Journal of
Plant Science & Research

Open Science Publications

Volume 9, Issue 2 - 2022

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Heterocystous Cyanoprokaryotes: *Anabaena* Bory ex Bornet et Flahault and *Trichormus* (Ralfs ex Bornet et Flahault) Komárek et Anagnostidis (Nostocaceae, Nostocales) from Tripura, India

Research Article

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Article Information: **Submission:** 04/07/2022; **Accepted:** 08/08/2022; **Published:** 10/08/2022

Abstract

Heterocystous blue green algae are most fascinating group of microorganisms due to their unique characteristic bestowed with diazotrophic nitrogen fixation. The blue green algae genera like *Anabaena* and *Trichormus* are common forms and often found growing in aquatic habitats. Present paper deals with the diversity of two blue green algal genera *Anabaena* and *Trichormus* from Tripura. In the present paper, we report total 18 species, out of which 12 species belong to the genus *Anabaena* and 6 species belong to the genus *Trichormus,* family Nostocaceae, order Nostocales, Cyanoprokaryota. Out of 18 species, 11 species of *Anabaena* and 6 species of *Trichormus* are new to the flora of Tripura, India.

Keywords: Biodiversity; Biotopes; Cyanoprokaryotes; Heterocysts; Rice field; Tripura

Introduction

Cyanoprokaryotes (Blue green algae/Cyanobacteria) are the first photosynthetic simple microorganisms and some of them particularly heterocystous forms are bestowed with unique potential of diazotrophic nitrogen fixation along with carbon fixation [1]. Because of these unique combinations of two entirely opposed physiological processes *i.e.* oxygen evolution as a by-product of carbon fixation via photosynthesis and diazotrophic nitrogen fixation they contribute significantly in the ecosystem as well as nitrogen economy [2]. They help in increasing the soil fertility and carbon sequestration. They gained a lot of attention in recent years because of their potential applications in biology, biotechnology and agriculture. The biomass of heterocystous blue-green algae is considered as one of the valuable natural source of bio-fertilizer to increase the fertility of the soil and improve physico-chemical characteristics of soils such as water-holding capacity and mineral nutrient status of the soil [3].

The cyanoprokaryotes are classified conventionally on the basis of morphological parameters [4,5] or following polyphasic approach [6]. Later, Komárek *et al.* [7] revised the system of classification of cyanoprokaryota based on molecular characterization, cellular ultra-

ISSN: 2349-2805

structure and thylakoid arrangement. Cyanobacteria represent a major component of the photosynthetic microorganism community of most of the aquatic and terrestrial ecosystems [8], but may grow in a wide range of habitats including rice fields. As the North Eastern part of India is considered as one of the mega hotspots for its diversity richness including cyanobacteria. Cyanobacteria are found in diverse habitats of Tripura, a north eastern state of the country India.

The genus *Anabaena* Bory ex Bornet et Flahault and Trichormus (Ralfs ex Bornet et Flahault) Komárek et Anagnostidis are environmentally and economically two important blue green algae and identified mainly on the basis of morphological characteristics, such as shape and size of trichomes and vegetative cells, size and location of heterocysts and akinetes [9]. The genus *Anabaena* was classified by Geitler [4] and Starmach [10] traditionally on the basic concept of containing a wide spectrum of planktic and benthic types. Desikachary [5] on the basis of morphological and ecological description, identified and accepted the genus *Anabaena* by the presence of uniform trichomes, absence of sheath or presence of more or less diffluent sheath forming free or floccose or soft mucilaginous thallus with heterocysts, generally intercalary and presence of a single or series of spores near the heterocyst or between the heterocysts. On the other hand, the genus *Trichormus* was traditionally described under the name *Anabaena*, but Komárek and Anagnostidis [11] described *Trichormus* as a separate genus using a polyphasic approach but the strategy of akinete formation in both the species is completely different [12]. Later 16s RNA sequencing confirmed the similarity of *Trichormus* with *Nostoc* and *Dolicospermum* [7,13].

