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CERTAIN COMMERCIALY INTERESTING TAXA OF PHORMIDIOIDEAE, PHORMIDIACEAE (OSCILLATORIALES CYANOPROKARYOTE) FROM POLLUTED SITES OF MEERUT, UTTAR PRADESH, INDIA

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ABSTRACT

The present paper deals with the diversity of non-heterocystous filamentous blue-green algal taxa of the family Phormidiaceae, Oscillatoriales, Cyanoprokaryote. Blue-green algal samples were collected from three different polluted water reservoirs of Meerut, U.P., India and identified upto the species level. The present study revealed the occurrence of total 15 strains of 08 species of 4 genera of subfamily Phormidioideae of the family Phormidiaceae, Oscillatoriales, Cyanoprokaryote viz. *Arthrospira khannae*, *A. maxima*, *Planktothrix agardhii*, *P. clathrata*, *P. isothrix*, *Planktothricoides raciborskii*, *Tychonema bornetii* and *T. sequanum*. The study also revealed the occurrence of potential strains of non-heterocystous filamentous blue green algae from three polluted water reservoirs of Meerut, U.P., India. Three taxa *Planktothricoides raciborskii*, *Tychonema bornetii* and *T. sequanum* are being reported first time from India.

Keywords : Blue-green Algae, Pollutants, Water Reservoirs

INTRODUCTION

The blue-green algae (cyanoprokaryotes/Cyanobacteria) are prokaryotic, autotrophic microorganisms and are found growing in a wide range of habitats including fresh water, polluted water, drains, walls, mountains, moist soils, caves, thermal springs and sub-aerial habitats (Whitton and Potts, 2000). They are arranged into three groups viz. Unicellular, Non-heterocystous filamentous and heterocystous filamentous forms (Komárek and Anagnostidis, 2005). Komárek and Anagnostidis (2005) arranged all the non-heterocystous cyanoprokaryotes under order Oscillatoriales. The family Phormidiaceae is further divided into three subfamilies 1. Phormidioideae, 2. Microcoleoideae and 3. Ammatoideoideae. The subfamily Phormidioideae includes 10 genera. The members of family Phormidiaceae are characterised by presence of long filaments, isopolar trichomes and hormogonia formation by fragmentation with the help of necredic cells. The members of subfamily Phormidioideae have cylindrical and isopolar trichomes and one trichome per sheath. The aim of the present study was to explore the blue-green algal flora of different polluted habitats of Meerut, Uttar Pradesh, India and to find out potential strains to use them in biomining of nutrients from

polluted water bodies and their exploitation for biologically active compounds in future.

In this present investigation we have collected the water samples from three different water reservoirs located at three different sites of Meerut, U.P., India. The study sites included in the present study were 1. Kali River, Garh Road, Meerut; 2. Seasonal water reservoir, Malian, Meerut and 3. Seasonal water reservoir, Lal Kurti bazar, Meerut, U.P. India. All the three water bodies were polluted by three different sources of pollutants, Kali River was polluted by municipal and industrial waste; Seasonal water reservoir, Malian, Meerut site was polluted by organic material released from animal slaughter house and Lal Kurti Bazar, Meerut site was polluted by dairy waste. All the collected samples were observed microscopically and their morphological details were recorded and identified upto the species level. In the present paper, eight members of subfamily Phormidioideae of the family Phormidiaceae, Oscillatoriales, Cyanoprokaryote including *Arthrospira khannae*, *A. maxima*, *Planktothrix agardhii*, *P. clathrata*, *P. isothrix*, *Planktothricoides raciborskii*, *Tychonema bornetii* and *T. sequanum* are being reported and described from polluted water reservoirs of Meerut, U.P., India.

MATERIALS AND METHODS

The study sites of the present investigation were Kali River, Water reservoir, Malian, and Lal Kurti Bazar, Meerut, U.P. India. Total 183 water samples were collected from the three selected sites in vials (Polylab) during May 2018-February 2021. All the collected samples were mixed thoroughly by magnetic stirrer (RQT-127A/D, REMI) and 5 ml from each samples were inoculated into the nitrogenous and nitrogen deficient liquid BG-11 medium (Stanier *et al.*, 1971) and maintained under controlled culture conditions (Temperature $28 \pm 2^\circ\text{C}$; light 4-6 KLux, 14:10 h light: dark cycle) for one week. For morphological observation slides were prepared from collected water samples, enriched and unialgal cultures and were observed with help of Trinocular Research Microscope (Olympus, CH20i) attached with digital Camera (Magnus, Magcam-DC10) and their morphological details were recorded with the help of image analysis software (MagVision). All the isolated strains were identified with the help of available monograph (Komárek and Anagnostidis, 2005).

