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New and rare records of filamentous green algae from Indian Sundarbans Biosphere Reserve

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Key words: Green algae, Indian Sundarbans, Morphotaxonomy,

Abstract

A total 36 taxa of filamentous green algae including chlorophytes and charophytes were recorded from different habitats of Indian Sundarbans, of which 31 taxa were newly reported from this World famous biosphere reserve. During regular exploration for 3 years, 7 species of *Spirogyra*, 5 species of each *Cladophora* and *Oedogonium*, 3 species of *Microspora*, 2 species of each *Chaetomorpha*, *Rhizoclonium*, *Ulothrix*, *Zygnema* and *Enteromorpha* and single species of each from *Ulva*, *Pithophora*, *Geminella*, *Temnogyra*, *Chara* and *Nitella* were recorded in fresh water to brackish water habitats of Indian Sundarbans. Two species of *Rhizoclonium* viz. *R. hookeri* and *R. fontanum* were found as epiphytic mat on mangrove tree trunk of *Avicennia alba* and *Bruguiera gymnorrhiza*. New and rare species were described compared to early records based on morphotaxonomy. Documentation of *Camera Lucida* drawing, light and scanning electron micrographs have also included in the present investigation.

Introduction

Sundarbans (21º31´ to 22º53´N and 88º37´ to 89 º 09´E) is the largest chunk of mangrove ecosystem of the world comprised of many islands and interconnected rivers lying along India and Bangladesh. The area is unique in terms of its vegetation, water quality and other bio-physical activities. The Indian land constantly inundated with saline water leading to its vegetation change including both flora and fauna (Sen and Naskar, 2003).

Green algae are one of the most important groups of plants which photosynthesize to produce starch. It has been reported that green algae also contain high amount of bioactive compounds viz., protein, lipid, pigments, antioxidants, essential amino acids and minerals (Satpati and Pal, 2011). It has been necessary to explore new and rare species of green algae from different habitats and to maintain in culture for future importance. Filamentous green algae were grown in large scale in different fresh and brackish water habitat of Indian Sundarbans which need to be surveyed and identified in detail for their biotechnological importance such as food, feed, medicine and bioenergy (Chatterjee *et al*., 2014; Satpati and Pal, 2015; Satpati *et al*., 2015; Satpati *et al*., 2015, 2016; Maurya *et al*., 2016). Here we tried to collect and identify some rare and new species from different parts of Indian Sundarbans for future research applications.

Green algal vegetations of Sundarbans have been reported by scientists of both the countries from time to time. An extensive exploration of Bangladesh Sundarbans has been done by Islam and his group and reported many new and rare species of green algae (Islam, 1972a, 1972b, 1973, 1974a). A variety of filamentous green algae viz. *Oedogonium*, *Mougeotia*, *Zygnema*, *Sirogonium*, *Spirogyra* and *Chloroclonium* were reported from Sundarbans area of Bangladesh (Islam, 1976, 1976a, 1977, 1979a, 1979b, 1984b). The detail survey of Indian land is still lacking and our previous and present investigations implicated the diversity and abundance of green algae in association to other algal groups.

The Indian part of Sundarbans is constantly molded and altered by tidal action, with erosion along estuaries and deposition silt from seawater (Sanyal and Bal, 1986). Prain (1903) described the algal flora of the mangrove forest of the Ganges-Brahmaputra delta. Some benthic forms of marine algae from Sundarbans were recorded by Santra and Pal (1988). The mangrove vegetation including algal flora and fauna of the Indian

Sundarbans has been made by few workers (Mandal and Naskar, 1994; Naskar and Santra, 1986; Naskar *et al*., 2000; Santra *et al*., 1991; Sen and Naskar, 2003).

In a recent survey of algal flora of Sundarbans, the present group was involved in documentation of cyanobacteria and algal flora of Sundarbans and already reported many of them from different habitat (Satpati *et al*., 2011, 2012, 2013; Barman *et al*., 2015). Our previous report demonstrated many species of green algae from diverse habitat of Indian Sundarbans (Satpati *et al*., 2013). A detail morphotaxonomic study of common seaweeds from Sundarbans was performed by present research group which include both red and green algae (Satpati *et al*., 2012). The detail morphological observations of *Spirogyra punctulata* was also done by the present group (Satpati and Pal, 2014). A new species of *Trentepohlia* viz., *T. sundarbanensis* from the tree trunk of *Avicennia alba* was reported by the same group (Satpati and Pal, 2015). In an initial study we investigated many species of algae from different groups but more extensive study is needed to discover many unidentified groups from diverse and unexplored area of Indian Sundarbans. The present study includes detail taxonomic descriptions of filamentous chlorophytes and charophytes from the part of the Sundarbans Biosphere Reserve and the new and rare records are listed.

Materials and methods

Survey and collection of algal samples

The aquatic and periphytic green algal forms from different habitats of Sundarbans like, bark, pneumatophores and other aerial root systems of mangrove plants, brick made shore line, concrete jetties, wooden and bamboo logs, fouling specimens from boats and launches were collected during both low and high tide conditions including man-made wetlands and riverine systems. The samples thus collected were thoroughly washed with running tap water or saline water and then with double distilled water to remove soil particles and other impurities. After washing the samples were preserved in 4% (v/v) formalin for taxonomic study.

Identification of algal samples

The slides were prepared with 20 % glycerine (v/v) and digital photographs were taken in Carl Zeiss Axioster plus Microscope by Cannon Power Shot 500D cameras. The *Camera Lucida* drawing was made and identification of taxa were done by standard monographs, like, Smith, 1950; Randhawa, 1959; Anand, 1981, 1998; Prescott, 1982; Carlos, 1999 and Krishnamurthy, 2000 and further confirmed by algae BASE (https://www.algaebase.org/search/species). The voucher specimens were made, number assigned and deposited in Calcutta University Herbarium (CUH/Al/MW).

Scanning electron microscopic (SEM) study

The morphology of selected filamentous algae were studied in detail by scanning electron microscopy. The SEM images were taken with the use of Carl Zeiss EVO 18 (EDS 8100) microscope with Zeiss Inca Penta FETX 3 (Oxford instruments) attachment. The sample materials were washed with phosphate buffer saline for 2-3 times and dried in room temperature with ethanol grade (30%-90%) for complete dehydration. After complete drying the samples were placed on carbon tape and put in Quorum (Q 150 TES) gold coater to coat the samples with gold. The photographs were taken at different magnification.

