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Influence of physical and chemical factors on the distributional pattern of *Cyanobacteria* in Kumaon Region

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Abstract. *Cyanobacteria* are a group of haploid oxygenic photosynthetic blue-green algal prokaryotes. They belong to the largest, most diverse and widely distributed group of Prokaryotes. These belong to the most archaic organisms on the earth. *Cyanobacteria* occur in a variety of habitats and its growth is influenced by several physical and chemical factors of the environment. This paper discusses the influence of several physical and chemical factors on the growth of *Cyanobacterial* diversity of Himalayas with special reference to Kumaon Himalayas.

Keywords: *Cyanobacteria*, Kumaon, Himalayas.

Rezumat. Cianobacteriile reprezintă un grup de alge albastre–verzi, procariote, haploide, cu fotosinteză oxigenică. Acestea aparţin celui mai mare, divers şi larg răspândit grup de procariote. Ele aparţin celor mai vechi organisme de pe Pământ. Cianobacteriile se găsesc într-o varietate mare de habitate iar creşterea lor este influenţată de o serie de factori de mediu fizici şi chimici. Aceasta lucrare prezintă influenţa câtorva factori fizici şi chimici asupra creşterii diverselor cianobacterii din Himalaya, în special a celor din regiunea Kumaon.

Cuvinte cheie: *Cyanobacteria*, Kumaon, Himalayas.

1. *Cyanobacteria*

Cyanobacteria, a group of haploid oxygenic photosynthetic blue-green algal prokaryotes, can be sharply distinguished from other groups of algae since they have low state of cell differentiation, blue-green colour of the cells, production of cyanophycean starch and absence of an organized nucleus in its cells (Singh 1961). They belong to the largest, most diverse and widely distributed group of prokaryotes.

Cyanobacteria are considered as the most archaic organisms on the earth as they dominated the biota in the Proterozoic era. Due to the occurrence of blue-green algae the Proterozoic era is also known as "Age of Cyanobacteria" (van den Hoek et al 1993). They occur in a great variety of natural habitats *viz.* fresh water, marine, epilithic, epipelic, epiphytic, endophytic and thermophilic etc., but are often abundant in fresh water, sea water and terrestrial environments (Fogg et al 1973).

Cyanobacteria were formerly called blue-green algae because they contain blue and green pigments. They are an ancient and heterogeneous group of prokaryotic photosynthetic organisms. The oxygen-containing atmosphere of Earth initially developed due to the oxygenic photosynthesis of cyanobacteria, similar to that of higher plants. Due to the similarities between chloroplasts and cyanobacteria, the latter are believed to be ancestors of higher plant chloroplasts. Chloroplasts probably originated from an endosymbiotic event between a cyanobacterium and another organism some hundreds of millions years ago. An oxidative atmosphere is therefore (in an evolutionary perspective) a relatively new phenomenon, and most enzymatic pathways generally used by present-day organisms were developed in an earlier anoxygenic environment. Due to its relatively late evolutionary appearance oxygen, and especially its derivatives, is harmful to many cellular components. A number of oxidative stress responses have evolved to avoid such cellular damages.

Cyanobacteria are very important organisms for the health and growth of many plants. They are one of very few groups of organisms that can convert inert atmospheric nitrogen into an organic form, such as nitrate or ammonia. It is these "fixed" forms of nitrogen which plants need for their growth, and must obtain from the soil. Fertilizers work the way they do in part because they contain additional fixed nitrogen which plants can then absorb through their roots.

Nitrification cannot occur in the presence of oxygen, so nitrogen is fixed in specialized cells called heterocysts. These cells have an especially thickened wall that contains an anaerobic environment. Heterocysts are also present in nitrogen fixing *Azotobacter* cells. The development of those structures is influenced by environmental conditions (Carpa et al 2008).

You can see these larger cells among the filaments of *Nostoc*, shown at right.

Many plants, especially legumes, have formed symbiotic relations with nitrifying bacteria, providing specialized tissues in their roots or stems to house the bacteria, in return for organic nitrogen. This has been used to great advantage in the cultivation of rice, where the floating fern *Azolla* is actively distributed among the rice paddies. The fern houses colonies of the cyanobacterium *Anabaena* in its leaves, where it fixes nitrogen (Aziz 2006). The ferns then provide an inexpensive natural fertilizer and nitrogen source for the rice plants when they die at the end of the season.

