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Research article

SURVEY AND IDENTIFICATION OF GENUS *NOSTOC* AND *ANABAENA* IN THE RICE FIELDS OF JORHAT DISTRICT, ASSAM.

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ABSTRACT: The present study deals with the investigation of the genus Anabaena and Nostoc of the rice field of Jorhat district. Cyanobacteria are one of the major components of the nitrogen fixing biomass in paddy fields which provides a potential source of nitrogen fixation at no cost. Due to the important characteristic of nitrogen fixation, cyanobacteria have a unique potential to contribute to enhance productivity in a variety of agricultural and ecological situations. The present work 14 species of Anabaena and 8 species of Nostoc had been isolated from Jorhat district of Assam.

Key words: Blue green algae, *Anabaena* and *Nostoc*, rice field.

INTRODUCTION

Cyanobacteria (also known as blue green algae) is a group of extraordinarily diverse Gram-negative prokaryotes that originated 3.5 billion years ago. Its distribution is ubiquitous in nature and are found everywhere including places with extreme climatic conditions such as in Antarctica, in hot springs [1] and even in oxic and anoxic environments [2]. The agronomic potential of blue green algae in rice cultivation was recognized in 1938 by De who attributed the natural fertility of tropical rice field due to nitrogen fixing blue green algae. The utilization of cyanobacteria in the rice fields has a great significance in increasing in the rice field's fertility. Cyanobacteria play an important role in maintenance and build up of soil fertility, consequently increasing rice growth and yield as a natural biofertilizer [3]. Biological nitrogen fixation is considered to be an important process which determines nitrogen balance in soil ecosystem [4]. Biofertilizer are the safe substitute to chemical fertilizer and most of the blue green algae function as biofertilizer. Nitrogen is one of the most important nutrients very essential for plant growth and a major factor that limits agricultural yield [5]. After water, nitrogen is the second limiting factor for plant growth in many rice fields and deficiency of this element is met by fertilizers [6]. Although blue green algae can grow in different cultivated or uncultivated soil they are very much abundant in rice field soil. They are abundantly present in rice field and help to maintain the fertility by performing biological nitrogen fixation and producing nitrogenous and non-nitrogenous compounds with the help of specialized cell called heterocyst [7]. The climate resistant spores of cyanobacteria are formed under unfavorable environment conditions that posses a special stucture (heterocyst) which contain nitrogenase enzyme playing a vital role in N fixation. Heterocyst forming species are special in N fixation and are able to convert N to ammonia, nitrites and nitrates which can be absorbed by plants for the construction of potential to reclaim high saline soil and application of cyanobacteria in rice field reduces the usage of chemical urea [8]. Heterocyst forming species are specialized for nitrogen fixation when there is scarcity of nitrogen able to fix nitrogen gas into ammonia, nitrites or nitrates. The different species have different numbers of heterocyst, some may produce so many heterocyst but some may not. The soil of many rice fields contains high density of cyanobacteria and over 50% of cyanobacterial genera in are heterocystous [9].

Rice production depends on the natural fertility of the soil. The continuing supply of nitrogen over the years despite removal of the element by the rice crop is claimed to result from the fixation of atmospheric nitrogen by micro organisms in paddy fields [10]. Most of the world's paddy field have been supporting rice crop for centuries without the addition of artificial fertilizers; it is possible that nitrogen depletion by the rice crop is being replenished mainly by these blue green algae [11]. Rice fields are temporary wetland ecosystems, with variable biodiversity and cyanobacterial are known to be an integral component of waterlogged rice fields. The rice field ecosystem provides a favourable environment for the growth of cyanobacteria with respect to their requirements for light, water, high temperature and nutrient availability.

This could be the reason for more abundant cyanobacteria growth in paddy soil than in upland soil. Soil fertility is generally improved by the organic matter produced by these organisms [12]. The capacity of several Blue Green Algae to fix the atmospheric nitrogen is a significant biological process of economic importance. Several reports are found on edaphic algae of rice fields of different states of India but the most commonly used nitrogen-fixing species are of genera *Anabaena, Calothrix, Nostoc, Schizothrix,* and *Scytonema* [13, 14]. In recent times, studies on cyanobacterial diversity has received due attention [2, 15].

However, work and publications on this group of microorganisms from Northeast India is sporadic despite the fact that this region falls within Indo-Malayan biodiversity hot spot [16]. Though rice is enormously cultivated in the Jorhat District of Assam, no concerned attempt has so far been made to record the occurrence and distribution of blue green algae in paddy fields of the Jorhat District. Therefore a systematic study on the distributional pattern of blue green algae mainly from the genus *Anabaena* and *Nostoc* and an attempt of finding the maximum heterocyst producing species in the rice fields was undertaken to prepare a detailed account of blue green algae of the rice fields in Jorhat District of Assam.

