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RESEARCH ARTICLE

Isolation, morphological and biopigments evaluation of the genera *Nostoc* and *Anabaena* (Nostocales) from Loktak Lake

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Abstract

Natural colourants such as phycobiliproteins are gaining importance over synthetic ones as they are non-toxic and non-carcinogenic. In this study, twenty-five (25) strains of *Nostoc* sp. and twenty-five (25) strains of *Anabaena* sp. from freshwater habitats of Loktak Lake were isolated, characterized and primarily screened for phycobiliproteins and chlorophyll-a. Among *Nostoc* genera, maximum amount of phycoerythrin was produced by *Nostoc* sp. BTA-61 (128.84±1.35 μgml^{-1}). *Nostoc commune* BTA-67 produced maximum amount of both phycocyanin (130.55±10.41 μgml^{-1}) and allophycocyanin (97.13±6.98 μgml^{-1}). *Nostoc commune* BTA-67 also showed the maximum chlorophyll-a content (28.90±0.17 μgml^{-1}). Within *Anabaena* sp., maximum phycocyanin amount was produced in *Anabaena iyengarii* BTA-74 (88.16±0.95 μgml^{-1}). *Anabaena* sp. BTA-964 (135.42±1.36 μgml^{-1}) and *Anabaena* sp. BTA-980 (50.71±1.70 μgml^{-1}) produced maximum amount of phycocyanin and allophycocyanin respectively. *Anabaena iyengarii* BTA-74 (16.43±0.17 μgml^{-1}) produced maximum amount of chlorophyll-a when compared to other *Anabaena* strains. These potent strains were found to be useful for industrial application.

INTRODUCTION

Loktak Lake has varied habitat patches (habitat heterogeneity) supporting a rich biodiversity. However, much work has to be done on the distribution and taxonomy of flora and fauna of this unexplored geographical area. Cyanobacteria are impressive ecosystem engineers with an evolutionary history stretching back at least 2.15 billion years (Hayes et al., 2007; Rasmussen et al., 2008). They are often referred as 'miniature factories' of the biological world and represent an alternative source of a variety of bioactive compounds, lipids/fatty acids, proteins, enzymes, pigments and compounds of pharmaceutical and nutraceutical value (Schaeffer and Krylov, 2000; Rastogi and Sinha, 2009). On account of their immense applied biotechnological potential, they are being explored widely. The diversity of cyanobacteria in nature has traditionally been studied by microscopy, which usually allows identification at the species level in contrast to many other bacteria. The untapped potential of cyanobacteria for

their scientific exploitation has been realized in recent years. It needs an extensive screening which is expected to result in the discovery of better cyanobacterial strains of immense industrial interest.

Algal protein either as a supplement or as an alternative source has received worldwide attention. Some strains of *Anabaena* and *Nostoc* are consumed as human food in Chile, Mexico, Peru and Philippines. *N. commune* with high amount of fibre and moderate protein is of potential use as a new dietary fibre source and can play an important physiological and nutritional role in human diet (Jeraci and Vansoest, 1986). The carotenoids and phycobiliproteins, characteristic of cyanobacteria have high commercial value. They are used as natural food colourants, as food additives to enhance the colour of the flesh of Salmonid fish and to improve the health and fertility of cattle.

Cyanobacteria, as specific group of microorganisms represent a potential source of commercially important chemicals and pharmaceutical products. Among them, phycobiliproteins are very interesting cell constituents with high commercial value. Because of their protein nature, unique colour, fluorescence and other properties a wide range of promising applications of phycobiliproteins are possible (Zhao et al., 1995; Rossano et al., 2003; Sekar and Chandramohan, 2008). Due to the toxic and possible cancer genetic effects of several synthetic dyes, there is an increasing preference to use natural colours such as phycobiliproteins. These pigments can be used as natural colourants in food and drug industry and in cosmetic preparation replacing the synthetic dyes (Cohen-Bazire and Bryant, 1982; Soni et al., 2006). Pioneering work of the last decades has raised the status of these microbes to a level where they are being viewed with favour in biotechnologically relevant spheres.

Keeping in view of the above potentialities of cyanobacteria, present study on cyanobacteria of Loktak Lake was planned to isolate *Anabaena* and *Nostoc* strains, screen and select the most promising cyanobacteria which can be used for biopigments. Preliminary screening was done based on their biochemical components such as pigment composition.