The cyanobacterium *Spirulina*, shown at right, has long been valued as a food source; it is high in protein, and can be cultivated in ponds quite easily. In tropical countries, it may be a very important part of the diet, and was eaten regularly by the Aztecs; it is also served in several Oriental dishes. In the US, the popularity of *Spirulina* is primarily as a "health food", being sold in stores as a dried powder or in tablet form.

Cyanobacteria appear as first community of organisms, as xeroseres and hydroseres, leading to the associations of higher plant associations. The different environmental conditions have triggered the cyanobacterial mass occurrence. Amongst them, the hydrogen ion concentration is an important factor followed by temperature, light, soil type and available nutrients. The mass occurrence of cyanobacteria has been reported to increase the frequency as well as the intensity of biotic community due to eutrophication (Kahru et al 1994; Finni et al 2001). The increasing light, temperature stimulate the growth of *Cyanobacteria*. The literature already suggests that the higher pH of water, scarcity of carbon dioxide and high amount of phosphorus is conducive to the production of the biomass of *Cyanobacteria* and algae.

The diversity of *Cyanobacteria* can be seen in the multitude of structural and functional aspects of cell morphology and in variations in metabolic strategies, motility, cell division, developmental biology etc. These produce extra cellular substances like cyanotoxins, which illustrates the diverse nature of their interaction with other organisms (Rizvi & Rizvi 1992). To date, 16S r-RNA has given the most detailed information on the relationships within the *Cyanobacteria* (Rudi et al 1997). Soil microflora consists of only about 01% of algae, out of which *Cyanobacteria* form a very small part yet they play an important role in soil conditioning and vitality of the soil (Khare et al 2009).

2. Description of Sites

Lying between the Latitudes 28°44' to 30°49' N and Longitudes 78°45' to 81°1' E, Kumaon is situated at the trijunction of Nepal, Tibet and India. The altitudinal range varies for 204m to 7,436m amsl The Kumaon division comprises four districts-Nainital, Udham Singh Nagar, Almora and Pithoragarh, which are divided into 14 tehsils and 41 blocks. The region exhibits socio-cultural unity amidst physical diversities.

The study area is situated in South-East to North of Kumaon Himalayas (between 20°00' - 30°00' N to 78°80' - 81° E), Uttarakhand, India. It comprises a group of low-lying hills with rivers, springs, streams, rivulets, pits and ponds etc. The elevation of different research sites ranges between 200-500m amsl.

The present work is a maiden attempt in respect to this region and includes the findings on ecological and taxonomic parameters of this important group of algae. The selection of the locality was made with the realization that the Himalayas represent one of youngest mountain chain of the world, ranging from Jammu and Kashmir to Arunachal Pradesh, covering a length about 2400km. Evidently such a vast area offers excellent habitats for an extremely large variety of vegetation, which has been consistently providing an unparallel attraction to the entire globe, coupled with a challenge to explore them from different points of views. The foot-hills of Kumaon Himalaya constitute the region, which has still been explored only to a limited extent.

The present investigation had been planned to study the ecology and biodiversity of *Cyanobacteria* of the foothills of Kumaon Himalayas from four research sites *i.e.* Kashipur, Rudrapur, Ramnagar and Haldwani. The first research site, Kashipur is situated at an altitude of 235m amsl, and 20^0 13' N latitude and 28^0 59' E longitude. The second research site, Rudrapur is situated at an altitude of 244m amsl, and a latitude of 29^0 03' N and longitude of 79^0 31' E. The third research site, Ramnagar is situated at an altitude of 330m amsl, latitude of 29^0 05' E and longitude of 79°05' E whereas the fourth research site, Haldwani is located at a latitude of 29^0 13' N and longitude of 79^0 31' E at 432m amsl. The area chosen for the analysis is a part of sub-Himalayan belt of Kumaon Division. During this analysis, an overall attempt has been made to survey the distribution pattern of the members of *Cyanobacteria* available in this region encompassing both, the attitude and a host of richness.

