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DIVERSITY OF THE GENUS *NOSTOC* VAUCHER (NOSTOCALES, CYANOPROKARYOTA) FROM TRIPURA, INDIA

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North Eastern Himalayan region of India is known for biodiversity richness of fauna and flora including microalgae and cyanoprokaryotes. Present paper deals with the diversity of genus *Nostoc* Vaucher from Indo-Bangla region of Tripura, India. The genus *Nostoc* is a filamentous, unbranched, heterocystous and diazotrophic Blue-green Alga. In the present investigation we report seventeen species of *Nostoc* from Tripura, India, out of which, twelve species are new addition to the flora of Tripura. Our study also revealed that out of total seventeen species of *Nostoc*, about 23.5% grow in rice fields and rest about 76.5 % flourish on other habitats of Tripura, India, which may be due to indiscriminate use of chemical fertilizers and pesticides.

Key words: Biodiversity, Cyanoprokaryotes, *Nostoc*, Tripura

The North-Eastern states including Tripura of India are considered as one of the Mega Hot spot of the world for its faunal and floral diversity richness including microalgae and Cyanobacteria (Cyanoprokaryotes / Blue-green Algae). However, Tripura State has been ignored by algologists for a long time for diversity evaluation of different algal groups from the state due to its non-accessibility and poor connectivity with rest part of the country. Tripura is a landlocked state of North-East Region of India and it is surrounded by Bangladesh from three sides West, North, South and only from East side connected with India. Details are given in modified Google geographic map (Fig.1). Tripura enjoy the highest rainfall during monsoon season (June to August) and lowest rainfall during winter season (November-January). Tripura faces highest temperature (32-36^{0}C) during pre-monsoon season (March-May) and lowest temperature (10-12^{0}C) during winter season (December-January).

The Blue-green algae (Cyanobacteria / cyanoprokaryotes) are one of the most important group of microorganisms with tremendous potential for their application in different fields. Taxonomically, they have been very complicated group of living organisms since long back and traditionally they were classified on the basis of morphological parameters (Geitler 1932, Desikachary 1959, Komárek 2013, Komárek & Anagnostidis, 1998 & 2005) but later on a new classification system was developed by integration of morphological features with molecular and genetic characters by Bergey's Manual of Systematic Bacteriology (Castenholz 2001). Recently a polyphasic approach is developed for the taxonomic assignments of the cyanoprokaryotes by incorporating molecular, physiological and ecological data with morphological features, and this polyphasic approach has become a very much fascinating system for nomenclature to solve the problem of classification of Blue-green Algae (Komárek & Anagnostidis 2005, Komárek 2013). By using polyphasic approach, nostocacean blue-green algae have been revised by Komárek (2013) and he classified Nostocales into 12 families. Traditionally, nostocalean members are characterised by presence of unbranched filaments differentiated into vegetative cells, heterocysts and akinetes. The genus Nostoc Voucher (Bornet and Flahault 1888) is a filamentous, heterocystous and diazotrophic Blue-green

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Alga (Cyanoprokaryote), and commonly occurs in both terrestrial and aquatic environments (Potts 2000), but may grow in a wide range of habitats including uncultivated and cultivated moist soils, sub-aerial habitats on tree barks, rocks, walls and exposed roof surfaces of buildings etc. *Nostoc* / *Anabaena* spp. also occur in symbiotic associations *(*Rasmussen and Nilsson 2001*)* with fungi (*Geosiphon*), bryophytes (*Anthoceros*), pteridophytes (*Azolla*), the gymnosperms (*Cycas*) and the angiosperm (*Gunnera).*

The genus *Nostoc* is characterized by presence of unbranched, heterocystous filaments with akinetes. *Nostoc* species form colonies with a range of characteristic shapes, sizes, smells, textures and colours. Colonies of *Nostoc* may be pigmented and can have a range of colours from dark green to black, yellow-green to red-brown. Brown or dark brown coloured colonies of *Nostoc* may be due to extracellular pigments the brownish Scytonemin, the violet nostocine A and intracellular mycosporine-like amino acids. These pigments protect the cells from UV radiation and desiccation (Castenholz and Garcia-Pichel 2012, Dodds *et al*. 1995). The trichomes of *Nostoc* spp. are found embedded in a thick layer of exopolysaccharides. All the species of *Nostoc* can be used as natural source of nitrogen fertilizers in rice fields due to their nitrogen fixing potential and for reclamation of soil (De 1939, Pereira *et al*. 2009, Singh, 1961). Some species of *Nostoc viz. N. flagelliforme, N. muscorum and N. sphaeroides* are being used for food delicacy and herbal values for hundreds of years (Gao, 1998). The genus *Nostoc* is distinguished from its close relative *Anabaena* by presence of terminal heterocyst and coiled filaments.