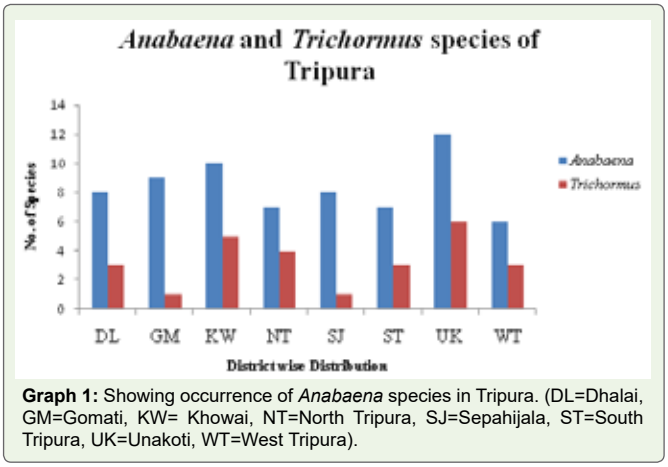
The main aim of the present investigation was to study the diversity and distribution pattern of the genus *Anabaena* and *Trichormus* from different habitats of Tripura, India. From the present study, we are reporting total 18 strains of which 12 species belonging to the genus *Anabaena viz. A. constricta*; *A. duployae*; *A. ghosei*, *A. hieronymii*; *A. minuta*; *A. oblonga*; *A. orientalis*; *A. papillosa*; *A. schauderi*; *A. sedovii*; *A. spinosa*, *A. torulosa* and 6 species belonging to the genus *Trichormus viz. T. azollae*; *T. ellipsosporus*; *T. gelatinicola*; *T. minor*; *T. naviculoides*; *T. subtropicus*. Out of total 18 strains, 17 strains (11 strains of *Anabaena* and 6 strains of *Trichormus*) are new to the flora of Tripura.

Material & Methods

The sites of present study were different biotopes of Tripura state of India. The Tripura lies between 22°56'-24°32' N latitude and 91°09- 92°20'E longitude (Figure 1A-B). Total 1150 algal samples were collected randomly from different habitats of Tripura during the year 2017-2021. All the collected samples were mixed thoroughly by homogenizer (Remi-RQT-127AD) and transferred into sterilized petridishes (Borosil) filled nitrogen deficient liquid and solid BG-11 culture medium [14], and total 149 strains of *Anabaena* and *Trichormus* were raised as unialgal cultures based on method described by Kant *et al*., [15]. Out of total 149 strains, 110 were of *Anabaena* and 39 strains of *Trichormus.* The morphological details of *Anabaena* and *Trichormus* strains were observed with the help of Trinocular Research Microscope (Olympus, CH20i microscope) fitted with digital camera (Magnus, Magcam DC10) and their morphological details were recorded. All the isolated strains of *Anabaena* and *Trichormus* were identified up to the species level with the help of available literatures and monographs [4-6]. Morphological details of eighteen strains, one strain from each species of *Anabaena* and *Trichormus* are being described in the present paper based on Nostocales [6].

Results

Survey, collection of samples from rice fields and uncultivated moist soils and microscopic analysis of algal growth of natural material and culture, and their analysis of revealed the occurrence of total 149 strains of two genera *Anabaena* and *Trichormus*. Out of which six strains of *Anabaena* usually grow in rice field and six strains grow in both types of biotopes rice field as well as uncultivated moist soils. However, as for as the occurrence of *Trichormus* is concerned three species *viz. T. ellipsosporus*, *T. minor* and *T. naviculoides* grow in uncultivated land and rest three grow in both rice field as well as moist soil of uncultivated land. Results also revealed maximum occurrence of *Anabaena* species in Unakoti district and minimum six species in West Tripura district (Graph 1). However, as for occurrence of *Trichormus* species are concerned maximum were found in Unakoti and minimum in Gomati and Sepahijala district of Tripura. Detailed results are given in tables 1-2 and figures 2A-2X.



Graph 1: Showing occurrence of *Anabaena* species in Tripura. (DL=Dhalai, GM=Gomati, KW= Khowai, NT=North Tripura, SJ=Sepahijala, ST=South Tripura, UK=Unakoti, WT=West Tripura).

Table 1: The occurrence of *Anabaena* species in different biotopes and districts of Tripura.

Species	Biotopes	Occurrence of *Anabaena* species							
		DL	GM	KW	NT	SJ	ST	UK	WT
A. constricta	RF/UL	-	+	+	+	+	+	+	-
A. duployae	RF	+	+	-	+	+	+	+	-
A. ghosei	RF	+	-	+	+	+	+	+	+
A. hierongmii	RF/UL	+	+	+	+	-	+	+	+
A. minuta	RF/UL	-	-	+	+	-	+	+	-
A. oblonga	RF	+	+	+	-	+	+	+	+
A. orientalis	RF/UL	+	-	+	+	+	-	+	+
A. papillosa	RF	+	+	+	+	+	-	+	+
A. schauderi	RF	+	+	+	-	-	-	+	+
A. sedovii	RF	-	+	-	-	-	+	+	-
A. spinosa	RF/UL	-	+	+	-	+	-	+	-
A. torulosa	RF/UL	+	+	+	-	+	-	+	-