3. Meteorological Studies

The climate of various research sites was determined by studying the different climatic or meteorological factors such as temperature, rainfall, relative humidity and intensity of light etc. variation in climatic conditions has a direct co-relation with variability of vegetation types. The following parameters have been studied for the present research work: temperature, rainfall, relative humidity, intensity of light.

3.1 Temperature

The climatic conditions of the foot-hills of Kumaon Himalayas are sub tropical, as such the temperature play a very important role. It regulates the major biological activities taking place in the body of organisms. The temperature variation is quite evident in Himalaya so much so that the Himalayas have a general zonation of vegetation form lower to the higher altitudes, as tropical sub-tropical and alpine. Nevertheless, there are practically no sharp boundaries between these vegetation zones due to difference in topography, soil and geology. Thus in the Himalayan range the temperature together with altitude and other factors become quite important in respect of diversity and distribution of vegetation.

3.2 Rainfall (Precipitation)

Rainfall is the chief source of soil water available to plants. It occurs as an interchange of water between the earth's surfaces and the atmosphere forming the water cycle. In India, the rainfall is caused by the monsoon. The amount of annual rainfall greatly determines the seasons of the year. It may be important in the regional distribution of the vegetation. Thus, precipitation plays a crucial role in the development and growth of vegetation of a particular area.

3.3 Relative Humidity

Atmospheric moisture in the form of invisible vapour constitutes the humidity and is expressed in terms of "Relative Humidity" or the amount of moisture in the air as percentage of the amount, which the air can hold at the saturation tolerance at the exisiting temperature, the high temperature increases the capacity of air to retain moisture and causes lower humidity, whereas, the low temperature causes higher relative humidity by decreasing the folding capacity of air for moisture.

3.4 Intensity of Light

Light is well known for its effects on the basic physiological processes of plants and thus plays an important role in the species composition and development of vegetation. It affects the nature and distribution of vegetation through its effects on photosynthesis, chlorophyll production, number and position of chloroplasts etc.

4. Pedological Studies

Each type of soil has its own physical and chemical characteristics, which affect the vegetation on it leading to a distinct flora. Consequently, it becomes very important to analyze the physical and chemical parameters of the soil.

For pedological studies, the soil samples from different research sites, with or without visual plant community/blue-green algae were collected from surface as well as from different depths of about 10-15 cm (Singh 1961). The samples were stored in sterile plastic bottles (2.5 x 5.5 cm) at 4°C and transported to the laboratory for physical as well as chemical analysis. The physical as well as chemical characters of the soil present at different sites were studied.

4.1 Physical Parameters. The following physical parameters were taken for study:

(i) Texture. The soil texture was determined by the relative proportion of mineral particles of different sizes present in the soil using the sieve method.

(ii) Temperature. Soil temperature is the result of heat gained by the absorption of solar heat energy. It was determined with the help of "Mercury glass Thermometer" with pointed steel for digging the soil.

(iii) Determination of pH. The pH values of the soil show much correlation with the soil type and profile horizon. It affects the plant growth, lime requirement and mineral nutrients in the soil. The pH of the soil was determined in soil suspension.

(iv) Electrical Conductivity. The conductivity is the measure of the ability of an aqueous solution to carry an electric current. This ability depends on the presence of the ions, on their total concentration, mobility and valency, and on the temperature of measurement. The electrical conductivity of soil was determined in soil-water (1:5) extract using a Digital Electrical ConductivityMeter (Symtronics Digital Electrical Conductivity Meter Ltd., India).

4.2 Chemical parameters. The following chemical parameters were taken for the study:

(i) Total Nitrogen (as N). The total nitrogen has been calculated according to the Kjeldahl method (Guebel et al., 1991).

(ii) Available Phosphorus. Available Phosphorus can be calculated from soil by Sodium bicarbonate. The estimation of phosphorus has been done by Olsen method (Carmo Horta 2007).

(iii) Available Potassium. The available potassium is usually determined in neutral normal ammonium acetate extract of soil. Available potassium changes in potassium acetate in this extract. It is estimated by photometer.

