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Algal diversity in foot hills of Eastern Himalayas-III (Cyanoprokaryota: Nostocales)

Mousumi Das[1] and Jai Prakash Keshri*[2]

1 & 2 Phycology Section, UGC Centre for Advanced Study (Phase-II), Department of Botany, The University of Burdwan, Golapbag, Burdwan – 713104, West Bengal, India. E-mail:- [1]mousumi373@gmail.com, [2]keshrijp@gmail.com

ABSTRACT

Himalayan region is one of the richest regions of flora and fauna in world. It is a focus for biologist for its rich biodiversity. Koch Bihar is one such district of West Bengal, situated in the foot of Eastern Himalaya known as 'Tarai'. So, at the point of biodiversity it is one of the most important places. Nostocales a group of cyanoprokarotes generally known as N_2 fixing group found abundantly in this district. In this paper a total of 25 taxa have been identified. Out of 25 taxa 3 taxa (***Aulosira cylindrica*** EI- Nayal, ***Microchaete diplosiphon*** Gomont ex Bornet et Flahault, ***Microchaete geoppertiana*** (Kirchner) Kirchner) are being reported for the first time from India, 4 taxa (***Anabaena oscillariodes*** Bory ex Bornet et Flahault var. ***angustus*** Bharadwaja, ***Calothrix clavatoides*** Ghose, ***Cylindrospermopsis gangetica*** (Nair) Komárek, ***Nostochopsis lobata*** Wood ex Bornet et Flahault) are being reported for the first time from Eastern India and 3 taxa (***Gloeotrichia intermedia*** (Lemmermann) Geitler, ***Scytonema javanicum*** Bornet ex Bornet & Flahault, ***Scytonema pascheri*** Bharadwaja) for the first time from from West Bengal in addition to the previous ones. A new combination ***Macrospermum iyengarii*** var. ***unispora*** (Singh in Tiwari et Pandey 1976) Keshri et Das comb. nov. has been proposed. 1 taxa (***Diplocolon indicum*** Keshri et Das sp. nov.) has been introduced as new science.

KEY WORDS: Nostocales, Cyanoprokaryotes, Koch Bihar, new species, new reports.

INTRODUCTION

Nostocales is one of the orders of cyanoprokarotes important from both agriculture and economic point of view. The important character of this group is the formation of heterocyst known as factory of N_2 fixation. So it can easily be used as bio-fertilizer for various crops. Koch Bihar is the district situated on the border of Bangladesh. Soil of the most part of the district is in having low nitrogen level and therefore underdeveloped in agriculture. The biodiversity of Nostocales may be used for biofertilizer production.

During the systematic investigations on the cyanoprokaryote flora of this area the authors contributed 35 taxa of Cyanoprokaryotes in their early two contributions (Das & Keshri 2017a, 2017b).

MATERIAL AND METHODS

All the samples were collected from various rice fields, damp soil, and river stream, attached and lodged on aquatic plants through the year round (Map-I). Samples were preserved in 5 % formalin. pH, temperature, habitat were also noted at the time of collection. Proper figure of desired algal sample were drawn under appropriate magnifications with the help of camera Lucida. Photomicrographs were taken using Carl Zeiss Axiostar plus research microscope with Nikon SLR model (D60) digital camera attachment system.

Map-1: Different collection spots of Koch Bihar District

RESULTS AND DISCUSSION**:**

In this investigation total 25 taxa of Nostocales were found from the Koch Bihar district at the foot hills of Eastern Himalayas.

1. ***Anabaena oscillariodes*** Bory ex Bornet et Flahault var. ***angustus*** Bharadwaja
[Desikachary 1959, p. 418, pl. 78, f. 1; Komárek 2013, p. 798, f. 998 b]
(Pl. I, Fig. 1; Pl. III, Fig. 26)

Length of the cell: 3-5 µm; Breadth of the cell: 3-6 µm; Length of the heterocyst: 7 µm – 8 µm; Breadth of the heterocyst: 8 µm; Length of the akinete: 14 µm – 16 µm; Breadth of the akinete: 6 µm – 8 µm.
Collection No. & Ecological notes: MD- 166, 10. 02. 2013, Pundibari, Koch Bihar, aquatic, attached with aquatic plant (pH- 6, Temp. 28^0C).
Distribution in India: Uttar Pradesh (Bharadwaja, 1935).
This is probably the first report of the taxon from Eastern India.

2. ***Anabaena torulosa*** (Carmichael) Lagerheim ex Bornet et Flahault
[Desikachary 1959, p. 415, pl. 71, f. 6; Komárek 2013, p. 801, f. 999]
(Pl. I, Fig. III; Pl. III, Fig. 27)

Length of the cell: 3-8 µm; Breadth of the cell: 3-5 µm; Length of the heterocyst: 7 µm – 9 µm; Breadth of the heterocyst: 6-8 µm; Length of the akinete: 11-14 µm; Breadth of the akinete: 6-12 µm.
Collection No. & Ecological notes: MD- 235, 16. 08. 2013, Kalakata, Koch Bihar, aquatic, attached with aquatic plant (pH- 6, Temp. 34^0C).
Distribution in India: Anadaman and Nicobar Islands (Prasad and Srivastava, 1992); Assam (Hazarika *et al.,* 2001, 2003; Ahmed, 2002; Hazarika, 2013); Bihar (Jha *et al.,* 1986); Gujarat (Patel *et al.,* 1974); Karnataka (Bongale and Bharati, 1980; Bongale, 1981); Madhya Pradesh (Jain, 2015); Maharashtra (Asthekar and Kamat, 1980; Kotle and Goyal, 1985); Manipur (Amita Devi *et al.,* 1999); Mizoram (Singh *et al.,* 1996); Nagaland (Singh *et al.,* 1997); Odisha (Sahu *et al.*, 1996; Sahu, 2000; Das, 2002; Pattanaik and Adhikary, 2002; Rath and Adhikary, 2005; Tirkey and Adhikary, 2005); Punjab (Grover and Pandhol, 1975; Pandhol and Grover, 1976; Sharma and Kanta, 1978); Rajasthan (Kamat, 1967; Srivastava, 1999); Tamil Nadu (Anand, 1989; Perumal and Anand, 2009; Silambarasan *et*

al., 2012), Tripura (Singh *et al.,* 1997b), Uttaranchal (Verma and Asthana, 2005), Uttar Pradesh (Kumar, 1970; Pal and Yadav, 1974; Pal, 1975), West Bengal (Banerji, 1938; Sinha and Mukherjee, 1975a; Santra, 1993).

