

(RESEARCH ARTICLE)



## Cyanophycean (Cyanobacterial) diversity from the Lakhimpur-Khiri District of Northern Uttar Pradesh, India

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### Abstract

In the present study, the cyanophycean diversity of the Lakhimpur-Khiri district, northern Uttar Pradesh, India, has been investigated for the first time. Algae samples were collected in plastic bottles and preserved in 3-4% formalin from Lakhimpur-Khiri district of northern Uttar Pradesh in different seasons from 2015 to 2016. The field photographs of the selected localities were also taken and the location of each site noted down. For the Microscopic study of Cyanophycean algae, the samples were stained with 1 % aqueous methylene blue solution according to the standard method. The observations and photomicrography were done with help of Nikon Labophot-11 microscope. A total of 31 cyanophycean algal taxa have been recorded from different water bodies of Lakhimpur-Khiri. These algal taxa belong to 14 genera and 9 families of the division Cyanophyta. Of these, *Oscillatoria* (7), *Phormidium* (4) and *Lyngbya* (3) are abundant.

**Keywords:** Algae; Cyanophyceae; Lakhimpur-Khiri; Oscillatoriaceae; Uttar Pradesh

### 1. Introduction

India has only 2.4% of the world's land area, but it contributes 8% of total global species diversity. Due to wide variation diversity and life forms, India comes under one of 12 Mega diversity countries in the world. Geographically Northern Uttar Pradesh lies at the bottom of the Himalaya, which is one of the hotspot of India. The present investigation of freshwater algal flora includes Lakhimpur-Khiri district of Northern Uttar Pradesh, India. Previously work on cyanophycean algal diversity of Uttar Pradesh has been done by several workers<sup>1-18</sup>. However, the cyanophycean flora of Lakhimpur-Khiri district had not been studied so far. Therefore, a comprehensive study on the cyanophycean flora of this region is included in the present investigation.

### 2. Material and methods

The algal sample were collected in different seasons from 2015 to 2016 in Lakhimpur-Khiri district of northern Uttar Pradesh ranging from 27.6 to 28.6 °N and 80.34 to 81.30 °E (Image- 1). The epiphytic forms were collected by simply squeezing submerged plants and planktonic forms with the help of planktonic mesh net (size 0.5 mm). The samples were stored in plastic bottles (250 ml). All these collections were fixed in 3-4% formalin immediately in the field and pictures of the selected localities were also taken with the help of Nikon COOLPIX S3700 Digital Camera. Microscopic study of Cyanophycean algae, the samples were stained with 1 % aqueous methylene blue solution and observed in Nikon Labophot-11 microscope.

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The taxonomic identification has been made by comparing each taxa with the original description of the holotype, although standard monographic and relevant research papers relating to the topic have also been consulted. The Monographs mainly consulted were of Desikachary<sup>2</sup>, Komárek *et al.*<sup>19-20</sup> and Komárek<sup>21</sup>

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### 3. Taxonomical description

Class: Cyanophyceae, Schaffner, 1909

Order: Synechococcales, L. Hoffmann, J. Komárek & J. Kastovsky, 2005

Family: Merismopediaceae, Elenkin, 1933

Genus- *Merismopedia* Meyen 1839

#### Key to the Species

- 1. Cells less than 2 in diameter ..... 2
- 1. Cells more than 2 µm in diameter ..... 3
- 2. Cells 0.4-2.0 µm in diameter, rectangular colonies ..... *M. tenuissima*
- 3. Cells 2.5 – 4.5 µm, colonies more or less flat ..... *M. elegans*

#### 3.1 *Merismopedia elegans* A. Braun (Pl. 1, Fig. A)

Komárek, J. and Anagnostidis, K., 1999, p. 180, fig. 227.

Colonies small to big, 16-4000 celled, outline usually rectangular, wavy, cells spherical or oblong, more or less closely arranged 5-6 × 5-7 µm; light blue-green to greenish.

**Locality:** Jashwant Nagar Lake, Lakhimpur

**Collection number:** UP/LMP/23

#### 3.2 *Merismopedia tenuissima* (Lemm.) Desikachary (Pl. 1, Fig. B)

Komárek, J. and Anagnostidis, K., 1999, p. 174, fig. 219.

Colonies flat, cells spherical or oval in shape, blue-green in colour, closely arranged, 16 - 100 celled; cells spherical or sub-spherical, 1.5-2.2 µm in diameter.

**Locality:** Sharda Sahayak River, Ramahipul, Lakhimpur

**Collection number:** UP/LMP/24

Genus- *Limnococcus* (Komárek & Anagnostidis) Komárková 2010

#### 3.3 *Limnococcus limneticus* (Lemmermann) Komárková et al. (Pl. 1, Fig. C)

Komárková, Jezberová, O. Komárek and Zapomelová; 2009, p. 79, pl. fig. 5 cl 4a, 4b.

Colonies 20-35 × 42-45 µm, spherical or sub-spherical, free-floating, 4-32 celled enclosed in a tabular gelatinous layer; cells 8-12 µm, colonial mucilage broad, sheath thick 5 µm diameter; distinct or diffluent, unlamellated, colorless.

**Locality:** Sharda River, Ludhauni, Lakhimpur

**Collection number:** UP/LMP/20

Family- Schizotrichaceae Elenkin, 1949

Genus- *Schizothrix* Kützing ex Gomont, 1892

### 3.4 *Schizothrix tinctoria* Gomont ex Gomont (Pl. 1, Fig. D)

Komárek and Anagnostidis, 2005, p. 284, fig. 376.