District wise occurence of *Anabaena* species in Tripura (DL=Dhalai, GM=Gomoti, KW=Khowai, NT=North Tripura, SJ=Sepahijala, ST=South Tripura, UK= Unakoti, WT= West Tripura, RF= Rice Field, UL= Uncultivated Land, MS=Moist Soil)

Citation: Sarma K, Kumar N, Pandey A, Halder NC, Das D, et al. Heterocystous Cyanoprokaryotes: *Anabaena* Bory ex Bornet et Flahault and *Trichormus* (Ralfs ex Bornet et Flahault) Komárek et Anagnostidis (Nostocaceae, Nostocales) from Tripura, India. J Plant Sci Res. 2022;9(2): 225

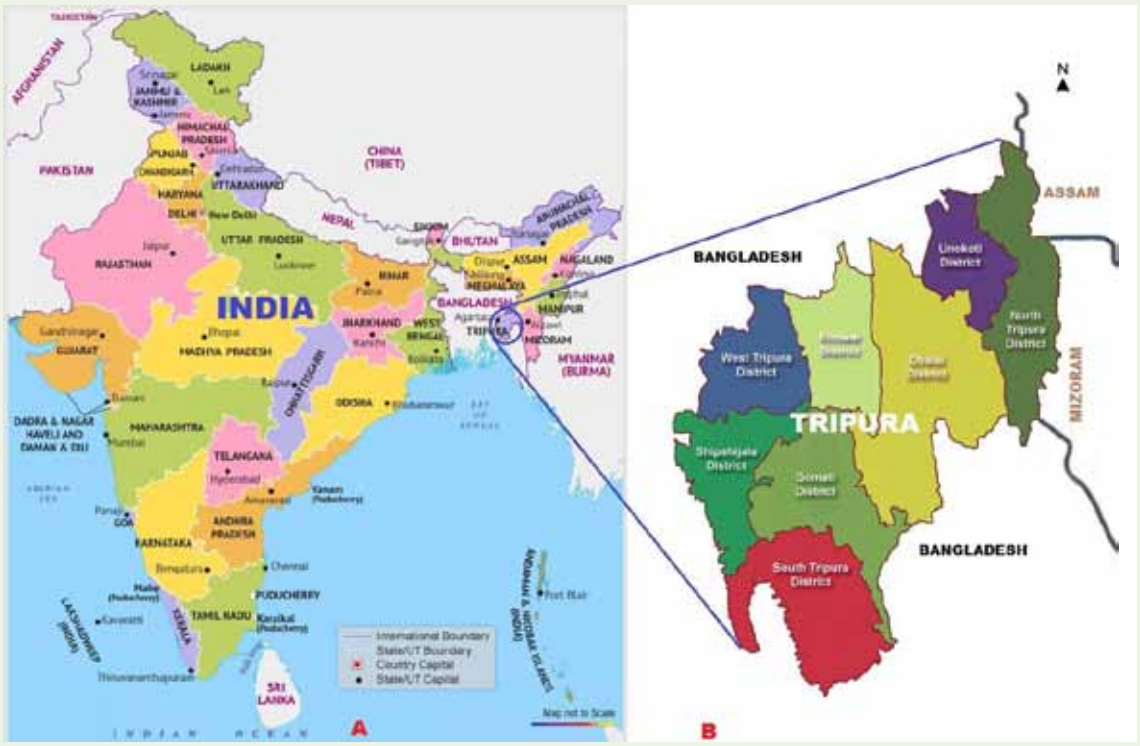


Figure 1: A. India map, B. Tripura map showing study area.

Table 2: Showing occurrence of *Trichormus* species in different biotopes and districts of Tripura.

