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Studies on Phenetic Diversity of Microalgae from Sediment Sample of Ramanadhi River, Tamil Nadu: Focus to Generic Level

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Abstract

The study of freshwater algae is really the study of organisms from many diverse habitats, some of which are not entirely "fresh." Aquatic ecologists also use the term "inland" waters to encompass a greater range of aquatic ecosystems. Even this term may be unsatisfactory, because algae occupy many other habitats, such as snow, soils, cave walls, and symbiotic associations. Organisms grouped together in this volume as freshwater algae fall into a large, but ecologically meaningful collection of environments: all habitats that are at least slightly wet, other than oceans and estuaries. One reason for such a broad scope is that inland saline lakes, snow and ice, damp soils, and wetlands are studied by phycologists and ecologists who also examine more traditional freshwater environments. Some genera with terrestrial species, such as *Vaucheria, Nostoc, Chlorella,* and *Prasiola,* also have species found principally in streams or lakes. There are no exclusively freshwater divisions of algae, but certain groups exhibit greater abundance and diversity within fresh waters, especially Cyanobacteria, Chlorophyta, and Charophyta. Within the green algae, conjugating greens and desmids (Zygnematales) comprise a very rich collection of species that almost exclusively occupy fresh water. Other groups, such as the diatoms and chrysophytes, are well represented in both spheres. Other groups, particularly the Phaeophyta, Pyrrophyta and Rhodophyta exhibit greater diversity in marine waters. The present study revealed as, Chlorophyta and cyanophyta were the dominant groups.

***Key words*:** Freshwater algae, Microhabitat, Sediment sample, Phenetic diversity, Microalgae

Microalgae are one of the most diverse groups of organisms, existing on the earth's crust for more than 3 billion years. The high adaptability potential of microalgae to withstand any adverse condition gives it an advantage to occupy almost all the types of ecosystems, providing us wide opportunities to screen them for different metabolites and bioactive compounds [1-2]. Advantage of using microalgae is its high biomass production ability per unit area of land compared to any traditional energy – plant sources [3]. However, these properties are not consistent among all the species of microalgae due to the influence of their surroundings and occurrence of evolution pressure. It has been estimated that more than 50,000 species of microalgae are present on earth, out of which 35,000 have been reported till date and only 15,000 are made in use [4-5] although algal culture collections are considered as a good source of microalgae studies but out of 50,000 species, expected to exist on earth, whereas only a few thousands are stored [6]. Thus, isolation, identification and characterization of microalgae from different habitats should be a continuous effort.

Microalgal classification and their taxonomic positioning have always been a challenging task for a long time, the identification of microalgae has been done based on their morphological and cytological features of vegetative stages during their life cycle [7]. The Present study aimed at identifying, characterizing and evaluating different freshwater microalgae from the Ramanadhi River in the region of India. In applied Phycology the term 'Microalgae' is generally used in its broadest sense to mean both prokaryotic cyanobacteria and eukaryotic microscopic algae [8]. Microalgae including Chlorophyceae, inhabit environments ranging from freshwater to extreme habitats such as snow, desert, sard and hot springs [9-11].

MATERIALS AND METHODS

Study area

Study area is presented in Ramanadhi is a river flowing in Tenkasi of the Indian state of Tamil Nadu. The river enters in Kadananadhi river in Kizha Ambur. Ramanadhi river and reservoir is located at the foot of the western ghats in Kadayam village of Ambasamudram Taluk in Tirunelveli District. This river is the main reason for the presence of many green fields in the Tenkasi District. It flows on many villages like Azwarkurichi, Ravanasamudram, Pottalpudur, Pillaukulam. The Ramanadhi has 7 anicuts, a reservoir of 4,300,000 cubic metres and irrigates 20.23 sq kilometers of wetlands. Length 23km. Limited for the total land required for an extent of 17.46.94 Hectare of dry land and 4.38.96 Hectare of waste lands with a total extent of 21.85.90 Hectare of land covering three

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villages namely Kadayam perumpathu-2, Avudayanoor villages in Tenkasi taluk and Vengedampatti village in Alangulam taluk of Tenkasi district for diversion of surplus water from Ramanadhi reservoir to Jambunadhi system of tanks and excavation of new canal from Padmanabaperi tank to Pungankulam and lower town tanks in Tenkasi and Alangulam taluks of Tenkasi district.

Sample collection

Samples were collected in aseptic polythene bottles in the field area which was added by FAA to preserve and neutralize the zooplankton activity. Wet mounts of fresh samples for microscopic analysis give the best results. If live material was not observed within 48 hours after collection, the samples were fixed in common fixative Lugol's solution (2g KI + 1g resublimed I + 300ml distilled water (DW) and stored in dark bottle at room temperature. Lugol's would stain starch dark blue-black, that could be utilized to separate chlorophyta from chrysophyta (which do not have true starch), because some species look morphologically similar to the green algae, 5 drops of Lugol's were added to give a pale straw colour to the sample and samples were stored in a cool dark place. Another sample fixative is 2-4% neutralized formalin.

Agricultural covering places

In Kadayam perumpathu- 2 village the total agricultural land area is 5.20.75 hectare. The total agricultural land area of Avudayanoor village is 5.96.84 Hectare. In Vengedampatti village the total agricultural land area is 6.29.35 Hectare. The cultivable plants such as Rice, Black gram, Siru kizhangu, Banana trees are harvested in this river.

