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DIVERSITY AND DISTRIBUTION PATTERN OF THE GENUS *OSCILLATORIA* VAUCHER EX GOM. (OSCILLATORIALES, CYANOPROKARYOTE) IN TRIPURA, INDIA

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ABSTRACT

Present paper deals with the diversity and distribution pattern of the genus *Oscillatoria* in Tripura, India. The genus *Oscillatoria* is a filamentous, unbranched, Non heterocystous and motile Blue-green Alga. In the present investigation we report sixteen species of the genus *Oscillatoria* from Tripura, India, out which, all the species are new addition to the flora of Tripura and seven species are new addition to Indian flora. Our study also revealed that out of total sixteen species of *Oscillatoria*, thirteen grow in rice fields and as well as in other habitats, but rest three taxa flourish only on specific habitats of Tripura, India.

Key words: **Biodiversity, Non-heterocystous Blue-green algae, Rice-fields, Tripura**

INTRODUCTION

The Blue-green algae (cyanoprokaryotes) are very important group of microbes with tremendous potential for their use as bio-fertilizer and soil conditioner in rice-fields and thus they contribute as primary colonizer in the ecosystem. Ever since it was revealed by De (1939) that blue-green algae add nitrogen to the soil, this group of microbes has became very much fascinating for the microbiologists (Singh, 1961) and they started exploring the entire country for these important micro-organisms and few algologists of the country made good efforts for compiling the information on blue-green algae from different habitats covering entire country excluding Tripura.

Traditionally, on the basis of morphological characteristics, the cyanoprokaryotes have been classified into three main groups including coccoid, Non-heterocystous filamentous and heterocystous forms (Geitler, 1939; Desikachary, 1959; Komarek and Anagnostidis, 1998, 2005; Komarek, 2013). The members of Oscillatoriales have characteristic filamentous thallus without heterocysts and akinetes. The family Oscillatoriaceae characterized by the circular trichome in cross section and further divided into two sub-families Oscillatorioideae and Homoeotrichoideae. The members of sub-family Oscillatorioideae have characteristic isopolar trichome with isomorphic ends in fully developed trichomes. However, the members of Homoeotrichoideae could be easily distinguished from Oscillatorioideae by the heteropolar trichome with wide basal end and narrowed hair like terminal end.

The genus *Oscillatoria* Vaucher *ex* Gomont (Oscillatorioideae, Oscillatoriaceae, Oscillatoriales, Cyanoprokaryota) is a non-heterocystous filamentous blue-green alga and its thallus is characterized by sheathless, straight trichomes or somewhat irregularly undulating, cylindrical sometimes screw like coiled at ends, mostly form mats, rarely solitary, 8-70 µm wide and exhibit extremely characteristic oscillatory movement by the trichomes. Cells are constantly wider than long and disc like. Cells are blue-green, olive or almost blackish, greenish-blue or yellowish-green in colour. Sheath usually absent, although they may occur under suboptimal conditions (Komarek and Anagnostidis, 2005). Trichomes with gliding motility by left or right handed rotations, movement's rate ranges from 1 to 11µm/s (Halfen and Castenholz, 2008). Cells divide very quick and transversely to the axis of trichomes. The genus *Oscillatoria* reproduce by means of breakdown of trichomes and short motile hormogonia are produced and get detached with the help of necridic cells. The species of *Oscillatoria* are widely distributed all over the globe and usually found growing in various habitats including marine, fresh water, shallow water bodies or marshes, swamps, lakes, pond, slow flowing rivers, sub-aerophytic on trees barks, wet rocks, soils of barren lands and rice fields. Globally, total 306 species of the genus *Oscillatoria* have been accepted taxonomically by the Aglaebase (Guiry and Guiry, 2021)