Thallus macroscopic, continuous, mucilaginous or fasciculate; filaments long, flaccid, joined to flowing penicillate fascicle, pseudobranching at ends; sheath narrow, colourless, not lamellated, diffuent at the margin; trichomes 6 µm broad, slightly constricted at cross walls; cells nearly isodiametric or shorter than breadth, apical cell rounded.

**Locality:** Ghavar River, Ranjeet Ganj, Lakhimpur

**Collection number:** UP/LMP/22

Order- Spirulinales J. Komárek et. al. 2014

Family- Spirulinaceae (Gomont) L. Hoffmann et. al. 2014

Genus- *Spirulina* Turpin ex Gomont, 1892

#### 3.4.1 Key to the Species

1. Trichomes coils loose, height greater or equal to the width ..... 2
1. Trichomes coils compact, height lower to the width of the coil ..... 3
2. Trichomes 1.8 - 2 µm broad, coil 3- 3.5 µm broad ..... *S. meneghiniana*
3. Trichomes up to 2 µm wide ..... 4
3. Trichomes more than 2 µm ..... 5
4. Trichomes bright green in colour, 1.5 µm and cells 3 µm long ..... *S. labyrinthiformis*
5. Coils touch each other, coils 3.5- 4.5 µm broad ..... *S. subsalsa*
5. Coils don't touch each other, coils 3.5 µm broad ..... *S. princeps*

### 3.5 *Spirulina labyrinthiformis* (Menegh.) Gomont (Pl. 1, Fig. E)

Komárek and Anagnostidis, 2005, p. 146, fig. 171.

Filaments green, regularly coiled, spirals close to each other, trichome 1.5 µm broad, green, cells 3 µm long.

**Locality:** Jonai River, Lakhimpur

**Collection number:** UP/LMP/12

### 3.6 *Spirulina meneghiniana* Zanard. ex Gomont (Pl. 1, Fig. F)

Desikachary 1959, p. 195, pl. 36, fig. 8; Komárek and Anagnostidis, 2005, p. 147, fig. 172

Thallus thin or thick, compact, blue-green, trichomes pale to blue-green in colour; trichome 1.8-2 µm broad, flexible, regularly or irregularly coiled, not constricted at cross walls, clockwise rotation, 3-3.5 µm broad, the distance between coil 3.5 µm, cell content homogenous, apical cell rounded.

**Locality:** Saryu River, 9 Km west from Nighasan, Lakhimpur

**Collection number:** UP/LMP/09

### 3.7 *Spirulina princeps* West and G.S. West (Pl. 1, Fig. G)

Desikachary, T. V., 1959, p. 197, pl. 36, fig. 7.

Trichomes green to olive-green in colour, zigzag in shape from the side view and spiral in top view, 3.5 µm broad, cell wall with special pore and perforation patterns, without any sheath, short, straight spirals coiled at a distance of 15.4 µm.

**Locality:** Jamauri River, Ranchorpur, Lakhimpur

**Collection number:** UP/LMP/14

### 3.8 *Spirulina subsalsa* Oersted ex Gomont (Pl. 1, Fig. H)

Komárek and Anagnostidis, 2005, p. 150, fig. 176.

Thallus dark blue-green to olive blue-green; spirals 3.5 - 4.5 µm broad; trichomes 4.6 µm broad, closely and loosely spiralled in the same trichome but generally tightly coiled, space absent between turns.

**Locality:** Saryu River, 9 Km west from Nighasan, Lakhimpur

**Collection number:** UP/LMP/09

Order- Chroococcales Schaffner, 1922

Family- Chroococcaceae Rabenhorst, 1863

Genus- *Chroococcus* Nägeli, 1849

#### 3.8.1 Key to the Species

1. Mucilaginous envelope enlarged, outline diffluent, or delimited ..... 2
2. Cells up to 10 µm in diameter, rarely few cells reach up to 15 µm ..... *C. minutus*
2. Cells more than 10 µm in diameter ..... *C. turgidus*

### 3.9 *Chroococcus minutus* (Kützing) Nageli (Pl. 1, Fig. I)

Komárek, J. and Anagnostidis, K., 1999, p. 297, pl. 1, fig. 391.

Cell 5 × 6.5 µm; solitary or form microscopic colony; cell spherical, oval or hemispherical, blue-green or yellow with granular content, enclosed by a broad, distinct margin.

**Locality:** Sukhni River, Lakhimpur

**Collection number:** UP/LMP/08

### 3.10 *Chroococcus turgidus* var. *maximus* Nygaard (Pl. 1, Fig. J)

Komárek, J. and Anagnostidis, K., 1999, p. 306, fig. 407 as *C. turgidus* (Kützing) Nägeli.

Colonies in groups of 2-4 or 8 cells, 30-35 µm diameter with colourless sheath, blue-green; 5- 8 µm in diameter, much lamellated in the inner regions; two-celled colonies 30 × 35 µm.

**Locality:** Gola Gokharnnath Temple, Lakhimpur

**Collection number:** UP/LMP/03

Order- Oscillatoriales Schaffner, 1922

Family- Gomontiellaceae Elenkin ex Geitler, 1942

Genus- *Komvophoron* K. Anagnostidis & J. Komárek, 1988

**3.11 *Komvophoron crissum* (Vozzennikova) Anagnostidis et Komárek (Pl. 1, Fig. K)**

Komárek and Anagnostidis, 2005, p. 333, fig. 460.

Trichomes short, multicelled, straight or slightly curved, distinctly constricted at thick hyaline cross walls; cells short-cylindrical or nearly isodiametric, 3.5-4 × 4-4.5 µm long, apical cells rounded.

