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Nostocales of Jammu, J&K, India

KEYWORDS: Cyanobacteria, diversity, Nostocales

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ABSTRACT *Cyanobacteria are the pioneer oxygenic, gram negative photosynthetic organisms which constitute a large group of prokaryotes. They exhibit great diversity of form and functions. The present study was emphasized to study the distribution of Cyanobacterial flora of order Nostocales of Jammu. The Cyanobacterial samples were collected from different seasons i.e., summer, rainy and winter. A total of 36 species belonging to 7 genera, 3 families and 2 sub-families. The genera include the species of Spirulina (2), Oscillatoria (21), Phormidium (3), Lyngbya (5), Nostoc (1), Aulosira (2) and Calothrix (2). The number put in parentheses represent the number of the species of a particular genus. Most of the species are lithophytic followed by epiphytic, planktonic, terrestrial, epipelic and miscellaneous habitats. Some of the taxa, fix atmospheric and have the capability to assimilate both carbon as well as nitrogen from the atmosphere.*

INTRODUCTION

Cyanobacteria, commonly known as Cyanophyta, Myxophyta, Cyanochloronta, blue-green algae, blue-green bacteria and most recently as cyanoprokaryotes. They are a group of gram negative photosynthetic bacteria that have colonized earth surface for nearly 3.5 billion years ago. They were probably the chief primary producer of organic matter and the first organisms to release elemental oxygen into the primitive atmosphere, which was until then free from O_2. They are most probably responsible for major evolutionary transformation leading to the development of aerobic metabolism and to the subsequent rise of higher plants and animal forms. They are simplest forms of algae, a representative of the plant kingdom. They are unique in their cosmopolitan nature, ranging in distribution from Arctic to Antarctic habitats. They may be single-celled or colonial. Colonies may form filaments, sheets or even hollow balls depending upon the species and environmental conditions.

The order Nostocales includes only filamentous forms which may or may not bear heterocyst. They may be lithophytic, planktonic, epiphytic, endophytic, terrestrial or epipelic and are capable to thrive in extreme environments such as rocky stones, hot springs, drought, desiccation, salinity and UV stresses. When environmental conditions are unfavourable or harsh, vegetative cells are modified into climate-resistant spores.

Some of the taxa, known as nitrogen-fixing Cyanobacteria (NFC), have the capability to assimilate both carbon as well as nitrogen from the atmosphere. NFC contains some thick walled special cells, the heterocysts which contain nitrogenase to help in the fixation of atmospheric nitrogen (Stewart *et al.* 1987) into nitrites and nitrates. Soil microalgae have received an increasing attention in the temperate countries, also because of their implication in reducing environmental pollution and removing soil compaction (Roger and Kulsooriya 1981).

Various workers have studied the Cyanobacterial flora of different parts of India. Some of them are Desikachary (1959), Singh *et al.* (1970), Bendre and Kumar (1975), Anand (1976, 1979), Sarma *et al.* (1979), Kumar (1985), Suseela and Goyal (1995), Ahmad *et al.* (1999), Tiwari *et al.* (2000), Habib (2001), Nayak *et al.* (2001), Kaushik and Prusanna (2002), Mishra and Pabbi (2004), Choudhury and Kennedy (2005), Chaudhary and Kumar (2005, 2006), Rai (2006), Nayak and Prasanna (2007), Digamabar Rao *et al.* (2008), Khare and Kumar (2009, 2010); Khare *et al.* (2009), Selvi and Shivkumar (2011) and Kumar (2002, 2009, 2010, 2012).

MATERIALS AND METHODS

Study Area

Jammu, known as the city of temples, is the winter capital of the J&K state, republic of India. It is also the Railhead of the state. It is situated on a hillock, on the bank of river Tawi and bound by Udhampur district in the north and north-east, Samba district in the east, Ranbir Singh Pura in the south-east and Akhnoor Tehsil in the west.

Geographically, Jammu is located at 74^0 24′ and 75^0 18′, East longitude and 32^0 50′ and 33^0 30′ North latitude at an altitude of 327m (1,073 ft) amsl. The temperature varies from cold in winter (with minimum temperature touching even 0.9^0 C to heat wave in summers when the temperature shoots up to 46^0 C

Fig. 1: (A) Map of Jammu & Kashmir showing the location of District Jammu. (B) Map of Jammu District showing the location of Tehsil Jammu along with adjoining Tehsils. (C) Location map Tehsil Jammu showing research sites.