The main aim of the present investigation was to study the diversity and distribution pattern of the genus *Oscillatoria* in different habitats of Tripura, India. We are

reporting here total sixteen taxa belonging to sixteen species of the genus *Oscillatoria* from Tripura, India, and these are *Oscillatoria confervicola* Corda, *O. helferiana* Corda, *O. juergensii* Corda, *O. leonardii* Compère, *O. limosa* Agardh ex Gomont, *O. major* Vaucher ex Hansgirg, *O. meslinii* Frémy, *O. nigro-viridis* Thwaites, *O. obtusa* Gardner, *O. ornata* var. *crassa* Rao, *O. princeps* Vaucher ex Gomont, *O. proboscidea* Gomont ex Gomont, *O. pseudominima* Skuja, *O. sancta* Kützing ex Gomont, *O. subbrevis* Schmidle, *O. tenuis* Agardh ex Gomont. All the sixteen strains are new addition to the flora of Tripura and six species including *Oscillatoria confervicola*, *O. helferiana*, *O. juergensii*, *O. leonardii*, *O. meslinii* and *O. pseudominima* are being reported first time from India.

MATERIALS AND METHODS

Total eight hundred Blue-green algal growth containing samples were collected randomly in vials from different habitats *viz*., drains, moist soils, rice field's soils, tree barks etc. of Kailashahar and Kumarghat areas of Unakoti District of Tripura, India during last four years December 2016 to November 2020. Five ml from each collected samples were grown in BG-11 liquid medium (Stainer *et al*., 1971) for enrichment culturing and remaining 45 ml from each were stored in vials and preserved in formaldehyde (5%v/v) and were labelled properly. Total forty nine strains of sixteen species of *Oscilltoria* were raised from enrichment cultures by repeated culturing and sub-culturing. All the forty nine strains were isolated and purified from mixed population of cyanoprokaryotes of two hundred samples, and their unialgal cultures were developed as described by Kaushik (1987). All the cultures are deposited in the Botany Department, Chaudhary Charan Singh University, Meerut, India. For morphological observations, slides were prepared from both enriched cultures as well as from preserved natural material and observed under the Trinocular Research Microscope (Olympus, CH20i) attached with digital camera (Magnus, Magcam DC 10). All the isolated strains of *Oscillatoria* were identified up to the species level with the help of available literatures (Geitler, 1939; Desikachary 1959; Tiwari *et al.,* 2013; Sikdar and Keshari, 2014; Kesharwani *et al*, 2015; Halder, 2017). We have followed Oscillatoriales (Komarek and Anagnostidis, 2005) for the morphological description of the all the species and details of sixteen strains, one strain from each species are described in the present paper.

MORPHOLOGICAL OBSERVATION

Description of *Oscillatoria* species:

Oscillatoria confervicola Corda **(Figs 2C & 3L)**:

Trichomes olive-green with fine slimy envelope, constricted at cross-walls, cells 4-5 µm long and 55-63 µm wide.

(Sample No. Kugt-529: Habitat: moist Rice field; Collection Date:15-07-2017; Site: Kumarghat, 24°169837'N, 92°037973'E)

O. helferiana Corda **(Figs 2G & 3N)**:

Trichomes not constricted at cross-walls, yellowish olive-green, cells 15-16 µm long and 52-54 µm wide, apical cells rounded.

(Sample No. Kugt-602: Habitat: moist Rice field; Collection Date: 07-12-2017; Site: Kumarghat, 24°169750'N, 92°038161'E)

O. juergensii Corda **(Figs 2J & 3O)**:

Thallus cespitose, trichomes not constricted at cross-walls, bright blue-green, cells 15 µm long and 53 µm wide.

(Sample No. Kugt-745: Habitat: Aquatic Rice field; Collection Date:04-11-2018; Site: Kumarghat, 24°169933'N, 92°038126'E)

O. leonardii Compère **(Figs 2C & 3D)**:

Trichomes solitary, 17-26 µm wide, slightly attenuated towards ends, not constricted at cross-walls, apical cells flattened-rounded, with thickened outer cell wall.