Morphological Description:

Arthrospira khanna Drouet et Strickland in Drouet (Fig. 4):

Arthrospira pellucidis Wang.

Thallus filamentous, trichomes solitary, free-floating, blue-green, 3-5.2 μm wide, regularly loosely screw-like coiled, not constricted or very slightly constricted at the granulated cross walls, slightly attenuated at the ends and capitate; coils about 20-22 μm wide, distance between spirals about 20-35 μm , cell content with aerotopes.

(Sample No. MTC-472; Collection Date: 05-09-2019; Habitat: Seasonal water reservoir; Site: Lalkurti Bazar, Meerut, U.P., India; $29^\circ 00' 12.2''\text{N}$; $77^\circ 42' 38.4''\text{E}$)

A. maxima Setchell et Gardner (Fig. 5)

Spirulina maxima (Setchell et Gardner) Geitler; *Spirulina geitleri* DeToni and sensu Fott & Karim; *Spirulina platensis* (Gomont) Geitler, *Oscillatoria pseudoplatensis* Bourrelly; *Spirulina maxima* Bernard.

Thallus filamentous, trichomes solitary, free-floating, grey-green, 6.5-10 μm wide, regularly loosely screw-like coiled, not constricted at the cross-walls, gradually slightly attenuated at the ends. Spirals sinistral, 40-60 μm wide, slightly narrowed towards ends. Distance between spirals 70-80 μm . Cells 5-7 μm long, with numerous aerotopes. Apical cells rounded with thickened outer cell wall.

(Sample No. MTC-572; Collection Date: 28-09-2019; Habitat: Seasonal water reservoir; Site: Malian, Meerut, U.P., India; $28^\circ 59' 57.6''\text{N}$; $77^\circ 38' 51.7''\text{E}$)

Planktothrix agardhii (Gomont) Anagnostidis et Komárek (Fig. 6)

Oscillatoria agardhii Gomont

Thallus filamentous, trichomes mostly solitary, free-floating, upto 300 μm long, straight or somewhat curved, sometimes joined to blue-green or olive green, microscopic, loose fascicles, occasionally forming benthic membranaceous coat (thallus), without sheaths, or very rarely and facultatively, especially in young stages, with fine sheaths.

Trichomes 2.3-9.8 μm wide, immotile, not constricted (or very slightly constricted) at the granulated cross-walls, gradually attenuated at the ends. Cells shorter than wide or frequently isodiametric, 2.3-9.8 μm wide and 4.6-19.6 μm long; cell content blue-green, with numerous aerotopes. Apical cells convex, often bluntly-conical or pointed, occasionally with convex calyptra, rarely capitate.

(Sample No. MTC-472; Collection Date: 05-09-2019; Habitat: Seasonal water reservoir; Site: Lalkurti Bazar, Meerut, U.P., India; $29^\circ 00' 12.2''\text{N}$; $77^\circ 42' 38.4''\text{E}$)

P. clathrata (Skuja) Anagnostidis et Komárek (Fig. 7)

Oscillatoria mougeotii var. *clathrata* skuja

Thallus filamentous, trichomes solitary, free-floating, forming blackish blue-green strata on mud; trichomes \pm straight or slightly flexuous, slightly constricted at cross-walls, cylindrical, 5-9 μm wide, slightly motile. Cells always shorter than wide, 2-3 μm long, blue green, with aerotopes. Apical cells cylindrical, widely-rounded, without, calyptras or thickened cells walls.

