

BLUE GREEN ALGAE FROM RICE FIELDS OF KARIMGANJ DISTRICT, ASSAM, NORTH EAST INDIA

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ABSTRACT

Cyanobacteria (blue green algae) are present abundantly in rice fields and are important in maintaining the rice field fertility through nitrogen fixation. An investigation on cyanobacteria (blue green algae) from the rice fields of Son beel and its nearby adjoining areas of Karimganj district, Southern Assam, India was carried out. A total of thirty four strains of filamentous cyanobacteria were isolated and classified according to their morphological characteristics. The cyanobacterial isolates were classified into ten genera, including seven heterocystous and three non heterocystous genera. The genera *Nostoc*, *Calothrix*, *Anabaena* and *Cylindrospermum* were the dominant heterocystous group while *Lyngbya*, *Oscillatoria* and *Phormidium* form the non-heterocystous group in the district.

Keywords: Blue green, cyanobacteria, Karimganj district, morphology, rice fields.

INTRODUCTION

Blue green algae are one of the main components of the microbiota in rice fields and play an important role in the maintenance and build-up of soil fertility, consequently increasing rice production (Song et al. 2005). They have an important role in the nitrogen fixation, particularly in rice fields (Hazarika et al. 2012). The rice fields are agronomically managed ecosystem, well known for the rich diversity of cyanobacteria (Dey et al. 2012). Rice fields constitute one of the favourable ecologies for the growth and proliferation of cyanobacteria meeting their requirements for light, water and higher temperature (Whitton and Potts 2000). Rice fields are a suitable environment for the growth of diazotrophic, oxygenic cyanobacteria by providing suitable temperature, nutrient and water facilities. Cyanobacteria in return, provide a large amount of nutrients, such as nitrogen and phosphorus needed for rice cultivation (Singh et al. 2014). Most rice fields have a natural population of cyanobacteria which provides a potential source of nitrogen fixation. Species of *Nostoc*, *Anabaena*, *Tolyphothrix*, *Aulosira*, *Cylindrospermum*, *Scytonema*, *Westiellopsis* and several other genera

are widespread in Indian rice field soils and are known to contribute significantly to their fertility (Venkataraman 1981; Rao et al. 2008; Choudhary et al. 2011). These nitrogen fixing organisms have attributed to the natural fertility of tropical rice fields. They are able to photosynthesize, fix atmospheric nitrogen, highly adaptive contributing to the productivity in various agricultural and ecological environments. Studies on cyanobacterial diversity has received due attention in the recent times (Thajuddin and Subramanian 2005). Rice fields are ideal habitats for blue green algae. Research on cyanobacterial flora from rice fields were also carried out in different parts of India (Nayak and Prasanna 2007; Dasgupta and Ahmed 2013; Singh et al. 2014). However, information on systematic study on cyanobacterial algae from this part of Southern Assam is scant. Only a few reports on the rich algal diversity from rice fields of Southern Assam are available during the last couple of decades (Nandi and Rout 2000; Deb et al. 2013). Rout and Dey (1999) investigated the algal flora from rice fields of Irongmara of Cachar district (Southern Assam). Borah et al., (2014) studied the morphology of two *N. commune* strains isolated from two different rice-growing agro-ecosystems

(flat and terrace paddy fields) of Dima Hasao district, Assam, North-East India and made a comparative analysis of the pigments and biochemical properties. The agroclimatic condition of the rice fields of Son beel and its nearby adjoining areas favors the growth of several rice cultivars along with luxuriant cyanobacterial population. Therefore, in this paper we intend to address some cyanobacterial strains and their morphological attributes from the selected rice fields of Karimganj district, in Southern Assam, India.