Species	Biotopes	Occurrence of *Trichormus* species							
		DL	GM	KW	NT	SJ	ST	UK	WT
Trichormus azollae	RF/MS	-	-	+	+	+	+	+	-
T. ellipsosporus	UL	+	-	+	-	-	+	+	+
T. gelatinicola	RF/UL	-	+	+	-	-	+	+	+
T. minor	UL	-	-	+	+	-	-	+	+
T. naviculoides	UL	+	-	+	+	-	-	+	-
T. subtropicus	RF/MS	+	-	-	+	-	-	+	-

District wise occurrence of *Trichormus* species in Tripura (DL=Dhalai, GM=Gomati, KW=Khowai, NT=North Tripura, SJ=Sepahijala, ST=South Tripura, UK=Unakoti, WT=West Tripura), RF= Rice Field, UL= Uncultivated Land, MS=Moist Soil)

Morphological Observation

Description of *Anabaena* and *Trichormus* species:

***Anabaena constricta* (Szafer) Geitler (Figure 2C-D & 2E)**

The colonies are usually microscopic, blackish-green or dark blue-green, mucilaginous mats. Trichomes cylindrical, 5-7 μm wide, composed from short, cylindrical to barrel–shaped cells. Heterocysts are intercalary, solitary, spherical, 3.9-4.8 μm in diameter, Absence of akinetes.

***Anabaena duployae* Welsh (Figure 2I)**

The colonies are usually microscopic, blue-green, free floating, mixed with other algae. The filaments presents as solitary or in small clusters. Trichomes straight or curved constricted at the cross-walls, sometimes enclosed in a thin, faint, colourless, diffluent mucilaginous sheaths. Cells are sub-oval, shorter than wide, with unclear presence of gas vesicles, 4-5 μm wide 6-7 μm long. Terminal cells do not differ from other vegetative cells. Heterocysts are sub-globular, shorter than wide, 8 μm wide and 8-9 μm long. Akinetes are intercalary, oval, single or in pairs, distant from heterocysts, 14-17 μm long 10-12 μm wide, with thick, smooth exospore.

***Anabaena ghosei* Welsh (Figure 2J)**

[syn.: *Anabaena variabilis* sensu Ghose]

The microscopic colonies are forming gelatinous, dark blue-green mats. Filaments short, 100-320 μm long. Trichomes without sheaths, constricted at the cross-walls. The cells are barrel-shaped, 4-4.5 μm long and 4-4.3 μm wide. Akinetes are oval, solitary, distant from heterocysts, 5.5-7.5 μm long and 4-5 μm wide.

***Anabaena hieronymii* Lemmermann (Figure 2K)**

[Syn.: *Anabaena hieronymusii* Lemmermann]

The microscopic colonies are mucilaginous, blue green forming amorphous mats. Filaments straight or slightly flexuous constricted at cross-walls, not attenuated towards ends. Cells are longer than wide, ellipsoidal, 5-6 μm long and 3-4 μm wide, with rounded terminal cells. Heterocysts are intercalary, solitary elongated, ellipsoidal, 9-10 μm long and 2.5-4.5 μm wide. Akinetes are cylindrical with rounded ends, distant from heterocysts usually in rows of 2-4, akinetes 20-36 μm long and 5-8 μm wide.

Citation: Sarma K, Kumar N, Pandey A, Halder NC, Das D, et al. Heterocystous Cyanoprokaryotes: *Anabaena* Bory ex Bornet et Flahault and *Trichormus* (Ralfs ex Bornet et Flahault) Komárek et Anagnostidis (Nostocaceae, Nostocales) from Tripura, India. J Plant Sci Res. 2022;9(2): 225

***Anabaena minuta* Welsh (Figure 2O)**

The colonies are microscopic, with solitary filaments, constricted at the cross-walls, very slightly attenuated towards ends. Cells are cylindrical to oval, 5 μm long and 2.5 μm wide. Heterocysts are intercalary or apical, 5-7 μm long and 3-4 μm wide. Akinetes are not observed.

***Anabaena oblonga* Wildemann (Figure 2P)**

The colonies are microscopic, pale yellow-green or blue-green, with filaments solitary or in mats. Trichomes irregularly flexuous and coiled, without mucilaginous envelopes, slightly narrowed towards ends, constricted at cross-walls. Cells barrel-shaped, isodiametric or shorter or longer than wide, with pale yellow-green or blue-green contents, 4-5 μm wide, end cells rounded or conical rounded. Heterocysts are cylindrical or oval, isodiametric or elongated, solitary, 6-11.2 μm long and 5-7.3 μm wide. Akinetes arise from heterocysts, solitary or often in pairs up to 4 in a row, widely cylindrical, with flattened ends, 9.6-25.6 μm long and 6-8.2 μm wide, with yellowish or brownish endospore and colourless exospore.

