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Diversity of cyanobacteria from freshwater bodies of krishnagar sadar subdivision of Nadia District, West Bengal, India

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Abstract

Cyanobacteria are photosynthetic prokaryotes that originated 3.5 billion years ago and are distributed throughout the world where moisture and light is available. A systemic survey of cyanobacteria was carried out in different freshwater bodies of Krishnagar Sadar subdivision of Nadia district, West Bengal throughout the year 2021. Krishnagar Sadar subdivision covers a vast area of 1,661.10km^2.The subdivision is totally surrounded by the river Ganga locally known as Bhagirathi and gives rise to many freshwater bodies which are the main reservoirs of many types of cyanobacteria. During this survey samples were collected from different freshwater bodies mainly rivers, drains, ponds, jheel, rice fields etc. Altogether 35 heterocystous and non-heterocystous cyanobacterial forms belonging to the 21 genera were documented from these freshwater bodies of the Krishnagar Sadar subdivision. The most common and dominant cyanobacterial genera were *Oscillatoria* representing 8 species followed by *Gloeothece*, *Gloeocapsa*, *Chroococcus*, *Phormidium*, *Anabaena*, *Cylindrospermum* and *Nostoc* each with two species. *Merismopedia*, *Aphanothece*, *Aphanocapsa*, *Lyngbya*, *Pseudanabaena*, *Westiellopsis*, *Nostochopsis*, *Stigonema*, *Tolypothrix*, *Calothrix*, *Gloeotrichia* and *Rivularia* with one species each.

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Introduction

Cyanobacteria are autotrophic prokaryotic organisms and they are among the most successful life forms present on the earth and are found throughout the world and can grow in any type of environment where light and moisture are available. (Schopf & Bonnie., 1987, Schopf., 2000).Cyanobacteria are also important members of symbiotic relationships with lichens, plants and other phototrophs (Villanueva *et al.*, 2018). Cyanobacteria are the primary producers of all types of habitat and produce 80% earth oxygen. (Srivastava., 2014). Morphologically cyanobacteria are unicellular to colonial (Chroococcales), with multicellular filaments (Oscillatoriales), with heterocystous trichomes with or without false branching (Nostacales) and with true branching (Stigonematales).

In West Bengal, a systematic survey of cyanobacteria was done by various workers. A systematic survey of cyanobacteria started in West Bengal in the late 18th century. Martens GV published three lists of Bengal algae including Kolkata flora (Martens GV., 1870a, 1870b, 1871). Prain in 1905 reported the algae flora of Hooghly, Howrah and South 24 Pargans (Prain., 1905). The algal flora of Bengal filter beds were studied by Bruhl & Biswas (Bruhl & Biswas., 1922), Biswas reported algal flora of Kolkata mainly Salt lake and Hooghly rivers (Biswas., 1925,1926,1942). Banerjee studied Myxophyceae of lower Bengal (Banerje., 1936, 1938). Gupta D recorded some new cyanobacteria in West Bengal in a series of publications (Gupta., 1965, 1975). Mukhopadhyay A and Chatterjee P reported a check list of blue green algae of the paddy fields of West Bengal (Mukhopadhyay & Chatterjee., 1981). Sen and Gupta reported different types of *Oscillatoria* from the Greater Calcutta and lower gangetic plains of West Bengal (Sen & Gupta., 1987, 1998). Sen and Naskar published the algal flora of Sundarban (Sen & Naskar., 2003). Mukhopadhyay & Naskar reported 17 cyanobacterial taxa from Metiabruz, Kolkata (Mukhopadhyay & Naskar., 2013). Banerjee and Pal reported 50 cyanobacterial taxa from different areas of West Bengal (Banerjee & Pal., 2017). Dey and Chakraborty reported different types of filamentous non-heterocystous cyanobacteria from Bidhannagar, North 24 Parganas.(Dey & Chakraborty., 2020). Very little work has been done on diversity of algal flora of Nadia district, Keshri *et al.* in 2013 studied phytoplanktonic diversity Baishar beel at Nadia district and reported 8 cyanobacterial taxa (Keshri *et al* 2013). As very little information is available on the freshwater cyanobacterial diversity of Nadia district of West Bengal, an attempt has been made to study the diversity of cyanobacteria from freshwater bodies of Krishnagar Sadar subdivision of Nadia district, West Bengal, India.

