic studies on this order have also been made by Naskar, *et*

Research Article

al., (2006) and Roy, et al., (2012) (West Bengal); Chaudhary (2009) (North Bihar); Singh, et al., (2014) (Jajmau, Kanpur).

MATERIALS AND METHODS

The cyanobacterial samples were collected from five sampling stations (Bithoorghat, Ranighat, Sarsaiyaghat, Golaghat and Jajmaughat) of River Ganga at Kanpur at monthly intervals with the help of plankton net and simultaneously preserved in FAA for further investigations. Identification of different genera and species of cyanobacteria has been made by using standard texts and monographs *i.e.* Desikachary (1959), Prescott (1962) etc. on the basis of their structures and measurements (Camera Lucida Diagrams).

OBSERVATIONS

The systematic enumeration of observed taxa as follows:

Class CYANOPHYCEAE Sachs

Order CHROOCOCCALES Wettstein

Family CHROOCOCCACEAE Naegeli

Genus MICROCYSTIS (Kuetzing)

Cells spherical or elongated, many in spherical, ellipsoidal or irregularly overlapping or net like colonies, free floating, often attached daughter colonies; cells homogenous colourless, often diffuent, mucilage, individual envelopes absent; cells generally arranged very densely, gas vacuole often present.

Microcystis aeruginosa (Kuetzing). Desikachary (1959) Pg. 93, Pl. 17, Figure 1,2,6 and Pl. 18, Figure 10
Colonies in young stage rounded or slightly longer than broad and solid, after maturation become clathrate, with distinct hyaline colonial mucilage; cells spherical and generally with gas vacuoles (Plate 01 & Figure 01).

Dimensions: Diameter of cells 4-7 μ .

Distribution: Found as planktonic form at Ranighat, Sarsaiyaghat, Golaghat and Jajmaughat.

Microcystis aeruginosa var. major (Smith). Desikachary (1959) Pg. 94, Pl. 17, Figure 2

Colonies oval, spherical or irregularly lobed, saccate and clathrate, numerous cells established within mucilaginous matrix; colonial mucilage hyaline and homogenous, retained a distinct shape; cells spherical, blue-green, cell content highly granular and with conspicuous pseudovacuols (Plate 01 & Figure 02).

Dimensions: Diameter of cells 4.5-5.5 μ .

Distribution: Found as planktonic form at Ranighat, Sarsaiyaghat, Golaghat and Jajmaughat.

Microcystis flos-aquae (Wittr.) Kirchner. Desikachary (1959) Pg. 94, Pl. 17, Figure 11 and Pl. 18, Figure 11

Colonies nearly spherical, ellipsoidal or somewhat elongated, not clathrate, with indefinite colonial mucilage; cells spherical with gas vacuoles (Plate 01 & Figure 05).

Dimensions: Diameter of cells 3.5-6.8 μ .

Distribution: Found as planktonic form at Sarsaiyaghat, Golaghat and Jajmaughat.

Microcystis marginata (Menegh.) Kuetzing. Desikachary (1959) Pg. 87, Pl. 17, Figure 3-5

Colonies rounded or irregularly flattened, more or less lenticular, margins of colonial mucilage extremely distinct, refractive, sometimes stratified; single colony ellipsoidal or ovoid; cells closely arranged in colony, cells also contains the gas vacuoles (Plate 01 & Figure 03).

Dimensions: Colony 150-160 μ long and 70-90 μ broad; diameter of cells 4-6 μ .

Distribution: Found as planktonic form at Ranighat and Sarsaiyaghat.

Microcystis robusta (Clark) Nygaard. Desikachary (1959) Pg. 85, Pl. 17, Figures 7-10

Colonies at first rounded, afterward become irregularly elongate and clathrate; sheath distinct, later gelatinizing; cells spherical, without gas-vacuoles (Plate 01 & Figure 06).

Dimensions: Cells 7-8.8 μ in diameter.

Distribution: Found as planktonic form at Ranighat and Golaghat.

Research Article

Microcystis viridis (A. Br.) Lemm. Desikachary (1959) Pg. 87, Pl. 18, Figure 1-6

Colonies rounded or rectangular, consisting of a huge number of partial daughter colonies surrounded by a common mucilaginous sheath, margins of colonial mucilage definite and highly refractive; cells spherical with gas-vacuoles (Plate 01 & Figure 04).

Dimensions: Cells 3.5-6.8 μ in diameter.

Distribution: Found as planktonic form at Sarsaiyaghat and Jajmaughat.