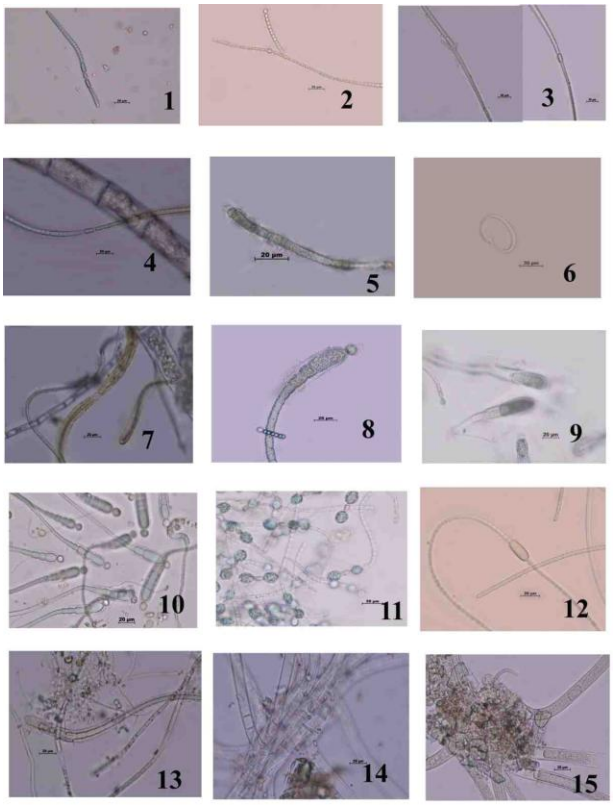

PLATE-I

1. ***Anabaena oscillariodes*** Bory ex Bornet et Flahauet ***var. angustus*** Bharadwaja
2. ***Anabaena torulosa*** (Carmichael) Lagerheim ex Bornet et Flahault
3. ***Aulosira cylindrica*** EI- Nayal
4. ***Aulosira prolifica*** Bharadwaja
5. ***Calothrix clavatoides*** Ghose
6. ***Cylindrospermopsis gangetica*** (Nair) Komárek
7. ***Diplocolon indicum*** Keshri & Das sp. nov.
8. ***Gloeotrichia ghosei*** R. N. Singh
9. ***Gloeotrichia intermedia*** (Lemmermann) Geitler
10. ***Gloeotrichia natans*** [Hedwig] Rabenhorst ex Bornet et Flahault
11. ***Macrospermum iyengarii*** var. ***unispora*** (Singh in Tiwari et Pandey 1976) Keshri & Das comb. nov.
12. ***Macrospermum volzii*** (Lemmermann) Komárek
13. ***Microchaete diplosiphon*** Gomont ex Bornet et Flahault
14. ***Microchaete geoppertiana*** (Kirchner) Kirchner
15. ***Microchaete tenera*** Thuret ex Bornet et Flahault

3. ***Aulosira cylindrica*** EI- Nayal
[Komárek 2013, p. 861, f. 1099]
(Pl. I, Fig. 3; Pl. III, Fig. 28)

Filaments dark blue-green with false branching; trichomes slightly curved and narrowed towards the ends; sheath colourless, firm closely attached to the trichomes; cells cylindrical and longer than broad; heterocyst intercalary, oval. Length of the cell: 15-23 µm; Breadth of the cell: 4-7 µm; Length of the heterocyst: 10-12 µm; Breadth of the cell: 7-10 µm.

Collection No. & Ecological notes: MD- 065, 27. 11. 2011, Garopara Mansai River, Koch Bihar, growing in free floating condition (pH- 6, Temp. 22^0C).

Distribution in India: This is probably the new report of the taxon from India.

Comments: Such specimens are actually confusing with *Aphanizomenon* Morren at a glance but it does not form coalescent mass as in the latter genus. The morphology of *A. cylindrica* EI – Nayal is distinctly similar to this specimen. Therefore its placement in *Aulosira* Kirchner ex Bornet et Flahault appears correct.

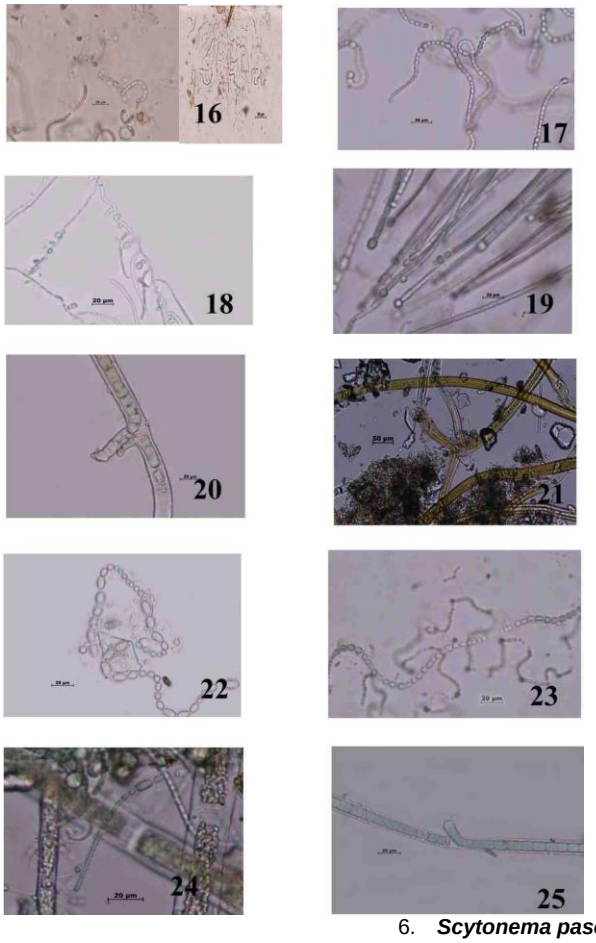

PLATE-II

1. ***Nostoc calcicola*** Brébisson ex Bornet et Flahault
2. ***Nostoc linckia*** (Roth) Bornet et Flahault
3. ***Nostochopsis lobata*** Wood (1869) ex Bornet et Flahault
4. ***Rivularia aquatica*** De – Wildeman
5. ***Scytonema javanicum*** Bornet ex Bornet & Flahault
6. ***Scytonema pascheri*** Bharadwaja
7. ***Trichormus fertilissimus*** (Rao) Komárek et Anagnostidis
8. ***Trichormus ellipsosporus*** (Fritsch) Komárek et Anagnostidis
9. ***Cylindrospermum michailovskoense*** Elenkin
10. ***Nodularia spumigena*** Mertens ex Bornet et Flahault