The taxonomy of genus *Nostoc* of Nostocaceae has been very complicated and it is a widely distributed blue-green alga with many morphotypes and genotypes. On the basis of morphology, total 226 species of *Nostoc* are listed in AlgaeBase (Guiry and Guiry 2020). However, based on molecular phylogeny, *Nostoc* is a highly heterogeneous genus of cyanoprokaryote and majority of species of *Nostoc* still need more detailed study in combination with their field based observations, ecology, culture based study alongwith molecular and biochemical profiling to assign proper position in taxonomy. The main aim of the present investigation was to study the diversity and occurrence of species of genus *Nostoc* from different habitats of Tripura, India. By present investigation we are reporting the seventeen species of *Nostoc* from Tripura. Out of these seventeen species of *Nostoc*, twelve species *viz. N. calcicola, N. ellipsosporum, N. foliaceum, N. gelatinosum, N. halophilum, N. kihlmanii, N. letestui, N. minutissimum, N. minutum, N. passerinianum, N. pruniforme* and *N. verrucosum* are new addition to the flora of Tripura, India. For identification of all the species of *Nostoc,* we followed here traditional concept of classification (Komárek 2013).

MATERIALS AND METHODS

Study site and Sampling: The study site of the present study was Tripura, India, which lies between 22°56'-24°32' N latitude and 91°09-92°20'E longitude. Details are given in the Map (Fig.1). Total 800 algal growth containing samples were collected randomly from different localities of Tripura during last ten years (April 2008-March 2018).

Enrichment culturing and purification of *Nostoc* strains: Collected samples were homogenized by homogenizer (Remi RQT-127AD) and were transferred into petridishes (Borosil) filled by nitrogenous and nitrogen deficient liquid and solid BG-11 culture medium (Stainer *et al.* 1971), and total 85 strains of 17 species of *Nostoc* were raised from enrichment cultures by repeated culturing and sub-culturing. All the strains were isolated and purified from mixed population of cyanoprokaryotes of eighty five samples and their unialgal cultures were developed as per standard described methods (Kaushik 1987,

Kant *et al*. 2005).

Microscopic analysis and Identification of *Nostoc* strains: The growth and morphological details of *Nostoc* strains were observed with the help of Trinocular Research Microscope (Olympus, CH20i microscope) and digital camera (Magnus, Magcam DC 10) and morphological observation were recorded. All the isolated strains of *Nostoc* were identified upto the species level with the help of available literatures and monographs (Geitler 1939; Desikachary 1959, Komárek 2013). Morphological details of seventeen strains, one strain from each species of *Nostoc* are described in the present paper.

MORPHOLOGICAL OBSERVATION :

Description of *Nostoc* species:

***Nostoc calcicola* Brébisson ex Bornet *et* Flahault (Figs. 2C & 5A)**

Colonies micro-macroscopic, irregular, flat, gelatinous, dirty olive-green, grayish blue green or yellowish-green, yellowish or colourless, up to 5 cm in diameter in nature. Filaments entangled, sheaths usually indistinct but more distinct at colonial margin. Vegetative cells barrel-shaped or spherical, pale blue-green and 2.5-3 µm in diameter. Heterocysts spherical, 4-5 µm in diameter. Akinetes spherical or slightly elongated, 4-7 µm long and 4-5 µm wide, with smooth, yellow cell wall.

***N. commune* Vaucher ex Bornet *et* Flahault (Figs.3C & 5L)**

Colonies usually macroscopic, gelatinous, initially ± spherical, up to 1.5 cm in diameter, later irregularly flattened, crispy or wavy, up to several cm in diameter, olive-green, yellow-brown or brown or dark brown, with firm periderm. Filaments flexuous, densely entangled, sheath visible mostly at the margin of colonies, yellow-brown, sometimes lamellated and constricted. Vegetative cells shortly barrel-shaped or spherical, slightly longer or shorter than wide, pale olive-green, 3-7 µm long and 4-6 µm wide. Heterocysts almost spherical, both terminal and intercalary, 5.5-8.4 µm long and 5-8 µm wide. Akinetes slightly larger than vegetative cells, with smooth, colourless cell wall.

***N. ellipsosporum* [Desmazières] Rabenhorst ex Bornet et Flahault (Figs.3F& 4G-4I)**

Synonym=N. wollnyanum Richter ex Wittrock *et* Nordstedt

Colonies micro-macroscopic, gelatinous, flattened, irregular, granular, olive green or reddish, brown. Filaments loosely entangled in common mucilaginous matrix. Trichomes flexuous, with sheaths distinct only at the periphery of colonies. Vegetative cells cylindrical, olive green or blue-green, 5-13 µm long and 4-5 µm wide. Heterocysts mostly spherical or elongated or cylindrical, 6-14 µm long and 6-9 µm wide. Akinetes ellipsoidal or long oval, 11-19 µm long and 6-8 µm wide.

***N. foliaceum* Mougeot (Figs. 2E & 5F)**

Colonies micro-macroscopic, mucilaginous, spherical or irregularly elongated with densely woven filamentous, colonies olive-green to yellowish brown, found on moist soil with mosses. Vegetative cells shortly barrel-shaped or almost spherical, 4-6 µm wide. Heterocysts ± spherical, 5-7 µm in diameter. Akinetes mostly oval, 6-7 µm long and 5-6 µm wide.

***N. gelatinosum* Schousboe ex Bornet *et* Flahault (Figs.2A & 5B)**

Colonies microscopic, irregular, flat, gelatinous, brown. Filaments freely arranged in colonies. Sheaths distinct only at the colonial margin, yellow-brown. Vegetative cells long cylindrical, 5-10 µm long and ±4 µm wide. Heterocysts oval to ellipsoidal, elongated, wider than vegetative cells, 6-10 µm long and ±5 µm wide. Akinetes elongated, oval and ornamented with short spines, 8-14 µm long and 6-8 µm wide.