Collection, Identification, Maintenance and Preservation of Samples

The samples were collected from the different habitats of the study area in different seasons i.e. summer, rainy and winter during 2011-2012. Cyanobacterial specimens growing on moist cemented walls, stones, bark of trees, soil, sand, in temporary and permanent water bodies like ditches and ponds were collected for the study. The samples were stored in sterile plastic bottles, and assigned accession number and

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recorded in field note book. On return to the laboratory, they were washed thoroughly with water and preserved in 4% formalin solution and deposited to the Algal Research Laboratory, Department of Botany, Sahu Jain PG College, Najibabad.

Semi-permanent slides were prepared from each sample for the identification of various taxa and observed under trinocular research microscope. Camera-lucida diagrams were sketched to study the taxa up to the level of class, order, family, genus and species level following the monograph of Desikachary (1959).

TAXONOMIC ENUMERATION OF SPECIES
Order : Nostocales Geitler

FAMILY GENUS	SPECIES (Accession No. & Collection Time)	HABIT, HABITAT AND COLLECTION SITES	PARAMETERS
Oscillatoriaceae (I) Spirulina	S. subsalsa Oerst. ex Gomont (R-04, Sept. 2011)	Epilithic- on moist stone, Manda Zoo, Manda	Trichome Breadth: 1.6-2.8 µ Spiral Breadth: 5.4-5.9 µ Distance between Spirals: 3.2-3.9 µ
	S. laxissima West, G.S. (W-07, Dec. 2011)	Epilithic- on moist wall of canal, Trikuta Nagar, Jammu.	Trichome Breadth: 0.7-0.9 µ Spiral Breadth: 4.2-4.6µ Distance between Spirals: 16.7-17.8µ
(II) Oscillatoria	O. obscura Bruhl et Biswas (S-16, Jun. 2011 & R-03, Aug. 2012)	Epilithic & Terrestrial- on the moist stones and moist soil, near Har ki Pauri, and Roop Nagar, respectively.	Cell Length: 0.9-1.4 µ Trichome Breadth: 3.6-4.3 µ
	O. subbrevis Schmidle (W-09, Jan. 2012 & R-17 Aug. 2012)	Epilithic & Planktonic- on moist wall of water canal and, in a temporary dith, Trikuta Nagar, Jammu.	Cell Length: 1.5 µ Trichome Breadth: 4.6-5.6 µ
	O. curviceps Ag. ex Gomont (W-13, Dec. 2011 & W-28, Dec, 2011)	Lithophytic (Epilithic)- on moist stones at Manda Zoo and Roop Nagar, Jammu.	Cell Length: 1.8-2.3 µ Trichome Breadth: 5.8-6.3 µ
	O. subtilissima Kütz. (R-13, Aug. 2011 & W-19, Jan. 2012)	Planktonic and Miscellaneous- in a temporary ditch, Panjtirthi, and on the plastic pipe, Trikuta Nagar.	Cell Length: 2.5 µ Trichome Breadth: 4.6 µ
	O. chlorina Kütz ex Gomont (R-09, Aug. 2011 & W-17&25, Jan. 2012)	Terrestrial & Planktonic- on moist soil and in a temporary ditch at Radhey Sham temple, Delli, Trikuta Nagar and Karan Nagar, respectively.	Cell Length: 4.6-6.2 µ Trichome Breadth: 5.6-5.9 µ