Results and discussion

The different algal species or the different groups prefer to grow in different degrees of salinity. The salinity range was from 0.6 to 25.5 ppt (Pers per thousand) in the study area, including fresh water to marine habitat. Among the filamentous chlorophytes, the most dominant species recorded were *Spirogyra* (7 species), followed by *Cladophora* (5 species), *Oedogonium* (5 species) and *Microspora* (3 species). Two species of each *Chaetomorpha*, *Rhizoclonium*, *Ulothrix*, *Zygnema* and *Enteromorpha* were reported from the study area. One species of each of *Ulva*, *Pithophora*, *Geminella*, *Temnogyra*, *Chara* and *Nitella* were recorded from the sampling sites. The identified algal taxa under different salinity level are given below in tabular format (Table 1). Most of the collected taxa were dominant in brackish water habitat except 7 species viz., *Rhizoclonium hookeri*, *Spirogyra plena*, *S. daedalea*, *S. brunnea*, *S. maravillosa*, *Chara braunii* and *Nitella mirabilis* of fresh or marine habitat.

Seasonal collections of algal samples were made from the distinct habitat of Indian Sundarbans mangrove forest areas and interconnected regions. The study period covered four dominant seasons of the year viz., summer (March-May), monsoon (June-September), post monsoon (October-November) and winter (December-February) (Table 2). The physico-chemical parameters varied annually from summer to winter, viz., pH ranges from 6.5-8.5. Both the air and water temperature (°C) varied from 17-23°C and 10-21°C respectively. All the species studied showed their dominance in winter and post monsoon and less dominance in summer and monsoon season respectively (Table 2).

Table 1. Details of sampling sites, voucher number, latitude- longitude, salinity and record status.

Name of taxa	Voucher number	Sampling site	Latitude and Longitude	Salinity (ppt)	Record status
Geminella minor	CUH/AL/MW-205	Sarberia	N 22º12.457', E 088º42.421'	8.7	New and rare record
Microspora willeana	CUH/AL/MW-209	Lothian island	N 21º42.343', E 088º18.893'	11.5	New record
M. floccosa	CUH/AL/MW-210	Sushni island	N 21º42.803', E 088º18.038'	22.1	New record
M. abbreviata	CUH/AL/MW-211	Suryamoni island	N 22º12.486', E 088º41.901'	12.5	New record
Oedogonium hindustanense	CUH/AL/MW-206	Rajbari, Malancha	N 22º12.459', E 088º42.425'	7.4	New record
O. mexicanum	CUH/AL/MW-186	Rajbari, Malancha	N 22º12.459', E 088º42.426'	6.9	New record
O. anomalum	CUH/AL/MW-187	Fraserganj	N 20º03.031', E 088º81.310'	11.6	New record
O. pringsheimii	CUH/AL/MW-212	Patibunia island	N 20º00.110', E 088º80.608	12.3	New and rare record
O. crispum	CUH/AL/MW-213	Fraserganj	N 20º03.031', E 088º81.311'	11.8	New and rare record
Ulothrix zonata	CUH/AL/MW-203	Namkhana	N 20º00.014', E 088º80.612'	8.4	New record
U. tenuissima	CUH/AL/MW-204	Namkhana	N 20º00.014', E 088º80.613'	7.9	New and rare record
Chaetomorpha ligustica	CUH/AL/MW-207	Dabu	N 22º05.588', E 088º39.614'	18.4	New and rare record
C. aerea	CUH/AL/MW-76	Hamanbere	N 22º12.449', E 088º41.882'	21.4	Naskar and Naskar, 2011
Rhizoclonium fontanum	CUH/AL/MW-121	Kala jungle	N 21º42.545', E 088º19.218'	11.5	New record
R. hookeri	CUH/AL/MW-158	Basanti	N 22º12.022', E 088º43.821'	0.9	Sen and Naskar, 2003
C. glomerata var. crassior	CUH/AL/MW-156	Lothian island	N 21º42.341', E 088º18.891'	8.7	New and rare record
C. prolifera	CUH/AL/MW-119	Hamanbere island	N 22º12.449', E 088º41.882'	12.5	New and rare record
C. rivularis	CUH/AL/MW-130	Patibunia island	N 20º00.110', E 088º80.608'	20.2	New record
C. aegagropila	CUH/AL/MW-157	Narayanitala	N 20º00.107', E 088º80.608'	19.6	New record

Continued Table 1

Name of taxa	Voucher number	Sampling site	Latitude and Longitude	Salinity (ppt)	Record status
C. fracta	CUH/AL/MW-66	Fraserganj	N 20º03.031', E 088º81.312'	13.2	New record
Pithophora roetlleri	CUH/AL/MW-188	Amarboni island	N 21º42.875', E 088º18.024'	15.2	New record
Ulva patengensis	CUH/AL/MW-154	Minakha	N 22º12.458', E 088º42.423'	11.2	Sen and Naskar, 2003
Enteromorpha gujratensis	CUH/AL/MW-155	Dabu	N 22º05.588', E 088º39.615'	19.4	New record
E. clathrata	CUH/AL/MW-125	Jharkhali	N 22º01.142', E	12.2	Naskar and

			088º41.166'		Naskar, 2011
Spirogyra maravillosa	CUH/AL/MW-127	Bhagabatpur	N 21º43.482', E 088º18.565'	2.2	New and rare record
S. brunnea	CUH/AL/MW-114	Bhagabatpur	N 21º43.482', E 088º18.563'	2.5	New record
S. daedalea	CUH/AL/MW-116b	Bhagabatpur	N 21º43.482', E 088º18.566'	3.1	New record
S. plena	CUH/AL/MW-147	Bhagabatpur	N 21º43.482', E 088º18.564'	3.4	New record
S. hyalina	CUH/AL/MW-148	Lothian island	N 21º42.345', E 088º18.894'	7.4	New record
S. setiformis	CUH/AL/MW-149	Lothian island	N 21º42.346', E 088º18.897'	6.9	Sen and Naskar, 2003
S. wabashensis	CUH/AL/MW-150	Henry island	N 20º03.031', E 088º81.308'	8.4	New and rare record
Temnogyra liana	CUH/AL/MW-132	Dobanki camp	N 21º42.346', E 088º18.894'	10.1	New and rare record
Zygnema collinsianum	CUH/AL/MW-152	Sudhanyakhali	N 21º42.346', E 088º18.897'	9.5	New and rare record
Z. oudhense	CUH/AL/MW-153	Sudhanyakhali	N 21º42.346', E 088º18.899'	11.5	New and rare record
Nitella mirabilis	CUH/AL/MW-219	Basanti	N 22º12.021', E 088º43.823'	0.9	New record
Chara braunii	CUH/AL/MW-217	Basanti	N 22º12.021', E 088º43.822'	1.1	New record

Table 2. Seasonal variation of algal taxa recorded (- absent, + present, ++ abundant, +++ dominant).