Material and methods

Study area

The studies were conducted from different Freshwater bodies of Krishnagar Sadar subdivision, Nadia, West Bengal, India. Krishnanagar Sadar subdivision is an administrative subdivision of Nadia district West Bengal, India. Covers a vast area of 1,661.10km²almost half of the district, the sub division lies in the eastern side of the state lies between 23° north Latitude and 88° east Longitude with average elevation 14 meters. Krishnanagar Sadar subdivision is a part of the large alluvial plain formed by the Ganges-Bhagirathi system. Krishnagar sadar subdivision bounded by Bhagirathi River on the west side and the Purba Bardhaman district lying across the river. A portion of the east forms the boundary with Bangladesh. The long stretch along the Bhagirathi has many swamps. The soil type of krishnagar sadar subdivision is mostly alluvial, due to the presence alluvial soil agriculture is the main source of income and rice is the main agricultural crops.

Collection and identification of samples

Samples were collected from different freshwater bodies, mainly river, drains, ponds, rice fields etc. from Krishnagar Sadar subdivision of Nadia district. Sampling was done with the help of fine forceps, scalpel, sampling bottles and clean polythene bags, then immediately brought to the laboratory assigned with numbers and collection date for record in the field note book before they are processed. At the sampling sites we also measured the water pH via universal pH paper.

Temporary slides were prepared for each sample for identification and were observed under trinocular bright-field microscope with attachment of a digital camera and computer with software (Olympus CH20i and Carl Zeiss Primo Star Microscope). The samples were identified based on their morphological features like colour of thallus, cell shape and cell size, shape, size heterocyst and akinete following the standard monographs of Desikachary (1959), Prescott (1962), Anand (1989) and Komarek & Anagnostidis (2005).

Purification, Maintenance and Preservation of the Samples

Pure culture was obtained by serial dilution and agar plate methods (Kaushik., 1987). The samples were maintained by culturing in freshly prepared BG-11±N medium both in solid and liquid culture (Rippka *et al*., 1979). A part of each collected cyanobacterial samples were preserved in 4% formaldehyde solution and were also deposited in the Phycology laboratory, P.G. Department of Botany, Ramakrishna Mission Vivekananda Centenary College for future references.

Results and discussion

The present investigation has revealed the freshwater cyanobacterial diversity of Krishnagar Sadar subdivision in Nadia district, West Bengal, India. The pH of the water bodies was measured and ranged from 6.8 to 8.6. Isolated cyanobacterial samples were observed under a microscope and important characters such as shape and size of the vegetative cell, heterocyst, and akinete were measured and identified with the help of monographs. In this study altogether 35 non-heterocystous and heterocystous cyanobacterial forms belonging to 21 genera were characterized and enumerated (Fig. 1, A-U and Fig.2, A-N). Among the 35 cyanobacterial types 21 non-hetrocystous cyanobacteria representing 10 genuses were recorded.

Among 21 non-heterocystous cyanobacteria 9 were coccoid type and 12 were filamentous type. Among the 14 heterocystous 3 were true branching heterocytous and 2 were false branching heterocystous cyanobacteria were recorded. *Oscillatoria* are the most dominant genera representing 8 species followed by *Gloeothece*, *Gloeocapsa*, *Chroococcus*, *Phormidium*, *Anabaena*, *Nostoc* and *Cylindrospermum* each with two species.

Merismopedia, *Aphanothece, Aphanocapsa*, *Pseudanabaena*, *Lyngbya*, *Westiellopsis*, *Nostochopsis*, *Stigonema*, *Tolypothrix*, *Calothrix*, *Gloeotrichia*, *Scytonem* and *Rivularia* with one species each. Cyanobacteria generally prefer neutral to slightly alkaline pH for optimal growth. (Kaushik 1994., Domnic and Madhusoodanan., 1999).