Materials and Methods

Description of study site

Loktak Lake, a Ramsar site located between longitudes 93º46' to 95º55' E and latitudes 24º25' to 24º42' N is the largest freshwater wetland in the North-east India and is situated in the southern part of the central plain of Manipur. It is considered to be the 'lifelines for the people of Manipur' due to its importance in their socio-economic and cultural life (Singh and Shyamananda, 1994). The lake is famous for its floating mats of vegetation locally called phumdis (local name for floating mats-heterogeneous mass of soil, vegetation and organic matter at various stages of decomposition), the only refuge of the endangered Sangai (Manipur brow-antlered deer) which is closer to extinction (LDA and WISA, 1998). Considering, its ecological status and biodiversity values, the lake was initially designated as a 'Wetland of International Importance' under the Ramsar Convention on March 23, 1990.

Collection of samples

Cyanobacterial samples, either planktonic or benthic; epilithic or epiphytic were collected from different ecological habitats like open water, shore of the lake and phumdis. The exposed surface of roots and stems of some angiospermic plants were also collected. All these polythene bags were labelled giving information regarding habitat and date of collection. Geographical details were also recorded using Global Positioning System, GPS (Garmin eTrex Vista).

Isolation of cyanobacteria

BG-11 medium (Stanier et al., 1971) was used for isolation of cyanobacteria. All samples were incubated in growth chamber at 28±2ºC with illumination of 54-67 µmol photons $m^{-2}s^{-1}$ by cool white fluorescent tubes. The flasks were regularly monitored for the algal growth.

Identification of cyanobacteria

Slides of the unialga was prepared on a clean glass slide along with cover slip and examined. Photomicrography was carried out using trinocular research microscope (NIKON Eclipse 80*i*) and Carl Zeiss fluorescence microscope, Axio Scope A1 coupled with Carl Zeiss Imaging Systems 32 software AxioVision 4.7.2 followed by taxonomical characterization of referring to monographs (Desikachary, 1959). Filament/trichome structure, constrictions, sheath, shape, position of heterocyst and akinete were the major points considered for taxonomical characterization. The identified cyanobacterial strains were deposited to Freshwater Cyanobacterial and Microalgal Repository of IBSD, Imphal, Manipur, India (National facility created by Department of Biotechnology, Government of India with reference No. BT/PR 11323/PBD/26/171/2008 dated 31-03-2009), Institute of Bioresources and Sustainable Development (IBSD), Imphal, Manipur, India with accession number for ready reference materials.

Maintenance of cyanobacterial strains

Most widely used method for laboratory maintenance of cultures is by storing them in agar slants. This is done by inoculating pure cultures into a nutrient agar medium which were solidified in sterile tubes. All the unialgal strains were maintained at a temperature of 19±1ºC under 25-30 µmol photon $m^{-2}s^{-1}$ of cool white fluorescent tubes. All the

strains were maintained in BG-11 agar slants and broth medium. The unialgal cyanobacterial strains maintained in Repository of IBSD were subcultured for every 3-4 months depending on the culture conditions.

Growth and culture conditions for analysis of phycobiliproteins and chlorophyll-a

Cyanobacterial strains (log phase of growth) were homogenized and 1 ml of the culture was inoculated into 250 ml cotton-plugged Erlenmeyer flasks containing 100 ml of BG-11 medium. The strains were allowed to grow in light intensity of 40 µmol photons m^{-2} s^{-1} provided by cool white fluorescent tubes following light:dark cycles of 14:10 h condition maintained at 28±2ºC. The flasks were stirred twice daily to allow uniform light penetration and circulation of air and nutrients. After 15 days of incubation, cells were harvested with the help of centrifuge (refrigerated Eppendorf centrifuge, 5430R) for the estimation of chlorophyll-a and phycobiliproteins and absorbance was measured using spectrophotometer (Shimadzu spectrophotometer, UV1800). The above parameters were conducted following the mentioned methods: Chlorophyll-a (McKinney, 1941) and phycobiliproteins (Bennett and Bogorad, 1973). All experiments were performed in triplicates.