Isolation and identification of microalgae

The microalgae strains were collected from different water bodies of Ramanadhi river in the region of India. The collected algae culture was grown in BG-11 liquid media, ½ Chev diatom media, Bold basal media and then transferred to agar plate containing antibiotics (Streptomycin and Tetracyclin) to avoid bacterial and fungal contamination. The colonies grew on the agar plates were then transferred to BG-11 agar plates with no antibiotics. Single algal colonies were picked from the agar plates using sterilized micro-tips and were then inoculated to 1ml BG-11 liquid media, ½ Chev diatom media, Bold basal media.

Morphological characterization

A light microscope was used to determine the primary morphological appearance of the isolates. For scanning microscopic (SEM) analysis, a drop of the algal sample was placed on a coverslip and air-dried.

Meaning of taxonomic key

A key is a device, when properly constructed and used, enables a user to identify an organism. Keys are devices consisting of a series of contrasting or contradictory statements to make comparisons and decisions based on statements in the key as related to the material to be identified. Thus, a taxonomic key is a device for quickly and easily identifying to which species unknown plants belong.

The present study - All the twelve species were present in the sediment samples of Ramanadhi river (Plate 1, Table 1). Morphometric characters of freshwater algae species for identified as follows in dichotomous Key.

1a. It forms a green turf on rock surfaces………………………………………………	It belongs to the class Trebouxiophyceae
1b. It forms a tuft like lateral branches…………………………………………………	1b
2a. Siphonous thallus without cross walls ………………………………………………	2a
2b. Filamentous thallus with true branching …………………………………………	2b
3a. Chloroplasts visible inside cells are golden brown ……………………………	It belongs to the class Bacillariophyceae
3b. Star shaped chloroplasts arranged along the axis of the cell ………………	It belongs to the class conjugatophyceae
4a. Uniseriate filaments, unbranched and intertwined ……………………………	4a
4b. Filament within a common sheath ……………………………………………………	It belongs to the order Nostocales
5a. Filament has a distinct sheath …………………………………………………………	It belongs to the order Oscillatoriales
5b. Filament has a gelatinous sheath ……………………………………………………	5b
6a. Cells ellipsoidal to spherical ………………………………………………………………	6a
6b. Uncial with a theca compost of cellulose plates…………………………………	It belongs to the order Gonyaulacales [12-16].

Fig 1 Dichotomous key for identifying the freshwater algae species

Table 1 Identify the species of freshwater microalgae

Name of organism	Group	Media used
Prasiola sp	Green algae	Bold Basal Media
Draparnaldia sp	Green algae	BG- 11 Media
Vaucheria sp	Yellow green algae	Bold Basal Media
Westielopsis sp	Blue green	Bold Basal Media
Tabellaria sp	Diatom	½ Chev diatom Media
Zygnema sp	Green	BG- 11 Media
Spirogyra sp	Green algae	BG- 11 Media
Scytonema sp	Blue green	Bold Basal Media
Lyngbya sp	Green algae	BG- 11 Media
Phormidium sp	Blue green	Bold Basal Media
Chloroccoccum sp	Green	Bold Basal Media
Ceratium sp	Dinoflagellates	½ Chev diatom Media

RESULTS AND DISCUSSION

The present study was amazing to see under a microscope magnification of 20x,40x, 100x and 200x to see enough detail to be able to identify many types of algae. There are twelve genera identified as follows (Plate 1).

1. *Prasiola* C. Agardh 1847

Class: Trebouxiophyceae
Order: Prasiolales
Family: Prasiolaceae
Genus: *Prasiola Agardh*

It is a dimorphic habitat of fresh and marine environment. Each individual plant is small but they usually grow side by side to form a green turf on rock surfaces.

Characteristic is apparently related to the stable substrata and the time for rhizoidal holdfast development; boulder substratum and hallow depth the genus *Prasiola* is characterized by a mono stromatic laminar thallus and vegetative cells with stellate or lobed chloroplasts containing a single pyrenoid. Reproduction is by nonmotile aplanospores produced in areas of thickening in membrane like forms. Sexual reproduction is by Oogamy: reproductive tissues (Haploid) developed in the upper part of membrane-like stage, some areas producing biflagellate male gametes and others nonmotile egg cells [17-23].

Plate 1 Identified types of algae

2. *Draparnaldia* Bory de saint – Vincent, 1808

Class: Chlorophyceae
Order: chaetophorales
Family: Chaetophoraceae
Genus: *Draparnaldia Bory de saint- Vincent.*

Filamentous fresh water green algae, a filament that has tuft like lateral branches with cells that are considerably smaller than those of the main axis and tapes to fine points. Laterals were alternate or opposite sometimes whorled, showing terminal short hairs and an often discernible central axis (rachis). *Draparnaldia* were attached to the substratum by a rhizoidal system consisting of undulating thick-walled colorless multicellular filaments, mostly growing downward from several main axis cells [24]. Secondary rhizoids had developed after about 2 weeks mostly originating from the lowest and slender primary and secondary rhizoids were mostly unbranched. Two types of asexual reproduction are presented. Zoospores are strictly aquatic reproductive stages and have a distinct upright system and prostrate system. Akinetes are Zoospores arrested in a parental filament.