4. ***Aulosira prolifica*** Bharadwaja

[Desikachary 1959, p. 426, pl. 81, f. 1 – 6; Komárek 2013, p. 863, f. 1105]
(Pl. I, Fig. 4; Pl. III, Fig. 29)

Length of the cells: 7 µm – 10 µm; Breadth of the cells: 5 µm – 8 µm; Sheath: 6 µm; Length of the heterocyst: 9 µm – 16 µm; Breadth of the heterocyst: 6 µm – 8 µm.

Collection No. & Ecological notes: MD- 127, 26. 10. 2012, Nishigange, Koch Bihar, aquatic, lodged on aquatic plant (pH- 6, Temp. 29^0C); MD- 129, 26. 10. 2012, Mathabhanga, Koch Bihar, aquatic, lodged on aquatic plant (pH- 6, Temp. 29^0C).

Distribution in India: Andhra Pradesh (Rao, 1938); Assam (Saikia and Bordoloi, 1994; Ahmed, 2001, 2002); Kerala (Anand and Shanta Kumar Hopper, 1995); Maharashtra (Ashtekar and Kamat, 1980, Chaporkar and Gangawane, 1984; Kotle and Goyal, 1985); Odisha (Sahu *et al.,* 1996; Das, 2002); Punjab (Grover and Pandhol, 1975; Pandhol and Grover, 1976; Sharma and Kanta, 1978), South India (Anand, 1989), Uttarakhand (Khan, 1970; Gupta, 2005), Uttar Pradesh (Bharadwaja, 1933; Kumar, 1970; Pal, 1975; Pandey, 1982; Pandey and Pandey, 1982; Chaturvedi and Habib, 1995; Verma and Chaturvedi, 2009), West Bengal (Sinha and Mukherjee, 1975a; Sengar and Pandey, 1985; Mazumdar & Chandra, 1987; Santra 1993).

5. ***Calothrix clavatoides*** Ghose
[Desikachary 1959, p. 531, pl. 113, f. 9; Komárek 2013, p. 256, f. 274]
(Pl. I, Fig. 5; Pl. III, Fig. 32)

Length of the cell: 1.2-5 µm; Breadth of the cell: 1.25-12.5 µm; Diameter of heterocyst: 20 µm.
Collection No. & Ecological notes: MD- 016, 03. 02. 2011, Sagar Dighi, Koch Bihar, attached on submerged stones (pH- 6, Temp. 16^0C).
Distribution in India: Punjab (Sharma, *et al.,* 1979); Tripura (Singh, *et al.,* 1997b); Uttarakhand (Khan, 1970); Uttar Pradesh (Prasad and Mahrotra, 1979; Prasad and Mahrotra, 1980; Verma and Chaturvedi, 2009).
This is probably the first report of taxon from Eastern India.

6. ***Cylindrospermopsis gangetica*** (Nair) Komárek
[Komárek 2013, p. 682, f. 840]
(Pl. II, Fig. 6; Pl. III, Fig. 30)

Length of the cell: 23 – 25 µm; Breadth of the cell: 2 – 4 µm; Heterocyst 6 – 8 µm long and 2 – 4 µm broad.
Collection No. & Ecological notes: MD- 105, 05. 08. 2012, Rajmata Dighi, Koch Bihar, aquatic, lodged on aquatic plant (pH- 5.5, Temp. 34^0C).
Distribution in Indian: Uttar Pradesh (Nair, 1967) as *Anabaenopsis gangetica* G. U. Nair.
This is probably the first report of the taxon from Eastern India.

PLATE-III

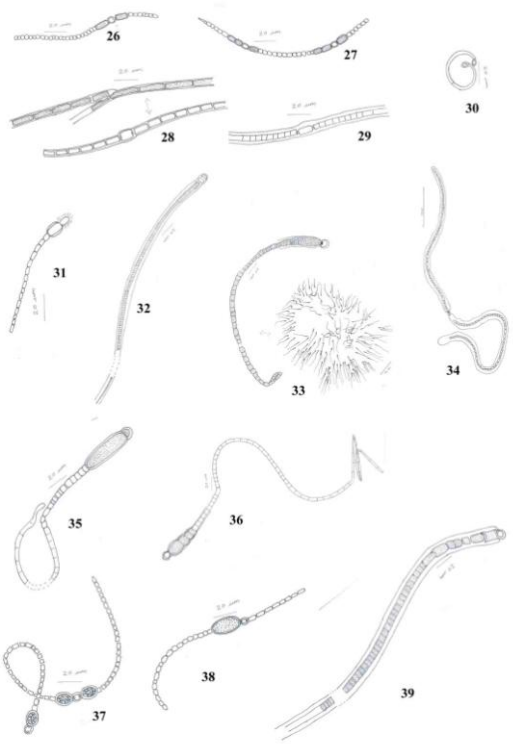

PLATE-III
1. ***Anabaena oscillariodes*** Bory ex Bornet et Flahauet ***var. angustus*** Bharadwaja
2. ***Anabaena torulosa*** (Carmichael) Lagerheim ex Bornet et Flahault
3. ***Aulosira cylindrica*** EI- Nayal
4. ***Aulosira prolifica*** Bharadwaja
5. ***Cylindrospermopsis gangetica*** (Nair) Komárek
6. ***Cylindrospermum michailovskoense*** Elenkin
7. ***Calothrix clavatoides*** Ghose
8. ***Gloeotrichia ghosei*** R. N. Singh
9. ***Diplocolon indicum*** Keshri & Das
10. ***Gloeotrichia intermedia*** (Lemmermann) Geitler
11. ***Gloeotrichia natans*** [Hedwig] Rabenhorst ex Bornet et Flahault
12. ***Macrospermum iyengarii*** var. ***unispora*** (Singh in Tiwari et Pandey 1976) Keshri & Das comb. nov.
13. ***Macrospermum volzii*** (Lemmermann) Komárek
14. ***Microchaete diplosiphon*** Gomont ex Bornet et Flahault