MATERIALS AND METHODS

2.1 Study area

The study was conducted in Karimganj district,

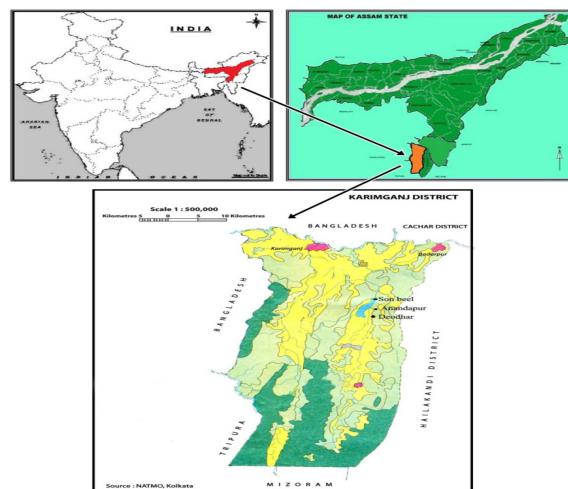


Figure 1
Map showing the study sites

2.2 Isolation, maintenance and identification of strains

Cyanobacterial strains were isolated from soil samples collected from the selected rice fields during 2012-2014 by the dilution plate method (Lukesova A. 1993). Dilutions (10^{-2} , 10^{-1}) were prepared from the soil suspensions obtained and 1ml were spread on solidified 1% BG-11_o (nitrogen free media) or BG-11 (with nitrogen source) media depending on suitability for various genera (Rippka et al. 1979). Plates were subsequently cultured and incubated at a temperature of $24^{\circ}\text{C} \pm 1$ under a 16:8 hour (light: dark) photoperiod at a light intensity of 2000-3000 lux. Unialgal cyanobacterial strains were carefully picked up and transferred onto petri plates with fresh agar medium. Repeated subculturing was performed a number of times until pure axenic culture were obtained. The axenic culture was then viewed and microphotography was

Southern part of the state of Assam situated between $24^{\circ}15' - 25^{\circ}55' \text{ N}$ and $92^{\circ}15' - 92^{\circ}35' \text{ E}$. The soil samples were collected from the selected rice fields of Son beel ($24^{\circ}42'05.9''\text{N}$ $92^{\circ}27'16.4''\text{E}$) and its adjoining areas of Anandapur ($24^{\circ}50'34.5''\text{N}$ $92^{\circ}27'16.5''\text{E}$) and Deodhar ($24^{\circ}42'06.4''\text{N}$ $92^{\circ}27'43.9''\text{E}$) located in Karimganj district, Southern Assam (Fig 1). This region experiences heavy rainfall during the months of May to September with high humidity of about 80%. The subtropical, warm, climatic condition of the district with a heavy summer rainfall favour the luxuriant growth of cyanobacteria in the rice field of this district.

done in Leica DM1000 microscope with software. The strains were identified based on their morphological features and phenotypic characters following standard keys (Prescott 1952; Desikachary 1959).

RESULTS AND DISCUSSIONS

3.1 Morphological characteristics

All the morphological characteristics viz. cell shape and size, heterocyst, akinetes shapes etc. presence or absence of sheath was studied. A total of thirty four cyanobacterial strains were obtained from the study sites including seven heterocystous forms: *Anabaena*, *Nostoc*, *Calothrix*, *Cylindrospermum*, *Microchaete*, *Hapalosiphon* and *Westiellopsis* and three non-heterocystous forms: *Oscillatoria*, *Phormidium* and *Lyngbya*.

***Anabaena anomala* Fritsch. Plate 1, Figure a.**

Order: Nostocales

Family: Nostocaceae

Thallus thin, gelatinous, blue green; trichome dense, irregularly aggregated, more or less contorted, moniliform, 2-5 μ m broad; filaments single and loosely coiled; apical cell subconical, apex obtuse; cells generally 2-4 μ m broad, spherical, as long as broad; heterocyst intercalary, commonly single, spherical, 3-4 μ m broad.

***Anabaena constricta* (Szafer) Geitler Plate 1, Figure b.**

Order: Nostocales

Family: Nostocaceae

Thallus filamentous dull olive green in colour; filaments solitary or in macroscopic mats on the substrate; trichomes uniserial, often moniliform, isopolar, 4.5-5.5 μ m broad; cells constricted cylindrical, barrel-shaped or spherical, shorter up to longer than wide, pale or bright blue-green or olive-green, with granular content 5-8 μ m long; terminal cells sometimes slightly elongated, conical; heterocyst spherical, widely oval or cylindrical, sometimes elongated, usually slightly greater than vegetative cells 5-7 μ m broad.