Results and Discussion

A total of 25 strains of *Nostoc* sp. and 25 strains of *Anabaena* sp. were isolated from freshwater habitats of Loktak Lake. These strains were listed in Table 1 and 2 alongwith their taxonomical and morphological characteristics. A view of Loktak Lake was presented in Fig 1(A & B). Fig 2(C & D) showed cyanobacteria growth attached on hydrophytes. All the isolated cyanobacterial strains were maintained on agar slants and broth medium in the Repository of IBSD-DBT, Imphal, Manipur (Fig 3E & F). In the present observation, it was observed that majority of *Nostoc* and *Anabaena* strains were associated with phumdis occurred mainly as epiphytic on the surfaces of the hydrophytes. This might be because of nutrients availability in phumdis of the lake.

Phycobiliproteins [phycoerythrin (PE), phycocyanin (PC), allophycocyanin (APC)] and Chlorophyll-a content were presented in Table 3. Among *Nostoc* genera, maximum amount of phycoerythrin was produced by *Nostoc* sp. BTA-61 (128.84±1.35 µgml^{-1}) than the other investigated strains. *Nostoc commune* BTA-67 produced maximum amount of both phycocyanin (130.55±10.41 µgml^{-1}) and allophycocyanin (97.13±6.98 µgml^{-1}). *Nostoc commune* BTA-67 also showed the maximum chlorophyll-a content (28.90±0.17 µgml^{-1}) with comparision to others. Regarding the genera *Anabaena*, maximum phycocyanin amount was produced in *Anabaena iyengarii* BTA-74 (88.16±0.95 µgml^{-1}). *Anabaena* sp. BTA-964 (135.42±1.36 µgml^{-1}) and *Anabaena* sp. BTA-980 (50.71±1.70 µgml^{-1}) produced maximum amount of phycocyanin and allophycocyanin respectively. *Anabaena iyengarii* BTA-74 (16.43±0.17 µgml^{-1}) produced maximum amount of chlorophyll-a when compared to other *Anabaena* strains. Since these isolates were found to be potent isolates, they can be commercialized. They can also be further genetically modified for better yield. Our findings reported in this paper are comparable to the previous workers (Cohen, 1986; Dainippon Patent, 1980; Dainippon Patent, 1981; Borowitzka, 1994). Similar observations were also reported by Singh et al. (2012) and Koijam and Tiwari (2012) in *Anabaena fuellebornii*, *Nostoc spongiaeforme*. The results of the present study suggest that some *Nostoc* and *Anabaena* strains had much higher content of phycobiliproteins compared to values found by Jelica et al. (2012).

Loktak Lake, being perennial ecosystem with variable cyanobacterial diversity was composed of optimum level of light, water, temperature and nutrient availability that provided a favourable environment for the luxuriant growth of cyanobacteria. The interplay among the other environmental parameters such as temperature, moisture content, availability of nutrients, etc. that are found in lake ecosystem also contributed towards shaping the cyanobacterial diversity. Cyanobacteria have been studied for a long time for their interesting morphology, diversity and physiology but pioneering work in the last decades has raised the level of these microbes to be viewed with favour in biotechnology-relevant fields. Therefore, it is essential not only to understand and describe the diversity of cyanobacteria in yet unexplored habitats but also to gainfully exploit them for various industrial applications. Higher growth rate and nutrient profile of cyanobacteria make them a potentially valuable source of nutrients (Cannell, 1989). The number of cyanobacterial species that are presently used for the commercial production of phycobiliproteins is very small. Nowadays, scientists are motivated to search for more potential species of cyanobacteria available in nature for exploiting them in a variety of ways to meet the demands. Availability on the characterization of these strains will enhance the appreciation of the role of cyanobacteria in the freshwater habitats of Loktak Lake and also in its intensified culture for fine chemicals. It is, therefore, very essential to prepare an excellent database by determining the biochemical composition of cyanobacteria which can be used as a potential food source. The analysis clearly revealed the need for a morpho-physiological and molecular approach for cyanobacterial characterization and their utilization in agriculture and industry.

