



Diversity of freshwater algae from Tamil Nadu

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ABSTRACT

Studies on the structure and reproduction of some freshwater micro and macroalgae from Tamil Nadu were carried out to reveal their phylogenetic interrelationship. The following twelve algae 1) *Chlamydomonas*, 2) *Chlorella*, 3) *Hydrodictyon*, 4) *Ulothrix*, 5) *Cladophora*, 6) *Chaetophora*, 7) *Spirogyra*, 8) *Zygnema*, 9) *Chara*, 10) *Nitella*, 11) *Batrachospermum* and 12) *Chroodactylon* coming under three classes of algae (Chlorophyceae, Charophyceae and Rhodophyceae) were observed. Among the taxa of Chlorophyceae, *Chlamydomonas* is motile form and *Chlorella* is non motile. *H. reticulatum* has coenobium (water-net), whereas *U. zonata*, *S. fluviatilis* and *Z. pectinata* were unbranched filamentous forms. Further, *C. glomerata* and *C. elegans* were having branched filamentous habit with heterotrichous plant body. The green algae showed diverse thallus with isogamy, anisogamy and oogamy type of reproduction. Further, specialization was observed in *Spirogyra* and *Zygnema* with conjugate type of sexual reproduction with amoeboid gametes. But, these two genera differ from the chloroplast pattern like band and stellate respectively. In Charophyceae, *Chara zeylanica* and *Nitella batrachosperma* showed oogamous type of reproduction with specialized sex organs (antheridium and oogonium) and in Rhodophyceae, *Chroodactylon* is unicells, pseudo filaments and cells are rectangular to ellipsoidal in shape. *Batrachospermum moniliforme* revealed much branched thallus with beaded appearance. Triphasic life cycle [(vegetative, gametophyte-haploid, sporophyte, carposporophyte (diploid or haploid) and tetrasporophyte (diploid))] was evident in this alga. The present investigation on some members of fresh water algae revealed biodiversity in structure, reproduction and taxonomy.

Introduction

Algae form a diverse assemblage of chlorophyllous organisms occurring in a wide variety of aquatic and terrestrial ecosystem. Blue green algae (Cyanophyceae) green algae (Chlorophyceae), diatoms (Bacillariophyceae) and euglenoid flagellates (Euglenophyceae) are the major components of freshwater habitats. They occur as planktonic, epiphytic, epizoic and endozoic form in the lotic and lentic types of water bodies. The varying nature of micro and macro habitats of indigenous freshwater system makes them the hot spot of diverse and rare algal communities. Algae, the primary producers are the large and morphologically diverse phototrophic group which occur in almost every habitat on earth. Tropical climatic conditions such as those prevailing in India provide favourable environment for the luxuriant growth of these organisms in the natural different ecosystems viz., freshwater bodies, oceans, saline backwaters, estuaries, effluents, polar regions and also hyper saline salt pans (Sudha *et al.*, 2007; Sivakumar and Senthilkumar, 2008; Shyamkumar *et al.*, 2013; Lewis-Oscar *et al.*, 2015).

In recent years, microalgae got wide popularity owing to their ability to meet various needs for human beings. Along

with their ecological significance, they offer a great potential tool as the organisms in the areas of biotechnology with regard to mariculture, food, feed, fuel, fertilizer, medicine and also for combating pollution (Thajuddin and Subramanian, 2005). In the present work, few freshwater macro phycophytes, from Chlorophycophyta and Rhodophycophyta were studied in detail. Biodiversity of freshwater macroalgae from Tamil Nadu is necessary to know the evolution of plant forms in water. Climax associations are approached in the algal communities of *Cladophora*, *Hydrurus* and *Lemanea* in swift waters of *Cladophora* and its associates on the rocky shores of lakes and sluggish streams and of sizable aquatic meadows of *Chara* in shallow parts them. To be sure, there are exchanges of gases, diffusion of mineral, salts and disintegration of plant parts which represent co-relationships between the plants and the water medium in which they grow, but the magnitude of such changes, except in very small pools and ponds is relatively too insignificant permanently to affect the entire body of water. Whatever, the habitat, algae are dependent upon such factors as light, oxygen, carbondioxide, proper temperatures, water and suitable mineral salts. Algal growth surface from the inadequacy of any of these factors, from the presence of chemical wastes and other deleterious. Substances, from