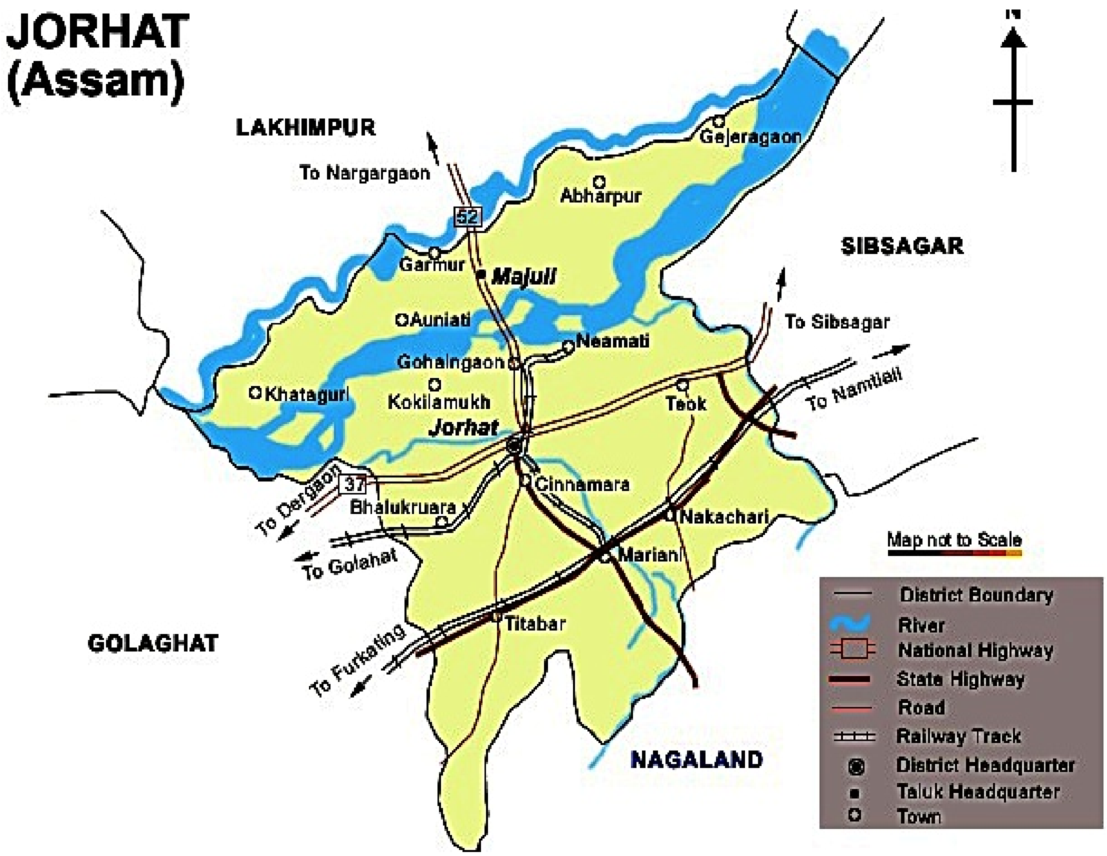

Figure 1: Area map of the study site.

MATERIAL AND METHODS

Study area: Jorhat district is situated in between 27.15 °N to 26.30° N latitude and 93.45° E to 94.30° E longitude. The district is surrounded by the Hill State of Nagaland in the south, Sivsagar district in the east, Golaghat district in the west and Lakhimpur district in the north. The Brahmaputra River flowing from East to West in the Northern part of the district forms the Majuli Island which is the biggest river island in the world. The district has an area of 2859.3 sq.K.M. and population 9.99 lacs (2001 Census).The climate of the district is subtropical. The temperatures vary between 15°C to 39°C. The district receives rainfall on an average at 2244 mm with South west Monsoon contributing about two third of the total rainfall. The soil is alluvial, deep to very deep, fine loam to clayed texture. The humid atmosphere and abundant rainfall offers good scope for growing a variety of plantation crops. The low land is suitable for rice cultivation while the highland offers excellent scope for pulses, tea, vegetables, banana, citrus and other horticultural crops. The economy of the district is predominantly agrarian in nature. Paddy is the major agricultural crop. Potato, pulses, Mustard, sugarcane and wheat are the other major crops grown in the district.

Collection, Isolation, and Identification of Samples

Algal samples from different localities of Jorhat district were collected during 2012-2013. The samplings were done randomly from both soil and water of the paddy fields. The collected samples were enriched initially in BG-11 medium in conical flask at 24+2°c under 2500 lux illumination using cool fluorescent tube for 10 days in culture room. Then the enriched culture samples were spread on algal broth agar plates and incubated at the above mentioned condition. After the incubation period time freshly grown individual colonies were picked out and transferred to BG-11 medium for pure culture in 250 ml conical flask. These culture flasks were shaken manually for 3-4 times a day. The purity of the culture was monitored by regular observation under microscope. The growth pattern and morphological examination of the cyanobacterial strains was carried out at different stages of growth under a Nikon microscope and the nature of filaments and the shape and size of vegetative cells, heterocyst and akinetes, were analyzed and assigned to different genera following the monograph of [17]. The collected and identified *Nostoc* and *Anabaena* species belonging to the family Nostaceae under the order Nostocales had been considered for the present work.

Heterocyst Frequency

It was determined by counting the number of heterocyst in a given filament and expressed as % frequency. The counting of heterocyst was done after 40 day of culture in the BG-11 medium when the nutrient in the culture media depletes as scarcity of nutrient induce the production of nutrient. Counts and measurements were made on a sufficient number of filaments, selected at random, to give a total of about 100 cells. The number of heterocyst per hundred vegetative cells is referred to as heterocyst frequency and determined by the method of Fogg [11]. Only cells with distinct polar nodule and a thick walled were considered as heterocyst. (Table 1)

RESULT AND DISCUSSION

1.Anabaena orientalis

Dixit,1936,The Myxophyceae of the Bombay Presidency, I, Proc. Indian Acad.Sci.,B,3:101,fig 3D,E; Desikachary,1959,Cyanophyta,405 pl. 77 fig.6.