(Sample No. Kugt-529: Habitat: moist rice field; Collection Date:15-07-2017; Site: Kumarghat, 24°169837'N, 92°037973'E)

O. limosa Agardh ex Gomont **(Figs 2I & 3I)**:

Thallus blackish blue green, olive green to brown, extended, thick, attached to the substrate, occasionally free-floating tufts at the water level or in solitary trichomes among other cyanoprokaryotes. Trichomes dark to bright blue-green to brown-violet, 9-22 µm wide, usually very long (up to 4mm), straight, rarely weakly curved, exceptionally with thin, unlayered colourless sheaths, not constricted at the granulated cross walls, slightly attenuated, motile, slowly gliding and oscillating, with left-handed rotation. Cells 1.5-5 (6) µm long; 3-5 times wide than long. Cell content finely granulated. Apical cells flat rounded, convex, with slightly thick-ended outer cell wall.

(Sample No. Kugt-725: Habitat: Aquatic Rice field; Collection Date: 01-07-2018;Site: Kumarghat, 24°169869'N, 92°037934'E)

O. major Vaucher ex Hansgirg **(Figs 2I & 3J)**:

Thallus membranaceous, flat, mucilaginous, blue-green. Trichomes 18-23 µm wide, blue-green, straight, not constricted at the granulated cross-walls. Cells 3-4 times wide than long, 4.5-6 µm long. Apical cells obtusely-rounded.

(Sample No. Kugt-725: Habitat: Aquatic Rice field; Collection Date: 01-07-2018; Site: Kumarghat, 24°169869'N, 92°037934'E)

O. meslinii Frémy **(Figs 2H & 3F)**:

Trichomes at the ends irregularly and loosely screw-like coiled, (7) 7.2-7.5 (7.8) µm wide, pale blue-green, slightly attenuated; cells 2-2.5 µm long, apical cells widely-rounded.

(Sample No. Kugt-496: Habitat: Aquatic Rice field; Collection Date: 02-05-2017;Site: Kumarghat, 24°169581'N, 92°038073'E)

O. nigro-viridis Thwaites **(Figs 2E & 3K)**:

Thallus olive-green or blackish-green, prostrate. Trichomes olive-green, straight or slightly wavy, constricted and granular at cross-walls, 7-12 (13) µm wide, at the ends slightly narrowed and often slightly arcuated (at well-developed trichome ends). Cells always shorter than wide, (2) 3-5 (6) µm long, with granular content. Apical cells conical-rounded, without calyptra, with slightly thickened outer cell walls.

(Sample No. Kugt-571: Habitat: Aquatic Rice field; Collection Date: 01-09-2017;Site: Kumarghat, 24°169581'N, 92°038003'E)

O. obtusa Gardner **(Figs 2J & 3E)**:

Trichomes straight or arcuate, bright blue-green, 23-25 µm wide, not constricted at cross-walls, cylindrical, apical cells flattened rounded with slightly thickened outer cell wall.

(Sample No. Kugt-745: Habitat: Aquatic Rice field; Collection Date: 04-11-2018; Site: Kumarghat, 24°169933'N, 92°038126'E)

O. ornata var. ***crassa*** Rao **(Figs 2D & 3M)**:

Trichomes solitary or in small clusters, flexuous, with straight or very slightly bent ends, distinctly constricted at cross-walls, not attenuated towards ends, 11-18 µm wide; cells blue-green, usually 4-6 time wide than long, 2-3 µm long; apical cells widely flat-rounded.

(Sample No. Kugt-739: Habitat: Aquatic Rice field; Collection Date:13-08-2018; Site: Kumarghat, 24°169735'N, 92°038171'E)

O. princeps Vaucher ex Gomont **(Figs 2A & 3C, 3H)**:

Thallus dark blue-green to blackish blue-green, thin, forming layered mats, or free-floating and forming clusters. Trichomes dark blue-green to brownish blue-green to (15) 20-50 (80) µm wide, straight or slightly curved, rigid, very long, motile with oscillation, left-handed rotation, not constricted at the ungranulated cross-walls, slightly attenuated at the ends, bent and nearly truncate, subcapitate. Cells discoid, short, 8-12 times wide than long, (2) 2.5-6.5 (8.7) µm long; cells finely granulated. Apical cells rounded, hemispherical or truncate.