destruction by animals and parasite fungi, and by the mere limitations of space. The growth of aquatic algae is governed by the same factors as determine the development of lower plants, but the intensity of availability of such factors may be very different. Microalgal biodiversity assessment and isolation of the strains are the basic stepping stones in the path of exploring their immense biotechnological applications. In the present work twelve taxa of freshwater micro and macro algae biodiversity in structure, reproduction and taxonomic assignment of Tamil Nadu were studied.

Materials and methods

The algal specimens for the present study were

collected from 1. Veeranam lake, 2. Perumal lake and 3. Kolavoy lake lentic type of freshwater bodies located in Tamil Nadu (Fig. 1). The collected freshwater algal specimens were allowed to float in a tray containing freshwater and made herbarium specimens for future identification and observation. The fresh specimens were observed under dissection microscope and research microscope (x 1250) for morphology, anatomy and cell wall patterns. These algae were observed for morphological parameters like habit and type of thallus. Construction, branching patterns, cellular external arrangement and internal details of cell and cell wall structure were observed under compound research microscope. Then, camera lucida diagrams were drawn for record and analyses.

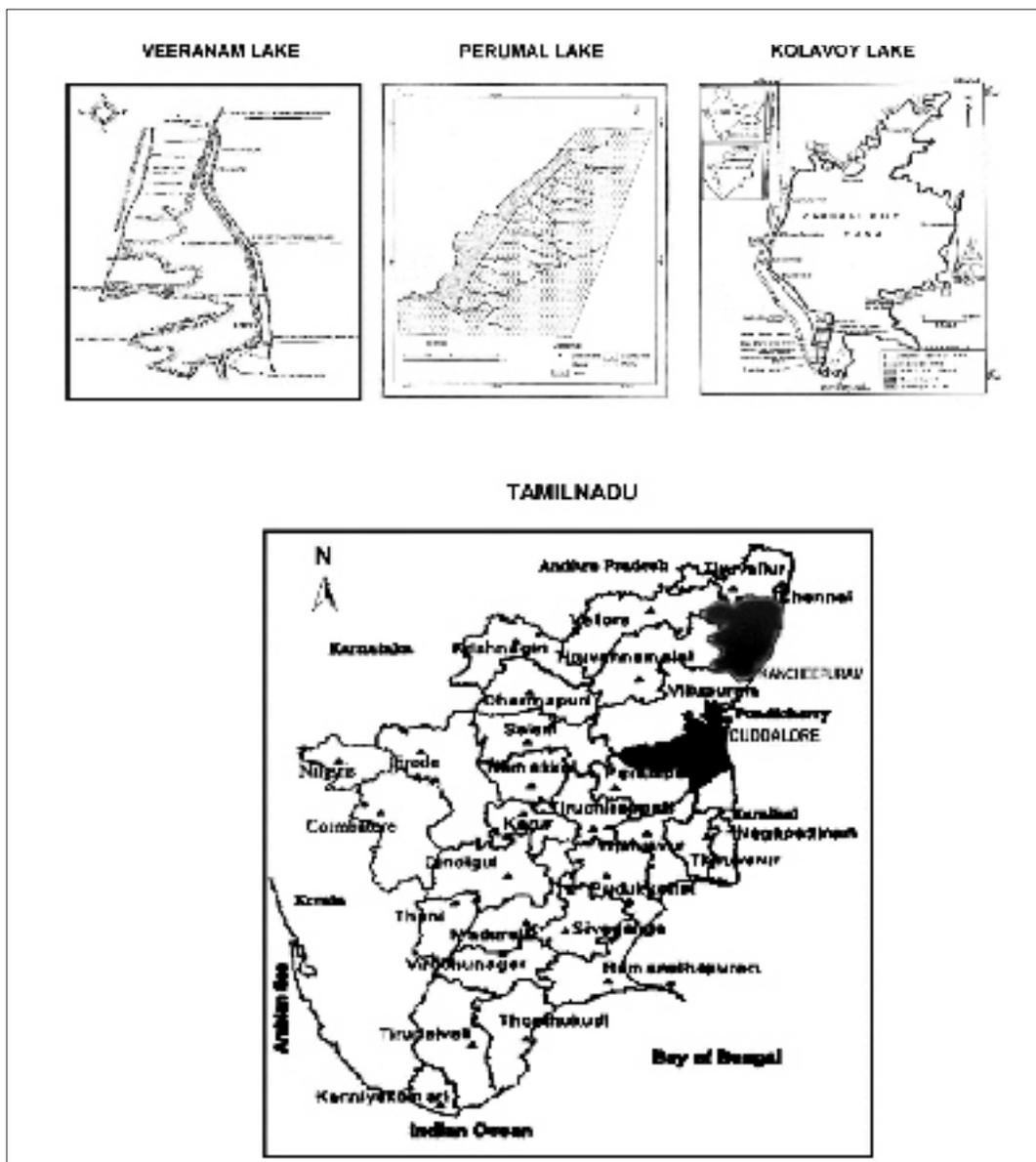


Fig. 1. Map showing the algae collection localities

The following algae were collected and identified by referring the publications of Fritsch (1965), John *et al.* (2003).
 1) *Chlamydomonas*, 2) *Chlorella*, 3) *Hydrodictyon reticulatum*;
 4) *Ulothrix zonata*; 5) *Cladophora glomerata*; 6) *Chaetophora*

elegans; 7) *Spirogyra fluviatilis*, 8) *Zygnema pectinatum*;
 9) *Chara zeylanica*; 10) *Nitella batrachosperma*,
 11) *Chroodactylon* and 12) *Batrachospermum moniliforme* (Plate-1).