Genus CHROOCOCCUS (Naegeli)

Cells spherical or sub-spherical, hemispherical, after division in small groups of 2-4 individuals, sometimes 4-16, rarely solitary, in a mucilaginous matrix; sheath of individual cells distinct, generally lamellated, homogenous, persistently or irregularly broken; reproduction by cell division and fragmentation of colonies; division of cells in three directions.

Chroococcus giganteus West. Desikachary (1959) Pg. 101, Pl. 26, Figure 1

Cells mostly two, rarely three or four together in groups, bright blue-green, sheath lamellated, 2-3 layered (Plate 01 & Figure 07).

Dimension: Without sheath 5.5-5.6 μ broad, with sheath 65-69 μ broad.

Distribution: Found as planktonic form at Ranighat, Sarsaiyaghat, Golaghat and Jajmaughat.

Chroococcus minor (Kuetzing) Naegeli. Desikachary (1959) Pg. 105, Pl. 24, Figure 1

Colony slimy, gelatinous, dirty blue-green or olive-green; cells spherical, cells solitary or in pairs, sometimes in the group of 4 or 8 cells; mucilaginous sheath colourless and very thin (Plate 01 & Figure 10).

Dimension: Diameter of cells 3-4 μ .

Distribution: Found as planktonic form at Bithoorghat, Ranighat, Sarsaiyaghat and Jajmaughat.

Chroococcus turgidus (Kuetzing) Naegeli. Desikachary (1959) Pg. 101-102, Pl. 26, Figure 6

Cells spherical or ellipsoidal, solitary or in the group of mostly 2-4 cells, blue-green or yellowish; sheath colourless, not distinctly lamellated (Plate 01 & Figure 09).

Dimension: Diameter of cells without sheath 10-20 μ and with sheath 20-35 μ .

Distribution: Found as planktonic form at Bithoorghat, Sarsaiyaghat and Golaghat.

Chroococcus tenax (Kirchner) Hieron. Desikachary (1959) Pg. 103, Pl. 26, Figure 7, 16

Cells mostly found in the group of 2-4 cells, sometimes 8-16 cells; cells blue-green or olive; sheath colourless or yellow or brown, thick, distinctly lamellated, lamellae 3-4 (Plate 01 & Figure 08).

Dimension: Diameter of cells without sheath 16-20 μ and with sheath 20-24 μ .

Distribution: Found as planktonic form at Ranighat, Golaghat and Jajmaughat.

GLOEOCAPSA (Kuetzing)

Colonies composed of 2-8 spherical cells without a number of concentric spherical envelopes; colonies solitary or many together forming an expanded mass, individual sheaths lamellated or non-lamellated.

Gloeocapsa compacta (Kuetzing). Desikachary (1959) Pg.121, Pl. 24, Figure 7

Colonies reddish brown, compact; cells blue-green; sheath non-lamellated (Plate 01 & Figure 11).

Dimension: Diameter of cells without sheath 2-2.5 μ ; with sheath up to 3.5 μ .

Distribution: Found as planktonic form at Bithoorghat, Ranighat and Jajmaughat.

Gloeocapsa kuetzingiana (Naegeli). Desikachary (1959) Pg.119, Pl. 23, Figure 4 and Pl. 24, Figure 12

Thallus thin, soft, brownish or blackish; cells densely arranged in colonies; sheath yellow to brown and non-lamellated (Plate 01 & Figure 12).

Dimension: Diameter of cells without sheath 2.8-3.9 μ ; with sheath 4.5-7 μ .

Distribution: Found as planktonic form at Ranighat, Golaghat and Jajmaughat.

Gloeocapsa quaternata (Naegeli). Desikachary (1959) Pg.120, Pl. 20, Figure 9

Colonies pale green or blackish, brownish or yellowish, expanded or forming tubercles; sheath lamellated; cells solitary or sometimes up to 8 cells in a colony (Plate 02 & Figure 1, 2).

Dimension: Diameter of cells without sheath 2.9-4.4 μ and with sheath 9-10 μ .

Distribution: Found as planktonic form at Bithoorghat, Ranighat and Golaghat.

Research Article

GLOEOTHECE (Naegeli)

Cells cylindrical to ellipsoidal, straight or bent, not attenuated at the ends, but broadly rounded, in small colonies.

Gloeotheca distans (Stizb.). Desikachary (1959) Pg. 130

Cells oval, up to 1.5 times as long as broad, pale greenish, content granular; sheath thin, colourless, lamellated, cells single or two in colonies; colonies oval or spherical (Plate 02 & Figure 04).

Dimension: cells 6.5-9.5 μ broad.