***N. halophilum* Hansgirg (Figs. 3B & 5C)**

Colonies micro-macroscopic upto 1.5 cm in diameter, spherical or amorphous, flattened, gelatinous, olive-green or brownish, with flexuous filaments. Vegetative cells, barrel-shaped or cylindrical or elongated, 5-8 µm long

Table 1: Showing occurrence of *Nostoc* species and their habitats in Tripura

Species	Habitats	Occurrence of *Nostoc* spp. in Tripura							
		NT	UK	DL	KW	GM	WT	SJ	ST
N. calcicola	SA/MS/UL	+	+	+	+	+	+	+	+
N. commune	UL/ MS	+	+	+	+	+	+	+	+
N. ellipsosporum	UL/ MS	+	+	+	+	-	+	-	+
N. foliaceum	SA/ UL	-	+	-	-	+	-	-	+
N. gelatinosum	UL/ MS	+	+	+	+	+	-	+	-
N. halophilum	RF/ MS	+	+	+	-	-	+	+	-
N. kihlmanii	UL/ MS	+	+	-	+	+	-	-	-
N. letestui	UL/ MS	-	+	+	-	+	-	+	+
N. linckia	UL/ MS	+	+	+	+	-	+	+	+
N. minutissimum	RF/ MS	+	+	-	+	-	+	+	-
N. minutum	RF/ MS	+	+	-	+	+	-	-	-
N. muscorum	UL/ MS	+	+	+	+	+	+	+	+
N. paludosum	RF/ MS	+	+	+	+	+	+	+	+
N. passerinianum	UL/ MS	+	-	-	-	-	-	-	-
N. pruniforme	TB / SA	+	+	-	+	+	+	+	+
N. punctiforme	UL/ MS	+	+	+	+	+	+	+	+
N. verrucosum	UL/ MS	-	+	-	-	-	-	-	-
		14	16	10	12	11	10	11	10

BW=Building Walls; RF=Rice Fields, R=Rocks, TB=Tree Bark; SA=Sub-aerial, MS=Moist Soil; UL=Uncultivated Land; NT=North Tripura, UK-Unakoti, DL=Dhalai, KW= Khowai, GM=Gomati, WT=West Tripura, SJ=Sepahijala, ST=South Tripura.

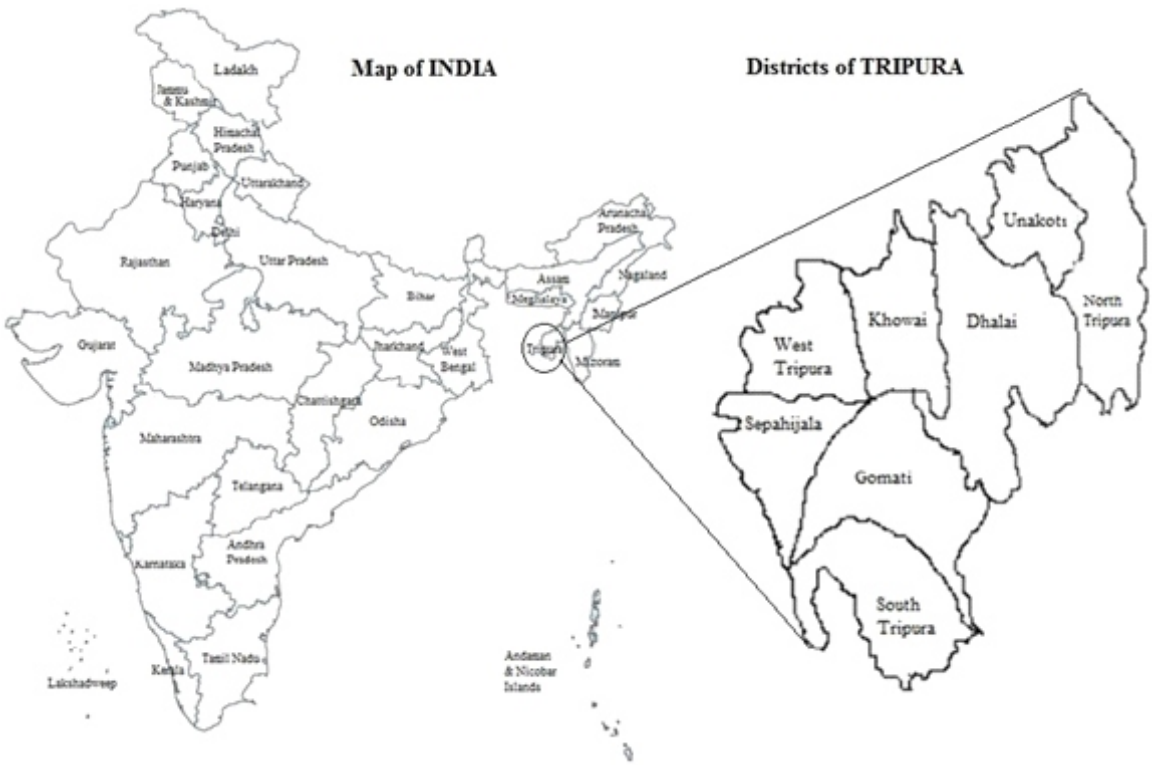

Figure 1: Google Map showing sampling site and study area of Tripura in map of India:

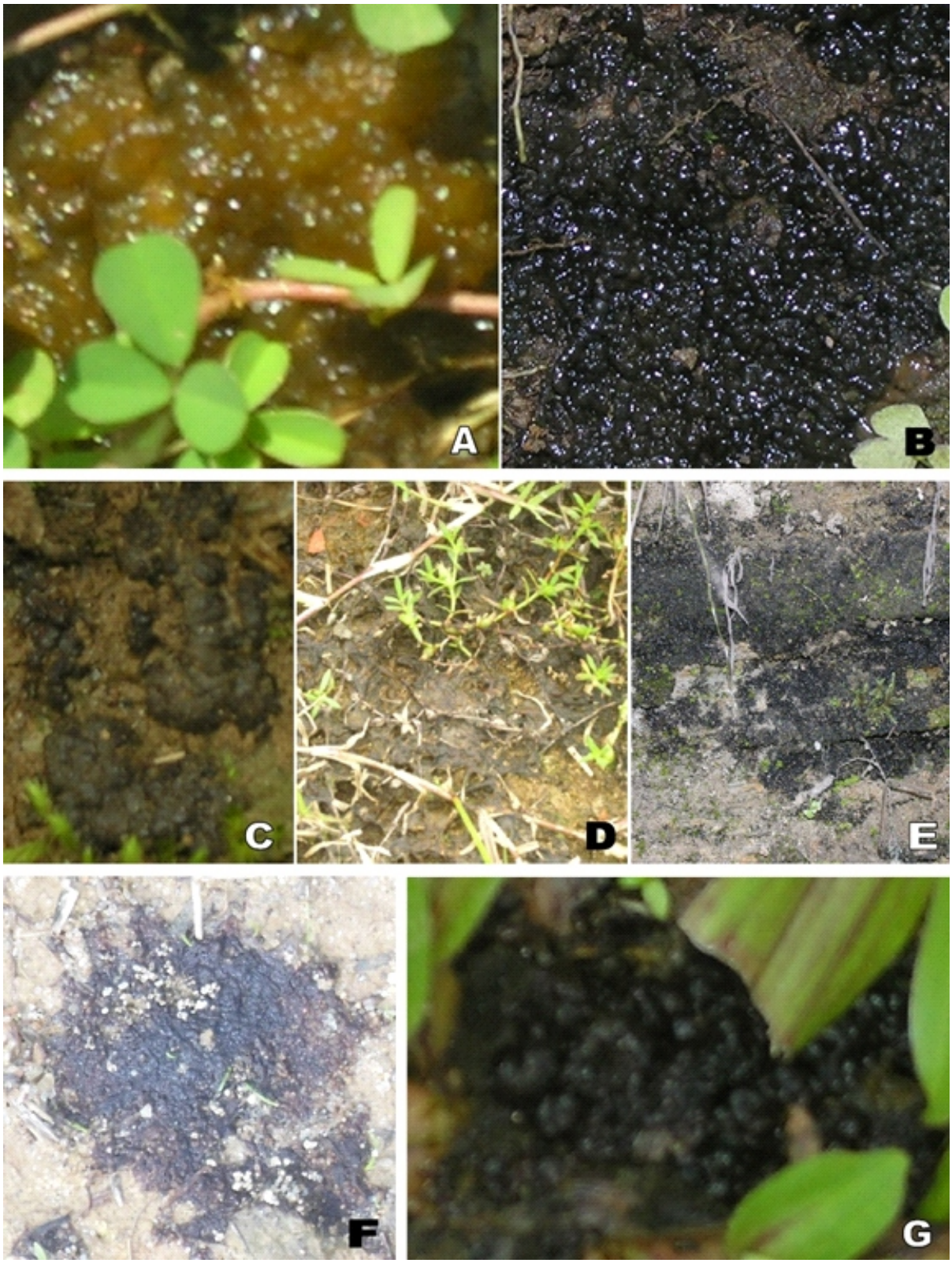

Figure 2 (A-G): Growth of *Nostoc* species in nature: A. *Nostoc gelatinosum* **B.** *N. letestui* **C.** *N. calcicola* **D.** *N. punctiforme* **E.** *N. foliaceum* **F.** *N. passerinianum* **G.** *N. paludosum*

Figure 3 (A-I): Growth of *Nostoc* species in natur**e: A.** *Nostoc minutissimum* **B.** *N. halophilum* **C.** *N. commune* **D.** *N. linckia* **E.** *N.muscorum* **F.** *N. ellipsosporum* **G.** *N. kihlmanii* **H.** *N. minutum* **I.** *N.verrucosum*