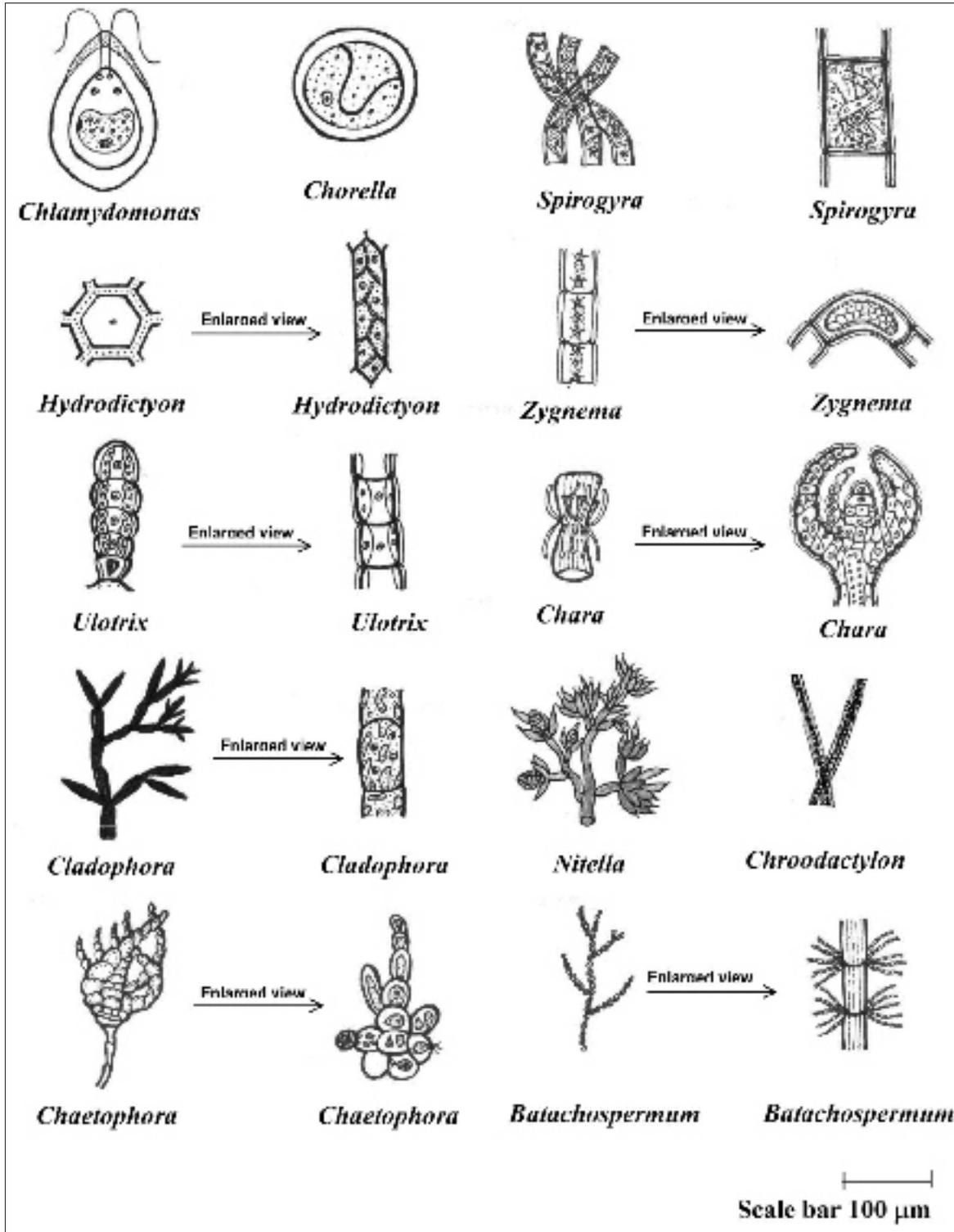


Plate-1. Algae collected from Veeranam, Perumal and Kolavoy lakes

Description of study areas

Veeranam lake

Location	: Lat. 11°17'N; Long. 79°32'E;
Shape of the lake	: Triangular (or) Elephant shape (South ↔ North)
Length of lake	: 15 km
Breadth of lake	: 5 km
Source of water	: Cauvery rivers, Sengal Odai, Karuvattu Odai and Rainwater
Water capacity	: 990 M.Cft
Water resource seasons	: Pre monsoon and Monsoon rain
Water usage	: rinking purpose Chennai metro water, Agriculture and Pisci culture
ollution	: Animal bathing, washes of utensils and anthropogenic activities

Perumal lake

Location	: Lat. 11°35'N; Long. 79°40'E;
Shape of the lake	: Rectangular
Length of lake	: 17 km
Breadth of lake	: 3 km
Source of water	: Canals, Rivulets, Rain water and Neyveli Lignite Corporation (NLC)
Water capacity	: 574 M.Cft
Water resource seasons	: Pre monsoon and Monsoon rain
Water usage	: Agriculture land and pisciculture
Pollution	: Animal bathing, washing of utensils water outlet drainage and anthropogenic activities

Kolavoy lake

Location	: Lat. 12°43'N; Long. 79°49'E;
Shape of the lake	: More or less triangular
Length of lake	: 8 km
Breadth of lake	: 3 km
Source of water	: Drainage from its free basin beside the surplus of 25 upper tanks and surplus into Palar river through Nenjal Maduvu
Water capacity	: 476.69 M.Cft
Water resource seasons	: Monsoon and Pre monsoon rain
Water usage	: Agriculture land and pisciculture
Pollution	: Animal bathing, washing, entry of municipal waste through pipeline Mahendra city water outlet drainage and anthropogenic activities

Observations

Chlamydomonas consists of a single biflagellated cell. It is a microscopic, unicellular organism and it exhibits a very primitive type of structure. They are ovoid, spherical, ellipsoidal or pyriform in shape. *Chlamydomonas* cells are provided with two anterior flagella, each flagellum arises from a basal granule the blepharoplast. The two flagella or cilia propel the organism by their lasting movements in water, pyrenoids store reserve starch in the form of layers around it, the stigma is oval or circular and it is sensitive to light.