***Anabaena orientalis* Dixit (Figure 2Q)**

The colonies are microscopic, gelatinous forming blue-green mat like clusters. Filaments single or in small, thin mat like clusters. Trichomes straight, slightly coiled, constricted at the cross-walls, attenuated towards ends. Cells pale blue green, cylindrical or slightly barrel-shaped, almost isodiametric or up to two times longer than wide, with finely granular content, 3.7- 4.8 μm wide and 2.5-8 μm long. Apical cells conical-rounded. Heterocysts are intercalary, solitary on both sides of heterocysts, solitary or (rarely) in pairs, ellipsoidal or oval, 13-24 μm long and 7.4-14.3 μm wide, with smooth surface, brownish endospore and colourless or slightly brownish exospore.

***Anabaena papillosa* Hirano (Figure 2L-N)**

The colonies are microscopic, blue-green, forming mats. Trichomes straight or slightly flexuous, constricted at the cross-walls, slightly narrowed towards ends. Cells are spherical to oval, barrel-shaped, blue-green, with "gas vesicles", isodiametric or elongated, 8-10 μm long and 7.5-8.8 μm wide. Heterocysts are similar to vegetative cells, mostly oval, 11-12 μm long and 10.5-11 μm wide. Akinetes are cylindrical to ellipsoidal-oblong, flattened at the poles, mostly solitary, distant from heterocysts, 35-55 μm long and 13-16 μm wide.

***Anabaena schauderi* Welsh (Figure 2G)**

The colonies are usually microscopic, mucilaginous, blue-green mats. Filaments solitary or several in mucilaginous tubes, distinctly constricted at the cross-walls, not attenuated towards ends. The cells are barrel-shaped, 4.6 μm long and 3.2-3.9 μm in wide. Heterocysts are ellipsoidal-oval, larger than vegetative cells, 6.5 μm long and 4.6 μm wide. Akinetes are oval distant from heterocysts, 10 μm long and 3.5- 4 μm wide.

***Anabaena sedovii* Kosinskaja (Figure 2A-B)**

The microscopic colonies are irregular, flat, gelatinous, dirty olive-green mats. Filaments solitary, straight or flexuous, short, often disintegrating, deeply constricted at the cross walls. Cells are barrel-shaped to spherical, bright blue green, 3-4.8 μm in diameter with rounded end cells. Heterocysts are solitary, intercalary, spherical usually of the same width, rarely a little wider in diameter of vegetative cells. Akinetes are solitary or in a row, cylindrical with rounded ends, with smooth, thin, colourless exospores, distant from the heterocysts or sometimes joint to both sides of heterocysts, 7.2-16.8 μm long and 3.6-5.4 μm wide.

***Anabaena spinosa* Laloraya et Mitra (Figure 2F)**

The colonies are microscopic, free-floating amongst other algae. Trichomes are straight or curved, moniliform, constricted at cross-walls, without mucilaginous sheaths. Cells are mostly spherical and isodiametric up to barrel-shaped, 3 μm wide; end cells truncate-conical, up to 5 μm long. Heterocysts are solitary, intercalary, spherical up to barrel-shaped, 4-5 μm long and 5 μm wide. Akinetes are spherical or slightly elongated, at one or both sides of a heterocysts, 12-14 μm in diameter, with thick, yellowish exospore with short spines.

***Anabaena torulosa* (Carmichael) Lagerheim ex Bornet et Flahault (Figure 2H)**

The colonies are microscopic, fine mucilaginous, confluent, blue green mats. Trichomes flexuous, cylindrical, joined and entangled in the mats, to the ends sometimes slightly narrowed. Cells are barrel-shaped, isodiametric or slightly shorter or longer than wide, blue green, 4.2-5 μm wide; with conical terminal cells. Heterocysts are ellipsoidal or almost spherical, 6-10 μm long and 6 μm wide. Akinetes are joined to both sides to heterocysts, solitary or in a rows, widened, cylindrical (sometimes slightly concave in the middle of sites), flat-rounded at the ends, 14-24 μm long 7-12 μm wide, with smooth, brownish exospore.

***Trichormus azollae* (Strasburger) Komárek et Anagnostidis (Figure 2W)**

[Syn.: ***Anabaena azollae* Strasburger**]

The colonies are usually microscopic, light blue-green or yellow-green mats, sometimes forming mucilaginous envelopes. Trichomes are relatively short, straight or irregularly bent, constricted at the cross-walls, not attenuated at the ends or very indistinctly attenuated. Cells are variable in form, sub-globose or elongated or broadly ellipsoidal, barrel-shaped to cylindrical. Cells 2.5-9.5 μm long and 1.8-5 μm wide, blue green, sometimes with prominent granules. Apical cells rounded, but often also conical. Heterocysts solitary, very rarely in pairs, intercalary or less commonly in terminal positions, broadly ellipsoidal, conical to cylindrical, distinctly larger than vegetative cells, 6-11.5 μm long and 5-9.5 μm wide. Akinetes are varying from elongate-ellipsoid to broadly cylindrical, up to 7 μm long and 4 μm wide.