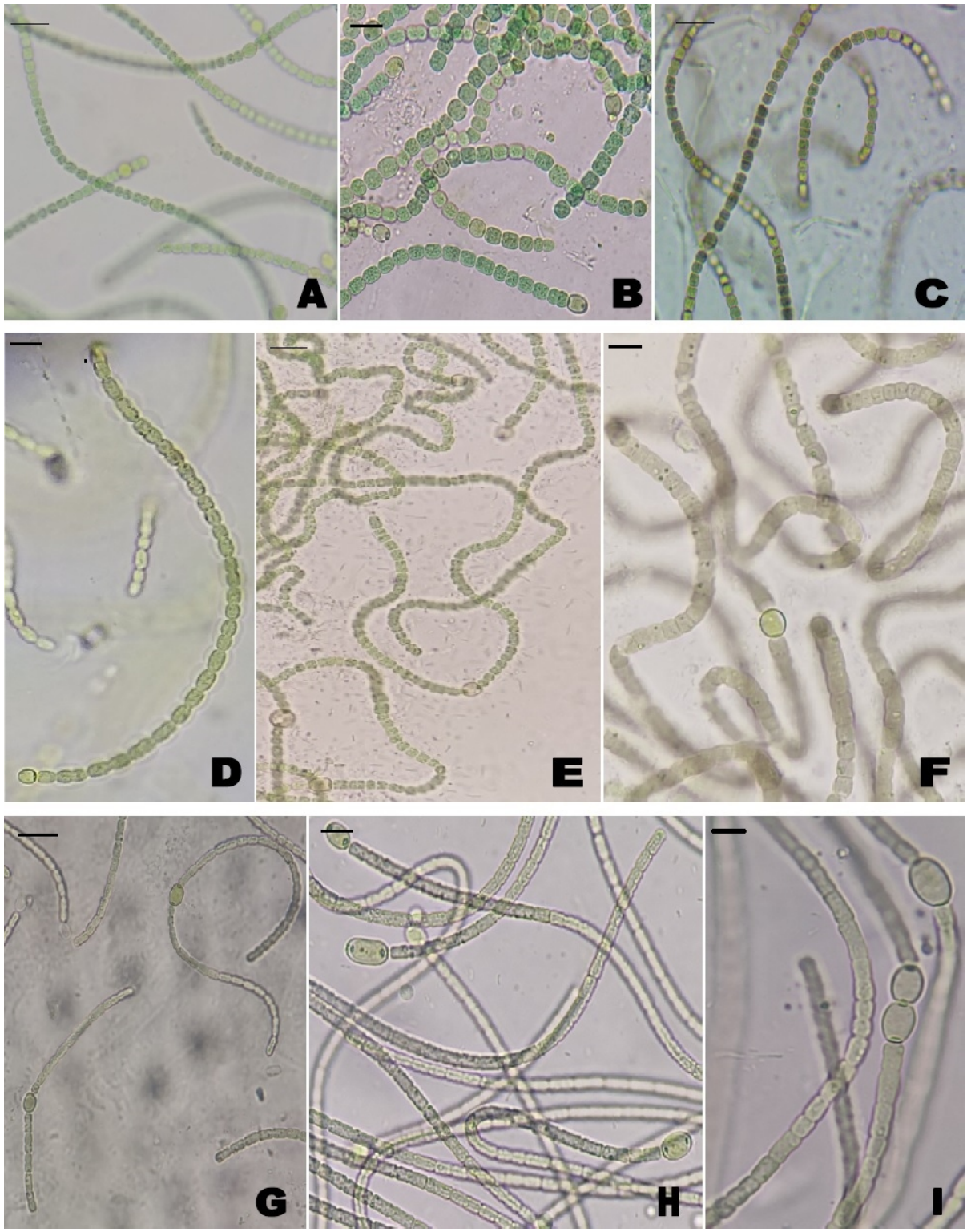

Figure 4 (A-I): Morphological details of *Nostoc* species in culture conditions: **A.** *Nostoc kihlmanii* **B.** *N. punctiforme* **C-D.** *N.muscorum* **E.** *N. minutum* **F.** *N. linckia*
(Scale Bar: A,C,E,G=20μm**;B,H=10**μm**;D,F,I=5**μm**)**