In this present study, observation made that niche habitats in Loktak Lake, Manipur especially wetlands are promising sources of potent cyanobacterial strains. In contrast with marine environment, freshwater sources have been less explored. Only little information were available on the diversity and cultural behaviour of cyanobacteria

from the Loktak Lake (Tiwari and Singh, 2005; Singh et al., 2012). Molecular typing and distribution of filamentous heterocystous cyanobacteria isolated from Loktak Lake has been carried out (Chingkheihunba and Arvind, 2011). Many of the metabolites are produced by the organisms in low amounts but there is no mass cultivation technology evolved for such potential cyanobacteria and in many cases, the method of industrial extraction is not optimized. Genetic approaches of potential isolates to construct cyanobacterial strains could be used to improve to natural colouring product from several living microorganisms. The present findings indicates that producing mass culture of potential cyanobacteria for industrial purposes represents a novel biotechnology which naturally prompts questions concerning the future for such kinds of the endeavour.

Table 1. Occurrence and comparative analysis of the genus *Nostoc*

Name of the strains	**Taxonomical enumeration**				
	Filament/ Trichome	**Sheath**	**Cell shape**	**Heterocyst**	**Akinete**
Nostoc sp. BTA-53	flexuous; curved	diffluent	barrel	sub-spherical	oblong
Nostoc paludosum Kutzing ex Born. et Flah. BTA-56	entangled	distinct and colourless	barrel to cylindrical	broader than vegetative cells	oval
Nostoc sp. BTA-60	flexuous	hyaline	barrel or spherical	both intercalary and terminal; sub-spherical	spherical
Nostoc sp. BTA-61	flexuous	thin and hyaline	quadratic	spherical	oblong
Nostoc commune Vaucher ex Born. et Flah. BTA-67	flexuous and entangled	distinct	barrel	spherical	oblong
Nostoc sp. BTA-80	flexuous	diffluent	quadratic	spherical	spherical
Nostoc muscorum BTA-950	flexuous	hyaline	barrel	spherical	oblong
Nostoc sp. BTA-978	flexuous	distinct	barrel	spherical	ellipsoidal
Nostoc sp. BTA-979	flexuous and loosely entangled	indistinct	barrel	spherical	sub-spherical
Nostoc calcicola Brebisson ex Born. et Flah. BTA-984	loosely entangled	hyaline	barrel	sub-spherical	sub-spherical
Nostoc sp. BTA-995	flexuous and loosely entangled	indistinct	cylindrical	sub-spherical	oval
Nostoc ellipsosporum (Desm.) Rabenh. ex Born. et Flah. BTA-999	flexuous and loosely entangled	indistinct	cylindrical	sub-spherical	ellipsoidal
Nostoc muscorum Ag. ex Born.et Flah. BTA-1001	flexuous and loosely entangled	distinct	barrel	spherical	oblong
Nostoc sp. BTA-1003	flexuous	indistinct	barrel	oval	ellipsoidal
Nostoc spongiaeforme Agardh ex Born. et Flah. BTA-1005	flexuous and loosely entangled	distinct	short and barrel	sub-spherical	oblong

Nostoc sp. BTA-1008	loosely contorted and flexuous	indistinct	barrel	spherical	oval to ellipsoidal
Nostoc ellipsosporum (Desm.) Rabenh. ex Born. et Flah. BTA-1011	flexuous and loosely entangled	indistinct	cylindrical	sub-spherical or oblong	ellipsoidal to oblong
Nostoc spongiaeforme Agardh ex Born. et Flah. BTA-1018	flexuous and loosely entangled	indistinct	cylindrical and partly barrel	intercalary and terminal; sub-spherical	oblong
Nostoc sp. BTA-1027	loosely entangled	distinct	barrel and partly quadratic	spherical	sub-spherical
Nostoc sp. BTA-1034	flexuous	diffluent	barrel and partly cylindrical	sub-spherical	oblong
Nostoc spongiaeforme Agardh ex Born. et Flah. BTA-1035	flexuous and loosely entangled	indistinct	partly cylindrical and partly barrel	sub-spherical	ellipsoidal
Nostoc sp. BTA-1046	flexuous	diffluent	barrel	sub-spherical	oblong
Nostoc sp. BTA-1055	loosely entangled	indistinct	cylindrical	sub-spherical	ellipsoidal
Nostoc spongiaeforme Agardh ex Born. et Flah. BTA-1056	flexuous and loosely entangled	indistinct	cylindrical	sub-spherical	ellipsoidal
Nostoc sp. BTA-1057	flexuous and entangled	hyaline	barrel	sub-spherical	spherical