**Locality:** Sukhni River, Lakhimpur

**Collection number:** UP/LMP/08

Family- Microcoleaceae O. Strunecky, et al. 2013

Genus- *Arthrospira* Sitenberger ex Gomont, 1892

**3.12 *Arthrospira gigantea* (Schmidle) Anagnostidis (Pl. 1, Fig. L)**

Komárek and Anagnostidis, 2005, p. 347, fig. 479.

Trichomes 5 µm wide, regularly loosely screw-like coiled, 12.3 µm wide, the distance between coiled 10 µm.

**Locality:** Saryu River, 9 Km west from Nighasan, Lakhimpur

**Collection number:** UP/LMP/09

**3.13 *Arthrospira platensis* Gomont (Pl. 1, Fig. M)**

Desikachary T.V., 1959, p. 190, pl. 35, figs. 4, 11.

Thallus greyish brown, trichome pale to blue-green, regular spiral, the distance between coiled 46 - 48 µm, the width of coil 31 µm, cells not constricted at joints, apical cells rounded.

**Locality:** Gomti River, Tedhenath Temple, Lakhimpur

**Collection number:** UP/LMP/17

Genus- *Kamptonema* O. Strunecký, et al., 2014

**3.14 *Kamptonema formosum* (Bory ex Gomont) Strunecký, Komárek and J. Šmarda (Pl. 1, Fig. N)**

Otakar Strunecký, Jiří Komárek and Jan Šmarda 2014, p. 204.

Thallus dark blue-green, trichome straight to flexuous, generally slightly constricted at the cross wall, apex slightly tapering and bent end cells blunt conical, nearly obtuse, not capitate, without calyptra, cells 6-8 × 6 µm, nearly quadrate up to 1/2 long as broad, septa rarely granulated.

**Locality:** Sharda Canal, Murawan Purwa, Lakhimpur

**Collection number:** UP/LMP/06

Genus- *Planktothrix* K. Anagnostidis & J. Komárek, 1988

**3.15 *Planktothrix planktonica* (Elenkin) Anagnostidis et Komárek (Pl. 1, Fig. O)**

Komárek and Anagnostidis, 2005, p. 355, fig. 494.

Trichomes solitary, cylindrical, 10.8 - 15.4  $\mu\text{m}$  wide, fine and distinctly constricted at the cross walls, not attenuated at ends; sheaths delicate, colorless; cells 6.7 – 7.7  $\mu\text{m}$  long, densely arranged aerotopes causing brown to blackish color of the trichomes, apical cell convex, wide, rounded, without calyptra.

**Locality:** Ghavar River, RanjeetGanj, Lakhimpur

**Collection number:** UP/LMP/22

Family- Oscillatoriaceae Engler, 1898

Genus- *Lyngbya* C. Agardh ex Gomont, 1892

### 3.15.1 Key to the Species

- 1. Trichomes constricted at cross walls ..... 2
- 1. Trichomes not constricted at cross walls ..... 3
- 2. Cells almost quadrate, 1/2 to 1/3 times as long as broad, slightly bend on one side .....  
..... *L. ceylanica* var. *constricta*
- 2. Cells broader than long, blue green, straight ..... *L. truncicola*
- 3. Sheath absent, cells 6 × 11.5  $\mu\text{m}$  ..... *L. natans*

### 3.16 *Lyngbya ceylanica* var. *constricta* Frémy (Pl. 1, Fig. P)

Desikachary T. V. 1959, p. 299, pl. 54, fig. 5.

Filament 15.5  $\mu\text{m}$  broad, slightly bend on one side, sheath thin, colourless, trichome 12  $\mu\text{m}$  broad, blue-green in colour, constricted at the cross wall, not attenuated at ends; cell quadrate, 1/2 to 1/3 times as long as broad, end cells rounded, calyptra absent.

**Locality:** Ghavar River, Ranjeet Ganj, Lakhimpur

**Collection number:** UP/LMP/22

### 3.17 *Lyngbya natans* Hansgirg (Pl. 2, Fig. A)

Prescott, G.W., 1982, p. 491, t. 110, f. 11.

Thallus benthic, later free-floating, blue-green; trichome generally straight, blue-green; cells broader than long, 6 × 11.5  $\mu\text{m}$ ; apical cell rounded.

**Locality:** Saryu River, 9 Km west from Nighasan, Lakhimpur

**Collection number:** UP/LMP/09

### 3.18 *Lyngbya truncicola* Ghose (Pl. 2, Fig. B)

Desikachary, T.V. 1959, p. 308, pl. 51, fig. 4; Komárek and Anagnostidis, 2005, p. 618, fig. 937.

Thallus thin, dirty blue-green; filament straight, parallel arranged, 14.4  $\mu\text{m}$  broad, not constricted at walls, ends not attenuated; sheath not lamellated, trichomes cylindrical, 11  $\mu\text{m}$  wide, cells broader than long, 3-6  $\mu\text{m}$  long, apical cell rounded, without calyptra.

**Locality:** Saryu River, 9 Km west from Nighasan, Lakhimpur

**Collection number:** UP/LMP/09

Genus- *Oscillatoria* Vaucher ex Gomont 1892

### 3.18.1 Key to the Species

1. End cells always without thickened wall, calyptra absent ..... 2
1. End cells with well-developed trichomes, distinctly thickened apical cell wall or with calyptra ..... 3
2. Trichomes up to 10 µm wide ..... 4
2. Trichomes more than 10 µm wide ..... 5
4. Trichome ends distinctly narrowed, slightly or distinctly arcuated ..... *O. perornata*
4. Trichome ends cylindrical, slightly straight, apical cell rounded ..... 6
6. Trichomes pale, yellow-grey, 1.5 µm long ..... *O. subbrevis*
6. Trichomes blue-green, grey violet, 1.5 µm long ..... *O. tenuis*
5. Trichomes 14 µm wide ..... *O. curviceps*
5. Trichomes more than 20-35 µm wide ..... *O. princeps*
3. Trichome ends distinctly screw-like coiled, broad, outer wall of terminal cells slightly thickened ..... *O. anguina*
3. Trichome ends straight or only slightly arcuate ..... 7
7. Apical cell in well-developed trichome, calyptra indistinct ..... *O. limosa*
7. Apical cell in well-developed trichome, with distinct calyptra ..... *O. sancta*

### 3.19 *Oscillatoria curviceps* Ag. ex Gomont (Pl. 2, Fig. C)

Komárek and Anagnostidis, 2005, p. 589, figs. 879.