***Trichormus* cf. *subtropicus* Silva and Silva & Pienaar (Figure 2R-S)**

The colonies are usually microscopic, pale yellow-green or olive-green, forming gelatinous mats. Filaments single or entangled, straight. Sheaths are mucilaginous, colourless, inconspicuous. Trichomes are constricted at the cross-walls. Cells are olive-green,

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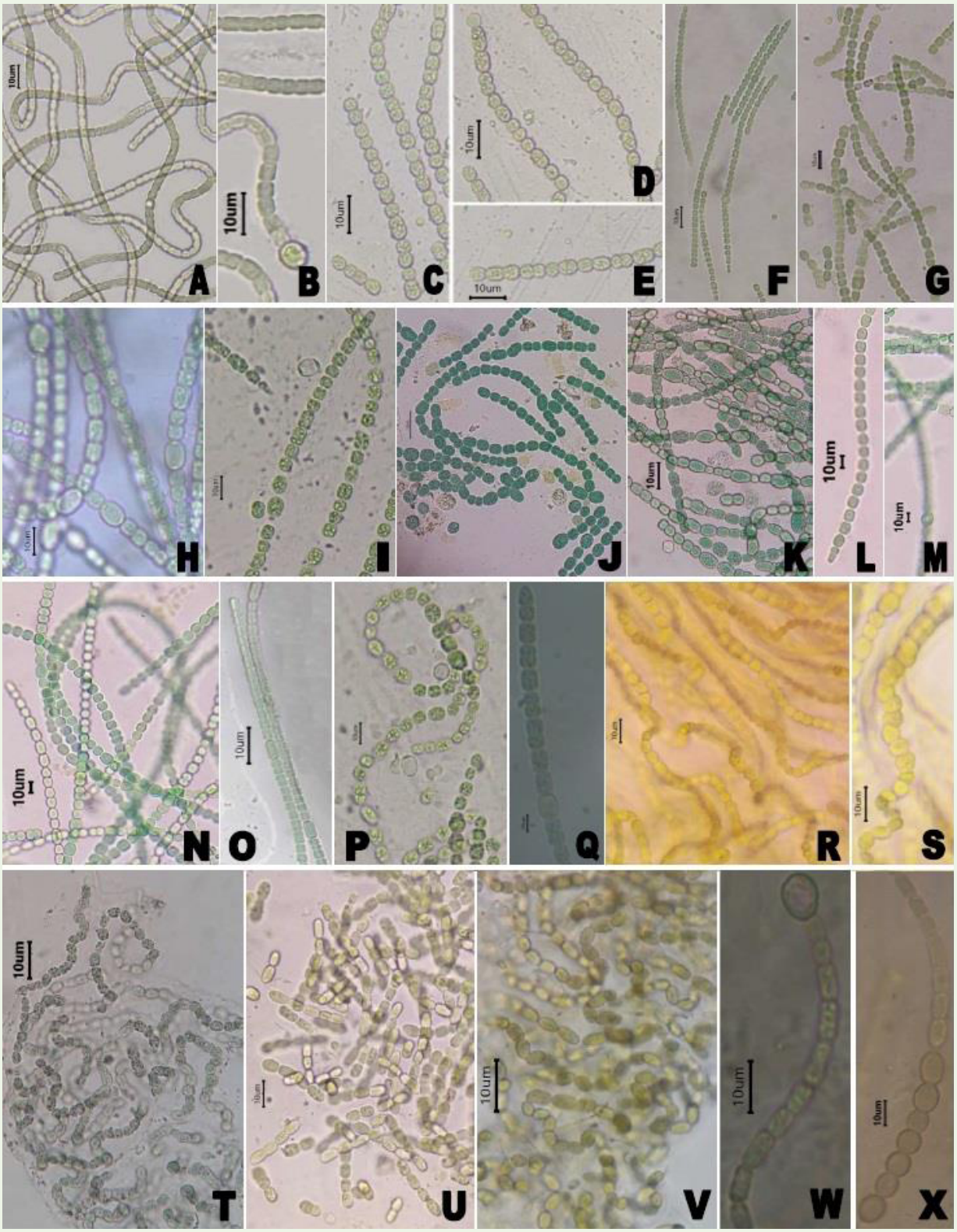

Figure 2: Description of Figures A-X: (A, B) *Anabaena* sedovii; (C, D, E) *A. constricta*; (F) *A. spinosa*; (G) *A. schauderi*; (H) *A. torulosa*; (I) *A. duployae*; (J) *A. ghosei*; (K) *A. hieronymii*; (L, M, N) *A. papillosa*; (O) *A. minuta*; (P) *A. oblonga*; (Q) *A. orientalis*; (R, S) *Trichormus* cf. *subtropicus*; (T) *T. ellipsosporus*; (U) *T. minor*; (V) *T. naviculoides*; (W) *T. azollae*; (X) *T. gelatinicola*.