7. ***Cylindrospermum michailovskoense*** Elenkin
[Desikachary 1959, p. 368, pl. 65, f. 1; Komárek 2013, p. 885, f. 1140]
(Pl. II, Fig. 24; Pl. III, Fig. 31)

Length of the cell: 3.5 µm – 5 µm; Breadth of the cell: 3 µm – 3.5 µm; Length of the heterocyst: 7 µm – 7.6 µm; Breadth of the heterocyst: 3 µm – 4 µm; Length of the akinete: 11 µm – 12.5 µm; Breadth of the akinete: 8.5 µm – 9.5 µm.
Collection No. & Ecological notes: MD- 068, 27. 11. 2011, Garopara Mansai River, Koch Bihar, free floating (pH- 6, Temp. 22^0C).
Distribution in India: Jammu and Kashmir (Kant and Gupta, 1998; Ara, *et al.,* 2002); Kerala (Anand and Shanthakumar Hopper, 1995; Madhusoodanan and Dominic, 1995); Maharashtra (Mahajan and Mahajan, 1988; Patil *et al.,* 2011); Manipur (Amita Devi, *et al.,* 1999); Mizoram (Singh, *et al.,* 1996); North India (Randhawa, 1936), Odisha (Sethi, *et al.,* 2012); South India (Anand, 1989); Uttar Pradesh (Singh and Chaturvedi, 1970; Pal, 1975; Prasad and Mehrotra, 1979, 1980), West Bengal (Sinha and Mukherjee, 1984; Santra, 1993).

8. ***Diplocolon indicum*** Keshri et Das sp. nov.
(Pl. I, Fig. 7; Pl. III, Fig. 34)

Many filaments are aggregated to form a colony; trichomes are surrounded by a thick yellow colored sheath and long up to 920 µm; cells are barrel shaped, more or less two times longer than broad; apical cell elongated with rounded end; heterocyst oval to cylindrical, intercalary in position but not covered by the sheath of the trichomes; akinete not observed.
Length of the cell: 11.5 µm – 23.4 µm; Breadth of the cells: 7.5 µm – 11.5 µm: Length of the heterocyst: 11.7 µm; Breadth of the heterocyst: 7.8 µm.
Holotype: MD- 087, 20. 02. 2012, Gouranga Bazar, Koch Bihar, found in a small, river like water body (pH- 5.5, Temp. 28^0C), deposited in the Algae Herbarium. Department of Botany, The University of Burdwan (BURD).
Comments: Morphologically the taxon fits well with the description assigned to the genus *Diplocolon* Nägeli. Komárek (2013) however doubts the validity of the taxon and put under *Sacconema* A. Borzi ex É. Bornet & C. Flahault as unclear taxa. But as the specimen tallies completely with the genus it has been considered as a valid taxon. This taxon differs from *Diplocolon heppi* Nägeli Rabenhorst sensu Bornet et Flahault 1887 in many features. Dimension and typical morphology of the taxon is completely different from the above mentioned species.

9. ***Gloeotrichia ghosei*** R. N. Singh
[Desikachary 1959, p. 561, pl. 118, f. 1 – 3; Komárek 2013, p. 367, f. 421]
(Pl. I, Fig. 8; Pl. III, Fig. 33)

Length of the cell: 6-12 µ; Breadth of the cell: 4-12 µm; Diameter of heterocyst: 14-16 µm; Length of the akinete: 30-36 µm; Breadth of the akinete: 14-16 µm.
Collection No. & Ecological notes: MD- 208, 04. 05. 2013, Purbo Barochoki, Koch Bihar; aquatic, attached and lodged on aquatic plants (pH- 6, Temp. 27^0C).
Distribution in India: Andaman & Nicobar Islands (Prasad and Srivastava, 1992); Bihar (Singh, 1939); Karnataka (Somashekar, 1983); Kerala (Anand and Shanta Kumar Hopper, 1995), Madhya Pradesh (Agarkar, 1967; Tiwari, 1972; Tiwari, *et al.,* 1979); Odisha (Sahu, 2000); Punjab (Grover and Pandhol, 1975); Uttarakhand (Verma and Asthana, 2005); Uttar Pradesh (Singh and Chaturvedi, 1970; Pal, 1975; Prasad and Mahrotra, 1980, Shukla, *et al.,* 1990; Verma and Chaturvedi, 2009); West Bengal (Sinha and Mukherjee, 1975).

10. ***Gloeotrichia intermedia*** (Lemmermann) Geitler
[Desikachary 1959, p. 560, pl. 116, f. 8; Komárek 2013, p. 361, f. 424]
(Pl. I, Fig. 9; Pl. III, Fig. 35)

Length of the cell: 4-15 µ; Breadth of the cell: 5-8 µm; Diameter of heterocyst: 14-16 µm; Length of the akinete: 48-52 µm; Breadth of the akinete: 18-20 µm.

Collection No. & Ecological notes: MD- 126, 26. 10. 2012, Khutamai, Koch Bihar, aquatic, attached with aquatic plant (pH- 6, Temp. 29^0C).
Distribution in India: Jammu & Kashmir (Anand, 1979; Ara and Rather, 2005); Kerala (Anand and Shanthakumar Hopper, 1995); Maharashtra (Suryavanshi, *et al.,* 2010); Tamil Nadu (Anand and Subhramanian, 1994); Tripura (Singh, *et al.,* 1997b); Uttarakhand (Khan, 1970; Gupta, 2005); Uttar Pradesh (Kumar, 1970; Pal and Yadav, 1974; Pal, 1975; Shukla, *et al.,* 1990).
This is the first report of the taxon from West Bengal.

