TAXONOMIC STUDY OF CHLOROPHYTA, CHAROPHYTA AND VAUCHERIOPHYTA FROM NORTH-EASTERN AREAS OF PAKISTAN

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TAXONOMIC STUDY OF CHLOROPHYTA,
CHAROPHYTA AND VAUCHERIOPHYTA FROM
NORTH-EASTERN AREAS OF PAKISTAN

Certified that this Ph. D. thesis has been completed

by

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under my supervision.

I permit it to be submitted to the
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Gulshan-e-Iqbal Campus Karachi
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Karachi-75270, Pakistan.
DEDICATION

I beg to dedicate this humble piece of research work in admiration and respect to my adorable mother, who always wished that I may accomplish it. I am indebted to her for the sublime love and deep affection which she had for me. Her inspiration has encouraged me at each step of my life. She always remained thoughtful about me and had uncountable and unrewardable favour for me.

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AVOWAL

This is to be declared that this thesis includes the original research work performed by me. All the collections were made with the kind help of Prof. Masud-ul-Hasan, Former Head, Department of Botany, Government College, University Lahore. The studies were conducted in the Phycology & Phycochemistry Lab. (Room No. 18), M. A. H. Qadri Biological Research Centre, University of Karachi, Karachi, where the general facilities were provided by the kind permission of Prof. Dr. Aqeel Ahmad, Director of the center. This work was supervised by Prof. Dr. Mustafa Shameel, and the entire thesis has been composed by me on P-4 computer.

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I. ABSTRACT

One hundred and thirty-nine species of planktonic, edaphic, epiokotic, epiphytic and epilithic green algae belonging to 3 phyla, 5 classes, 13 orders, 14 families and 26 genera have been collected from various freshwater habitats in the north-eastern areas of Pakistan. For this purpose several districts of the Punjab e.g. Gujranwala, Jauharabad, Jhang, Kasur, Lahore, Sargodha, Shiekhupura and Sialkot, certain areas of Attock and Swat in N.W.F.P. like Bahrain and Kalam as well as Chenari, Muzaffarabad and Neelum Valley in Azad Kashmir were surveyed during December 2003 and July 2005. They have been morphologically and cytologically investigated, taxonomically determined and described on the basis of such characters. Although all of them appeared to be taxonomically known species, but most of them were described for the first time from their area of collection.

As a result of taxonomic studies members of the phylum Chlorophyta with 22 genera and 127 species were found to be more prevalent than other two phyla of green algae, while Vaucheriophyta included 3 genera and 10 species and Charophyta contained only 1 genus with 2 species and thus appeared to be the smallest phylum in diversity. Zygnemales was the most commonly distributed order with 5 genera and 63 species (45.3 %). It was followed by the order Oedogoniales with 2 genera and 28 species (20.1 %), while Prasiolales, Sphaeropleales and Botrydiales were poorly distributed orders with only 1 genus and 1 species each (0.7 %). As a result of that Zygnemophyceae appeared to be the most highly distributed class with 7 genera and 91 species (65.5 %) as compared to
others. It was followed by the class Ulvophyceae with 11 genera and 25 species (20.1 %). The class Siphonocladosphyceae appeared to be the least distributed class of the phylum Chlorophyta having 4 genera and 8 species (5 %).

*Spirogyra* with its 42 species was the most commonly occurring genus. It was followed by the genera *Oedogonium* with 26 species and *Zygnema* with 10 species. Next common were the genera *Ulothrix* with 8 species and *Zygmemopsis* with 6 species. Except *Ulothrix* all these genera belong to the class Zygmemophyceae. Poorly distributed genera were *Binuclearia, Chaetophora, Cylindrocapsa, Geminella* and *Heterothrichopsis* among class Ulvophyceae, *Hallasia* among Zygmemophyceae, *Sphaeroplea* among Siphonocladosphyceae and *Botrydium* among class Vaucherioiphyceae, which were represented by a single species each. *Aphanochaete, Bulbochaete, Chara, Cladophora, Coleochaete, Pithophora, Tribonema* and *Uronema* were slightly better in their diversity, as each of them was represented by two species each.

An overwhelming amount of the collected species was found in the free-floating or planktonic condition (75. 5 %). Next category of habitats, in which they were collected, is epiphytic condition (15. 8 %). Only a few species occurred in the edaphic and epilithic conditions (3.6 %), and epioikotic condition was the least occurring habitat (1.4 %). No epipsammic or epipellic alga was collected. These conditions were mainly represented by species of the phylum Chlorophyta. In the phylum Vaucherioiphyta no species was found in the epioikotic or epilithic condition. Among Charophyta, apart from epilithic and epiphytic habitats all the other categories were missing.

Largest number of species was found in the Lahore District (17. 3 %), which was followed by the collections made from Sheikhupura District (14 %). This was further
followed by Kasur and Sialkot districts (12.1 % each). The cold areas of Swat and Azad Kashmir also displayed an appreciable number of species (9.3 & 9.8 % respectively). The areas of Attock and Pasroor were quite poor in the distribution of algae (3.3 %). Smallest number of species was observed in Sargodha and Jauharabad districts (1.9 & 2.3 % respectively). The class Zygnemophyceae was well represented at all the 12 localities, but the class Ulvophyceae was not found at Sargodha District. The class Siphonocladosphyceae was not present at several localities. The phyla Vaucherophyta and Charophyta were found to be poorly represented at several localities, due to small number of species collected.

*Spirogyra* was the most commonly collected genus, found at all the investigated localities except Sargodha District. Next to it was *Zygnema*, which was further absent at Jauharabad District. Further next were *Ulothrix* and *Oedogonium*, which were collected from 8 different localities. *Binuclearia*, *Botrydium*, *Geminella*, *Hallasia*, *Heterothrichopsis* and *Sphaeroplea* were the least occurring genera, they were collected from one locality only. While *Aphanochaete*, *Bulbochaete*, *Chaetophora*, *Chara*, *Coleochaete*, *Cylindrocapsa*, *Tribonema* and *Uronema* were slightly better, as they occurred at two different localities.

The largest number of collected species was found in spring (31.6 %), their frequency of occurrence remained almost the same during summer and winter (24.6 & 26.3 % respectively), and they were collected in smallest number in autumn (17.5 %). It appeared that they started growing in winter, reached to a maximum growth during spring and began to disappear in autumn. The seasonally resistant most common genera were *Oedognium*, *Pithophora*, *Spirogyra*, *Stigeoclonium*, *Ulothrix* and *Zygnema*, which were
found to grow in all the four seasons. *Binuclearia, Cylindrocapsa, Geminella* and *Hallasia* were only collected during spring, *Heterothrichopsis* was only found in summer, *Chaetophora* and *Chara* occurred only during autumn, while *Aphanochaete, Botrydium* and *Sphaeroplea* thrived only in winter. Species of these genera could not be collected during other seasons. The remaining genera were found in certain seasons of the year but remained absent during others.
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خلاصة

پاکستان کے شمال شرقی علاقہ میں کئے جانے والے دونوں طرف کے آداب میں دو کور فاکا اور دو کور پوکا (ای) کا اہمیت مطالعہ

بڑا اشتغال (ای) کی اپنی سوانح (ای) میں ایک اور غیر اوریون، زمین دوسرے طرف سے بڑا اشتغال کی

اور ہر کی افواتی اتقان 36 مکالمے، 56 جھنڈا، 48 منہگان اور 37 اجتہاد اور 26 اجتہاد سے تنا، پاکستان کے شمال شرقی علاقہ میں پہنچ جانے والی اردویں اوریون کی مالکیت کے تحت ہم سے دوسرے طرف کا اشتغال کی ماہی پر پہنچ ہوئی ہے۔

ابتدا میں اوریون سے اورہاں یا معاصر اوریون اور سے چنان ہی اوریون اور سائر الشیواں کا جدید پہنچ ہوا ہے۔

کیا اوریون کی افواتی اور دوسرے طرف کے ایک اور دوسرے طرف کے اوریون سے دوسرے طرف کی اوریون کی افواتی اور دوسرے طرف کی اوریون سے دوسرے طرف کی اوریون کی افواتی کا مالکیت کے تحت ہم سے دوسرے طرف کی اوریون کی افواتی اور دوسرے طرف کی اوریون کی افواتی کا مالکیت کے تحت ہم سے دوسرے طرف کی اوریون کی افواتی کا مالکیت کے تحت ہم سے دوسرے طرف کی اوریون کی افواتی کا مالکیت کے تحت ہم سے دوسرے طرف کی اوریون کی افواتی کا مالکیت کے تحت ہم سے دوسرے طرف کی اوریون کی افواتی کا مالکیت کے تحت ہم سے دوسرے طرف کی اوریون کی افواتی کا مالکیت کے تحت ہم سے دوسرے طرف کی اوریون کی افواتی کا مالکیت کے تحت ہم سے دوسرے طرف کی اوریون کی افواتی کا مالکیت کے تحت ہم سے دوسرے طرف کی اوریون کی افواتی کا مالکیت کے تحت ہم سے دوسرے طرف کی اوریون کی افواتی کا مالکیت کے تحت ہم سے دوسرے طرف کی اوریون کی افواتی کا مالکیت کے تحت ہم سے دوسرے طرف کی اوریون کی افواتی کا مالکیت کے تحت ہم سے دوسرے طرف کی اوریون کی افواتی کا مالکیت کے تحت ہم سے دوسرے طرف کی اوریون کی افواتی کا مالکیت کے تحت ہم سے دوسرے طرف کی اوریون کی افواتی کا مالکیت کے تحت ہم سے دوسرے طرف کی
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رکنی دالیں بنیادتاتن آئی آس کے بعد بنیادتاتن الوداع کی اجتماع اور 23 اړوی (12 افریم) پی مشتقل پایی گئی۔ ساتھی ملاکلا دوسری کے اجتماع اور 8 اړوی پی مشتقل بہر ہوے۔ ہمہ کلا کہ ہم باکری کی چھوٹی تیز ہدایت کے ساتھ دالیں بنیادتاتن کے کئے ترہیار کردی۔

اے کی جو پشاپ یور۔ اس ایک اور مثال کے ساتھ سب سے زادہ پیلی جن اور میں نیم تابی بنی۔ جب دوسرے نمبر پی 14 اړوی 23 اړوی اور گریمئی ایک ایک اړوی کے ساتھ پیلی جن اس کے بعد پیلی جن دوسرے دالیں بنیادتاتن ملی قرار ہوئے ہوئے اړوی اور گریمئی 9 اړوی کے ساتھ قرار ہوئے۔ اس اور چوکھو کی ساتھ ختم کریں میں جزیرہ سے دوسرے دالیں بنیادتاتن کے دوسرے دالیں بنیادتاتن کے زکوتو کی سے ختم کریں میں سے دوسرے دالیں بنیادتاتن کے ممبیچ کی سے ختم کریں میں سے دوسرے دالیں بنیادتاتن کے دوسرے دالیں بنیادتاتن کے ممبیچ کی سے ختم کریں میں سے دوسرے دالیں بنیادتاتن کے دوسرے دالیں بنیادتاتن کے ممبیچ کی سے ختم کریں میں سے دوسرے دالیں بنیادتاتن کے دوسرے دالیں بنیادتاتن کے ممبیچ کی سے ختم کریں میں سے دوسرے دالیں بنیادتاتن کے دوسرے دالیں بنیادتاتن کے ممبیچ کی سے ختم کریں میں سے دوسرے دالیں بنیادتاتن کے دوسرے دالیں بنیادتاتن کے ممبیچ کی سے ختم کریں میں سے دوسرے دالیں بنیادتاتن کے دوسرے دالیں بنیادتاتن کے ممبیچ کی سے ختم کریں میں سے دوسرے دالیں بنیادتاتن کے دوسرے دالیں بنیادتاتن کے ممبیچ کی سے ختم کریں میں سے دوسرے دالیں بنیادتاتن کے دوسرے دالیں بنیادتاتن کے ممبیچ کی سے ختم کریں میں سے دوسرے دالیں بنیادتاتن کے دوسرے دالیں بنیادتاتن کے ممبیچ کی سے ختم کریں میں سے دوسرے دالیں بنیادتاتن کے دوسرے دالیں بنیادتاتن کے ممبیچ کی سے ختم کریں میں سے دوسرے دالیں بنیادتاتن کے دوسرے دالیں بنیادتاتن کے ممبیچ کی سے ختم کریں میں سے دوسرے دالیں بنیادتاتن کے دوسرے دالیں بنیادتاتن کے ممبیچ کی سے ختم کریں میں سے دوسرے دالیں بنیادتاتن کے دوسرے دالیں بنیادتاتن کے ممبیچ کی سے ختم کریں میں سے دوسرے دالیں بنیادتاتن کے دوسرے دالیں بنیادتاتن کے ممبیچ کی سے ختم کریں میں سے دوسرے دالیں بنیادتاتن کے دوسرے دالیں بنیادتاتن کے ممبیچ کی سے ختم کریں میں سے دوسرے دالیں بنیادتاتن کے دوسرے دالیں بنیادتاتن کے ممبیچ کی سے ختم کریں میں سے دوسرے دالیں بنیادتاتن کے دوسرے دالیں بنیادتاتن کے ممبیچ کی سے ختم کریں میں سے دوسرے دالیں بنیادتاتن کے دوسرے دالیں بنیادتاتن کے ممبیچ کی سے ختم کریں میں سے دوسرے دالیں بنیادتاتن کے دوسرے دالیں بنیادتاتن کے ممبیچ کی سے ختم کریں میں سے دوسرے دالیں بنیادتاتن کے دوسرے دالیں بنیادتاتن کے ممبیچ کی سے ختم کریں میں سے دوسرے دالیں بنیادتاتن کے دوسرے دالیں بنیادتاتن کے ممبیچ کی سے ختم کریں میں سے دوسرے دالیں بنیادتاتن کے دوسرے دالیں بنیادتاتن کے ممبیچ کی سے ختم کریں میں سے دوسرے دالیں بنیادتاتن کے دوسرے دالیں بنیادتاتن کے ممبیچ کی سے ختم کریں میں سے دوسرے دالیں بنیادتاتن کے دوسرے دالیں بنیادتاتن کے ممبیچ کی سے ختم کریں میں سے دوسرے دالیں بنیادتاتن کے دوسرے دالیں بنیادتاتن کے ممبیچ کی سے ختم کریں میں سے دوسرے دالیں بنیادتاتن کے دوسرے دالیں بنیادتاتن کے ممبیچ کی سے ختم کریں میں سے دوسرے دالیں بنیادتاتن کے دوسرے دالیں بنیادتاتن کے ممبیچ کی سے ختم کریں میں سے دوسرے دالیں بنیادتاتن کے دوسرے دالیں بنیادتاتن کے ممبیچ کی سے ختم کریں میں سے دوسرے دالیں بنیادتاتن کے دوسرے دالیں بنیادتاتن کے ممبیچ کی سے ختم کریں میں سے دوسرے دالیں بنیادتاتن کے دوسرے دالیں بنیادتاتن کے ممبیچ کی سے ختم کریں میں سے دوسرے دالیں بنیادتاتن کے دوسرے دالیں بنیادتاتن کے ممبیچ کی سے ختم کریں میں سے دوسرے دالیں بنیادتاتن کے دوسرے دالیں بنیادتاتن کے ممبیچ کی سے ختم کریں میں سے دوسرے دالیں بنیادتاتن کے دوسرے دالیں بنیادتاتن کے ممبیچ کی سے ختم کریں میں سے دوسرے دالیں بنیادتاتن کے دوسرے دالیں بنیادتاتن کے ممبیچ کی سے ختم کریں میں سے دوسرے دالیں بنیادتاتن کے دوسرے دالیں بنیادتاتن کے ممبیچ کی سے ختم کریں میں سے دوسرے دالیں بنیادتاتن کے دوسرے دالیں بنیادتاتن کے ممبیچ کی سے ختم کریں میں سے دوسرے دالیں بنیادتاتن کے دوسرے دالیں بنیادتат
کسی کے سروال ور چکے ہے اور واقعی اور ور 9.8 اور 8.9 فیصد کے معاہدہ کے تحت فرمائہ سال میں ہونے والے اور ور یا اور ور سے جنگ کا انعقاد کے بعد واقعی کے زیر معاہدہ اور ور کے معاہدہ کا انعقاد کے بعد واقعی کے زیر معاہدہ ہو گیا۔

اصل میں کسی اور ور کا انعقاد (پہلی معاہدہ) 9.8 اور 9.9 فیصد کے معاہدہ کے تحت کا انعقاد کے بعد واقعی کے زیر معاہدہ ہو گیا۔

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II. INTRODUCTION

Algae are heterogenous, polyphyletic assemblage of very simple, water loving, autotrophic organisms having no sterile layer of jacket-cells around their reproductive organs and lacking true embryogenesis (Shameel 2003). As primary producers, they are an important component of aquatic ecosystem, being inhabitants of moist, freshwater, brakish water and marine environments of our biotope (Shameel 2002b). Taxonomically they are distributed in three kingdoms: Monera, Protista and Protoctista and have been classified in 19 different phyla according to the newly proposed system (Shameel 2001).

Professor S. L. Ghose was the first phycologist to work on the algal flora of the areas now included in Pakistan, he described a number of blue-green algae from Lahore (Ghose 1919, 1924). Under his guidance one student investigated diatoms from Punjab (Abdul-Majeed 1935). Professor M. S. Randhawa was another phycologist to work on green algae of this area and described several new species (Randhawa 1936a, b).

After the creation of Pakistan, Professor Chaudhri Sultan Ahmad (1910-1983), the greatest botanist of the country, took a keen interest in the algal flora of the Punjab and supervised the M. Sc. thesis of M. A. F. Faridi in 1953 on Charophyta. Later on Professor M. A. F. Faridi (1927-1985) appeared to be a great Phycologist, he published over 70 research papers on the algal flora of the Punjab, N.W.F.P., Balochistan and Azad Kashmir and described 10 new species of algae (Faridi 1955, 1956, 1971, 1978, Faridi et al. 1981, 1982). He also produced several students like Profs. I. Ilahi (Siddiqui), I. Haq, F. Hussain, F. M. Sarim and Dr. G. Anjum, who made further valuable

Professor Masud-ul-Hasan appeared to be a energetic specimen collector and an excellent field observer. He travelled all the districts of the Punjab, made a huge collection of algae, and made a valuable contribution on the algal taxonomy of this area (Masud-ul-Hasan 1978a, b, 1980, Masud-ul-Hasan & Zaib-un-Nisa 1986, Masud-ul-Hasan & Batool 1987, Masud-ul-Hasan & Yunus 1989, Masud-ul-Hasan & Nizamuddin 1995, Masud-ul-Hasan et al. 1995 etc.). During last stage of his service at Govt. College, Lahore (now converted to a University) he helped Dr. Sabeen Naz in the collection and identification of blue-green algae from Punjab, N.W.F.P. and Azad Kashmir, who made several detailed publications on the Cyanophyta of these areas (Naz et al. 2003, 2004a-g, 2005). These efforts resulted in a thorough and complete revision on the taxonomy of blue-green algae from north-eastern areas of Pakistan.

A young and very energetic researcher, Dr. Muhammad Khan Leghari explored various water bodies and freshwater reservoirs around Islamabad and in the north-eastern areas of Pakistan. As a result of that the conducted several limnological surveys (Leghari et al. 2002, 2003a, b, 2004, 2005a, b, Leghari & Leghari 2002, Leghari & Ghafar 2006) and made a good collection of algae, he also obtained algae from other sources (Leghari et al. 2005c, Leghari & Naseem 2006). With his colleagues and associates he also
investigated diatoms of these areas (Leghari et al. 1991, 1995, Leghari & Sultana 1993). Most of such studies were survey reports rather than classical taxonomic works.

The emerging picture of the freshwater algal flora of Pakistan from the foregoing literature survey revealed lack of information about detailed taxonomic description and systematic account of green algae from these areas. Therefore, a wide-range research programme was developed with joint collaboration of Prof. Masud-ul-Hasan to make a detailed investigation on the taxonomy of green algae inhabiting the freshwater environment of various districts of the Punjab and certain areas of N.W.F.P. and Azad Kashmir. Among green algae, those belonging to the phyla Chlorophyta, Charophyta and Vaucheriophyta were selected for the present study.
III. MATERIALS & METHODS

1. LOCALITIES OF COLLECTION

Pakistan is situated in South Asia at the northern boundary of the Arabian Sea. Geographically it lies between 23-37º N and 31-81º E. It comprises of four provinces: N. W. F. P. (North Western Frontier Province), the Punjab, Balochistan and Sindh and includes some portion of the disputed territory of Jammu and Kashmir, called as Azad Kashmir (Fig. 1). Freshwater Chlorophyta (green algae), Charophyta (stonewort algae) and Vaucheriophyta (yellow-green algae) were collected mainly from north-eastern region of Pakistan during December 2003 and July 2005. Collections have been made from various areas of the districts of Gujranwala, Jauharabad, Jhang, Kasur, Lahore, Sargodha, Sheikhupura and Sialkot in the province of the Punjab (Fig. 2). Material has also been collected from Chenari, Muzaffarabad and Neelum Valley from Azad Kashmir as well as from Attock, Bahrain and Kalam (Swat) in N. W. F. P. Planktonic, edaphic, epipsammic, epilithic, epioikotic as well as epilithic algae were collected from various freshwater habitats e.g. rain pools, temporary ponds, permanent water reservoirs, rivers, rivulets, brooks, brooklets, rice fields, canals, irrigation channels, tankes, lakes etc. at different seasons of the year (Photograph No. 1-4).

2. COLLECTION OF MATERIALS

The algal specimens growing in paddy fields were collected with the help of forceps. Some material was also scrapped from the surface of moist soil for edaphic
algae. Very small and floating (planktonic) forms were collected with the help of sieve with medium sized meshes epipsammic, epilithic and epioikotic (benthic) algae were gently detached from their respective substrata without beaking the holdfast. Twigs of submerged water plants having epiphytic algae were also cut into pieces and put into vials. The specimens were observed in the field under field-microscope for preliminary identification. The material was numbered, dated and preserved in 5 % Formalin.

3. FIELD OBSERVATIONS

Measurement of surface temperature, pH and electric conductivity of water of the habitat have been made and water depth was noted wherefrom the algal material was collected. Field observations concerning colour, water appearance, turbidity and nature of the flora growing in association with the collected material have been taken. Later on, most of the voucher specimens were kept in the research lab. of Prof. Masud-ul-Hasan at Lahore. Their duplicates have also been kept in the Phycology & Phycochemistry Lab. (Room No. 18), M. A. H. Qadri Biological Research Centre, University of Karachi.

4. STUDY OF MATERIAL IN THE LABORATORY

The collected materials were brought to the laboratory and each collection was examined under microscope for separation of various types present. The specimens were slightly stained with iodine solution to make cell-walls and other structures more clearly visible. In some cases, semi-permanent slides were prepared in glycerine, ringed and sealed with enamal paint. After a detailed investigation under microscope (Olympus, Japan; objective 20X, eye-piece 10X), sketches were
made with the help of camera lucida and various dimensions were measured with the help of calibrated ocular micrometer.

5. PERMANENT SLIDES

In order to prepare permanent slides the samples were washed with distilled water so that the formaline may be removed. Then the material was put in watch-glass containing 10% glycerine, which was placed in an oven for 24 to 48 hours at a temperature of 60 °C. After evaporation of water the material was left in pure glycerine. Then slides were made by mounting the material in a drop of pure glycerine on a clear and dry slide. It was covered with rounded cover slip, which was later ringed with enamel paint.

6. IDENTIFICATION OF THE COLLECTED MATERIAL

Fig. 1. Map showing geographical position of Pakistan.
Fig. 2. Map indicating the location of collection.
Photograph 1. Neelum Valley, Azad Kashmir, algae growing in between stones.
Photograph 2. Raja-Jhang Village, Kasur District, algae growing at the bottom of an irrigation channel.
Photograph 3. Kotli-Bajuwan Village, Sialkot Districts, algae growing as epilithon.
Photograph 4. Attock, N. W. F. P., algae clinging at the roof of a cave.
IV. RESULTS

On the basis of their morphological, cytological and reproductive characteristics an attempt was made to identify green algae, belonging to the phyla Chlorophyta, Charophyta and Vaucheriophyta upto species level. The following 139 species have been identified and taxonomically described, they are systematically arranged according to the recently proposed classification (Shameel 2001).

PHYLUM  CHLOROPHYTA (Green Algae)

Coenocytic or simple, multicellular organization of thallus; pigmentation: chlorophyll a & b; flegellation: 2 or 4, terminal, whiplash, isokontic flagella; storage product: starch found inside chloroplast; cell-wall constituent: cellulose.

CLASS  ULVOPHYCEAE

Filamentous or thalloid algae; cell division as usual, without any abnormality; chloroplasts variable in shapes; sexual reproduction by iso-, aniso- or oogamy.