Name of taxa	**Summer (March-May)**	**Monsoon (June-September)**	**Post monsoon (October-November)**	**Winter (December-February)**
Geminella minor	-	++	+++	++
Microspora willeana	-	+	++	+++
M. floccosa	+	-	+	++
M. abbreviata	-	+	-	+++
Oedogonium hindustanense	+	-	++	+++
O. mexicanum	-	+	+	++
O. anomalum	-	+	++	+
O. pringsheimii	+	-	++	+++
O. crispum	+	+	++	++
Ulothrix zonata	+	-	++	+++
U. tenuissima	-	+	++	+
Chaetomorpha ligustica	-	+	++	-
C. aerea	+	+	++	++
Rhizoclonium fontanum	+	-	+	++
R. hookeri	-	+	-	+
C. glomerata var. crassior	+	-	++	+
C. prolifera	-	++	+++	+++
C. rivularis	-	+	++	+++
C. aegagropila	+	-	+	++
C. fracta	+	+	++	+
Pithophora roetlleri	+	-	+	++
Ulva patengensis	-	+	+	++
Enteromorpha gujratensis	-	+	++	++
E. clathrata	+	-	+	++
Spirogyra maravillosa	-	-	++	+++

S. brunnea	-	-	+++	++
S. daedalea	+	-	++	++
S. plena	-	+	++	+++
S. hyalina	-	++	+++	++
S. setiformis	-	-	++	++
S. wabashensis	+	-	+++	++
Temnogyra liana	+	-	++	+++
Zygnema collinsianum	-	-	++	+++
Z. oudhense	-	+	+	++
Nitella mirabilis	+	-	+	+
Chara braunii	-	+	+	++

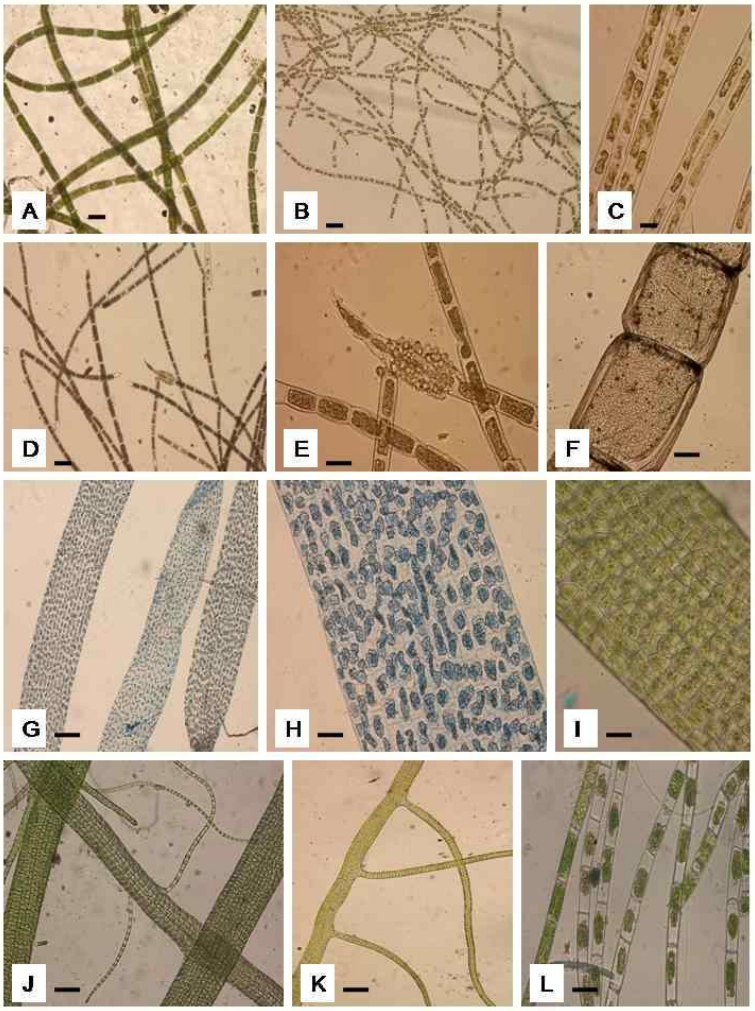

Fig. 1. Microphotographs of A. *Microspora floccosa*; B-C. *Rhizoclonium fontanum*; D-E. *R*. *hookeri*; F. *Chaetomorpha ligustica*; G-H. *Ulva patengensis*; I-J. *Enteromorpha clathrata*; K. *E*. *gujratensis*; L. *Microspora abbreviata*. Scale bar: A, C, L-10 µ; B, E, F, G-K- 50 µ; D- 100 µ.

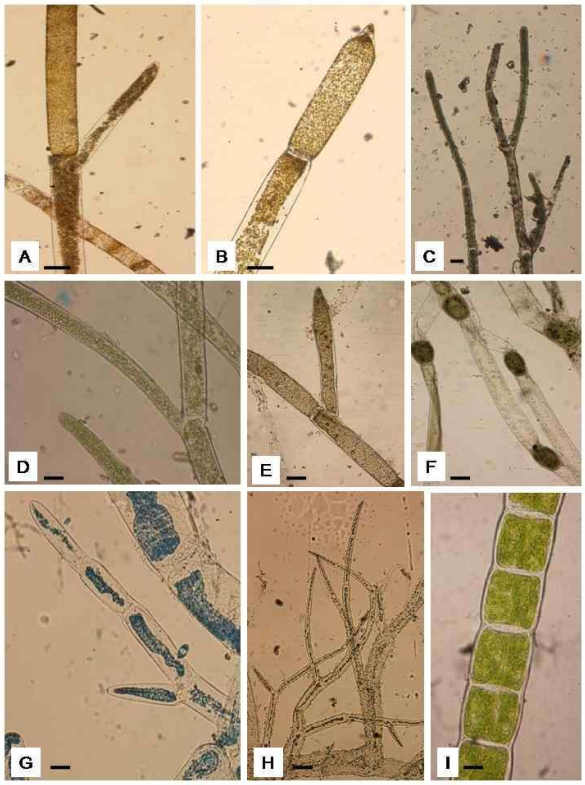

Fig. 2. Microphotographs of A-B. *Cladophora prolifera*; C-D. *C. rivularis*; E. *C. glomerata* var. *crassior*; F. *Pithophora roettleri*; G. *Cladophora aegagropila*; H. *C. fracta*; I. *Chaetomorpha aerea*. Scale bar: A-B, D- 100 µ; C, E-I- 50 µ