3. *Vaucheria* Ap.de Candolle 1801

Class: Xanthophyceae
Order: Vaucheriales
Family: Vacheriaceae
Genus: *Vaucheria Ap.de Candolle*

Xanthophyte, yellow-green alga, a siphonous thallus without cross walls separating the nuclei and multiple chloroplasts, Plant body of *Vaucheria* is filamentous, much branched, coenocytic and siphonaceous thallus. The coenocytic body contains many nuclei septa may be form during injury or on development of sex organ but the filaments are normally septate the filamentous body has a thin outer wall. It is made up of outer pectic and inner cellulosic layers. In the center of the filament a continuous vacuole is present. Which is filled with cell sap the nucleus remain towards the vacuole and chromatophores towards the periphery. It contains the pigment like chlorophyll a, chlorophyll e, carotenoids and xanthophylls. Carotenoids are present in more amount than chlorophylls. The reserve food material is oil. *Vaucheria* reproduces by all three means: vegetative, asexual and sexual; asexually by the formation of various types of spores such as zoospores, aplanospores and akinetes; multiflagellate and multinucleate zoospores are known as synzoospores and akinetes multiflagellate and multinucleate zoospores are known as synzoospores or compound zoospors, thick walled, small multinucleate segments are called akinetes or hypnospores or cysts. The flagella are unequal discussion in length dissimilar (one whiplash and other tinsel) and laterally inserted.

4. *Ceratium* Schrank 1973

Class: Dinophyceae
Family: Ceratiaceae
Genus: Ceratium

Dinoflagellate, a unicell with a theca composed of cellulose plates with color extensions or horns and a transverse flagellum and trailing longitudinal flagellum. Cells spindle – Shaped, long, epitheca tapers into a long apical horn and hypotheca tapers into a long left antapical horn. Apical and antapical horns equal or subequal in length and slightly curved. A reduced right antapical horn may be present widest point adjacent to the cingulum [25]. Cells needle shaped, very long, epitheca tapers into a long apical horn and hypotheca tapers into a long left antapical horn. Apical and left antapical horn equal or subequal in length. Apical horn being slightly curved and left antapical horn notably curved [26]. Cell body covered with coarse reticulation in the form of ridges. Epitheca convex cell body well differentiated from the apical horn. Right antapical horn arises immediately behind the cingulum and bends laterally anteriorly left antapical horn bends around toward the dorsal side of the cell so that its distal part is directed ventrally right widest point adjacent to the antapical horns [27]. Cell body subtrapezoidal with convex epitheca posterior membrane supported with strong spines [28]. Body flattened; with one anterior and one to four posterior horn- like processes; often large; chromatophores yellow, brown, or greenish; color variation conspicuous; fission is said to take place at night and in the early morning; fresh or salt water. The cell is characteristic in form, having a single anterior and two or three posterior horns, and is compressed dorsoventrally. An apical pore opens at the end of the straight anterior horn. The wall consists of four pre singular and four apical plates in the epicone and of five post singular and two antapical plates in the hypocone. These plates are thick and reticulated. There is also a thin ventral plate articulated with the pre singular and post singular ones and connected with the girdle and sulcus. The nucleus is located centrally. The chromatophores are usually yellowish brown, numerous and discoidal [29]. *Ceratium* may reproduce sexually (two parent cells) or asexually (one parent cell). In asexual reproduction the pellicle pulls apart and exposes the naked cell. The cell then increases in size and divides, creating 4-8 daughter cells, each with two flagella.

5. *Tabellaria* Ehrenberg ex Kutzing 1844

Class: Bacillariophyceae
Order: Tabellarials
Family: Tabellariaceae
Genus: *Tabellaria Ehrenberg ex Kutzing*

It is a pennate diatom. Cuboid Shape a colony with rectangular cells seen in side (girdle) view attached at their edges by mucilage pads in a zigzag fashion. Chloroplasts visible pads in inside cells are golden brown, equal in width (Proximal width/apical width ratio around 1:1). Two or Four septa in girdle view, open septa bands and copulae and linear colonies with cells joined at an angle of around 1800 when observed in untreated material [30-31]. Small sharp spines can be observed on the valve face/mantle junction, areolae are almost always rimmed by donut- like structures [32]. It is known to be very variable in valve size and shape and the observations of the valves in the neotype population [33]. The longer specimens of the type material and that the shape variability increases as specimen length decreases as highlighted in [34]. In *Tabellaria* species include the proximal inflation generally twice as wide as the apical inflation thin "Shafts" between these inflations a broad range in both length / width ratio (2-10) and proximal width / apical width ratio (1.2-2.8) Closed copulae and Zigzag to star – shaped colonies [35].

6. *Zygnema* C. A. Agardh 1817

Class: Conjugatophyceae
Order: Zygnematales
Family: Zygnemataceae
Genus: *Zygnema Agardh*

Zygnema is a Conjugating green alga, unbranched filament without a gelatinous matrix free floating mass of filaments although young plants may be found anchored to streambeds with a holdfast star shaped chloroplasts arrayed along the axis of the cell. *Zygnema* generally will produce spore like akinetes for asexual reproduction or reproduce sexually via conjugation tubes filamentous conjugating green microalgae different for closely related unicellular desmids. It is a very common widespread and unbranched conjugate algae. Thallus is filamentous unbranched not very long bright green in vegetative condition. enveloped by a soft mucilaginous sheath. It may be attached to a substrate by means of rhizoid. Vegetative cells cylindrical, length is equal to or greater than width. Uninucleate with 2 characteristic axial stellate chloroplasts each containing a single large central pyrenoid. It has two cell layers of vegetative cells. Inner is cellulosic whereas outer one mucilaginous, thinner and end walls plane. Vegetative multiplication occurs by means of breaking of fragments. Asexual reproduction takes place by aplanospores and akinetes. Sexual reproduction occur by means of isogamy. Zygospore formed in one of the gametangia or conjugation canal. Zygospore spherical or compressed globose to ovate or ellipsoid thick walled and brown or blue; mature zygospore wall is usually three layered; outer and middle. layers generally ornamented. Most of the species of the genus are homothallic and life cycle is haplobiontic type [36].