Distribution: Found as planktonic form at Bithoorghat, Sarsaiyaghat and Jajmaughat.

Gloeotheca rhodochlamys (Skuja). Desikachary (1959) Pg. 125, Pl. 23, Figure 13-14

Thallus minute and microscopic, more or less rounded, form an expanded gelatinous mass, blue-green; cells ellipsoidal or cylindrical with rounded ends; adult colonies contain 4-16 cells in each envelope; spores globose or ellipsoidal (Plate 02 & Figure 03).

Dimension: colonies 12-20 μ broad; cells 2-3 μ broad and 3.5-5.5 μ long; spores 4-5 μ broad and 7-8 μ long.

Distribution: Found as planktonic form at Bithoorghat and Sarsaiyaghat.

APHANOCAPSA (Naegeli)

Cells spherical or nearly spherical, many loosely arranged without an order, forming a formless gelatinous mass, mucilage homogenous, colourless, cells often with a thin more or less gelatinous individual sheath.

Aphanocapsa biformis (A.Br.). Desikachary (1959) Pg. 134, Pl. 21, Figure 3-4

Thallus olive green, mucilaginous; cells spherical with a special envelope, loosely arranged, 2-4 cells together in a common mucilaginous envelope (Plate 02 & Figure 13).

Dimension: Diameter of cells 5-7 μ .

Distribution: Found as planktonic form only at Bithoorghat.

Aphanocapsa littoralis (Hansgirg). Desikachary (1959) Pg. 131, Pl. 21, Figure 1

Thallus amorphous without any definite shape, gelatinous, blue-green; cells spherical or sub-spherical, single or paired, densely or sparsely aggregated (Plate 02 & Figure 05).

Dimension: Diameter of cells 5.5-6.5 μ .

Distribution: Found as planktonic form at Bithoorghat and Golaghat.

Aphanocapsa montana (Cramer). Desikachary (1959) Pg. 135, Pl. 20, Figure 8

The shape of colony irregular, mucilaginous, yellow-green or blue-green; cells spherical, single or paired, mucilage colourless and diffluent (Plate 02 & Figure 08).

Dimension: Diameter of cells 3-4.2 μ .

Distribution: Found as planktonic form at Bithoorghat, Golaghat and Jajmaughat.

Aphanocapsa muscicola (Menegh.) Wille. Desikachary (1959) Pg. 135, Pl. 21, Figure 7

Colonies microscopic; cells spherical, blue-green, 2-4 cells together, daughter cells often together in a common mucilaginous envelope, mucilage thick (Plate 02 & Figure 07).

Dimension: Diameter of cells 2.5-3.4 μ .

Distribution: Found as planktonic form at Bithoorghat, Golaghat and Jajmaughat.

Aphanocapsa pulchra (Kuetzing) Rabenhorst. Desikachary (1959) Pg. 132, Pl. 21, Figure 2

Thallus mucilaginous, homogenous, blue-green, tuberculate, attached or free; cells spherical, loosely arranged, single or in pairs; individual sheath of cells indistinct (Plate 02 & Figure 06).

Dimension: Diameter of cells 3.8-4.7 μ .

Distribution: Found as planktonic form at Bithoorghat and Jajmaughat.

APHANOTHECE (Naegeli)

Cells ellipsoidal to cylindrical, straight or slightly bent, many in a shapeless colony, mucilage homogenous.

Aphanothece castagnei (Breb.) Rabenhorst. Desikachary (1959) Pg. 140, Pl. 21, Figure 8

Colonies mucilaginous without any definite shape, slimy, blue-green; cells ellipsoidal or cylindrical, generally densely arranged; sheath diffluent, colourless (Plate 02 & Figure 09).

Dimension: Cells 2.5-3.5 μ broad and 5-8 μ long.

Research Article

Distribution: Found as planktonic form at Sarsaiyaghat and Golaghat.

Aphanothece naegelii (Wartm.). Desikachary (1959) Pg. 141, Pl. 22, Figure 7

Thallus mucilaginous, yellow brown or olive-green; cells oval, after division become spherical, blue-green; sheath diffluent (Plate 02 & Figure 11).

Dimension: cells 4-5 μ broad and 7-8 μ long.

Distribution: Found as planktonic form at Ranighat and Sarsaiyaghat.

Aphanothece pallida (Kuetzing) Rabenhorst. Desikachary (1959) Pg.140- 141, Pl. 22, Figure 3

Thallus mucilaginous, soft, blue-green or brownish; cells oblong, ellipsoidal or cylindrical, blue-green; sheath very distinct in the peripheral part of thallus, diffluent in the inner portion (Plate 02 & Figure 10).