***Anabaena doliolum* Bharadwaja. Plate 1, Figure c.**

Order: Nostocales

Family: Nostocaceae

Thallus mucilaginous, pale blue green; trichome single, free swimming, slightly curved or slightly coiled, 3-4 μ m broad, slightly tapering at the ends, apical cell conical, almost pointed apex; cells barrel shaped as long as broad or a little longer or shorter than broad, 3-4 μ m broad, 5-7 μ m long; heterocyst barrel shaped, 4-5 μ m broad and 5-6 μ m long, episore thick, smooth, hyaline or yellow.

***Anabaena flos aquae* (Lyngb.) De Brebisson. Plate 1, Figure d.**

Order: Nostocales

Family: Nostocaceae

Thallus filamentous, colony spread out, olive green in colour; trichomes planktonic, very flexuous and contorted, sometimes coiled in an irregular spiral fashion, entangled; cells spherical to subcylindric, 3-5 μ m in diameter, 5-7 μ m long, cell contents granular with conspicuous pseudovacuoles; heterocyst globose, 4-7 μ m broad, 6-10 μ m long; spores cylindrical, sausage shaped, in a series, crowded near the centre of a tangle of filaments, 4-7 μ m in diameter.

***Anabaena gelatinicola* Ghose. Plate 1, Figure e.**

Order: Nostocales

Family: Nostocaceae

Thallus thick, blue green, broad, gelatinous. Trichome densely arranged and coiled, sometimes straight, cells subspherical 3-4 broad, acute apex, heterocyst oblong 4-5 broad, spores ellipsoid or oblong, in series, away from the heterocyst.

***Anabaena orientalis* Dixit. Plate 1, Figure f.**

Order: Nostocales

Family: Nostocaceae

Thallus dark green colour, filaments densely entangled forming a globular pattern, expanding, highly mucilaginous, dense at some portions; trichome single, straight or slightly bent; 4-5 μ m broad, cells quadrate, rarely slightly barrel shaped, 3-6 μ m long, end cell conical with rounded apex; heterocysts single, intercalary, slightly ellipsoidal with rounded end walls, 5-6 μ m broad and 7-8 μ m long; spores ellipsoidal in shape, one in each side of the heterocyst, 7-8 μ m broad and 9-10 μ m long.

***Anabaena iyengarii* var *tenuis* Rao, C.B. Plate 1, Figure g.**

Order: Nostocales

Family: Nostocaceae

Thallus light green in colour, filaments attached; trichomes without sheath, 5-6 μ m broad; cells slightly shorter than broad, 4-5 μ m length; heterocyst spherical, 5-6 μ m in diameter; spores developing at the old stage on both sides of the heterocyst, ellipsoidal, 9-12 μ m long, 7-8 μ m broad; end cell of the trichome conical shape.

***Anabaena oryzae* Fritsch. Plate 1, Figure h.**

Order: Nostocales

Family: Nostocaceae

Thallus filamentous, soft, olive green in colour, gelatinous, attached, membranous; trichomes short, straight, densely aggregated cells generally parallel, 4-5 μ m broad, 7-8 μ m long; heterocyst terminal and intercalary, broader than the vegetative cells, 3-5 μ m broad, terminal ones conical and twice longer than broad, intercalary ones single or 2-3 in series, barrel shaped.

***Aulosira aenigmatica* Fremy. Plate 1, Figure i.**

Order: Nostocales

Family: Nostocaceae

Thallus expanded, woolly type, dark blue green, filaments densely entangled, more or less intricate, suberect, 6-8 μ m broad; sheath colourless, close to trichome, membranous thin; trichome dark blue

green 5-6 μ m broad, more or less constricted at the cross walls; cells almost cylindrical, subquadrate, both longer and shorter than broad, contents finely granular, 5-6 μ m broad; apical cells attenuated, obtuse conical, heterocyst oblong, cylindrical or spherical, single or two, 4-6 μ m broad,

***Calothrix braunii* (A. Br.) Bornet et Flahault. Plate 1, Figure j.**

Order: Nostocales

Family: Rivulariaceae

Thallus caespitose, reddish brown, filaments straight, parallel, swollen at the base; sheath thin, close to the trichome, colourless; trichomes parallel, gradually tapering to a point, compactly arranged to form a colonial expanse, 5-6 μ m broad, constricted at the cross walls; cells cylindrical, longer than broad; heterocyst basal, hemispherical, 6-7 μ m broad.