5. General Water Studies

Water samples from streams, rivers, and ponds were collected under aseptic condition in sterile plastic containers (2.5 x 5.0 cm) and stored at 4°C, then they were transported to the laboratory for further study.

5.1 Physical Parameters. The following physical parameters were taken for study:

(a) pH. The pH of the water body directly affects the life cycle of blue-green algae. pH of water samples was determined in the field and also in the laboratory with the help of a Digital pH Meter equipped with soil state combination electrode [HANNA instruments (Mauritius) Ltd., Made in Portugal].

(b) Temperature. Water temperature affects the structure of proteins/enzymes taking part in various biological pathways. The temperature was determined by using the Mercury Glass Thermometer.

6. Taxonomic Studies

The samples with visible growth of blue-green algae have been collected into sterile plastic bottles (2.5 *x* 5.0 cm), on returning to the laboratory; they were washed thoroughly in water and transferred to airtight glass containers, and preserved in 4% formalin solution. The microslides were prepared from the fixed as well as fresh algal materials for microscopic observations. Microscopic slides of algal samples were observed under a Trinocular Research Microscope (Olympus Ltd., India). Camera-Lucida drawings have been sketched and the drawings were analyzed on the basis of morphological observations. Consulting the pertinent literature in the field (Aziz 2006; Naz et al 2004; Fogg et al 1973; Marutha Ravindran et al 2006), the cyanobacterial specimens were identified at the level of class, order, family, genus and species and morphological variations of different specimens were also analyzed.

7. Result and General Discussion

The foot-hills of Kumaon Himalayas along with the border of Uttar Pradesh and Uttarakhand are rich in rivers, rivulets and stagnant water bodies of different nature. The favourable climatic conditions and mineral rich alluvial soil basin of the entire sub Himalayan belt have resulted in high fertility to these water bodies, inviting luxurious growth of diverse algae, particularly the blue-green algae.

It is well known that nutrient pool is high in the foot-hills of Kumaon Himalayas, as such the distribution and growth of cyanobacterial flora is luxurious in terrestrial and aquatic eco-systems. The present investigation has been undertaken to study the diversity of *Cyanobacteria* of this particular region. A perusal of literature has rewarded that there is a direct relationship between the algal vegetation and various ecological factors. This has been substantiated under the present work; also, since distributional pattern of cyanobacterial flora is very well correlated with the meteorological, pedological and aquatic features of the region.

Of all four-research sites, Kashipur is located at the lowest altitude (235m amsl), while the Haldwani is located at the highest altitude (432m amsl). Rudrapur and Ramnagar are situated in (244m amsl, and 330m amsl altitude) respectively. The soil is loam, clay and silt in Kashipur, sandy loam and silt sand in Rudrapur, silty loam in Ramnagar and loamy sand and clay in Haldwani.

Haldwani experiences the lowest annual temperature (27.5^{0}C), as against Kashipur with the highest value (32.0^{0}C). Rudrapur and Ramnagar experience the annual average temperature ranges, in between Haldwani and Kashipur *i.e.* 31.3^{0}C and 30.8^{0}C, respectively. Haldwani has the lowest annual average rainfall (14.6 cm). On the other hand, Kashipur experiences highest (15.5 cm). Rudrapur and Ramnagar recorded 14.7 cm and 14.9 cm annual average rainfall, respectively. Kashipur experiences highest annual average relative humidity (78.7%) and Haldwani the lowest (76.2%). Ramnagar has highest annual average light intensity (850 Lux) and Rudrapur lowest (648 Lux). Kashipur and Haldwani have 773 and 722 Lux, respectively. Various physico- chemical parameters for all sites have been recorded. The soil of all the sites is slightly alkaline in nature (pH above 7.5). Kashipur has highest soil temperature (31^{0}C), whereas Haldwani has lowest (26.0^{0}C). The water temperature recorded at Kashipur is highest (29.6^{0}C) and Haldwani lowest (22^{0}C). Rudrapur and Ramnagar have 25.0^{0}C and 24.5^{0}C water temperature, respectively.