	O. grunowiana Gomont (W-04, Jan. 2012)	Epilithic- on the moist wall of temple, Roop Nagar, Jammu.	Cell Length: 2.2-2.9µ Trichome Breadth: 3.5-4.3µ
	O. boryana Bory ex Gomont (S-06, June 2011)	Epilithic - on moist stones at Manda Zoo, Manda.	Cell Length: 4.2-4.5µ Trichome Breadth: 6.1-6.4µ
	O. proteus Skuja (R-14, Aug. 2012)	Epilithic- on the moist wall of Shiv temple, Roop Nagar, Jammu	Cell Length: 3.2-3.6µ Trichome Breadth: 5.4-6.1µ
	O. jasorvensis Vouk. (R-10, Aug. 2011)	Epilithic- on the moist wall at Kacchi Chawni, Jammu	Cell length: 2.6-2.9 µ Trichome Breadth: 3.6-3.8 µ
	O. raoi De Toni, J. (R-15, Aug. 2012)	Epilithic- on the moist wall of Shiv temple, Roop Nagar, Jammu.	Trichome Breadth: 5.3-5.7µ Cell Length: 3.2-3.6µ
	O. amphibia Ag. ex Gomont (R-07, Aug. 2011 & W-13, Jan. 2012)	Epilithic & Terrestrial, on the moist wall and on the moist soil, Karan Nagar and Roop Nagar, Jammu.	Cell Length: 5-2-5.9µ Trichome Breadth: 2.5-3.0µ
	O. amoena (Kütz.) Gomont (R-06, Aug. 2011)	Epilithic- on moist stones at Manda Zoo, Manda.	Trichome Breadth: 4.4-4.7 µ Cell Length: 3.0-3.3 µ
	O. amoena var. non-granulata (W-14, Jan. 2012)	Epilithic- on the moist cemented wall of a water tank, Roop Nagar, Jammu.	Cell Length: 3.2-3.7µ Trichome Breadth: 3.1-3.8µ
	O. cortiana Meneghini ex Gomont (R-11, Aug. 2012)	Epilithic- on moist stones at Manda Zoo, Manda.	Trichome Breadth: 5.6-6.2µ Cell Length: 6.1-6.7µ
	O. prolifica (Grev.) Gomont (W-09, Jan. 2012)	Epilithic- on moist wall of water canal and, in a temporary dith, Trikuta Nagar, Jammu	Cell Length: 1.2-1.5µ Trichome Breadth: 3.0-3.6µ
	O. animalis Ag. ex Gomont (S-03 & 12, Jun. 2011)	Epilithic & Planktonic- on the moist stones and in a temporary ditch, Trikuta Nagar and Manda, respectively.	Cell Length: 1.8-2.4µ Trichome Breadth: 3.5-4.4µ
	O. foreaui Frémy (S-02, Jun. 2012)	Epilithic- on moist stones at Manda Zoo, Manda.	Trichome Breadth: 4.5-4.7 µ Cell Length: 2.3-2.6 µ
	O. chilkensis Biswas (W-03, Jan. 2012 & R-06, Aug.2011)	Epilithic- on the moist wall, railway road, Trikuta Nagarand on moist stones at Manda Zoo, Manda.	Trichome Breadth: 3.3-4.5 µ Cell Length: 1.5-1.8 µ
	O. sancta (Kütz.) Gomont (R-06, Aug. 2012)	Epilithic- on moist stones at Manda Zoo, Manda..	Trichome Breadth: 14.7-15.5µ Cell Length: 3.2-3.6 µ
	O. vizagapatensis Rao C.B. (S-10, Jun. 2012 & R-08, Aug. 2011)	Epilithic- on moist cemented wall of tap water, Manda Zoo, Manda and on moist stones, Roopnagar, respectively.	Trichome Breadth: 9.3-9.8 µ Cell Length: 1.8-2.2 µ
	O. limosa Ag. ex Gomont. (W-18, Jan. 2012 & S-11, Jun. 2011)	Epilithic & Epiphytic, on moist stones at Manda Zoo, Manda and on moist bark of Acacia modesta near Matadoor stand,Panjtirthi, respectively.	Trichome Breadth: 12.2-12.5 µ Cell Length: 1.2-1.8 µ