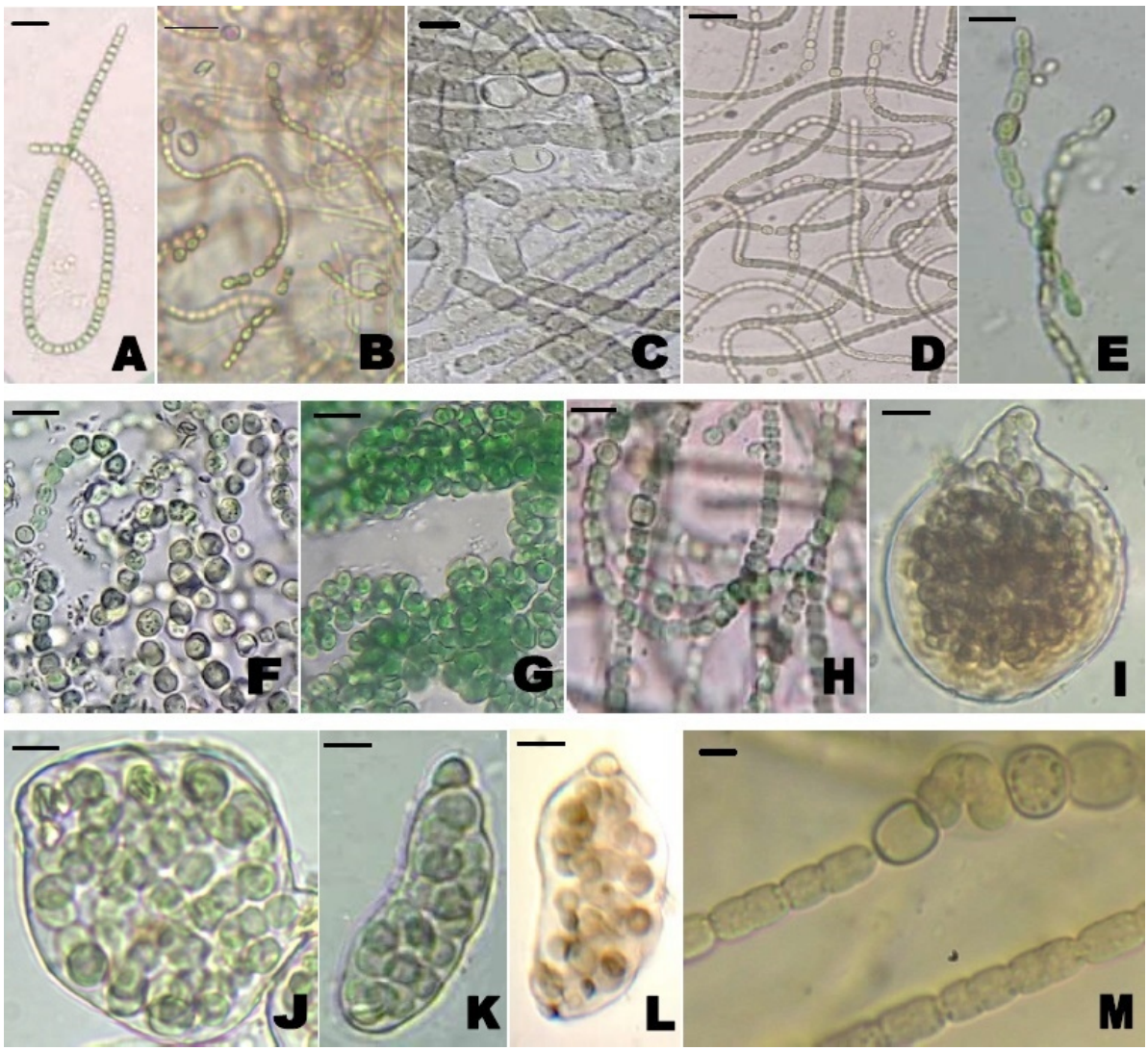

Figure 5 (A-M): Morphological details of Nostoc species in culture conditions:**A.** *Nostoc calcicola* **B.** *N. gelatinosum* **C.** *N. halophilum* **D.** *N. letestui* **E.** *N. minutissimum* **F.** *N. foliaceum* **G.** *N.paludosum* **H.** *N.passerinianum* **I.** *K. N.pruniforme* **L.** *N.commune* **M.** *N. verrucosum*
(Scale Bar: A,B,D,G,I,J=20µm; H=10µm; C,E,F,K,L,M=5µm)

and 3-4 µm wide. Heterocysts 6-8 µm long and 3-4 µm wide. Akinetes spherical to ellipsoidal, 6-15 µm long and 5-7 µm wide.

***N. kihlmanii* Lemmermann (Figs. 3G & 4A):**
=*N. planctonicum* Poreckij *et* Cernov
Colonies microscopic, spherical or ellipsoidal, up to 4-7 mm in diameter, olive green or pale blue-green, later dark blue or bluish-whitish, rarely composed of two or a few colonies together. Trichomes irregularly entangled, without individual sheaths. Vegetative cells spherical or barrel-shaped, isodiametric or a little longer or shorter than wide, with aerotopes, 3.2-6 µm long and 3-7.5 µm wide. Heterocysts solitary or rarely in series, spherical or ellipsoidal, 5.5-11 µm in diameter. Akinetes not known.

***N. lestestui* Fremy (Figs. 2B & 5D):**
Colonies micro-macroscopic, hemispherical, joined to the substrate, upto 2 cm in diameter, firm, commonly more together, forming crustaceous mats, often diversified in radial lobes, which join together, but can disintegrate one from another. Filaments radially

organized, ± freely entangled, dense at the colonial periphery. Sheaths diffluent, colourless. Vegetative cells shortly barrel-shaped to spherical, 5.7-6.5 µm long and 5.5-6.5 µm wide. Heterocysts spherical or slightly shortened, ±10 µm in diameter. Akinetes not known.

***N. linckia* [Roth] Bornet *et* Flahault (Figs. 3D & 4F):**

=*N. confusum* Agardh ex Bornet *et* Flahault incl.; *N. piscinale* Kützing ex Bornet *et* Flahault; *N. rivulare* Kützing ex Bornet *et* Flahault

Colonies microscopic, fine, thin mucilaginous, spherical and freely attached to submerged plants or other substrate, later irregularly clustered, liberating easily from the substrate and free-floating in the form of irregular, amorphous, fragile, brownish or yellowish-brown or dirty olive green gelatinous cluster. Filaments flexuous and densely entangled. Sheaths colourless, usually visible only in marginal part of the colonies. Vegetative cells spherical or barrel-shaped, 3.5-5 µm long and 3-4.7 µm wide. Heterocysts spherical, 4.5-7 µm in diameter. Akinetes spherical or oval, 7-10 µm long and 6-8 µm wide.

***N. minutissimum* Kützing ex Bornet *et* Flahault (Figs. 3A & 5E)**

Colonies small, micro-macroscopic up to 3 mm in diameter, initially ± spherical and hard with firm periderm, gelatinous, dark blue-green, olive-green to brown, with densely entangled filaments; later form more flattened and irregular. Sheaths confluent. Vegetative cells barrel-shaped or spherical, isodiametric or longer than wide, blue-green, 2.2 µm long and 1-1.8 µm wide. Heterocysts ± spherical or barrel-shaped, 2-2.8 µm in diameter. Akinetes oval, 5.4-6 µm long and 2-4 µm wide.