11. ***Gloeotrichia natans*** [Hedwig] Rabenhorst ex Bornet et Flahault
[Desikachary 1959, p. 561, pl. 118, f. 7, 15; Komárek 2013, p. 361, f. 426]
(Pl. I, Fig. 10; Pl. III, Fig. 36)

Length of the cell: 7- 24 µm; Breadth of the cell: 1-7 µm; Diameter of heterocyst: 7-12 µm; Length of the akinete: 28-30 µm; Breadth of the akinete: 12-14 µm.
Collection No. & Ecological notes: MD- 011, 30. 10. 2010, Dewanhat, Koch Bihar; semi-aquatic, found in rice field (pH- 6, Temp. 20^0C).
Distribution in India: Andra Pradesh (Kumaraswamy, *et al.,* 2013); Maharashtra (Kamat, 1975; Bhosale and Dhumal, 2012; Patil, 2015); Madhya Pradesh (Agarkar, 1967; Khare, 2014); Tamil Nadu (Desikachary, 1959; Rajagopal, *et al.,* 2010); Uttarakhand (Habib, 2001; Verma and Asthana, 2005); Uttar Pradesh (Pal and Yadav, 1974; Chaturvedi and Pandey, 1976; Verma and Chaturvedi, 2009); West Bengal (Sinha and Mukherjee, 1975; Sen, 2006; Halder and Sinha, 2013).

12. *Macrospermum iyengarii* var. ***unispora*** (Singh in Tiwari et Pandey 1976) Keshri et Das comb. nov.
[Desikachary 1959, p. 408, pl. 78, f. 5,7 as *A. iyengarii* Bharadwaja var. *unispora* Singh, R. N.]
(Pl. I, Fig. 11; Pl. III, Fig. 37)
Filament blue-green, arranged in a colony; Cells cylindrical and longer than broad; apical cell rounded; heterocyst solitary, intercalary and oval in shape; akinete large attached to heterocyst.
Length of the cell: 3 µm – 6 µm; Breadth of the cell: 2 µm – 3 µm; Length of the Heterocyst: 5 µm – 10 µm; Breadth of the Heterocyst: 5 µm – 8 µm; Length of the Akinete: 12 µm – 16 µm; Breadth of the Akinete: 10 µm – 14 µm.
Collection No. & Ecological notes: MD-119, 26. 10. 2012, Sutka Bari, Koch Bihar; aquatic, lodged on aquatic plants (pH- 5.5, Temp. 29^0C).
Comment: It is close in most respect to *Anabaena iyengarii* Bharadwaja var. *unispora* Singh R. N. but Komárek (2013) suggested placing it under *Macrospermum* Komárek which appears to be justified & therefore new combination has been proposed.
Distribution in India: Andaman & Nicobar Islands (Prasad and Srivastava, 1992); Bihar (Singh, 1939); Karnataka (Tiwari, 1972; Tiwari and Pandey, 1976); Maharashtra (Barhate and Tarar, 1983); Uttar Pradesh (Pal, 1975; Misra and Srivastava, 2005); West Bengal (Mukhopadhyay and Chatterjee, 1981; Mazumdar and Chandra, 1987) all as *A. iyengarii* Bharadwaja var. *unispora* Singh R. N.

13. ***Macrospermum volzii*** (Lemmermann) Komárek
[Desikachary 1959, p. 403, pl. 77, f. 1 as *Anabaena volzii* Lemmermann 1904; Komárek 2013, p. 871, f. 112, 117, 118]
(Pl. I, Fig. 12; Pl. III, Fig. 38)

Length of the cell: 4.5 µm – 6 µm; Breadth of the cell: 2.5 µm – 4 µm; Length of the heterocyst: 8 µm – 10 µm; Breadth of the heterocyst: 6 µm – 8 µm; Length of the akinete: 30 µm – 32 µm; Breadth of the akinete: 14 µm – 16 µm.
Comment: Heterocysts observed in our specimen are narrower.
Collection No. & Ecological notes: MD- 053, 19. 10. 11, Panisala, Koch Bihar; aquatic, lodged on aquatic plants (pH- 5.5, Temp. 30^0C).
Distribution in India: Andaman and Nicobar Islands (Prasad and Srivastava, 1992); Bihar (Singh, 1961; Laloraya and Mitra, 1973; Jha, *et al.,* 1986; Verma, *et al.,* 1990); Gujarat (Kamat, 1967); Karnataka (Tiwari, 1972; Laloraya and Mitra, 1973; Tiwari, 1975; Tiwari and Pandey, 1976; Bongale and Bharati, 1980; Bongale, 1981; Singh and Bongale, 1990), Kerala (Parukutty, 1940; Laloraya and Mitra, 1973; Shaji and Panikkar, 1994; Anand and Shanthakumar

Hopper, 1995; Madhusodanan and Diminic, 1995); Madhya Pradesh (Bendre and Agarkar, 1965; Agarkar, 1967); Maharshtra (Kamat, 1963, 1968); North India (Prasad and Mehrotra, 1979); Odisha (Laloraya and Mitra, 1973; Tiwari, 1975; Tiwari and Pandey, 1976); Tamil Nadu (Srinivasan, 1979; Ramakrishnan and Kannan, 1992; Anand and Subramanian, 1994; Selvi and Sivakumar, 2012); Uttar Pradesh (Gupta, 1957, 1966; Singh, 1961; Kusumlata, 1965; Pandey, 1965; Verma, 1965; Pal and Yadav, 1974; Prasad and Mehrotra, 1980; Mishra, *et al.,* 2001; Perumal and Anand, 2009; Verma and Chaturvedi, 2009); West Bengal (Kachroo, 1959; Sinha and Mukherjee, 1975, Santra, 1993) all as *Anabaena volzii* Lemmermann 1904
This is a more or less common taxon.
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14. ***Microchaete diplosiphon*** Gomont ex Bornet et Flahault
[Komárek 2013, p. 409, f. 490]
(Pl. I, Fig. 13; Pl. III, Fig. 39)
Filaments solitary, slightly narrowed towards the apices; sheath colourless with 2 layer, thin; trichomes narrowed towards the ends; cells are cylindrical, barrel-shaped; heterocyst basal and spherical in shape.
Breadth of filament: 10 – 13 µm; Length of the cell: 3 – 14 µm; Breadth of the cell: 6 – 8 µm and diameter of the heterocyst: 6 – 8 µm.
Collection No. & Ecological notes: MD- 016, 03. 02. 2011, Sagar Dighi, Koch Bihar, attached on submerged stones (pH- 6, Temp. 16^0C).
Distribution in India: This is probably the first report of the taxon from India.