Order  Ulotrichales

Filamentous, with a parietal chloroplast of varied shape. Detailed characters are given below in the family description.
Family Ulotrichaceae

It includes all the unbranched filamentous genera, in which the cells are uninucleate having a single girdle shaped chloroplast, with the cell-wall not composed of overlapping H-pieces. Almost all genera are known to produce bi- or quadriflagellate zoospores. Sexual reproduction is known only for a few genera, and in all cases thus far recorded, is isogamous and with a union of biflagellate gametes. The present collection included the following five genera, which may be distinguished as follows:

1. Filaments in sheath, cells cylindrical………………………………………..*Geminella*

   Filaments without sheath, cells not cylindrical………………………………………..2

2. Filaments not attached by a holdfast………………………………….*Heterotrichopsis*

   Filaments attached by holdfast………………………………………………………...3

3. Apical cell pointed……………………………………………………….*Uronema*

   Apical cell not pointed……………………………………………………………..4

4. Protoplast in one section……………………………………………………….*Ulothrix*

   Protoplast in two sections……………………………………………………….*Binuclearia*

*Binuclearia* Wittrock 1887: 7

It consists of simple filamentous forms, filaments comprised of simple cells united in linear series. There is no broad gelatinous sheath. When young the filaments are attached by a mucilaginous disc. The basal cell is not specialized but the terminal cell has a cellulose cap, other cells are cylindrical. Cell-wall is thick, lamellated; the transverse septa are stratified. The protoplast is concentrated in a small portion and separated from each other, each protoplast contains a nucleus and a laminate, girdle shaped chloroplast,
shiny volutin granules are present at the end of the protoplast. Chloroplast has one marginal pyrenoid, food reserves are starch and volutin. The transverse septa are thick and stratified in older cells, separating the protoplast. Reproduction is by thick walled akinetes or by fragmentation, asexual reproduction is by quadriflagellate zoospores formed singly in each cell. Only following species was collected:

**B. tectorum (Kützing) Berger ex Wichmann 1937: 56**


*Fig. 3*

**Basionym:** Gloeotila tectorum Kützing.

**Synonymy:** B. tatrana Wittrock 1887: 1.

**Morphological characters:** Filaments uniseriate, unbranched, with cylindrical cells.

**Cytological features:** Cells 11-12 μm broad, 23-24 μm long; chloroplast parietal, plate like, with a conspicuous pyrenoid.

**Reproductive structures:** Reproduction by akinetes, quadriflagellate zoospores.

**Locality:** Lahore District: Dinanath (1-8-2004).

**Geographical distribution:** Previously recorded from Himalayas (Randhawa 1948), Chennai (Iyengar 1960).

**Remarks:** The collection was made during summer from paddy fields, where it occurred in free-floating condition in massive quantity.
Geminella Turpin 1828: 329 *emend.* Lagerheim 1883

It comprises uniseriate filamentous algae, mostly free-floating, rarely sessile. The filaments are enclosed by a mucilaginous envelope varying in its relative width, but always hyaline and homogenous. The cells are cylindrical, ellipsoidal or oblong, mostly separated by mucilage and scarcely adherent to each other. They contain a laminate chloroplast, partially filling the cell, pyrenoid may or may not be present. Reproduction is by fragmentation, aplanospores and akinetes; swarmers are produced by a few species only. The following species could be collected:

**G. ordinata** (W. West et G. S. West) Heering 1914: 41


Fig. 4

**Basionym:** *Hormospora ordinata* W. West et G. S. West.

**Morphological characters:** Unbranched filamentous algae, surrounded by mucilagenous sheath.

**Cytological features:** Cells arranged in a row with equidistant intervening spaces, inside a gelatinous sheath; cells 4-6 μm broad and 7-9 μm long; chloroplast parietal, laminate and has one pyrenoid.

**Reproductive structures:** Reproduction by fragmentation, aplanospores and akinetes.

**Locality:** Sheikhupura District: Sattarwala (15-5-2004).

**Geographical distribution:** Previously reported from Europe, Asia, America and South-Africa.
Fig. 3. *Binuclearia tectorum*

Fig. 4. *Geminella ordinata*

Fig. 5. *Heterothrichopsis viridis*
Remarks: The collections were obtained during spring in free-floating state, from stagnant water ponds.

**Heterothrichopsis Iyengar et Kanthamma 1941: 105**

It includes unbranched filamentous forms made up of a few cells, placed in a row. Each cell contains a single nucleus and one or 2-4 parietal plate-like chloroplasts, with one or more pyrenoids in each. In very young cell there is only one chloroplast, but as the cells become older the number of chloroplast increases to 2, 4 or 8. The cell-wall is thin and uniform, reproduction usually occurs by fragmentation. Asexual reproduction takes place by aplanospores, so far no zygospore or gamete has been observed. The present collection included its following species:

**H. viridis** (Iyengar et Kanthamma 1940: 167) Iyengar et Kanthamma 1941: 105

(Ramanathan 1964: 97)

Fig. 5

**Basionym:** *Ulotrichopsis viridis* Iyengar et Kanthama 1940: 167.

**Morphological characters:** Filaments unbrached and 4-celled.

**Cytological features:** Cells 6-8 μm broad and 14-16 μm long; chloroplasts 2-4 with a pyrenoid in each.

**Reproductive structures:** Reproduction by aplanospores.

**Locality:** Sheikhupura District: Aliwala (30-8-2004).

**Geographical distribution:** Previously known from India.
Remarks: The specimens were collected during summer. It was found in stagnant water channels in free-floating state.

*Ulothrix* Kützing 1833: 517

Thalli are made up of simple unbranched filaments of undefined length, special holdfast cells may be found at the base of filaments. Growth of filament is diffused by cell division (holdfast does not divide). Chloroplast is single, girdle shaped, parietal band, partly or fully encircling the protoplast, pyrenoid is one or more in each cell. A small nucleus is present, generally placed internally to the chloroplast. Vegetative multiplication is by fragmentation. Asexual reproduction is by zoospores of two types *i.e.* biflagellated microzoospores and quadriflagellated macrozoospores, which are formed in all except basal cells. Sexual reproduction is by isogamy. The following six species of this genus were collected, which may be distinguished as follows:

1. Each cell contains one pyrenoid only..................................................2
   Each cell contains more than one pyrenoids........................................3
2. Cell-wall thickened.................................................................*U. aequalis*
   Cell-wall thin and somewhat mucilaginous......................................*U. tenerrima*
3. Cells contain more than 6 pyrenoids..............................................4
   Cells contain less than 6 pyrenoids.................................................5
4. Cells containing 6 pyrenoids.......................................................*U. flacca*
   Cells containing several pyrenoids...............................................6
5. Cells more than 11 µm in breadth...............................................*U. tenuissima*
   Cells less than 11 µm in breadth....................................................7
6. Cells up to 12 µm long...............................................................*U. variabilis*
   Cells more than 12 µm long..........................................................*U. zonata*
7. Cells up to 8 µm in breadth.......................................................*U. cylindrica*
   Cells more than 8 µm in breadth....................................................*U. moniliformis*
**U. aequalis** Kützing 1845: 197


**Fig. 6**

**Synonymy:** *Hormidium cateniforme* Kützing 1847: 177, *Ulothrix cateniformis* (Kützing) Kützing 1849: 347.

**Morphological characters:** Filament very long, composed of cylindrical cells.

**Cytological features:** cells cylindrical, 15-17 μm broad; cell-wall somewhat thickened; chloroplast broad, girdle shaped, covering more than half the wall surface; containing one pyrenoid.

**Reproductive structures:** Asexual reproduction by quadriflagellated macrozoospores and aplanospores, biflagellated or qudriflagellated microzoospores also present.

**Locality:** Lahore District: fountain of zoo (3-8-2003).

**Geographical Distribution:** Previously reported from Europe, America, New Zealand and Asia.

**Remarks:** Its specimens were collected from fountain of zoological garden during summer in free-floating state. The temperature was 37.2 °C and pH about 7.5.

**U. cylindrica** Prescott 1944: 349

(Prescott 1962: 96, Ramanathan 1964: 36)

**Fig. 7**

**Morphological characters:** Filaments unbranched, long curved and lightly entangled.
Cytological features: Cells elongate, cylindrical, 7-8 µm in width and 25-26 µm long; cell-wall thin and not constricted at joints; chloroplast a broad band, nearly equal to the cell in length and covering ¾ of the wall circumference; pyrenoids 2-5.

Reproductive structures: Reproduction by fragmentation and zoospores.

Locality: Pasroor District: Mutaik-Raypootan Village (4-3-2003).

Geographical distribution: America and India (Ramanathan 1964).

Remarks: It was collected during spring from standing water being attached with stones.

**U. flacca** (Dillwyn 1805: 49) Thuret in Le Jolis 1863: 56


Fig. 8

Basionym: *Conferva flacca* Dillwyn 1805: 49 (1802-1809).


Morphological characters: Filament bright to dark-green, entangled often in large skeins.

Cytological features: Cells cylindrical, 34-35 µm in diameter; each cell with six pyrenoids.

Reproductive structures: Reproduction by fragmentation and zoospores.

Fig. 6. *Ulothrix aequalis*

Fig. 7. *Ulothrix cylindrica*

Fig. 8. *Ulothrix flacca*
Geographical distribution: Previously reported from Europe, Asia, Australia, New Zealand, America.

Type locality: Swansea, Glamorgan, Wales.

Remarks: Collected in summer from slow running water in free-floating state.

_U. moniliformis_ Kützing 1849: 347


Fig. 9

Synonymy: _Hormiscia moniliformis_ (Kützing) Rabenhorst.

Morphological characters: Filaments light or yellow-green, clearly constricted at the cross-walls.

Cytological features: Cells 9-11 µm broad and 12-14 µm long (cells 6-9 µm in diameter); chloroplast on one side of the cell, rarely forming a girdle, usually with one or two but sometimes more pyrenoids.

Reproductive structures: Reproduction by akinetes or by quadriflagellate zoospores.

Localities: Kasur District: 23 km away from Kasur (15-6-2005); Sheikhupura District: near Sheikhanwala (30-8-2003).


Remarks: The observed specimens were collected from road-side puddles during summer in free-floating state.
**U. tenerrima** (Kützing 1833: 3861) Kützing 1843: 253


**Fig. 10**

**Basionym:** *Conferva tenerrima* Kützing 1833: 3861.

**Synonymy:** *Ulothrix subtilis* var. *tenerrima* (Kützing) Kirchner, *Hormiscia subtilis* var. *variabilis* (Kützing) Kirchner, *Ulothrix variabilis* Kützing 1849, *Microspora tenerrima* (Kützing) Gay 1886.

**Morphological characters:** Filaments attached or free-floating, mucilaginous.

**Cytological features:** Cells 8.0-9.5 μm broad and 4.0-5.5 μm long; cell-wall thin, somewhat mucilaginous; chloroplast girdle shaped, encircling more than half the width of the cell, with one pyrenoid.

**Reproductive structures:** Reproduction by fragmentation and zoospores.

**Localities:** Gujranwala District: Nandipur (7-12-2003); Jauharabad District: Jauharabad (25-4-2004); Lahore District: Hunjarwala field (16-8-2004), near Wahga Border (25-12-2004); Sheikhupura District: between Mureedke and Narang Mundi (12-9-2004).

**Geographical distribution:** Previously reported from Europe, America, New Zealand, Sri Lanka, Myanmar, Central India (Ramanthan 1964) and also from Pakistan: Lahore (Randhawa 1948).

**Remarks:** It was collected from five different places of the Punjab during all the four seasons *i.e.* spring, summer, autumn and winter. It appeared to grow throughout the year. Slight morphological changes were found in various specimens due to different
ecological conditions. The massive growth of this species occurred in paddy fields. It was found to grow in canal side ponds and stagnant water pools in attached condition mixed with other algae.

**U. tenussima** Kützing 1833: 517


**Fig. 11**

**Synonymy:** *Ulothrix tenuis* Kützing 1843.

**Morphological characters:** Filament long, composed of cylindrical cells.

**Cytological features:** Cells mostly 16-18 \( \mu \)m in breadth, 3-5 \( \mu \)m in length and 14-30 \( \mu \)m thick; chloroplast a broad band, with two or more pyrenoids.

**Reproductive structures:** Zoospores formed in somewhat swollen cells.

**Localities:** Lahore District: fountain of zoo (3-8-2004); Sheikhupura District: near Sheikhhanwala (28-2-2004); Azad Kashmir: Neelum Valley (15-12-2004).

**Geographical distribution:** Previously reported from Europe, America, New Zealand, India, Myanmar and Pakistan.

**Remarks:** The collection work was carried out during late summer and winter from three different places. During winter it was collected from cold water of ponds and in late summer it was obtained from fountain water locality and road-side puddles in free-floating state.
Fig. 9. *Ulothrix moniliformis*

Fig. 10. *Ulothrix tenerrima*

Fig. 11. *Ulothrix tenuissima*
\textit{U. variabilis} (Kützing) Kützing 1849: 349


\textbf{Fig. 12}

\textbf{Basionym:} \textit{Hormidium variabilie} Kützing.

\textbf{Synonymy:} \textit{U. subtilis} var. \textit{variabilis} Kirchner.

\textbf{Morphological characters:} Filaments long, slender and entangled, forming cottony masses, rarely with a pointed basal cell.

\textbf{Cytological features:} Cells 7 μm broad, 10-12 μm long, cylindrical; chloroplast a parietal folded plate, not filling more than half the circumference of the cell, appearing as a plate covering one side of the cell.

\textbf{Reproductive structures:} Reproductive organs were not observed.

\textbf{Locality:} Lahore District: Punjab University Old Campus (16-12-2004).

\textbf{Geographical Distribution:} World wide: Europe, Africa, America and Asia.

\textbf{Remarks:} Patches of soil with algal growth have been collected during winter. It occurred on wet soil surface in soil-binding habitat in massive quantity. It differed from \textit{U. tenerrima} in having much longer cells than that.

\textit{U. zonata} (Weber \textit{et} Mohr 1804: 97) Kützing 1833: 251

Fig. 13

**Basionym:** *Conferva zonata* Weber et Mohr 1804: 97.


**Morphological characters:** Filament long, stout, variable in diameter, attached in earlier stages, later free with cylindrical cell.

**Cytological features:** Cells varying in width and length, length generally smaller than width, cells 27-48 µm broad and 30-53 µm long; chloroplast band-shaped, broad, covering only the median region of the cell and containing more than one pyrenoids, often several; end cell rounded.

**Reproductive structures:** In the present collection reproductive structures were not seen.


**Geographical distribution:** Worldwide occurrence, previously recorded from various parts of India: Mumbai, Assam, Bengal etc.

**Remarks:** Collection was made along the canal-side ponds and also from slow running water of the river during winter in free-floating state. Specimens of the present collection differed in the structure of their apical cell and holdfast from *U. zonata* var. *faridii*
Shameel 1978: 378 (= U. shameellii Faridi in Faridi et al. 1982: 184), which was described earlier from Swat (Shameel 1978, 1984, Faridi et al. 1982).

Uronema Lagerheim 1887: 517

The characteristic feature of the algae included under this genus is the terminal cell of the filaments which is often tapering to an acuminate tip. It comprises of simple, unbranched filaments, mostly attached by a narrow basal cell or disc. The following two species of this genus were collected, which may be distinguished as follows:

1. Cells less than 12 μm broad, 1-3 pyrenoids………………………………U. confervicola

Cells more than 12 μm broad, 2-3 pyrenoids………………………………U. gigas

U. confervicola Lagerheim 1887: 518


Fig. 14


Morphological characters: Filaments many celled, straight, long, attached by a disc formed by basal cell.

Cytological features: Cells cylindrical, 4-8 μm broad and 5.6-21.0 μm long; basal cell 5-6 μm broad, 15-16 μm long; terminal cell pointed, 15-20 μm long; chloroplast extending the full length of the cell, parietal, encircling the protoplast and containing 1-3 pyrenoids.

Reproductive structures: Aplanospores and zoospores were not observed.

Geographical distribution: Previously reported from America, Europe, Africa and India (Ramanathan 1964).

Remarks: It was collected during spring, found attached to the margins of puddles mixed with *Microspora tumidula* Hazen.

*U. gigas* Vischer 1933: 74

(Ramanathan 1964: 53)

Fig. 15

Morphological characters: Filaments a few mm long, unbranched, constricted at intervals.

Cytological features: Cells 13-14 μm broad and 10-11 μm long; pyrenoids 2-3 in each cell; terminal cell elongated.


Geographical distribution: Previously reported from Europe: Switzerland.

Remarks: Collection work was carried out during summer, from the river side in free-floating state.

Order Prasiolales

Thallus filamentous and foliose; cells with stellate chloroplast; reproduction by bi- or quadri-flagellate zoospores and oogamy.
Family **Cylindrocapsaceae**

The thallus is filamentous, unbranched type with oblong or cylindrical cells surrounded by tough, often lamellated mucilaginous sheath. In older portions or under certain conditions of growth the cells become often irregularly arranged in a pseudoparenchymatous manner due to the division of cells in more than one plane and formation of septa in oblique or diagonal to the longitudinal axis. Each cell has several layered thick wall which is refractive, made up mostly of cellulose. The sheath is pectose *i.e.* made of pectic acid. The nature of chloroplast is not definitely known, it may be stellate or massive without any distinct pattern. It is axial each with a central pyrenoid, cells are uninucleated. Vegetative reproduction by fragmentation, asexual reproduction is by bi- or quadriflagellate zoospores, which are sometimes replaced by aplanospores. The zoospores are distinguished being larger and smaller, the smaller ones are known as androspores. Sexual reproduction is oogamous, filaments are homothallic or heterothallic. The present collection included the following genus only.

**Cylindrocapsa**  *Reinsch 1867: 66*

It includes unbranched filamentous algae with oblong-ellipsoid, cylindrical or short, quadrate cells. The cell are arranged mostly uniseriately, but rarely they are biseriate, multiseriate or in irregular portions. Vegetative reproduction takes place by fragmentation. Asexual reproduction by biflagellate zoospores has been recorded in some species, sexual reproduction is oogamous. Only following species was included in the present collection.
**C. involuta** Reinsch 1867: 66


**Fig. 16**

**Morphological characters:** Thallus polymorphic, filaments well-formed, unbranched, uniseriate, but portions appearing multicellular and parenchymatous.

**Cytological features:** Filamentous cells cylindrical, constricted at cross walls; cells 8-9 μm broad and 5-9 μm long; cell-wall thick, hyaline; chloroplasts massive, with a single or many pyrenoids.

**Reproductive structures:** Filaments dioecious; oogonia formed by the enlargement of one or more cells, being globose or pyriform, 9-12 μm broad and 11-13 μm long, dark reddish brown in colour; antheridia one or more in a row, formed by the repeated division of cell contents into 2, 4, 8 or 16 proplasts; antheridium 13-17 μm broad and 13-17 μm long.

**Localities:** Sheikhupura District: Faizpura Village (30-4-2004); Sialkot District: Darganwali Village (25-5-2004).

**Geographical distribution:** Previously reported from Europe & India (Ramanathan 1964).

**Remarks:** The observed specimens were collected during spring from ponds as free-floating, entangled masses and from road-side puddles.

**Order Microsporales**

Filamentous thallus; cell-wall composed of H-pieces. Detailed characters are given below in the family description.
Fig. 16. *Cylindrocapsa involuta*: a. uniseriate filament, b. becoming parenchymatous, c. antheridium formation, d. oogonium formation.
Family Microsporaceae

It comprises unbranched filamentous algae found mostly in freshwater. The cells are cylindrical or slightly barrel shaped, cell-wall is made up of “H-shaped” pieces in such a way that each protoplast is enclosed by overlapping halves of two successive H-shaped pieces. Shape of chloroplast varies with age and species of Microspora, it may be parietal plate, perforated or apparently reticulate. Pyrenoids are absent, nucleus is large, distinct and centrally placed. This family includes a single genus, which has been collected and described below.

Microspora Thuret 1850: 221

It comprises unbranched filaments, which are evidently sessile when young, but mostly free-floating when mature. The cells are cylindrical or slightly barrel shaped, with a cell-wall nearly homogenous in appearance in some species, but in most cases composed of H-pieces. So articulated that each protoplast is enclosed by the overlapping halves of two successive H-pieces, at the equatorial region; while in others they are heavily impregnated with wall material and appear striated. Reproduction is by formation of aplanospores and zoospores which may be bi- or quadri-flagellated. Sexual reproduction is not known. The following four species of this genus were collected, which may be distinguished as follows:

1. Cells constricted at the cross-walls.............................................................2
   Cells not constricted at the cross-walls...............................................\textit{M. wittrockii}

2. Cells always constricted at the cross-walls..........................................\textit{M. tumidula}
   Cells some times constricted at the cross-walls....................................3
3. Cells more than 15 µm broad.............................................\textit{M. loefgrenii}
   Cells less than 15 µm broad.............................................4

4. Cells up to 24 µm long......................................................\textit{M. floccosa}
   Cells less than 24 µm long.............................................\textit{M. tenerrima}

\textbf{\textit{M. floccosa} (Vaucher 1803: 131) Thuret 1850: 221}


\textbf{Fig. 17}

\textbf{Basionym:} \textit{Prolifera floccosa} Vaucher 1803: 131.

\textbf{Synonymy:} \textit{Lyngbya floccosa} (Vaucher) Hassall 1845: 223.

\textbf{Morphological characters:} Filaments unbranched, light blue in colour, on fragmentation
disassociate into H-pieces.

\textbf{Cytological features:} Cells generally cylindrical, seldom constricted at the cross-walls, 23-24 µm long and 13-15 µm broad; cell-wall in two sections overlapping in mid regions as indicated by broken ends of filament where section of terminal cell protrudes.

\textbf{Reproductive structures:} Thick walled akinetes were not observed.

\textbf{Locality:} Lahore District: Ghulam Colony (16-7-2004).

\textbf{Geographical distribution:} Widely distributed in North America, Europe, Asia (including India), Africa, Australia, New Zealand (Ramanathan 1964).

\textbf{Type locality:} Near Geneva, Switzerland.
Remarks: The collection was made during summer from paddy fields, where it occurred in massive growth and in free-floating condition.

*M. loefgrenii* (Nordstedt 1882) Lagerheim 1887: 417


**Fig. 18**

**Basionym:** *Conferva loefgrenii* Nordstedt 1882.

**Morphological characters:** Unbranched filaments.

**Cytological features:** Cells slightly swollen, short, cylindrical or rectangular, 15-17 µm broad and two times as long as broad; H-pieces clearly seen in the mid region; chloroplast net like, nearly covering the entire cell lumen.

**Reproductive structures:** A sexual reproduction by thick walled aplanospores.

**Locality:** Jhang District: Trimmu Head Works (22-1-2004).

**Geographical distribution:** Previously reported from Europe, Asia, Africa, North and South America.

**Remarks:** It was collected during winter, occurring in ponds mixed and attached with other algae.

*M. tenerrima* (Kützing) Gay 1886, *nom. nov.*

(Ramanathan 1964: 136)

**Fig. 19**

**Basionym:** *Conferva tenerrima* Kützing 1843, *nom. nov.*
**Synonymy:** *Ulothrix tenerrima* (Kützing 1843) Kützing 1853: 253.

**Morphological characters:** Thallus unbranched filaments, on fragmentation dissociate into H-pieces.

**Cytological features:** Cells short, cylindrical, 13-15 µm long and 6-7 µm broad; chloroplast varies in appearance either a parietal, folded, discontinuous plate or a mesh work of strands; cell-walls in two sections overlapping in the mid region, as indicated by the broken ends of the filaments where the section of the terminal cell protrudes.

**Reproductive structures:** In present collection reproductive structure were not observed.

**Locality:** Lahore Districts: Lakho Dahr (10-12-2004).

**Geographical distribution:** Cosmopolitan.

**Remarks:** The specimens were collected from a temporary pond near Lakho Dahr, Lahore during winter. They were found in free-floating state and low quantity because the temperature was not favourable for their growth.

**M. tumidula** Hazen 1902: 177


**Fig. 20**

**Morphological characters:** Unbranched filamentous forms.
Fig. 17. *Microspora floccosa*

Fig. 18. *Microspora losfgrenii*

20 μm

Fig. 19. *Microspora tenurina*

Fig. 20. *Microspora tumidula*: a. aplanospores formation, b. akinetes formation.
**Cytological features:** Cells nearly cylindrical, slightly constricted at cross-walls, 7-8 µm broad and 6.0-11.5 µm long; cell-wall thin; chloroplast dense, perforated, covering large portion of the cell contents.

**Reproductive structures:** Vegetative reproduction by akinetes, 8-11 µm thick, rounded or somewhat flattened, formed singly in each cell, released by a break up of the filaments into H-pieces; sexual reproduction doubtfully recorded.

**Localities:** Kasur District: 15 km away from Kasur (28-1-2004); Sialkot District: Darganwali Village (25-5-2003).

**Geographical distribution:** Recorded in brooks and stagnant waters of Europe, Asia (including India), Africa, North and South America (Ramanathan 1964).

**Remarks:** It was collected from two different localities of the Punjab during winter and spring being attached with the other free-floating algae. It was found in road-side puddles and temporary ponds, mixed with *Uronema confervicola* Lagerheim.

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*M. wittrockii* (Wille 1881: 20) Lagerheim 1887: 417


**Fig. 21**

**Basionym:** *Coferva wittrockii* Wille 1881: 20.

**Morphological characters:** Unbranched filaments.

**Cytological features:** Cells cylindrical, not constricted at cross-walls, 22-24 µm broad and 33-35 µm long; chloroplast in the form of thin sheet with perforation.

**Reproductive structures:** Aplanospores and hypnosporas were not observed.
Fig. 21. Microspora wittrockii

Geographical distribution: Asia, Africa, Europe, North and South America (Ramanathan 1964).