***Calothrix braunii* (A.Br.) Bornet et Flahault.**

Plate 1, Figure k.

Order: Nostocales

Family: Rivulariaceae

Thallus caespitose, blue green, filaments straight, swollen at the base; sheath thin, close to the trichome, colourless; trichome parallel, gradually tapering to a point, compactly arranged to form a colonial expanse, 4-5 μ m broad, constricted at the cross walls; cells cylindrical, 6-7 μ m broad at the base, heterocyst hemispherical, basal.

***Calothrix fusca* (Kutz.) Bornet et Flahault. Plate**

1, Figure l.

Order: Nostocales

Family: Rivulariaceae

Thallus filamentous, dark green coloured, floccose, filaments solitary, gradually tapering from base to apex, bent at the base and distinctly swollen up to 15 μ broad; sheath thick, colourless, gelatinous, broad, diffuent at the apices; trichome 5-7 μ m broad, ending in a long thin hair, not constricted at the cross walls; cells at base shorter than broad, but at apices somewhat cylindrical, 4-7 μ m long, cell contents light blue green, homogenous; heterocyst basal, single, hemispherical, 5-9 μ m broad, smaller than the basal cell of the trichome.

***Calothrix marchica* Lemmermann. Plate 2, Figure a.**

Order: Nostocales

Family: Rivulariaceae

Filaments blue green or brownish, slightly bent, single, 7-10 μ m broad at the base with thin

colourless sheath; trichome brownish green, constricted at the cross walls; cells quadratic, shorter or longer than broad, 4-7 μ m long and 3-7 μ m broad; heterocyst single, basal and spherical, 4-5 μ m broad.

***Calothrix marchica* var *crassa* Rao, C.B. Plate 2, Figure b.**

Order: Nostocales

Family: Rivulariaceae

Filaments in groups and closely entangled, sheath thin firm, hyaline, trichomes 6-4 broad, constricted at the septa, ends tapering without a hair, end cell conical with a rounded apex, sometimes pointed, cells quadratic as well as shorter or longer than broad, 2-4 long, at the apices upto 4 long, heterocyst single, basal, spherical or subspherical, 7-11 broad and upto 7 long.

***Calothrix marchica* var *intermedia* Rao, C.B.**

Plate 2, Figure c.

Order: Nostocales

Family: Rivulariaceae

Thallus filamentous, brownish green, filaments in groups of two or three, slightly attenuated 7-10 μ m broad; trichome 6.5-7 μ m broad, constricted at the cross walls; sheath thin, firm, hyaline; cells moniliform, somewhat quadratic, shorter or longer than broad, 5.5-6 μ m long; end cells slightly conical or obtuse with rounded ends; heterocyst basal, single, globose, 7-8 μ m broad, cell wall smooth thick.

***Cylindrospermum catenatum* Ralfs ex Bornet et Flahault. Plate 2, Figure d.**

Order: Nostocales

Family: Nostocaceae

Thallus mucilaginous, united to form dark green patches in young cultures, becomes yellowish with age, then brownish after akinete formation; filaments united by their confluent mucilage; cells rectangular to short cylindric, finely granulated content, slightly constricted at the cross walls 4-5 μ m broad and 4-7 μ m long; heterocyst terminal formed after trichome fragmentation, ovate to ellipsoid 4-5 μ m in diameter, 4-6 μ m long; akinetes oblong formed in a series adjacent to the heterocyst with a smooth outer wall when mature, 7-10 μ m broad, 13-18 μ m long.

***Cylindrospermum majus* Kutz. Plate 2 Figure e.**

Order: Nostocales

Family: Nostocaceae

Thallus expanded, bluish green in colour, mucilaginous patch, filaments densely entangle; sheath indistinct; trichomes 3-5 μm broad, constricted at the cross walls; cells cylindrical longer than broad, 3-5 μm broad and 4-6 μm long; heterocyst terminal, unipored, obtusely conical, 4-6 μm broad, 4-5 μm long; akinetes ellipsoidal with a roughened and punctuate wall, distinctly papillate and 8-10 μm broad, 16-19 μm long, cell wall smooth and thin.