Thallus light or dark blue-green with granulated cross walls; trichomes generally straight, bent at the end or spirally coiled, not attenuated or very little attenuated, without any constrictions at the cross-walls, 9.2-12.3 × 14 µm, cells 1/3-1/6 as long as broad, end-cells flat rounded, not capitate.

**Locality:** Korekuniya Choti Canal, Mohamadpur, Lakhimpur

**Collection number:** UP/LMP/18

### 3.20 *Oscillatoria limosa* Ag. ex Gomont (Pl. 2, Fig. D)

Tiffany, L. H., and Britton, M. E. 1952, p. 342, pl. 93, fig. 1076

Thallus blackish to dark blue-green to brown, attached to substrate; trichome more or less straight, dark blue-green to brown or olive-green, cross-walls not constricted, end walls broadly rounded; cells 3-4.6 × 30.6 µm, 1/3-1/6 as long as broad, cross-walls granulated; end-cell flatly rounded, outer membrane slightly thickened.

**Locality:** Saryu River, 9 Km west from Nighasan, Lakhimpur

**Collection number:** UP/LMP/09

### 3.21 *Oscillatoria perornata* Skuja (Pl. 2, Fig. E)

Desikachary, T.V. 1959, p. 205, pl. 41, figs. 8, 9, 14.

Trichomes solitary, flocculent mass or in clusters, pale blue-green, free-floating, slightly flexuous with constricted cross-walls; cells finely granulated, apical cell conical in shape, bent or curved and rounded;  $2.4 \times 15 \mu\text{m}$ , granules present throughout the cell.

**Locality:** Sharda Barrage and River, Lakhimpur

**Collection number:** UP/LMP/07

### 3.22 *Oscillatoria princeps* Vaucher ex Gomant (Pl. 2, Fig. F)

Desikachary, T.V. 1959, p. 210, pl. 31, figs. 1, 10, 11, 13, 14.

Trichome solitary or loosely entangled to form blue-green to brownish floating mass, apices slightly tapering, straight or slightly curved and, straight, but not constricted at cross walls,  $20\text{-}35 \times 4\text{-}6.2 \mu\text{m}$ ; cells  $1/4$  to  $1/8$  times shorter than broad, cell content olive blue-green, homogenous, without any gas-vacuoles and granules, cell wall thick, smooth; end cells flatly rounded, slightly capitate or with a slightly thickened membrane.

**Locality:** Saryu River, 9 Km west from Nighasan, Lakhimpur

**Collection number:** UP/LMP/09

### 3.23 *Oscillatoria sancta* Kutz. ex Gomont (Pl. 2, Fig. G)

Tiffany, L. H., and Britton, M. E. 1952, p. 342, pl. 93, fig. 1078.

Thallus dark blue-green in colour, steel blue to black blue, thin, shining, mucilaginous, gelatinous, sometimes olive green, trichomes aggregated to form dark-green mass, straight, rarely tapering toward apex; apical cell slightly capitate, with calyptra and thickened outer membrane; cross walls slightly constricted and granular; cells  $6 \times 25 \mu\text{m}$ , cell contents coarsely granular, olive or green in color.

**Locality:** Saryu River, 9 Km west from Nighasan, Lakhimpur

**Collection number:** UP/LMP/09

### 3.24 *Oscillatoria subbrevis* Schmidle (Pl. 2, Fig. H)

Desikachary, T.V. 1959, p. 207, pl. 37, fig. 2; pl. 40, fig. 1.

Trichomes solitary, straight or slightly curved but not attenuated at the apices, cells  $1.5 \times 5 \mu\text{m}$ ; cells  $1/3$  to  $1/4$  times as long as broad, granules and gas vacuoles absent, cell ends rounded, cell content olive blue-green and homogenous, calyptra absent.

**Locality:** Gola Gokharnnath Temple, Lakhimpur

**Collection number:** UP/LMP/03

### 3.25 *Oscillatoria tenuis* C. Agardh ex Gomont (Pl. 2, Fig. I)

Desikachary, T.V. 1959, p. 222, pl. 42, fig. 15.

Thallus flat, in form of clusters, blue-green to olive green, usually thin and mucilaginous; trichome thin, solitary or aggregated to form slimy masses, straight or slightly curved, with or without constrictions at cross walls; cells  $4 \times 11.5 \mu\text{m}$ , quadrate or shorter than broad; gas vacuole absent, with or without granules, if granules present then confined to septa and end cells region only; end cells rounded or hemispherical, non-capitate, without calyptra, cell wall smooth and thick.