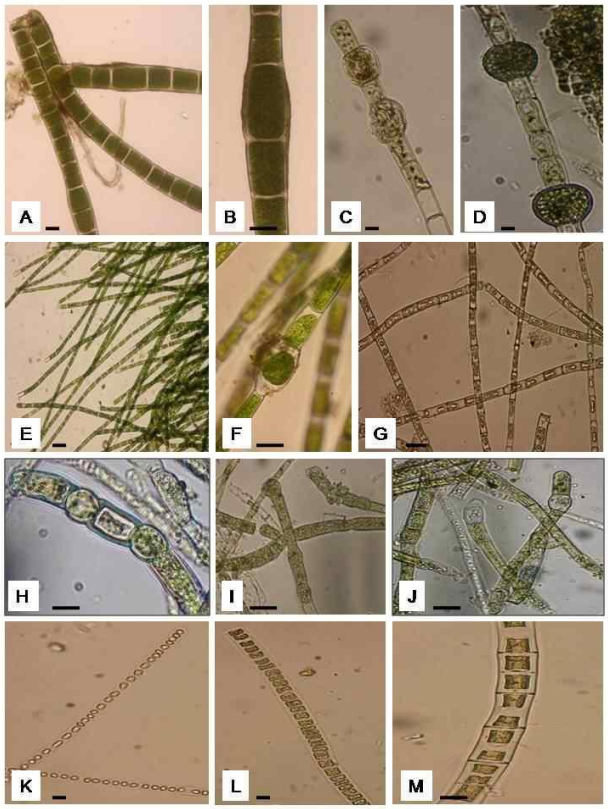

Fig. 3. Microphotographs of A-B. *Microspora willeana*; C. *Oedogonium crispum*; D. *O. pringsheimii*; E-F. *O. anomalum*; G-I. *O. mexicanum*; J. *O. hindustanense*; K. *Geminella minor*; L. *Ulothrix zonata*; M. *U. tenuissima*. Scale bar: A-B, C, K- 10 µ; D, L-M- 20 µ; E-G, J- 50 µ; H-I- 30 µ.

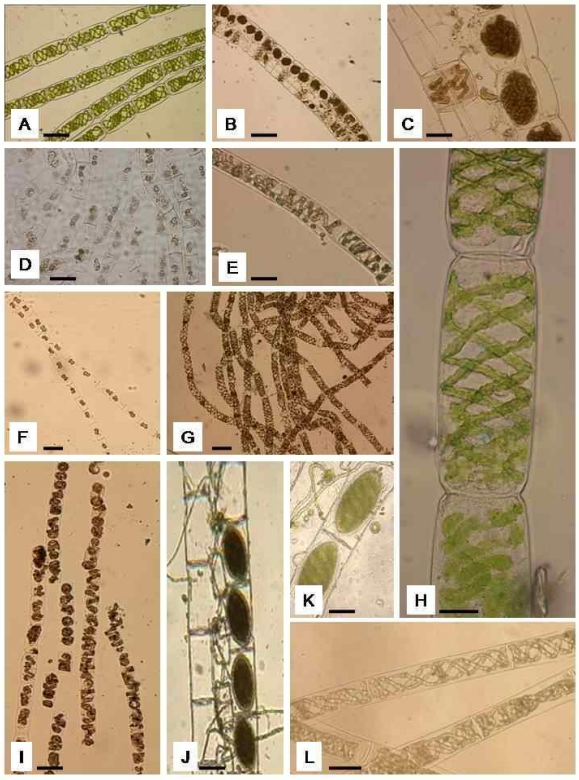

Fig. 4. Microphotographs of A. *Spirogyra maravillosa*; B-C. *S. brunnea*; D. *Zygnema collinsianum*; E. *Spirogyra daedalea*; F. *Zygnema oudhense*; G. *Spirogyra plena*; H. *S. hyalina*; I. *Temnogyra liana*; J-K. *Spirogyra setiformis*; L. *S. wabashensis*. Scale bar: A, C-D, G, K, L- 50 µ; B, J- 100 µ; E- 40 µ; F- 60 µ; H-I- 20 µ.

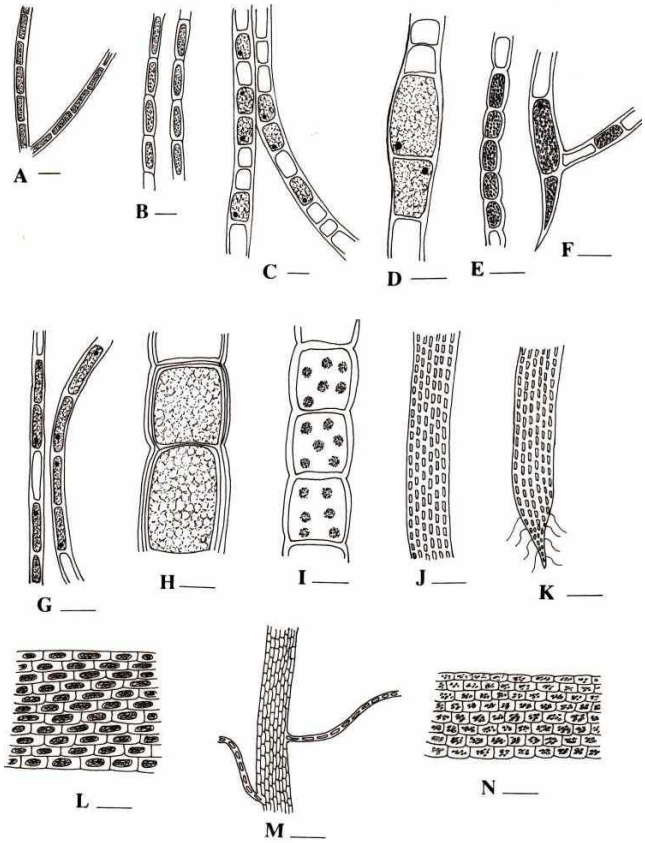

Fig. 5. Line drawings of A. *Microspora floccosa*; B. *Microspora abbreviata*; C-D. *Microspora willeana*; E-F. *Rhizoclonium hookeri*; G. *R. fontanum*; H. *Chaetomorpha ligustica*; I. *C. aerea*; J-L. *Ulva patengensis*; M-N. *Enteromorpha clathrata*. Scale bar: A-D, I-10 µ; E-F- 100 µ; G-N- 50 µ.

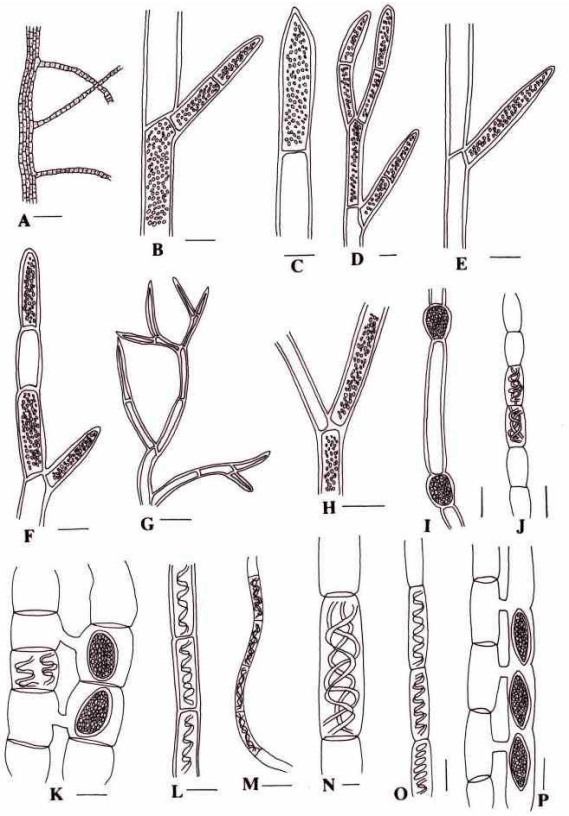

Fig. 6. Line drawings of A. *Enteromorpha gujratensis*; B-C. *Cladophora prolifera*; D. *C. rivularis*; E. *C. glomerata var. crassior*; F. *C. aegagropila*; G. *Cladophora fracta*; H-I. *Pithophora roetlleri*; J. *Spirogyra maravillosa*; K. *S. brunnea*; L. *S. daedalea*; M. *S. plena*; N. *S. hyalina*; O. *Temnogyra liana*; P. *S. setiformis*. Scale bar: A, D-K, M-50 µ; B-C, P- 100 µ; L- 40 µ; N-O- 20 µ.