Remarks: The collection was made during summer from bank of a canal in free-floating state. The climate of Sheikhupura District is of semi-arid type. The soil at the place of collection was made up of silt, clay and large proportion of sand with pH 8 i.e. slightly alkaline.

Order Chaetophorales

Simple or branched, heterotrichous filaments; with plasmodesmata. Detailed characters are given below in the family description.

Family Chaetophoraceae

Individuals having branched filaments with basal distal differentiation. Branches terminate in a sharp point or in setae which may be several cells in length. Several genera have thalli enclosed in either firm and tough or in soft and amorphous mucilage. There are two general plans of growth. Some of them have prostrate development which may or may not give rise to erect branches. Others develop into erect thalli with little or no prostrate portion, but may have downwardly directed rhizoidal branches. Asexual reproduction is by zoospores and sexual by isogametes. The following two genera of this family were collected, which may be distinguished as follows:

1. Filaments poorly branched, enclosed in a thin mucilage…………………Stigeoclonium

   Filaments much branched, enclosed in firm, copious mucilage……………Chaetophora
Chaetophora Schrank 1789: 125

Thallus consisting of highly branched filaments, arising from a prostrate palmelloid mass of cells and enclosed by a mucilage of such firm consistency as to give the thallus a definite shape, such as globose, hemispherical or arbuscular. Branches tapering to either a blunt point or a long, multicellular, hyaline hair. Chloroplast is a parietal band, which in the upper cells completely covers the lateral walls, with one or more pyrenoids. Zoospores and isogametes are formed in the outer cells of the branches. Present collection included the following species:

C. attenuata Hazen 1902: 213


Fig. 22

Morphological characters: Thallus richly branched, branches radiating out from a common centre, embedded in compact mucilage to form smaller and larger globules.

Cytological features: Terminal cells of branches prolonged into long, colourless hairs; cells 5-6 µm broad and 18-19 µm long.

Reproductive structures: Reproductive structures were not observed.

Locality: Lahore District: Lakho Dahr (3-10-2004).

Geographical distribution: Previously reported from U.S.A.: Michigan.

Remarks: The collection work was done during autumn in the freshwater ponds. The specimens were obtained in the vegetative stage, being epiphytic on sub-merged grasses and water plants.
**Stigeoclonium Kützing 1843: 253**

Thalli heterotrichous with prostrate portion more developed than the erect part, coated with soft, inconspicuous mucilage. Erect portion is branched, the branches are mostly opposite or alternate according to species, ending in sharp points or taper to setae. The cells are cylindric or tumid. The chloroplast is a parietal plate with one pyrenoid. Some species have downwardly growing branches with irregularly thickened walls. Asexual reproduction is by bi- and quadri-flagellated zoospores. The following four species of this genus were collected, which may be distinguished as follows:

1. Branching alternate................................................................................................2
   Branching opposite................................................................................................3

2. Filaments short, tufted......................................................................................S. nanum
   Filaments elongated...........................................................................................S. elongatum

3. Cells more than 19 µm long..............................................................................S. tenue
   Cells less than 19 µm long...............................................................................S. lubricum

**S. elongatum (Hassall 1843: 428) Kützing 1849: 355**


Fig. 23

**Basionym:** Draparnaldia elongata Hassall 1843: 428.

**Synonymy:** Myxonema attenuatum Hazen 1902: 206, Stigeoclonium attenuatum (Hazen 1902) Collins 1909: 221

**Morphological characters:** Thalli alternately branched with elongated filaments; filaments 5.5-7.6 µm broad; ultimate branches gradually tapered.
Fig. 22. *Chaetophora attenuata*

Fig. 23. *Stigeoclonium elongatum*

Fig. 24. *Stigeoclonium lubricum*
Cytological features: Vegetative cells 5.5-7.6 µm broad; terminal cells modified into setae.

Reproductive structures: Reproductive structure were not observed.

Localities: Lahore District: fountain of Minar-e-Pakistan (10-4-2004), Handoo Village (5-5-2004), Mahmood Booti (2-7-2004); Sialkot District: near Ravi Marala Link Sambraal Road (6-4-2004).

Geographical distribution: Previously reported from Asia, America, Europe and New Zealand.

Type locality: England: Horse trough near Chestnut.

Remarks: It was collected during spring and summer from three different places of the Punjab. It was found growing in attached condition with sub-merged plants in stagnant water pools, paddy fields, tube well houses, road-side puddles and fountain of historical places.

*S. lubricum* (Dillwyn 1809: pl. 57) Kützing 1843: 1898


**Fig. 24**

Basionym: *Coferva lubrica* Dillwyn 1809: pl. 57.

**Morphological characters:** Thallus with prostrate and erect portions.

**Cytological features:** Cell-wall thick; cells 10-13 µm broad and 15-19 µm long; terminal cells modified into setae.

**Reproductive structures:** Reproductive organs were not observed.

**Localities:** Gujranwala District: Nandipur (19-2-2004), Singh Village (11-12-2004); Jhang District: Rabwah: (15-8-2004); Lahore: fountain of Badshahi Mosque (3-4-2003), Handoo Village (4-3-2004), Mahmood Booti (2-7-2003); Kasur District: Galwedah (11-3-2004); Azad Kashmir: Neelum Valley (5-4-2004).

**Geographical distribution:** Previously known from U.S.A. and other countries.

**Remarks:** It was collected during winter, spring and summer seasons from six different places of the Punjab (plane areas) and one place of Azad Kashmir (mountain area). It occurred in a variety of habitats such as discharge box of tube well, fountains, rice fields, road-side ponds, canal pools and stagnant water ponds, being epiphytic on sub-merged grasses.

*S. nanum* (Dillwyn 1809: pl. 30) Kützing 1849: 354


**Fig. 25**

**Basionym:** *Conferva nana* Dillwyn 1809: pl. 30.

Morphological characters: Thallus of short tufted filaments, branches arising alternately and tapering to a blunt point.

Cytological features: Cells of branches scarcely smaller than those of main axis, 9-11 µm broad, those of branches 4-9 µm broad; chloroplast parietal, reticulate; hair forming cells colourless; posterior portion extensively pseudoparenchymatous or filamentous; cells sub-globose, giving rise to vertical branches.

Reproductive structures: Reproductive structures were not observed.


Geographical distribution: Previously reported from U.S.A. and other countries of the world.

Remarks: It was collected during winter and was found in ponds on sub-merged plants (epiphytic along with *Aphanochaete* spp.) and canal-side ponds.

*S. tenue* (C. A. Agardh 1824: 34) Kützing 1843: 253

Fig. 25. *Stigeoclonium nanum*

Fig. 26. *Stigeoclonium tenue*
Basionym: *Draparnaldia tenuis* C. A. Agardh 1824: 34.


**Morphological characters:** Filaments with opposite branching; ultimate ends tapering.

**Cytological features:** Lower cells cylindrical, 9.0-12.5 μm broad and 23.0-43.5 μm long.

**Reproductive structures:** Reproductive structures were not observed.

**Localities:** Lahore: fountain of Minar-e-Pakistan (6-4-2004); Sheikhupura District: between Narang Mundi and Mureedke (20-9-2004); Sialkot District: near Bajra Village (25-5-2004).

**Geographical distribution:** Previously reported from India, U. S. A. (Forest 1954).

**Remarks:** The specimens were collected during spring and autumn being attached with rocks. It occurred in fountains, rice fields and permanent ponds, mixed with *Spirogyra* spp.

**Order Coleochaetales**

Branched filaments or discoid thalli, sheathed setae present; oogamous sexual reproduction; motile cells with a covering of scales.

**Family Aphanochaetaceae**

It is composed of genera in which cells have various types of bristles or hairs on their walls. The hairs arise either from the wall or from the protoplast and protrude through a pore in the wall. Some hairs have a sheated base. Algae are either unicellular or pseudo-filamentous. In general, they are prostrate or creeping. The chloroplast is a
parietal plate. Most of the algae included here are oogamous, with certain cells forming oogonia and antheridia. The present collection included only following genus:

*Aphanochaete* A. Braun 1851: 196

They algae are epiphytic on various aquatic plants. The thalli may be prostrate or with slightly erect open branches. Each cell has a parietal chloroplast with pyrenoids. Some cells may bear fragile hair, which are easily broken off. Reproduction is by quadriflagellated zoospores. Sexual reproduction, when present, is isogamous; the gametes being quadriflagellate. The following two species of this genus were collected, which may be distinguished as follows:

1. Cells spherical………………………………………………………………………………*A. repens*
   Cells rounded or slightly rectangular………………………………………………*A. polychaete*

*A. polychaete* (Hansgirg) Fritsch 1902: 411

(John *et al.* 2005: 434)

**Fig. 27**

**Basionym:** *Herposteiron polychaete* Hansgirg.

**Morphological characters:** Thallus sparsely branched, creeping or filamentous.

**Cytological features:** Cells rounded or slightly rectangular, 13-14 µm broad and 14-16 µm long; septa arising from the dorsal wall of each cell.

**Reproductive structures:** Reproductive structures were not observed.

**Locality:** Gujranwala District: Nandipur (19- 2-2004).

**Geographical distribution:** World wide.
Remarks: It was collected during winter and was found in a canal-side pond, epiphytic on submerged plants.

*A. repens*  A. Braun 1851: 196


**Fig. 28**

Synonymy: *Herposteiron repens* (A. Braun 1851) Wittrock 1872.

Morphological characters: Filaments creeping; setae borne singly on mature cells, up to 100 μm long.

Cytological features: Cells almost spherical, 5-10 μm broad and 8-16 μm long, constricted; each with parietal, plate-like chloroplast.

Reproductive structures: Reproductive organs were not observed.


Geographical distribution: Previously reported from Europe and U.S. A.

Remarks: Collections have been made during winter. It was found in a stagnant water pond, mixed with other free-floating, filamentous algae like *Cladophora* spp.

Family Coleochaetaceae

The thallus is either cushion-shaped or disc-like, some cells produce setae with a sheath at the base; thalli are mostly epiphytic; reproduction is by zoospores, sexual reproduction is oogamous. The following genus was present in the collected material.
**Coleochaete de Brébisson 1844: 29**

Thallus may be much branched and orbuscular; closely adhered to substratum. Some are discoid due to the marginal cell division in a radial and tangential direction; each cell contains a parietal, luminate chloroplast with pyrenoids; some cells bear setae, each with a basal sheath or collar; sheath and hairs are delicate and readily break off near the base; asexual reproduction is by biflagellated zoospores, produced singly by cells, aplanospores are also produced; sexual reproduction is oogamous; female reproductive cell has a trichogyne; antheridia are small cells, each producing a biflagellated spermatozoid. The following two species of this genus were collected, which may be distinguished as follows:

1. Cells oblong to pyriform.......................................................... C. pulvinata
2. Cells irregularly polygonal............................................................ C. scutata

**C. pulvinata A. Braun in Kützing 1849: 425**


**Fig. 29**

**Morphological characters:** Thallus heterotrichous, forming a cushion of irregularly branched filaments, radiating from a common center.

**Cytological features:** Cells oblong to pyriform, somewhat inflated anteriorly, 10-12 µm long and almost as broad as long.

**Reproductive structures:** In the present specimens reproductive structure were not seen.

**Locality:** Lahore District: Mahmood Booti (24-5-2005).

**Geographical distribution:** Worldwide.
Remarks: The observed specimens have been collected during summer. They were epiphytic on culum of *Paspalum distichum* in high quantity in the paddy fields.

**C. scutata de Brébisson 1844: 29**


**Fig. 30**

Morphological characters: The thallus is flat, 54-59 µm in diameter, formed from lateral fusion of radiating branching filaments, irregular in outline.

Cytological features: Cells irregularly polygonal, some with erect setae; vegetative cells 3-4 µm in diameter.

Reproductive structures: In present collection reproductive structure were not observed.

Locality: Jhang District: Rabwah (21-3-2004).

Geographical distribution: Previously reported from U. S. A.: Michigan, Wisconsin.

Remarks: The collections were made along the bank of river Chenab near Rabwah during summer. It was found as epiphytic on hydrophytes.

Class Zygnemophyceae Shameel 2001: 242

Filamentous thalli; peculiarity either in the form of cell division by cap-cell formation or in sexual reproduction by conjugation.
Order Oedogoniales

Cell division by cell-cap formation; sexual reproduction by oogamy; reproductive bodies stephanokontic. Detailed characters are given below in the family description.

Family Oedogoniaceae De Bary 1854: 94

Filaments may be unbranched while some genera are branched. Vegetative cells are uninucleated, cylindrical or with rounded ends. Chloroplast is a reticulate, parietal plate with numerous pyrenoids. During cell division caps are formed. Basal cell is specialized to serve as holdfast, terminal cell may be rounded or projects into a sheath. Asexual reproduction is by stephanokontic zoospores. Zoosporangia are box-like cells occurring in series, each producing a zoospore. Sexual reproduction is oogamous, oogonia are swollen, each with a large egg. Antheridia are also box like cells, each with a stephanokontic antherozoid. Species may be macrandrous or nannandrous, macrandrous species may be unisexual or bisexual. Nannandrous species have dwarf filaments (nannandria) produced from special stephanokontic cells known as androspores. Nannandrous species may be androsporous or gynandrosporous. The following two genera of this family were collected, which may be distinguished as follows:

1. Thallus branched……………………………………………………….Bulbochaete

Thallus unbranched………………………………………………………..Oedogonium

Bulbochaete  C. A. Agardh 1817: 17

Thallus is branched, filamentous, attached, some cells bear bulbous base, hairs are laterally or anteriorly present. Most species are epiphytic, cells are pyriform, reproduction
is oogamous. The following two species of this genus were collected, which may be distinguished as follows:

1. Branching occasional, cells up to 16 µm broad.................................\textit{B. mirabilis}

   Branching very common, cells more than 16 µm broad.......................\textit{B. intermedia}

\textbf{\textit{B. intermedia} De Bary 1854: 72}


Fig. 31


\textbf{Morphological characters:} Branched filaments; branching bilateral, attached to other filamentous algae.

\textbf{Cytological features:} Vegetative cells 17-20 µm broad and 35-70 µm long, sub-cylindrical or pyriform, 10-12 µm wide at septa, 17-18 µm wide at upper side (maximum width); hairs colourless, very long, 3-4 µm broad, with bulbous base (7-6 µm wide), alternate or on the same side; terminal cells with two hairs.

\textbf{Reproductive structures:} Reproductive structures were not observed.


\textbf{Geographical distribution:} Previously reported from U.S.A., Canada, Greenland, Europe, Africa and Australia.
Fig. 31. *Bulbochaete intermedia*

Fig. 32. *Bulbochaete mirabilis*
Remarks: Collection has been worked out during winter. It was found in ponds, epiphytic on other algae.

*B. mirabilis* Wittrock 1871: 171


Fig. 32


Morphological characters: Thallus small, richly branched; branching unilateral, attached by basal cells.

Cytological features: Cells 14-16 µm broad and 17-19 µm long, bearing a long colourless hair with bulbous base.

Reproductive structures: Antheridia and oogonia were not observed.

Locality: Lahore District: Lakho Dahr (30-3-2004).

Geographical distribution: Previously reported from U.S.A., Greenland, Europe, Siberia, Mongolia, Africa and Australia.

Remarks: The collection work was carried out during spring. It occurred in freshwater ponds, epiphytic on *Vaucheria* spp.

*Oedogonium* Link 1820: 5

Unbranched filaments of cells, which are slightly broader at anterior ends or almost cylindrical. Thalli are attached by means of basal holdfast, intercalary cells are
with one or more ring-like caps immediately below cross-walls. Cells are uninucleate, with reticulate chloroplast and many embedded pyrenoids. Thalli may be monoecious or dioecious, macrandrous or nannandrous having small male filaments, swarvers are stephanokontic. Oogonium has a slit or pore for the entry of sperms. Oospores may be globose, ellipsoidal, oblong or ovoid. The oospore wall may be smooth, spiny, scrobiculate, ribbed or striated. The following 24 species of this genus were collected, which may be distinguished as follows:

1. Terminal cell pointed.................................................................2
   Terminal cell not pointed.........................................................3

2. Terminal cell sharply pointed..............................................O. curtum
   Terminal cell spiny.................................................................O. pachydermum

3. Suffultory cell prominent....................................................4
   Suffultory cell not prominent..................................................5

4. Pore superior.................................................................O. laeve
   Pore nearly median...............................................................O. suecicum

5. Oogonium wall dentate......................................................6
   Oogonium wall smooth..........................................................7

6. Oogonial wall striated.......................................................O. exospireale
   Oogonial wall not striated....................................................8

7. Pore median.................................................................O. sociale
   Pore apical.........................................................................9

8. Oogonium up to 41 μm long................................................O. argentum
   Oogonium more than 41 μm long............................................O. foveolatum
9. Oospores completely filling the oogonia

Oospores not completely filling the oogonia

10. Antheridium up to 7 μm broad..................................................O. urbicum

Antheridium more than 7 μm broad..................................................12

11. Thalli monoecious........................................................................13

Thalli dioecious.............................................................................14

12. Thalli monoecious........................................................................O. globosum

Thalli dioecious.............................................................................O. irregulare

13. Epiphytic on Pithophora...............................................................O. pithophorae

Not epiphytic on Pithophora...........................................................15

14. Basal cell slightly swollen............................................................O. cardiacum

Basal cell not swollen....................................................................16

15. Vegetative cells less than 14 μm broad...........................................17

Vegetative cells more than 14 μm broad..........................................18

16. Vegetative cell more than 82 μm long.........................................O. grande

Vegetative cell less than 82 μm long................................................19

17. Vegetative cells up to 8 μm broad.................................................O. curvum

Vegetative cells more than 8 μm broad............................................20

18. Oogonium up to 38 μm long.......................................................O. plusiosporum

Oogonium more than 38 μm long...................................................O. obsoletum

19. Pore remiform.............................................................................O. rufescens

Pore not remiform.........................................................................21

20. Oogonium pyriform....................................................................O. pyriforum
Oogonium not pyriform.................................................................22

21. Vegetative cells irregularly swollen........................................O. nanum

Vegetative cells not irregularly swollen........................................23

22. Vegetative cell up to 35 µm long..............................................O. vaucherisi

Vegetative cell more than 35 µm long..........................................24

23. Vegetative cells up to 76 µm long............................................O. indicum

Vegetative cells up to 62 µm long..................................................25

24. Oospores ellipsoido-ovoid.......................................................O. pseudoboscii

Oospores globose.................................................................O. tyrolicum

25. Vegetative cells upto 13 µm broad.............................................O. inerme

Vegetative cells more than 13 µm broad.................................O. plagiostomium

**O. argentum** Hirn 1900: 289


**Fig. 33**

**Morphological characters:** Dioecious, unbranched filaments.

**Cytological features:** Vegetative cells 16-18 µm broad and 80-160 µm long.

**Reproductive structures:** Macrandrous; oogonium one, globose, 39-41 µm long, pore superior; outer layer of oospore wall scrobiculate. In observed specimens antheridia were not seen.

**Locality:** N.W.F.P.: Swat: Bahrain and Kalam (12-8-2004).

**Geographical distribution:** Previously reported from Brazil, U.S.A.: Michigan.
Remarks: Collection was made during summer, from slow running water channel in free-floating condition.

**O. cardiacum** (Hassall 1845: 203) Wittrock 1871: 135


Fig. 34

**Basionym:** *Vesiculifera cardiaca* Hassall 1845: 203.


**Morphological characters:** Filaments attached by a basal cell.

**Cytological features:** Basal cell slightly swollen; other cells cylindrical, 27-29 μm broad and 68-70 μm long; upper cell with minute tip.

**Reproductive structures:** In the present material reproductive organs were not observed.

**Locality:** Lahore District: Mureedke (8-3-2004).

**Geographical distribution:** U.S.A., Canada, Paraguay, England, Denmark, Sweden, Finland, France, Germany, Switzerland and Australia.

Remarks: The collection was made during spring. It was obtained from road-side ponds, epiphtic along with *Azolla pinnata* R. Br.

**O. curtum** Wittrock *et Lundell in* Wittrock 1870: 121

Fig. 33. Oedogonium argentum: a. a cell, b. oospore formation.

Fig. 34. Oedogonium cardiacum

Fig. 35. Oedogonium curium: a. small filament, b. oogonium.
Fig. 35

**Morphological characters**: Monoecious, unbranched filaments.

**Cytological features**: Terminal cells elongated; vegetative cells 10-11 μm broad and 70-80 μm long.

**Reproductive structures**: Macrandrous thalli; oogonium globose, 40-41 μm broad and 47-48 μm long; pore superior, oogonial wall smooth; antheridia 1-4, division horizontal.

**Locality**: N.W.F.P.: Swat: Kalam (12-8-2004).

**Geographical distribution**: Finland, Germany, Latvia, Sweden

**Remarks**: The collection was made during summer, from slow running water in attached condition and mixed with other free-floating algae.

*O. curvum* F. G. Pringsheim 1858: 69


Fig. 36

**Morphological characters**: Monoecious; unbranched filaments, usually irregularly curved.

**Cytological features**: Vegetative cells 6-8 μm broad and 32-38 μm long, basal cell elongated.

**Reproductive structures**: Oogonia 1-6, depressed-globose; oospores depressed-globose, filling or not filling oogonium; spore wall smooth; antheridia 1-7, one sperm in each.

**Locality**: Kasur District: Keothe (6-1-2004).

**Geographical distribution**: Previously reported from U.S.A., Germany, Spain and Sweden.
Fig. 37. *Oedogonium exospirale*: a. basal cell, b. vegetative cell, c. nannandrium and oogonium.

Fig. 36. *Oedogonium curvum*
Remarks: Collection has been made from freshwater ponds during winter season in free-floating state.

**O. exospirale** Tiffany 1924: 184

(Tiffany 1926: 102, 1930: 122)

Fig. 37

**Morphological characters:** Dioecious, unbranched filaments; basal cell swollen on the upper side.

**Cytological features:** Vegetative cells 13-14 μm broad and 68-69 μm long.

**Reproductive structures:** Nannandrous; oogonium one, globose, 40-41 μm broad and 47-48 μm long, pore median; ovum nearly filling the oogonium, outer layer marked with 4-5 spiral ribs; lower cell swollen as sufflutory; oospores 37-38 μm broad and 37-38 μm long; dwarf male stipe 14-16 μm broad and 30-40 μm long.

**Locality:** N.W.F.P.: Swat: Kalam (12-8-2004).

**Geographical distribution:** Previously reported from Brazil, U.S.A.: Iowa, Ohio and Mississippi.

Remarks: The collection was made from slow running water of river, during summer in the free-floating state.

**O. foveolatum** Wittrock 1878: 133

(Hirm 1900: 106, Tiffany 1930: 95)

Fig. 38

**Morphological characters:** Dioecious, unbranched filaments.
**Cytological features:** Vegetative cells 16.5-18.5 μm broad and 57-59 μm long.

**Reproductive structures:** Macrandrous; oogonium one, sub-ellipsoid to globose, 44-45 μm broad and 57-58 μm long; antheridia 1-7; sperms two, division horizontal; outer oospore-wall is scrobiculate; oospore 33.5-35.5 μm broad and 40-42 μm long.

**Localities:** Lahore District: Bhani Village (16-4-2004); N.W.F.P.: Swat: Kalam (12-8-2004).

**Geographical distribution:** Previously reported from Brazil (St. Thomas), India and Iceland.

**Remarks:** The collection was made from stagnant water ponds of border area and slow running water of river in bloom composition during spring and summer.

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**O. globosum Nordstedt 1878: 20**

(Hirn 1900: 94, Tiffany 1930: 74, Prescott 1962: 178)

**Fig. 39**

**Morphological characters:** Monoecious, unbranched filaments.

**Cytological features:** Vegetative cells 12-14 μm broad and 40-48 μm long; basal cell elongated.

**Reproductive structures:** Macrandrous thalli; oogonium one, globose, pore superior; ova 46-48 μm in diameter, quite filling oogonium; oogonium wall smooth; antheridia 4, 8-10 μm broad and 5-7 μm long; sperms two, division horizontal; oospores 37-39 μm in diameter.

**Localities:** Lahore District: Bhani Village near border area (16-4-2004); N.W.F.P.: Swat: Kalam (12-8-2004).
Fig. 38. *Oedogonium foveolatum*: a. vegetative cell, b. oospore formation.

Fig. 39. *Oedogonium globosum*
**Geographical distribution:** Previously reported from U.S.A., Greece, Serbia, India and Australia.

**Remarks:** Collections were obtained during spring and summer, from stagnant water ponds and slow running water of the river being attached with rocks.

**O. grande** Kützing 1845: 200


**Fig. 40**

**Morphological characters:** Dioecious, unbranched filaments.

**Cytological features:** Vegetative cells 26-27 μm broad and 82-84 μm long.

**Reproductive structures:** Macrandrous thalli; oogonium 1-5, sub-ovoid, 44-46 μm broad and 82-84 μm long; oospore of the same form as oogonium which completely fills or not; spore-wall smooth; male filament not seen.

**Locality:** Kasur District: Al-Feroze Town (9-12-2004).

**Geographical distribution:** U.S.A.: California, Mississippi, Ohio, Pennsylvania; Sweden; Switzerland and Australia.

**Remarks:** The collection was obtained from temporary ponds of the village in winter being attached with the walls of ponds.