(Sample No. MTC-572; Collection Date: 28-09-2019; Habitat: Seasonal water reservoir; Site: Malian, Meerut, U.P., India; $28^\circ 59' 57.6''\text{N}$; $77^\circ 38' 51.7''\text{E}$)

P. isothrix (Skuja) Komárek et Komarkova (Fig. 8)

Planktothrix mougeotii (Bory ex Gomont) Anagnostidis et Komárek; *Oscillatoria agardhii* var. *isothrix* Skuja; *Oscillatoria mougeotii* Bory ex Gomont (*Phormidium formosum*)

Thallus filamentous, trichomes free-floating, solitary, usually straight or somewhat slightly curved, rarely in small clusters without definite arrangement, usually very long (up to 3.5mm), blue-green or grey-green, 5.5-10 μm wide, slowly motile with peculiar oscillation, very slightly constricted at the usually inconspicuous cross-walls, but with a single row of prominent granules on each side, cylindrical and not attenuated at the ends. Cells slightly shorter than wide or nearly isodiametric, 1-5.5 μm long, with irregular aerotopes. Apical cells cylindrical and widely-rounded or flat-rounded, rarely slightly conical.

(Sample No. MTC-1072; Collection Date: 20-02-2021; Habitat: Kali River; Site: Garh Road, Meerut, U.P., India; $28^\circ 56' 52.1''\text{N}$; $77^\circ 45' 53.4''\text{E}$)

Planktothricoides raciborskii (Woloszynska) Suda et Watanabe (Fig. 9)

[syn.: *Oscillatoria raciborskii* Woloszynska; *Planktothrix raciborskii* (Woloszynska) Anagnostidis et Komárek]

Thallus filamentous, trichomes solitary, yellowish-green, 5.4-12.2 μm wide, shortly attenuated at the ends and curved, occasionally with fine sheaths; apical cells conical or bluntly-pointed to rounded.

(Sample No. MTC-865; Collection Date: 26-02-2020; Habitat: Kali River; Site: Garh Road, Meerut, U.P., India; $28^\circ 56' 52.1''\text{N}$; $77^\circ 45' 53.4''\text{E}$)

Tychonema bornetii (Zukal) Anagnostidis et Komárek (Fig. 10)

Lyngbya bornetii Zukal; *Oscillatoria bornetii* (Zukal) Forti

Thallus filamentous, trichomes in fine, mat like mucilaginous thallus, olive-green, variously shaped. Trichomes straight or slightly curved, cylindrical and narrowed towards end, rarely with thin sheaths, 9.5-16 µm wide. Cells nearly isodiametric, rarely somewhat longer than wide, mostly 3.7-10.9 µm long and 1.2-7.2 µm wide, mostly ± colourless or pinkish to olive green, rarely to violet. Apical cells widely- rounded, hemispherical, or flat-rounded, feebly capitate, with slightly thickened outer cell wall.

(Sample No. MTC-1072; Collection Date:20-02-2021; Habitat: Kali River; Site: Garh Road, Meerut, U.P., India; 28°56'52.1"N; 77°45'53.4"E)

T. sequanum (Coute) Angnostidis et Komárek (Fig. 11)

[syn.; *Oscillatoria exilis* var. *sequana* Coute]

Thallus filamentous, trichomes solitary, straight, slightly constricted at cross-walls, slightly curved and rounded at the ends, 2.5-5 µm wide; cells isodiametric to longer than wide, with distinctly keratomized ("vacuolized") content, 4-6 µm long.

(Sample No. MTC-1075; Collection Date: 12-03-2021; Habitat: Kali River; Site: Garh Road, Meerut, U.P., India; 28°56'52.1"N; 77°45'53.4"E)