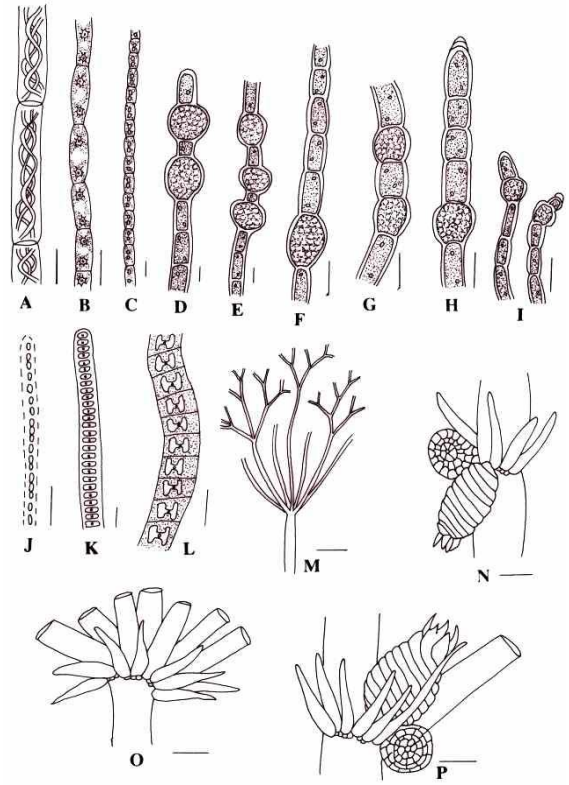

Fig. 7. Line drawings of A. *Spirogyra wabashensis*; B. *Zygnema collinsianum*; C. *Z. oudhense*; D. *Oedogonium crispum*; E. *O. pringsheimii*; F. *O. anomalum*; G-H. *O. mexicanum*; I. *O. hindustanense*; J. *Geminella minor*; K. *Ulothrix zonata*; L. *U.*

tenuissima; M-N. *Nitella mirabilis*; O-P. *Chara braunii*. Scale bar: A-B, F-I- 50 µ; C- 60 µ; D, J- 10 µ; E, K-L- 20 µ; M, O- 1 cm; N, P- 200 µ.

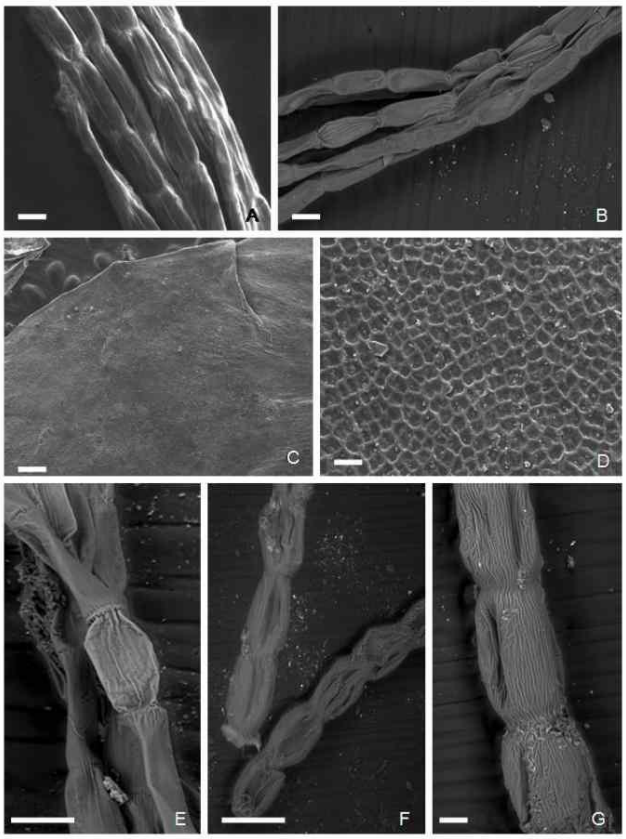

Fig. 8. Scanning electron micrographs of some selected filamentous chlorophytes. A. *Rhizoclonium fontanum* (×1.00KX); B. *R. hookeri* (×500X); C. *Ulva patengensis* (×100X); D. Cellular details of *U. patengensis* (×1.00KX); E. *Pithophora roettleri* (×1.00KX); F. *Chaetomorpha aerea* (×250X); G. *C. ligustica* (×500X). Scale bar: A, E- 30 µ; B, C, F- 100 µ; D- 10 µ; G- 50 µ.

Taxonomic enumeration

Systematic accounts of 36 taxa of green filamentous algae have been provided with microphotographs. Except *Enteromorpha clathrata, Chaetomorpha aerea, Ulva patengensis*, *Rhizoclonium hookeri* and *Spirogyra setiformis*, all other 31 taxa were recorded as new and rare species from Indian Sundarbans biosphere reserve. The taxonomic descriptions of the identified taxa are enumerated below:

Division: Chlorophyta

Class: Trebouxiophyceae

Order: Chlorellales

Family: Chlorellaceae

1. *Geminella minor* (Nägeli) Heering (Fig. 3K; Fig. 7J)

Basionym: *Homospora minor* Nägeli

[Prescott, 1982; John, 2002; Hu and Wei, 2006; Tsarenko, 2011]

Filament short, uniseriate; cells cylindrical embedded in a gelatinous sheath, 4-10 µ in diameter; chloroplasts ring like, covering the entire lateral walls.

Occurence- Aquatic; Voucher number- CUH/Al/MW-205

Order: Sphaeropleales

Family: Microsporaceae

2. *Microspora willeana* Lagerheim (Figs. 3A-B; Figs. 5C-D)

[Prescott, 1962, 1982; Hu and Wei, 2006; Tsarenko, 2011]

Plants green; filaments long; cell wall thin; cells cylindrical, 10-15 µ in diameter and 10-20 µ long; chloroplasts densely padded and perforated.