**O. indicum** Hirn 1900: 269

(Tiffany 1930: 139)

**Fig. 41**
Fig. 40. *Oedogonium grande*: a. basal part, b. oogonium, c. oospore formation.

Fig. 41. *Oedogonium indicum*: a. basal part, b. oogonia.
**Morphological characters:** Dioecious, unbranched filaments.

**Cytological features:** Vegetative cells 25-27 μm broad and 57-76 μm long.

**Reproductive structures:** Nannandrous; oogonia 1-2, depressed-globose or depressed obovoido-globose 49-51 μm broad and 57-64 μm long, oospores depressed-globose, completely filling oogonium; spore-wall smooth.

**Locality:** Kasur District: Kot Mela Ram (28-1-2004).

**Geographical distribution:** Previously reported from India.

**Remarks:** The collection was obtained from temporary ponds of the village during winter in free-floating state.

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**O. inerme** Hirn 1900: 287

(Tiffany 1930: 166)

(Fig. 42)

**Morphological characters:** Dioecious, unbranched filaments.

**Cytological features:** Vegetative cells 11-13 μm broad.

**Reproductive structures:** Macrandrous; oogonium one, 30-32 μm broad and 33-35 μm long; oospores not filling the oogonium, 23-25 μm broad and 25-27 μm long; spore-wall smooth; male filament with antheridia not observed.

**Locality:** Sheikhpura District: Sattarwala Village (15-8-2004).

**Geographical distribution:** Previously reported from France, India.

**Remarks:** The collections were made during summer from paddy fields in free-floating state. The soil at the place of collection was made up of silt, clay and large proportion of sand with pH 8.0.
**O. irregulare** Wittrock 1871: 128


**Fig. 43**

**Morphological characters:** Dioecious and unbranched filaments.

**Cytological features:** Vegetative cells 19-21 μm broad and 62-64 μm long.

**Reproductive Structures:** Oogonium one globose, 39-40 μm broad and 41-43 μm long; oospores globose, completely filling oogonium, spore wall smooth; oospores 38 μm and 37 μm long.

**Locality:** Sargodha District: Sargodha (22-4-2005).

**Geographical distribution:** Previously reported from Denmark, Sweden, Canada, U.S.A.: Michigan, Illinois, Ohio, Florida, India, Myanmar.

**Remarks:** The collection has been made from slow running water channels during spring. It was obtained in free-floating state.

**O. laeve** Wittrock 1875: 8


**Fig. 44**

**Morphological characters:** Monoecious, unbranched filaments.

**Cytological features:** Vegetative cells 13-14 μm broad and 27-28 μm long.

**Reproductive structures:** Macrandrous; oogonium one, globose, pore superior; oogonial wall smooth; antheridia in series of 4-6, 6-7 μm broad and 10-11 μm long; oospores 23-24 μm broad and 27-28 μm long.
Fig. 42. **Oedogonium inerme**

Fig. 43. **Oedogonium irregularare.**

Fig. 44. **Oedogonium leave:** a. basal part, b. oogonium

20 μm


Remarks: The collection has been made from slow running water of the river during summer in large quantity in free-floating state as well as attached by the sides of river.

**O. nanum** Wittrock 1875: 37

(Hirn 1900: 305, 1930: 109, Prescott 1962: 185)

Fig. 45

Morphological characters: Dioecious, unbranched filaments.

Cytological features: Vegetative cells often irregularly swollen, 6-10 μm broad and 30-33 μm long.

Reproductive structures: Macrandrous; oogonia 1-3, ovoid to broadly ellipsoid, 24-26 μm broad and 32-34 μm long; oospores ovoid to globoso-ellipsoid, usually filling the oogonium; spore-wall smooth; antheridia were not observed.


Geographical distribution: Previously reported from India, U.S.A.: Iowa.

Remarks: The specimens were collected during winter in attached condition. It was obtained from stagnant water ponds along with *Pithophora* spp.

**O. obsoletum** Wittrock 1874: 9

(Hirn 1900: 83, Tiffany 1930: 69, John et al. 2005: 426)

Fig. 46

Synonymy: *Oedogonium vernal* Wittrock.
Fig. 45. *Oedogonium nanum*

Fig. 46. *Oedogonium obsoletum*: a. vegetative cell, b. oospore formation.
Morphological characters: Monoecious, unbranched filaments.

Cytological features: Vegetative cells 13-14 μm broad and 64-65 μm long.

Reproductive structures: Macrandrous; oogonium one, sub-globose, pore a little above median, 34-35 μm broad and 44-45 μm long; oospores not completely filling the oogonia; spore-wall smooth; antheridia were not seen.


Remarks: It was found in slow running water channel during summer in free-floating state.

O. pachydermum Wittrock et Lundell 1871: 125

(Hirn 1900: 188, Tiffany 1930: 115, Prescott 1962: 192)

Fig. 47

Morphological characters: Unbranched filaments.

Cytological features: Terminal cell spiny; vegetative cells 23-24 μm broad and 99-100 μm long.

Reproductive structures: In this collection no reproductive structures was observed.


Geographical distribution: Previously reported from Finland and Sweden.

Remarks: The collection was made only in vegetative stage from the rice fields near Hunjawal during autumn being attached with the soil.
Fig. 47. *Oedogonium pachydermum*: a, terminal cell, b, small filament, c, vegetative cell.

20 μm

Fig. 48. *Oedogonium pithophorae*
O. pithophorae Wittrock 1878: 141

(Hirn 1900: 167, Tiffany 1930: 112)

Fig. 48

**Morphological characters:** Monoecious, unbranched filaments.

**Cytological features:** Basal cell elongated; vegetative cells 9-11 \( \mu \)m broad and 19-32 \( \mu \)m long.

**Reproductive structures:** In the present collection reproductive structures were rarely present.

**Localities:** Lahore District: Mahmood Booti (2-7-2004); Sheikhupura District: between Mureedke and Narang Mundi (12-9-2004).

**Geographical distribution:** Previously reported from West India (Tiffany 1930), West Indies.

**Remarks:** It was collected from two different areas of the Punjab during summer and autumn in association with *Pithophora* spp. as epiphyte. The massive growth of this species was found in paddy fields being attached with the soil.

O. plagiostomum Wittrock *ex* Hirn 1875: 41


Fig. 49

**Morphological characters:** Dioecious, unbranched filaments.

**Cytological features:** Vegetative cells 21-23 \( \mu \)m broad and 57-59 \( \mu \)m long.
Reproductive structures: Macrandrous thalli; oogonium obovoid, 41-43 \(\mu\)m broad and 49-51 \(\mu\)m long; oospores sub-globose, filling entire oogonium; spore-wall smooth, spores 40-42 \(\mu\)m broad and 47-48 \(\mu\)m long; antheridal filaments were not observed.


Geographical distribution: Previously reported from India, South Africa, Sweden and U.S.A.

Remarks: The collections were made during spring and autumn in free-floating state from slow running water and paddy fields, from two different places of the Punjab.

\textit{O. plusiosporum} Wittrock 1875: 11

(Wolle 1887: 72, Hirn 1900: 84, Tiffany 1930: 70, Prescott 1962: 180)

Fig. 50

Morphological characters: Monoecious, unbranched filaments.

Cytological features: Vegetative cells 13-14 \(\mu\)m broad and 51-52 \(\mu\)m long.

Reproductive structures: Macrandrous; oogonium one, globose, pore a little above median, 34-35 \(\mu\)m broad and 37-38 \(\mu\)m long; oospores 30-31 \(\mu\)m broad and 34-35 \(\mu\)m long; anthredia 6-8 \(\mu\)m broad and 11-12 \(\mu\)m long.


Remarks: The collection was carried out during summer. It was found in slow running water-pools in free-floating condition.
Fig. 49. *Oedogonium plagiostomum*

Fig. 50. *Oedogonium pliosporum*: a. vegetative cell, b. oogonium.
**O. pseudoboscii** Hirn 1895: 291


**Fig. 51**

**Synonymy:** *Oedogonium neglectum* Hirn 1895: 21.

**Morphological characters:** Unbranched, monoecious filaments.

**Cytological features:** Vegetative cells 18-20 µm broad and 138-140 µm long.

**Reproductive structures:** Oogonium 1, ellipsoid, 62-64 µm broad and 101-103 µm long; oospore ellipsoido-ovoid, lower part of oogonium inflated; spore wall smooth; oospore 56-58 µm broad and 87-89 µm long.

**Locality:** Sargodha District: Sargodha (22-4-2005).

**Geographical distribution:** Previously reported from Russia, Finland, U. S. A.: Wisconsin, Alabama, Massachusetts.

**Remarks:** The specimens were collected during spring from a slow running water channel. They were found in free-floating state and growing in massive quantity, because the environmental conditions like pH and temperature of water were suitable for its growth.

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**O. pyriforme** Wittrock 1875: 39


**Fig. 52**

**Morphological characters:** Monoecious, unbranched filaments.

**Cytological features:** Vegetative cells 14-18 µm broad and 39-49 µm long.
Fig. 51. *Oedogonium pseudoboscii*

Fig. 52. *Oedogonium pyriforme*: a. vegetative cell, b. oogonium.

Fig. 53. *Oedogonium rufescens*

20 μm
Reproductive structures: Macrandrous; oogonium occurs singly, 39-41 μm long and 44-46 μm broad, operculate; oospores pyriform, not completely filling the oogonia, pore above the median; oospores 35.5-37.5 μm in diameter, spore-wall smooth; antheridia two, 10-12 μm broad and 8-12 μm long; two sperms in each antheridium, division horizontal.

Localities: Lahore District: Salamatpura, near border area (2-4-2004); N.W.F.P.: Swat: Usla and Utrod River in Kalam (13-8-2004).

Geographical distribution: Previously reported from Canada, Columbia, India and Australia (Tasmania).

Remarks: It has been collected during spring from Punjab and during summer from N.W.F.P. It was found on rock surfaces along the river and mainly from road-side puddles of the villages in attached state.

O. rufescens Wittrock 1871: 134


Fig. 53

Morphological characters: Dioecious, unbranched filaments.

Cytological features: Vegetative cells 8-11 μm broad and 23-34 μm long.

Reproductive structures: Macrandrous thalli; oogonia 1-3, obovoid or depressed obovoido-globose, pore median, reniform, 21-22 μm broad and 22-23 μm long; oospores
globose or depressed-globose, 20-21 µm in diameter; filling oogonium or so, spore-wall smooth.

**Localities:** Lahore District: Hunjarwal (16-8-2004); Jauharabad District: near Jauharabad (25-4-2004); N.W.F.P.: Attock (12-1-2004).

**Geographical distribution:** Previously reported from U.S.A. (Ohio), Sweden, Denmark, France, Austria, England, Germany, Latvia, South Africa, Southern Tibet.

**Remarks:** It occurred in stagnant water ponds mixed with other free-floating algae during winter and spring and also found in Hunjarwal rice fields during summer.

**O. sociale** Wittrock 1882


**Fig. 54**

**Synonymy:** *O. ochroleucum* Kützing in Rabenhorst 1862.

**Morphological characters:** Dioecious, unbranched filaments, attached by basal spherical holdfast.

**Cytological features:** Terminal cell rounded, cell-wall smooth, vegetative cells 13-16 µm broad and 35-82 µm long.

**Reproductive structures:** Macrandrous thalli; oogonium one, sub-globose, 33-36 µm broad and 40-43 µm long, pore median; oospores globose, almost filling the oogonia, 31-32 µm broad and 31-33 µm long; spore-wall smooth.

**Localities:** Lahore District: between Bund Road and Mureedke (17-3-2004); Sargodha Districts: Sargodha (22-4-2005); Sheikhupura District: between Mureedke and Narang Mundi (20-9-2004); N.W.F.P.: Swat: Kalam (12-8-2004).
**Fig. 54. Oedogonium sociale:** a. vegetative cell, b. filament with oogonium.

**Fig. 55. Oedogonium suecicum:** a. basal cell, b. oogonium and suffultory cell.
**Geographical distribution:** Previously reported from China, U.S.A.: Wisconsin, Illinois, Mississippi; Austria, Sweden, Latvia, Canada, Germany, Myanmar, India, Tibet, Australia (Tiffany 1930).

**Remarks:** It was collected from three different places during spring, summer and autumn seasons. Morphological differences were seen within specimens collected from different localities and due to seasonal variations. Higher growth was found in rice fields as compared to other localities such as slow running water of the river where they occurred as epiphyte on *Spirogyra* spp.

**O. suecicum Wittrock 1874: 30**


**Fig. 55**

**Synonymy:** *Oedogonium trichosporum* Itzig in Rabenhorst 1868: 426.

**Morphological characters:** Dioecious, unbranched filaments.

**Cytological features:** Basal cell elongated, vegetative cells 10-12 µm broad and 75-78 µm long.

**Reproductive structures:** Macrandrous thalli; oogonium occurs singly, with or without suffultory cell, sub-globose, pore slightly above median, oogonial wall echinate; oospores globose, nearly filling the oogonium, 26-28 µm broad and 30-31 µm long; antheridia 3-5 in a series, each with single sperm; sperm 10-11 µm broad and 10-11 µm long.

**Locality:** N.W.F.P.: Swat: Kalam (12-8-2004).
Fig. 56. *Oedogonium tyrolicum*: a. vegetative cell, b. oospore formation.

Fig. 57. *Oedogonium urbicum*: a. vegetative cell, b. oogonium.

20 μm
**Geographical distribution:** Previously reported from Canada, U.S.A., Austria, Denmark, Germany, Finland, France, Latvia, Iceland, Norway, Sweden, South Africa and Australia.

**Remarks:** It occurred in slow running water of river and was collected during summer in free-floating state.

*O. tyrolicum* Wittrock 1875: 12


*Fig. 56*

**Morphological characters:** Monoecious, unbranched filaments.

**Cytological features:** Vegetative cells, 10-15 $\mu$m broad and 60-65 $\mu$m long.

**Reproductive structures:** Macrandrous thalli; oogonium one, ellipsoid, pore superior (not clear); oospores globose, not filing the oogonium; oogonial wall smooth; anthidia were not seen.

**Locality:** N.W.F.P.: Swat: between Bahrain and Kalam (12-8-2004).

**Geographical distribution:** Austria, England, Sweden, U.S.A.: Massachusetts, Iowa.

**Remarks:** Collection work was done during summer, it occurred in free-floating state in slow running water of the river.

*O. urbicum* Wittrock 1874: 13

(Hirn 1900: 91, Tiffany 1930: 69, John *et al.* 2005: 432)

*Fig. 57*
Synonymy: *Oedogonium tumidulum* Pringsheim 1855: 158.

Morphological characters: Monoecious, unbranched filaments.

Cytological features: Vegetative cells 13-14 \( \mu m \) broad and 78-79 \( \mu m \) long.

Reproductive structures: Macrandrous thalli; oogonium one, ellipsoido-globose, 37-39 \( \mu m \) broad and 40-41 \( \mu m \) long, pore above median; oogonial wall smooth; antheridia 6-7 \( \mu m \) broad and 13-14 \( \mu m \) long; sperm two, division horizontal.


Geographical Distribution: Previously reported from U.S.A., France Germany and Sweden.

Remarks: The collection was obtained during summer in free-floating condition from river.

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*O. vaucheri* (Le Clerc 1817: 474) A. Braun 1855: 40


Fig. 58


Morphological characters: Monoecious; unbranched filaments.

Cytological features: Vegetative cells 20-21 \( \mu m \) broad and 34-35 \( \mu m \) long.

Reproductive structures: Macrandrous thalli; oogonium one, obovoid to globose, 37-40 \( \mu m \) broad and 44-46 \( \mu m \) long, pore superior; oogonial wall smooth; antheridia 1-4, 6-7 \( \mu m \) broad and 15-17 \( \mu m \) long; sperm two, division horizontal.
Fig. 58. *Oedogonium vaucheri*: a. vegetative cell, b. oogonia.

Geographical distribution: Previously reported from U.S.A., France, Germany, Denmark, India, Italy, Sweden and Switzerland.

Remarks: The collection was made during summer, where it occurred in free-floating state in the river water.

Order Zygnemales

Thallus secretes copious mucilage; unbranched filaments, cell division normal, cells uninucleated having prominent chloroplast and a row of pyrenoids; chloroplast bar like, stellate, or ribbon like; cell-wall three layered, outer being slimy and amorphous, inner two layers fibrillar; reproduction by fragmentation or by aplanospore formation; sexual reproduction by conjugation, fusion of amoeboid gametes through a close passage (conjugation tube); conjugation may be scalariform or lateral, reproductive bodies aflagellated.

Family Zygenemaceae

Filamentous, normally unbranched, free-floating, planktonic; filaments straight or spirally twisted; cell-wall without pores or external marking; chloroplasts few, axial plate, ribbon like bodies, spirally coiled and cushion shaped; no basal differentiation except for some rhizoidal out-growths; reproduction by fragmentation or by aplanospore formation; sexual reproduction by conjugation, fusion of amoeboid gametes mostly through conjugation tube formed between gametangia; zygospores formed either in the
conjugation tube or within one of the gametangia (isogamy or anisogamy). Following five genera were collected which may be distinguished as follows:

1. Chloroplasts ribbon like ................................................................. Spirogyra

   Chloroplasts otherwise ................................................................. 2

2. Chloroplasts many, 2-7 ................................................................. Hallasia

   Chloroplast only 1 or 2 ................................................................. 3

3. Chloroplast one, axial plate .......................................................... Mougeotia

   Chloroplasts two, stellate ............................................................. 4

4. Zygospores mostly spherical .................................................... Zygnema

   Zygospores quadrate ................................................................. Zygnemopsis

**Hallasia Rosenvinge 1924: 212**

At the beginning of spore formation the number of chloroplasts increases up to seven. It forms 1-3 sporelings on the germination of aplanospores. Only the following species could be collected:

**H. reticulata Rosenvinge 1924: 209**

(Transeau 1951: 61, Randhawa 1959: 186)

**Fig. 59**

**Morphological characters:** Unbranched filaments.

**Cytological features:** Vegetative cells 18-20 μm broad and 35-100 μm long, 2-7 stellate chloroplasts in each cell.
Fig. 59. *Hallasia reticulata*: a. vegetative cells, b. aplanospore formation.
**Reproductive structures:** Reproduction by aplanospores only, aplanospores ellipsoid up to 35 \( \mu m \) in diameter and 60 \( \mu m \) long, median spore-wall yellow, scrobiculate or irregularly reticulate; sporogenous cells longer than broad, length up to 240 \( \mu m \). On germination the content of the spores may become divided into 20 or 30 parts from each of which a new filament develops. Sometimes only a filament develops from a spore.

**Locality:** Lahore District: Minar-e- Pakistan (21-3-2004).

**Geographical distribution:** Previously reported from Denmark: Copenhagen.

**Remarks:** Specimens were collected from fountain of the historical place at the beginning of spring in free-floating state. It was found in vegetative condition as well as in reproductive state.

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**Mougeotia C. A. Agardh 1824: 35**

Filaments unbranched, consisting of cylindrical cells; cells many time longer than broad, with plane end walls; chloroplast a flat axial plate with the nucleus apposed to the cell-wall, where two chloroplasts occur in each cell the nucleus situated in between the chloroplasts; pyrenoids arranged in one or many rows; reproduction in the majority of species by zygospores while in some by aplanospores; conjugation largely scalariform, rarely lateral and isogamous in all species except three; conjugation canal bulges and gametangia cut off by one or two walls; zygospores spheroid, ovoid, ellipsoid, doliform or quadrato-ovoid. The following four species could be collected, which may be distinguished as follows:

1. Vegetative cells more than 22 \( \mu m \) broad

   
   
   Vegetative cells up to 22 \( \mu m \) broad
2. Vegetative cells more than 120 µm long……………………………….. *M. elegantula*

Vegetative cells up to 120 µm long………………………………………………..3

3. Vegetative cells up to 14 µm broad………………………...…………….. *M. calcarea*

Vegetative cells more than 14 µm broad ……………………………..*M. sphaerocarpa*

**M. calcarea (Cleve 1868) Wittrock 1872: 40**


**Fig. 60**

**Basionym:** *Sphaerospermum calcarea* Cleve 1868.

**Morphological characters:** Filaments 13-14 µm broad.

**Cytological features:** Vegetative cells 57-109 µm long; chloroplasts with 4-5 pyrenoids in a single row; cells elongating, becoming geniculate before spore formation.

**Reproductive structures:** Conjugation scalariform; zygospores formed in the conjugating tube and extending in both gametangia, globose 28-29 µm in diameter; spore wall smooth, colourless; aplanospores were not observed.

**Locality:** Sargodha District: Sargodha (12-4-2004).

**Geographical distribution:** Previously reported from India, Brazil Greenland, Canada, and U.S.A: Michigan.

**Remarks:** Speciemens were collected near Sargodha City during spring. They were found in free-floating in vegetative, as well as reproductive states.
Fig. 60. Mougeotia calcarea: a. part of filament, b. zygospore formation.

Fig. 61. Mougeotia elegantula: a. vegetative cell, b. scalariform conjugation.
M. elegantula Wittrock 1872: 40


Fig. 61

Morphological characters: Filaments very slender, becoming geniculate in conjugation.

Cytological features: Vegetative cells 4-6 µm broad and 140-143 µm long; chloroplast with 4-8 pyrenoids in a row.

Reproductive structures: Conjugating cells geniculate; conjugation scalariform, sporangium dividing both gametangia; zygospores quadrate 16-18 µm broad and 16-18 µm long with rounded corner; spore-wall hyaline and smooth.

Locality: Sialkot District: Head Marala (7-7-2004).

Geographical distribution: Europe, China, U.S.A.

Remarks: The collection work was carried out during summer in mixed and attached condition with sub-merged grasses. Specimens were found in stagnant water channels. They occurred in vegetative as well as reproductive stages. The temperature, locality and pH of water were favourable for their growth.

M. genuflexa (Dillwyn) C.A. Agardh 1824: 83


Fig. 62

Basionym: Conferva genuflexa Dillwyn.
Morphological characters: Filaments slender.

Cytological features: Vegetative cells 33-53 μm broad and 84-86 μm long, often geniculate and attached to other similar cells, forming extensive nets; sometimes with rhizoidal branches.

Reproductive structures: Conjugation stage was not found in the present material.


Geographical distribution: Europe, China (Kiangni), Manchuria, Morocco.

Remarks: The collection work was carried out in the autumn season from a village, which was totally a cultivated area. During this season rich growth of algae occurred as compared to other seasons, as heavy rainfall took place. This species was found in free-floating state in stagnant water pools.

\[\text{M. sphaerocarpa} \quad \text{Wolle 1887: 227}\]


Fig. 63

Morphological characters: Unbranched filaments.

Cytological features: Vegetative cells 18-22 μm broad and 60-120 μm long; chloroplast plate like; pyrenoids 4-7 in a regular row..

Reproductive structures: Conjugation scalariform; zygospores formed in greatly enlarged conjugating tube and extending somewhat into both gametangia; zygospores ovoid to sub-globose, 38-40 μm broad and 44-46 μm long.
Fig. 62. Mougeotia gemiflexa

Fig. 63. Mougeotia sphaerocarpa: a. vegetative cell, b. zygospore formation.

20 µm
Localities: Kasur District: Kot Mela Ram (8-10-2004); Azad Kashmir: Neelum Valley (6-4-2004).

Geographical distribution: U.S.A., China, India.

Remarks: Specimens were collected from two different places in different. During autumn it occurred in massive quantity in planktonic form. It was raining heavily during this time and many stagnant ponds were formed which provided favourable condition for its growth, as compared to those found during spring.