DISCUSSIONS

Ever since it came to the knowledge that Blue-green algae can fix atmospheric nitrogen and may save chemical fertilizer upto some extent (De,1939), they become more charismatic microbes for the scientists all over the globe (Singh, 1961; Stewart *et al.* 1968; Roger and Kulasooria, 1980; Spiller and Gunasekaran, 1990; Yamaguchi, 1997; Whitton and Potts, 2000). In India, the blue-green algae have been studied in quite details (Mitra, 1951; Desikachary, 1959; Bharadwaja, 1963; Pandey and Mitra, 1965; Vashishta, 1965; Singh and Chaturvedi, 1970; Kamat, 1972; Tiwari, 1972, Grover and Pandhol, 1975; Sinha and Mukharjee, 1975; Tiwari and Pandey, 1976; Dabral *et al.*, 1978; Prasad and Mehrotra, 1978, 1979, 1980; Pandey and Chaturvedi, 1979; Prasad and Srivastava, 1985; Pandey and Tripathi, 1987, 1988; Anand, 1989; Santra and Pal, 1991; Prasad and Misra, 1992; Santra, 1993; Tiwari *et al.*, 2000; Kumawat and Jawale, 2001, 2006; Hazarika *et al.*, 2002; Tiwari, *et al.*, 2004; Kant *et al.*, 2005, 2006; Mishra and Srivastava, 2005; Adhikary, 2007; Dhingra and Ahluwalia, 2007; Tiwari *et al.*, 2007, 2013, Mishra *et al.*, 2008; Kant *et al.*, 2020a-b; Sarma *et al.*, 2020) but most of them have ignored Meerut and adjoining area except few (Kumar, 1970; Bendre and Kumar, 1975) and could not cover most of the area or specialised habitats of Meerut of Western U.P., India.

Globally, Geitler (1932) classified the members of non-heterocystous filamentous Blue-green algae into single order, single family and 18 genera. Desikachary (1959) described non-heterocystous Blue-green algae from India by following the classification of Geitler (1932) and arranged all non-heterocystous filamentous forms into single order Oscillatoriales, single family Oscillatoriaceae and 16 genera. Drouet (1968) studied the Oscillatoriales in detail from the samples collected from nature and culture; and arranged non-heterocystous filamentous blue-green algae into single family, 6 genera and 24 species. Recently, Komárek and Anagnostidis (2005) compiled an exclusive detail on Oscillatoriales covering world genera and they arranged all the taxa in a single order, 6 families and 12 sub-families; 50 genera.

Kumar (1970) surveyed Sardhana and adjoining area of Meerut, Western U.P., India and reported 106 species of 22 genera of blue-green algae but ignored members most of the members of Phormidiaceae and reported only two species of *Arthrospira*. In addition, Bendre and Kumar (1975) made exhaustive floristic survey and reported 131 taxa of blue-green algae from Meerut and adjoining area, and out of which 9 species were of *Phormidium* and two species of *Arthrospira* of Phormidiaceae. In present study, we are reporting 8 taxa of the family Phormidiaceae of order Oscillatoriales, cyanoprokaryotes from three different polluted water reservoirs from Meerut, U.P., India and out them three taxa *Planktothricoides raciborskii*, *Tychonema bornetii* and *T. sequanum* are being reported first time from India.

Arthrospira species are one of the commercially interesting blue green algae and are being cultivated in large scale all over the globe and contributing significantly to the economy of the many countries. There are 44 species of *Arthrospira* are known globally and out them 20 have been accepted taxonomically. The *Planktothricoides* is very less studied taxa and total 2 species of *Planktothricoides* are known globally and have been accepted taxonomically. *Planktothrix* is another genus of the group and 21 species of *Planktothrix* are known globally and out of them 16 have been accepted taxonomically. *Tychonema* is another genus of the Oscillatoriales and 10 species are known globally and out of them 6 have been accepted taxonomically in AlgaeBase (Guiry and Guiry, 2021). In present investigation we are reporting three taxa *viz.* *Planktothricoides raciborskii*, *Tychonema bornetii* and *T. sequanum* first time from India.

CONCLUSIONS

In present study, it is concluded that polluted habitats of Meerut, U.P., India have very rich algal flora and harbour good numbers of many useful blue-green algal strains and form algal bloom in water reservoirs. Many of these bloom forming genera may be potential candidate of value added natural products and can be exploited at commercial scale.