Dimension: Cells 4-8 μ broad and 7-12 μ long.

Distribution: Found as planktonic form at Ranighat and Golaghat.

Aphanothece saxicola (Naegeli). Desikachary (1959) Pg. 138, Pl. 22, Figure 11

Thallus mucilaginous, colourless, more or less spherical; cells cylindrical, straight or slightly bent, blue-green, densely arranged; sheath mostly diffluent (Plate 02 & Figure 12).

Dimension: Cells 1.5-2.5 μ broad and 2-3 μ long.

Distribution: Found as planktonic condition only at Golaghat.

SYNECHOCOCCUS (Naegeli)

A cylindrical oblong unicell, or ellipsoidal unicell; sometimes 2-4 cells seriatly united as a result of cell division in a one plane; cells pale blue-green.

Synechococcus aeruginosus (Naegeli). Prescott (1962) Pg.461, Pl. 102, Figure 6-8

Cells oblong or cylindrical, 2-3 times their diameter in length, ends broadly rounded; solitary or in pairs (Plate 02 & Figure 15).

Dimension: Diameter of cells 6.5-13.5 μ and 12-22 μ long.

Distribution: Found as planktonic form at Bithoorghat, Ranighat and Jajmaughat.

SYNECHOCYSTIS (Sauvageau)

Cells spherical, solitary or in pairs after division, or rarely in colonies of few cells, without distinct mucilaginous sheath.

Synechocystis aquatilis (Sauvageau). Desikachary (1959) Pg. 144, Pl. 25, Figure 9

Cells spherical, single or in pairs, blue-green, sheath indistinct (Plate 02 & Figure 14).

Dimension: Diameter of cells 4.5-6.5 μ .

Distribution: Found as planktonic form at Sarsaiyaghat, Golaghat and Jajmaughat.

MERISMOPEDIA (Meyen)

Cells 4-16 or more in tabular colonies in homogenous mucilage, generally in fours, arranged in a single plane; cells globose, sub-spherical, blue-green.

Merismopedia glauca (Ehrenb.). Desikachary (1959) Pg. 155-156, Pl. 29, Figure 5

Colonies mostly small with 16-64 cells, rarely more; cells oval or spherical, closely arranged (Plate 02 & Figure 19).

Dimension: Colony 50-140 μ broad; cells 3.5-6.3 μ broad.

Distribution: Found as planktonic form at Bithoorghat, Ranighat, Golaghat and Jajmaughat.

Merismopedia punctata (Meyen). Desikachary (1959) Pg. 155, Pl. 23, Figure 5 and Pl. 29, Figure 5

Colonies small, 4-64 cells; cells not closely arranged, spherical or oval, blue-green (Plate 02 & Figure 18).

Dimension: Colony 50-55 μ broad; cells 2.6-3.8 μ broad.

Distribution: Found as planktonic form only at Bithoorghat.

Merismopedia tenuissima (Lemm.). Desikachary (1959) Pg. 155, Pl. 29, Figure 7 and Pl. 30, Figure 8,9

Cells blue-green closely arranged in colonies of 16-100 cells; cells spherical or sub-spherical (Plate 02 & Figure 16, 17).

Dimension: Diameter of cells 1.5-2.2 μ .

Distribution: Found as planktonic form at Ranighat, Golaghat and Jajmaughat.