**Locality:** Kathina River, Sikanderabad, Lakhimpur

**Collection number:** UP/LMP/16

Genus-*Phormidium* Kützing ex Gomont, 1892



### 3.25.1 Key to the Species

- 1. Trichomes cylindrical along their whole length, apical cells widely rounded, calyptra absent ..... 2
- 1. Thallus otherwise ..... 3
- 2. Trichomes 3 µm wide, cells granular, apical cell rounded; calyptra absent ..... *P. rimosum*
- 2. Trichomes 6 µm wide, granules, apical cell rounded ..... *P. tergestinum*
- 3. Trichomes shorty or gradually narrowed towards ends, apical cells well developed, calyptra present ..... *P. amoenum*
- 3. Trichomes cylindrical, with cells always distinctly shorter than wide, attenuated towards ends, calyptra absent ..... *P. ambiguum*

### 3.26 *Phormidium ambiguum* Gom. (Pl. 2, Fig. J)

Desikachary, T.V, 1959, p. 266, pl. 45, fig. 5-8.

Thallus expanded, bright blue-green to dark green or yellowish-green, rarely solitary, filaments elongated, variously curved and entangled, rarely straight paralleled, arranged, 4 – 4.5 µm wide, generally constricted or not constricted, granulated or non-granulated cross walls, straight, not capitate; cells smaller than wide or isodiametric, 1.8 -3 µm long, cell content frequently with dispersed large granules; apical cells rounded or rarely slightly thickened outer wall, without calyptra.

**Locality:** Saraiya River, Sikanderabad, Lakhimpur

**Collection number:** UP/LMP/15

### 3.27 *Phormidium amoenum* Kutzing (Pl. 2, Fig. K)

Komárek and Anagnostidis, 2005, p. 470, fig. 705.

Thallus gelatinous, dark blue-green, finely membranous; sheath generally absent if present then very thin, trichomes straight, dull to dark blue-green, 4.5 – 6 µm wide, slightly constricted at the ends, wall non-granulated, gradually attenuated at ends; apical cell longer than other, cells capitate, conical with depressed calyptra.

**Locality:** Saraiya River, Sikanderabad, Lakhimpur

**Collection number:** UP/LMP/15

### 3.28 *Phormidium rimosum* (Komárek) Anagn. and Komárek (Pl. 2, Fig. L)

Komárek and Anagnostidis, 2005, p. 440, fig. 641.

Trichomes blue-green, short, sheathed, attached to trichome, confluent within the colony, cylindrical, not constricted or slightly constricted at the cross-walls; not attenuated towards ends; cells broader than long, 3 × 6 µm, granulated; apical cell rounded; calyptra absent.

**Locality:** Kathina River, Sikanderabad, Lakhimpur

**Collection number:** UP/LMP/16

### 3.29 *Phormidium tergestinum* (Kutzing) Anagnostidis et Komárek(Pl. 2, Fig. M)

Komárek and Anagnostidis, 2005, p. 451, fig. 662.

Thallus leathery or membranous, soft attached to a substrate, free-floating, blackish brown to blackish steel blue; trichome straight or slightly curved, 6 µm broad, motile; cells 4.5 - 5 µm, contents homogenous, sometimes with large granules, apical cell rounded.

**Locality:** Ghaghra River, Sisaiya, Baharaich Road, Lakhimpur

**Collection number:** UP/LMP/21

Order- Nostocales, Borzi, 1914

Family –Fortieaceae Komárek et al., 2014

Genus- *Aulosira* O. Kirchner ex É. Bornet & C. Flahault, 1886

**3.30 *Aulosira fertilissima* var. *tenuis* Rao, C.B. (Pl. 2, Fig. N)**

Desikachary 1959, p. 431, pl. 80, figs. 2-5; Komárek, J., 2005, p. 861, fig. 1100.

Thallus expanded, membranous, dark, blue-green; trichomes straight or flexuous, parallel, densely intricate or rarely with very short pseudobranches; cells 7-12 × 12-13 µm, initially cylindrical but barrel-shaped at time of maturity, cell content granular with sheath thick; heterocysts intercalary, oblong or oval in shape.

**Locality:** Saryu River, 9 Km west from Nighasan, Lakhimpur

**Collection number:** UP/LMP/09

Family- Nostocaceae Eichler, 1886

Genus- *Nostoc* Vaucher ex Bornet & Flahault, 1886

**3.31 *Nostoc carneum* C. Agardh ex Bornet and Flahault (Pl. 2, Fig. O)**

Prescott, G.W., 1951, P. 380.

Thallus variously shaped, verrucose, blue-green, violet or brownish, filaments flexuous, loosely entangle sheath diffuent in inside, more or less distinct along the periphery, yellowish-brown; trichome 8 µm broad; cells cylindrical, barrel-shaped; heterocyst slightly globose or oblong 12 µm broad, somewhat longer than broad; spores oblong, epispore smooth, at first colourless then yellowish.