7. *Spirogyra* Link in C. G. Nees 1820

Class: Zygnematophyceae
Order: Zygnematales
Family: Zygnemataceae
Genus: *Spirogyra Link in CG Nees*

The thallus is composed of uniseriate filaments, unbranched and intertwined calls are uni nucleated and cylindrical (40.0-04.0µm in length). Parietal chloroplasts are ribbon like coiled and spirally arranged in the cell membrane. Green unbranched filaments. It forms free-floating mats in shallow waters. The differences were mainly found in the number of pyrenoids and the arrangement of the chloroplast spirals, which were in condensed or scattered forms. The arrangement of chloroplast spirals and pyrenoids of patterns 1 and 5 were highly condensed and compacted, while patterns 2, 3 and 4 were relatively scattered [37]. Vegetative reproduction takes place in fragmentation. Sexual reproduction is isogamous.

8. *Scytonema* C. Agardh ex E. Bornet and C. Flahault 1886

Class: Cyanophyceae
Order: Nostocales
Family: Scytonemataceae
Genus: *Scytonema Agardh ex Bornet and Flahault*

Filamentous cyanobacterium, a filament within a common sheath that produces double false branches that result from breakage and further growth of each fragment. The trichomes of *Scytonema* consist of more or less cylindrical cells and are usually of uniform diameter throughout. Sometimes slight or marked constrictions appear at the transverse walls. The trichomes are surrounded by sheaths of extremely fine texture and may be hyaline or yellowish or brownish in colour. The sheath may be homogenous throughout stratified, stratifications are either parallel or oblique. The filaments show characteristic false branching. The trichome, during the process of multiplication, becomes fragmented, either due to disintegration of the intercalary cells or due to formation of separating disks or hetero cysts. These fragments are immobile and begin to grow within the original sheath. The branching results due to interruption of such newly formed trichomes at certain points. As a result, portions of one or both the trichomes perforate the firm sheath and grow out as laterals, which secrete a distinct sheath of their own. These false branches usually appear in parts and occupy approximately the middle portion between two hetero cysts. The hetero cysts are intercalary in origin, occur singly or in series of two or three. They are more or less of the same size as the vegetative cells.

Reproduction by means of hormogones is usually the only method of multiplication. Akinetes are rarely formed in this alga. Cylindrical filaments and cylindrical trichomes of the same width along the whole length up to the ends. Firm and slightly lamellated, but relatively thin colorless or yellowish sheath. Quadratic cells in old trichomes. Terminal cells are widely rounded at the ends and do not differ distinctly from other vegetative cells [38].Colorless firm sheaths usually indistinctly narrowed trichomes in the middle parts, mostly not constricted at cross walls and with tendency to fragmentation in shorter segments of trichomes in our populations characteristic terminal meristematic zones were observed terminal cells are widely rounded [39].Cylindrical filaments and trichomes not narrowed in the middle and not distinctly widened at the ends, often constricted at cross walls. The trichomes are composed only of relatively uniform short cells usually distinctly shorter than wide, rarely up to isodiametric in short segments, sheaths are firm thickened lamellate and often structured from outside when old frequently of yellow- brown color. The cluster is mostly by very variable and forms several slightly different types the taxonomic evaluation of which is not clear. The thickened, laminated yellow-brown and from outside usually regulate sheaths belong to the main character of this group cells are mostly isodiametric in old trichomes and short in terminal parts of branches [40]. Cluster is distinctly phenotypically different from the typical *Scytonema* and was classified as a separate subgenus or clearly narrated in the middle parts usually with distinctly long narrow and cylindrical cells, the cells are shortened and widened only in terminal parts up to shortly barrel shaped from sheaths are firm wide lamellate and often yellow brown [41-42].

9. *Phormidium* Kuetzing Ex Gomont 1893

Class: Cyanophyceae
Order: Nostocales
Family: Oscillatoriaceae
Genus: *Phormidium Kuetzing ex Gomont*

Filaments many forming a gelatinous sheath present, more or less firm, apices often attenuated, straight or bent, never regularly spirally coiled apical cells in many species with a calyptra. Single trichome filaments. *Phormidium* morphologically difficult to separate given the similarities in cell dimensions at cross – walls and presence of tapering and calyptra in mature trichomes. Trichomes were intensely motile gliding, rotating constricted slightly at cross walls tapered towards apices which possessed rounded to rounded- conical apical cells lacking calyptra. It is a filamentous cyanobacteria [43]. In *Phormidium* the sheath contains cellulose. *Phormidium* *c*ells divide via transfers fission. where each cell reaches the size of the parent before dividing again. The trichomes break down into harmogonia for reproduction.

10. *Chlorococcum* Meneghini 1843

Class: Chlorophyceae
Order: Chlamydomonadales
Family: Chlorococcaceae
Genus: *Chlorococcum Meneghini*

Vegetative cells solitary or in temporary groups of indefinite form never embedded in gelatin cells ellipsoidae to spherical. The reproduction is mainly asexual, by zoospores (or aplanospores in case of water stress) or sexual by isogametes. *Chlorococcum* genus is distinguished from other spherical, zoospore producing algae by three attributes [45]. A hollow, parietal chromatophore (chloroplast) with or without an open surface; One or more pyrenoids; Biflagellate zoospores which do not become spherical upon cessation or motility but retain an avoid, ellipsoid shape for some days. This genus is cosmopolitan. It has been isolated from hot springs in central Asian and also in soils of Antarctica. This microalga can be collected from aquatic and aerial environments and also from soil and rocky areas [44].