Chlorella is a unicellular and non-motile organism, cells are spherical, ellipsoidal having cellulose cell wall. Chloroplast is partial cup-shaped with or without pyrenoids. The single nucleus is in the colourless central cytoplasm. *Chlorella* cells are rich in protein, carbohydrate and minerals. Multiplication takes place by autospores.

Hydrodictyon reticulatum is a common Indian species. Occurrence predominantly in slit freshwater ponds and in rice fields. The algae is in the form of hollow cylindrical mesh and closed at both ends. The colony consists of 500 to 5000 cells or more in number. All the cells are united, to form a network like structure (lattice). The interspaces of each network are made up of five or six cells and therefore, pentagonal or hexagonal in shapes. The mature coenobium may sometime be as long as 30 cm. The young cells are generally uninucleate with a parietal, band shaped chloroplast having a single pyrenoid. As the cells grow and enlarge they become coenocytic. Further, growth of a cell forms band-shaped chloroplast become reticulate and forms many pyrenoids. Mature cells, which may sometimes measures 3 mm in length, contain a large central vacuole which displaces the cytoplasm towards, the periphery of the cell. Reproduction is by means of asexual and sexual. Thousands of zoospores are produced with in a single cell. By progressive cleavage of the protoplast uninucleate, biflagellated zoospores are formed in the coenocytic cell. There is no increase in the number of cells. Sexual reproduction is by means of isogamous. The gametes are formed through the same process like that of zoospores. The gametes are uninucleate and biflagellate. Plasmogamy and karyogamy take place and the diploid zygote is formed. The zygote undergoes a period of rest. On coming to rest zoospores withdraw their flagella, increase in size and each metamorphous into a polyhedral stage. Then it becomes a adult plant.

Ulothrix zonata is a common freshwater species found in flowing water in autumn and spring. It occurs attached to stones forming bright, green masses. *Ulothrix* is an extremely common alga of filamentous or confervoid kind growing by preference in running streams or in water which is constantly renewed as in brooks and open water sources. It is multicellular, long filamentous unbranched and uniseriate alga. When young

the filaments are being green and remain attached to some substratum but later on they may become free floating. Three types of cells can be recognized. Apical cell, basal rhizoidal cell and middle cells. The cells are broader than long. The cells are surrounded by a thick or thin cylindrical, cell wall which may be either smooth or stratified. The cell has girdle shaped chloroplast and pyrenoids. Reproduction through vegetative, asexual and sexual methods. The zoospores are of different kinds.

Cladophora glomerata is widely distributed in freshwater. It is a common Indian freshwater algae attached to the shells of snails. The plant body is multicellular, filamentous, branched and appears like a small herbaceous plant. The branching is lateral. A branch arises as a lateral outgrowth of the parent cell near its upper end just below the septum. Due to evection the branch is pushed further up and the main axis is pushed on to one side thus giving the appearance of a dichotomy. Stratified or lamellated nature of the cell wall is clearly seen. Reproduction is effected by asexual (zoospores) and sexual (isogametes) methods.

Chaetophora elegans is a freshwater green alga, attached to water plants, stones, pebbles and shells, submerged in standing water, commonly at the edge of ponds, lakes, marshes and bogs. The vegetative body consists of a few celled prostrate system and a less branched erect system. The branching filaments are hardly visible with naked eyes. The prostrate part remains attached to some object in water and sometimes produces rhizoids from the older cells. The erect part develops from the prostrate part. Each cell of the filament contains a single plate-like, parietal chloroplast with usually 1 or 2 pyrenoids in it and a single nucleus. *Chaetophora* reproduces both asexually and sexually. Asexual reproduction by means of megazoospores. Sexual reproduction by means of isogametes.

Spirogyra fluviatilis and *Zygnema pectinatum* are unbranched filamentous freshwater algae. The plant body is filamentous, green, simple, unbranched, consisting of row of cylindrical cells. They are free floating. The cells are cylindrical in shape with protoplast differentiated into a plasma membrane, cytoplasm, nucleus, chloroplast with pyrenoids and a large central vacuole. The chloroplast in *Spirogyra* shows ribbon shaped, whereas it is stellate in *Zygnema*. Reproduction by means of amoeboid gametes (sexual) and fragmentation of older parts (vegetative).