Occurence- Terrestrial, epiphytic; Voucher number- CUH/Al/MW-209

3. *M. floccosa* (Voucher) Thuret (Fig. 1A; Fig. 5A)

Basionym: *Prolifera floccosa* Vaucher

[Prescott, 1962, 1982; Hu and Wei, 2006; John, 2011; Tsarenko, 2011]
Cell wall thin; cells cylindrical, sometimes swollen, 12-20 µ in diameter and 25-37 µ long; chloroplast usually reticulate.
Occurence- Terrestrial, epiphytic; Voucher number- CUH/Al/MW-210

4. *M. abbreviata* (Rabenhorst) Lagerheim (Fig. 1L; Fig. 5B)
Basionym: *Conferva abbreviata* Rabenhorst
[Day *et al*., 1995; Hu and Wei, 2006; John, 2011; Tsarenko, 2011]
Plants green; filaments unbranched; cells 5-7 µ in diameter and 7-15 µ long, quadrate to cylindrical; chloroplasts perforated, net like.
Occurence- Terrestrial, epiphytic; Voucher number- CUH/Al/MW-211

Order: Oedogoniales
Family: Oedogoniaceae

5. *Oedogonium hindustanense* Kamat (Fig. 3J; Fig. 7I)
[Gonzalves, 1981; Mrozinska, 1985]
Plants green, macrandrous, dioecious; filaments long, sometimes curved; vegetative cells rectangular, 15-25 µ in diameter and 20-40 µ long; oogonium ovoid, 20-35 µ in diameter and as broad as long.
Occurence- Aquatic; Voucher number- CUH/Al/MW-206

6. *O. mexicanum* Wittrock ex. Hirn (Figs. 3G-I; Figs. 7G-H)
Synonym: *O. mexicanum* Wittrock
[Tiffany, 1930; Gonzalves, 1981; Prescott, 1982; Mikhailyuk, 2011]
Plants green, macrandrous, dioecious; filaments long; vegetative cells cylindrical, 34-40 µ in diameter and 60-100 µ long; oogonium 50-62 µ in diameter and 70-100 µ long, cylindrical to ovoid in shape.
Occurence- Aquatic; Voucher number- CUH/Al/MW-212

7. *O. anomalum* Hirn (Figs. 3E-F; Fig. 7F)
Synonym: *O. stagnale* var. *variabile* M. Lewin
[Tiffany, 1930; Prescott, 1962, 1982; Gonzalves, 1981; Mrozinska, 1985; Cambra Sánchez *et al*., 1998]
Plants green, macrandrous, dioecious; filaments long; vegetative cells cylindrical, stout, 35-45 µ in diameter and 85-120 µ long; oogonium solitary, ovoid to cylindrical in shape, 50-60 µ in diameter and 60-80 µ long.
Occurence- Aquatic; Voucher number- CUH/Al/MW-213

8. *O. pringsheimii* Cramer (Fig. 3D; Fig. 7E)
[Jao, 1979; Gonzalves, 1981; Prescott, 1982; Mrozinska, 1985; Day *et al*., 1995; Hu and Wei, 2006; Mikhailyuk, 2011; Keshri, 2012]
Plants green, macrandrous, dioecious; filaments long; vegetative cells cylindrical, 15-20 µ in diameter and 40-80 µ long; number of oogonium varies from 1-5, globose, 35-40 µ in diameter and 36-50 µ long.
Occurence- Aquatic; Voucher number- CUH/Al/MW-214

9. *O. crispum* Wittrock ex. Hirn (Fig. 3C; Fig. 7D)
Synonym: *O. hispanicum* M. Lewin
Basionym: *Vesiculifera crispa* Hassall
[Jao, 1979; Prescott, 1982; Mrozinska, 1985; Day *et al*., 1995; Hu and Wei, 2006; Mikhailyuk, 2011; Huxley and Pentecost, 2011]
Plant green, macrandrous, monoecious; filaments long; vegetative cells cylindrical, 10-15 µ in diameter and 40-70 µ long; oogonium solitary, globose, 40-50 µ in diameter and as long as broad.
Occurence- Aquatic; Voucher number- CUH/Al/MW-215

Class: Ulvophyceae
Order: Ulotrichales
Family: Ulotrichaceae

10. *Ulothrix zonata* (F. Weber & Mohr) Kützing (Fig. 3L; Fig. 7K)
Synonym: *U. crispa* (Berkeley) Kützing; *Sphaeroplea crispa* Berkeley
Basionym: *Conferva zonata* F. Weber & D. Mohr
[Prescott, 1962; Prescott, 1982; Day *et al*., 1995; Hu and Wei, 2006; Burova *et al*., 2011; John, 2011]
Filaments green, attached to the substratum, long, stout; cells cylindrical, sometimes slightly swollen with constrictions at the cross walls, cells 20-40 µ in diameter and 20-60 µ long; cell wall thick; chloroplasts form a complete circular band in the midregion of the cell.
Occurence- Aquatic; Voucher number- CUH/Al/MW-203

11. *U. tenuissima* Kützing (Fig. 3M; Fig. 7L)
Synonym: *U. tenuis* Kützing

[Prescott, 1962, 1982; Day *et al*., 1995; Hu and Wei, 2006; Zarina *et al*., 2007; Burova *et al*., 2011; John, 2011]
Filaments green, attached to the substratum, long, cells cylindrical, shorter than wide, 15-20 µ in diameter, thin walled and not constricted at the cross walls; chloroplasts band like.
Occurence- Aquatic; Voucher number- CUH/Al/MW-204

Order: Cladophorales

Family: Cladophoraceae

12. *Chaetomorpha ligustica* (Kützing) Kützing (Fig. 1F; Fig. 5H; Fig. 8G)
Synonym: *Conferva ulothrix* Lyngbye; *C. capillaris* (Kützing) Rabenhorst
Basionym: *Conferva ligustica* Kützing
[Silva *et al*., 1987; Krishnamurthy, 2000; Brodie *et al*., 2007; Selivanova and Zhigadlova, 2009; Burova *et al*., 2011; Sfriso, 2011; Almeida *et al*., 2012; Cormaci *et al*., 2014]
Plants grass green; filaments uniseriate; cell wall thick, multilayered; cells 250-300 µ in diameter and 350-450 µ long.
Occurence- Aquatic; Voucher number- CUH/Al/MW-207

13. *C. aerea* (Dillwyn) Kützing (Fig. 2I; Fig. 5I; Fig. 8F)
Basionym: *Conferva aerea* Dillwyn
[Wynne, 1986; Krishnamurthy, 2000; Brodie *et al*., 2007; Norris, 2010; Burova *et al*., 2011; Sfriso, 2011; Almeida *et al*., 2012; Ding and Luan, 2013]
Plants grass green to yellowish green, 5-10 cm in height; cells cylindrical, 400-620 µ in diameter and almost as long as broad, basal cell elongate, 200-240 µ in diameter and 5-10 times as long.
Occurence- Epiphytic on pneumatophores; Voucher number- CUH/Al/MW-76