***Cylindrospermum muscicola* var *longispora* Dixit.**

Plate 2 Figure f.

Order: Nostocales

Family: Nostocaceae

Thallus filamentous, expanding, olive green in colour, colony mucilaginous; trichome 2-3 μm broad, 4-5 μm long; heterocyst 5-6 μm broad and 7-12 μm long; akinetes ovoid 8-12 μm broad and 18-21 μm long with smooth walls.

***Cylindrospermum stagnale* (Kutz.) Bornet & Flahault. Plate 2 Figure g.**

Order: Nostocales

Family: Nostocaceae

Thallus floccose, expanding, blue green in colour, filaments entangled or parallel in a mucilaginous expanse, attached or free floating; trichomes 3-4 μm broad, constricted at the cross walls, cells nearly quadrate, or cylindrical often 3-4 times as long; heterocyst subspherical or oblong, 5-8 μm broad, 7-11 μm long; akinetes cylindrical with rounded ends, 9-10 μm broad and 21-25 μm long, with smooth outer layer.

***Hapalosiphon intricatus* West and West. Plate 2 Figure h.**

Order: Stigonematales

Family: Stigonemataceae

Thallus filamentous, floccose, green in colour, filaments with uniseriate trichomes; sheath thin and colourless; branching present, with unilateral short branches which are flexuous, lateral branching long and mostly branching from one side of the main axis; cells ovate, barrel shaped or short cylindric, 5-7 μm broad; branches crooked arising at various angles from the main axis; heterocyst intercalary, cylindrical or quadrate rounded.

***Lyngbya martensiana* (Menegh.) Gomont. Plate 2 Figure i.**

Order: Nostocales

Family: Oscillatoriaceae

Thallus caespitose, mucilaginous, blue green, filaments much entangled and interwoven, bright blue green, long flexible, somewhat straight; trichome 6-10 μm broad, cross walls not constricted and sometimes granulated; sheath colourless, firm, thick, lamellated, extending beyond the apices of trichomes; cells $\frac{1}{2}$ - $\frac{1}{4}$ times as long as broad, 1.5-2.5 μm long; end cells round, without calyptre, not capitates; cell wall thick smooth.

***Microchaete robusta* Setchell & Gardner. Plate 2**

Figure j.

Order: Nostocales

Family: Microchaetaceae

Thallus filamentous, blackish brown in colour, forming a wooly type thin film; trichomes solitary, slightly attenuated towards the end; cells quadrate 8-9 μm broad, 9-11 μm long; cell contents granular at the cross walls; basal heterocyst globose, intercalary heterocyst quadrate; sheath distinct, thick, colourless and lamellated, 7-8 μm broad and 6-7 μm long.

***Nostoc carneum* Ag. ex Born. et Flah. Plate 2**

Figure k.

Order: Nostocales

Family: Nostocaceae

Thallus at first globose, irregularly expanding, gelatinous and flesh coloured reddish brown in colour, filaments loosely contorted, flexuous and sheath indistinct; trichome 3-4 μm broad; cells cylindrical and oblong, longer than broad, 3-5 μm broad and 6-7 μm long; heterocyst subspherical and oblong shaped 4-5 μm broad; spores ellipsoidal, 4-6 μm broad and 7-8 μm long.

***Nostoc commune* Vaucher ex Born. et Flah. Plate 2**

Figure l.

Order: Nostocales

Family: Nostocaceae

Thallus firm, gelatinous, light blue green, filaments flexuous, closely entangled forming globose membranous structure at young stage, later flattened, expanding, membranous or leathery, sometimes irregularly torn, often perforated; sheath mostly distinct only at the periphery, thick yellowish brown, inside the thallus more or less distinct, hyaline; trichome 5-6 μm broad, cells spherical, 4-6 μm long; heterocyst nearly spherical about 7 μm broad; epispore smooth colourless.

***Nostoc ellipsosporum* (Desm.) Rabenh. ex Born. et Flah. Plate 3**

Figure a.