**Locality:** Sharda Canal, Murawan Purwa, Lakhimpur

**Collection number:** UP/LMP/06

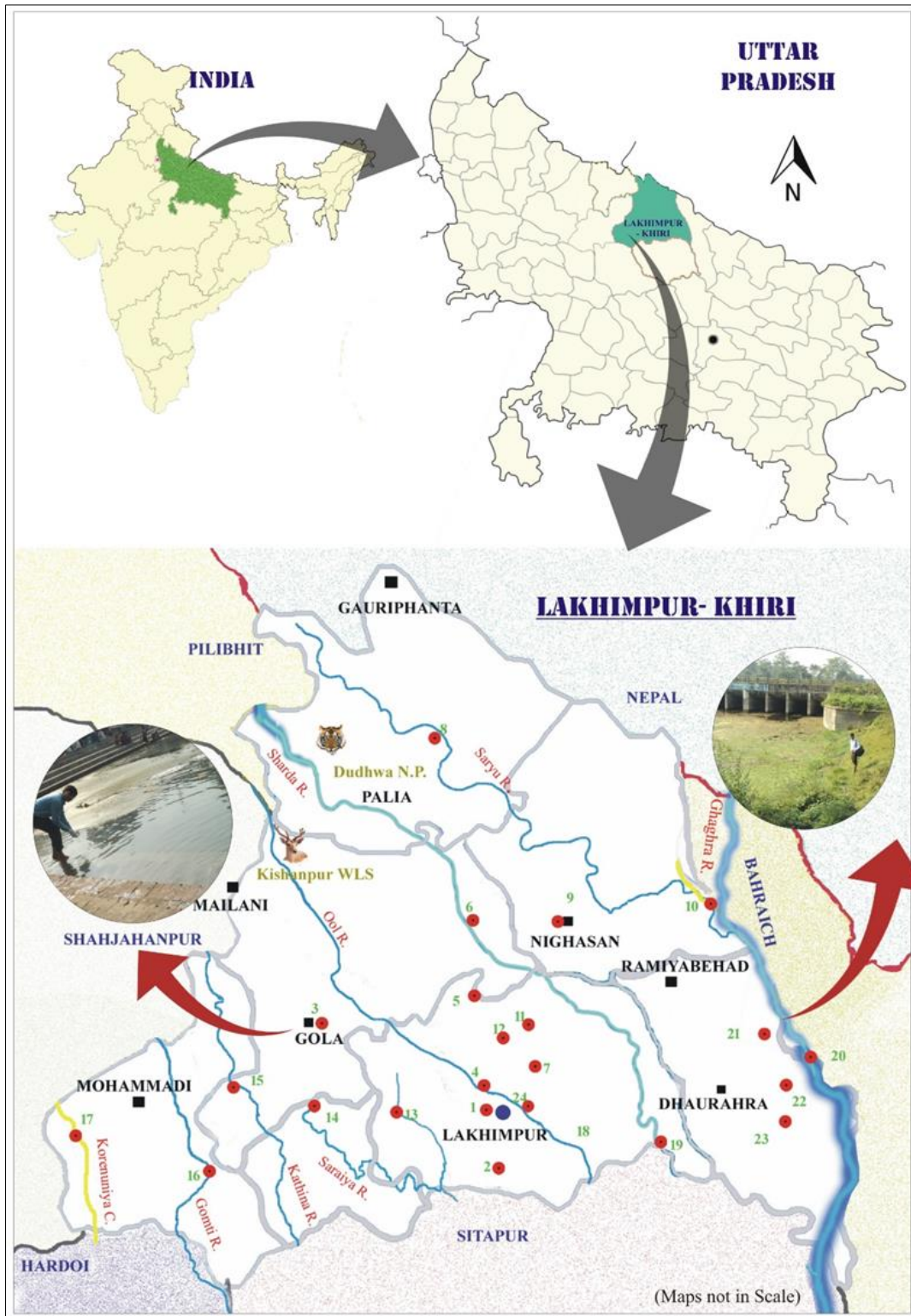
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#### **4. Results and Discussion**

A total of cyanophycean taxa belonging to 14 genera were identified from various samples collected from different water bodies. Out of 31, 10 species are new to Uttar Pradesh and they are first time reported from Lakhimpur-Khiri district. Members of the family Oscillatoriaceae occur in dominance; especially species of *Oscillatoria* (7), *Phormidium* (4) and *Lyngbya* (3) are present in great abundance (Table-1). These findings show the significance of the present study. Heterocystous cyanophycean forms (e.g. *Aulosira fertilissima*, *Nostoc* and *Nostoc carneum*) have been reported during the study. These taxa are responsible for nitrogen fixation, thus enriching soil nutrients by fixing atmospheric Nitrogen gas into Ammonia, Nitrites (NO<sub>2</sub>) or Nitrates (NO<sub>3</sub>). This activity of microorganisms is beneficial to plants and can be used as bio-fertilizers.