Trichomes singlet straight or slightly curved, 2.5-4μ broad, cells quadrate or cylindrical, rarely slightly barrel shaped, up to twice as long as broad, 3.7-4-8μ long, end cell conical with round apex, heterocyst singlet intercalary or cylindrical or slightly ellipsoidal with rounded end walls, 4.8- 5.5μ broad, and 7.4-9.2μ long, spores one each side of a heterocyst, ellipsoidal, 7.4-9.2μ broad and 14.8-16.6μ long.

Collection No.: 2,5,29,55, 59. Plate no:I Fig:1

2.Anabaena spiroides klebahn, 1895, Flora, 80: 125, pl.4, fig11; Geilter,1932, Kryptogamen flora, Leipzing, 881;Desikachary,1959,Cyanophyta,395 plate 71 fig.9.

Trichomes singlets, free floating, regularly spirally coiled, with and mucilaginous sheath, spirals 45-54μ broad and 40-50 μ distant; cells spherical,6.1-8μ broad, mostly somewhat shorter than broad, with gas vacuoles; heterocyst subsphericals,7μ broad; spores at first spherical ,later elongate, slightly bent, in optical longitudinal section hexagonal, next to the heterocyst or away from it,14μ broad.

Collection No.: 12,22,69,86. Plate no: I Fig:2

3.Anabaena torulosa (Carm.) Lagerh. ex Born., É. & Flahault, C. (1886 '1888'). Revision des Nostocacées hétérocystées contenues dans les principaux herbiers de France (quatrième et dernier fragment). *Annales des Sciences Naturelles, Botanique, Septième Série* 7: 177-262 Komárek, J. (2013). *Süsswasserflora von Mitteleuropa. Cyanoprokaryota: 3rd part: heterocystous genera*. Vol. 19 pp. [i]-xviii, [1] -1130. Desikachary, 1959, Cyanophyta, 315 pl. 71, fig.6

Thallus mucilaginous, thin, blue green; trichome 4.2-5μ broad, apical cell actually conical barrel shaped, as long as or somewhat shorter than broad; heterocysts subspherical or ovoid,6μ broad and 6-10μ long; spores on both sides of the heterocysts, developed centripetally, single or many sub-cylindrical with rounded ends, sometimes constricted in the middle,7-12μ broad, up to twice as long as broad, epispore smooth and pale brown in colour.

Collection No.: 10,25,29,38. Plate no:I Fig:3

4.Anabaena oscillarioides Bory ex Born.et.Falh., 1822,Borry,Diet.,class.d'hist,nat.,1:308;

Fremy,1929, Myxo.d'Afr.equat.franc., 371,fig307;Geilter,1932, Kryptogamenflora, Leipzing, 886, fig. 567e; Fremy, 1933, Cyano . Cotes d'Eur., 185, pl.61, fig 5; Desikachary, 1959, Cyanophyta, pg 417, pl. 7 fig.97.

Thallus gelatinous, dark green, trichomes 4.2-6µ (general 5-6)µ broad cells barrel- shaped as long as broad, or somewhat longer or shorter than broad, end cells rounded; heterocysts spherical or oval, 6-8µ broad,6-10µ long; spores on both sides of heterocyst ;single or2-3,at first oval, later rounded cylindrical,8-10µ broad(more commonly 10µ),20-40µ long, epispore smooth and pale brown.
Collection No.: 22,37,39,72,85. Plate no: I Fig:4

5.Anabaena gelatinocola Ghose 1924: 341, A systematic and ecological account of a collection of blue-green algae from Lahore and Simla. *Journal of the Linnean Society (Botany)* 46: 333-346. pl. 31: fig. 8; Geitler, L. (1932). Cyanophyceae. In: *Kryptogamen-Flora von Deutschland, Österreich und der Schweiz. Ed. 2*. (Rabenhorst, L. Eds) Vol. 14, pp. 673-1196, I - [vi]. Leipzig: Akademische Verlagsgesel lschaft. Desikachary,1959, Cyanophyta, Pg. 39, Pl. 76, fig.6.
Thallus thick, gelatinous; trichomes mostly solitary, spirals densely arranged and coiled, not screw like, sometime straight; cells subspherical,6-7.5µ broad, apex acute; heterocyst 7-8µ broad, spherical; spores in series, away from the heterocyst, spherical, about 14µ in diameter.
Collection No.: 20,25,39,46,52. Plate no:I Fig:5

6.Anabaena Iyengarii Bharadwaja,1935,The Myxophyceae of the United Provinces, I,Proc.Indian Acad.Sci.,B,2:105, fig. 6H-K (as "*iyengarii"*); Desikachary, T.V. (1959). *Cyanophyta*. Pg. 407, Pl. 78, fig.2New Delhi: ICAR
Trichome single or irregularly curved,5.2-6.3µ broad, end-cell conical with rounded apex; cells barrel shaped ,as long as broad ,or slightly shorter or longer than broad; heterocyst barrel shaped, rarely spherical,7.3-8.4µ broad and 7.3-10.5µ long; spores ellipsoidal often in long or short chains, rarely single on both side of the heterocysts,8.4-10.5µ broad and 10.5-21µ long, epispore thick, smooth and yellowish brown.
Collection No.: 6, 23, 49,55,74. Plate no: I Fig:6