Table 2. Occurrence and comparative analysis of the genus *Anabaena*

Name of the strains	**Taxonomical enumeration**				
	Filament/ Trichome	**Sheath**	**Cell shape**	**Heterocyst**	**Akinete**
Anabaena sp. BTA-69	flexuous	diffluent	barrel	intercalary; sub-spherical	oblong
Anabaena variabilis Kutzing ex Born. et Flah. BTA-72	flexuous	hyaline and colourless	barrel	spherical	oval
Anabaena iyengarii Bharadwaja BTA-74	curved; rounded apex	distinct	barrel; end cell conical	barrel	ellipsoidal
Anabaena circinalis Rabenhorst ex Born. et Flah. BTA-945	flexuous and entangled	hyaline and indistinct	barrel or spherical	sub-spherical	cylindrical
Anabaena sp. BTA-949	flexuous	thin and hyaline	barrel; end cell conical	spherical	oblong
Anabaena sp. BTA-958	straight	absent	barrel	spherical	oblong

Anabaena sp. BTA-964	flexuous	hyaline	barrel	spherical	oval
Anabaena sp. BTA-980	bent	absent	barrel	sub-spherical	ellipsoidal
Anabaena ambigua Rao, C. B. BTA-983	bent; enclosed in a mucilaginous sheath	thin and hyaline	barrel; constriction at the joints	spherical; broader than cells	ellipsoidal
Anabaena sp. BTA-988	bent	hyaline	barrel; granulated	oblong	ellipsoidal

Name of the strains	**Taxonomical enumeration**				
	Filament/ Trichome	**Sheath**	**Cell shape**	**Heterocyst**	**Akinete**
Anabaena sp. BTA-996	bent	hyaline	barrel; end cell conical	sub-spherical	oval
Anabaena sp. BTA-997	flexuous	thin and hyaline	barrel or sub-quadrate	spherical	oblong
Anabaena sp. BTA-1004	slightly curved	hyaline	barrel	oval	oblong
Anabaena sp. BTA-1006	bent	thin and hyaline	barrel	oval	oblong
Anabaena anomala Fritsch BTA-1007	bent	diffluent	barrel; apical cell rounded	barrel	ellipsoidal
Anabaena ballyganglii Banerji BTA-1009	circinate	hyaline	barrel; long and broad; granular contents	sub-spherical	ellipsoidal
Anabaena circinalis Rabenhorst ex Born. et Flah. BTA-1010	circinate; seldom straight	hyaline	barrel	sub-spherical	oblong
Anabaena variabilis Kutzing ex Born. et Flah. BTA-1012	straight; slight bent	colourless	barrel	spherical or oval	oblong
Anabaena sp. BTA-1025	bent	thin and hyaline	barrel to quadratic	sub-spherical	oval
Anabaena oryzae Fritsch BTA-1026	short to straight; aggregated	colourless	barrel; longer than broad	oval; broader than vegetative cells	ellipsoidal
Anabaena variabilis Kutzing ex Born. et Flah. BTA-1030	straight	diffluent	barrel, end cells conical	spherical or oval	oblong
Anabaena iyengarii Bharadwaja BTA-1033	curved; end cell conical	hyaline	barrel	sub-spherical	ellipsoidal
Anabaena iyengarii Bharadwaja BTA-1058	curved; end cell conical	diffluent	barrel	spherical	ellipsoidal
Anabaena vaginicola Fritsch et Rich BTA-1074	straight and parallel	distinct	sub-quadrate to cylindrical; conical apical cell	cylindrical	oblong or cylindrical
Anabaena variabilis Kutzing ex Born. et Flah. BTA-1075	bent	hyaline	barrel	spherical or oval	oblong

Table 3. Analysis of cyanobacterial strains for phycobiliproteins and chlorophyll-a