(Sample No. Kls-589: Habitat: Drain; Collection Date: 04-09-2017;Site: Kailashahar, 24°315578'N, 91°996932'E)

O. proboscidea Gomont ex Gomont **(Figs 2F and 3A)**:

Thallus membranaceous, thin to thick, soft, dark green to blackish-green, or in solitary trichomes among other cyanoprokaryotes. Trichomes bright blue-green, (9) 11-18 (23) µm wide, straight, sporadically irregularly screw-like coiled, rarely with thin, colourless sheaths, motile with left-handed rotation, not constricted at the ungranulated cross-walls, distinctly attenuated, slightly curved, capitate. Cells 3-6 times wide than long, (1.5) 2-4 (7.7) µm long. Apical cells flat-rounded, hemispherical.

(Sample No. Kls-577: Habitat: Drain; Collection Date: 03-09-2017; Site:Kailashahar, 24°315449'N, 91°997217'E)

O. pseudominima Skuja **(Figs 2H &3Q)**:

Trichomes straight or slightly coiled, not attenuated toward ends, pale blue-green or olive-green. 1.4-1.7 µm wide, not constricted at cross-walls, cylindrical, rounded at the ends, cells 3.5-8 µm long, with solitary granules at cross-walls.

(Sample No. Kugt-496: Habitat: Aquatic Rice field; Collection Date: 02-05-2017;Site: Kumarghat, 24°169581'N, 92°038073'E)

O. sancta Kützing ex Gomont **(Figs 2B &3G)**:

Thallus dark brownish blue-green, thin shining, mucilaginous, gelatinous, sometimes slightly layered. Trichomes bright blue-green or brown-violet, (6.6) 7-18.5 (20) µm wide, very long, straight or slightly curved, rarely with thin sheaths, slightly constricted at the granulated cross-walls, not attenuated at the ends, motile, with left-handed rotation. Cells discoid, 3-6 times wide than long, (1.5) 1.8-5 (6-7) µm long. Apical cells hemispherical or flattened, slightly capitate to wart-like with thickened calyptroid outer cell wall.

(Sample No. Kls-746: Habitat: Moist soil; Collection Date: 05-11-2017; Site: Kailashahar, 24°316534'N, 91°997388'E)

O. subbrevis Schmidle **(Figs 2G & 3P)**:

Trichomes solitary, yellowish grey to green-yellowish, 4-10.5 (12) µm wide, usually straight, occasionally arched, not or sometimes some constricted at the non granulated cross-walls, not attenuated at the ends. Cells shorter than wide, discoid, 1-2 (2.5) µm long. Apical cells rounded, without calyptra.

(Sample No. Kugt-602: Habitat: moist rice field; Collection Date: 07-12-2017; Site: Kumarghat, 24°169750'N, 92°038161'E)

O. tenuis Agardh ex Gomont **(Figs 2E& 3B)**:

Thallus flat, in the form of mats or clusters, blue-green or olive-green, usually thin, mucilaginous. Trichomes straight or very slightly irregularly curved, not constricted or very slightly constricted at cross walls, without granulation at cross-walls, blue green or greyish-violet, 5-14 (15) µm wide, cylindrical, not attenuated, but very rarely slightly curved at the ends. Cells always shorter than wide, 2-3.5 (4.8-6) µm long, sometimes with scattered solitary granules; apical cells rounded, not capitate.