11. *Westiellopsis* Janet 1941

Class: Cyanophyceae
Order: Nostocales
Family: Hapalosiphonaceae
Genus: *Westiellopsis*

Thallus filamentous with true branching filaments of two kinds. Primary filaments slightly thicker and more or less creeping secondary filaments generally thinner and growing erect, filaments without a sheath and consisting of a single row of cells heterocyst intercalary, the dilated terminal portions of secondary branches of profuse transverse and longitudinal divisions forming chains of rounded cells. Thallus filamentous with true branching. Filaments of two kinds, primary filaments slightly thicker and more or less creeping, secondary filaments thinner and generally growing erect. Filaments without a sheath and consisting of one row of cells; with barrel shaped cells 8-12μ broad as long as or slightly longer, hetero cysts intercalary, oblong- cylindrical 5.5-6μ broad and 10.05-22μ long gonidia formed singly in each cell of pseudo hormocysts; the dilated terminal portions of the secondary branches by profuse transverse and longitudinal division, form clusters of rounded cells (pseudo hormocysts the contents of which escape as gonidia and develop into new alga [46].

12. *Lyngbya* Agardh Ex Gomont 1892

Class: Cyanophyceae
Order: Oscillatoriales
Family: Oscillatoriaceae
Genus: *Lyngbya Agardh ex Gomont*

Thallus is filamentous. Filaments are interwoven to form an expanded thallus mass. Each filament has a distinct sheath (thin to thick) trachoma thin, colorless, brown, blue to purple filaments sometimes spirally coiled. Cells are 2-3times wider than logger. Cells contain granular and vacuolated cytoplasm. Cells are filamentous and macroscopic up to several centimeters in diameter with layered or stratified and brownish colored sheaths. Filaments are unbranched or Pseudo branched cell division occurs crosswise perpendicular to the long axis of the trichome and reproduction is by hormogonium formation. It is a fast growing, unicellular, marine non- heterocystous cyanobacterium that forms long unbranched filaments inside sheath they reproduce asexually [47]. *Lyngbya* mats are usually dark blue to black benthic mats may float to the surface due to trapped gases when they float to the surface the mats oxidize and turn yellow- orange [48]. Reproduction asexually. Filaments form motile hormogonia.

Bold basal media enhances the green algae, Yellow green algae, Blue green algae group.BG-11 enhances only the green algae group and ½ Chev diatom media enhances the Diatom and Dinoflagellates group. The genera *Chlorococcum*, *spirogyra* and *Phormidium* were the most frequent and dominant in terms of algae density [49]. A table of twelve microalgal species were isolated namely: *Prasiola*, *Draparnaldia, Vaucheria, Ceratium, Tabellaria, Zygnema, Spirogyra*, *Scytonema*, *Phormidium*, Thallus is filamentous, filaments are interwoven to form an expanded thallus mass. Each filament has a distinct sheath (thin to thick) Trichome thin, colourless, brown, blue to purple filaments sometimes spirally coiled. Cells are 2 to 3 times wider than longer. Cells contain granular and vacuolated cytoplasm. The genus *Scytonema* is an important component of microphyte communities in terrestrial habitats particularly in tropical regions many species seem to have pantropical distribution, but the populations from various distant regions need taxonomic revision and their areas of distribution must be checked. The molecular determination of different populations must be preferred in taxonomic evaluation of the samples, but the precise reassessment of their morphology and study of life cycles is still an essential part of the modern polyphasic analyses. Relatively broad diversity of *Scytonema* like types over the tropical countries was documented in numerous articles [39], [41], [46], [50-51]. These records need comparative analysis and further revision according to the modern criteria both molecular and morphological before a new taxonomic system can be accomplished.

Agricultural uses of freshwater algae

Algae play an important role in agriculture where they are used as biofertilizer and soil stabilizers. Blue green algae have been found to be an easily available and economically cheap resource material for production and use as biofertilizers. These are free living photoautotrophic micro-organisms many of which also fix atmospheric nitrogen and are found in abundance in rice fields [52]. Blue green algae is one of the potent substitutes of urea and can be used extensively in paddy fields. Considering this blue- green algae has been developed as a biofertilizer especially for low land rice and can be produced economically [53]. The beneficial effects of microalgae and cyanobacteria in agricultural practices is undeniable, one of the major limitations to the use of these micro-organisms or compounds is the high costs typically associated with microalgal / cyanobacterial biomass production and compounds extraction on the other hand, application of microalgal /cyanobacterial extracts requires the extraction of the interest metabolites, being the most commonly used methods very expensive [54-55].

Blue green algae are treated as biofertilizers from olden days. *Nostoc, Oscillatoria, Scytonema, spirulina* etc. are used as fertilizers to rice fields. All these algae fix the atmospheric nitrogen. Cultivation of *spirulina* gaining importance as feed for fish, poultry and cattle. Our Country has more of alkaline soils or sterile soils. Blue green algae like *Nostoc, Oscillatoria, Scytonema, spirulina* are used to modify these soils into fertile soil. Because the fixed nitrogen into soil. Nearly they fixed four hundred kilogram of nitrogen per year. Soil erosion is also reduced by these algae [56]. Microalgae are beneficial for soil fertility, plant growth, biocontrol and nutrient cycling in agricultural settings. Microalgae also fix carbon dioxide through photosynthesis for carbon capture and some produce exopolysaccharides that improve soil structure. Cyanobacteria in particular, are considered biofertilizers due to their long-known ability to fix atmospheric nitrogen and more recently for solubilizing immobilized phosphorous. Furthermore, microalgae can be grown on nutrient that can be recycled for plant growth with a slower nutrient release rate than chemical fertilizers. In the case of microalgae, *Haematococcus pluvialis* and *Chlorella zofingiensis*, together with *Chlorococcum* species account for the major natural sources, while only the former has received FDA approval for use as human nutritional supplement, with the others being primarily used as aquaculture feed [61-62].