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(III) Phormidium	P. fragile (Meneghini) Gomont (W-09, Dec 2011 & R-06, Aug. 2011)	Epilithic- on moist wall of water canal, Trikuta Nagar, Jammu.	Trichome Breadth: 1.2-2.4 µ Cell Length: 1.6-2.0 µ
	P. tenue (Menegh.) Gomont (R-08, Aug. 2012)	Epipelic, on the moist sand at the bank of river Tawi, Jammu.	Trichome Breadth: 1.2-2.7 µ Cell Length: 2.5-3.1 µ
	P. anomala Rao, C.B. (S-03, Jun. 2011)	Epilithic- on moist stones at Manda Zoo, Manda.	Trichome Breadth with sheath:13.7-13.9 µ Trichome Breadth without sheath: 10.5-10.8µ Cell breadth: 2.4-2.7 µ
(IV) Lyngbya	L. mesotricha Skuja (W-06, Dec. 2011 & R- 12, Aug 2011)	Epipelic- on the moist sand at the bank of river Tawi, Jammu.	Trichome breadth: 2.2-3.1 µ Cell length: 3.8-4.4µ
	L. holdenii Forti. (W-15, Jan. 2012 & R-16, Aug 2011)	Epilithic- on the moist moist wall of tap water tank, Manda Zoo and on moist wall of a drain, Panjtirthi.	Trichome Breadth: 3.3-3.6µ Cell Length: 3.4-3.8 µ
	L. dendrobia Bruhl et Biswas. (S-13, Jun. 2011)	Epilithic- on moist stones at Manda Zoo, Manda.	Sheath Thickness: 1.0-1.3µ Trichome Breadth: 7.2-9.2µ Cell Length: 4.5-5.6µ
	L. baculum Gomont. (W-23, Jan. 2012 & S-02, Jun. 2011)	Epiphytic and Epilithic- on the moist bark of a dead plant, Roop Nagara and on moist wall of a drain, Trikuta Nagar.	Filament Breadth: 12.4- 12.7µ Trichome Breadth: 7.3-7.7 µ Cell Length: 3.5-3.8 µ
	L. limnetica Lemmermann (W-26, Jan. 2012)	Epilithic- on moist stones at Manda Zoo, Manda.	Filament Breadth: 1.6-1.8 µ Trichome Breadth: 1.4-1.6 µ Cell Length: 1.1-1.3 µ
Nostocaceae Sub-family: Anabaenae (V) Nostoc	N. commune Vauchaer ex Born. et Flah. (W-03, Jun. 2011 & R-09, Aug 2011)	Epilithic- on the moist wall of temple, Roop Nagar, Jammu and on moist wall of a drain, Panjtirthi.	Trichome Breadth: 5.3-5.6 µ Cell Length: 5.2-5.4µ
Sub-family: Aulosirae (VI) Aulosira	A. prolifica Bharadwaja (S-26, Jun. 2011 & W-23, Jan. 2012)	Epilithic- on moist stones & cemented walls, and bank of Tawi river.	Filament Breadth: 4.5-5.1 µ Trichome Breadth: 3.1-4.5 µ Cell length: 2.5-3.1 µ Heterocyst Diameter: 3.1-3.7 µ
	A. laxa Kirchner ex Born. et Flah. (S-03, Jun. 2011)	Epilithic- on moist stones at Manda Zoo, Manda.	Trichome Breadth: 4.2-5.2µ Cell length: 3.5-4.2 µ Heterocyst diam: 5.0-5.6 µ
Rivulariaceae (VII) Calothrix	C. fusca (Kütz.) Bornet et Flahault (S-05, Jun. 2011& R- 05, Aug. 2011)	Epiphytic- on the moist stem of a dead plant, Roop Nagar, Jammu and on moist leaves submerged in a pond, Paloura.	Filament Length: 170-230 µ Filament Breadth at the base: 12.5-15.3 µ Trichome Breadth: 6.5-7.3 µ Cell Length: 4.3-5.1 µ Heterocyst Diam.:3.8-4.7 µ
	C. elenkinii Kossinskaja (S-03, Jun. 2011)	Epilithic-, on moist stones at Manda Zoo, Manda.	Filament length: 145-160 µ Basal cells breadth: 6.1-6.4 µ Middle cells breadth: 3.4-3.7µ Heterocyst basal breadth: 5.3-5.6 µ

RESULTS AND CONCLUSIONS

The Cyanobacterial flora of order Nostocales includes 36 species belonging to 7 genera and 3 families. The genera include the species of *Spirulina*, *Oscillatoria*, *Phormidium*, *Lyngbya*, *Nostoc*, *Aulosira* and *Calothrix*. The highest number of species has been reported from family Oscillatoriaceae (31) followed by Nostocaceae (3) and Rivulariaceae (2), respectively.