Research Article

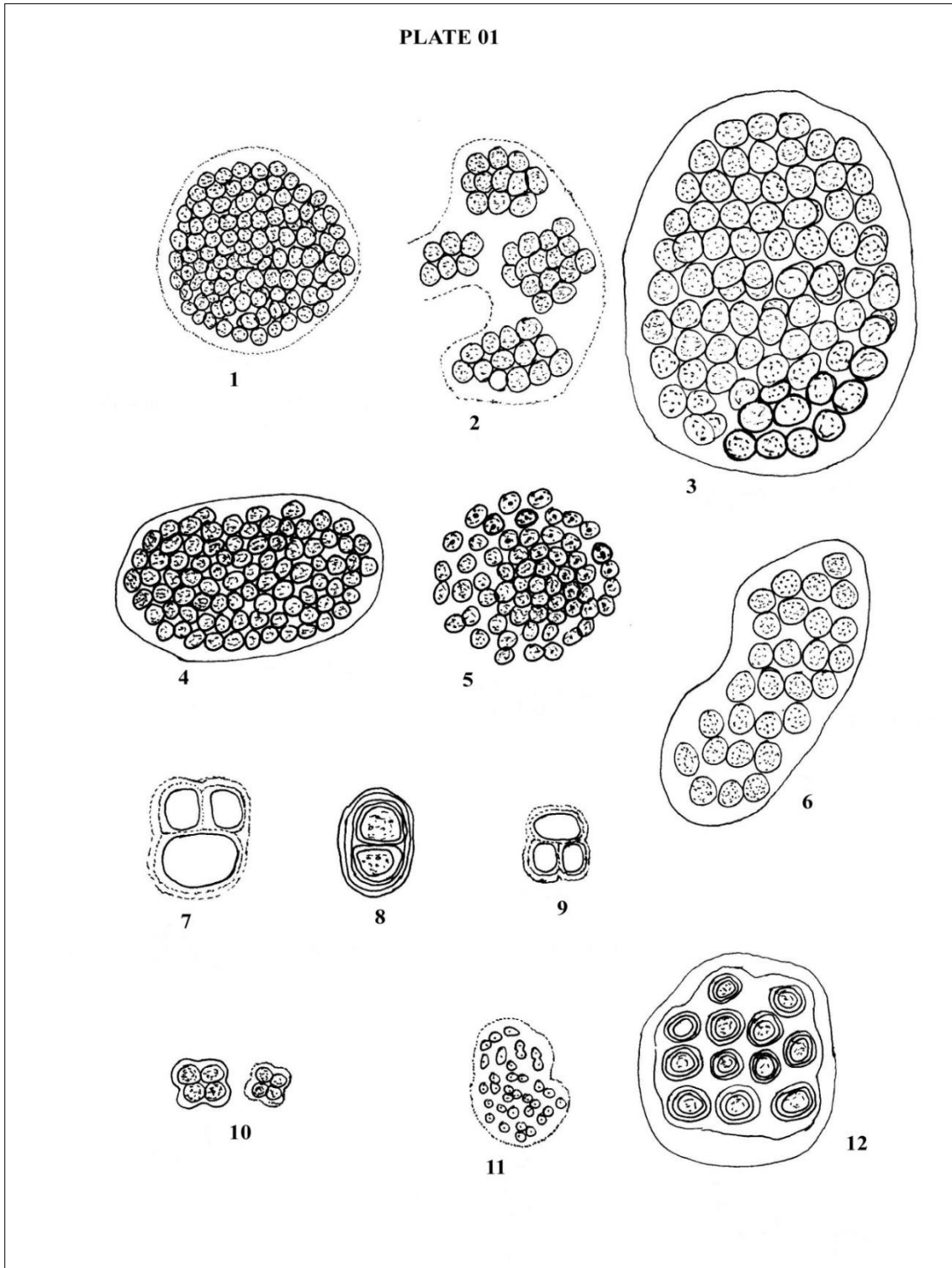