Name of the strains	Phycobiliproteins (µgml^{-1})			Chl-a (µgml^{-1})
	Phycoerythrin (PE)	Phycocyanin (PC)	Allophycocyanin (APC)	
Nostoc sp. BTA-53	113.09 ± 2.31	62.21 ± 1.79	4.78 ± 1.56	10.60 ± 0.06
Nostoc paludosum BTA-56	12.52 ± 0.98	53.81 ± 1.22	23.89 ± 2.34	6.75 ± 0.22
Nostoc sp. BTA-60	36.18 ± 1.02	63.64 ± 2.03	16.80 ± 1.36	3.07 ± 0.12
Nostoc sp. BTA-61	128.84 ± 1.35	62.95 ± 3.02	14.71 ± 0.87	3.64 ± 0.30
Nostoc commune BTA-67	29.83 ± 4.23	130.55 ±10.41	97.13 ± 6.98	28.90 ± 0.17
Nostoc sp. BTA-80	44.62 ± 1.16	26.42 ± 0.70	9.04 ± 0.26	9.89 ± 0.05
Nostoc muscorum BTA-950	3.07 ± 0.70	8.89 ± 2.55	5.97 ± 1.54	17.72 ± 0.29
Nostoc sp. BTA-978	49.03 ± 1.98	27.46 ± 1.46	1.74 ± 0.66	3.95 ± 0.64
Nostoc sp. BTA-979	2.61 ± 0.26	51.47 ± 2.67	4.88 ± 0.83	3.95 ± 0.34
Nostoc calcicola BTA-984	22.10 ± 1.00	40.69 ± 0.53	10.19 ± 1.22	11.39 ± 0.76
Nostoc sp. BTA-995	73.08 ± 0.52	29.87 ± 0.32	3.87 ± 0.52	5.98 ± 0.16
Nostoc ellipsosporum BTA-999	6.84 ± 0.40	5.67 ± 0.24	0.65 ± 0.14	2.01 ± 0.51
Nostoc muscorum BTA-1001	7.62 ± 1.60	107.16 ± 2.45	45.26 ± 3.05	3.13 ± 0.02
Nostoc sp. BTA-1003	1.75 ± 0.12	28.66 ± 2.57	6.43 ± 0.69	2.22 ± 0.02
Nostoc spongiaeforme BTA-1005	2.88 ± 0.24	17.72 ± 3.24	0.27 ± 1.77	2.01 ± 0.09
Nostoc sp. BTA-1008	8.51 ± 0.66	11.29 ± 0.85	5.39 ± 1.02	0.68 ± 0.09
Nostoc ellipsosporum BTA-1011	9.01 ± 0.99	14.30 ± 1.79	10.81 ± 1.05	2.91 ± 0.20
Nostoc spongiaeforme BTA-1018	12.17 ± 0.10	6.93 ± 0.08	5.45 ± 0.38	2.22 ± 0.49
Nostoc sp. BTA-1027	4.14 ± 0.21	68.96 ± 3.78	2.66 ± 0.58	3.49 ± 0.36
Nostoc sp. BTA-1034	9.16 ± 0.58	8.28 ± 0.28	0.73 ± 0.38	3.00 ± 0.55
Nostoc spongiaeforme BTA-1035	2.57 ± 0.27	5.10 ± 0.87	2.78 ± 0.39	3.91 ± 0.06
Nostoc sp. BTA-1046	4.84 ± 0.69	19.62 ± 1.86	2.15 ± 1.09	1.15 ± 0.18