Cyanobacteria are generally absent in slightly acidic pH below 4. In our present study cyanobacteria were found between 6.5-8.6pH. Dey and Chakraborty reported 32 non-hetrocystous cyanobacteria at pH between 6.8-8 (Dey and Chakraborty,. 2021). Nayak and Prasanna reported that the majority of the cyanobacteria present are between 8.2-8.6pH (Nayak and Prasanna, 2007). Heterocytous cyanobacteria play an important role in rice field soil fertility. They can fix atmospheric nitrogen. In our present study 14 heterocystous cyanobacteria were found from rice fields.

Enumeration of cyanobacteria

Gloeothece samoensis Wille Fig. 1 A; Anand (1989), page: 27, Fig. 27. Colonies single forming expanded mass, sheath lamellated , cells ellipsoidal,5-7µm board.

Gloeothece sp. Fig. 1 B; Colonies many forming expanding mass with a number of concentric envelops, sheath lamelated, cells are ellipsoidal boardly rounded.

Gloeocapsa polydermatica Kützing Fig. 1 C; Anand (1989), page: 27, Fig. 24. Colonies 1-2, forming expanded mass of cell spherical, with a number of concentric envelops, cells upto 5µm board.

Gloeocapsa nigrescens Nägeli Fig.1 D; Desikachary (1959), Page: 117, Plate: 24, Fig. 15. Colonies single to many forming expanded mass, cells spherical with prominent sheath cells upto13.5µm diameter.

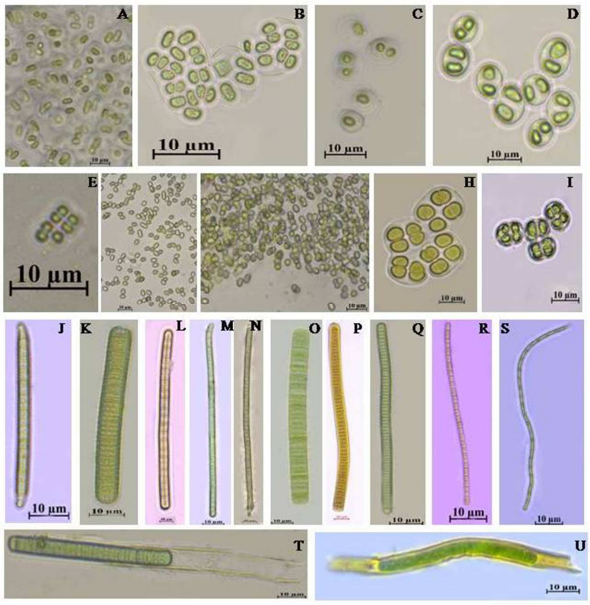

Fig. 1. (A-U) A- *Gloeothece samoensis* Wille. B- *Gloeothece* sp. C- *Gloeocapsa polydermatica* Kützing. D- *Gloeocapsa nigrescens* Nägeli. E- *Merismopedia elegans* A. Braun ex Kützing. F- *Aphanothece stagnina* (Spreng) A. Br G- *Aphanocapsa pulchra* (Kutz.) Rabenh. H- *Chroococcus tenax* (Kirchn.) Hieron. I- *Chroococcus indicus* Zeller. J- *Oscillatoria acuminata* Gomont. K- *Oscillatoria irrigua* Kützing ex Gomont. L-*Oscillatoria sancta* Kützing ex Gomont. M- *Oscillatoria earlei* Gardner (after Gardner). N- *Oscillatoria acutissima* Kufferath. O- *Oscillatoria vizagapatensis* C.B.Rao. P- *Oscillatoria subbrevis* Schmidle. Q- *Oscillatoria willei* Gardner em. Drouet. R- *Pseudanabaena limnetica* (Lemmermann) Komárek. S- *Phormidium tenue* (Menegh.) Gomont. T- *Phormidium ambiguum* Gomont. U- *Lyngbya majuscula* Harvey ex Gomont.