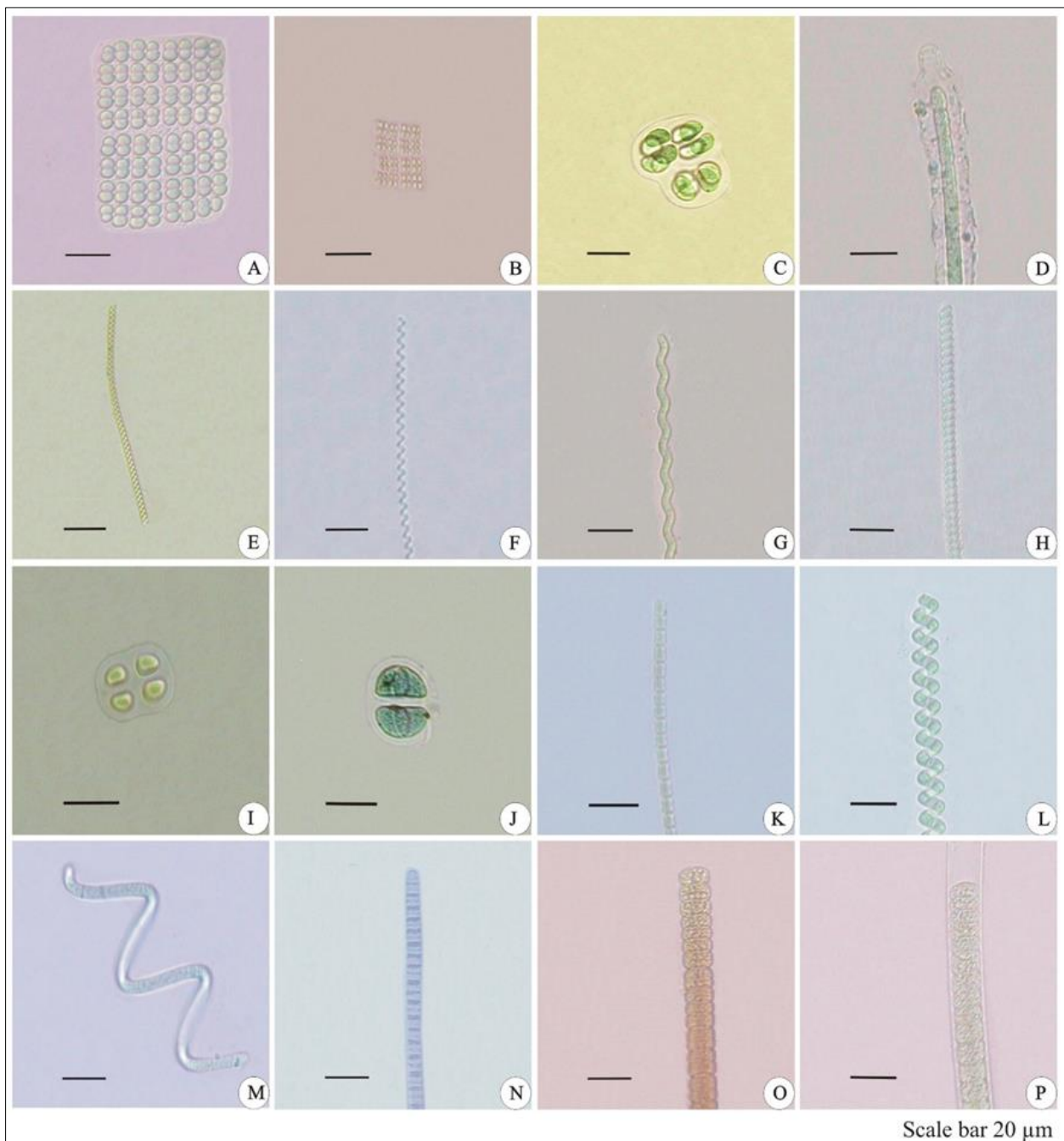
**Table 1** Algal species new to the studied area and Uttar Pradesh

S. No.	Species name	New to Lakhimpur-Khiri	New to U.P.
	<i>Merismopedia elegans</i>	Yes	
	<i>Merismopedia tenuissima</i>	Yes	
	<i>Limnococcus limneticus</i>	Yes	
	<i>Schizothrix tinctoria</i>	Yes	Yes
	<i>Spirulina labyrinthiformis</i>	Yes	
	<i>Spirulina meneghiniana</i>	Yes	
	<i>Spirulina princeps</i>	Yes	
	<i>Spirulina subsalsa</i>	Yes	
	<i>Chroococcus minutes</i>	Yes	
	<i>Chroococcus turgidus</i> var. <i>maximus</i>	Yes	
	<i>Komvophoron crissum</i>	Yes	Yes
	<i>Arthrospira gigantean</i>	Yes	Yes
	<i>Arthrospira platensis</i>	Yes	
	<i>Kamptonema formosum</i>	Yes	
	<i>Planktothrix planktonica</i>	Yes	Yes
	<i>Lyngbya ceylanica</i> var. <i>constricta</i>	Yes	Yes
	<i>Lyngbya natans</i>	Yes	Yes
	<i>Lyngbya truncicola</i>	Yes	
	<i>Oscillatoria curviceps</i>	Yes	
	<i>Oscillatoria limosa</i>	Yes	
	<i>Oscillatoria perornata</i>	Yes	
	<i>Oscillatoria princeps</i>	Yes	
	<i>Oscillatoria sancta</i>	Yes	
	<i>Oscillatoria subbrevis</i>	Yes	
	<i>Oscillatoria tenuis</i>	Yes	
	<i>Phormidium ambiguum</i>	Yes	
	<i>Phormidium amoenum</i>	Yes	Yes
	<i>Phormidium rimosum</i>	Yes	Yes
	<i>Phormidium tergestinum</i>	Yes	Yes
	<i>Aulosira fertilissima</i>	Yes	
	<i>Nostoc carneum</i>	Yes	Yes