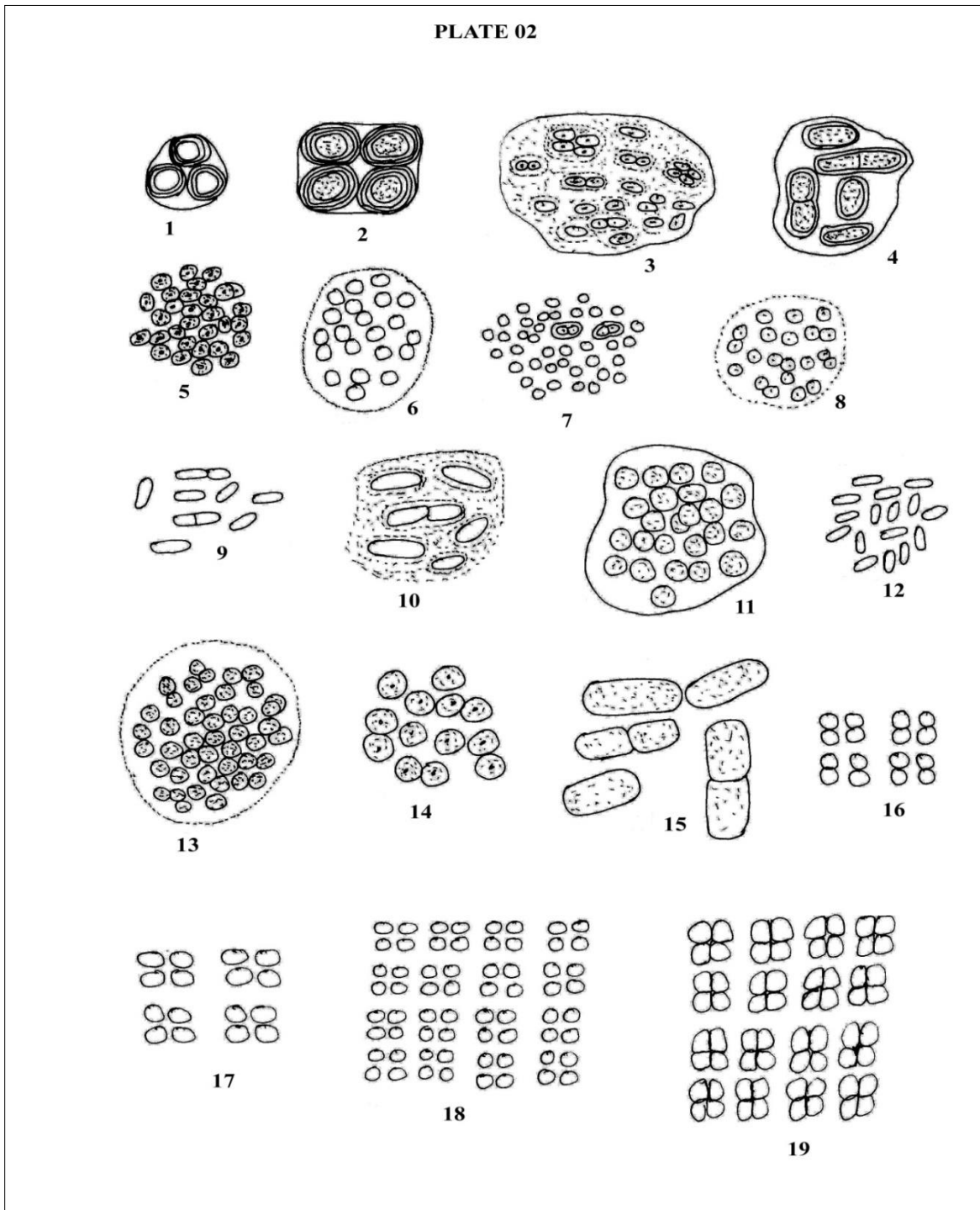