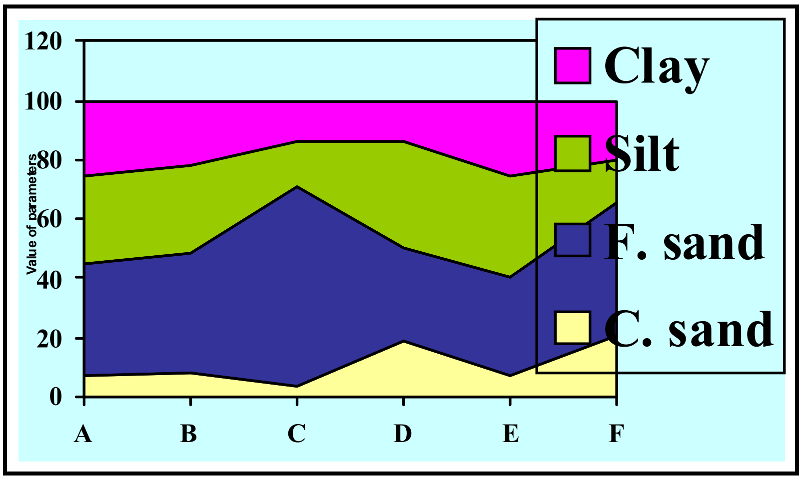

Figure 1. Soil texture of different kinds of soils (A=Kashipur Awas-Vikas Colony; B=Kashipur Nagarpalika Area; C=Rudrapur Pattharchata Nala; D=Rudrapus Danpur Village; E=Ramnagar; F=Haldwani)

In respect to electrical conductivity, soil of Pattharchata Nala from Rudrapur has exhibited highest electrical conductivity (1230 micros/mhos/cm) and Ramnagar lowest (190 micro/mhos/cm). The soil of Awas-Vikas Colony (Kashipur) maintain electrical conductivity 850 micro/mhos/cm, that of Nagarpalika (Kashipur) have 360 micro/mhos/cm and Haldwani have 200 micro/mhos/cm, respectively. Awas-Vikas Colony of Kashipur has highest amount of nitrogen (0.25% by mass) and Haldwani has lowest (0.03% by mass). Nagarpalika areas of Kashipur; Ramnagar; Pattharchata Nala and Danpur village of Rudrapur have 0.12; 0.11; 0.05 and 0.04% nitrogen by mass in the soil. The data in respect to the available phosphorus and potassium has also been recorded. The soil of Awas-Vikas Colony of Kashipur has highest phosphorus (0.0055%) and soil of Danpur village of Rudrapur has highest potassium (0.056%). Ramnagar has lowest phosphorus (0.0004%) and Haldwani has lowest potassium (0.0020%). The soil of Awas-Vikas Colony of Kashipur has 0.0194% potassium. The soil of Nagarpalika area of Kashipur has 0.0037% and 0.0120% phosphorus and potassium, resectively. Pattharchata Nala and Danpur village of Rudrapur have phosphorus as 0.0016% and 0.0033%, respectively and potassium 0.0045% and 0.056% (Tables 1-2).

Table 1

Meteorological data recorded at various research sites

Parameters	Research Sites															
	Kashipur				Rudrapur				Ramnagar				Haldwani			
	S	W	R	M	S	W	R	M	S	W	R	M	S	W	R	M
Average atmospheric temperature (°C)	35.3	26.4	34.4	32.0	36.8	23.4	33.9	31.3	35.3	23.9	33.3	30.8	33.1	20.9	28.7	27.5
Average rainfall (cm)	7.0	3.0	36.5	15.5	6.9	2.3	34.9	14.7	5.8	2.7	36.4	14.9	6.0	2.9	35.0	14.6
Average relative humidity (%)	71.8	90.8	73.5	78.7	69.8	90.0	71.5	77.1	70.7	89.5	72.0	77.4	65.5	90.2	73.0	76.2
Average intensity of light (lux)	1050	368	900	773	947	325	673	648	1120	470	861	850	985	315	865	722

Note: S= Summer; W= Winter; R= Rainy; M= Mean

Table 2

Pedological features (including water, pH and temperature) of various research sites in the Kumaon Region