7.Anabaena variabilis Kutzing ex Bornet, É. & Flahault, C. (1886 '1888'). Revision des Nostocacées hétérocystées contenues dans les principaux herbiers de France (quatrième et dernier fragment). *Annales des Sciences Naturelles, Botanique, Septième Série* 7: 177-262 Desikachary, T.V. (1959). *Cyanophyta*. Page 410, Plate 171,fig:5, New Delhi: ICAR
Thallus gelatinous, dark green; trichomes without any sheath,flexuous,4-6µ broad,more often 4.2-5µ broad slightly constricted at the cross walls, end cells conical, obtuse; cells barrel shaped, sometime with gas vacuole,2.5-6µ long; heterocyst spherical or oval,6µ broad, up to 8µ long; spores formed centrifugally, not contiguous with the heterocyst, barrel shaped, in series,7-9(-11)µ broad, 8-14µlong,epispore smooth, or with fine needles, colorless or yellowish brown.
Collection No.: 9,29,65,76,84. Plate no: I Fig: 7

8.Anabaena doliolum Bharadwaja 1935,The Myxophyceae of the United Provinces,I,Proc.Indian Acad.Sci.,B,2:105, fig.6A,D; Desikachary, T.V. (1959). *Cyanophyta*. Page 410, Pl. 78, fig.3. New Delhi: ICAR.
Plant mass mucilaginous, pale blue green; trichome single, free swimming, straight, curved or slightly coiled,3.6-4.2µ broad, slightly tapering at the ends, with conical apical cells, possessing almost pointed apex, cells barrel shaped, as long as broad or little longer or shorter than broad; heterocyst barrel shaped,5.2-6.3µ broad and 6.3-9.4µ long; spores ellipsoidal, with almost pointed apices in short or long chains, adjoining the heterocyst but developed centrifugally, epispore thick, smooth and hyaline or yellow brown, 4.2-6.2µ broad and 6.3-11.5µ long.
Collection No.:22,34,37,58, 58. Plate no:I Fig:8

9.Anabaena fertilissima Rao, C.B. (1937). The Myxophyceae of the United Provinces, India - III. *Proceedings of the Indian Academy of Sciences B* 6(6): 339-375,fig.6A-C *;* Desikachary, T.V. (1959). *Cyanophyta*. Page 398, Plate 74, fig.1, New Delhi: ICAR.
Trichome single, bent, with almost rounded end cells, up to 35 µ long, 5-6µm broad, at the apex 4 µ broad, cells barrel shaped, 4-8 µ long, heterocyst almost spherical, 6-8 µ broad, spores in long chains; often making the whole trichome spongy, adjoining the heterocysts but formed centrifugally, almost spherical, with a smooth hyaline outer wall.
Collection No.: 27,37,46,56,77. Plate no:I Fig:9

10.Anabaena oryzae Fritsch, F.E. (1949). The genus *Anabaena* with special reference to the species recorded from India and the adjacent Asiatic mainland. *Journal of the Indian Botanical Society* 28: 135-161.; Komárek, J., Anagnostidis, K. (1989). Modern approach to the classification system of Cyanophytes 4 - Nostocales. *Algological Studies* 56: 247-345. Desikachary, T.V. (1959). *Cyanophyta*. Page 396, Plate 72, New Delhi: ICAR.
Thallus soft green, gelatinous, membranous, trichome short, straight, densely aggregated, generally parallel cells 2.5-3 µ broad, more or less barrel shaped,1½ -2 times as long as broad; heterocyst terminal and intercalary, broader than the vegetative cells.
Collection No.:10,30,42,56,65,68. Plate no: II Fig:10

11.Anabaena vaginicola Fritsch, F.E., Rich, F. & Stephens, M.L. (1930). Contributions to our knowledge of freshwater algae of Africa. 7. Freshwater algae (exclusive of diatoms) from Griqualand West. *Transactions of the Royal Society of South Africa* 18: 1-92, figs 1-32. Desikachary, T.V. (1959). *Cyanophyta*. Page 401, Plate 73, New Delhi: ICAR.

Trichomes many in a common mucilaginous sheath, rarely single, more or less parallel,4-4.5µ broad, single trichome with sheath11.5µ broad many trichome in a sheath,17-21µ broad sub quadrate, to elongate cylindrical; apical cell acuminate conical; heterocysts cylindrical,4-5µ broad,6-10µlong spores short cylindrical or oblong, contigeous with the heterocysts, often 4-5 in series, wall hyaline,6.5-10µbroadand 12-17.5µ long.

Collection No.:7,16,24,45,39,53,72. Plate no: II Fig:11

12. Anabaena naviculoides F.E. Fritsch, F.E. (1949). The genus *Anabaena* with special reference to the species recorded from India and the adjacent Asiatic mainland. *Journal of the Indian Botanical Society* 28: 135-161. . Desikachary, T.V. (1959). *Cyanophyta*. Page 410, Plate 72. . New Delhi: ICAR.

Trichome elongate, moniliform, apices acuminate; cells 3.2-6µ,heterocyst intercalary ,single, barrel shaped,4-5µ broad,as long as or lsightly longer than broad; spores ellipsoidal, end acute; exospores thin hyaline, more or less 12.5µ long,6-7µ broad and 8.5-9µ long.