Order: Nostocales

Family: Nostocaceae

Thallus colonial, gelatinous, reddish brown, irregularly expanded attached by the lower surface, to the substratum on solid medium; filaments flexuous loosely entangled; trichome about $4\mu\text{m}$ broad; cells cylindrical $6\text{-}9\mu\text{m}$ long; heterocyst subspherical or oblong $6\text{-}7\mu\text{m}$ broad and $6\text{-}11\mu\text{m}$ long; spores ellipsoidal to oblong cylindrical, in long chains, $6\text{-}8\mu\text{m}$ broad and $8\text{-}11\mu\text{m}$ long, episore smooth.

Nostoc muscorum* Ag. ex Born et Flah. Plate 3*Figure b.**

Order: Nostocales

Family: Nostocaceae

Thallus gelatinous, colonial, dark blue green in colour, colony wide round, bottom dwellers; filaments highly coiled and densely entangled; trichome $3\text{-}4\mu\text{m}$ broad; cells spherical to barrel shaped, short; heterocyst nearly spherical and $4\text{-}7\mu\text{m}$ broad.

Nostoc linckia* (Roth.) Bornet ex Born. et Flah.*Plate 3 Figure c**

Order: Nostocales

Family: Nostocaceae

Thallus varying in size sometimes punctiforme, at first globose later irregularly expanding, torn gelatinous, blue green or blackish green; filaments densely entangled, flexuous or highly coiled; sheath diffused and colourless inside, distinct only in the peripheral portion; trichomes $4\text{-}5\mu\text{m}$ broad, pale blue green; cells short barrel shaped; heterocyst subspherical; spores subspherical $4\text{-}6\mu\text{m}$ broad, $7\text{-}8\mu\text{m}$ long; episore smooth.

Nostoc paludosum* Kutz ex Born et Flah. Plate*3 Figure j.**

Order: Nostocales

Family: Nostocaceae

Thallus microscopic, punctiform, gelatinous, colony oblong or subspherical; trichomes coiled in a wide and copious gelatinous investment $3\text{-}4\mu\text{m}$ broad; sheath broad, colourless or yellowish brown; cells barrel shaped, as long as broad $3\text{-}4\mu\text{m}$ broad, pale blue green; heterocyst ovate, broader than the vegetative cells $3\text{-}5\mu\text{m}$ broad; spores oval, in short series with a smooth colourless membrane, $4\text{-}4.5\mu\text{m}$ broad and $6\text{-}8\mu\text{m}$ long.

Nostoc punctiforme* (Kutz.) Hariot. Plate 3*Figure e.**

Order: Nostocales

Family: Nostocaceae

Thallus sub globose, olive green in color scattered or confluent, attached, colonies small, mucilaginous; filaments flexuous, densely entangled; sheath delicate, hyaline, mucous; trichome $3\text{-}4\mu\text{m}$ broad, contorted; cells compressed globose, blue green; heterocyst $4\text{-}5\mu\text{m}$ broad; spores subspherical or oblong $5\text{-}6\mu\text{m}$ broad, $5\text{-}8\mu\text{m}$ long; episore thick and smooth.

***Nostoc punctiforme* (Kutz.) Hariot. Plate 3 Figure f.**

Order: Nostocales

Family: Nostocaceae

Thallus sub-globose upto 2mm diameter, filaments scattered, flexuous, densely entangled; trichome; sheath delicate, hyaline; cells barrel shaped or ellipsoidal $3\text{-}5\mu\text{m}$ broad, $2\text{-}3.5\mu\text{m}$ long, blue green; heterocyst globose, $3\text{-}5\mu\text{m}$ broad, akinete sub spherical or ovate $5\text{-}6\mu\text{m}$ broad and $5\text{-}8\mu\text{m}$ long.

***Nostoc punctiforme* (Kutz.) Hariot. Plate 3 Figure f.**

Order: Nostocales

Family: Nostocaceae

Thallus filamentous, expanding, colony globose, scattered, dark green, evenly distributed, free floating, mucilaginous and planktonic in nature; filaments flexuous, densely entangled; sheath hyaline; cells short barrel shaped $2\text{-}4.5\mu\text{m}$ broad and $2\text{-}3\mu\text{m}$ long; heterocyst globose $3\text{-}6\mu\text{m}$ broad and $4\text{-}6\mu\text{m}$ long; akinete ovate or oblong $1\text{-}2\mu\text{m}$ broad and $2\text{-}3\mu\text{m}$ long.