Name of the strains	Phycobiliproteins (µgml^{-1})			Chl-a (µgml^{-1})
	Phycoerythrin (PE)	Phycocyanin (PC)	Allophycocyanin (APC)	
Nostoc sp. BTA-1055	73.86 ± 5.10	32.44 ± 1.89	7.03 ± 0.95	3.28 ± 0.85
Nostoc spongiaeforme BTA-1056	46.30 ± 2.11	24.03 ± 1.01	5.97 ± 0.61	3.55 ± 0.26
Nostoc sp. BTA-1057	0.44 ± 0.16	1.04 ± 0.29	4.67 ± 0.29	0.13 ± 0.04
Anabaena sp. BTA-69	86.96 ± 2.11	43.13 ± 0.95	10.01 ± 0.56	2.48 ± 0.28
Anabaena variabilis BTA-72	1.16 ± 0.25	4.38 ± 0.49	1.87 ± 0.38	1.33 ± 0.02
Anabaena iyengarii BTA-74	88.16 ± 0.95	53.76 ± 1.08	5.92 ± 0.63	16.43 ± 0.17
Anabaena circinalis BTA-945	20.01 ± 0.33	41.61 ± 2.42	10.51 ± 0.71	4.81 ± 0.20
Anabaena sp. BTA-949	1.44 ± 0.20	6.60 ± 0.24	1.45 ± 0.22	2.55 ± 0.15
Anabaena sp. BTA-958	0.29 ± 0.10	0.51 ± 0.12	0.36 ± 0.19	0.81 ± 0.02
Anabaena sp. BTA-964	4.72 ± 0.36	135.42 ± 1.36	36.03 ± 3.96	4.77 ± 0.18
Anabaena sp. BTA-980	3.50 ± 0.31	103.29 ± 1.51	50.71 ± 1.70	11.42 ± 1.01
Anabaena ambigua BTA-983	5.79 ± 0.42	91.03 ± 0.91	38.75 ± 0.86	4.48 ± 0.33
Anabaena sp. BTA-988	14.77 ± 1.47	4.45 ± 0.64	2.09 ± 0.32	7.06 ± 0.13
Anabaena sp. BTA-996	0.98 ± 0.19	6.31 ± 0.37	2.34 ± 0.73	1.88 ± 0.16
Anabaena sp. BTA-997	4.63 ± 1.15	6.54 ± 1.69	3.59 ± 0.94	2.35 ± 0.07
Anabaena sp. BTA-1004	2.27 ± 0.11	18.75 ± 1.03	1.45 ± 0.05	0.40 ± 0.01
Anabaena sp. BTA-1006	3.88 ± 0.07	42.39 ± 2.11	9.28 ± 1.32	4.80 ± 0.64
Anabaena anomala BTA-1007	1.61 ± 0.13	27.76 ± 1.04	3.79 ± 1.91	2.55 ± 0.21
Anabaena ballyganglii BTA-1009	2.01 ± 1.01	4.36 ± 0.68	4.53 ± 3.39	0.65 ± 0.06
Anabaena circinalis BTA-1010	2.40 ± 0.93	28.86 ± 0.60	5.86 ± 1.46	0.12 ± 0.04
Anabaena variabilis BTA-1012	4.72 ± 0.07	89.14 ± 0.92	26.35 ± 0.17	0.95 ± 0.01

All experiments were replicated three times and results are presented as mean ±SD

Name of the strains	Phycobiliproteins (µgml^{-1})			Chl-a (µgml^{-1})
	Phycoerythrin (PE)	Phycocyanin (PC)	Allophycocyanin (APC)	
Anabaena sp. BTA-1025	3.29 ± 0.07	41.59 ± 0.48	6.45 ± 0.46	0.70 ± 0.10

Anabaena oryzae BTA-1026	18.56 ± 2.34	35.14 ± 1.24	14.00 ± 3.12	6.95 ± 0.47
Anabaena variabilis BTA-1030	2.54 ± 0.41	3.11 ± 0.35	3.57 ± 0.56	1.98 ± 0.56
Anabaena iyengarii BTA-1033	0.59 ± 0.20	0.94 ± 0.29	0.92 ± 0.34	0.22 ± 0.02
Anabaena iyengarii BTA-1058	2.52 ± 0.62	30.44 ± 2.61	2.74 ± 0.76	1.30 ± 0.18
Anabaena vaginicola BTA-1074	1.45 ± 0.23	17.93 ± 1.12	3.64 ± 0.42	0.29 ± 0.04
Anabaena variabilis BTA-1075	1.15 ± 0.12	5.06 ± 0.30	1.26 ± 0.44	3.52 ± 0.18

All experiments were replicated three times and results are presented as mean ±SD

Fig1(A & B). Different view of Loktak Lake

Fig 2(C & D). Cyanobacterial growth attached on hydrophytes

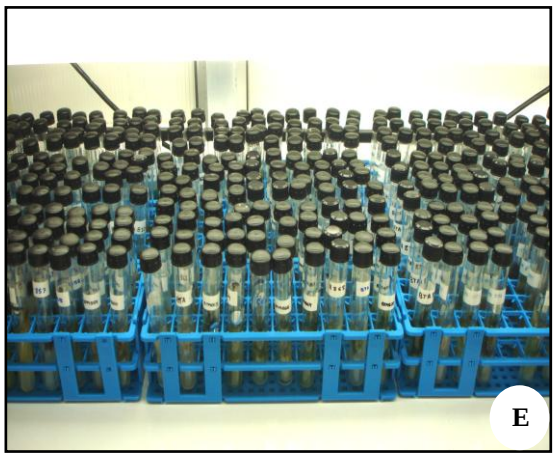

Fig 3(E & F). Maintenance of cyanobacterial strains in the Repository

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Conflict of Interest

The authors declare that they have no conflict of interest.

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