Collection No.:16,25,32,58,61,71. Plate no:II Fig:12

13.Anabaena khannae Skuja, H. (1949). Zur Süsswasseralgenflora Burmas. *Nova Acta Regiae Societatis Scientiarum Upsaliensis, Series 4* 14(5): 1-188, pls I-XXXVII. Desikachary, T.V. (1959). *Cyanophyta*. Page 396, Plate 75. . New Delhi: ICAR.

Trichomes 2.5-4 µ broad, cells barrel shaped, apex rounded; heterocyst terminal or intercalary, barrel shaped; apex rounded, 3-3.5 µ broad.3.5-6 µ long.

Collection No.: 7,11,22,35,50,55,63. Plate no: II Fig:13

14.Anabaena utermohli Geitler, L. (1925). Cyanophyceae. In: *Die Süsswasser-Flora Deutschlands, Österreichs und der Schweiz*. (Pascher, A. Eds) Vol.12, pp. 1-450. ; Desikachary, T.V. (1959). *Cyanophyta*. Page 415, Plate 74.fig .2, New Delhi: ICAR.

Trichomes single, free floating; cells 4-4.5 broad,4-4.6 long, often with gas vacuoles; heterocyst somewhat elongate,4-4.5 broad,4.7-5.3 long; spores 7-8 broad, 19-20 long smooth and colourless.

Collection No.: 5,8,23,26,31,45,66,82. Plate no:II Fig:14

15.Nostoc muscorum *Agardh. ex.* Bornet, É. & Flahault, C. (1886 '1888'). Revision des Nostocacées hétérocystées contenues dans les principaux herbiers de France (quatrième et dernier fragment). *Annales des Sciences Naturelles, Botanique, Septième Série* 7: 177-262. Desikachary, T.V. (1959). *Cyanophyta*. Page 385, Plate 70.fig .2, New Delhi: ICAR.

Thallus gelatinous, membranous, irregularly expanded, attached by the lower surface,
tuberculate, dull olive 2-5 µ in diameter.; filaments densely entangled; sheath distinct only at the periphery of the thallus, yellowish brown; trichome 3-4 µ broad; cells short barrel shaped to cylindrical, up to twice as long as broad; heterocyst nearly spherical,6-7 µ broad; spores oblong, many in series, 4-8 µ broad, 8-12 µ long, epispore smooth and yellowish.

Collection No.:3,13,18,29,39,59,87. Plate no:II Fig:15

16.Nostoc calcicola *Brebisson ex* . Bornet, É. & Flahault, C. (1886 '1888'). Revision des Nostocacées hétérocystées contenues dans les principaux herbiers de France (quatrième et dernier fragment). *Annales des Sciences Naturelles, Botanique, Septième Série* 7: 177-262.; Geilter,1932, Kryptogamenflora, Leipzing, 886, fig.534. Desikachary, T.V. (1959). *Cyanophyta*. Page 384, Plate 68.fig .1, New Delhi: ICAR.

Thallus mucilaginous, slightly diffluent, expanded, olive, grey or blue green, often up to 5 cm in diameter filament loosely entangled; sheath mostly indistinct, or distinct only at the periphery of the thallus, colorless or yellowish brown; trichome 2.5µ broad, pale blue green; cells barrel shaped, sub spherical, rarely longer than broad; heterocyst sub spherical, 4 µ broad; spores sub spherical, 3.4-4.5 µ broad, with smooth yellowish membrane.

Collection No.: 17.19.27,29,49,56. Plate no:II Fig:16

17.Nostoc commune *Vaucher ex Born.et Flah.,Voucher,1803,Histoire des Conferves d'eau douce, 222, pl.16, fig.1;Fremy,1929,Myxo.d'Afr.equat. franc.,342, fig.283;* Geilter, 1932, Kryptogamenflora, Leipzing, 886, fig.534. Desikachary, T.V. (1959). *Cyanophyta*. Pg. 387, Pl. 68. fig.3. New Delhi: ICAR.

Thallus firm, gelatinous, at first globose, later flattened, expanding undulated, membrane or leathery, sometimes irregularly torn, often perforated, blue green, olivaceous or brown; filamentous flexuous, entangled; sheath mostly distinct only at the periphery, thick yellowish brown, often laminated, inside the thallus more or less distinct, but hyaline; trichome4-5µ broad, cells short barrel shaped or nearly spherical, mostly shorter or little longer than broad,5µ long; heterocyst nearly spherical, about 7µ broad, spore only once observed, as big as the vegetative cells epispore smooth coloueless.

Collection No.: 6,15,20,25,35,62,69,75. Plate no: II Fig:17

18. Nostoc ellipsosporum Rabenhorst ex Bornet, É. & Flahault, C. (1886 '1888'). Revision des Nostocacées hétérocystées contenues dans les principaux herbiers de France (quatrième et dernier fragment). *Annales des Sciences Naturelles, Botanique, Septième Série* 7: 177-262. Rabenhorst, L. (1865). *Flora europaea algarum aquae dulcis et submarinae*. Sectio II. Algas phycochromaceas complectens. pp. 1-319, 71 figs. Lipsiae [Leipzig]: Apud Eduardum Kummerum.*; Forti1907, Sylloge Algarum,5:398; Fremy, 1929,Myxo. d' Afr. equat. franc. , 339, fig. 280;* Geilter,1932, Kryptogamenflora, Leipzing, 841, fig.533; Desikachary, T.V. (1959). *Cyanophyta*. Page 383, Pl. 69.fig .5, New Delhi: ICAR.