(Sample No. Kugt-571: Habitat: Aquatic Rice field; Collection Date: 01-09-2017; Site: Kumarghat, 24°169581'N, 92°038003'E)

DISCUSSIONS

The non-heterocystous filamentous Blue-green algae are very common forms and have been reporting from different habitats of India. The non-heterocystous filamentous Blue-green algae have been studied globally by the numerous phycologists (Drouet, 1968; Castenholz, 1968; Baker and Bold, 1970; Faridi and Khalil, 1974; Gomont, 1892; Hindak, 1985; McGregor, 2007). Globally, till date total 52 genera of Non heterocystous filamentous blue-green algae are known (Komarek and Anagnostidis, 2005). Worldwide, total 306 species of the genus *Oscillatoria* have been accepted taxonomically in the AglaeBase (Guiry and Guiry, 2021).

In India, members of Oscillatoriales have been studied in details by many phycologists (Mitra, 1951; Kamat, 1962; Tiwari, 1975; Grover and Pandhol, 1975; Prasad and Srivastava,1985; Anand, 1989; Singh and Bisoyi, 1989; Santra, 1993; Kumawat and Jawale, 2006; Hazarika *et al*., 2002; Mishra *et al*., 2008), but most of them could not reach to Tripura, due to which very scanty information is available on Non-heterocystous blue-green algae from this diversity rich state of North East region of India. Till now, total 614 taxa of eighteen genera, out of which 208 taxa of 126 species of the genus *Oscillatoria* are kwon from India (Tiwari *et al.,* 2007) excluding Tripura. Although few phycologists (Singh *et al*, 1997; Das *et al*., 2010; Ghosh *et al*., 2019; Bharati *et al*., 2020; Kant *et al*, 2020a-b; Sarma *et al.,*2020) tried to explore the area but could not compiled the information on

Oscillatoriales, because most of the phycologists either ignored non-heterocystous blue-green algae or identified upto the genus level and reported few species.

CONCLUSION

On the basis of present investigation, it is concluded that Tripura has a very rich diversity of non-heterocystous Blue-green algae in addition to the heterocystous forms and there are good chances of new strains, which may be new to the science and new addition to the flora of Tripura. It needs more extensive study to develop comprehensive information on such important group of microorganisms with tremendous potential. The occurrence of more than 50% non heterocystous forms of blue-green algae in rice fields are an indication of their tolerance of toxic chemicals *viz.* fertilizers, pesticides etc in rice fields. Appearance of more than fifty percent of taxa of *Oscillatoria* in rice fields are also indicative measures of application chemical fertilizers by the farmers of the Tripura in their rice fields and many of them may be very much useful for harnessing of toxic chemicals from rice field soils of the Tripura which needs more attempts for investigations and thorough research.