**Spirogyra** Link 1820: 5

Filaments are free-floating and rarely attached. Cells are cylindrical, much longer than broad, with plane, colligate, semi-replicate or replicate septa. The chloroplasts are 1-16, spirally arranged, parietal, ribbon like bodies with numerous prominent pyrenoids, nucleus is centrally situated in protoplasmic strands in the form of primordial utricle. Reproduction is by fragmentation or by zygospores and aplanospores. Conjugation is scalariform or lateral, zygospores are usually ellipsoid but rarely may be ovoid or lenticular. The median spore-wall is pale-yellow to chestnut-brown in colour and is either smooth or variously ornamented. After a large survey following 42 species have been collected which may be distinguished as follows:

1. Chloroplast one

2. Chloroplasts more than one

3. Vegetative cells up to 35 µm broad

4. Vegetative cells more than 35 µm broad

5. Vegetative cells up to 30 µm broad

*S. submarina*
Vegetative cells more than 30 µm broad……………………………………..6

4. End wall plane……………………………………………………………………..7
   End wall replicate……………………………………………………………………..8

5. End wall reticulate……………………………………………………………………..9
   S. nyctigama
   End wall plane……………………………………………………………………..9

6. Vegetative cells up to 138 µm long……………………………………………….10
   Vegetative cells more than 138 µm long…………………………………………11

7. Vegetative cells up to 125 µm long………………………………………………...12
   Vegetative cells more than 125 µm long…………………………………………13

8. Conjugation tube formed by one gametangium only…………………………..14
   S. pseudospeeriana
   Conjugation tube formed by both gametangia……………………………………..14

9. Chloroplast swollen……………………………………………………………….15
   S. juergensii
   Chloroplast not swollen……………………………………………………………….15

10. Chloroplasts making half spiral…………………………………………………...16
    S. crassa
    Chloroplasts making complete spiral………………………………………………16

11. Chloroplasts making up to 3 turns in each cell………………………………...17
    S. dubia
    Chloroplasts making more than 3 turns in each cell……………………………..17

12. End wall slightly swollen…………………………………………………………17
    S. mirabilis
    End wall not swollen………………………………………………………………17

13. Zygospores ovoid…………………………………………………………………18
    S. subsala
    Zygospores ellipsoid………………………………………………………………18

14. Zygospores ovoid…………………………………………………………………19
    Zygospores ellipsoid………………………………………………………………19

15. Zygospores ellipsoid………………………………………………………………19

16. Zygospores ellipsoid………………………………………………………………20
15. Mesosporium granulated .................................................. S. kaffirita
    Mesosporium smooth ................................................. 21
16. Zygospores up to 51 µm broad .......................................... 22
    Zygospores more than 51 µm broad ............................. 23
17. Zygospores up to 28 µm long ......................................... 24
    Zygospores more than 28 µm long ............................. 25
18. Mesosporium smooth .................................................. S. fragilis
    Mesosporium irregularly reticulate .............................. S. populata
19. Zygospores with pointed end ........................................... S. farlowii
    Zygospores without pointed end .................................. 26
20. Vegetative cells up to 90 µm long ................................ S. jaoi
    Vegetative cells more than 90 µm long ........................ S. semiornata
21. Vegetative cells more than 200 µm long ........................ S. singularis
    Vegetative cells less than 200 µm long ........................ 27
22. Zygospores ovoid .................................................... S. dacimina
    Zygospores ellipsoid ................................................ 28
23. Zygospores ellipsoid ................................................ S. hyalina
    Zygospores lenticular ............................................... S. majuscula
24. Conjugation only scalariform ........................................ 29
    Conjugation both lateral and scalariform ....................... 30
25. Conjugation only scalariform ....................................... 31
    Conjugation both lateral and scalariform ....................... 32
26. Mesosporium smooth .................................................. S. arta
Mesosporium foveolate...........................................................................S. tandae

27. Zygospores up to 52 µm broad.........................................................S. luteriana

Zygospores more than 52 µm long..................................................S. peripingeriens

28. Zygospores with rounded end..........................................................S. buchetii

Zygospores not with rounded end...................................................S. irregularis

29. Zygospores ovoid.............................................................................S. paludosa

Zygospores elliptoid...........................................................................33

30. Zygospores polymorphic.................................................................S. pratensis

Zygospores elliptoid...........................................................................34

31. Mesosporium smooth......................................................................35

Mesosporium reticulate......................................................................36

32. Zygospores polymorphic.................................................................S. varians

Zygospores elliptoid...........................................................................37

33. Zygospores not with rounded end....................................................S. gracilis

Zygospores without rounded end.....................................................S. intorta

34. Zygospores with pointed end............................................................S. gibberosa

Zygospores not with pointed end.....................................................S. parvula

35. Zygospores polymorphic.................................................................S. polymorpha

Zygospores elliptoid...........................................................................38

36. Zygospores up to 38 µm long............................................................S. daedlea

Zygospores more than 38 µm long...................................................S. oudhensis

37. Zygospores more than 47 µm long....................................................S. communis

Zygospores up to 47 µm long.............................................................39
38. Vegetative cells less than 99 µm long ........................................40
   Vegetative cells more than 99 µm long ..................................41
39. Conjugation tube formed by one gametangium only ..................S. chenii
   Conjugation tube formed by both gametangia .........................S. teodorisci
40. Fertile cells slightly inflated ..............................................S. silvicola
   Fertile cells strongly inflated ..........................................S. reflexa
41. Mesosporium yellow .......................................................S. borgeana
   Mesosporium yellowish-brown ...........................................S. fennica

**S. arta** Jao 1935: 602

(Transeau 1951: 210, Randhawa 1959: 354)

**Fig. 64**

**Morphological characters:** Unbranched filaments.

**Cytological features:** Vegetative cells 13-15 µm broad and 227-229 µm long, with replicate end wall; chloroplast one, making 3-8 turns in the cell.

**Reproductive structures:** Conjugation scalariform; tube formed by both gametangia; fertile cell enlarged, rarely inflated; zygospores ellipsoid to cylindrical, 23-25 µm broad and 51-53 µm long; median spore-wall yellow and smooth.

**Locality:** Jhang District: near Chund (30-2-2004).

**Geographical distribution:** India (Mumbai), China.

**Remarks:** The collection work was carried out during winter, from stagnant water ponds. It occurred in free-floating state mixed with other planktonic algae.
Fig. 64. *Spirogyra arta*: a. vegetative cell, b. zygospore formation.

Fig. 65. *Spirogyra borgeana*: a. vegetative cell, b. zygospore formation.
**S. borgeana** Transeau 1915: 23


**Fig. 65**

**Morphological characters:** Unbranched filaments.

**Cytological features:** Vegetative cells 29-35 μm broad and 108-110 μm long, with plane septa; chloroplast one, making 1.5-4 turns in the cell.

**Reproductive structures:** Conjugation scalariform; tube formed by both gametangia; fertile cell inflated on the outer side, cylindric on the conjugation tube; zygospores ellipsoid, 29-38 μm broad and 45-60 μm long; mesosporium yellow and smooth.

**Localities:** Kasur District: Gajumata Village (22-12-2004); Azad Kashmir: Chenari (28-4-2004).

**Geographical distribution:** Previously reported from Czechoslovakia, China, Tibet and U.S.A.: Iowa, Illinois, Michigan, Indiana and Ohio.

**Remarks:** It was collected during winter and spring from Punjab and Azad Kashmir respectively. It was found in stagnant water pools and temporary ponds and occurred in free-floating state.

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**S. buchetii** Petit 1913: 40


**Fig. 66**

**Morphological characters:** Unbranched filaments.
**Cytological features:** Vegetative cells 45-47 μm broad and 102-104 μm long, with plane end walls; chloroplasts two, making 3-4 turns in the cell.

**Reproductive structures:** Conjugation scalariform; tube formed by both gametangia; fertile cell shortened and inflated to 50 μm; zygospores ellipsoid, with rounded ends, 50-51 μm broad and 71-72 μm long; median spore-wall yellow and smooth.

**Locality:** Sheikhupura District: between Mureedke and Narang Mundi (20-9-2004).

**Geographical distribution:** Previously reported from China, Moroacco, U.S.A.: Indiana, Sulliran County (Randhawa 1959).

**Remarks:** It was collected during autumn from paddy fields in free-floating state. It occurred in large quantity because the temperature, light intensity and water quantity were suitable for its growth.

*Fig. 67*

**S. chenii Jao 1935: 587**


**Morphological characters:** Unbranched filaments.

**Cytological features:** Vegetative cells 17-18 μm broad and 88-95 μm long, with plane septa; chloroplast one, making 1-5 turns in the cell.

**Reproductive structures:** Conjugation scalariform and lateral; tube formed by male gametangia; fertile cells inflated up to 40 μm; zygospores ellipsoid, 28-30 μm broad and 45-47 μm long; mesosporium smooth.

**Locality:** Azad Kashmir: Chenari (28-4-2004).

**Geographical distribution:** China, Szeck Rep.
Fig. 66. *Spirogyra buchettii*

Fig. 67. *Spirogyra cheni*: a. part of filament, b. lateral conjugation, c. scalariform conjugation.
Remarks: The collection has been made during spring from Azad Kashmir. It was found in stagnant water pools in planktonic state.

*S. communis* (Hassall) Kützing 1849: 439


Fig. 68

**Basionym:** *Zygnema commune* Hassall.

**Synonymy:** *Spirogyra flavescens* (Hassall) Cleve f. *parva* (Hassall) Cooke.

**Morphological characters:** Unbranched filaments.

**Cytological features:** Vegetative cells 18-28 μm broad and 35-90 μm long, with plane end walls; chloroplast one, making 1.5-4 turns in the cell, narrow.

**Reproductive structures:** Conjugation scalariform and lateral; conjugation tube formed by both gametangia; fertile cells cylindric, rarely enlarged; zygospores ellipsoid, 19-29 μm broad and 36-78 μm long; median spore-wall yellow and smooth.

**Localities:** Gujranwala District: Nandipur (19-2-2004); Kasur District: 22 km away from Kasur (9-12-2004), Lulyani Village (22-12-2004).

**Geographical distribution:** Previously reported from India, New Caledonia, U.S.A.

**Remarks:** It was collected from two different areas of Kasur and one of Gujranwala districts during winter in free-floating state. It occurred in road-side puddles and freshwater ponds. Size of cells differed due to the change of localities and ecological conditions.
Fig. 68. *Spirogyra communis*: a. vegetative cell, b. zygospore formation.

Fig. 69. *Spirogyra crassa*
**S. crassa Kützing 1843: 280 emend. Czurda 1932**


**Fig. 69**

**Morphological characters:** Filaments coarse, stout, giving a glassy touch.

**Cytological features:** Vegetative cells 108-118 μm broad and 126-130 μm long, squarish in shape; chloroplasts 6-10, each a half spiral, bearing numerous big pyrenoids.

**Reproductive structures:** In collected specimens conjugation stages were not observed.

**Locality:** Kasur District: Lulyani Village (6-1-2004).

**Geographical distribution:** Australia, Europe, India, South Africa and U.S.A.

**Remarks:** The collection has been made from road-side puddles along the village during winter in low quantity. It occurred in planktonic condition.

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**S. crassoidea Transeau 1937: 636**

(Transeau 1951: 195, Randhawa 1959: 377)

**Fig. 70**

**Morphological characters:** Unbranched filaments.

**Cytological features:** Vegetative cells 150-160 μm broad and 140-175 μm long, with plane end-walls; chloroplasts 3-8, making 0.5-3 turns in the cell.

**Reproductive structures:** Such structures could not be observed.

**Locality:** Kasur District: Amir Maman Village (22-12-2004).

Remarks: Specimens were collected from the village during winter in free-floating state. Material was found only in vegetative stage. During rainy season many temporary ponds are created, where it was found in large quantity, as the temperature and water pH were suitable for its growth.

\textit{S. dacimina} (Müller) Kützing 1843: 279


Fig. 71

Morphological characters: Unbranched filaments.

Cytological features: Vegetative cells 34-36 \( \mu \text{m} \) broad and 101-104 \( \mu \text{m} \) long, with plane end walls; chloroplasts three, making one turn in the cell.

Reproductive structures: Conjugation scalariform; tube formed by both gametangia; fertile cell cylindric; zygospores ovoid, 43-45 \( \mu \text{m} \) broad and 73-75 \( \mu \text{m} \) long; median spore-wall yellow and smooth.

Locality: Sialkot District: Head Marala (7-7-2004).

Geographical distribution: Previously reported from Asia, India, Europe, U.S.A. West Indies, Java and South America.

Remarks: Specimens have been collected during summer season from Punjab. They were obtained from stagnant water ponds where they occurred in free-floating and planktonic state in large quantity. High temperature appeared favourable for their growth.
Fig. 70. *Spirogyra crassoidea*

Fig. 71. *Spirogyra dacimina*: a. vegetative cell, b. zygospore formation.
**S. daedalea** Lagerheim 1888: 592

(Transeau 1951: 166, Randhawa 1959: 314)

**Fig. 72**

**Morphological characters:** Unbranched filaments.

**Cytological features:** Vegetative cells 6-19 \( \mu \text{m} \) broad and 30-38 \( \mu \text{m} \) long; septa of plane type; each cell with a spiral chloroplast making 5-6 turns.

**Reproductive structures:** Conjugation scalariform; zygospores brown, 36-42 \( \mu \text{m} \) in diameter; mesosporium reticulate.

**Locality:** Lahore District: Jinnah Garden (21-3-2004).


**Remarks:** The specimens were collected from fountain of Jinnah Garden during spring season being attached with other free-floating algae, where the temperature was 25.5\(^{\circ}\)C and pH about 7.5.

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**S. dubia** Kützing 1855: 188


**Fig. 73**

**Morphological characters:** Unbranched filaments.

**Cytological features:** Vegetative cells 46-49 \( \mu \text{m} \) broad and 60-250 \( \mu \text{m} \) long, with plane end walls; chloroplasts 2-3 in each cell.
Fig. 72. *Spirogyra daedleu*: a. vegetative cell, b. zygospore formation.

Fig. 73. *Spirogyra dubia* a. vegetative cell, b. zygospore formation.
Reproductive structures: Conjugation scalariform; fertile cells largely swollen; zygospores ellipsoid, 42-53 μm broad and 77-79 μm long; mesosporium thick, smooth and brown; exosporium thin and yellow.

Locality: Sialkot District: Head Marala (7-7-2004).


Remarks: The collection was carried out during rainy season of summer. The specimens were found in stagnant water ponds in free-floating state. The water was slightly alkaline (pH 8.0). It was found in vegetative as well as reproductive states.

_S. farlowii_ Transeau 1915: 29


Fig. 74

Morphological characters: Filaments rather long with cylindrical cells.

Cytological features: Vegetative cells 20-31 μm broad and 125-126 μm long; with alternate, replicate end-walls; chloroplast one, making 4-6 turns in the cell.

Reproductive structures: Conjugation scalariform (lateral conjugation was not observed); tube formed by both gametangia (mainly male gametangium); female gametangium inflated up to 47-48 μm mostly on inner side; zygospores ellipsoid with ends more or less broadly pointed; 30-32 μm broad and 57-58 μm long; median spore-wall yellow and smooth; aplanospores were not observed.

Locality: Gujranwala District: Nandipur (4-4-2004).

Geographical Distribution: China, India and U.S.A.
Remarks: Collections were made during spring season. The specimens were collected from canal-side ponds in attached condition and mixed with submerged grasses. The temperature, locality and pH of water were favourable for their growth.

*S. fennica* C. Creutz 1924: 4


*Fig. 75*

**Morphological characters:** Unbranched filaments.

**Cytological features:** Vegetative cells 12-16 µm broad and 99-125 µm long, with plane end-walls; chloroplast one.

**Reproductive structures:** Conjugation scalariform; tube formed by both gametangia; fertile cells shortened and inflated up to 29-38 µm; zygospores ellipsoid, 29-38 µm broad and 56-59 µm long; median spore-wall yellow-brown and smooth.

**Locality:** Kasur District: Lulyani Village (22-12-2004).

**Geographical distribution:** China, Finland and South Africa.

Remarks: Collections were made during winter season. Specimens were collected in free-floating, vegetative as well as reproductive states and in low quantity.

*S. fragilis* Jao 1935: 590

(Transeau 1951: 152, Randhawa 1959: 383)

*Fig. 76*

**Morphological characters:** Unbranched filaments.
Fig. 74. *Spirogyra farlowii*

Fig. 75. *Spirogyra fennica*

Fig. 76. *Spirogyra fragilis*
Cytological features: Vegetative cells 24-30 μm broad and 66-160 μm long, with plane end-walls; chloroplast one, making 2-4 turns in the cell.

Reproductive structures: Conjugation scalariform; tube formed by both gametangia; fertile cells slightly inflated, usually a little more on conjugation side; the female gametangia often separate from each other after conjugation; zygospores ellipsoidal with more or less rounded ends, 22-29 μm broad and 36-42 μm long; median spore-wall yellow and smooth.

Localities: Kasur District: Dullamkurd Village (22-12-2004), Keothe (8-10-2004).

Geographical distribution: U.S.A.: Texas, Johnson City; China.

Remarks: Collections were made from two different localities and in different seasons i.e. autumn and winter from Kasur District. It was found in temporary ponds and roadside puddles in attached as well as in free-floating state. The visited areas were mostly water logged or toxic water tanneries.

*S. gibberosa* Jao 1935: 586

(Transeau 1951: 155, Randhawa 1959: 295)

Fig. 77

Morphological characters: Unbranched filaments.

Cytological features: Vegetative cells 19-21 μm broad and 73-75 μm long, with plane end-walls; chloroplast one, making 2-8 turns in the cell.

Reproductive structures: Conjugation lateral; zygospores ellipsoid with more or less pointed ends; 21-23 μm broad and 36-38 μm long; median spore-wall smooth.

Locality: Sialkot District: Bhelo-Mahar (6-4-2004).
**Geographical Distribution:** U.S.A., Central and Western Europe.

**Remarks:** The collection work was carried out in spring season from a village. This species occurred in water bloom in stagnant water pools.

*S. gracilis* (Hassall) Kützing 1849: 438


![Fig. 78](image)

**Basionym:** *Zygnema gracile* Hassall.

**Morphological characters:** Unbranched filaments.

**Cytological features:** Vegetative cells 22-24 μm broad and 74-76 μm long; chloroplast one, making 4 turns in the cell.

**Reproductive structures:** Conjugation scalariform; zygospores ellipsoidal, 22-24 μm broad and 52-54 μm long, with rounded ends.

**Locality:** Sheikhupura District: near Burji-Atari Village (15-3-2004).

**Geographical distribution:** China, Siam, Europe and U.S.A.: Colorado, Texas, Missouri and Michigan.

**Remarks:** The collections have been made from slow running water channels of a village. It occurred in the beginning of spring in planktonic condition.
Fig. 77. *Spirogyra gibberosa*

Fig. 78. *Spirogyra gracilis*: a. vegetative cell, b. zygospore formation.

20 μm
**S. hyalina** Cleve 1868: 17


**Fig. 79**

**Morphological characters:** Unbranched filaments, 49-51 µm long.

**Cytological features:** Vegetative cells 51-62 µm broad and 93-121 µm long, with plane end-walls; chloroplasts 3, making 0.5 to 3 turns in the cell.

**Reproductive structures:** Conjugation scalariform; tube formed by both gametangia; fertile cells cylindrical; zygospores ellipsoidal, 43-56 µm broad and 77-92 µm long; median spore-wall brown and smooth; aplanospores similar, somewhat smaller.

**Localities:** Jhang District: Rabwah (20-3-2004); Sheikhupura District: near Rana Bhatti Village (15-3-2004), between Mureedke and Narang Mundi (20-9-2004); Azad Kashmir: Neelum Valley (5-4-2004).

**Geographical distribution:** Widely distributed: India, Pakistan, China, Sweden, Puerto Rico, U.S.A.: Iowa, Mississippi (Randhawa 1959).

**Remarks:** It was collected from different areas of the Punjab (plain area) and Azad Kashmir (mountain area). The collected specimens were found growing during spring and autumn. The cell size of those growing in autumn was large and growth rate was also high. It occurred in free-floating state, in slow running water channels and rice field areas, in vegetative as well as reproductive phases.
Fig. 79. *Spirogyra hyalina*: a. vegetative cell, b. zygospore formation.

Fig. 80. *Spirogyra intorta*: a. vegetative cell, b. zygospore formation.
**S. intorta** Jao 1935: 590

(Transeau 1951: 150, Randhawa 1959: 294)

**Fig. 80**

**Morphological characters:** Filaments generally curved to spirals.

**Cytological features:** Vegetative cells 25-29 μm broad and 128-130 μm long, with plane end-walls; chloroplast one, making 3.5-6 turns in the cell.

**Reproductive structures:** Conjugation scalariform; tube formed by both gametangia; fertile cells cylindric, sometimes slightly enlarged; zygospores ellipsoid, 26-28 μm broad and 49-52 μm long; median spore-wall yellow and smooth.

**Locality:** Sialkot District: Head Marala (7-7-2004).

**Geographical distribution:** China, U.S.A.: Texas, Johnson City.

**Remarks:** It occurred in planktonic state in temporary ponds. It was collected during summer and rainy season.

**S. irregularis** Nägeli 1849: 440


**Fig. 81**

**Morphological characters:** Unbranched filaments.

**Cytological features:** Vegetative cells 33-36 μm broad and 124-126 μm long, with plane end-walls; chloroplasts two, making 4-5 turns in the cell.

**Reproductive structures:** Conjugation scalariform; tube formed by both gametangia, fertile cells cylindric; zygospores ellipsoid, 28-42 μm broad and 47-70 μm long; episporium thick and transparent.
Localities: Jhang District: Chenab near Riwaz Bridge Chund (23-1-2004); Sialkot District: Bhelo-Mehar (6-4-2004); Azad Kashmir: Neelum Valley (20-3-2004).

Geographical Distribution: Central and Western Europe, U.S.A.

Remarks: The collections were carried out during winter and spring from Punjab. It was also collected from Azad Kashmir during spring. The filaments were found in temporary ponds, along the river side near Chenab and stagnant water with the pH nearly 7.5 in free-floating state.

*S. jaoi* Ley 1944: 99

(Transeau 1951: 220, Randhawa 1959: 363)

Fig. 82

Morphological characters: Unbranched filaments.

Cytological features: Vegetative cells 19-22 μm broad and 76-90 μm long, with replicate end-walls; chloroplast one in the cell.

Reproductive structures: Conjugation scalariform; tube formed by both gametangia; zygospores ovoid, 30-32 μm broad and 75-77 μm long; spore-wall two layered, outer thin and wrinkled, inner yellow and smooth.

Locality: Kasur District: Kot Mela Ram (9-12-2004).

Geographical distribution: China, India.

Remarks: It was collected during winter. It was raining heavily during this time and many stagnant ponds were formed which provided favourable condition for its growth. It occurred in massive quantity and in free-floating state.
Fig. 81. Spirogyra irregularis: a. vegetative cell, b. zygospore formation.

Fig. 82. Spirogyra jaoi: a. vegetative cell, b. zygospore formation.
**S. juergensii** Kützing 1845: 222


**Fig. 83**

**Morphological characters:** Filaments moderately stout.

**Cytological features:** Vegetative cells 25-65 μm broad and 58-126 μm long, with occasionally plane septa; swollen chloroplast one, making 2-8 turns in the cell.

**Reproductive structures:** Conjugation scalariform; gametangia cylindrical not swollen on either side; zygospores ellipsoid, enlarged, 20-52 μm broad and 49-100 μm long; mesosporium yellow and smooth.

**Localities:** Gujranwala District: Nandipur (19-2-2004); Jhang District: Chenab near Riwaz Bridge Chund (23-1-2004); Kasur District: Kasur (22-12-2004), Kot Ilm Din (28-1-2004); Lahore District: Hunjarwal (25-8-2004), near Bhaseen Village (26-3-2004); Pasrur District: Kotray Village (4-3-2004).

**Geographical distribution:** Australia, Europe, India (Mumbai), South America, U.S.A., Pakistan: Lahore (Randhawa 1959).

**Remarks:** It was collected from different places of the Punjab during summer, winter and spring seasons in the free-floating state. Cytological differences were observed within specimens due to different localities and temperature variations. It was found in vegetative as well as reproductive conditions. During rainy season many temporary ponds were created, where it occurred in large quantity because high temperature and water pH
Fig. 83 *Spirogyra juergensii*: a. vegetative cell, b. scalariform conjugation.

Fig. 84 *Spirogyra kaffrita*: a. vegetative cell, b. zygospore formation.
were suitable for its growth. It was obtained from different habitats, such as road-side puddles near border areas, paddy fields, ponds along the river-side near Chenab and permanent pools. Specimens were found mixed with *Spirogyra mirabilis* (Hassall) Kützing and *S. pseudospreeiana* Jao.

**S. kaffīrita** Transeau 1934: 228

(Transeau 1951: 166, Randhawa 1959: 382)

Fig. 84

**Morphological characters:** Unbranched filaments.

**Cytological features:** Vegetative cells 40-42 μm broad and 60-62 μm long, with plane end-walls; chloroplast one, making 2-4 turns in the cell.

**Reproductive structures:** Conjugation scalariform; tube formed by both gametangia; fertile cells inflated to inner side; zygospores ellipsoid; 44-45 μm broad and 61-62 μm long; median spore-wall yellow and finally granulated.

**Locality:** N.W.F.P.: Swat: side of Utrod River in Kalam (13-8-2004).

**Geographical distribution:** South Africa: Cape colony.

**Remarks:** Collection was made during summer. It was found in slow running water along the river side, where it occurred in free-floating state.

**S. luteriana** Petit 1879: 79

(Transeau 1951: 160, Randhawa 1959: 308)

Fig. 85

**Morphological characters:** Unbranched filaments.
Cytological features: Vegetative cells 37-64 μm broad and 88-122 μm long, with plane end-walls; chloroplast one, very close, making 3-8 turns in the cell.

Reproductive structures: Conjugation scalariform; tube formed by both gametangia; zygospores polymorphic varying from globose to ellipsoid or irregular, 34-52 μm broad and 90-100 μm long; spore-wall brown and smooth.

Localities: Lahore: Hunjarwal (25-8-2004), Lakho Dehr Village near border area (12-3-2004); Sheikhupura District: between Mureedke and Narang Mundi (12-9-2004); N.W.F.P.: Swat: between Bahrain and Kalam (13-8-2004).

Geographical distribution: Europe, India (Mumbai), South Africa (Randhawa 1959).

Remarks: Collections were made from various areas of the Punjab and N.W.F.P. during spring, summer and autumn seasons being attached with submerged grasses as well as in free-floating state. Cytological changes were observed within different specimens. Those collected from two different rice fields, occurred in large quantity. Rice is cultivated in summer season, algae usually prefer intense sunlight and high temperature for their growth, and such conditions are available in the rice fields. The specimens were also found in slow running water along the river-side and road-side puddles of a village near border area.

S. majuscula  Kützing 1849: 441


Fig. 86

Synonymy: Spirogyra orthospira Nägeli.
Fig. 85. Spirogyra luteriana: a. vegetative cell, b. zygospore formation.