Site	Physical Parameters								Chemical Parameters		
	Coarse Sand %	**Fine Sand %**	**Silt %**	**Clay %**	**Soil Texture**	**pH soil water**	**Temp. soil water**	**E.C. Micros/ mhos/cm**	**Total N %**	**P (ppm)**	**K(ppm)**
Kashipur (Awas -Vikas) 235m amsl	7.08	37.24	30.24	25.44	Loam, clay & silt	8.2 7.5	31.00 29.60	850	0.25	0.0055	0.019
Kashipur (Nagar Palika) 235m amsl	7.72	40.92	29.44	21.92	Loam, clay & silt	7.9 7.5	31.00 29.60	360	0.12	0.0037	0.012
Rudrapur (Pattharchata) 244m amsl	3.3	67.9	15.2	13.6	Loamy sand	7.6 7.2	30.00 25.00	1230	0.05	0.0016	0.0045
Rudrapur (Danpur Village) 244m amsl	18.8	31.6	36.0	13.6	Sandy loam & silt	8.2 7.2	30.00 25.00	620	0.04	0.0033	0.056
Ramnagar 330m amsl	6.68	33.96	34.08	25.28	Silty loam	8.2 7.4	27.00 24.5	190	0.11	0.0004	0.005
Haldwani 432m amsl	20.72	44.40	14.72	20.16	Loamy sand & silt	7.9 7.1	26.00 22.00	200	0.03	0.0009	0.01

Light and temperature conditions have a direct effect on the population dynamics of cyanobacterial flora. Bright light favours the growth the members of order *Chroococcales,* whereas dim light enhance the presence of the members of order *Nostocales*. Similarly, a moderate temperature between 20-40°C is found suitable for the luxurious growth of cyanobacterial taxa at all the sites. In respect to electrical conductivity, the scenario is quite different as high value of electrical conductivity favours the occurrence of the members of order *Nostocales*, on the other hand low value of this parameter declines the presence of the members of order *Nostocales*. A similar finding reveals that water temperature also imparts effect on the formation of heterocystous species. It has been indicated by the researcher that high value of water temperature increases the possibility of the number of heterocystous species.

Overall study of the four-research sites have brought up the conclusion that the maximum number of cyanobacterial taxa have been reported from Haldwani, which is situated at highest altitude (432m amsl) and has minimum percentage of nitrogen in the soil as compared to the remaining sites. In contrast to this, the minimum number of cyanobacterial species has been reported from Kashipur, which is situated at lowest altitude (235m amsl) and has maximum percentage of nitrogen in the soil among all the four-research sites. This has allowed the researcher to bring out the fact that high altitude and less percentage of nitrogen in the soil increases the possibility of the occurrence of the members of this algal group (Table 3).

Table 3

Topological features and their bearingon the taxonomic enumeration of the species at various research sites

Sites	Altitude (m amsl)	Latitude (N) Longitude (E)	Taxonomic Position				Orderwise Species Number	
			Species	Genera	Families	Orders	Orders	Species
Kashipur	235 m amsl	Long.: 28° 59′ E Lat. : 20° 13′ N	59	19	06	03	*Chroococcales* *Chamaesiphonales* *Nostocales* *Stigonematales*	12 00 42 02
Rudrapur	244 m amsl	Long.: 70° 30′ E Lat.: 29° 03′ N	70	23	08	04	*Chroococcales* *Chamaesiphonales* *Nostocales* *Stigonematales*	20 02 47 01
Ram Nagar	365 m amsl	Long.: 79° 05′ E Lat.: 29° 40′ N	60	20	05	03	*Chroococcales* *Chamaesiphonales* *Nostocales* *Stigonematales*	23 01 36 00
Haldwani	423m amsl	Long.: 79° 31′ E Lat.: 29° 40′ N	71	23	08	04	*Chroococcales* *Chamaesiphonales* *Nostocales* *Stigonematales*	22 01 46 02

Thus, a total of 170 Species, 38 Genera, 11 Families and 04 Orders have been recorded. Members of Order *Pleurocapsales* are totally absent.