Commercial and industrial applications of microalgae

Some of the most biotechnologically relevant microalgae are the green algae *Chlorella vulgaris, Haematococcus pluvialis, Dunaliella salina* and the Cyanobacteria, *Spirulina maxima* which are widely commercialized and used, mainly as nutritional supplements for humans and as animal feed additives. Another potential micro algae is used as food is the green algae *Chlorella*. Now a days *Chlorella*, like *Spirulina* is mainly sold in health food stores and as a fish food. The major economic important product of *Chlorella* are several by-products that are used in fruit and vegetable preservatives [57]. At present microalgal market is dominated by *Chlorella* and *Spirulina* [58-59], mainly because of their high protein content, nutritive value, and moreover they are easy to grow. Microalgae are employed in agriculture as biofertilizers and soil conditioners. The majority of Cyanobacteria are capable of fixing atmospheric nitrogen and are effectively used as biofertilizers. Cyanobacteria play an important role in maintenance and build-up of soil fertility, consequently increasing rice- growth and yield as a natural biofertilizer [60]. The algal production technology developed and reported by different Algologists is very simple in operation and easy in adaptability by Indian farmers. Microalgae contain numerous bioactive compounds that can be harnessed for commercial use. They have emerged as important sources of proteins and valuable added compounds with pharmaceutical and nutritional importance. Similarly, according to ethylene production existed before land plants colonized the earth as evidenced by unambiguously homologous ethylene- signaling pathways in *Spirogyra* and *Arabidopsis*; implying that cell elongation was possibly ancestral ethylene production response. Some of the described species have been studied and known to have potential applications in agriculture, energy, food and pharmaceutical industries because of their ability to produce oil, fix atmospheric nitrogen, and also have high vitamin, mineral and protein contents among others [63-64].

CONCLUSION

The present findings conclude as totally twelve different species of freshwater algae were identified. Further, its features and biochemical content were analyzed for their ability to produce based on their growth characteristics. More over the biomass and their vegetation leads to conserve sustainable environment. Freshwater algae, particularly blue-green algae, offer significant potential in agriculture as biofertilizers and soil stabilizers. Their ability to fix atmospheric nitrogen and modify alkaline or sterile soils into fertile ones makes them invaluable resources for enhancing soil fertility and crop yields, particularly in rice fields. Despite their undeniable benefits, the high costs associated with microalgal biomass production and extraction of compounds pose limitations to their widespread use. Moreover, microalgae and cyanobacteria have commercial and industrial applications beyond agriculture, serving as nutritional supplements, animal feed additives, and sources of bioactive compounds with pharmaceutical and nutritional importance. Species like *Chlorella vulgaris*, *Haematococcus pluvialis*, *Dunaliella salina*, and *Spirulina maxima* dominate the microalgal market due to their high protein content, nutritive value, and ease of cultivation. Furthermore, ongoing studies on the potential applications of algae in various industries, including agriculture, energy, food, and pharmaceuticals, underscore their versatility and importance as valuable resources for sustainable development.

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LITERATURE CITED

1. Wu L, Xu L, Hu C. 2015. Screening and characterization of oleaginous micro algal species from Northen Xinjian. *Journal of Microbiology Biotechnology* 25: 910-917. https://dio.org/10.4014/jmb.1411.11075.
2. Dantas DMDM, Oliveira YBDC Costa RMPB.day Gracas carneiroda – Cunha M. Galvez M,de Souza Bezerra R. 2019. Evaluation of antioxidant and antibacterial capacity of green microalgae scenedesmus subspicatus. *Food Science Technology*