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quadratic, longer than wide, 3.4-4.3 μm long and 3.1-5 μm wide. Heterocysts are intercalary, subspherical, quadratic to cylindrical, 5.3-7.8 μm long and 3.7-5.9 μm wide. Akinetes are in rows, sub-spherical or oblong, 5-9.3 μm long and 5.3-7.8 μm wide.

***Trichormus ellipsosporus* (Fritsch) Komárek et Anagnostidis (Figure 2T)**

The colonies are microscopic, pale blue-green, with irregularly entangled filaments. Trichomes enveloped by thick, unclear, gelatinous envelope, constricted at the cross-walls. Cells long barrel shaped up to cylindrical, 3.6-7.5 μm long and 3-5 μm wide. Apical cells cylindrical and rounded. Heterocyst slightly wider than vegetative cells, spherical, oval to cylindrical, 5-9-11.5 μm long and 4.5-8.9 μm wide, also occurring in terminal position, spherical or elongated. Akinetes are in rows distant from heterocyst, ellipsoidal, slightly wider than vegetative cells 7.5-15.6 μm long and 4.6-8 μm wide.

***Trichormus gelatinicola* (Ghose) Komarek et Anagnostidis (Figure 2X)**

[**syn.:** ***Anabaena gelatinicola* Ghose**]

The colonies are microscopic, mucilaginous, light blue-green or olive green thick mats. Trichomes are mostly solitary, spirally coiled in circular formations, less frequently straight or slightly flexuous, constricted at the cross-walls. Cells are sub spherical, 6-7.5 μm wide; and cells conical narrowed and pointed. Heterocysts are spherical, 7-8 μm wide. Akinetes are in rows, distant from heterocysts, spherical, ± 14 μm in diameter.

***Trichormus minor* (Laloraya et Mitra) Komarek et Anagnostidis (Figure 2U)**

[**syn.:** ***Anabaena catenula var. minor* Laloraya et Mitra**]

The colonies are microscopic, gelatinous, expanded, blue green or yellow brown. Trichomes free floating, curved, with diffluent, mucilaginous envelopes. Cells are yellow-brown, cylindrical-rounded, 3.5-5 μm long and 3.5-4 μm wide, with rounded end cells. Heterocysts are terminal and intercalary, akinetes many in chains, mostly cylindrical, sometimes oblong, 10-18.5 μm long and 5-6.5 μm wide, with smooth exospore.

***Trichormus naviculoides* (Fritsch) Komarek et Anagnostidis (Figure 2V)**

[**syn.:** ***Anabaena naviculoides* Fritsch**]

The colonies are microscopic, flat, mucilaginous, blue green forming thin mats. Trichomes long, cylindrical, flexuous or coiled, constricted at the cross-walls. Cells are barrel-shaped, iso-diametrical or shorter or longer than wide, 3.5-5 μm wide. Apical cells are conical and obtusely acuminate. Heterocyst is single, intercalary, barrel-shaped, iso-diametric or longer than wide, 5-6 μm wide. Akinetes are serially in rows, sometimes slightly irregularly situated, to irregularly aggregated, ellipsoidal, narrowed and obtuse towards ends, 8.5-12.5 μm long and 5.5-7 μm wide, with thin, hyaline cell-wall and wide hyaline, gelatinous envelope.