***N. minutum* Desmazieres ex Bornet et Flahault (Figs. 3H & 4E)**

Colonies micro-macroscopic, small, spherical or irregular or flattened, up to 10 mm in diameter, green, with ± firm periderm, with densely entangled filaments. Filaments flexuous, often enveloped by individual sheaths. Vegetative cells barrel-shaped, ± isodiametric or slightly longer or shorter than wide, 3-5 µm long and 2.5-5 µm wide, terminal cells usually slightly conical. Heterocysts ± spherical, 3.5-6 µm in diameter. Akinetes oval, 6-7 µm long and 4.5-5 µm wide.

***N. muscorum* Agardh ex Bornet et Flahault (Figs. 3E & 4C-4D)**

=*Desmonostoc muscorum* (Agardh ex Bornet *et* Flahault) Hrouzek *et* Ventura

Colonies micro-macroscopic, new colonies ± hemispherical, later forming mucilaginous, flattened mats, up to several cm in diameter, blue-green, later yellow-brown to olive-green, with densely entangled filaments. Filaments irregularly flexuous. Sheaths distinct at the margin of colonies, yellow-brown. Vegetative cells shortly barrel shaped to cylindrical, isodiametric or slightly longer or shorter than wide, 4-6.5 µm long and 2.7-5 µm wide. Heterocysts spherical or barrel-shaped, 4-7 µm long and 4-7 µm wide. Akinetes oval, 6.3-12 µm long and 4-8 µm wide.

***N. paludosum* Kützing ex Bornet *et* Flahault (Figs. 2G & 5G):**

=*N. entophytum* Bornet *et* Flahault; *N. cuticulare* (Brébisson) Bornet *et* Flahault

Colonies micro-macroscopic, in clusters, irregular mucilaginous mass, blue green with freely or densely arranged coiled trichomes. Colonial sheath colourless / yellowish and gelatinous. Vegetative cells barrel-shaped or ellipsoidal, dark blue-green, isodiametric or slightly longer or shorter than wide, 2-6 µm long and 3-5 µm wide. Apical cells cylindrical and rounded. Heterocysts rounded or barrel-shaped or elongated, 4-7 µm in diameter. Akinetes spherical or oval, 6-9 µm long and 4-6.5 µm wide.

***N. passerinianum* [DeNotaris] Bornet *et* Thuret ex Bornet *et* Flahault (Fig.2F& 5H):**

Colonies micro-macroscopic, amorphous, olive green or dirty blue green or yellowish brown with densely arranged ± parallel trichomes. Vegetative cells barrel-shaped to ellipsoidal, light blue-green to brownish blue-green, 5-7 µm long and 4-5 µm wide. Heterocysts slightly elongated, 5-6 µm long and 5.5-6.5 µm wide. Akinetes rare, spherical

or oval, 6-7 µm long and 5-6 µm wide.

***N. pruniforme* [Linnaeus] Agardh ex Bornet *et* Flahault (Figs. 5I-5K)**

Colonies micro-macroscopic, spherical, oval or ovoid, 1.5 - 5 (6) cm in diameter, with smooth periderm, inside with soft mucilage, olive-green, bluish, pale blue green, grayish or brownish; with irregularly entangled trichomes. Individual envelopes around trichomes sometimes clearly visible, particularly in peripheral parts, colourless or yellowish. Vegetative cells barrel-shaped, isodiametric or slightly longer or shorter than wide, 4-7.5 µm long and 4-6.7 µm wide. Heterocysts spherical or slightly oval, 6-7 µm in diameter. Akinetes rare, spherical or oval, about 10 µm in diameter.

***N. punctiforme* (Kützing ex Hariot) Hariot (Figs. 3D & 4B)**

=*N. hederulae* [Kützing] Meneghini ex Bornet *et* Flahault

Colonies micro-macroscopic, small, spherical, subaerophytic, attached to the substrate, dark blue-green or blackish, usually 1-2 mm in diameter, later confluent into a blackish gelatinous mass, several cm large. Filaments very densely entangled, coiled, in young stages agglomerated together. Sheaths thin, colourless, usually indistinct. Vegetative cells shortly barrel-shaped to ellipsoidal or spherical, blue-green, 2.6-5.5 µm wide. Heterocysts barrel-shaped or spherical, 4-6.5 µm in diameter. Akinetes spherical or slightly elongated, 5-8 µm long and 5-6 µm wide.

***N. verrucosum* [Linnaeus] Vaucher ex Bornet *et* Flahault (Figs.3I & 5M)**

=*N. rothii* Agardh ex Bornet *et* Flahault

Colonies micro-macroscopic, semispherical, lobate or amorphous, attached firmly the substrate, yellow brown to dark brown, usually upto 5 cm in diameter. Filaments flexuous, densely entangled. Vegetative cells shortly barrel-shaped, light blue-green, 3-4.5 µm wide. Heterocysts spherical or slightly oval, both terminal and intercalary in position, 5 µm wide. Akinetes spherical or oval, 5-7 wide.