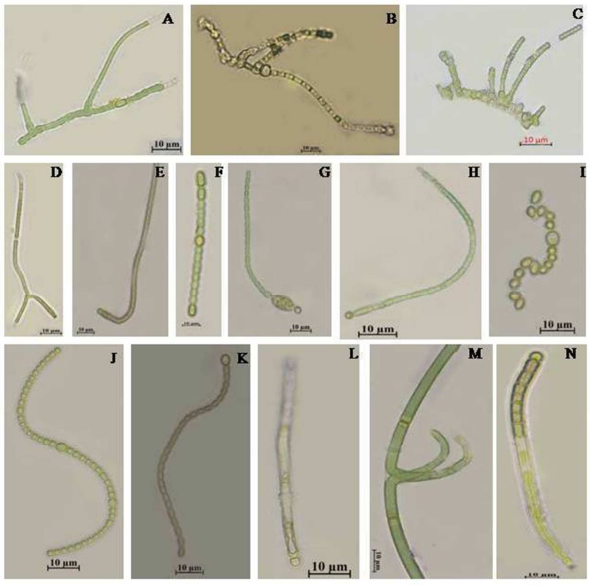

Fig. 2. (A-N) A- *Westiellopsis prolifica* Janet. B- *Nostochopsis lobatus* Wood em. Geitler. C-*Stigonema dendroideum* Frémy. D- *Tolypothrix distorta* Kützing ex Bornet & Flahault. E- *Calothrix clavata* G.S.West. F- *Anabaena anomala* Fritsch. G- *Cylindrospermum muscicola* Kützing ex Bornet & Flahault. H- *Cylindrospermum stagnale* Kütz. ex Bornet & Flahault. I- *Nostoc linckia* (Roth) Bornet & Thur. J- *Anabaena oryzae* Fritsch. K- *Nostoc muscorum* Ag. ex Born. et Flah. L- *Gloeotrichia raciborskii* Wołoszyńska. M- *Scytonema simplex* Bharadwaja. N- *Rivularia aquatica* De Wildeman.

Merismopedia elegans A.Braun ex Kützing Fig. 1, E; Prescott(1962), Page: 459, Plate: 101, Fig. 1. Colonies irregularly loosely arranged small, 2-4 rows in a single plane, cells slightly spherical, cells 5-7µm board and 6-9µm long.

Aphanothece stagnina. (Spreng) A. Br Fig. 1, F; Desikachary(1959), Page: 137, Plate: 21, Fig. 10. Thallus mucilaginous, cells slightly ellipsoidal to oval, blue green in colour, cells up to 6.5µm boards.

Aphanocapsa pulchra (Kutz.) Rabenh Fig. 1, G; Anand(1989), page: 22, Fig. 3. Colony gelatinous, cells spherical loosely arranged, pale blue green colour with individual sheath, 3-5µm diameter.

Chroococcus tenax (Kirchn.) Hieron Fig., 1. H; Desikachary(1959), Page: 103, Plate:26, Fig. 16.Cells are in small group mostly 2-4 blue green in colour, verydistinctly lamellated,cells 20-26µm long.

Chroococcus indicus Zeller Fig. 1, I; Anand (1989), page: 25, Fig. 12. Cells spherical,in a group of 4 with a thin sheath 6-15µm in diameter. Sheath not lamellated colourless.

Oscillatoria acuminata GomontFig. 1 J; Desikachary (1959), Page: 240, Plate: 38, Fig. 7. Thallus blue green, trichomes straight, end sharply bent pointed,5-6µm long without calyptras.

Oscillatoria irrigua Kützing ex Gomont; Fig., 1. K; Anand (1989), page: 40, Fig. 78. Thallus blackish blue green, trichomes straight end cell slightly convex, with a thick outer membrane, 6-13µm board.

Oscillatoria sancta Kützing ex Gomont Fig., 1. L; Prescott (1962), Page: 490, Plate: 110, Fig. 4. Thallus dark blue, slightly gelatinous, trichomes straight, not curved or bent towards the end, 10-22µm long, 3-6µm board.

Oscillatoria earlei Gardner (after Gardner) Fig. 1, M; Desikachary (1959), Page: 238, Plate: 38, Fig. 15. Trichomes straight, curved at the end, not constricted at the cross wall, 2-2.5µm board.