14. *Rhizoclonium fontanum* Kützing (Figs. 1B-C; Fig. 5G; Fig. 8A)
[Prescott, 1962, 1982; Krishnamurthy, 2000; Hu and Wei, 2006; Zarina *et al*., 2007]
Filaments grass green, coarse, sometimes crooked or straight; cells cylindrical or plate like; rhizoidal branches are frequent, branches multicellular; cells 10-25 µ in diameter and 50-80 µ long.
Occurence- Terrestrial, epiphytic on mangrove roots; Voucher number- CUH/Al/MW-121

15. *R. hookeri* Kützing (Figs. 1D-E; Figs. 5E-F; Fig. 8B)
[Prescott, 1982; Krishnamurthy, 2000; Hu and Wei, 2006; Kim *et al*., 2010]
Filaments grass green, crisp, freely branching; cells cylindrical, sometimes inflated, 55-65 µ in diameter and 280-450 µ long; rhizoidal branches present.
Occurence- Aquatic; Voucher number- CUH/Al/MW-158

16. *Cladophora glomerata* var. *crassior* (C. A. Agradh) Hoek (Fig. 2E; Fig. 6E)
Synonym: *Cladophora crispata* (Roth) Kützing; *Conferva bullosa* Linnaeus
Basionym: *Conferva crispata* var. *crassior* C. Agardh
[Prescott, 1962; Hoek, 1963; Cambra Sánchez *et al*., 1998; Krishnamurthy, 2000; John, 2002; Hu and Wei, 2006]
Plants grass green, slender, 15-22 cm in height; filaments entangled, crisp, crowded in upper parts; terminal branches long; cells 35-90 µ in diameter and 5-7 times as long.
Occurence- Terrestrial on mangrove roots; Voucher number- CUH/Al/MW-156

17. *C. prolifera* (Roth) Kützing (Figs. 2A-B; Figs. 6B-C)
Synonym: *C. multifida* Brand; *C. scoparia* Kützing
Basionym: *Conferva prolifera* Roth
[Hoek, 1963; Burrows, 1991; Krishnamurthy, 2000; Hoek and Chihara, 2000; Leliaert and Coppejans, 2003; Brodie *et al*., 2007; Dawes and Mathieson, 2008; Ding and Luan, 2013; Cormaci *et al*., 2014]
Plants dark green, caespitose, up to 10-12 cm in height; filaments thick, dichotomously branched; cells 120-300 µ broad, cells in upper branches 4-6 times long and in lower branches 8-12 times long.
Occurence- Aquatic; Voucher number- CUH/Al/MW-119

18. *C. rivularis* (Linnaeus) Hoek (Figs. 2C-D; Fig. 6D)
Synonym: *C. insignis* (C. Agradh) Kützing; *Prolifera crispa* Vaucher; *Conferva insignis* C. Agardh
Basionym: *Conferva rivularis* Linnaeus
[Krishnamurthy, 2000; Pedroche *et al*., 2005; Burova *et al*., 2011]
Plants light green to yellowish green in colour, floating, composed of straight, coarse and sparsely branched filaments; branches arising at right angle to the main axis and very slightly smaller; cells cylindrical, club shaped, 35-70 µ in diameter and 100-250 µ long.
Occurence- Terrestrial on mangrove roots; Voucher number- CUH/Al/MW-130

19. *C. aegagropila* (Linnaeus) Trevisan (Fig. 2G; Fig. 6F)
Synonym: *Aegagropila linnaei* Kützing; *Cladophora holsatica* Kützing
Basionym: *Conferva aegagropila* Kützing

[Hoek, 1963; Krishnamurthy, 2000; John, 2002; Brodie *et al*., 2007; Sfriso, 2011]
Plants yellowish green, filaments entangled and irregular in arrangement, filaments with branches; cells irregularly inflated or sub-cylindrical, 25-55 µ in diameter and 32-240 µ long.
Occurence- Aquatic; Voucher number- CUH/Al/MW-157

20. *C. fracta* (O. F. Müller ex Vahl) Kützing (Fig. 2H; Fig. 6G)
Synonym: *Conferva flavescens* (Roth) Kützing; *Cladophora vitrea* Kützing
Basionym: *Conferva fracta* O. F. Müller ex Vahl
[Prescott, 1962, 1982; Hoek, 1963; Krishnamurthy, 2000; John, 2002; Hu and Wei, 2006; Burova *et al*., 2011; Sfriso, 2011; Cormaci *et al*., 2014]
Plants dark green, branching throughout; branching sparse, distant and making wide angles; filaments are many celled; cells 60-80 µ in diameter and 2-5 times as long; cells at the branches are 20-30 µ in diameter and 2-3 times as long.
Occurence- Terrestrial on mangrove roots; Voucher number- CUH/Al/MW-66

Family: Pithophoraceae

21. *Pithophora roettleri* (Roth) Wittrock (Fig. 2F; Figs. 6H-I; Fig. 8E)
Synonym: *P. varia* Wille; *Conferva oedogonia* Montagne
Basionym: *Ceramium roettleri* Roth
[Krishnamurthy, 2000; Boedeker *et al*., 2012]
Plants grass green, 10-12 cm in height; filaments with branches; cells cylindrical, narrowing at the apices, 70-95 µ in diameter and 4-5 times as long; akinetes both intercalary and terminal, variable in shape, ovate to cylindrical, 60-100 µ in diameter and 70-220 µ long.
Occurence- Aquatic; Voucher number- CUH/Al/MW-216

Order: Ulvales

Family: Ulvaceae

22. *Ulva patengensis* Salam and Khan (Figs. 1G-H; Fig. 5L; Fig. 8C-D)
[Silva, 1996; Krishnamurthy, 2000]
Plants green, up to 4.5 cm in height, broadly ovate in shape, rarely incised, base of the blade tapering and terminated to short stipe attached by holdfast; cells polygonal in cross section, 5-8 µ across; chloroplasts lining the cell wall.
Occurence- Aquatic; Voucher number- CUH/Al/MW-154

23. *Enteromorpha gujratensis* Kale (Fig. 1K; Fig. 6A)
[Krishnamurthy, 2000]
Plants yellowish-green, submerged, also slimy to touch; filaments cylindrical, sub-solid at base, irregularly branched, sometimes uniseriate; cells arranged in linear series and rectangular in shape, 10-35 µ long and 15-40 µ broad.
Occurence- Aquatic; Voucher number- CUH/Al/MW-155