15. ***Microchaete geoppertiana*** (Kirchner) Kirchner
[Komárek 2013, p. 403, f. 481]
(Pl. I, Fig. 14; Pl. IV, Fig. 40)
Few filaments are together to form a small group, sometimes solitary, filament slightly curved, blue-green in colour; sheath thin and colourless; trichomes not attenuated at the ends; cell wall not constricted and cell cylindrical in shape; heterocyst terminal in position and oval to spherical in shape.
Length of the cell: 7 – 16 µm, Breadth: 6 – 8 µm; Breadth of filament: 10 – 12 µm; Diameter of Heterocyst: 10 – 12 µm.
Collection No. & Ecological notes: MD- 215, 06. 05. 2013, Natabari, Koch Bihar; aquatic, lodged on aquatic plants (pH- 6, Temp. 32^0C).
Distribution in India: This is the first report of the taxon from India.

16. ***Microchaete tenera*** Thuret ex Bornet et Flahault
[Desikachary 1959, p. 513, pl. 105, f. 1, 2; Komárek 2013, p. 405, f. 482]
(Pl. I, Fig. 15; Pl. IV, Fig. 41)

Breadth of filaments: 11 – 13 µm; Length of cells: 6 – 11 µm; Breadth of cells: 9 – 11 µm; Diameter of terminal Heterocyst: 10 – 13 µm.
Collection No. & Ecological notes: MD- 313, 09. 02. 2014, Vatkuar par, Koch Bihar; aquatic, lodged on aquatic plants (pH- 6, Temp. 18^0C).
Distribution in India: Karnataka (Bongale and Bharati, 1980), Kerala (Anand and Shantakumar Hopper, 1995); Madhya Pradesh (Jain, 2015); Manipur (Oinam, *et al.,* 2011); Tamil Nadu (Desikachary, 1959; Anand, 1989), Uttar Pradesh (Rao, 1937; Bendre and Kumar, 1975; Prasad and Mehrotra, 1980; Verma and Chaturvedi, 2009), West Bengal (Mukhopadhyay and Chatterjee, 1981).

17. ***Nodularia spumigena*** Mertens ex Bornet et Flahault
[Desikachary 1959, p. 423, pl. 80, f. 13, 14; Komárek 2013, p. 907, f. 1177 – 1181]
(Pl. II, Fig. 25; Pl. IV, Fig. 42)

Length of the cell: 3.5 µm – 4 µm; Breadth of the cell: 10 µm – 12 µm; Breadth of the sheath: 18 µm – 20 µm; Length of the heterocyst: 10 µm – 11 µm; Breadth of the heterocyst: 10 µm – 11.5 µm.
Collection No. & Ecological notes: MD- 058, 19. 10. 11, Panisala, Koch Bihar, aquatic, lodged on aquatic plants (pH- 5.5, Temp. 30^0C).

Distribution in India: Assam (Nandi and Rout, 2000); Bihar (Sinha and Srivastava, 1980); Himachal Pradesh (Dwivedi, *et al.,* 2008); Kerala (Vijayan and Roy, 2015); Maharashtra (Kamat, 1975; Suryavanshi, *et al.,* 2010; Bhosale and Dhumal, 2012); Madhya Pradesh (Mishra and Purohit, 1979); Punjab (Randhawa, 1936; Sharma, *et al.,* 1979); Tamil Nadu (Desikachary, 1959); Uttar Pradesh (Bharadwaja, 1935; Prasad and Mahrotra, 1979; Verma and Chaturvedi, 2009); Rajasthan (Vaidya and Patel, 1968); West Bengal (Sinha and Mukherjee, 1975).

PLATE-IV

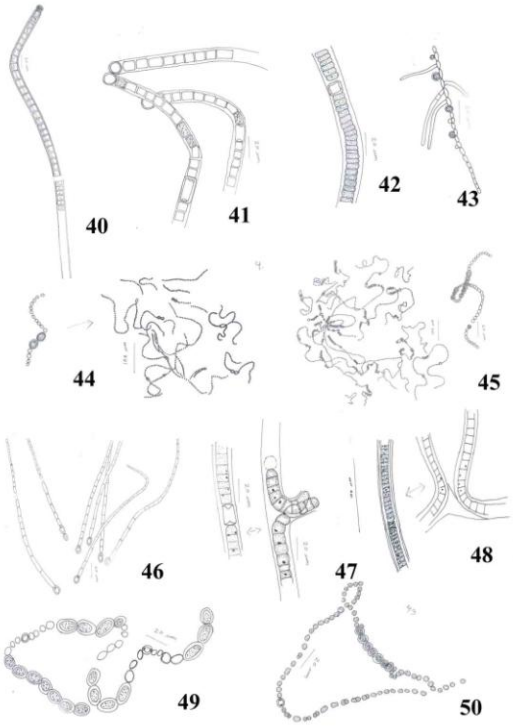

PLATE-IV

1. ***Microchaete geoppertiana*** (Kirchner) Kirchner
2. ***Microchaete tenera*** Thuret ex Bornet et Flahault
3. ***Nodularia spumigena*** Mertens ex Bornet et Flahault
4. ***Nostochopsis lobata*** Wood (1869) ex Bornet et Flahault
5. ***Nostoc calcicola*** Brébisson ex Bornet et Flahault
6. ***Nostoc linckia*** (Roth) Bornet et Flahault
7. ***Rivularia aquatica*** De – Wildeman
8. ***Scytonema javanicum*** Bornet ex Bornet & Flahault
9. ***Scytonema pascheri*** Bharadwaja
10. ***Trichormus fertilissimus*** (Rao) Komárek et Anagnostidis
11. ***Trichormus ellipsosporus*** (Fritsch) Komárek et Anagnostidis

18. ***Nostoc calcicola*** Brébisson ex Bornet et Flahault
[Desikachary 1959, p. 384, pl. 68, f. 1; Komárek 2013, p. 984, f. 1280]
(Pl. II, Fig. 16; Pl. IV, Fig. 44)