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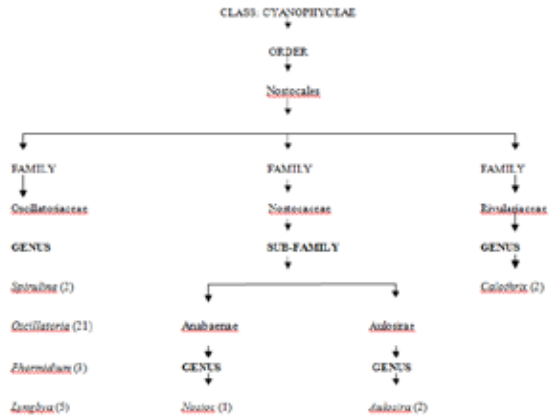

Fig. 2: Systematic position of various taxa reported from the research sites of Jammu. The number put in parentheses represents the number of species.

Table 1: Composition of the number of heterocystous and non-heterocystous species of order Nostocales of Jammu.

NON-HETEROCYSTOUS		HETEROCYSTOUS	
Genera	No. of species	Genera	No. of species
Spirulina Oscillatoria Phormidium Lyngbya	02 21 03 05	Nostoc Aulosira Calothrix	01 02 02
Total	31	Total	05

Having 21 species, genus *Oscillatoria* dominates the family Oscillatoriaceae which is followed by *Lyngbya* (5), *Phormidium* (3) and *Spirulina* (2) [Fig. 3]. Most of the species occur in lithophytic (epilithic) (31) habitat followed by epiphytic (4), planktonic (3), terrestrial (2), epipelic (2) and miscellaneous (1) habitats. They have a capability to sustain in almost every habitat. Some species commonly occur in two or more habitats [Fig. 4]. Most of the species found in rainy (19) season followed by winter (16) and summer (14) [Fig. 5]. Most of the species (86%) belongs to non-heterocystous forms and only 14% favours the heterocystous taxa [Fig. 6].

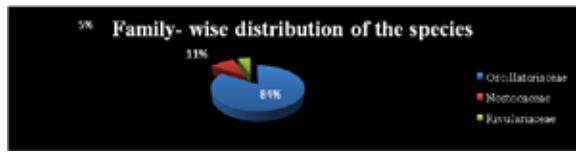

Fig. 3: Family-wise distribution of the species in the order Nostocales at Jammu.

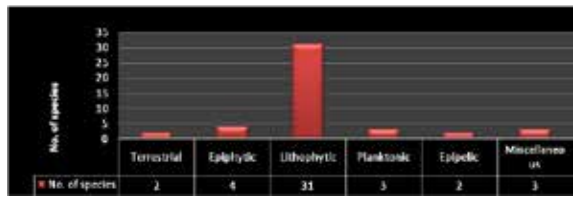

Fig. 4: Habitat-wise distribution of species of order Nostocales reported from Jammu.

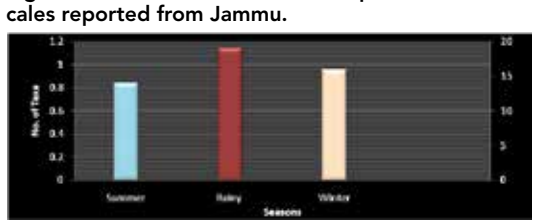

Fig. 5: Seasonal diversity of cyanobacterial taxa of order Nostocales reported from Jammu.

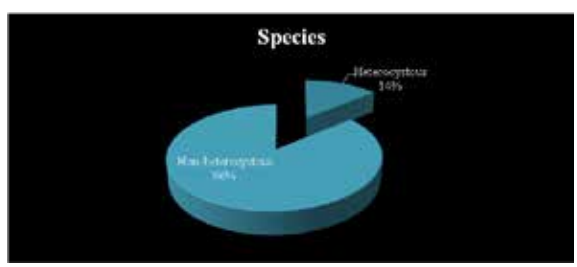

Fig. 6: Percentage of heterocystous and non-heterocystous species of order Nostocales reported from Jammu.

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