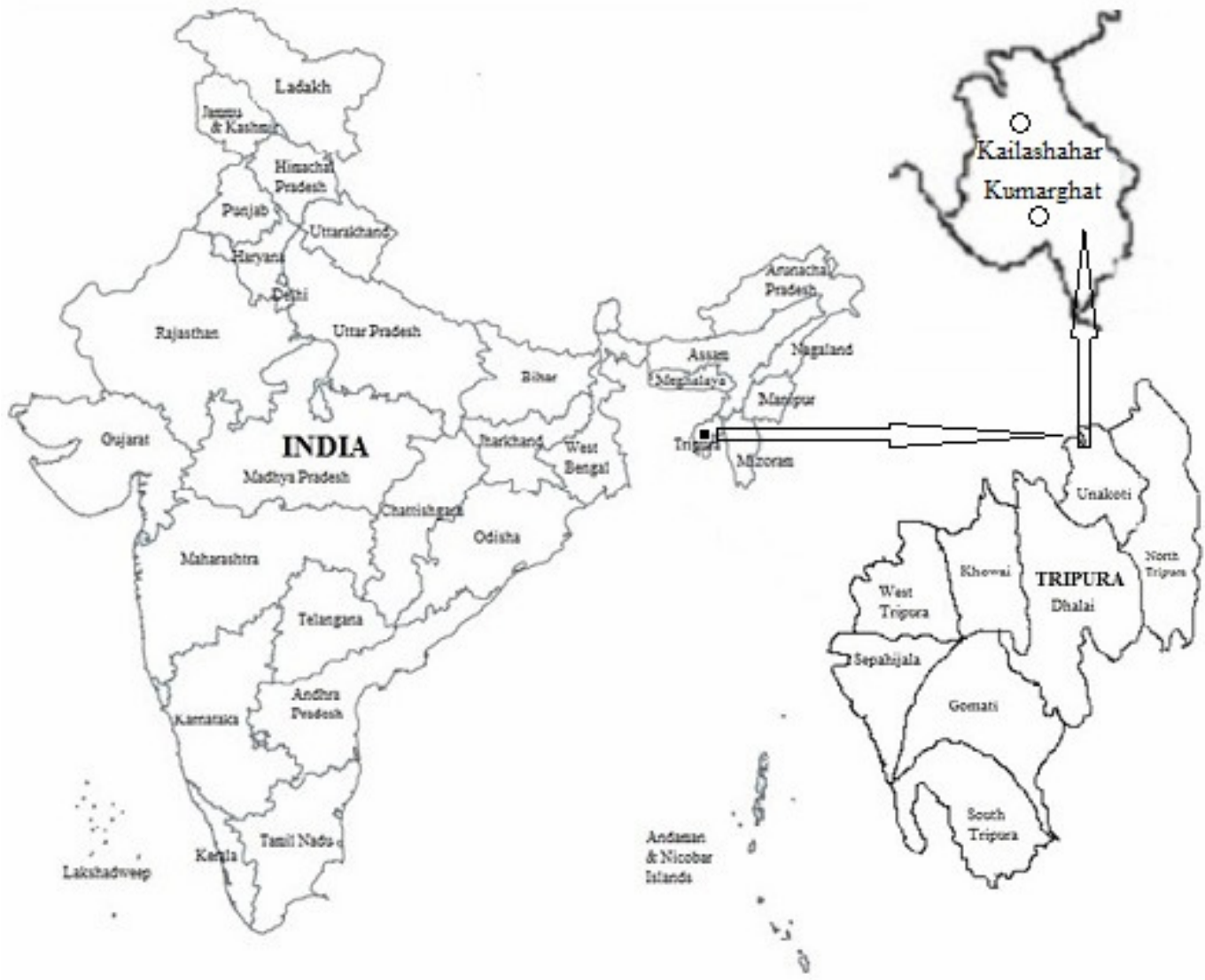

Fig. 1 : Google Map showing sampling sites and study area of Tripura in India Map