Oscillatoria tenuis* Ag.(after Gomont). Plate 3*Figure g.**

Order: Nostocales

Family: Oscillatoriaceae

Thallus thin, blue green forming a slimy mass; trichome thin, fragile, solitary or aggregated, straight or slightly curved, not attenuated at the apices, slightly constricted at the cross walls $4\text{-}6\mu\text{m}$ broad; cells quadrate or shorter than broad $2\text{-}4\mu\text{m}$ long, cell contents light blue green, homogenous, mostly granulated at the septa; end cells rounded or hemispherical not capitate, calyptora absent with thickened outer membrane.

Phormidium tenue* (Menegh.) Gom. Plate 3*Figure h.**

Order: Nostocales

Family: Oscillatoriaceae

Thallus light blue green, thin membranous, expanded; trichome straight or slightly bent, densely entangled, slightly constricted at the cross

walls, attenuated at the end cells 1-2 μm broad, light blue green; sheath thin, diffluent; cell up to 3 times longer than broad 2-6 μm long; septa not granulated; end cells acute conical; calyptra absent.

***Westiellopsis prolifica* Janet. Plate 3 Figure i.**

Order: Stigonematales

Family: Stigonemataceae

Thallus floccose, planktonic green colour, filamentous, with branching of two kinds. Main filament torulose; cells barrel shaped 5-10 μm broad, branch filaments thinner and elongate, not constricted at the cross walls; cells elongate cylindrical 4-6 μm broad; heterocyst oblong cylindrical 5-8 μm broad and 8-10 μm long. The presence of both heterocystous and non heterocystous forms of cyanobacteria has been observed in the rice fields of Karimganj district. In the present study rich diversity of heterocystous cyanobacteria with 31 species represented with 8 genera 2 orders have been reported. Nayak and Prasanna (2007) recorded more heterocystous forms while studying cyanobacterial abundance and diversity in rice field soils of India. The heterocystous forms were also found to be more abundant in similar studies made by others (Bharadwaj and Baruah. 2013; Tiwari et al. 2015). Thirty four cyanobacterial species belonging to Nostocaceae, Rivulariaceae, Microchaetaceae, Stigonemataceae and Oscillatoriaceae family were recorded from the rice fields. Out of this, highest number of heterocystous strains were represented by *Nostoc*(9), followed by *Anabaena*(8), *Calothrix*(6), *Cylindrospermum*(4) while *Hapalosiphon*, *Microchaete*, *Westiellopsis* and *Aulosira* are each represented by single species. The non heterocystous genera *Oscillatoria*, *Lyngbya* and *Phormidium* are also represented by single strains. The two heterocystous genera *Anabaena* and *Nostoc* forms over 90% of the filamentous cyanobacteria isolated from the rice

fields. This observation is in conformity with the findings elsewhere (Prasanna R. et al. 2009; Karabi and Sarma 2015). Similar findings are also observed by Dasgupta and Ahmed (2013) where the rice field cyanobacterial biodiversity from 3 different subdivisions viz –Tezpur, Biswanath chariali, Gahpur of Sonitpur district of Assam (India) were studied. The distributional pattern showed that the genera *Nostoc*, *Anabaena*, *Aulosira*, *Calothrix* *Westiellopsis* and *Aphanocapsa* were the dominant rice field blue green algae in the district. Singh et al. 2014 phenotypically characterized twenty nine strains of cyanobacteria, comprising two unicellular, four colonial, nine unbranched nonheterocystous, 12 unbranched heterocystous, and two pseudo branched cyanobacteria from the paddy fields of Chattisgarh state, India where the phenotypic attributes were observed to be strain specific. Free-living photosynthetic strains of cyanobacteria capable of fixing nitrogen have been isolated and used in biofertilizer consortia in south-east Asian countries and the potential impact of these organisms on agriculture through their use as biofertilizers, soil conditioners, plant growth regulators and soil health ameliorators is well recognized (Whitton 1992). A rich diversity of heterocystous cyanobacteria from rice fields of Cuddalore district in Tamilnadu state where 30 species, represented with 7 genera under single order and three families have been reported (Selvi et al. 2012). Cyanobacteria are known to be an integral component of rice fields where they play an important role in building soil fertility. They were mainly ascertained by the variations in the morphological structures and distinctive characters during their young and old stages of growth. The abundance, diversity, distribution and presence of several heterocystous forms of cyanobacteria are an indicator of low nitrogen content in rice fields