The specimens gathered from all the four collection sites have received an identical treatment to avoid any discrepancy due to climatic hazards. The cyanobacterial flora of various research sites of foot-hills have been recorded separately and then combined to study the 'Cyanobacterial Flora of Foot-hills of Kumaon Himalayas'. All in all, the foot-hills of Kumaon Himalayas as a whole exhibited 170 species of 38 genera of 11 families and 04 orders (Khare 2007). A summarized account of the species recorded during the study is presented below:

FLOW CHART SHOWING TAXONMIC ENUMERATION OF THE TAXA RECORDED FROM THE FOUR RESEARCH SITES OF THE SUB- HIMALAYAN BELT OF KUMAON REGION.

PHYLUM: CYANOPHYTA
CLASS: CYANOPHYCEAE

ORDER: CHROOCOCCALES
FAMILY: CHROOCOCCACEAE
GENUS: *Microcystis*

1 *M.stagnalis*
2 *M. pulverea*
3 *M. pulverea var. incerta*
4 *M. ramosa*
5 *M. holsatica*
6 *M. orissica (v. nov.)*
7 *M. flos-aquae*
8 *M. marginata*
9 *M. viridis*

GENUS: *Chroococcus*

10 *C. pallidus*
11 *C. minutus*
12 *C. minor*
13 *C. hansgirgi*
14 *C. gomontii*
15 *C. dispersus*
16 *C. minimus*
17 *C. cohaerens*
18 *C. varius*
19 *C. schizodermaticus*

GENUS: *Gloeocapsa*

20 *G. livida*
21 *G. punctata*
22 *G. coracina*
23 *G. gelatinosa*

GENUS: *Gloeothece*

24 *G. samoensis*

GENUS: *Aphanocapsa*

25 *A. crassa*
26 *A. elachista*
27 *A. elachista var. irregularis*
28 *A. elachista var. conferta*
29 *A. biformis*
30 *A. pulchra*
31 *A.koordersi*
32 *A. muscicola*
33 *A. grevellei*
34 *A. montana*

GENUS: *Aphanothece*
35 *A. naegelli*

GENUS: *Synechococcus*
36 *S. cedrorum*
37 *S. aeruginosus*

GENUS: *Synechocystis*
38 *S. pevalekii*

GENUS: *Coelosphaerium*
39 *C. confertum*

GENUS: *Merismopedia*
40 *M. punctata*
41 *M. minima*
42 *M. tenuissima*
43 *M. marsonii*

GENUS: *Dactylococcopsis*
44 *D. raphidioides*

FAMILY: ENTOPHYSALIDACEAE

GENUS: *Chlorogloea*
45 *C. microcystoides*
46 *C. fitschii*

ORDER: CHAMAESIPHONALES

FAMILY: CYANIDIACEAE

GENUS: *Chroococcidiopsis*
47 *C. indica*

FAMILY: DERMOCARPACEAE

GENUS: *Dermocarpa*
48 *D. clavata var. minor (v. nov.)*

GENUS: *Stichosiphon*
49 *S. sansibaricus*

ORDER: NOSTOCALES

FAMILY: OSCILLATORIACEAE

GENUS: *Arthrospira*
50 *Arthrospira gomontiana*
51 *A. platensis var. non constricta*
52 *A. tenuis*
53 *A. massartii var. minor (v. nov.)*
54 *A. spirulinoides f. tenuis*

GENUS: *Spirulina*
55 *Spirulina subsalsa*
56 *S. gigantea*
57 *S. major*
58 *S. princeps*
59 *S. labyrinthiformis*
60 *S. meneghiniana*
61 *S. laxissima*
62 *S. laxissima f. major*