PLATE 1

Figures: *Microcystis aeruginosa*(1), *Microcystis aeruginosa* var. *major* (2), *Microcystis marginata*(3), *Microcystis viridis*(4), *Microcystis flos-aquae*(5), *Microcystis robusta*(6), *Chroococcus giganteus*(7), *Chroococcus tenax* (8), *Chroococcus turgidus*(9), *Chroococcus minor*(10), *Gloeocapsa compacta*(11), *Gloeocapsa kuetzingiana* (12)

Research Article



Figures: *Gloeocapsa quaternata* (1,2), *Gloeotheca rhodochlamys* (3), *Gloeotheca distans* (4), *Aphanocapsa littoralis* (5), *Aphanocapsa pulchra* (6), *Aphanocapsa muscicola* (7), *Aphanocapsa montana* (8), *Aphanocapsa biformis* (13), *Aphanothece castegnii* (9), *Aphanothece pallida* (10), *Aphanothece naegelii* (11), *Aphanothece saxicola* (12), *Synechocystis aquatilis* (14), *Synechococcus aeruginosus* (15), *Merismopedia tenuissima* (16,17), *Merismopedia punctata* (18), *Merismopedia glauca* (19)

Research Article

DISCUSSION

Kanpur is an industrial city of North India and situated on the bank of river Ganga. The Kanpur city is famous for its leather industries. The river receives a huge amount of domestic and industrial effluents. So, this condition of river supports the growth of various kinds of algae especially cyanobacteria. The current study was based on the preliminary investigations on the diversity of different members of order Chroococcales from the five sampling stations of River Ganga at Kanpur. During the present study total 9 genera and 29 species of Chroococcales have been indentified between Bithoorghat to Jajamaughat, during the period from February 2013 to January 2014. The 6 genera and 13 species (*Aphanocapsa littoralis*, *A. montana*, *A. muscicola*, *A. pulchra*, *Chroococcus minor*, *C. turgidus*, *Gloeocapsa compacta*, *G. quaternata*, *Gloeothece distans*, *G. rhodochlamys*, *Merismopedia glauca*, *M. punctata* and *Synechococcus aeruginosus*) were recorded from Bithoorghat, 6 genera and 15 species (*Aphanothece naegelii*, *A. pallida*, *Chroococcus giganteus*, *C. minor*, *C. tenax*, *Gloeocapsa compacta*, *G. kuetzingiana*, *G. quaternata*, *Merismopedia glauca*, *M. tenuissima*, *Microcystis aeruginosa*, *M. aeruginosa var. major*, *M. marginata*, *M. robusta* and *Synechococcus aeruginosus*) from Ranighat, 5 genera and 13 species (*Aphanothece castagnii*, *A. naegelii*, *Chroococcus giganteus*, *C. minor*, *C. turgidus*, *Gloeothece distans*, *G. rhodochlamys*, *Microcystis aeruginosa*, *M. aeruginosa var. major*, *M. flos-aquae*, *M. marginata*, *M. viridis* and *Synechocystis aquatilis*) from Sarsaiyaghat, 7 genera and 19 species (*Aphanocapsa biformis*, *A. littoralis*, *A. montana*, *A. muscicola*, *Aphanothece castagnii*, *A. pallida*, *A. saxicola*, *Chroococcus giganteus*, *C. turgidus*, *C. tenax*, *Gloeocapsa kuetzingiana*, *G. quaternata*, *Merismopedia glauca*, *M. tenuissima*, *Microcystis aeruginosa*, *M. aeruginosa var. major*, *M. flos-aquae*, *M. robusta* and *Synechocystis aquatilis*) from Golaghat and 8 genera and 17 species (*Aphanocapsa montana*, *A. muscicola*, *A. pulchra*, *Chroococcus giganteus*, *C. minor*, *C. tenax*, *Gloeocapsa compacta*, *G. kuetzingiana*, *Gloeothece distans*, *Merismopedia glauca*, *M. tenuissima*, *Microcystis aeruginosa*, *M. aeruginosa var. major*, *M. flos-aquae*, *M. viridis*, *Synechococcus aeruginosus* and *Synechocystis aquatilis*) from Jajmaughat. The sampling has not been done in the months of July and August 2013 due heavy rain and flood in the river Ganga at Kanpur. This study was aimed to provide the systematic and detailed description of observed members of order Chroococcales from different sampling stations of River Ganga at Kanpur.

REFERENCES

- Ahmad MR (1972). Algae of Allen Forest Lake, Kanpur, India. I. Cynaophyceae. *Nova Hedwigia*. **23**(1) 125-129.
- Bharadwaja Y (1933). Contributions to our knowledge of the Myxophyceae of India. *Annals of Botany*. **47** 117-143.
- Bhardwaja Y (1935). The Myxophyceae of United Provinces, India-I. *Proceedings of the Indian Academy of Science, Section B* **2**(1) 95-107.
- Bullerjahn GS and Post AF (2014). Physiology and molecular biology of aquatic cyanobacteria. *Frontiers in Microbiology* **5**359.
- Chaudhary KK (2009). Occurrence of chroococcaceae during rice cultivation in North Bihar, India. *Bangladesh Journal of Plant Taxonomy* **16**(1) 57-63.
- Desikachary TV (1959). *Cyanophyta*, (Indian Council of Agricultural Research, New Delhi, India).
- Ghose SL (1919). The Myxophyceae of Lahore. *Journal of the Indian Botanical Society* **1**(1) 8-13.
- Ghose SL (1923). A systematic and ecological account of collection of blue green algae from Lahore and Shimla. *Journal of the Linnean Society (Botany)* **46**333-346.
- Ghose SL (1926). On some myxophyceae of Rangoon. *Journal of the Burma Research Society* **15**(3) 244-253.
- Ghose SL (1927a). The Myxophyceae of Rangoon,II. *Ibid* **16**(3) 220-267.
- Ghose SL (1927b). The Myxophyceae of Rangoon,III. *Ibid* **17**(3) 237-243.
- Gupta PK, Tiwari P and Gupta R (2006).Cyanobacteria and associated environmental factors in Lake Nainital, Uttaranchal, India. *Journal of Ecophysiology and Occupational Health* **6**175-183.