20 μm

Fig. 86. Spirogyra majuscula: a. vegetative cell, b. zygospore formation.
**Morphological characters:** Filaments of stout cells.

**Cytological features:** Vegetative cells 50-52 μm broad and 112-138 μm long, with plane end-walls; chloroplasts three, making 1-2 turns in the cell.

**Reproductive structures:** Conjugation scalariform; tube formed by both gametangia, fertile cells cylindrical, short and slightly inflated; zygospores lenticular, 46-62 μm broad and 43-88 μm long; median spore-wall brown and smooth; aplanospores similar but smaller than zygospores.

**Localities:** Lahore: Dinanath (25-8-2004); Sheikhupura District: between Mureedke and Narang Mundi (12-9-2004); Sialkot District: near Chobara Village (25-5-2004).

**Geographical distribution:** India, China, Europe, South Africa, Brazil, U.S.A.: Washington and Texas (Randhawa 1959).

**Remarks:** The collections were made during spring, summer and autumn seasons. The specimens were collected from three different localities of the Punjab, and cytological as well as reproductive differences were observed within these specimens. It was found to grow in permanent ponds and paddy field areas, where it occurred in massive quantity being attached with culm of submerged grasses.

*S. mirabilis* (Hassall) Kützing 1849: 438

**Fig. 87**


**Basionym:** *Zygema mirabile* Hassall.

**Morphological characters:** Filaments consist of slender cells.
**Cytological features:** Vegetative cells 29-31 μm broad and 122-125 μm long, with plane end-walls, slightly swollen; chloroplast one, making 3-4 turns in the cell.

**Reproductive structures:** Reproduction by aplanospores, sporangia slightly inflated; aplanospores ovoid to ellipsoid, 29-35 μm broad and 31-39 μm long; median spore-wall yellow-brown and smooth.

**Locality:** Pasrur District: Kotray Village (4-3-2004).

**Geographical distribution:** Afghanistan, China, Europe, Siberia, Manchuria, U.S.A. (Randhawa 1959).

**Remarks:** The collection work was carried out in the beginning of spring, from a village. Specimens were found in free-floating state mixed with different species such as *Spirogyra juergensii* Kützing and *S. pseudospreeiana* Jao.

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*S. nyctigama* Transeau 1938: 525


**Fig. 88**

**Morphological characters:** Unbranched filaments.

**Cytological features:** Vegetative cells 37-38 μm broad and 150-160 μm long, with replicate end-walls; chloroplast one, making 2-5 turns in the cell.

**Reproductive structures:** Conjugation scalariform; tube formed by both gametangia; zygospores ellipsoid, median spore-wall yellow-brown and smooth.

**Localities:** Jauharabad District: Jauharabad (25-2-2004); N.W.F.P.: Attock (12-1-2004).

**Geographical distribution:** India: Mumbai, South Africa: Cape Town.
Fig. 87. Spirogyra mirabilis: a. vegetative cell, b. lateral conjugation.

Fig. 88. Spirogyra nystigama: a. vegetative cell, b. scalariform conjugation.
Remarks: It was collected in free-floating state during winter season. It occurred in Jauharabad along streaks in flowing streams and about two miles away from Attock in temporary ponds in free-floating state.

*S. oudhensis* Randhawa 1938: 348

(Randhawa 1959: 315)

**Fig. 89**

Morphological characters: Unbranched filaments.

Cytological features: Vegetative cells 33-35 μm broad and 85-87 μm long; end-walls plane; chloroplast one, making 3-4 turns in the cell.

Reproductive structures: Conjugation scalariform; zygospores oval, 34-36 μm broad and 53-55 μm long; mesosporium bears broad reticulation on the surface.


Geographical distribution: Previously reported from India.

Remarks: The collection was made during autumn from paddy fields, where it occurred in the free-floating state and in massive quantity.

*S. paludosa* Czurda 1932: 167


**Fig. 90**

Morphological characters: Unbranched filaments.
Fig. 89. *Spirogyra oudhensis*: a. vegetative cell, b. zygospore formation.

Fig. 90. *Spirogyra paludosa*: a. vegetative cell, b. zygospore formation.

\[20 \, \mu m\]
Cytological features: Vegetative cells 18-20 μm broad and 5-6 times as long as broad, with plane septa; chloroplast one in each cell.

Reproductive structures: Conjugation scalariform; female cells containing zygospores, slightly swollen; zygospores ellipsoid, much longer than broad, 26 μm broad and 44-46 μm long; exosporium hyaline and smooth, mesosporium light brown in colour.

Localities: Jauharabad District: Jauharabad (25-4-2004); N.W.F.P.: Attock (12-1-2004).


Remarks: It was found in two different places during winter and spring in free-floating state. Collection work was carried out in Jauharabad from long streaks in flowing streams and in N.W.F.P. about two miles away from Attock.

*S. parvula* (Transeau) Czurda 1932: 170


Fig. 91

Basionym: *Spirogyra catenaeformis* var. *parvula* Transeau.

Morphological characters: Unbranched filaments.

Cytological features: Vegetative cells 19-22 μm broad and 108-120 μm long, with plane septa; chloroplast one, making 2-4 turns in the cell.

Reproductive structures: Both lateral and scalariform conjugations were seen; conjugation tube formed by both gametangia, female cells become swollen; zygospores occur in pairs in lateral conjugation; zygospores ellipsoid, 23-28 μm broad and 53-55 μm long; mesporium smooth and bluish-green in colour.
Fig. 91. *Spirogyra parvula*: a. vegetative cell, b. lateral conjugation, c. scalariform conjugation.

Fig. 92. *Spirogyra peipingensis*: a. vegetative cell, b. zygospore formation.
Localities: Sheikhupura District: Sattarwala Village (5-3-2004); Azad Kashmir: Neelum Valley (20-3-2004).


Remarks: Collections have been made during spring season. The specimens were obtained from bank of a canal in Sheikhupura District, where the soil was of semi-arid type, the pH of soil was $8.0$ i.e. alkaline. In Azad Kashmir it occurred in planktonic condition in stagnant water ponds.

*S. peipingensis* Jao 1939: 155


Fig. 92

Morphological characters: Unbranched filaments.

Cytological features: Vegetative cells $104-157 \mu m$ broad and $156-200 \mu m$ long, with plane end-walls; chloroplast one, making 5-7 turns in the cell.

Reproductive structures: Conjugation scalariform; tube formed by both gametangia; gametangia cylindrical and shortened; zygospores lenticular, $117-120 \mu m$ broad and $78-86 \mu m$ long; mesosporium yellow-brown and smooth.

Localities: Gujranwala District: Nandipur (19-2-2004); Sialkot District: Head Marala (7-7-2004).


Remarks: It was collected from two different places of the Punjab during winter and summer. In the specimens collected during summer the cell size was larger and growth
rate was higher as compared to those found in winter. It was found in canal side ponds and stagnant water pools in free-floating state.

**S. polymorpha** Kirchner 1878: 124

(Transeau 1951: 161, Randhawa 1959:309)

**Fig. 93**

**Morphological characters:** Unbranched filaments.

**Cytological features:** Vegetative cells 29-30 \( \mu m \) broad and 47-73 \( \mu m \) long, with plane end-walls; chloroplast one, making 1-8 turns in the cell.

**Reproductive structures:** Conjugation scalariform; tube formed by both gametangia; fertile cells inflated to 28-33 \( \mu m \); zygospores polymorphic, varying in shape from ellipsoid to ovoid and globose, 30-33 \( \mu m \) broad and 39-42 \( \mu m \) long; median spore-wall yellow and smooth.

**Locality:** Kasur District: Kasur (22-12-2004).

**Geographical Distribution:** China and Europe.

**Remarks:** Collections were made from stagnant water ponds during winter. It occurred in massive quantity and in free-floating condition.

**S. papulata** Jao 1935: 598


**Fig. 94**

**Morphological characters:** Unbranched filaments.
Fig. 93. *Spirogyra polymorpha*

Fig. 94. *Spirogyra papulata*: a. vegetative cell, b. scalariform conjugation.
Cytological features: Vegetative cells 28-32 µm broad and 64-176 µm long, with plane end-walls; chloroplast one containing large pyrenoid.

Reproductive structures: Conjugation scalariform; tube formed by both gametangia; zygospores ellipsoid, very rarely sub-globose, 22-25 µm broad and 27-30 µm long; median spore-wall irregularly reticulate, golden-yellow at maturity.


Geographical distribution: China: Szechawan.

Remarks: The collection was carried out during winter from stagnant water ponds, they were found mixed with other free-floating algae. No cytological and reproductive differences were observed within these specimens.

\textbf{S. pratensis} Transeau 1914: 292


Fig. 95

Morphological characters: Unbranched filaments.

Cytological features: Vegetative cells 18-20 µm broad and 115-122 µm long, with plane end-walls; chloroplast one, making 1-6 turns in the cell.

Reproductive structures: Reproduction by both zygospores and aplanospores; conjugation lateral and scalariform; tube formed by both gametangia; fertile cells enlarged or fusiform, inflated to 38 µm; sterile cells cylindric or inflated up to 90 µm in diameter; spores ellipsoid or ovoid or cylindrico-ovoid, 23-27 µm broad and 49-57 µm long; median spore-wall yellow and smooth.
Fig. 95. *Spirogyra pratensis*: a. vegetative cell, b. zygospore formation.

Fig. 96. *Spirogyra pseudopreciana*: a. vegetative cell, b. zygospore formation.
Localities: Kasur District: Dullamkhurd Village (22-1-2004).


Remarks: It was collected during winter from a village in free-floating state. This species was found in low quantity because the temperature and light intensity of winter are unfavourable for its growth. It occurred in vegetative as well as reproductive conditions.

_S. pseudospreeiana_ Jao 1935: 663

(Transeau 1951: 204, Randhawa 1959:365)

**Fig. 96**

Morphological characters: Unbranched filaments.

Cytological features: Vegetative cells 29-30 μm broad and 62-63 μm long, with replicate end-walls; chloroplast one, making 4-5 turns in the cell.

Reproductive structures: Conjugation scalariform; conjugation canal formed by male gametangia alone; gametangia slightly swollen, more towards the conjugation tube; zygospores ellipsoid and elongated, 19-20 μm broad and 167-168 μm long; mesoporum yellow-brown and smooth.

Locality: Pasrur District: Kotray Village (4-3-2004).

Geographical distribution: India (Randhawa 1959), China: Szechawan.

Remarks: Collections were made during spring, from road-side ponds. It was found associated with _Spirogyra juergensii_ Kützing and _S. mirabilis_ (Hassall) Kützing in the free-floating state.
S. reflexa Transeau 1915: 28


Fig. 97

Morphological characters: Unbranched filaments.

Cytological features: Vegetative cells 34-35 μm broad and 78-79 μm long, with plane end-walls; chloroplast one, making 3-8 turns in the cell.

Reproductive structures: Conjugation scalariform; tube formed by male gametangium; fertile cells strongly inflated and enlarged; zygospores ellipsoidal, 37-38 μm broad and 52-58 μm long; spore-wall yellowish-brown.


Remarks: Collections were made along the river-side during rainy season of summer. The alga was found in the free-floating state.

S. semiornata Jao 1935: 604

(Transeau 1951: 205, Randhawa 1959: 35)

Fig. 98

Morphological characters: Unbranched filaments.

Cytological features: Vegetative cells 28-30 μm broad and 102-104 μm long, with replicate end-walls; chloroplast one, making 2-6 turns in the cell.

Reproductive structures: Reproduction by zygospores, tube formed by both gametangia; female gametangium slightly swollen; zygospores ovoid, 34-36 μm broad
Fig. 97. *Spirogyra reflexa*

Fig. 98. *Spirogyra semiornata*
and 78-92 μm long; mesosporium yellowish-brown and smooth; aplanospores not observed.

**Locality:** Gujranwala District: Nandipur (4-4-2004).

**Geographical distribution:** Previously reported from China.

**Remarks:** The collection work was carried out during April 2004. The specimens were found growing during spring, the cell size was large and growth rate was also high. It occurred in canal-side pond, mixed with other planktonic algae.

*S. silvicola* Britton 1943: 799

(Transeau 1951: 151, Randhawa 1959: 403)

**Fig. 99**

**Morphological characters:** Unbranched filaments.

**Cytological features:** Vegetative cells 30-32 μm broad and 79-95 μm long, with plane end-walls; chloroplast one, making 1-5 turns in the cell.

**Reproductive structures:** Conjugation scalariform; tube formed by both gametangia; zygospores ellipsoid, 34-36 μm broad and 44-48 μm long.

**Locality:** Jhang District: near Chund (23-1-2004).

**Geographical distribution:** U.S.A.: Illinois, Somme Forest, Cook County, Texas, Austin (Transeau 1951).

**Remarks:** It was collected during winter from stagnant water ponds being associated with other free-floating algae. In winter the growth rate was slow, therefore it was found in low quantity, but it occurred in vegetative as well as reproductive conditions.
Fig. 99. *Spirogyra silvicola*: a. vegetative cell, b. scalariform conjugation.

Fig. 100. *Spirogyra singularis*: a. vegetative cell, b. zygospore formation.
**S. singularis** Nordstedt 1880: 118


**Fig. 100**

**Morphological characters:** Unbranched filaments.

**Cytological features:** Vegetative cells 30-40 μm broad and 50-247 μm long, with plane end-walls; chloroplast one, making 2-7 turns in the cell.

**Reproductive structures:** Conjugation scalariform, tube formed by both gametangia; male cells cylindric, female ones enlarged towards the tube; fertile cells cylindrical, rarely enlarged; zygospores ellipsoid, 23-41 μm broad and 37-69 μm long; median spore-wall yellow and smooth.

**Localities:** Jhang District: Chenab near Riwaz Bridge, Chund (22-1-2004); Kasur District: Kot Ilm Din (28-1-2004), Lulyani Village (22-12-2004); Lahore District: Dinanath (25-8-2004); Sheikhupura District: between Mureedke and Narang Mundi (20-9-2004); Azad Kashmir: Neelum Valley (20-3 & 5-4-2004).

**Geographical distribution:** China, Finland, South Africa, Brazil, U. S. A., New Zealand, India: Mumbai, Varanasi (Randhawa 1959).

**Remarks:** It was collected from different districts of the Punjab and Azad Kashmir. Collection work was carried out in the Punjab especially during summer and autumn, from two different rice fields where it occurred in massive quantity and planktonic state, as compared to those obtained during winter season where it was found in low quantity. In Azad Kashmir it was collected twice during spring stagnant water ponds.
**S. submarina** (Collins 1909) Transeau 1915: 110


**Fig. 101**

**Morphological characters:** Unbranched filaments.

**Cytological features:** Vegetative cells 26-30 μm broad and 78-160 μm long, with plane end-walls; chloroplasts 2-3, making 1-3 turns in the cell.

**Reproductive structures:** Conjugation scalariform; tube formed by both gametangia; zygospores cylindric, 30-48 μm broad and 54-61 μm long.

**Localities:** Jhang District: near Trimmu Head Works (23-1-2004); Azad Kashmir: Chenari (28-4-2004), Neelum Valley (20-3-2004).

**Geographical distribution:** China: Peiping, Nanking; Bermuda; India; U.S.A.: Massachusetts, Connecticut.

**Remarks:** Collections have been made from two different places of Azad Kashmir and one in the Punjab during winter and spring seasons. The cells were found in small size and low quantity stagnant water ponds and on river-side along with the other free-floating algae.

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**S. subsalsa** Kützing 1845: 222


**Fig. 102**

**Morphological characters:** Unbranched filaments.
Fig. 101. Spirogyra submersa: a. vegetative cell, b. zygospore formation.

Fig. 102. Spirogyra subsalsa: a. vegetative cell, b. zygospore formation.
Cytological features: Vegetative cells 23-25 μm broad and 57-130 μm long, with plane end-walls; chloroplast one, making 2-3 turns in the cell.

Reproductive structures: Conjugation scalariform; tube formed by both gametangia; fertile cells inflated; zygospores ovoid, 23-30 μm broad and 41-49 μm long; mesosporium yellow-brown and smooth.


Remarks: The collection was made during spring from Neelum Valley and from Swat during spring. It was found in vegetative as well as reproductive conditions, mixed with other free-floating algae. It also occurred on rock surface as epilithon along the river-side.

S. tandae Randhawa 1938: 350

Fig. 103

Morphological characters: Unbranched filaments, with long cells.

Cytological features: Vegetative cells 18-24 μm broad and 9-10 times longer up to (208 μm); chloroplast one, making 5-6 turns in the cell, narrow; cross-walls replicate (in vegetative phase all replicate, in reproductive phase replicate and plane septa alternate in position).
Fig. 103. *Spirogyra tandae*

Fig. 104. *Spirogyra teodoresci*: a. vegetative cell, b. scalariform conjugation.
Reproductive structures: Conjugation scalariform; conjugation tube short and broad; female cells cylindrically inflated (up to 36 μm); zygospores oval to ellipsoidal, 32-35 μm broad and 60-65 μm long; mesosporium foveolate.


Remarks: The collection was made from canal side-ponds in free-floating state during winter season. The cell size was small, growth rate was also low, therefore it was found in low quantity.

S. teodoresci Transeau 1934: 420

(Randhawa 1959: 296, Prescott 1962: 322)

Fig. 104

Morphological characters: Unbranched filaments.

Cytological features: Vegetative cells 25-30 μm broad and 43-53 μm long, with plane end-walls; chloroplast one, making 1-5 turns in the cell.

Reproductive structures: Conjugation lateral and scalariform, tube formed by both gametangia; fertile cells strongly inflated on the conjugation side; zygospores ellipsoid, 26-30 μm broad and 43-47 μm long; median spore-wall yellow and smooth.

Locality: Kasur District: Jhulkey Village (22-12-2004).

**Remarks:** Collection has been made during winter, it was obtained in free-floating state. It occurred in vegetative as well as reproductive phases in stagnant water ponds of a village.

*S. varians* (Hassall) Kützing 1849: 439


**Basionym:** *Zygnema varians* Hassall.

**Morphological characters:** Unbranched filaments.

**Cytological features:** Vegetative cells 29-35 µm broad and 49-70 µm long, with plane end-walls; chloroplast one, making 1-2 sometimes 5 turns in the cell.

**Reproductive structures:** Conjugation lateral and scalariform, tube formed by both gametangia; fertile cells usually inflated towards the conjugation side only or rarely on both sides; some of the sterile cells usually inflated upto 64 µm; zygospores mostly ellipsoid usually some of them ovoid or globose, 30-35 µm broad and 49-51 µm long; median spore-wall yellow and smooth; aplanospores 30-31 µm broad and 243-244 µm long.

**Localities:** Gujranwala District: Nandipur (19-2-2004); Sheikhupura District: between Mureedke and Narang Mundi (24-8-2004); Sialkot District: Langarwal Village (25-5-2004).
Fig. 105. *Spirogyra varians*: a. vegetative cell, b. lateral conjugation, c. lateral conjugation, d. scalariform conjugation.
**Geographical distribution:** Asia (including India), Africa, U.S.A., Australia, New Foundland (Randhawa 1959).

**Remarks:** It was collected from three different localities of the Punjab during winter, spring and summer seasons in free-floating state. The collection has been made from stagnant water of a village and paddy fields during summer, in large quantity as compared to those collected during winter from canal side-ponds of Nandipur. Slight morphological, cytological and reproductive variations were found due to the different ecological conditions. Some epiphytes were present on the filaments, which is a rare phenomenon in *Spirogyra* spp.

**Zygnema C. A. Agardh 1824: 77**

Filaments unbranched with short cylindric cells; each cell with two stellate chloroplasts, with a central prominent pyrenoid; single nucleus lying in between the two chloroplasts; reproduction scalariform or chain conjugation; zygospores mostly spherical; mesosporium may be smooth or variously ornamented; parthenosporules may also be formed. From present collection 10 species were obtained which may be distinguished as follows:

1. Vegetative cells less than 38 µm broad…………………………………………………………2
   Vegetative cells more than 38 µm broad………………………………………………..3
2. Conjugation only scalariform…………………………………………………………………………………4
   Conjugation both lateral and scalariform………………………………………………………5
3. Vegetative cells up to 60 µm long……………………………………………………Z. kashmirense
   Vegetative cells more than 60 µm long …………………………………..Z. czurdae
4. Vegetative cells up to 35 µm long………………………………………………...Z. khannae
   Vegetative cells more than 35 µm long………………………………………….6
5. Vegetative cells up to 52 µm long…………………………………………………Z. insigne
   Vegetative cells more than 52 µm long…………………………………………..7
6. Zygospores more than 34 µm broad  …………………………………………..Z. normani
   Zygospores up to 34 µm broad………………………………………………………8
7. Zygospores up to 39 µm long…………………………………………………..Z. gangeticum
   Zygospores more than 39 µm long …………………………………………...Z. fanicum
8. Zygospores more than 37 µm long……………………………………………...Z. cyaneum
   Zygospores up to 37 µm long………………………………………………………9
9. Vegetative cells 43 µm long……………………………………………………Z. subcruciatum
   Vegetative cells 70 µm long………………………………………………………...Z. himalayense

Z. cyaneum Czurda 1932: 127

(Czurda 1932: 127, Transeau 1951: 38, Randhawa 1959: 246)

Fig.106

Morphological characters: Unbranched filaments.

Cytological features: Vegetative cells 30-32 µm broad and 55-60 µm long.

Reproductive structures: Conjugation scalariform, zygospores in one of the gametangia; receptive gametangia cylindric; zygospores globose, 30-34 µm broad and 38-45 µm long; median spore-wall thick and smooth.


Geographical distribution: Previously reported from U.S.A., India.
Fig. 106. Zygnema cyaneum

Fig. 107. Zygnema czurdae
Remarks: It was collected in free-floating state during spring season. It was found in slow running water of the stagnant ponds at Azad Kashmir in low quantity.

**Z. czurdae** Randhawa 1936: 239


**Fig. 107**

**Morphological characters:** Unbranched filaments.

**Cytological features:** Vegetative cells 32-38 μm broad and 132-136 μm long; chloroplast showing tiny protuberances.

**Reproductive structures:** In the present specimens reproductive stages were not found.

**Locality:** N.W.F.P.: Swat: between Bahrain and Kalam (13-8-2004).

**Geographical distribution:** Previously reported from India.

Remarks: The collection was carried out during summer. It was obtained in planktonic state from slow running water of stagnant ponds between Bahrain and Kalam.

**Z. fanicum** Li 1934: 212

(Transeau 1951: 35, Randhawa 1959: 239)

**Fig. 108**

**Morphological characters:** Unbranched filaments.

**Cytological features:** Vegetative cells 30-34 μm broad and 51-69 μm long; cells contain stellate chloroplasts with several long lobes.

**Reproductive structures:** Conjugation scalariform and lateral; receptive gametangia slightly enlarged; zygospores globose, 44-45 μm in diameter; mesosporium yellow and
Fig. 108. *Zygnema fanicum*: a. vegetative cell, b. scalariform conjugation, c. lateral conjugation, d. aplanospore.
sharply pitted, pits 2-3 µm apart; aplanospores globose, 33-35 µm broad and 36-38 µm long.

**Localities:** Sheikhupura District: near Sheikhmanwala (15-3-2004); Azad Kashmir: Neelum Valley (5-4-2004).

**Geographical distribution:** China: Hupeh, Kiangsi, Anhwei, Szechwan, Shantung (Transeau 1951); India.

**Remarks:** Collection was made from stagnant water ponds and road-side puddles during spring, where it occurred in free-floating state and mixed with other planktonic algae.

**Z. gangeticum Rao 1937: 270**


![Fig. 109](image)

**Morphological characters:** Unbranched filaments.

**Cytological features:** Vegetative cells 17-25 µm broad and 50-65 µm long.

**Reproductive structures:** Conjugation scalariform and lateral; zygospores formed in conjugation tubes and extending into gametangia; zygospores globose to ovoid, 32-39 µm broad and 30-46 µm long; median spore-wall yellow-brown and smooth.

**Localities:** Kasur District: Kamal Chishti Village (22-12-2003); Sialkot District: Jhamkay Village (25-5-2004).

**Geographical distribution:** India: U. P., Ganges River (Randhawa 1959).

**Remarks:** Specimens were collected from two different areas of the Punjab at the winter and spring seasons, slight morphological, cytological and size differences in reproductive organs were found among them. In Sialkot District it was found in temporary puddles
Fig. 109. *Zygnema gangeticum*: a. vegetative cell b. zygospore.

Fig. 110. *Zygnema himalayense*
near residential areas. The temperature was high, pH of water was nearly 8.0 i.e. slightly alkaline and water remained stagnant. Such conditions were favourable, therefore, it occurred abundantly as compared to those found in Kasur District. In both areas it was found in vegetative as well as reproductive states.

**Z. himalayense** Randhawa 1940: 129

(Transeau 1951: 23, Randhawa 1959: 218)

**Fig. 110**

**Morphological characters:** Unbranched filaments.

**Cytological features:** Vegetative cells 20.4-22.4 μm broad and 68-70 μm long and have two stellate chloroplasts, which are connected by a cytoplasmic isthmus.

**Reproductive structures:** Conjugation scalariform; zygospores bluish-green in colour, 35-37 μm long and 64-66 μm in diameter.