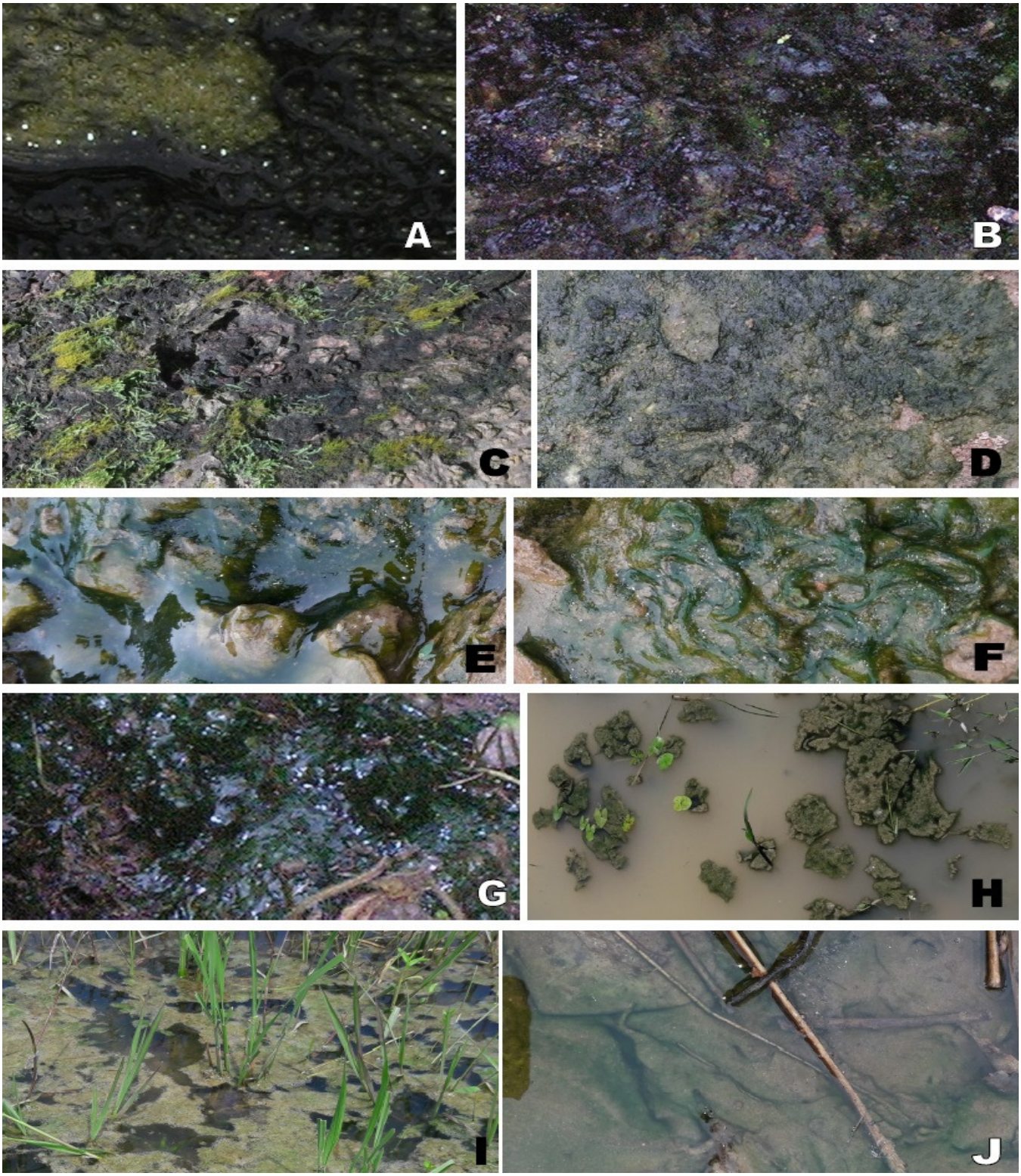

Fig. 2 : Growth of *Oscillatoria* species in nature:

Description of Figures 2A-2J:
A. *Oscillatoria princeps,* **B.** *O. sancta,* **C.** Mixed growth of *O. comfervicola* and *O. leonardii,* **D.** *O. ornata var. crassa,* **E.** Mixed growth of *O. nigro-viridis* and *O. tenuis,* **F.** *O. proboscidea,* **G.** Mixed growth of *O. helferiana* and *O. subbrevis,* **H.** Mixed growth of *O. pseudominima* and *O. meslinii,* **I.** Mixed growth of *O. limnosa* and *O. major.* **J.** Mixed growth of *O. juergensii* and *O. obtusa*