Research Article

- Kirtikar KR (1886).** A new species of alga, *Conferva thermalis Birwoodii*. *Journal of Bombay Natural History Society* **1** 135-138.
- Kumar M (2010).** Cyanoprokaryotes of Guptsahastradhara (H.P.) *Biohelica* **1(2)** 32-35.
- Kumar M, Gupta RK, Bhatt AB and Tiwari SC (2011).** Epiphytic cyanobacterial diversity in the sub-Himalayan belt of Garhwal region of Uttarakhand, India. *Journal of Plant Science* **877–89**.
- Laxmi Narayana JSS (1965).** Studies on phytoplankton of river Ganges, Varanasi. *Hydrobiologia* **25**119-137.
- Montagne C (1849).** Sixieme centurie de plantes cellulaires nouvelles tant di indigenes qu exotiques. Dec. 7 A.X. *Annales Des Sciences Naturelles Botanique* 3rd ser. **12285-320**.
- Naskar VM, Naskar KR and Sen CR (2006).** A systematic account of Chroococcales (Myxophyceae) from brackish water wetlands of North 24-Parganas district, West Bengal. *Environment and Ecology* **24(3)** 655-657.
- Parikh A, Shah V and Madamwar D (2006).** Cyanobacterial flora from polluted industrial effluent. *Environmental Monitoring and Assessment* **116**91- 102.
- Parukutty PR (1939).** Collection of algae from Assam. *Proceedings of the Indian Academy of Science, Section B* **9(5)** 229-235.
- Parukutty PR (1940).** Myxophyceae of Travancore State of India. *Ibid* **B 11(3)**117-124.
- Patil KJ, Mahajan RT and Mahajan SR (2012).**Phytonic diversity of Jalgaon district, Maharashtra (India).*Journal of Algal Biomass Utilization* **3(2)** 71-102.
- Prescott GW (1962).** *Algae of the Western Great Lakes Area* (Wm. C. Brown Company Publishers, Dubuque, Iowa, US).
- Rao CB (1936).** The Myxophyceae of the United Province, India-II. *Ibid* **3(2)** 165-174.
- Rao CB (1937).** The Myxophyceae of the United Province, India-III. *Ibid* **6(6)** 339-375.
- Rao CB(1938a).** The Myxophyceae of the Orissa Province, India-I. *Ibid* **8**157-170.
- Rao CB (1938b).** The Myxophyceae of the Madras Province, India-I. *Journal of the Indian Botanical Society* **17**81-96.
- Rao CS (1939).** The Myxophyceae of the Bihar Province, India-I. *Proceedings of the Indian Academy of Science, Section B* **9(3)**142-150.
- Rao CS (1940).** The Myxophyceae of the Delhi Province, India-I. *Ibid* **11(3)** 125-131.
- Rishi V and Awasthi AK (2015).** Biodiversity of Cyanobacteria in River Ganga at Kanpur, Uttar Pradesh, India. *Indian Journal of Plant Sciences* **4(1)** 78-86.
- Roy S, Mustafa G and Keshri JP (2012).**Observations on some members of Chroococcales (Cyanophyta) from Burdwan, West Bengal, India with a note on their ecology.*Journal of Economic & Taxonomic Botany* **36(2)** 292-303.
- Saha SK, Das R, Bora KN and Uma L (2007).** Biodiversity of epilithic cyanobacteria from freshwater streams of Kakoijana reserve forest, Assam, India. *Indian Journal of Microbiology* **47**219–232.
- Shukla BK (1983).** Studies on algae and their significance. Ph. D. Thesis, Kanpur University.
- Singh A, Tiwari V and Mohan J (2014).**Chroococcales in River Ganga at Jajmau Ghat, Kanpur. *Tropical Plant Research* **1(1)**28-30.
- Singh RN (1939a).** An investigation into the algal flora of paddy field soils of the United province-I. *Indian Journal of Agricultural Sciences* **9(10)** 55-77.
- Singh RN (1939b).** The myxophyceae of United Province, India, IV. *Proceedings of the Indian Academy of Science, Section B* **9**63-68.
- Singh VP (1941).** On a collection of algae from Chamba State (Punjab) I. *Proceedings of the Indian Academy of Science, Section B* **14**250-255.
- Tiwari D and Shukla M (2007).** Algal biodiversity and trophic status of some temporary water bodies of Kanpur. *Nature Environment and Pollution Technology* **6(1)** 85-90.
- Tiwari D, Patrik JM and Singh S (2001).**Algal Dynamics of the river Ganga at Kanpur. *Phykos* **5**115-126.

Research Article

Tomitani A, Knoll AH, Cavanaugh CM and Ohno T (2006). The evolutionary diversification of cyanobacteria: molecular phylogenetic and paleontological perspectives. *Proceedings of National Academy of Sciences, U.S.A.* **103** 5442–5447.

Tripathi AK and Pandey SN (1989). Studies on algae of polluted ponds of Kanpur II. Qualitative, quantitative and periodical occurrence of the blue-green algae of Chandrai pond. *Research Journal of Plant, Animal and Environmental Sciences* **5**(1) 89-93.

Whitton BA and Potts M (2000). Introduction to the cyanobacteria. In: *The Ecology of Cyanobacteria: Their Diversity in Time and Space*, edited by Whitton, and Potts, (Netherlands, Dordrecht, Kluwer Academic Publishers) 1-11.