**Locality:** Sheikhupura District: near Sheikhanwala (15-3-2004).

**Geographical distribution:** India: at an elevation of 5,750 feet in the Himalaya mountains (Transeau 1951).

**Remarks:** Collections were made during spring in free-floating state. It was found in road-side puddles of Sheikhupura, where pH of water was 7.5 i.e. slightly alkaline.

**Z. insigne** (Hassall) Kützing 1849: 444

Fig. 111. *Zygoma insigne*: a. vegetative cell, b. scalariform conjugation, c. lateral conjugation, d. aplanospores.
Fig. 111

**Basionym:** *Tyndaridea insignis* Hassall.

**Synonymy:** *Zygnema leispermum* f. *megaspora* W. West.

**Morphological characters:** Unbranched filaments.

**Cytological features:** Vegetative cells 22-56 μm broad and 26-52 μm long.

**Reproductive structures:** Conjugation scalariform and lateral; two empty gametangia alternate with two zygospores, each in one gametangium; receptive gametangia cylindrical and enlarged; zygospores globose to sub-globose, 29-31 μm broad and 30-35 μm long; median spore-wall yellow-brown and smooth; aplanospores ovoid, 22-24 μm broad and 32-34 μm long, otherwise like zygospores.

**Localities:** Gujranwala District: Nandipur (4-4-2004); Lahore District: Batapur (27-9-2004), Salamatpura (11-3-2004); Sialkot District: (25-5-2004), Ravi-Marala link Submaral Road (6-4-2004); N.W.F.P.: Attock (12-1-2004); Azad Kashmir: Neelum Valley (5-4-2004).

**Geographical distribution:** U.S.A., South America, Europe, China, Sikkim, India, Australia (Randhawa 1959).

**Remarks:** The collection work was carried out from different areas of the Punjab, N.W.F.P. and Azad Kashmir during spring, autumn and winter seasons. It was mainly collected from rice fields, tube-well houses near border areas, ponds and puddles, but some collections were also made from gently flowing portion of streams along the roadside. It was found in vegetative as well as reproductive states, mixed with other free-floating algae. Slight cytological differences were found among different specimens.
Z. kashmirense Misra 1937: 112

(Randhawa 1959: 235)

Fig. 112

Morphological characters: Unbranched filaments.

Cytological features: Vegetative cells 39-41 μm broad and 57-60 μm long.

Reproductive structures: Specimens were found only in vegetative state.


Remarks: The species occurred in summer season, in flowing water of Kalam River in free-floating state during which temperature, light intensity, water quantity and pH conditions were suitable for its growth.

Z. khannae Skuja 1949: 99

(Transeau 1951: 44, Randhawa 1959: 255)

Fig. 113

Morphological characters: Unbranched filaments.

Cytological features: Vegetative cells 23-25 μm broad and 33-35 μm long; with two stellate chloroplasts, which are connected by a cytoplasmic isthmus.

Reproductive structures: Conjugation scalariform; aplanospores 22-24 μm broad and 43-45 μm long.

Locality: Sheikhupura District: near Sheikhanwala (15-3-2004).

Fig. 112. Zygnema kashmirense

Fig. 113. Zygnema khannae: a. vegetative cell, b. aplanospore.
Remarks: Collections were made during spring season in free-floating state. It was found in stagnant water ponds along the roadside puddles, where the pH of water was 7.5.

Z. normani Taft 1934: 213


Fig. 114

Morphological characters: Unbranched filaments.

Cytological features: Vegetative cells 24-28 µm broad and 30-73 µm long.

Reproductive Structures: Conjugation scalariform; zygospores in one of the gametangia greatly inflated on conjugation side; zygospores globose or sub-globose; 36-46 µm broad and 35-45 µm long; median spore-wall yellow-brown, scrobiculate; pits 3-4 µm in diameter 2.5-4.0 µm apart.

Localities: Kasur District: Galwedah (9-12-2004), Raja Jung Village (22-12-2004).

Geographical distribution: U.S.A.: Oklahoma (Transeau 1951); India.

Remarks: The collections were carried out from two different stagnant water ponds and areas of Kasur District during winter season in free-floating state. Slight cytological and reproductive differences were found among these specimens, because it occurred in two different ecological conditions.

Z. subcruciatum Transeau 1934: 212

(Transeau 1951: 34, Randhawa 1959: 236)
Fig. 114. *Zygnema normani*: a. vegetative cell, b. conjugation.

Fig. 115. *Zygnema subcruciatum*: a. conjugation, b. zygospore.
Morphological characters: Unbranched filaments.

Cytological features: Vegetative cells 25-26 μm broad and 42-43 μm long.

Reproductive structures: Conjugation scalariform; zygospores in one of the gametangia; receptive gametangia cylindrical or enlarged, mostly on the inner side; zygospores globose to ovoid, 24-33 μm broad and 31-37 μm long; median spore-wall brown, finally scrobiculate.

Locality: Pasrur District: Kot Libajuva Village (4-3-2004).


Remarks: The collection was carried out during spring, from surface of large ponds as free-floating masses. It was found in vegetative as well as reproductive stages.

Zygnemopsis (Skuja) Transeau 1934: 203

Unbranched, free floating filaments of cylindrical cells; two axial cushion shaped or stellate chloroplasts with a central prominent pyrenoid in each cell, sandwiching the single nucleus embedded in the cytoplasm; conjugation scalariform or lateral; conjugating tube very wide; zygospores quadrate in shape and zygospore-wall 2-3 layered; cavity of conjugant cell surrounding the zygospores inlined with shiny colourless gel; some species produce aplanospores; mesosporium may be smooth or variously ornamented. Following six species were collected which may be distinguished as follows:

1. Reproduction by aplanospores........................................................................................................2

Reproduction by zygospores........................................................................................................3
2. Aplanospores ellipsoid………………………………………………...Z. saravatiensis
   Aplanospores globose, sub-globose or quadrate…………………………Z. lahaulense
3. Zygospores cuboid with projecting corner………………………………..Z. splendens
   Zygospores not as above........................................................................4
4. Deposition of shiny, white, pectic lamellae in gametangia.........................Z. indica
   No deposition of such lamellae in gametangia.......................................5
5. Zygospores up to 27 \( \mu m \) in diameter..............................................Z. spiralis
   Zygospores more than 27 \( \mu m \) in diameter....................................Z. hesaragattense

**Z. hesaragattense** Iyengar in Randhawa 1959: 207

(Randhawa 1959: 207)

Fig. 116

**Morphological characters:** Unbranched filaments.

**Cytological features:** Vegetative cells 11-13 \( \mu m \) broad and 84-86 \( \mu m \) long with two chloroplasts.

**Reproductive structures:** Conjugation scalariform; zygospores formed in very much distended conjugation canal and extending completely across both the gametangia; mesosporium granular, golden-brown; zygospores 40-42 \( \mu m \) in diameter.

**Locality:** Azad Kashmir: Neelum Valley (5-4-2004).

**Geographical distribution:** Previously reported from India.

**Remarks:** It was collected in free-floating state during spring season from slow running water of Azad Kashmir.
**Z. indica** Randhawa 1937: 297


**Fig. 117**

**Morphological characters:** Unbranched filaments.

**Cytological features:** Vegetative cells 14-15 μm broad and 4-6 times longer, 90-92 μm long; with two semi-stellate chloroplasts each with one pyrenoid.

**Reproductive structures:** Reproduction by zygospore and aplanospore; conjugation canal-wide, deposition of shiny white, pectic lamellae in gametangia; zygospores globose or quadrately-ovoid, 35-36 μm broad and 38-40 μm long; spore-wall verrucose; some zygospores also triangular; aplanospores smaller *i.e.* 16-17 μm broad and 21-22 μm long in size.

**Locality:** Gujranwala District: Nandipur (19-2-2004).

**Geographical distribution:** India and Pakistan.

**Remarks:** Collections were made in winter in free-floating state. During this period temperature remained moderate, therefore less growth appeared. It was found in vegetative as well as reproductive conditions in stagnant water ponds.

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**Z. lahaulense** Randhawa 1958

(Randhawa 1959: 201)

**Fig. 118**

**Morphological characters:** Unbranched filaments.
Fig. 116. *Zygnemopsis hesaragattense*: a. vegetative cell, b. zygospore formation.

Fig. 117. *Zygnemopsis indica*: a. vegetative cell, b. zygospore formation.

Fig. 118. *Zygnemopsis lahaulense*
Cytological features: Vegetative cells 13.6-16.0 μm broad and 60-86 μm long; with two stellate chloroplasts.

Reproductive structures: Reproduction entirely by aplanospores, which are swollen on one or both sides and filled with shiny pectic material; spores globose, sub-globose or quadrate, 21-28 μm in diameter, yellow-brown.


Geographical distribution: India (Randhawa 1959).

Remarks: Specimens were obtained from two different localities of the Punjab during winter. They were found in stagnant water channel of Chenab River. During this collection they occurred in limited quantity in free-floating state. In the present collection conjugation stages were not observed.

Z. saravatiensis Iyengar in Randhawa 1959: 204

(Randhawa 1959: 204)

Fig. 119

Morphological characters: Unbranched filaments.

Cytological features: Vegetative cells 12-14 μm broad and 68-70 μm long; chloroplasts two, axial cushions, with a central pyrenoid.

Reproductive structures: Reproduction mostly by aplanospores, which are ellipsoid, 22-24 μm broad and 33-35 μm long.


Geographical distribution: Previously reported from India.
Remarks: The specimens were obtained from road-side puddles near a village during spring in free-floating state. The soil of Sheikhpura District is of semi-arid type. The soil at the place of collection was made up of silt, clay and large proportion of sand with pH 8.0.

**Z. spiralis (Fritsch) Transeau 1934: 214**


**Fig. 120**

Morphological characters: Unbranched filaments.

Cytological features: Vegetative cells 16-18 μm broad and 47-49 μm long; each cell contains two stellate chloroplasts.

Reproductive structures: Conjugation scalariform; zygospores quadrately-ovoid, 25-27 μm broad and 46-48 μm long.


Geographical distribution: U.S.A.: Wisconsin, Michigan (Prescott 1962); South Africa: Table Mountain, wet rock on slope (Transeau 1951); India.

Remarks: The collection was made from roadside puddles in a village during spring season. It was found in free-floating and massive quantity in the vegetative as well as reproductive stages.

**Z. splendens Randhawa 1937: 297**

(Transeau 1951: 55, Randhawa 1959: 1960)
Fig. 119. Zygnemopsis saravatienis: a. vegetative cell, b. zygospore formation.

Fig. 120. Zygnemopsis spirilis: a. vegetative cell, b. zygospore formation.

Fig. 121. Zygnemopsis splendens
**Morphological characters:** Unbranched filaments.

**Cytological features:** Vegetative cells 13-14 μm broad and 51-53 μm long; chloroplasts two, with single pyrenoid and plane septa.

**Reproductive structures:** Conjugation scalariform; protoplasm secretes a shining white, pectic, cellulose substance in a homogenous mass; zygospores cuboid with projecting corner, 27-29 μm broad and 34-35 μm long.

**Locality:** Azad Kashmir: Neelum Valley (5-4-2004).

**Geographical distribution:** India: Faizabad, U.P.; China (Transeau 1951).

**Remarks:** Collections have been made during spring. It occurred in stagnant water ponds in massive quantity and in free-floating state.

**CLASS SIPHONOCLADOPHYCEAE SHAMEEL 2001: 242**

Green algae; thallus coenocytic, siphonaceous, filamentous or thalloid.

**Order Cladophorales**

Chloroplast reticulate, reproductive organs opening by fissures or simple pore.

Detailed description may be found in the family characters, as given below:

**Family Cladophoraceae**

Coenocytic or multinucleate thalli; with thick walled cylindrical cells, united end to end in simple or branched filaments; chloroplast a parietal, net like or fragmented or reticulate sheet, encircling the protoplast; pyrenoids at many intersections of the
reticulum; filaments coarse and wiry, mostly unattached and branched; branching regular or irregular, no arbuscul plane of growth, some species with short rhizoidal branches; asexual reproduction by means of quadriflagellate zoospores and aplanospores; sexual reproduction iso- and aniso-gamous. Following three genera were collected which may be distinguished as follows:

1. Filaments with akinetes.......................................................... *Pithophora*

2. Filaments without akinetes......................................................

2. Branches small............................................................................. *Rhizoclonium*

Branches large.................................................................................. *Cladophora*

**Cladophora Kützing 1843: 262, nom. cons.**

Large, sometimes coarse tufts of branching filaments, composed of long and often multinucleate cells; chloroplast characteristically a reticulate cylinder, sometimes dissociate to form a network of small, discoid chloroplasts. Following two species were collected which may be distinguished as follows:

1. Plants trichotomously branched............................................. *C. aegagropila*

2. Plants dichotomously branched............................................. *C. crispata*

**C. aegagropila** (Linnaeus 1753: 1167) Rabenhorst 1868: 343


**Fig. 122**

**Basionym:** *Conferva aegagropila* Linnaeus 1753: 1167.

**Morphological characters:** Thalli considerably branched and bushy in form; ultimate branches not differing greatly in size form the main ones; pattern of branching appearing to be trichotomous by displacement (eversion).

**Cytological features:** Cells of many branches may be swollen at the apex; cells width usually 45-90 μm.

**Reproductive structures:** Reproductive organs were not observed.

**Localities:** Lahore District: Mahmood Booti (2-7-2004); Sheikhupura District: paddy fields near Mureedke and Narang Mundi (20-9-2004); Azad Kashmir: Neelum Valley (20-3, 5-4-2005).

**Geographical distribution:** Sweden, China and Srilanka.

**Type locality:** A lake in Sweden.

**Remarks:** The collections were carried out from three different areas during spring, summer and autumn seasons being attached with submerged grasses. In Lahore it was collected in summer season. The pH of water in rice fields, wherefrom algae were collected, was slightly alkaline (8.0), therefore it was found in massive quantity. In Azad Kashmir it was obtained during spring from stagnant water ponds in small amount. Slight cytological differences (especially cell width) were observed among different specimens.

*C. crispata* (Roth 1797: 178) Kützing 1843: 264

Fig. 122. *Cladophora aegagropila*

Fig. 123. *Cladophora crispata*
**Fig. 123**

**Basionym:** *Conferva crispata* Roth 1797: 178.

**Morphological characters:** Branches diverging at conspicuously wide angles, giving the impression of dichotomy (evection); no glomerate fascicles formed.

**Cytological features:** Cells generally cylindrical, width 49-51 μm or more.

**Reproductive structures:** In the present collection reproductive organs were not observed.

**Locality:** Azad Kashmir: Neelum Valley (20-3-2004).


**Remarks:** It was collected from Azad Kashmir during spring in free-floating state. This species occurred in slow running water of streams throughout the region. During this study it was found only in vegetative form and not in reproductive phase.

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**Pithophora Wittrock 1877: 48**

The side branches formed in this genus are almost at right angle to the main filament. There seems to be a tendency for the first cross walls in a branch to form at some distance above its junction. The main character of the genus is the presence of conspicuous akinetes, which occupy various cells, sometimes alternating with vegetative cells and which have been used as a basis for species determination. Following two species were collected which may be distinguished as follows:

1. Akinetes rectangular, up to 125 μm broad ..............................................*P. cleveana*

   Akinetes polymorphic, more than 125 μm broad......................................*P. oedogonia*
**P. cleveana** Wittrock

*Fig. 124*

**Morphological characters:** Branches emerging below the septum of main filament.

**Cytological features:** Cells 5-6 times longer than broad.

**Reproductive structures:** Akinetes intercalary, about 120-125 μm broad, almost rectangular in shape.

**Locality:** Lahore District: Mahmood Booti (2-7-2004).

**Geographical distribution:** U.S.A., Germany.

**Remarks:** The collection work was carried out in summer season in free-floating state from a village of border area of Lahore. During this season border area shows rich growth of green algae as compared to other areas of Lahore, because it is totally a cultivated area for rice, other grains and crops. Therefore, this alga was found in large quantity. The collected specimens were found in reproductive condition.

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**P. oedogonia** *(Montagne 1850)* Wittrock 1877: 55


*Fig. 125*

**Basionym:** *Conferva oedogonia* Montagne 1850.

**Morphological characters:** Filaments rarely branched and consistently cask-shaped, 46-82 μm wide and 200-925 μm long; with three orders of branching.

**Cytological features:** Vegetative cells 60 μm broad and 600-630 μm long (cells many times longer than broad); chloroplast reticulate, embedded with pyrenoids.
Fig. 124. *Pithophora cleveana*: a. vegetative filament with branching, 
b. filament with akinetes.

Fig. 125. *Pithophora oedogonia*: a. tip of a filament, b. emergence of a branch, 
c. spherical akinetes, d. cylindrical akinetes, e. filament with rectangular akinetes.
Reproductive structures: Akinetes intercalary, about 77-192 μm broad and 162-300 μm long, variously shaped: e.g. spherical, rectangular, cylindrical, barrel-shaped but never consistently hexagonal.

Localities: Kasur District: Al-Feroze Town (28-1-2004); Lahore District: Mahmood Booti (2-7-2004); Sheikhupura District: between Mureedke and Narang Mundi (12-9-2004); Sialkot District: near main G.T. Road (25-5-2004).


Remarks: Specimens were collected from four different localities of the Punjab during all the four seasons i.e. spring, summer, autumn and winter in the free-floating state. They were obtained from rice fields in spring and autumn and from other water sources during summer and winter. Morphological and reproductive variations were observed within the specimens collected from different localities and seasonal temperatures. Usually they it occurred in massive quantity.

**Rhizoclonium Kützing 1843: 261**

Filaments contain both branched and unbranched forms. The branching is almost at right angles, and the first cross wall of the branches is formed away from the junction. However, a transition of branches may be observed through short unicellular side stump to multicellular branches of indefinite length, the branches are far smaller. The uniserate filaments possess occasional or numerous, short, septate or non-septate, colourless branches. The number of nuclei per cell ranges from 1-4. Chloroplast is a reticulate plate or a pattern of small chloroplasts. Asexual reproduction is by means of biflagellate
zoospores which, in some species, are said to possess unequal flagella. Following three species have been collected which may be distinguished as follows:

1. Filaments unbranched............................................................... *R. hieroglyphicum*
   Filaments branched................................................................. 2

2. Mostly branched................................................................. *R. fontanum*
   Rarely branched................................................................. *R. riparium*

*R. fontanum* Kützing 1843: 261

(Prescott 1962: 142, Zaman & Hussain 2006: 80)

**Fig. 126**

**Morphological characters:** Filaments branched, with long cells; branches of one order in between the two adjoining cells at right angle to the parent filament; cross walls laid down some distance from it.

**Cytological features:** Cells cylindrical, with uneven lateral walls.

**Reproductive structures:** In present collection reproductive structure were not observed.

**Locality:** Siakot District: Sambaral (6-4-2004).

**Geographical distribution:** U.S.A (Prescott 1962).

**Remarks:** Collection was made from stagnant water ponds during spring, where it occurred in free-floating state. Although, the pH of water, light intensity and temperature of this area were suitable for its growth, but it was found only in vegetative form.
**R. hieroglyphicum** (C. A. Agardh 1827) Kützing 1843: 206


**Fig. 127**

**Basionym:** *Conferva hieroglyphica* C. A. Agardh 1827.

**Synonymy:** *Rhizoclonium aponinum* Kützing 1845, *Microspora fontinalis* (Berkeley) De Toni.

**Morphological characters:** Unbranched long filaments with long cells, tips of the filament rounded.

**Cytological features:** Vegetative cells 23-112 μm broad and 102-663 μm long; chloroplast reticulate or broken; pyrenoids many.

**Reproductive structures:** Asexual reproduction by zoospores, 50-65 μm broad and 150-275 μm long.

**Localities:** Kasur District: Hawailyan Village (22-12-2004); Sheikhupura District: near Rana Bhatti (2-4-2004); Sialkot District: Adamkay Village (25-5-2004).

**Geographical distribution:** U.S.A.: N.F.K. (Forest 1954), Mountain of Mississippi; Czech Rep.

**Type locality:** cave near Carlsbad, Karlovy Vary, Czech Rep.

**Remarks:** The collection was carried out during winter and spring in free-floating state. It occurred in drainage and temporary pond water. The water was highly polluted in irrigation channels. In different localities and under various ecological conditions this species occurred sometimes in low and sometimes in high quantity.
Fig. 126. *Rhizoclonium fontanum*

Fig. 127. *Rhizoclonium hieroglyphicum*: a. a cell, b. part of a filament, c. zoospores.
**R. riparium** (Roth 1806: 216) Harvey 1849: 1037


**Fig. 128**

**Basionym:** *Conferva riparia* Roth 1806: 216.


**Morphological characters:** Rarely branching filaments with long cells.

**Cytological features:** Cells 44-46 μm broad and 180-375 μm long; chloroplast reticulate.

**Reproductive structures:** In the present collection reproductive structures were not observed.

**Locality:** Kasur District: Lulyani Village (6-1-2004).

**Geographical distribution:** U.S.A., Germany, Croatia.

**Syntype localities:** North Sea, Germany; Dubrovnik, Croatia.

**Remarks:** It was collected from stagnant water ponds of a village during winter in free-floating state. The temperature of water was about 6 °C. The species was only found in vegetative condition.

**Order Sphaeropleales**

Unbranched, free-floating filaments; protoplasm multinucleated, segregated into bands by vacuoles.
Fig. 128. *Rhizoclonium riparium*

Fig. 129. *Sphaeroplea annulina*: a. a cell, b. part of a cell.
Family Sphaeropleaceae

Same characters as have been given above. It included only the following genus:

*Sphaeroplea* C. A. Agardh 1824: 76

Free-floating filaments of long, cylindrical multinucleate units, with thickened cross walls. The cells are divided into protoplamic sections by large vacuoles. Chloroplasts numerous, ovate, narrow and ring like, which vary in shape with age and so grouped as to form up to 30 parietal bands or zones within each cell. Sexual reproduction is oogamous, non motile eggs and antherozoids are produced in unmodified vegetative cells in the same or in separate filaments. Zygospores are red, with thick decorated walls. Only the following species could be collected:

*S. annulina* (Roth 1806: 211) C. A. Agardh 1824: 76


Fig. 129

**Basionym:** *Conferva annulina* Roth 1806: 211.

**Synonymy:** *Sphaeroplea armenica* Kützing, *S. leibleinii* Kützing, *S. trevirani* Kützing.

**Morphological characters:** Free-floating, unbranched filaments.

**Cytological features:** Long cylindrical cells, recognizable in vegetative condition because of numerous septation of cytoplasm with vacuoles between them, giving a sort of
ladder effect in the cell; end walls unevenly thickened, side walls relatively thin; cell
length 470-480 μm and width 35-40 μm long.

**Reproductive structures:** Sexual reproduction oogamous; zygospore-wall not smooth,
but decorated with spines.

**Locality:** N.W.F.P.: Attock (12-1-2004).

**Geographical distribution:** U.S.A., Europe, India.

**Remarks:** The collection work was carried out during winter season, specimens were
found mixed with different free-floating algae. It occurred in vegetative as well as
reproductive conditions. During this season temperature, pH of water and light intensity
were favourable for its growth.

**PHYLUM CHAROPHYTA**

Pigmentation: chlorophyll a & b; flagellation: two, anisokontic, sub-terminal,
whiplash flagella; storage product: starch; cell-wall constituents: cellulose & heavy
calcification; reproduction: oogamy, no zoospores; thallus body with precise
segmentation into nodes and internodes, corticated or ecorticated.

**CLASS CHAROPHYCEAE**

Same characters as have been described above.

**Order Charales**

Same as above, it is the only orders of the phylum/ class. Details for
distinguishing characters have been given below in the family description.
Family Characeae

In the taxonomy of this family the arrangement of the sex organs, the presence and absence of cortical cells and their number and arrangement are the major fundamental characteristics upon which differentiation has been made. It included only the following genus:

**Chara** Linnaeus 1753: 1156

Stem and branchlets corticate or ecorticate; stipulodes present, though sometimes rudimentary; branchlets of 4 or more segments; bract cells 4 or more at the node; nucules and globules produced one above the other from periphery of branchlet nodes, globule below the nucule, oospores terete; cortex haplostichous, diplostichous or tripllostichous; stipulodes in a single or double rows. Following two species were collected which may be distinguished as follows:

1. Stem slender, narrow, 375-500 µm in diameter..........................C. aspera
   Stem stout, broad, 1,000-1,400 µm in diameter.........................C. globularis

**C. aspera** Detharding *ex* Willdenow 1809: 298


**Fig. 130**

**Synonymy:** Chara delicatula Desvaux *in* Loisielieur 1810: 137, C. intertexta Desvaux 1810, C. fallax C. A. Agardh 1824, C. galioides C. A. Agardh *nom. illeg.* 1824, C. pulchella var. aspera (Willdenow) Wallroth 1833, C. pulchella var. delicatula (Desvaux)

**Morphological characters:** Thalli monoecious, up to 15 cm long, incrusted with lime; stem slender, narrow, 375-500 µm in diameter; internode as long or twice as long as the branchlets; stem cortex triplostichous; stipulodes in a double whorl, those of the upper whorl tough, short, better developed than those of the usually rudimentary, lower whorl; branchlets 7-8 in whorl, usually curved, composed of 8-11 segments of which the upper 1-3 are ecoricate, the other diplostichous, corticate; bracteoles somewhat longer than the oogonium.