Thallus gelatinous, expanded, filament flexuous, trichome about 2.5-4 µ broad; cells cylindrical size 3.2-4.6 µ broad, 6-13.2 µ long; heterocyst sub-spherical 6-7µ broad, 6-14µ long; spores ellipsoidal, cylindrical,5-7.2 µ broad,14-18.5µ long, epispore smooth.

Collection No.: 17,19,25,35,54,78. Plate no: II Fig:18

19.Nostoc punctiforme (Kutzing) Hariot, P. (1891). Le genre *Polycoccus* Kützing. *Journal de Botanique [Morot]* 5: 29-32.*; Fremy,1929.Myxo.d'Afr.equat.franc.,331,fig.274;* Geilter,1932, Kryptogamenflora, Leipzing, 834, Desikachary, T.V. (1959). *Cyanophyta*. Pg. 374, Pl. 69.fig .1, New Delhi: ICAR.

Thallus sub globose up to 2mm diameter, scattered or confluent, attached filament flexuous, densely enlangled; sheath deliacate,hyaline,mucous,trichome3-4µ broad, cells short barrel shaped or ellipsoidal, blue green,heterocysts4-6.5µbroad;spores sub spherical, or oblong,5-6µ broad and 5-8µ long, epispore thick and smooth.

Collection No.: 5,16,19,20,26,49,76,85,88. Plate no:III Fig:19

20.Nostoc linckia (Rothmaller) Bornat *ex Born.et Flah.,1880,Bornet in Bornet and Thuret,Notesalgologiques, II,86,pl.18,fig.12;Fremy,1929.Myxo.d'Afr.equat.franc.,332,fig.276;*Geilter,1932, Kryptogamenflora, Leipzing, 838, fig.528. Fremy,1933, Cyano. Cotes d'Eur., 175,pl.58,fig.1 Desikachary 1959, Page 377, Plate 67; Desikachary, T.V. (1959). *Cyanophyta*. Pg. 377, Pl. 69. fig . 4, New Delhi: ICAR.

Thallus varying in size, sometimes punctiform, sometime tuberculate, at first globose later irregularly expanding, torn, gelatinous, blue green to violet, or blakish green or brown; filements densely entangled, flexuous or highly coiled; sheath diffluent and colourless inside, distinct only at the peripheral portion; trichomes3.5-4µbroad, pale blue green; cells short barrel shaped; heterocysts sub spherical; spores subspherical, 6-7µ broad,7-8µ long, epispore smooth.

Collection No.: 9,15,16,27,38,36,474,89. Plate no: III Fig: 20

21.*Nostoc spongiformae* var. tenue Rao C.B. 1936,The Myxophyceae of United Provinces-II,Proc.IndianAcad.Sci., 3:170,fig.2F;Forti,1907, Sylloge Algarum,5:397;Fremy,1929.*d 'Afr .Equat. franc, 337, fig. 279;* Geilter,1932, Kryptogamenflora, Leipzing, 839, fig.531; Desikachary, T.V. (1959). *Cyanophyta*. Pg. 380, Plate 68.fig .2, New Delhi: ICAR.

Trichomes about 3-3.7 µ broad, blue green to violet; cells sub-spherical those adjoining the heterocyst slightly 2.8-6 µ long, heterocyst sub-spherical or spherical,4-6 µ broad and5.5-9 µ long; spores spherical; subspherical,4.5-7.3µ broad and 4.5-8 µ long.

Collection No.:15,18,24,33,55,72,77,79 Plate no: III Fig:21

22***. Nostoc hatei*** Dixit, S.C. (1936). The Myxophyceae of the Bombay Presidency, India - I. *Proceedings of the Indian Academy of Sciences, Section B* 3: 93-106, fig.4; Komárek, J. (2013). *Süsswasserflora von Mitteleuropa. Cyanoprokaryota: 3rd part: heterocystous genera*. Vol. 19 pp. [i]-xviii, [1]-1130. Heidelberg: Springer Spektrum. Desikachary, T.V. (1959). *Cyanophyta*. Pg.389, pl.67 fig.2, New Delhi: ICAR.

Trichomes 3.7 broad, densely entangled; cells spherical; heterocyst single, or in short chains of 2-5 cells, almost spherical rarely slightly barrel shaped,3.6-5 broad and 5 long

Collection No.: 2,25,31,42. Plate no: III Fig:22

Table 1: Heterocyst frequency (%) of different Blue green algae isolated from rice field of Jorhat district