Oscillatoria acutissima Kufferath Fig. 1, N; Prescott (1962), Page: 484, Plate: 108, Fig.15 Trichomes solitary gradually tapering at the apex slightly bent apical cell acute, cells 2µm diameter, not constricted with the cross wall.

Oscillatoria vizagapatensis C.B.Rao Fig. 1, O; Desikachary (1959), Page: 205, Plate:39, Fig. 16 Thallus blue green trichomes straight, cells broadly rounded with a thickend outer wall, trichomes 8-10.8µm board.

Oscillatoria subbrevis Schmidle Fig. 1, P; Desikachary (1959), Page: 207, Plate: 37, Fig. 2 Trichomes straight not tapering towards the apex, end cell rounded withoutcalyptras, trichomes 1-2µm and 5-6µm board.

Oscillatoria willei Gardner em. Drouet. Fig. 1, Q; Desikachary (1959), Page: 217, Plate: 40, Fig. 5. Trichomes pale blue green, 2-6µm board, constricted at the crosswalls, ends not capitates, and end cells rounded without a thickened membrane.

Pseudanabaena limnetica (Lemmermann) Komárek Fig. 1, R; Komárek (2005), Page: 84, Fig. 60. Trichomes solitary, slightly curved, single not forming a thallus, without sheath, cells cylindrical 2-4µm wide.

Phormidium tenue (Menegh.) Gomont Fig. 1, S; Desikachary (1959), Page: 259, Plate:43, Fig. 13. Thallus blue green trichomes slightly bent 1-3µm board septa not granulated.

Phormidium ambiguum Gomont Fig. 1, T; Anand (1989), page: 41, Fig. 105. Thallus more or less expanded, trichomes slightly constricted at the cross wall, 4-6µm board, sheath thin, end cell rounded, calyptras absent.

Lyngbya majuscula Harvey ex Gomont 1892 Fig. 1, U; Desikachary (1959), Page: 313, Plate: 48, Fig. 7. Filament long straight, trichomes bluish green not constricted, cell 22-40µm board, sheath hyaline.

Westiellopsis prolifica Janet. Fig. 2, A; Anand (1989), page: 58, Fig. 186. Filaments loosely entangled with short barrel shaped cylindrical cell, lateral branchesclearly seen, latetral branches thinner and elongated, main filament 5-10µm board, heterocyst oblong to cylindrical, 5-6µm board, 10-20µm long.

Nostochopsis lobatus Wood em. Geitler Fig. 2, B; Anand (1989), page: 58, Fig. 185. Thallus spherical, more or less irregularly lobed, sparsely branched with lateral branches,cells are slightly barrel shaped 3-5.5µm board. Heterocyst intercalary 6-9µm board.

Stigonema dendroideum Frémy Fig. 2, C; Desikachary (1959), Page: 609, Plate: 137, Fig. 3, 4. Thallus extended filaments creeping entangled, richly branches with secondary branching, cells 13-20µm board, heterocyst sparse intercalary.

Tolypothrix distorta Kützing ex Bornet & Flahault Fig. 2, D; Desikachary (1959), Page: 495, Plate: 102, Fig. 1. Thallus expanded blue green colour, filaments showing false branching, sharply erect, heterocyst single nearly spherical, and filament 9-10µm board.

Calothrix clavata G.S.West Fig. 2, E; Anand (1989), page: 55, Fig. 174. Filaments group of small bundles, sheath very thin, heterocyst at the basal position, single basal position heterocst 2-4µm board.

Anabaena anomala Fritsch Fig. 2, F; Desikachary (1959), Page: 398, Plate: 73, Fig. 2. Thallus mucilaginous, trichomes irregularly arranged, cells rounded, cells 2-3µm board. Heterocyst intercalary 3-6µm board.

Cylindrospermum muscicola Kützing ex Bornet & Flahault Fig. 2, G; Desikachary (1959), Page: 366, Plate: 65, Fig. 3. Thallus mucilaginous, trichomes uniform width cells cylindrical,cells 3-5.5µmlong. Large akinete is present next to the terminal hetrocyst, heterocyst 4-5µm board and 5-7.5µm long.