DISCUSSION

The taxonomy of the genus *Nostoc* is very complicated with many morphotypes and genotypes. It is a filamentous and heterocystous Blue-green Alga (cyanoprokaryote) and its trichomes are differentiated into vegetative cells, heterocysts, akinetes (Castenholz 1989; Komárek & Anagnostidis 1989). The genus *Nostoc* has been classified under the family Nostocaceae, order Nostocales by traditional classification (Komarek & Anagnostidis, 1989, Komárek 2013) and subsection IV according to bacteriological classification (Castenholz and Waterbury, 1989). The family Nostocaceae is characterized morphologically by presence of isopolar filaments, absence of branching, presence of heterocysts and facultative presence of typical paraheterocytic or apoheterocytic akinetes (Komárek 2010).

Although, Montagne (1849) reported *Calothrix indica* first time from Assam (a North Eastern State) of India, but this area has been neglected for long time because of various reasons and obstacles. Later on, a lot of work on diversity of blue-green Algae from Indian habitats was taken up by many algologists (Mitra 1950, Desikachary; 1959, Singh 1961, Anand 1989, Pandey 1965, Tiwari 1972, Laloraya and Mitra 1973, Santra 1993, Kant *et al*. 2004, 2005, 2006, Singh *et al.* 2008., Tiwari and Pandey 1976, Tiwari *et al.* 2018).

Desikachary (1959) reported total 677 taxa (541 species 102 varieties and 34 forma) from India. Srinivasan (1965) listed 326 taxa, which were first described from India. Sarma and Khan (1980) listed 91 genera and 817 taxa of blue-green algae from India. Anand (1989) made a comprehensive survey of Blue-green Algae of rice fields of Tamil Nadu and Kerala and described 182 species of 31 genera. Sahu *et al*. (1996) reported 143 from rice-fields of Orissa. Santra (1993) reported 682 species of 67 genera from West Bengal. Tiwari *et al* (2007, 2018) made an exhaustive survey by covering more than one dozen states and

reported total 97 genera and 1528 taxa (1083 species and 445 varieties and forma) from India.

Being the Mega Hot Spot of the world for Biodiversity, North Eastern Region of India was totally ignored upto 1996 and most of the algologists could not reach to this biodiversity rich region of the country to explore the algal biodiversity of most of the area of Himalayan range of North East India because of so many reasons, but one of them might be the poor transport connectivity of the Tripura from rest part of India. Later on serious attempt were made to explore the North East Region of India by few phycologists (Singh *et al*. 1997, Tiwari *et al*. 2005. Adhikary *et al*. 2010. Bhakta *et al*. 2010. Das *et al*. 2010, Syiem *et al*. 2010, Das and Adhikary 2012 Kant 2012, Gosh *et al*. 2019 Bharati *et al*. 2020) worked on blue-green algae of North East states including Tripura.

Globally, on the basis of morphology approximately 226 species of *Nostoc* have been listed and out these, 107 species have been taxonomically accepted in AlgaeBase (Guiry & Guiry 2020). Komárek (2013) has described 85 species but recognized only 23 species of *Nostoc*. Desikachary (1959) reported total 23 species of *Nostoc* from India. Tiwari *et al* (2007) made an a exhaustive study on diversity of blue green algae from different habitats of India and they reported total fifty five taxa (41 species and 14 varieties and forma) *Nostoc* from Indian habitats excluding Tripura. In our present study, we report the occurrence of 17 species of *Nostoc* from Tripura, out these total 17 species, 5 species *viz*. *N. commune, N. linckia, N. muscorum, N. paludossum* and *N. punctiforme* were reported by different phycologists (Singh *et al*. 1997, Das *et al*. 2010; Bharati *et al*. 2020) and 12 species *viz*. *N. calcicola, N. ellipsosporum, N. foliaceum, N. gelatinosum, N. halophilum, N. kihlmanii, N. letestui, N. minutissimum, N. minutum, N. passerinianum, N. pruniforme* and *N. verrucosum* and new reports from Tripura, India.

Tiwari *et al.* (2007) in his study revealed that out of 55 taxa, 42 taxa (34 species and eight varieties and forma) grow in rice field soils of India. They also pointed out that out of total reported taxa more than 75% grow on rice field, but our present study revealed that out total 1 species, 4 species grow in rice fields, which is approximately 23.5% of total species of *Nostoc* from Tripura, India. Observations on occurrence and distribution pattern of *Nostoc* species in all the eight district of Tripura also revealed the occurrence of maximum species (16) in the survey of in the area of Unokoti district and minimum species (10) were encountered each from Dhalai, West and South Tripura districts of Tripura state. Detailed results are given in Table-1. Occurrence of maximum number of species in Unakoti district and less numbers in Dhalai, West Tripura and South Tripura districts of Tripura may be due to frequent and comparatively less covered area in the field observations from the respective districts of Tripura.

CONCLUSION

On the basis of fields and culture based morphological observations, it is concluded that North eastern states including Tripura, India, harbour a very rich diversity of blue-green algae including *Nostoc* species. Further, it is also concluded that occurrence of comparatively less numbers of *Nostoc* species in rice field may be due to indiscriminate application of toxic chemicals including fertilizers and pesticides in the rice fields, but certainly climatic conditions of Tripura favour the luxuriant growth of heterocystous cyanoprokaryotes including *Nostoc* in other habitats.

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