S. No	Cyanobacterial Strain	R 1	R 2	R 3	Mean ± SE
1	*Anabaena orientalis*	16.43	13.89	18.04	16.12 ± 1.20
2	*Anabaena spiroides*	12.25	16.62	18.53	15.80 ± 1.85
3	*Anabaena torulosa*	10.75	15.17	13.02	12.98 ± 1.27
4	*Anabaena oscillarioides*	10.53	8.94	10.02	9.83 ± 0.468
5	*Anabaena oryzae*	15.72	13.97	17.25	15.64 ± 0.947
6	*Anabaena Iyengarii*	13.53	16.84	14.64	15.00 ± 0.972
7	*Anabaena variabilis*	12.64	18.54	10.16	13.78 ± 2.48
8	*Anabaena doliolum*	6.76	9.64	15.92	10.77 ± 2.70
9	*Anabaena fertilissima*	17.45	16.82	15.37	16.54 ± 0.615
10	*Anabaena khannae*	6.52	8.64	8.04	7.73 ± 0.63
11	*Anabaena vaginicola*	9.50	8.90	13.17	10.52 ± 1.33
12	*Anabaena naviculoides*	13.97	15.83	12.43	14.07 ± 0.982
13	*Anabaena gelatinocola*	10.05	13.63	8.74	10.80 ± 1.46
14	*Anabaena utermohli*	11.86	13.67	10.21	11.91 ± 0.999
15	*Nostoc muscorum*	13.05	15.43	12.70	13.72 ± 0.857
16	*Nostoc calcicola*	10.85	12.54	10.61	11.33 ± 0.607
17	*Nostoc commune*	13.31	10.81	9.65	11.26 ± 1.07
18	*Nostoc ellipsosporum*	14.76	14.93	12.90	14.19 ± 0.50
19	*Nostoc punctiforme*	10.98	12.63	11.04	11.55 ± 0.54
20	*Nostoc linckia*	14.43	10.76	12.98	12.72 ± 1.06
21	*Nostoc spongiformae*	12.03	10.64	9.11	10.59 ± 0.843
22	Nostoc hatei	13.62	12.85	12.43	12.96 ± 0.384

Algal flora appears to be more abundant in cultivated soil than in uncultivated one [18]. Role of cyanobacteria in improving soil health and fertility is well known Region-based specific cyanobacterial isolates could be more effective in such applications as they are pre-acclimatised to the existing environmental conditions. Knowledge of cyanobacterial diversity of a region may help in selecting appropriate cyanobacterial inocula to be applied as biofertilizer consortia in crop fields as well as help in finding strains with other biotechnological potentials. Therefore an extensive study was made to find out the occurrence and abundance of heterocystous blue green algae population in different rice field of Jorhat District, of Assam, India. The present work established the existence of 14 species of *Anabaena* and 8 different species of *Nostoc* in different part of the district Jorhat, Assam. All are heterocystous blue green algae and fixes biological nitrogen in the rice field. The distribution of these heterocystous forms might be indicating the lower nitrogen status in both the rice fields. The maximum heterocyst frequency is shown by *Anabaena fertilissima* under the genus *Anabaena* and *Nostoc ellipsosporum* under genus *Nostoc*. Presence of these heterocystous cyanobacteria in the paddy fields might be contributing to certain extent towards the nitrogen budget. *Anabaena* and *Nostoc* is the dominant genus of soil micro flora in India and found in Tamil Nadu, Assam, Hariyana, Kerala and West Bengal. [13] Blue green algae (BGA) are the most promising biological systems, adding the nitrogen to the paddy field [19]. In conclusion, the present study documented a remarkable biodiversity of *Nostoc* and *Anabaena* where *Anabaena* was the dominant genus of soil micro flora in the rice fields of studied area.