3. Mata TM, Martins AA, Caetano NS. 2010. Microalgae for biodiesel production and other application: A review. *Review Sustain Energy Rev* 14: 217-237.
4. Marcel Martirez Porchas FV. 2017. Microbial metagenomics in aquaculture: A potential tool for a deeper insight into the activity. *Rec. Aquac.* 9: 42-56
5. Borowitzka MA. 2013. Species and strain selection. *In*: Michael A, Borowitzka NRM(EDS) Algea for biofuels and energy springer. *Dordrecht*: 77-89.
6. Mondal M, Gaswami S, Ghash A, Oinam G, Tiwari ON, Das P, Gayen K, Mandal MK, Halder GN. 2017. Production of biodiesel form microalgae through biological carbon capture: A review. 3 *Biotech* 7: 1-21.
7. Darienko T, Gustavs L, Egger A, Wolf W, Preschool T. 2015. Evaluating the species boundaries of green rnicroalgae (coccomyxa, Trebouxiophcea, chlorophyta) using integrative taxonomy and DNA barcoding with further implication for the species identification in environmental samples. *PLoS One* 10: 1-31. https://dio.org/10.1371/*journal pone*.0127838.
8. Masajidak J, Torzillo G. 2008. Reference module in earth systems and environmental sciences. http://dx.doi.org/10.1016/13978-0-12-409548-9.09373-8.
9. Aguilera A, Souza Egipsy V, Amils R. 2012. Photosynthesis in extreme environments. *In*: Artificial photosynthesis, in extreme environments. *In*: Artificial photosynthesis, Isted: Najafpour, MM., Ed: In: Tech: Rijeka, *Croatia*. pp 271-288.
10. Patel A, Matsakas L, Rova U, Christaks Poulos P. 2019. A perspective in biotechnological application of thermophiles microalgae and cyanobacteria. *Bioresources Technology* 278: 424-434.
11. Jonker CZ, Van Ginkel C, Olivier J. 2013. Association between physical and geochemical characteristics of thermal springs and algal diversity in limpop province, *South Africa Water SA* 39: 95-104.
12. Boergesen F. 1938. Contribution to a south Indian marine Algal flora III. *Journal of the India Botanical Society* 17: 205-242.
13. Chapman VJ. Chapman DJ. 1981. *The Algae*. 2nd Edition. Macmillan Press Limited London.
14. Fritsch FE. 1935. *The Structure and Reproduction of Algae*. Vol I. Cambridge University Press London.
15. Fritsch FE. 1997. *The Structure and Reproduction of the Algae*. Vol-2. Cup-Vikas Students Edition.
16. Mahendra Perumal G, Anand N. 2009. Manual of Freshwater Algae of Tamil Nadu.
17. Agardth JG. 1947. Nya Alger fran mexico oversight al kongl vetenskaps Akademiens for handlinglar 4: 5-17.
18. Knebel G. 1936. Monographic der algenreihe der Prasiolales, insbersondere von Prasiola crispa Hedwigia 75: 1-120.
19. Ortega MM. 1984. Catalogo de algas conrinentales recientes de mexico Universidad Nacional Antonoma de Mexico- Mexico.
20. Ramirez V, Beltran MY, Bajorge GM, Carmona J, Cantoral VE, Valadez F. 2001. Flora algal del riola Magdalena, Distrito Federal. Maxico. Boletin de la scociedad Botanica de Mexico 68: 51-73.
21. Ramirez V, Cantoral UE. 2003. Flora algal del rios templados en la zona occidental de la Cuenca del valle de Mexico. *Anales del Instituto de Biologia* 74: 143-194.
22. Ramirez RR, Carmona J. 2005. Taxonomy and distribution of freshwater Prasiola (Prasiolales, Chlorophyta) in central Mexico. *Cryptogamic Algologie* 26: 177-188.
23. Pang W, Jiang X, Cao Y, Leliaert F, Wang Q. 2021. Morphological and filogenetic data confirm the identity of *Prasiola fluviatilis* from glacier streams in the Tianshan Mountains, China. *Cryptogamie Algologie* 42(4): 47-58.
24. Printz H. 1964. Die Cheatophoralen der Binnengewasser. *Hydrobiologia* 24: 1-376.
25. Steidinger KA, Foust AM, Hernandez – Becerril DU. 2009. Dinoflagellates of the Gulf of Mexico. *In*: Tunnel JW Jr Felder D.L and Earl SA biota. Vol 1 Biodiversity Harte Research Institute of Gulf of Mexico studies series, Texas A&M University press. Corpus Christi, USA. pp 131-154.
26. Graham HW & Bronikovsky N (1944) The genus ceratium in the pacific and north Atlantic oceans. Scientific results of cruise VII of the Carnegie during 1928-1929 under command of captain J.P Ault Carnegie Institution of Washington publication 565 washington DC VII + 209pp.
27. Licea S, Zamudio ME, Luna R, Soto J. 2004. free living dinoflagellates in the southern Gulf of Mexico report of data (1979-2002). *Phycol. Research* 52: 419-428.
28. Wood EJF. 1968. Dinoflagellates of the Caribbean sea and adjacent areas university of Miami press Coral Gables Florida. pp 142.
29. Yuri B. Okolodkov. 2010. Acta *Botanica mexicana* version online ISSN 2448-7589 version mpresa ISSN 0187-7151.
30. Zach O. 1979. Plankton unter suchungen am wolfgangsee undam schwar zensee- OKOL Zeits chrift fur Okologie. *Natur – und Umweltschutz* 4: 7-11
31. Kobayasi H, Idel M, Mayama S, Nagumo T. 2006. Atlas of Japanese Diatoms based on electron microscopy-531, Uchida Rokakuho Publishing Co., Ltd Tokyo
32. Krammer K, Lange- Bertalot H. 1991. Bacillariophyceae,3. Teil: Centrales fragilariacean, Eunotiaceae. *In*: (Eds) Ettl H. Gerloff J Heynig H, Mollenhauer D. Subswasserflora von mitteleuropa B and 2/3 -576pp. Gustav Fischer Verlag, Stuttgart – Jena
33. Hassal AH. 1845. A history of the British freshwater algae, including description of the desmideae and diatomaceae 447: London.
34. Theriot E, Ladewski TB. 1986. Morphometric analysis of shape of specimens from the neotype of *Tabellaria flocculosa* (Bacillariophyceae). *American Journal of Botany* 73: 224-229.
35. Lange – Bertalot H, Hofmann G, Werum M, Cantonati M. 2017. Freshwater benthic diatoms of central Europe: over 800 common species used in ecological assessment. English edition with updated taxonomy and added species. *In*: (Eds) Cantonati M, Kelly MG, Lange- Bertalot H. Koeltz Botanical Books Schmitten- oberreifenberg. pp 942.
36. Smith GM. 1950. Freshwater algae of the United States. 2nd Edition. MCGraw – Hill London UK.
37. Pheravut Wongsawad, Yuwadee Peerapornpisal. 2014. Morphological and molecular prifilling of Spirogyra from northeastern and northern Thailand using inter simple sequence repeat markers. *Saudi Journal of Biological Sciences* 22(4): 382-389.
38. Bornet E, Flahault C. 1887.Revision des *Nostocacees heterocystees* continues dans le *Principaux herbiers* de France. Annales des Sciences Naturelles. *Botanique Septieme* 5: 51-129.
39. Gardner NL. 1927. New Myxophyceae from porto Rico. Mem New York. *Botany* 2: 1-508.