Discussion

Cyanobacteria (Blue-green Algae) have been most interesting group of microorganisms since long decade because of their contribution as primary colonizer in the ecosystem and nitrogen fixation [16-20]. The taxonomy of the filamentous heterocystous Blue-green algal genera including *Anabaena* and *Trichormus* has been very much disputed due to their many morphotypes and genotypes. Trichomes of both the genera *Anabaena* and *Trichormus* are differentiated into vegetative cells, heterocysts, akinetes [21]. As the taxonomic entry totally depend on trichome and characteristics of the vegetative cell, heterocyst and akinetes. The genus *Anabaena* and *Trichormus* are controversial due to the occasional absence of these characters and due to phenotypic changes under different environmental conditions. Currently, the genera *Anabaena* and *Trichormus* belong to order Nostocales, family Nostocaceae and subsection IV.I by bacteriological classification [22]. At the world level total 339 species of *Anabaena* [23] and 44 species of *Trichormus* [24] are listed in the database, out of which 223 species of *Anabaena* and 36 species of *Trichormus* have been accepted taxonomically in Algae Base. Komárek [6] reported 88 species of *Anabaena* and 34 species of *Trichormus*. Desikachary [5] reported total 37 taxa of *Anabaena* including 25 species 11 varieties and one forma.

In India, the blue-green algae have been explored by numerous phycologists from different states and some of important contribution include Mitra [25], Desikachary [5], Bharadwaja [26], Pandey and Mitra [27], Tiwari [28], Sinha and Mukharjee [29], Tiwari and Pandey [30], Prasad and Mehrotra [31], Anand [32], Santra [33], Tiwari *et al.* [19], Roy *et al.* [34], Snehee and Verma [35], Singh *et al.* [36], Maurya and Paliwal [37] and Singh *et al.* [38], but most of the North Eastern region of India still remains less explored [39, 43-45]. Although few phycologists explored the blue-green algae of North Eastern states of India. The rice fields of Tripura have been explored by a few researchers in search for the cyanobacterial diversity [42], but information on growth and occurrence of heterocystous forms including *Anabaena* and *Trichormus* are very scanty from Tripura.

Tiwari *et al.* [19] made an exhaustive survey based on literature of Indian phycologists and reported total one hundred taxa including sixty five species and thirty five variety and forma of *Anabaena* from all the types of Indian habitats [42], out of which total fifty eight species including thirty eight species and twenty variety and forma were from rice field soils of the country and they revealed that out thirty eight species of rice field soils only five species including *Anabaena ambigua*, *A. sphaerica*, *A. fertilissima, A. oryzae* and *A. variabilis* are common species of *Anabaena* of rice fields but ignored the rice field soils of Tripura in their study. Bhattacharya and Gupta [46] reported nine species of *Anabaena* on algal collection in Central National Herbarium (CAL). Singh *et al.*, [39], reported total eight species of *Anabaena* from rice field's soils of Tripura. Occurrence of maximum (12) species of *Anabaena* and (06) species of *Trichormus* in Unakoti district and minimum (06) species of *Anabaena* in West Tripura and one species of *Trichormus* in Gomoti and Sepahijala district may be due to more and less collection of samples from the respective districts of the Tripura. However, as for occurrence of *Trichormus* species are concerned maximum were found in Unakoti and minimum in Gomati district of Tripura.

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In our present study, we are reporting 18 species belonging to two heterocystous blue green algae, *Anabaena* and *Trichormus*, out of which except *A. torulosa*, eleven species of the genus *Anabaena viz. A. constricta*; *A. duployae*; *A. ghosei*, *A. hieronymii*; *A. minuta*; *A. oblonga*; *A. orientalis*; *A. papillosa*; *A. schauderi*; *A. sedovii*; *A. spinosa*, *A. torulosa* and 6 species of the genus *Trichormus viz. T. azollae*; *T. ellipsosporus*; *T. gelatinicola*; *T. minor*; *T. naviculoides*; *T. subtropicus* are new to the flora of Tripura.

Conclusion

On the basis of field's survey and collection of blue-green algal growth samples, and culturing and their morphological observations, it is concluded that, rice fields of Tripura, India harbour a good number of heterocystous cyanobacteria but most of them belong to *Anabaena* and *Trichormus* species. Further, it is also concluded that occurrence of the species *Anabaena* and *Trichormus* in the rice fields are comparatively more in numbers, which may be used as bio-inoculants of biofertilizer in the rice fields of Tripura and but needs more thorough study before using them as bio-inoculants.

Acknowledgement

Authors (RK, KS & DD) are thankful to the Principal, Ramkrishna Mahavidyalaya, Kailashahar, Tripura for providing necessary facilities. Authors are also thankful to the Head, Botany Department, Chaudhary Charan Singh University, Meerut for providing necessary facilities. We are also thankful to Dr. G.L. Tiwari, Ex. Professor and Head, Botany Department, Allahabad University, Prayagraj, India for identification of *Anabaena* and *Trichormus*. Authors (RK, KS & DD) thankfully acknowledge financial support by the Ministry of Environment, Forest and Climate Change, Govt. of India, New Delhi.

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