Cylindrospermum stagnale Kütz. ex Bornet & Flahault. Fig. 2, H; Prescott (1962), Page: 531, Plate: 122, Fig. 16. Thallus mucilaginous, trichomes constricted at the cross wall, cells slightly swollen 3-5µm board, and heterocyst terminal globular 5-7µm in diameter. Akiente is present adjacent to the heterocyst.

Nostoc linckia (*Roth*) *Bornet* & Thur Fig. 2, I; Prescott (1962), Page: 523, Plate: 119, Fig. 15. Thallus gelatinous irregularly expanded, cells are slightly sub globose 3-4.5µm board. Heterocyst sub spherical 6-7µm board, 7-8µm long.

Anabaena oryzae Fritsch. Fig.2. J; Desikachary (1959), Page 396, Plate: 72, Fig. 3. Thallus soft green, gelatinous, trichome short, straight, generally parallel cells 2-3µm broad, more or less barrel shaped, 1-2 times as long as broad, heterocysts terminal and intercalary.

Nostoc muscorum Ag. ex Born. et Flah Fig. 2, K; Desikachary (1959), Page: 385, Plate: 70, Fig. 2. *Thallus mucilaginous membranous trichomes µm* board, cells slightly barrel shaped, heterocyst nearly spherical 6-8µm board.

Gloeotrichia raciborskii Wołoszyńska Fig. 2, L; Desikachary (1959), Page: 562, Plate: 118, Fig. 14. *Thallus spherical mucilaginous, trichomes 6-8*µm board,sheath at the base, heterocyst basal, spherical 5-6µm board.

Scytonema simplex Bharadwaja Fig. 2 M; Anand (1989), page: 53, Fig. 167. Thallus blue green irregularly bent loosely arranged, false branching present, branching single, heterocyst intercalary filaments up to 16µmboards.

Rivularia aquatica De Wildeman Fig. 2 N; Anand (1989), page: 56, Fig. 183. Filaments compactly arranged, sheath very thin, cells at the base broader, towards the end narrower, heterocyst basal oval 7-10.5µm boards, akinete absent.

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References

Anand N. 1989. Hand book of blue-green algae. Bishen Singh Mahendra Pal Singh, Dehradun 79 p.

Banerjee JC. 1936. Studies on the Myxophyceae of lower Bengal-I. The *Journal* of *Indian Botanical Society* **152,** 85-302.

Banerjee JC. 1938. Studies on myxophyceae of lower Bengal II. Journal of Department of Science Calcutta University **1,** 95-109.

Banerjee S, Pal R. 2017. Morphotaxonomic study of blue green algae from pristine areas of West Bengal with special reference to SEM studies of different morphotypes and four new reports. Phytomorphology **67,** 67-83.

Biswas K. 1926. Flora of the Salt lakes, Calcutta. Journal of Department of Science Calcutta University **8,** 1-47.

Biswas K. 1942. The role of common algal communities of the river Hoogly on the drinking water, Calcutta 150 Annals of the royal botanic garden, Calcutta 189- 206.

Biswas K.1925. Road slime of Calcutta. Journal of Department of Science Calcutta University **7,** 1-10.

Bruhl P, Biswas K. 1922. Algae of Bengal Filter beds. Journal of Department of Science Calcutta University **4,** 1-17.

Desikachary TV. 1959. Cyanophyta. Indian Council of Agricultural Research, New Delhi 686p.

Dey HS, Chakraborty S. 2020. Diversity of Non-Heterocystous Filamentous Cyanobacteria from Freshwater Bodies of Bidhannagar, North 24 Parganas, West Bengal. Asian Journal of Biological and Life Sciences **9(3),** 386-390.

Dominic TK, Madhusoodanan PV. 1999. Cyanobacteria from extreme acidic environments. Current Science **77(8),** 1021-1022.

Gupta D. 1965. Some new records of blue green algae from West Bengal-I. Bulletin of the Botanical Society of Bengal.**19(1),** 1-2.