Chara (Characeae) and *Nitella* (Nitelloideae) are contrasting freshwater algae occurring in running and shallow water in ponds and pools. The plants of *Chara* are of great ecological value. As they are covered with calcium carbonate deposits, they deposit lot of calcium in the bottom of lake, and after a considerable time the whole lake of ponds is filled up with calcareous deposits. The plant has well-developed rhizoids,

green vegetative shoot and reproductive structures. The rhizoids are uniseriately branched and obliquely septate. The central axis has nodes and internodes. The vegetative system has limited and unlimited growth of branches. The limited growth also known as leaves grow in whorls from the nodes of the axis. These leaves do not grow further after attaining a definite length. The cortical cells are present in *Chara*, whereas there are no cortical cells in *Nitella*. The *Nitella* is like *Chara*, has a joint central main axis with a whorl of branches arising from each joint (node). It is anchored to the soft substratum by multicellular branched colourless rhizoids. The plant thus has the appearance of miniature horsetails. In their equisetoid habit *Nitella* and *Chara* differ from all green algae. Reproduction is by oogamous type with antheridium and oogonium development. A special type of gamete formation and egg for fertilization results a diploid zygote. There is no alternation of generation and diploid to diploid plant is through sexual reproduction only.

Chroodactylon hansging is unicells, mucilaginous cells or *psuedo* filaments with 0-6 false branches cells rectangular to ellipsoidal, loosely arranged in a linear fashion within a broad mucilaginous matrix. Chloroplasts are blue coloured, axial and star shaped. Filaments 20-120 μm long, cells 5-10 μm wide 5-15 μm long.

Batrachospermum moniliforme, is an inland freshwater form widely distributed in tropical, subtropical and temperate regions. It often occurs in running streams and attached to stones. Adult plants of *Batrachospermum*, which may upto 15 cm long, are generally bluish green, olive-green soft and mucilaginous to touch. To the naked eye, each plant appears as a branching chain of beads. The algae is differentiated into a prostrate system that serves to anchor it to the substratum and an erect branched system made up of whorls which floats freely in water. The thallus is uniaxial. Its primary axis consists of a uniseriate row of large cylindrical cells, frequency terminating in a semispherical apical cell. The axial filament is differentiated into nodes and internodes and is corticated. From the nodes arise two kinds of branches, the branches of limited growth which are generally formed singly and monopodially and like the primary axis are further differentiated into nodes and internodes. The nodal branches of limited growth are composed of moniliform cells and arise from just below septa of the axial filament or from branches of unlimited growth whose cells are uninucleate and contain several parietal chromatophores, each with a single pyrenoid. Reproduction by means of typical triphasic life cycle. *Batrachospermum* reproduces sexually by the formation of spermatia and eggs, whereas asexually by carpospore. The spermatia are carried passively along water currents to the carpogonia. After fertilization reduction division occur in the zygote. From the germination haploid nuclei, successive division occurs and gonimoblast filaments arise from them. The

terminal cells of the gonimoblasts later differentiate into carposporangia within which the carpospores are formed singly. The cluster of gonimoblasts filaments along with associated carposporangia constitute the carposporophyte which grows as a parasite on the female gametophyte. The carpospore from the carposporangia are haploid. Cystocarp is formed from the assembles of all. Each carpospore on germination forms a branched, heterotrichous, protonema like *Batrachospermum* and was previously believed to be an independent algal genus *Chantransia*. Almost all freshwater species of *Chantransia* have been found to be the juvenile stage of *Batrachospermum*. The adult *Batrachospermum* plant arises from the *Chantransia* stage as a lateral outgrowth (Plates 1-12).