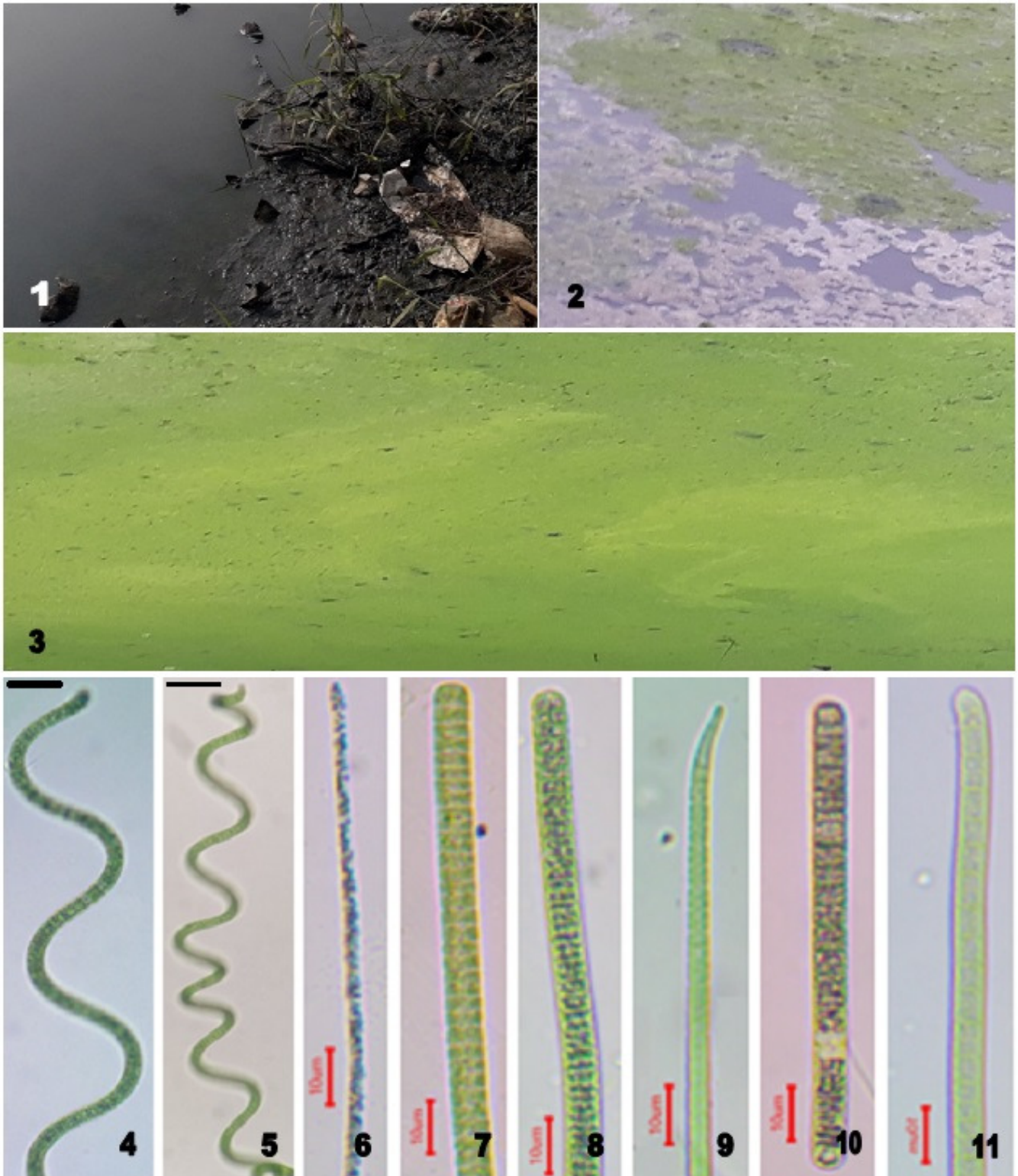
**Explanation of Figures 1-11:**

Fig. 1 : Kali river site with polluted water and growth of mixed pollution of blue-green algae

Fig. 2 : Water reservoir, Modinagar site with mixed pollution of algae bloom

Fig. 3 : Seasonal Water reservoir, Lal Kurti bazaar, Meerut site with dairy waste, domestic animals and with algae bloom

Fig. 4 : *Arthrospira khannae*

Fig. 5 : *A. maxima*

Fig. 6 : *Planktothrix agardhii*

Fig. 7 : *P. clathrata*

Fig. 8 : *P. isothrix*

Fig. 9 : *Planktothricoides raciborskii*

Fig. 10 : *Tychonema bornetii*

Fig. 11 : *T. sequanum*

Scale Bar Fig.4= 20 μ m and Fig.5=30 μ m

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