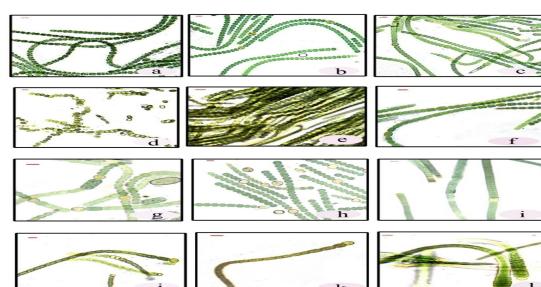


Plate 1

a) *Anabaena anomala* b) *Anabaena constricta* c) *Anabaena doliolum* d) *Anabaena flos aquae* e) *Anabaena gelatinicola* f) *Anabaena orientalis* g) *Anabaena iyengarii* var *tenuis* h) *Anabaena oryzae* i) *Aulosira aenigmatica* j) *Calothrix braunii* k) *Calothrix braunii* l) *Calothrix fusca*; Scale = 5 μm

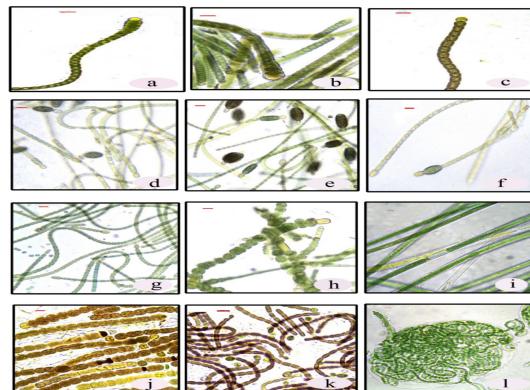


Plate 2

a) *Calothrix marchica* b) *Calothrix marchica* var. *crassa* c) *Calothrix marchica* var *intermedia* d) *Cylindrospermum catenatum* e) *Cylindrospermum majus* f) *Cylindrospermum muscicola* var *longispora* g) *Cylindrospermum stagnale* h) *Hapalosiphon intricatus* i) *Lyngbya martensiana* j) *Microchaete robusta* k) *Nostoc carneum* l) *Nostoc commune*; Scale =5µm

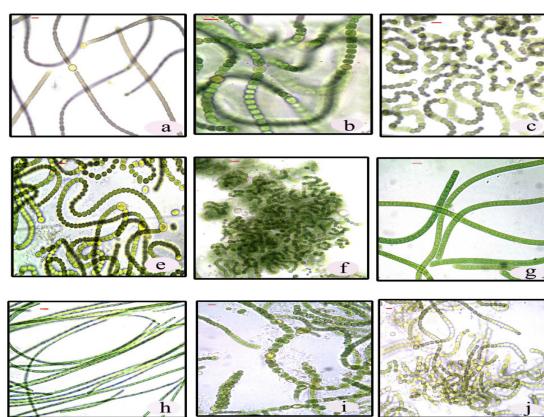


Plate 3

a) *Nostoc ellipsosporum* b) *Nostoc muscorum* c) *Nostoc linckia*
 e) *Nostoc punctiforme* f) *Nostoc punctiforme* g) *Oscillatoria tenuis* h) *Phormidium tenue*
 i) *Westiellopsis prolifica* j) *Nostoc paludosum* Scale = 5µm.

CONCLUSION

As rice is cultivated widely in the studied region, emphasis can be given for the association of mineral and nitrogen supplements with the nitrogen fixing cyanobacteria for increasing the agricultural yield of the region. This paper highlights the importance of morphological characterization and identification of the cyanobacterial strains for their application in the rice fields for management of nitrogen fertilizer can be used for sustainable agricultural practices.

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