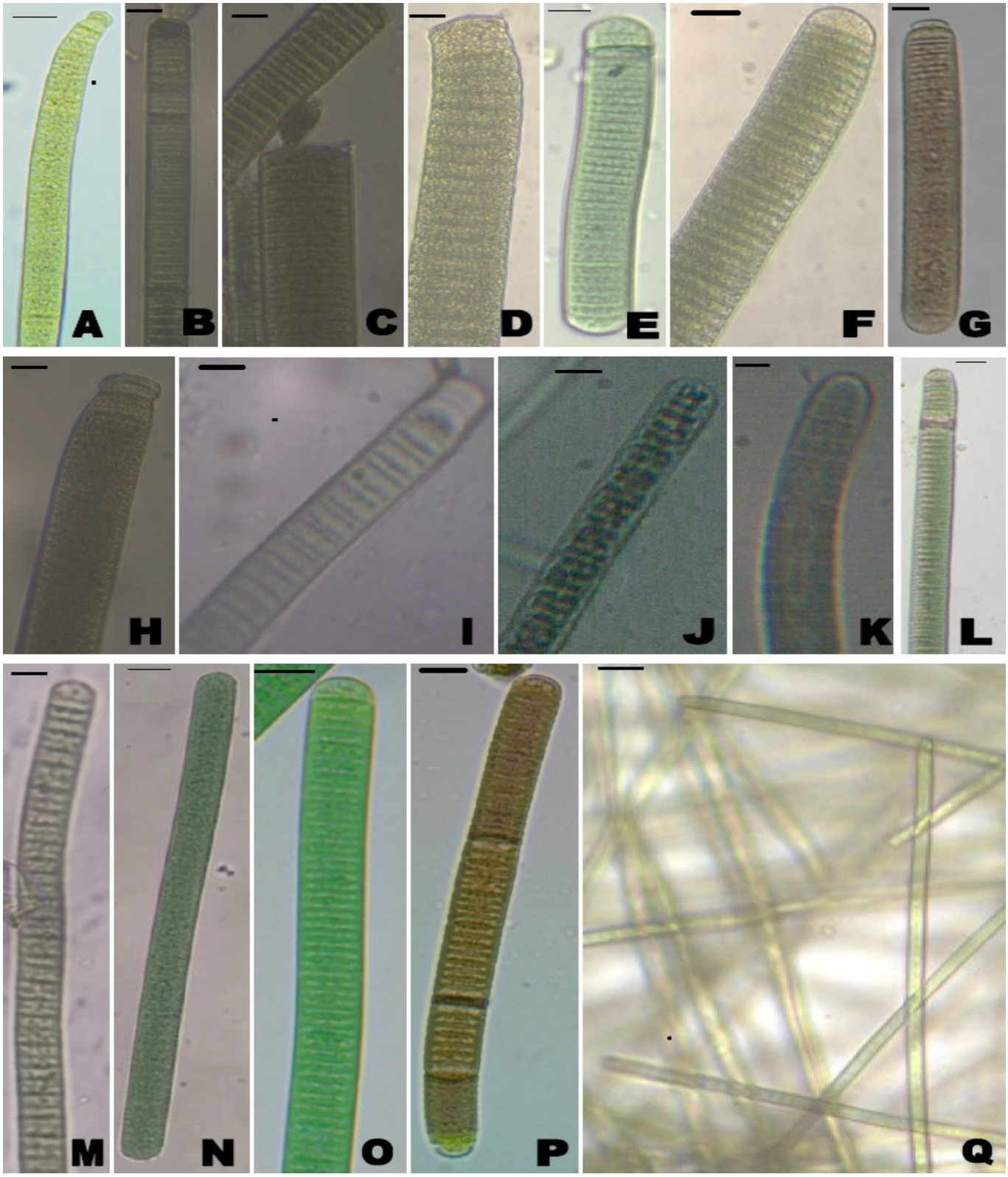

Fig. 3 : Morphological details of *Oscillatoria* species in enriched culture conditions:

Description of Figures 3A-3Q:

Figure 3-(**A**) *Oscillatoria proboscidea*; **(B)** *O. tenuis*; **(C-H**) *O. princeps*; **(D)** *O. leonardii*; (**E**) *O. obtusa*; **(F)** *O. meslinii*; (**G**) *O. sancta***; (I)** *Oscillatoria limosa*; **(J)** *O. major* **(K)** *O. nigro-viridis*; **(L)** *O. comfervicola*; (**M**) *O. ornata var. crassa*; **(N)** *O. helferiana*; **(O)** *O. juergensii*; (**P**) *O. subbrevis*; (**Q**) *O. pseudominima* (Scale bar-L,N,O=50µm; A,C,E,H,I,J=20µm D,M,G=10µm; Rest=5µm)

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