Gupta D. 1975. Some new records of blue green algae from West Bengal-II. Bulletin of the Botanical Society of Bengal **29,** 29-31.

Kaushik BD. 1987. Laboratory Methods for Blue Green Algae. Associated Publishing Company. New Delhi 171p.

Kaushik BD. 1994. Algalization of rice in salt-affected soils. Annals of Agricultural Research **14,** 105-106.

Keshri JP, Ghosh S, Bhattacharyya S. 2013. A survey of phytoplankton diversity in Baishar beel of Nadia district of West Bengal. International Journal of Current Research and Review **5(19),** 8.

Komarek J, Anagnostidis K. 2005. Cyanoprokaryota- 2. Teil/ 2nd part : Oscillatoriales. Elsevier /Spektrum **19(2),** 759

Martens GV. 1870a. A third list of Bengal algae, determined by Dr. G.v. Martens, Professor of Botany in Stuttgard, communicated through Mr. S. Kurz. Proceedings of the Asiatic Society of Bengal 9-12.

Martens GV. 1870b. A fourth list of Bengal algae, determined by Dr. G.v. Martens, Professor of Botany in Stuttgard, communicated through Mr. S. Kurz. Proceedings of the Asiatic Society of Bengal 257-260.

Martens GV. 1871a. A fifth list of Bengal algae, determined by Dr. G.v. Martens, communicated by S. Kurz, Esq. Proceedings of the Asiatic Society of Bengal 170-173.

Mukhopadhyay A, Chatterjee P. 1981. A checklist of blue green algae from the paddy fields of 24-parganas and Howrah districts of West Bengal-I. Phykos **20(1&2),** 81-84.

Mukhopadhyay ST, Naskar N. 2013. Study on the occurrence of algae from Metiabruz, Kolkata, and West Bengal, India. Journal of Biodiversity and Environmental Sciences **3(1),** 1-6.

Nayak S, Prasanna R. 2007. Soil pH and its role in cyanobacterial abundance and diversity in rice field soils. Applied ecology and environmental Research **5(2),** 103 - 113.

Prain D. 1905. The vegetation of the districts of Hughli-Howrah and the 24-Pergunnahs. *Records of the Botanical Survey of India* **3,** 143-339.

Prescott GW. 1962. Algae of the Western Great Lakes Area.2nd Ed. W.M.C. Brown Company Publishers, Dubuque Lowa 982p.

Rippka R, Deruelles J, Waterbury JB, Herdman M, Stanier RY. 1979. Generic assignments, strain histories and properties of pure cultures of cyanobacteria. Microbiology **111(1),** 1-61.

Schopf JW, Bonnie MP. 1987. Early Archean (3.3-billion to 3.5-billion-year-old) microfossils from Warrawoona Group, Australia. Science **237,** 70-73.

Schopf JW. 2000. The fossil record: tracing the roots of the cyanobacterial lineage. The ecology of cyanobacteria. Springer, Dordrecht 13-35.

Sen CR, Gupta D. 1987. The genus *Oscillatoria* Vaucher from Greater Calcutta. Bull. Bot. Soc. Bengal **41(1),** 41-45.

Sen CR, Gupta DD. 1998. The genus *Oscillatoria* Vaucher from Lower Gangetic Plains of West Bengal. Phykos **37(1&2),** 89-93.

Sen N, Naskar KR. 2003. Algal flora of Sundarbans Mangals. Daya Publishing House, New Delhi 1-317.

Srivastava N, Suseela MR, Toppo K. 2014. Freshwater cyanobacteria of Sai River near Lucknow, Uttar Pradesh. Tropical Plant Research **1(2),** 11-16.

Villaneuva CD, Hašler P, Dvořák P, Poulíčková A, Casamatta DA. 2018. *Brasilonema lichenoides* sp. nov. and *Chroococcidiopsis lichenoides* sp. nov. (cyanobacteria): two novel cyanobacterial constituents isolated from a tripartite lichen of headstones. Journal of Phycology **54,** 224–233.