40. Gomont M, Schmidt I. 1901. Part IV- Fresh water Chlorophyceae- Marine algae (chlorophyceae, phaeophyceae, Dictyotales, Rhodophyceae) Myxophyceae Hormogoneae- peridimales. *Botanist Tidsskrift* 24(2): 157-221.
41. Sant Anna C, Pereira HASL, Bicudo RMT. 1978. Contribuicao ao conhecimento das cyanophycea do purque estudnal das fontes do I Piranga Sao Paulo. *Brazil Rev. Brasil Biol*. 38: 321-337.
42. Komarek, Celia L, Sant Anna, Marketa Bohunicka, Jan mares Guilherme S Hentschke, Janaina Rigonata, Marli F. Fiore. 2013. Phenotype diversity and phylogeny of selected scytonema-species (Cyanoprokaryota) from SE Brazil. *Fottea Olomouc* 13(2): 173-200.
43. Petr Hasler, Petr Dvorak, Jeffrey R Johansen, Miloslave kitner, Vladen Ondrej, Aloisie Poulickova. 2012. *Fottea olomouc* 12(2) :341-356.
44. Watanabe S, Lewis L. 2017. Phylogenetic interpretation of light and electron microscopic features of selected members of the phylogroup Moewusinia (Chlorophyceae), with new generic taxonomy. *Phycologia* 56: 329-353.
45. Bold H, Parker BC. 1962. Some supplementary attributes in the classification Chlorococcum species. *Arch. Microbiology* 42: 267-288.
46. Desikachary TV. 1959. *Cyanophyta*. Indian Council of Agricultural Research, New Delhi. pp 686.
47. Hojun Lee, Jihal Park. 2021. Natural bioactive compounds.
48. Hoyer MV, Canfield DE. 1996. Proc Rainbow River Lyngbya workshop, 24-25 Gainesville, Florida; Southwest Florida water Management district. SWIM Department, Brookville, *Florida* 44.
49. Linton EW, Karnkowska – Ishikawa A. Kimji Shin W. Bennett M. Kwiatowski J, Zakrys B, Triemer RE. 2010. Reconstructing euglenoid evolutionary relationships using three genes: Nuclear SSU and LSU and chloroplast 16s rDNA Sequences and the description of Euglenaria gen. nov. (Euglenophyta). *Protist* 161: 603-619.
50. Skuja H.1949. Susswasseralgen flora Burmas Nova Acta Reg. Soc. SC. Upsal Ser 4. 14: 1-188.
51. Coute A, Tell G, Therezien Y. 1999. Cyanophyceae (Cyanobacteria) aerophiles de Nouvelle – Caledonie – Cryptogamie / *Algologie* 20: 301-344.
52. De PK. 1939. The role of blue green algae in nitrogen fixation in rice fields. *Proc. R. Soc. Land B:* 127(846): 121-139.
53. Pabbi S. 2008. Cyanobacterial Biofertilizers. *Journal of Eco-friendly Agriculture* 3(2): 95-111.
54. Pan S, Jeevanandam J, Danquah MK. 2019. Benefits of algal extracts in sustainable agriculture. *In*: Grand Challenges in Marine Biotechnology. *Springer Science and Business Media* LLC, Berlin, Germany. pp 501-534.
55. Renuka N, Guldhe A, Prasanna R, Singh P, Bux F. 2018. Microalgae as multifunctional options in modern agriculture. Current trends, prospects and challenges. *Biotechnology. Adv.* 36: 1255-1273.
56. Ahmed AAS. 2009. Cyanobacterial application for the improvement of soil fertility. *M. Sc. Thesis*, Botany Department Faculty of Science. Appl. Beni-Suef, University, Beni- Suef, Egypt.
57. Hills C, Nakamura H. 1978. *Food from Sunlight*. World Hunger Research Publication., Creek, CA.
58. Becker W. 2004. Microalgae in human and animal nutrition. *In*: (Eds) A. Richmond. Handbook of Micro Algal Culture, Blackwell, Oxford: 312-351.
59. Pulz O, Gross W. 2004. Valuable products from biotechnology of microalgae. *Applied Micro Biology and Biotechnology* 65: 635-648.
60. Song T, Martensson L, Eriksson T, Zheng W, Rasmussen U. 2005. Biodiversity and seasonal variation of the cyanobacterial assemblage in a rice paddy field in Fujian, China. *The Federation of European Materials Societies Microbiology Ecology* 54: 131-140.
61. Li J, Zhu D, Niu J, Shen S, Wang G. 2011. And economic assessment of Astaxanthin production by large scale cultivation of *Haemtococcus pluvialis*. *Biotechnology Adv*. 29: 568-574.
62. Liu J, Sun Z, Gerken H, Liu Z, Jiang Y, Chen F. 2014. Chlorella Zofingiensis as an alternative microalgal producer of Astaxanthin: Biology and industrial potential. *Marine Drugs* 12: 3487-3515.
63. Ju C, Van De poel B, Cooper ED, Thierer JH, Gibbons TR, delwiche CF. 2015 conservation of ethylene as a plant hormone over 450 million years of evolution. *Natural Plants* 1(1): 1-7.
64. Singh PK, Kumar A, Kumar SV, Srivastava AK. 2020. *Advances in Cyanobacterial Biology*. Academic Press Inc.