Length of the cell: 2 µm – 4 µm; Breadth of the cell: 2 µm – 3.5 µm; Length of the heterocyst: 3 µm – 4 µm; Breadth of the cell: 1 µm – 2 µm; Length of the akinete: 8 µm – 10 µm; Breadth of the akinete: 6.5 µm – 7.5 µm.
Collection No. & Ecological notes: MD- 126, 26. 10. 2012, Khutamai, Koch Bihar; aquatic, lodged on aquatic plant (pH- 6, Temp. 29^0C).
Distribution in India: Arunachal Pradesh (Singh, *et al.*, 1997a), Assam (Saikia and Bordoloi, 1994; Hazarika, *et al.,* 2001, 2003; Ahmed and Kalita, 2002); Bihar (Singh, 1961; Laloraya and Mitra, 1973; Jha, *et al.,* 1986; Verma, *et al.,* 1990); Jammu and Kashmir (Goyal, *et al.,* 1984; Kant and Gupta, 1998; Ara, *et al.,* 2002); Karnataka (Tiwari, 1972; Tiwari and Pandey, 1976; Bongale, 1981; Singh and Bongale, 1990); Kerala (Parukutty, 1940; Laloraya and Mitra, 1973; Anand and Shanthakumar Hopper, 1995; Madhusodanan and Dominic, 1995); Maharashtra (Gonzalves and

Gangla, 1949; Kotle and Goyal, 1985; Chaporkar and Gangawane, 1984); Manipur (Oinam, *et al.,* 2011); Mizoram (Singh, *et al.,* 1996), Nagaland (Singh, *et al.,* 1997), North India (Reddy, *et al.,* 1986), Odisha (Tirkey and Adhikary, 2005); Rajasthan (Pandey, *et al.,* 1998; Pandey, 2002); South India (Anand, 1989); Tamil Nadu (Anand, 1980; Anand and Revathi, 1987; Ramakrishnan and Kannan, 1992; Perumal and Anand, 2009; Selvi and Sivakumar, 2012); Uttarakhand (Khan, 1970; Gupta, 2005; Verma and Asthana, 2005); Uttar Pradesh (Kumar, 1970; Singh, 1961; Prasad and Mehrotra, 1980; Chadha and Pandey, 1983; Mishra, *et al.,* 2001); West Bengal (Mukhopadhyay and Chatterjee, 1981; Pal and Santra, 1982; Chatterjee and Chatterjee, 1983; Santra, 1993; Keshri and Adhikary, 2013).
This is a more or less common taxon.

19. ***Nostoc linckia*** (Roth) Bornet et Flahault
[Desikachary 1959, p. 377; Komárek 2013, p. 968, f. 1260]
(Pl. II, Fig. 17; Pl. IV, Fig. 45)

Length of the cell: 3 µm – 4 µm; Breadth of the cell: 5 µm – 6 µm; Diameter of the heterocyst: 3 µm – 4 µm; Diameter of the akinete: 8 µm – 10 µm.
Collection No. & Ecological notes: MD-130, 27. 10. 2012, Rajbari Park, Koch Bihar; aquatic, growing in a small pond (pH- 6, Temp. 28^0C).
Distribution in India: Arunachal Pradesh (Singh, *et al.,* 1997a), Assam (Hazarika, *et al.,* 2001), Bihar (Laloraya and Mitra, 1973), Jammu and Kashmir (Goyal, *et al.,* 1984), Karnataka (Tiwari, 1972; Tiwari and Pandey, 1976; Bongale and Bharati, 1980), Madhya Pradesh (Bendre and Agarkar, 1965; Agarkar, 1967), Maharashtra (Gonzalves and Gangla, 1949; Ashtekar and Kamat, 1980; Kotle and Goyal, 1985; Thakur and Behera, 2008), Mizoram (Singh, *et al.,* 1996), Odisha (Sahu, *et al.,* 1996), Punjab (Sharma, *et al.,* 1979), Rajasthan (Srivastava, 1999), South India (Anand, 1989), Tamil Nadu (Srinivasan, 1979; Perumal and Anand, 2009), Tripura (Singh, *et al.,* 1997b), Uttarakhand (Gupta, 2005; Verma and Asthana, 2005), Uttar Pradesh (Rao, 1937; Pandey, 1965; Pal and Yadav, 1974; Bendre and Kumar, 1975; Pal, 1975; Chaturvedi and Pandey, 1976; Prasad and Mehrotra, 1980; Mishra, *et al.,* 2001), West Bengal (Mukhopadhyay and Chatterjee, 1981; Maity and Santra, 1985; Santra, 1993; Mandal and Rath, 2013; Bhattacharya, *et al.,* 2014).
This is a more or less common taxon.

20. ***Nostochopsis lobata*** Wood ex Bornet et Flahault
[Desikachary 1967, p. 570, pl. 120, f. 1 – 8; Komárek 2013, p. 546, f. 667 – 670]
(Pl. II, Fig. 18; Pl. IV, Fig. 43)

Length of the cell: 3.91 µm – 7.82 µm; Breadth of the cell: 1.95 µm – 3.91 µm; Heterocyst: 7.82 µm.
Collection No. & Ecological notes: MD- 033, 20. 02. 2011, Baneswar, Koch Bihar; found in floating water of Gadadhar River (pH- 6, Temp. 24^0C).
Distribution in India: Karnataka (Desikachary, 1946); Madhya Pradesh (Agarkar, 1967); Maharashtra (Patil and Neelima, 2013); Manipur (Amita devi, *et al.,* 1999); Nagaland (Singh, *et al.,* 1997); Uttarakhand (Khan and Rawa,t 1972); Uttar Pradesh (Singh, 1939; Prasad and Mehrotra, 1979; Prasad and Mehrotra, 1980).
This is probably the first report of the taxon from Eastern India.

21. ***Rivularia aquatica*** De – Wildeman
[Desikachary 1959, p. 552; Komárek 2013, p. 308, f. 354]
(Pl. II, Fig. 19; Pl. IV, Fig. 46)

Length of the cell: 5.87µm – 15.64µm, Breadth of the cell: 1.96 µm – 7.82 µm; Length of Heterocyst: 12µm – 14 µm; Breadth of the heterocyst: 8µm – 10 µm.
Collection No. & Ecological notes: MD- 315, 09. 02. 2014, Pokhihaga bill, Koch Bihar; aquatic, lodged on aquatic plants (pH- 6, Temp. 34^0C).
Distribution in India: Assam (Dasgupta and Ahmed, 2013); Jammu and Kashmir (Kant and Gupta, 1998); Madhya Pradesh (Bendre and Agarkar, 1965; Agarkar, 1967; Khare, 2014); Tamil Nadu (Anand, 1989; Madhumathi and Vijayakumar, 2013); Uttarakhand (Khan, 1970; Gupta 2005); Uttar Pradesh (Singh and Chaturvedi, 1970; Pal and Yadav, 1974; Bendre and Kumar, 1975); West Bengal (Halder and Sinha, 2013a).