GENUS: *Oscillatoria*
63 *Oscillatoria formosa*
64 *O. boryana*
65 *O. tenuis*
66 *O. princeps var. minor (v. nov.)*
67 *O. animalis*
68 *O. animalis f. tenuior*
69 *O. acuta*
70 *O. brevis*
71 *O. grunowiana*
72 *O. deflexa*
73 *O. minnesotensis*
74 *O. obscura*
75 *O. jasorvensis*
76 *O. deflexa var. crassa*
77 *O. irrigua*
78 *O. terebriformis*
79 *O. geitleriana*
80 *O. subproboscidea var. minor (v. nov.)*
81 *O. chlorina*
82 *O. pseudogeminata*
83 *O. proteus*
84 *O. amoena*
85 *O. amoena var. nongranulata*
86 *O. pseudogeminata var. unigranulata*
87 *O. rubescens*
88 *O. agardhii*
89 *O. splendida*
90 *O. schultzii*
91 *O. subtilissima*
92 *O. mougeotii*
93 *O. cortiana*
94 *O. angusta*
95 *O. grunowiana var. articulata*
96 *O. subbrevis*
97 *O. subbrevis f. major*
98 *O. vizagapatensis*
99 *O. foreauii*
100 *O. prolifica*
101 *O. earlei*
102 *O. acuminata*
103 *O. salina*
104 *O. salina f. major*
105 *O. paucigranata*
106 *O. martini*
107 *O. formosa f. loktakenisis*
108 *O. anguina*
109 *O. laete virens*
110 *O. amphibia*
111 *O. limosa*
112 *O. chilkensis*
113 *O. curviceps*

114 *O. cruenta*
GENUS: *Crinalium*
115 *C. magnum*
GENUS: *Katagnymene*
116 *K. pelagica*
GENUS: *Phormidium*
117 *Phormidium bohneri*
118 *P. autumnale*
119 *P. fragile*
120 *P. abronema*
121 *P. papyraceum*
122 *P. ambigum*
123 *P. usterii*
GENUS: *Lyngbya*
124 *L. gracilis*
125 *L. aerugineo-coerulea*
126 *L. borgerti*
127 *L. kashyapii*
128 *L. cryptovaginata*
129 *L. contorta*
130 *L. corticola var. minor (v. nov.)*
131 *L. martensiana*
132 *L. infixa*
133 *L. holdenii*
134 *L. putealis var. minor (v. nov.)*
135 *L. lagerheimii*
136 *L. baculum*
137 *L. dendrobia*
GENUS: *Schizothrix*
138 *S. fuscesens*
GENUS: *Symploca*
139 *S. thermalis*
FAMILY: NOSTOCACEAE
SUB- FAMILY: ANABAENAE
GENUS: *Cylindrospermum*
140 *C. stagnale*
141 *C. alatosporum*
142 *C. majus*
GENUS: *Nostoc*
143 *N. maculiforme*
144 *N. piscinale*
145 *N. paludosum*
146 *N. microscopicum*
147 *N. muscorum*
148 *N. punctiforme*
GENUS: *Anabaena*
149 *A. variabilis*
150 *A. fertilissima*
151 *A. circinalis var. crassa*
GENUS: *Psedanabaena*
152 *P. catenata*
GENUS: *Raphidiopsis*
153 *R. curvata*
SUB-FAMILY: AULOSIRAE
GENUS: *Aulosira*
154 *A. fritschii var. major* (v. nov.)
155 *A. fertilissima*
156 *A. prolifica*
157 *A. pseudoramosa*
158 *A. laxa*
GENUS: *Hormothamnion*
159 *H. solutum*
FAMILY: SCYTONEMATACEAE
GENUS: *Plectonema*
160 *P. terebrans*
161 *P. gracillimum*
GENUS: *Pseudoscytonema*
162 *P. malayensa*
GENUS: *Camptylonemopsis*
163 *Camptylonemopsis lahorensis*
164 *C. minor*
FAMILY: MICROCHAETACEAE
GENUS: *Microchaete*
165 *M. aeruginea var. minor (v. nov.)*
FAMILY: RIVULARIACEAE
GENUS: *Calothrix*
166 *Calothrix fusca*
ORDER: STIGONEMATALES
FAMILY: NOSTOCHOPSIDACEAE
GENUS: *Nostochopsis*
167 *N. lobatus*
168 *N. radians*
169 *N. hansgirgi*
FAMILY: STIGONEMATACEAE
GENUS: *Westiella*
170 *W. intricata*

Evidently the region of the foot-hills of Kumaon Himalayas is copiously rich in cyanobacterial flora but has remained neglected for a long time from the point of view of its taxonomic studies. Evidently, it needs thorough investigations to explore all possibilities of deciphering specimens with interesting features, from the academic as well as economic parameters.

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