Discussion

The present investigation has revealed variabilities in the morphology, structure, reproduction and taxonomic position of the twelve algae studied. Among the green algae, *H. reticulatum* is a water-net with a larger coenobium. It has number of small meshes and all meshes form a large coenobium. Each cell become a polyhedral in shape with reticulate chloroplast. *Cladophora glomerata* and *Chaetophora elegans* are with less branched form and the cells are long with discoid chloroplast. *Spirogyra fluviatilis* and *Zygnema pectinatum* belonging to conjugates, have distinct chloroplast. *Spirogyra* is having ribbon shaped chloroplast whereas *Zygnema* possesses star-shaped chloroplast. The members of Chlorophyta have wide range of reproduction from asexual by zoospores and sexual by isogamy, anisogamy and oogamous types. In sexual reproduction, among Chlorophyta particularly conjugales, amoeboid non-motile gametes (+ and -) are characteristic features. The others are having isomorphic alternation of generation.

Chara zeylanica and *Nitella batrachosperma* belonging to Charales showed well developed root, shoot and sex organs thereby showing their advanced thallus organization among algae. They are having the efficiency of calcium carbonate fixation in the thallus and forms a sediment over the place where they are abundant growth. The reproduction in Charales is oogamous type with well developed oogonium and antheridium. This alga revealed some of the Bryophyte characters like protonemal formation and gemma formation during its life cycle. Thus, *Chara* stands first, in the evolution of higher plants. *Chroodactylon*, a freshwater red alga collected from Kolavoy lake is added the list of freshwater algal biodiversity of India with new record. Unicells, mucilaginous masses of cells or pseudo filaments, pit connection and pit plugs are absent. Pseudo filaments with 0-6 μm false branches, cell rectangular to ellipsoidal, loosely arranged in a linear fashion within a broad mucilaginous matrix, filaments 20-120 μm long; cells 5-10 μm wide, 5-15 μm -long. This species is

occasional in hard water with submerged vegetation, where it occur as an epiphytic and probably also free floating or large filamentous algae. Although it is widespread, so far it is not reported in Indian waters. *Batrachospermum moniliforme* is a red alga showing beaded nature of thallus. The thallus remains attached to some hard substratum by a prostrate shoot which sends off numerous primary thalli floating on water. The basal cells of the whorl of shoot filaments develop threads of cells which grow downward over the cells of the thallus forming a cortex. Both sexual and asexual method of reproduction occur. There are two distinct stages or forms in the life history of the plant, the mature form reproducing sexually and the juvenile form reproducing asexually. Thus, the formation of male, female and sporophyte (carpospore) of *Batrachospermum* shows triphasic life cycle. Thus, the study revealed the biodiversity of micro and macroalgae was evident.

Studies on the structure, distribution and reproduction of 12 fresh water micro and macro algae from Tamil Nadu were carried out during 2015-2016 to find out their relationship. They are *Chlamydomonas*, *Volvox*, *H. reticulatum*, *U. zonata*, *C. glomerata*, *C. elegans*, *S. fluviatilis*, *Z. pectinatum*, *C. zeylanica*, *N. batrachosperma*, *Chroodactylon* and *B. moniliforme* belonging to three Classes namely Chlorophyta, Charophyta and Rhodophyta. Among Chlorophyta, *Chlamydomonas* is motile form and *Chlorella* is non motile *H. reticulatum* shows coenobium plant body, whereas *U. zonata*, *S. fluviatilis* and *Z. pectinata* are having unbranched filaments. Further *C. glomerata* and *C. elegans* are having branched filaments with heterotrichous thallus. Thus, green algae showed diversity in thallus with isogamy, anisogamy and oogamous type of reproduction. Further, special feature was seen in *Spirogyra* and *Zygnema* with conjugation type of sexual reproduction. *Chara* and *Nitella* were studied for comparison between them. They showed oogamous type of reproduction with specialized sex organs. There is no alternation of generation. *Batrachospermum* showed angiospermic like plant body with triphasic life cycle and alternation of generation. The present study added in freshwater algal biodiversity of India with new record of *Chroodactylon* collected from Kolavoy lake. Thus, the present study among some members of fresh water micro and macroalgae revealed biodiversity with morphology, reproduction and taxonomic validation.

Acknowledgement

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