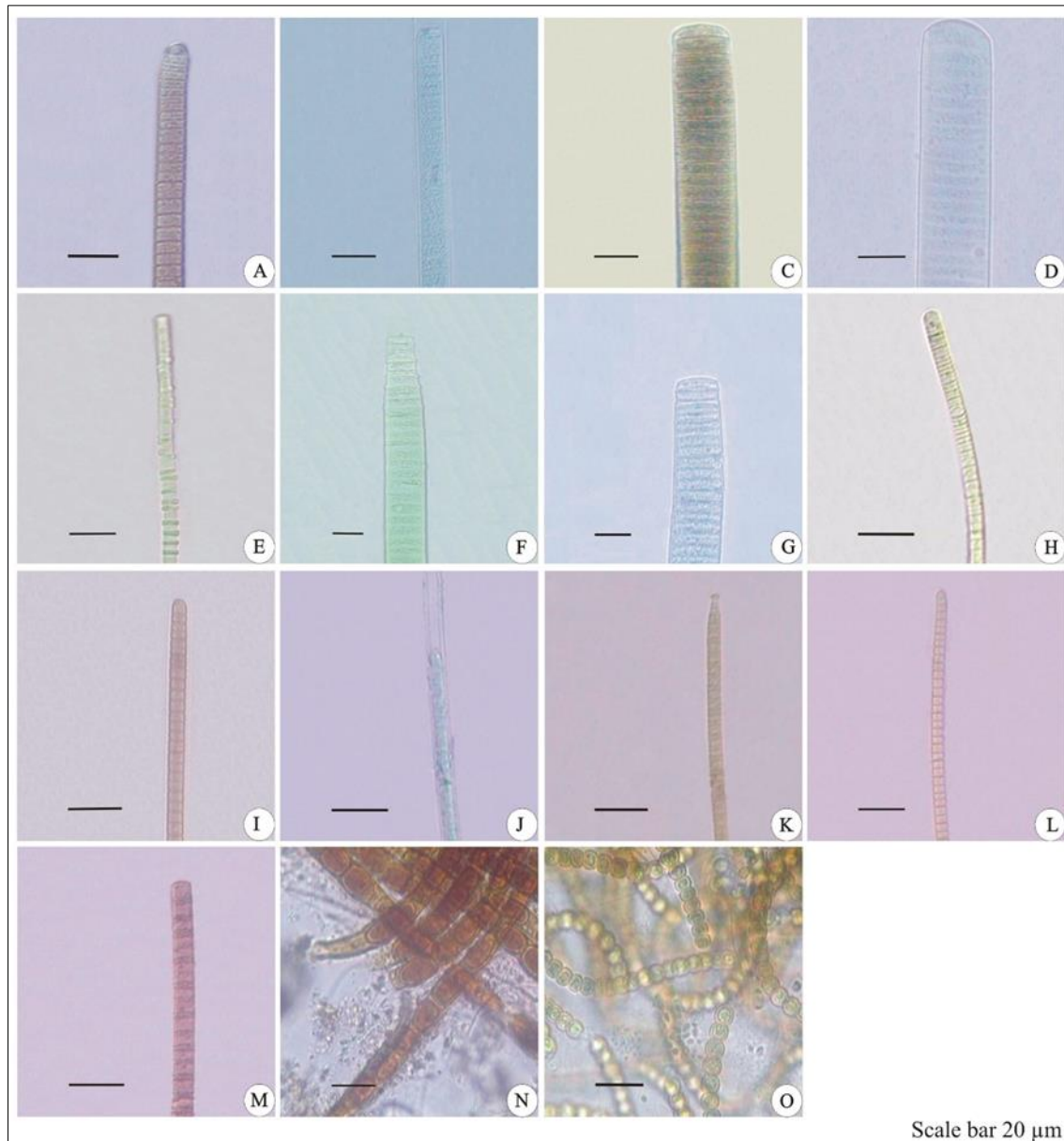


1. Lakhimpur crossing; 2. Mendhak Mandir, Oyl; 3. Gola Gokharnnath; 4. Sandwa River; 5. Sharda canal, Murawan purwa; 6. Sharda barrage and River; 7. Sukhni River; 8. Saryu River, 9 km west from Nighasan; 9. Jhauraha River, Nighasan; 10. Ghaghra feeder canal, Dhakerwa; 11. Jonai River; 12. Khannaut River, Lilaotinath Temple; 13. Jamauri River, Ranchorpur; 14. Saraiya River, Sikanderabad; 15. Kathina River, Sikanderabad; 16. Gomti River, Tedhenath Mandir; 17. Korekuniya choti canal, Mohamadpur; 18. Ool River, Baharaich-Lakhimpur road; 19. Sharda River, Ludhauni; 19. Ghaghra River, Sisaiya, Baharaich road; 21. Ghavar River, Ranjeet ganj; 22. Jashwant Nagar lake; 23. Sharda sahayak River, Ramahipul; 24. Deveshwar Nath Temple, Devkali.

**Figure 1** Map showing study area of Northern Uttar Pradesh and Lakhimpur- kheri district showing collection sites



**Plate-1** A. *Merismopedia elegans*, B. *Merismopedia tenuissima*, C. *Limnococcus limneticus*, D. *Schizothrix tinctoria*, E. *Spirulina labyrinthiformis*, F. *Spirulina meneghiniana*, G. *Spirulina princeps*, H. *Spirulina subsalsa*, I. *Chroococcus minutus*, J. *Chroococcus turgidus* var. *maximus*, K. *Komvophoron crissum*, L. *Arthrospira gigantea*, M. *Arthrospira platensis*, N. *Kamptonema formosum*, O. *Planktothrix planktonica*, P. *Lyngbya ceylanica* var. *constricta*.



**Plate 2** A. *Lyngbya natans*, B. *Lyngbya truncicola*, C. *Oscillatoria curviceps*, D. *Oscillatoria limosa*, E. *Oscillatoria perornata*, F. *Oscillatoria princeps*, G. *Oscillatoria sancta*, H. *Oscillatoria subbrevis*, I. *Oscillatoria tenuis*, J. *Phormidium ambiguum*, K. *Phormidium amoenum*, L. *Phormidium rimosum*, M. *Phormidium tergestinum*, N. *Aulosira fertilissima* var. *tenuis*, O. *Nostoc carneum*.

## 5. Conclusion

The Cyanophycean flora play a very important role in maintaining the nitrogen cycle in the ecosystem. In the present study 31 species have been recorded from different water bodies of Lakhimpur-Khiri region. The present study recorded both heterocystous and non- heterocystous algal forms and all these forms play an important role in nitrogen fixation. Therefore, they are important bio-fertilizer sources for improving the physico-chemical characteristics of soil such as water holding capacity and mineral nutrient status of degraded lands. In addition to nitrogen fixation, they are excellent accumulators or degraders of various environmental contaminants such as herbicides, heavy metals and pesticides. Thus, these cyanophycean algal forms can be used in environmental and agricultural practices as safe and environmentally friendly.

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## Compliance with ethical standards

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### *Disclosure of conflict of interest*

None.

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