24. *E. clathrata* (Roth) Greville (Figs. 1I-J; Figs. 5M-N)
Synonym: *Ulva clathrata* (Roth) Agardh
Basionym: *Conferva clathrata* Roth
[Smith, 1944; Burrows, 1991; Day *et al*., 1995; Zemke-White and Ohno, 1999; Krishnamurthy, 2000; Hayden *et al*., 2003; Ding and Luan, 2013]
Plants yellowish-green, free floating, profuse branching throughout, round; cells arranged in series, elongated, 27-40 µ long and 10-22 µ broad; chloroplasts lining the cell wall.
Occurence- Aquatic; Voucher number- CUH/Al/MW-125

Division: Charophyta

Class: Conjugatophyceae

Order: Zygnematales

Family: Zygnemataceae

25. *Spirogyra maravillosa* Transeau (Fig. 4A; Fig. 6J)
[Randhawa, 1959; Kadlubowska, 1984]
Filaments green; vegetative cells 20-30 µ in diameter and 100-250 µ long with plane end walls; chloroplasts 2-3, spirally arranged, making 2-5 turns in the cell.
Occurence- Aquatic; Voucher number- CUH/Al/MW-127

26. *S. brunnea* Czurda (Figs. 4B-C; Fig. 6K)
[Transeau, 1951; Randhawa, 1959; Kadlubowska, 1984; Lewis and Entwisle, 2007]
Filaments green, vegetative cells 50-70 µ in diameter and 120-260 µ long, with plane end walls; chloroplasts 3-5, spirally arranged, making 2-3 turns; zygospores ovoid, 55-60 µ in diameter and 70-85 µ long.

Occurence- Aquatic; Voucher number- CUH/Al/MW-114

27. *S. daedalea* Lagerheim (Fig. 4E; Fig. 6L)

[Randhawa, 1959; Prescott, 1982]

Filaments green, slimy to touch; vegetative cells 35-40 µ in diameter and 150-220 µ long, end walls plane; chloroplasts 1, making 4-5 turns; zygospores formed by scalariform conjugation, 25-30 µ in diameter and 36-45 µ long.

Occurence- Aquatic; Voucher number- CUH/Al/MW-116b

28. *S. plena* (West & G. S. West) Czurda (Fig. 4G; Fig. 6M)

Basionym: *S. decimina* var. *plena* West & G. S. West

[Transeau, 1951; Randhawa, 1959; Kadlubowska, 1984; Jao, 1988]

Filaments green; vegetative cells 35-45 µ broad and 55-85 µ long, end walls plane; 2-3 chloroplasts spirally coiled; zygospores ovoid, 40-44 µ broad and 60-75 µ long.

Occurence- Aquatic; Voucher number- CUH/Al/MW-147

29. *S. hyalina* Cleve (Fig. 4H; Fig. 6N)

[Transeau, 1951; Randhawa, 1959; Kadlubowska, 1984; Jao, 1988; Shahida *et al*., 2005; Petlovany, 2014]

Filaments green; vegetative cells 45-65 µ broad and 80-240 µ long, end walls plane; chloroplasts 2-4 making 1-3 turns; zygospores ellipsoid, 40-55 µ broad and 65-80 µ long.

Occurence- Aquatic; Voucher number- CUH/Al/MW-148

30. *S. setiformis* (Roth) Martens ex Meneghini (Figs. 4J-K; Fig. 6P)

Basionym: *Conferva setiformis* Roth

[Kützing, 1845; Transeau, 1951; Randhawa, 1959; Kadlubowska, 1984; Jao, 1988; Lewis and Entwisle, 2007; Johnson, 2011]

Filaments green; vegetative cells 90-120 µ broad and 120-140 µ long, end walls plane; chloroplasts 3-5 making 1-2 spiral turns; zygospores oval, 80-85 µ broad and 90-110 µ long.

Occurence- Aquatic; Voucher number- CUH/Al/MW-149

31. *S. wabashensis* Tiffany (Fig. 4L; Fig. 7A)

Synonym: *Temnogyra wabashensis* (Tiffany) Yamagishi

[Randhawa, 1959; Yamagishi, 1963; Kadlubowska, 1984]

Filaments green; vegetative cells 35-55 µ broad and 125-240 µ long, end walls plane; chloroplasts 2-4, making 1-4 turns; zygospores ellipsoid, 50-70 µ broad and 100-140 µ long.

Occurence- Aquatic; Voucher number- CUH/Al/MW-150

32. *Temnogyra liana* (Transeau) Yamagishi (Fig. 4I; Fig. 6O)

Synonym: *Spirogyra liana* Transeau

[Transeau, 1951; Randhawa, 1959; Kadlubowska, 1984; Jao, 1988; Drummond *et al*., 2005]

Filaments green; vegetative cells 10-15 µ broad and 70-140 µ long, end walls plane; chloroplast 1, making 2-5 turns; zygospores ellipsoid, 20-27 µ broad and 35-50 µ long.

Occurence- Aquatic; Voucher number- CUH/Al/MW-132

33. *Zygnema collinsianum* Transeau (Fig. 4D; Fig. 7B)

[Transeau, 1951; Randhawa, 1959; Kadlubowska, 1984]

Filaments green, vegetative cells 18-25 µ in diameter and 40-60 µ long; chloroplasts star shaped, two in each cell, rounded, each with a conspicuous pyrenoid.

Occurence- Aquatic; Voucher number- CUH/Al/MW-152

34. *Z. oudhense* Randhawa (Fig. 4F; Fig. 7C)

[Randhawa, 1959]

Filaments green; vegetative cells are 20-30 µ broad and 50-72 µ long; chloroplasts star shaped, two in each cell, stellate, each with a conspicuous pyrenoid.

Occurence- Aquatic; Voucher number- CUH/Al/MW-153

Class: Charophyceae

Order: Charales

Family: Characeae

35. *Chara braunii* Gmelin (Figs. 7O-P)

Synonym: *C. songarica* F. J. Ruprecht; *C. flexilis* G. B. Amici

[Prescott, 1982; Moore, 1986; Hussain and Khoja, 1999; Schubert and Blindow, 2004; Langangen, 2007; Kato *et al*., 2011; Urbaniak and Gabka, 2014]

Plants grass green, plant body well differentiated into nodes and internodes; single whorls of stipulodes are present at the node; internodes uncorticated; sex organs monoecious, borne at the same node; oogonium 0.6-1 mm long, subtended by bracts; antheridium small, 0.2- 0.3 mm in diameter.

Occurence- Aquatic; Voucher number- CUH/Al/MW-217

36. *Nitella mirabilis* O.Nordstedt ex J.Groves (Figs. 7M-N)

Synonym: *N. mirabilis* var. *libera* F. S. Han & H. L. Fu

[Wood, 1962; Wood and Imahori, 1965; Han and Li, 1994]

Plant body grass green, differentiated into nodes and internodes; sex organ bearing branches repeatedly forked and terminating at the same level; sex organ monoecious; antheridium terminal, small, 0.15-0.3 mm in diameter; oogonium borne laterally to the antheridia, globose, 0.3-0.4 mm in diameter.

Occurence- Aquatic; Voucher number- CUH/Al/MW-219

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