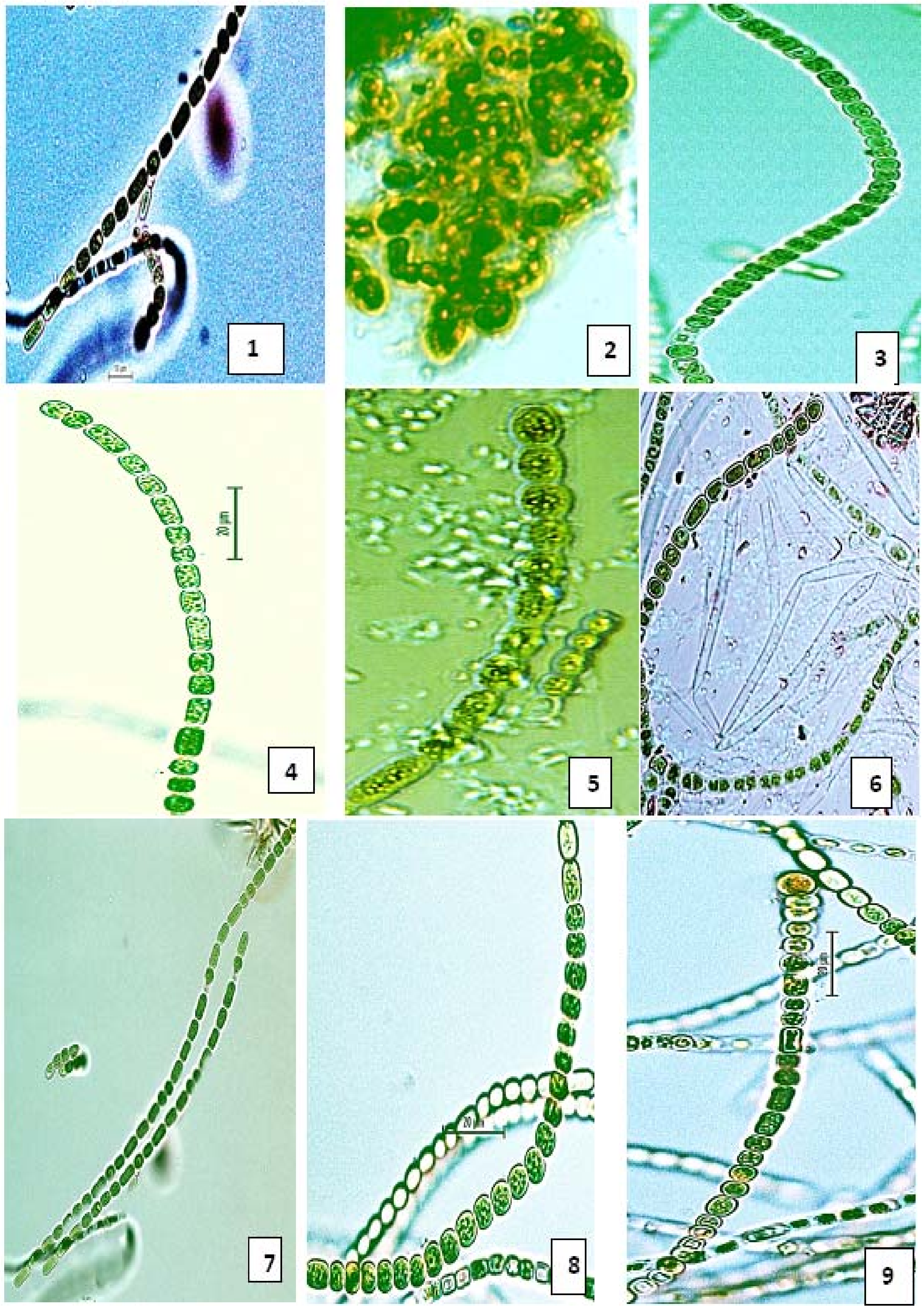

PLATE-I

Figure:(1)*Anabaena orientalis*,(2*) A.spiroides*, (3) *A.torulosa*, (4)*A.oscillaroides, (*5)*A.gelatinicola,*

(6) *A.Iyengarii*, (7*) A.variabilis*,(8*) A.doliolum*,(9)*A. fertilissima*. (Magnification 400X)

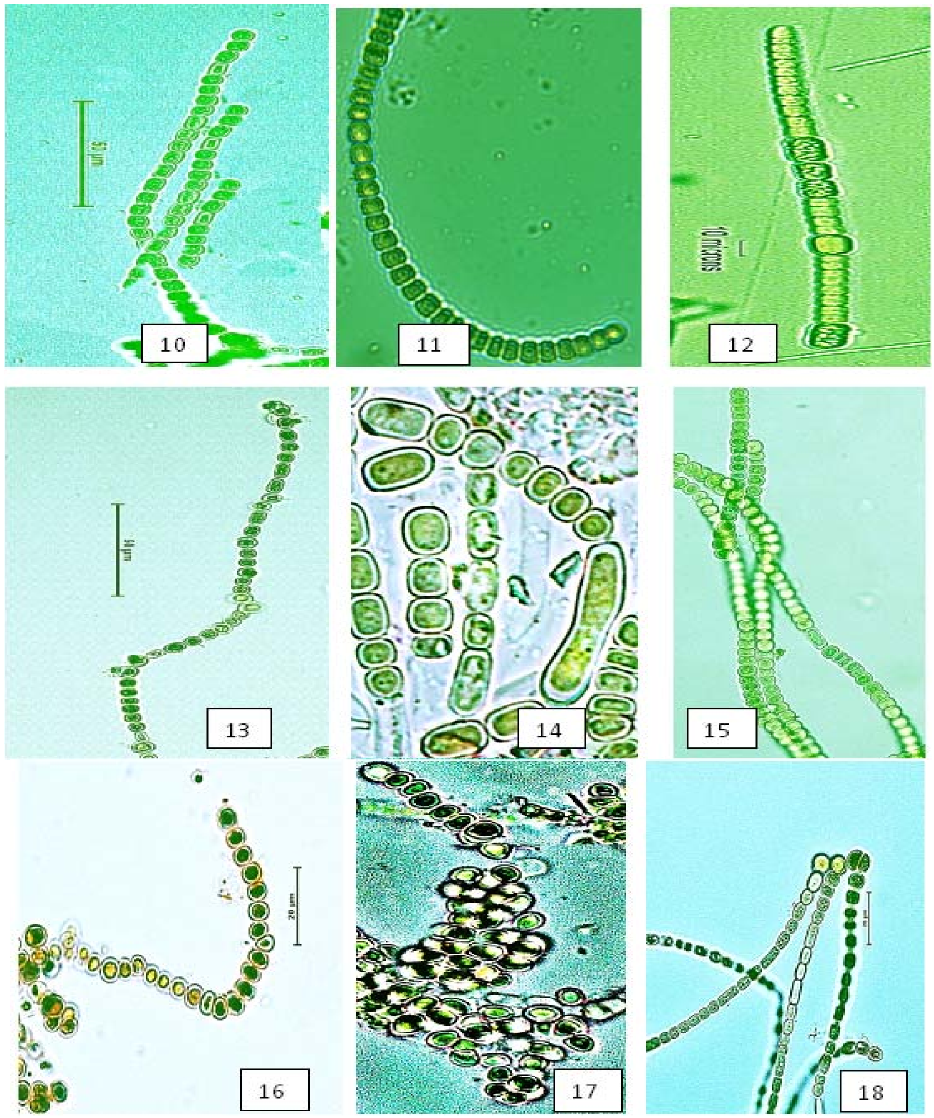

PLATE-II

Figure: (10)*Anabaena oryzae*,(11)*A.vaginicola*,(12)*A.naviculoides*,(13)*A.khannae*,(14)*A.utermohli*, (15*)Nostoc muscorum*,(16)*N,calcicola*,(17)*N.communae*,(18)*N.ellipsosprum.*

PLATE-III

Figure: (19) *Nostoc punctiformae*,(20)*N.linckia*,(21)*N.spongiformae*,(22) *N.hatei*

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