22. *Scytonema javanicum* Bornet ex Bornet & Flahault
[Komárek 2013, p. 76, f. 38]
(Pl. II, Fig. 20; Pl. IV, Fig. 47)

Breadth of the sheath: 8 µm; Length of the cell: 14-16 µm; Breadth of the cell: 10-12 µm; Length of the heterocyst: 18-20 µm; Breadth of the heterocyst: 8-10 µm.
Collection No. & Ecological notes: MD- 242, 06. 10. 2013, Salbagan forest, Koch Bihar, terrestrial, grow on tree trunk (Temp. 30^0C).
Distribution in India: Andaman & Nicobar Islands (Prasad and Srivastava, 1992); Jammu & Kashmir (Ara, *et al.,* 2002; Ara and Rather, 2005); Maharashtra (Hansgirg, 1892; Marathe, 1970); North India (Prasad and Mehrotra, 1979); Odisha (Sahu, 2000); Rajasthan (Gupta and Kumar, 1968); Tamil Nadu (Frémy, 1942; Desikachary, 1959); Uttarakhand (Verma and Asthana, 2005); Uttar Pradesh (Rao, 1937; Singh, 1959; Khan and Kumari, 1972; Bendre and Kumar, 1975; Pal, 1975; Prasad and Mahrotra, 1979, 80; Verma and Chaturvedi, 2009).
This is probabably the first report of the taxon from West Bengal.

23. ***Scytonema pascheri*** Bharadwaja
[Desikachary 1959, p. 463, pl. 89, f. 3; Komárek 2013, p. 132, f. 122]
(Pl. II, Fig. 21; Pl. IV, Fig. 48)

Sheath: 11 µm; Length of the cell: 7.5 µm – 15.15 µm; Breadth of the cell: 12 µm – 14 µm; Length of the heterocyst: 6µm - 8µm; Breadth of the heterocyst: 14 µm – 16 µm.
Collection No. & Ecological notes: MD- 005, 24. 10.2010, Balarampur road, Koch Bihar, terrestial, found in rice field (pH- 5.5, Temp. 22^0C).
Distribution in India: Delhi (Rao, 1940); Madhya Pradesh (Agarkar, 1967; Bendre and Agarker, 1965); Rajasthan (Srivastava and Nigam, 1980); and Tamil Nadu (Desikachary, 1959).
This is probably the first report of the taxon from West Bengal.

24. ***Trichormus ellipsosporus*** (Fritsch) Komárek et Anagnostidis
[Desikachary 1959, p. 411, pl. 72, f. 1 as *Anabaena variabilis* Kützing var. *ellipsospora* Fritsch 1949; Komárek 2013, p. 935, f. 1217]
(Pl. II, Fig. 22; Pl. IV, Fig. 49)

Length of the cell: 3 µm – 12 µm; Breadth of the cell: 3 µm – 8 µm; Diameter of the heterocyst: 6 µm – 8 µm; Length of the akinete: 18 µm – 20 µm; Breadth of the akinete: 10 µm – 12 µm.
Collection No. & Ecological notes: MD- 095, 01. 07. 2012, Dewanhat, Koch Bihar, found in small water body (pH- 5.5, Temp. 28^0C)
Distribution in India: Maharashtra (Patil, *et al.,* 2011).

25. ***Trichormus fertilissimus*** (Rao) Komárek et Anagnostidis
[Desikachary 1959, p. 398, pl. 74, f. 1 as *Anabaena fertilissima* Rao 1937, Komárek 2013, p. 940, f. 1225]
(Pl. II, Fig. 23; Pl. IV, Fig. 50)

Length of the cell: 3.5 µm – 8 µm; Breadth of the cell: 3.5 µm – 6 µm; Length of the heterocyst: 7 µm – 10 µm; Breadth of the cell: 8 µm – 10 µm; Length of the akinete: 5.5 µm – 10 µm; Breadth of the akinete: 7 µm – 10 µm.
Collection No. & Ecological notes: MD- 217, 06. 05. 2013, Natabari, Koch Bihar; aquatic, lodged on aquatic plants (pH- 6, Temp. 32^0C).
Distribution in India: Assam (Hazarika, *et al.,* 2001, 2003), Bihar (Jha, *et al.,* 1986), Jammu & Kashmir (Goyal, *et al.,* 1984; Kant and Gupta, 1998); Karnataka (Bongale and Bharati, 1980; Somashekar, 1983, 1984); Kerala (Shaji and Panikkar, 1994); Madhya Pradesh (Bendre and Agarkar, 1965; Agarkar, 1967), Maharashtra (Asthekar and Kamat, 1980, Chaporkar and Gangawane, 1984; Kotle and Goyal, 1985; Bhoge and Ragothman, 1986); North East India (Reddy, *et al.,* 1986); Odisha (Ranideep, *et al.,* 2013); Punjab (Sharma, *et al.,* 1979); Tamil Nadu (Anand, 1989; Perumal and Anand, 2009; Madumathi, *et al.,* 2012; Selvi and Sivakumar, 2012); Tripura (Singh, *et al.,* 1997b); Uttarakhand (Verma and Asthana, 2005); Uttar Pradesh (Singh and Chaturvedi, 1970; Prasad and Mehrotra, 1980; Chaturvedi and Habib, 1995; Mishra, *et al.,* 2001); West Bengal (Mukhopadhyay and Chatterjee, 1981; Chatterjee

and Chatterjee, 1983; Santra, 1993) all as *Anabaena fertilissima* Rao C.B. 1937, Sikkim [Das and Adhikary, 2014 as *Trichormus fertilissimus* (Rao) Komárek et Anagnostidis].
This is a fairly common taxon in India.

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