**Anatomical features:** Stem cortex triplostichous, primary cortical cells broader than the secondry ones; spine cells usually minute, papiliform; bract cells 5-7, anterior pair only developed, anterior ones 0.5-1 time the length of oogonium.

**Reproductive structures:** Antheridia and oogonia together at the three lower branchlets; node solitary; antheridia 350-560 µm in diameter; oogonia 750-1,000 µm long, 500-700 µm wide; spiral cells showing 14-15 convolutions; coronula 100-240 µm high, 180-260 µm wide at the base; individual cells convent; oospore black, 625-670 µm long, 340-550 µm wide with 12-14 thin ridges, terminating in basal claws.

**Locality:** Sheikhupura District: between Mureedke and Narang Mundi (12-9-2004).

**Geographical distribution:** India: Varanasi (U.P.); Pakistan: Lahore, Nurpur (Pal *et al.* 1962).

**Remarks:** The collection was made during autumn being attached with stones in the rice fields of Sheikhupura. The ecological conditions were not favourable for its growth, therefore, it was found in low quantity.
Fig. 130. *Chara aspera*: a. vegetative branch, b. part of branchlet with antheridium and oogonium.

Fig. 131. *Chara globularis*: a. a branch of vegetative thalli, b. branchlet with antheridium and oogonium, c. single oogonium.
C. globularis Thuillier 1799: 472


**Fig. 131**

**Synonymy:** Chara fragilis Desvaux *in* Loiselieur 1810, C. fragilis var. subverrucosa A. Braun, C. leptosperma A. Braun.

**Morphological characters:** Thalli monoecious, incrusted, up to 60 cm high; stem stout, broad, 1,000-1,400 μm in diameter; internodes 1-2 times the length of the branchlets; irregular, multicellular bulbils sometimes present; stipulodes in double whorls; rudimentary, greatly reduced and inconspicuous branchlets 7-8 in a whorl; straight, very long, consisting of 8-11 segments of which the upper 1-3 are ecorticate; bracteoles somewhat developed, shorter than or as long as the oogonium.

**Anatomical features:** Cortex triplostichous, regular; cells of primary and secondary series of equal width; spine cells rudimentary, visible only in very young internodes; cortical cells of branchlets twice as numerous as the bract cells; bract cells usually 7, varying in length, equal or somewhat shorter than the oogonium; only one anterior pair developed, posterior cell rudiments at fertile nodes, at sterile nodes frequently absent.

**Reproductive structures:** Antheridia and oogonia solitary, at the lowest branchlets nodes; antheridia 300-450 μm diameter; oogonia 800-1,100 μm long, and 350-450 μm wide; 11-14 well pronounced ridges prolong downward.

**Locality:** Sheikhupura District: between Mureedke and Narang Mundi (12-9-2004).

**Geographical distribution:** India, Pakistan: Lahore (Pal et al. 1962).
Remarks: Collections were made during autumn in attached condition, from paddy fields. It occurred in limited quantity due to the unfavourable conditions but was found in vegetative as well as reproductive conditions.

**PHYLUM VAUCHERIOPHYTA** Shameel 2001: 243

Pigmentation: chlorophyll a & c₁, no fucoxanthin; flegellation: two, heterokontic flagella; storage products: mannitol, glucose & lipid; cell-wall constituent: cellulose; filamentous or coenocytic, siphonaceous thalli.

**CLASS VAUCHERIOPHYCEAE** SHAMEEL 2001: 243

Same characters as have been given above.

**Order Tribonematales**

Filamentous organisms, not coenocytic; cell-wall composed of two pieces. The detailed characters have been given in the family description, as written below:

**Family Tribonemataceae**

The filaments are unbranched, uniseriate and composed of more or less cylindrical cells. There is basal-distal differentiation in young filaments, which are attached by a stipe and an adhesive disc. In nearly all forms, the two-piece construction of the cell-wall is clearly evident, the junction of the piece occurring at the mid region of
the cell, when the filaments fragment, the cells dissociate at the planes of junction with the result that H-pieces are formed. There are two to several parietal, disc like chromatophores. It included only the following genus:

**Tribonema Derbès et Solier 1856: 1**

Filaments unbranched, uniseriate; cells uniformly cylindrical or slightly barrel-shaped; cell-wall consists of two equal or slightly equal halves; when filament becomes dissociated into H-pieces, they can be detected; end of filaments appear as a cylinder; chromatophores discoid, light yellow-green, two to several in the cell, without pyrenoid; reproduction by fragmentation and by heterokont zoospores which are liberated by separation of H-pieces; sexual reproduction isogamous; statospores and aplanospores also formed. The following two species of this genus were collected, which may be distinguished as follows:

1. Vegetative cells small, 3-6 µm in diameter…………………………………... **T. vulgare**

   Vegetative cells large, 8.9-10.9 µm in diameter…………………………………... **T. pyranigerum**

**T. pyranigerum Pascher**

**Fig. 132**

**Morphological characters:** Filaments simple, unbranched, pale in colour.

**Cytological features:** Vegetative cells 8.9-10.9 µm in diameter and 25-27 µm long, cylindrical; chromatophores numerous; cell-wall composed of sections which adjoin and overlap in the mid region; terminal cells thus show H-shaped section.
Reproductive structures: In the collected material reproductive structures were not observed.

Locality: Lahore District: Nishtar colony (20-7-2004).

Geographical distribution: Worldwide.

Remarks: The observed specimens were collected from summer season in the free-floating state, from a pond.

T. vulgare Pascher 1923


Synonymy: Tribonema bombycina (C. A. Agardh) Derbes et Solier 1856: 18, Conferva bombycina C. A. Agardh.

Morphological characters: Filaments simple, unbranched, pale in colour.

Cytological features: Vegetative cells, 3-6 μm in diameter and 10-36 μm long, cylindrical and rectangular in shape; chromatophores numerous; cell-wall composed of sections which adjoin and overlap in the mid region; terminal cells thus show H-shaped section; lateral walls somewhat convex; plastids pale-green, parietal disc or folded plates.

Reproductive structures: In the present collection reproductive organs were not seen.


Geographical distribution: Worldwide.

Remarks: It was collected during winter season in free-floating state, from freshwater ponds. It was found in vegetative as well as reproductive forms.
Order **Botrydiales** Pascher 1931: 324

Upper portion of thallus aerial and globose, lower portion buried in the soil; multinucleate thallus; colourless rhizoids.

**Family Botrydiaceae**

Same characteristics as have been described for the order. Following genus has been collected which is characterized as follows:

**Botrydium** Wallroth 1815: 153

Coenocytic thallus, aerial vesicular portion may be 1-2 µm in diameter, in most cases globose or may be cylindrical; tough wall and a thin layer of cytoplasm containing many nuclei and chromatophores; rhizoidal portion colourless which penetrates in the soil. Only following species could be collected:

**B. granulatum** (Linnaeus) Greville 1830: 196


**Fig. 134**

**Morphological characters:** Multinucleate, globose or pyriform thallus, visible to the nacked eye, diameter 1.5-24.0 µm; on wet soil with considerable quantity; anchored to the soil with colourless, branched, rhizoidal system.

**Cytological features:** Coenocyte having the diameter from 1.5 up to 24 µm.
Fig. 132. Tribonema pyranigerum

Fig. 133. Tribonema vulgare

Fig. 134. Botrydium granulatum
Reproductive structures: Reproductive structures were not observed.


Remarks: Collection was made during winter in the attached condition. It was raining heavily during this month and many stagnant ponds were formed which provided favourable condition for its growth.

Order Vaucheriales (Nägeli) K. Bohlin 1901

Multinucleate, coenocytic, branched filaments. Detailed characters have been given in the family description, as below:

Family Vaucheriaceae S. F. Gray 1821: 288

Filamentous or saccate thalli; have many discoid chloroplasts within a reticular cytoplasm and accumulate food as oil; asexual reproduction by aplanospores or zoospores; sexual reproduction isogamous, anisogamous or oogamous. It included only the following genus:

Vaucheria De Candolle 1801: 20

Much branched, filamentous, coenocytic forms; thallus consists of a mat of filaments, some of which vegetative and some reproductive; wall has an outer layer of pectose and an inner one of cellulose; thalli form green, velvety expanses, when immersed grow with many erect branches in penicillate tufts; food reserve oil; sexual reproduction oogamous, mostly monoecious; sex organs sessilis and located either on the
main filament or at the end of special branches; oogonium round or oval, has a wall with a wide pore when mature, and is cut off from the stalk or main filament by a cross wall; antheridium cut off by a cross-wall from the stalk or main filament. Following seven species were collected which may be distinguished as follows:

1. Filaments less than 50 µm broad .................................................. 2
   Filaments more than 50 µm broad ............................................. 3

2. Oogonium one ........................................................................ 4
   Oogonia more than one ............................................................. 5

3. Antheridia and oogonia borne on the same filament ................. \( V. \ amphi\)bia
   Antheridia and oogonia borne on different filaments .................. 6

4. Oogonium up to 65 µm broad .................................................. \( V. \ longata \)
   Oogonium more than 65 µm broad ............................................. \( V. \ terrestris \)

5. Oogonia up to 2 on a branch .................................................. \( V. \ hamata \)
   Oogonia more than 2 on a branch .......................................... \( V. \ debaryana \)

6. Reproductive organs sessile .................................................. \( V. \ bursata \)
   Reproductive organs pedicellate ............................................. \( V. \ discoidea \)

\textbf{V. amphibia} Randhawa 1939: 541


\textbf{Fig. 135}

\textbf{Morphological characters:} Filaments branched, 52-58 µm broad.
Reproductive structures: Oogonia and antheridia on the same filament; oogonia spherical 70-91 μm diameter; oospores completely filling the oogonium, dark in colour; antheridium terminal, coiled 26-39 μm broad.

Localities: Gujranwala District: Dandh Valley (11-12-2004); Lahore District: Nasir Bagh (22-12-2004).

Geographical distribution: Europe, India and Pakistan.

Remarks: Collections were made from two different localities of the Punjab during winter. It was found in roadside ponds in the free-floating state and also on the moist soil.

\[ V. \textit{bursata} \ (O. \ F. \textit{Müller} 1788: 96) \ C. \ A. \textit{Agardh} 1811: 21 \]


Fig. 136

Basionym: \textit{Conferva bursata} O. F. Müller 1788: 96.


Morphological characters: Filaments 50-60 μm broad.

Cytological features: Vegetative cells 50-55 μm broad.

Reproductive structures: Oogonia occur singly, mostly sessile, ovate or oblong-ovate, 75-76 μm broad and 85-87 μm long; beak short, parallel to the filament; antheridium
Fig. 135. *Vaucheria amphibia*: a: antheridium, b: oogonium.

Fig. 136. *Vaucheria bursata*
behind a single oogonium on a short slightly curved pedicel, hooked to circinate, 18-19
µm broad; oospores fill the oogonium, dark spotted membrane, three layered, 49-50 µm
broad and 61-63 µm long; zoosporangia ovoid, clavate, terminal on a branch.

**Locality:** Pasrur District: Mutaike Raypootan Village (3-4-2004).

**Geographical distribution:** U.S.A., Europe, Australia, Japan, India: Varanasi, Kolkata,
Delhi, Lucknow (Venkataraman 1961).

**Type locality:** Bad Meinberg, Southwest of Hannover, Germany.

**Remarks:** The collections were made from a village of Pasrur District during spring. It
was found growing at the surface of moist soil as well as in the free-floating state.

**V. debaryana** Woronin 1880: 425


**Fig. 137**

**Morphological characters:** Filaments 27-44 µm broad.

**Reproductive structures:** Oogonia 1-3, oval or spherical, with a short, straight, terminal
beak, shortly stalked, 45-60 µm broad and 50-70 µm long, situated under the
antheridium; oospores 44-48 µm broad and 48-50 µm long; oospore-membrane three
layered; antheridium straight, broader than stalk, opening by 1-4 lateral pores.

**Locality:** N.W.F.P.: Attock: two miles east of Khairabad (12-1-2004).

**Geographical distribution:** U.S.A., China and Europe.
Fig. 137. *Vaucheria debaryana*

Fig. 138. *Vaucheria discoidea*: a: oogonia, b: antheridium and oogonium, c: sex organs.
Remarks: It was collected from slow running water stream of a bridge near Attock during winter season. The specimens were found in free-floating state in massive quantity. It occurred only in reproductive forms.

**V. discoidea** Taft 1937: 557


Fig. 138

Morphological characters: Filaments 110-170 µm broad.

Reproductive structures: Oogonia (3-4) 6-16 usually 8, ovoid to oblong, more or less oblique, pedicellate, borne at the periphery of a disc-like expansion of the short lateral branches; 71-73 µm disc, sometimes terminal on the main filament; mature oospores not observed; antheridium single, circinate on a pedicel above the disc, 34-44 µm broad.

Locality: Sialkot District: Sambaral (6-4-2004).


Remarks: The collection was carried out during spring from stagnant water ponds. It occurred in the free-floating state, only in reproductive form.

**V. hamata** Walz 1866: 148


Fig. 139

Morphological characters: Filaments 36.5-38.5 µm broad.
Reproductive structures: Oogonia 1-2, ovoid to convexo-concave, borne on the shorter division of an apparently forking branch; longer division recurved bearing the hooked or circinate antheridia or an oogonium on each division; oogonia 50-52 µm broad and 50-75 µm long, membrane four layered; antheridium in a plane at an angle to that of the oogonium, 12-14 µm broad; aplanosporangia terminal, clavate.

Locality: Pasrur District: Mutaiker Raypootan Village (4-3-2004).


Remarks: The collections were made during spring. It was found on the moist soil surface and in water pools of a village in free-floating state.

V. longata Blum 1953: 492


Fig. 140

Morphological characters: Filaments 43-45 µm broad.

Reproductive features: Oogonia and antheridia born on stalk of special fruiting branches, each fruiting branch bearing one oogonium and 1-3 antheridia; oogonia globose to sub-ovoid, 62-65 µm broad and 70-74 µm long, borne at the end of a short pedicel at the base of the antheridial pedicel; oospores 54-56 µm broad and 57-59 µm long; membrane thin; antheridia circinate with a single terminal pore, narrowing towards the tip, 17-19 µm broad.

Locality: Jhang District: Rabwah, Kot Ameer Shah (10-3-2004).

Geographical distribution: Previously reported from Sweden, Germany and U.S.A.
Fig. 139. Vaucheria hamata

Fig. 140. Vaucheria longata

Fig. 141. Vaucheria terrestris
Remarks: Collection was made at the village of Kot Ameer Shah near Rabwah during spring. It was found growing on moist surface of the soil in large quantity.

*V. terrestris* Lyngbye *emend* Walz 1866: 149


**Fig. 141**

**Morphological characters:** Filaments 43-50 µm broad.

**Reproductive structures:** Oogonia single, 90-95 µm broad and 108-110 µm long, planoconvex, 60-65 µm broad and 80-85 µm long; membrane four layered; antheridium by the side of oogonium, 10-16 µm broad.

**Locality:** Lahore District: Sharifpura Village near border area (16-7-2004).

**Geographical distribution:** France, Greenland, China, India and Australia.

Remarks: Collection was made during summer, from a village near border area. During rainy season many ponds were created, where it was found growing in large quantity because high temperature and water pH were suitable for its growth. It occurred in free-floating state.
GENERAL DISCUSSION

One hundred and thirty-nine species of planktonic (free-floating), edaphic, epiokotic, epiphytic and epilithic green algae belonging to 3 phyla, 5 classes, 13 orders, 14 families and 26 genera have been collected from various freshwater habitats in the north-eastern areas of Pakistan. For this purpose several districts of the Punjab e.g. Gujranwala, Jauharabad, Jhang, Kasur, Lahore, Pasrur, Sarghoda, Sheikhupura and Sialkot, certain areas of Attock and Swat in N.W.F.P. like Bahrain and Kalam as well as Chenari, Muzaffarabad and Neelum Valley in Azad Kashmir were surveyed during December 2003 and July 2005 (Table I). On the basis of their morphological and cytological characteristics an attempt was made to identify the collected specimens up to species level. They have been identified, taxonomically described and systematically arranged according to the recently proposed classification (Shameel 2001). Although, all of them appeared to be taxonomically known species (Wolle 1887, West 1904, Pascher 1925, West & Fritsch 1927, Smith 1950, Prescott 1962, Akiyama & Yamagishi 1981, Wehr & Sheath 2003, John et al. 2005), but most of them were described for the first time from their area of collection.

1. TAXONOMIC DIVERSITY

As a result of taxonomic studies, members of the phylum Chlorophyta with 22 genera and 127 species were found to be more prevalent than other two phyla of green
algae, while phylum Vaucheriophyta included 3 genera and 10 species. The phylum Charophyta contained only 1 genus with 2 species and thus appeared to be the smallest phylum in diversity (Table I). Similar observations were made on algal diversity recently studied in Peshawer Valley of Pakistan (Nawaz & Sarim 2004, Zaman & Sarim 2005, Zaman & Hussain 2006).

The class Zygnemophyceae with its new concept (Shameel 2006), appeared to be the largest class with 7 genera and 91 species. It exhibited the largest diversity and 65.5% of the collected algae belonged to this class (Fig. 142). It was followed by the class Ulvophyceae with 11 genera and 25 species, which included 20.1% of the collected algae. It is quite obvious, because several genera of the latter are marine while the former is exclusively freshwater (Sze 1996, Lee 1999, Graham & Wilcox 2000, Hoek et al. 2002, John et al. 2005, Wahid & Khan 2006). The class Siphonoclado phyceae appeared to be the least distributed class of the phylum Chlorophyta having 4 genera and 8 species and contained only 5% of the total algae collected. This is due to the fact that this class is mainly found in the marine environment (Shameel & Tanaka 1992, Silva et al. 1996, Akatsuka 1994, Dave 1998).

The class Vaucheriophyceae with 3 genera and 10 species was not commonly represented in the collected material, although it overwhelmly occurs in the freshwater environment (Goetz 1897, Brown 1929, Li 1936, Randhawa 1939, 1942, Venkataraman 1961, Faridi & Hussain 1977). Its proportion in the diversity was only 3.6%. Among all the classes, Characeae with 1 genus and 2 species was least represented in the present collection, which indicated only 1.5% diversity. In the previous studies also it was
observed that Charophytes are not so commonly represented in Pakistan (Faridi 1955, Pal et al. 1962, Sarim 1991, Langangen & Leghari 2001, Shameel 2002a, 2005).

At ordinal level, Zygnemales was most commonly distributed with 5 genera and 65 species. This order showed the largest diversity and included 45.3 % of the collected algae in it (Fig. 143). It was followed by the order Oedogoniales with 2 genera and 28 species including 20.1 % of the total collected algae. While rest of the orders were represented very poorly (> 9 %) among the collected population. Prasiolales, Sphaeropleales and Botrydiales were the most poorly distributed orders with only 1 genus and 1 species each, showing only 0.7 % representation by each one of them in the population of the collected algae. As the orders Zygnemales and Oedogoniales belong to the class Zygnemophyceae, it appeared to be the most highly distributed class as has already been described above. In previous studies, The orders Zygnemales and Oedogoniales were found to be very widely and very well represented in the Indian Sub-continent (Rao 1937, Randhawa 1959) as well as in other parts of the world (Tiffany 1930, Czurda 1932, Transeau 1951).

2. SPECIES DIVERSITY

*Spirogyra* with its 42 species was the most commonly occurring genus (Table II). It was followed by the genera *Oedogonium* with 26 species and *Zygnema* with 10 species. Next common were the genera *Ulothrix* with 8 species and *Zygnemopsis* with 6 species, except *Ulothrix* all these genera belong to the class Zygnemophyceae. Such observations have also been made in several previous studies made on the specific diversity of these

Poorly distributed genera were *Binuclearia*, *Chaetophora*, *Cylindrocapsa*, *Geminella* and *Heterothrichopsis* among class Ulvophyceae, *Hallasia* among Zygnemophyceae, *Sphaeroplea* among Siphonoclado phyceae and *Botrydium* among class Vaucheriophyceae, which were represented by a single species each. While *Aphanochaete*, *Bulbochaete*, *Chara*, *Cladophora*, *Pithophora*, *Coleochaete*, *Tribonema* and *Uronema* were slightly better in their diversity, as each of them was represented by two species. Some of these genera have been observed to be poorly distributed at other places also (Wittrock 1887, Tiffany 1928, Fritsch 1929, Wichmann 1937, Palik 1950, Hoek 1963, Faridi & Haq 1972).

### 3. HABITAT DIVERSITY

Out of the total investigated species in the present collection, an overwhelming amount was found in the free-floating or planktonic condition (Table III). Almost 75.5 % of the collected species occurred in this condition (Fig. 144). Most of such species were not real plankton, but they were found in the detached condition during collection. In a previous study made on the occurrence of blue-green algae from the north-eastern areas of Pakistan, a similar observation was also made, where species of the Cyanophyta were predominantly found to occur in the planktonic condition (Naz 2004). No epipsammic or
epipelic alga was observed in the present collection. Next category, in which individuals were collected, is the epiphytic condition. About 15.8% of the collected species were found as epiphytes. These were the two major habitats, in which collected algae commonly occurred, while in other habitats they were very poorly represented. Only a few species occurred in the edaphic (3.6%), epilithic (3.6%) and epioikotic habitats. The last mentioned was the least represented (1.6%) habitat. In the above-mentioned previous study, the collected blue-green algae occurred in edaphic habitat in an appreciable amount (Naz 2004).

The above mentioned conditions were mainly represented by the species of the phylum Chlorophyta, and its three classes behaved similarly except Siphonocladoiphyceae. In this class, no species was found in the epilithic, epioikotic or edaphic habitats. It is due to the fact that they are poorly represented in the freshwater environment (Dawson 1966, Lüning 1985, Shameel & Tanaka 1992, Silva et al. 1996, Dave 1998). The freshwater grass-green algae mostly occur in the free-floating condition (Round 1973, 1981, Lüning 1985, Lobban & Harrison 1997). Under the phylum Vaucheriophyta, no species was found in the epioikotic or epilithic condition. They usually occur in the free-floating and edaphic conditions (Li 1936, Randhawa 1939, Venkataraman 1961). Apart from epilithic and epiphytic habitats all the other categories were missing among collected species of the Charophyta. But it is not so important, because only two species could be collected and therefore no valid generalization may be made with these data. Usually, they mainly grow in the benthic condition, attached at the bottom of slow running water channel (Wood 1965, Krause 1997, Langangen & Leghari 2001, Shameel 2002a).
4. DIVERSITY OF LOCALITIES

In the present study collections were made from 12 different localities. The largest number of species was found in the Lahore District (Table II), displaying 17.3% diversity of the collected species (Fig. 145). In a previous study, greatest diversity was exhibited by the collections of blue-green algae made at Lahore and its surroundings (Naz 2004). Other groups of freshwater algae were also found in abundance at Lahore (Masud-ul-Hasan 1978a, b, 1980, Masud-ul-Hasan & Yunus 1989). It was followed by the collections of Sheikhupura District with a diversity of 14%. Similar observation was also made on the distribution of blue-green algae in the above mentioned previous study (Naz 2004). These areas were further followed by Kasur and Sialkot districts, showing 12.1% diversity each.

The cold areas of Swat and Azad Kashmir also displayed an appreciable number of species, having 9.3% and 9.8% diversities, respectively. In other studies also a large number of algal species have been collected from these areas (Siddiqui & Faridi 1964, Anjum et al. 1982, Anjum & Faridi 1985, Masud-ul-Hasan & Zeb-un-Nisa 1986, Nawaz & Sarim 2004, Zaman & Sarim 2005, Zaman & Hussain 2006). The areas of Attock and Pasroor were quite poor in the distribution of algae, exhibiting a diversity of 3.3% each. A poor algal diversity was also observed at Attock by Faridi et al. (1981). The smallest number of species was observed in Sargodha and Jauharabad districts, with a very slight difference, showing diversities of 1.9% and 2.3%, respectively. A poor collection of different phyla of freshwater algae was also recorded for these districts in certain previous studies (Masud-ul-Hasan & Batool 1987, Naz 2004).
Above-mentioned observations are quite obvious regarding the species of the phylum Chlorophyta as a whole. Its class Zygnemophyceae was well-represented at all the 12 localities, but the class Ulvophyceae was not found at Sargodha Districts. It is quite obvious, because this area showed the lowest diversity of algal growth (Masud-ul-Hasan & Batool 1987, Naz 2004). However the class Siphonoclado phyceae was not present at several localities, due to its poor representation in the freshwater environment (Shameel & Tanaka 1992, Silva et al. 1996, Lobban & Harrison 1997, Dave 1998). Due to quite small number of species collected, the above mentioned conditions are not clear among members of the phyla Charophyta and Vaucheriophyta. Therefore, no valid conclusions may be drawn about them.

*Spirogyra* was the most commonly collected genus. Its different species were found growing at all investigated localities except Sargodha District. Next to it was *Zyg nema*, which was further absent from Jauharabad District. Further were *Ulothrix* and *Oedogonium*, which were collected from 8 different localities. *Binuclearia, Botrydium, Geminella, Hallasia, Heterothrichopsis* and *Sphaeroplea* were the least occurring genera. They were collected from one locality only. While *Aphanochaete, Bulbochaete, Chaetophora, Chara, Coleochaete, Cylindrocapsa, Tribonema* and *Uronema* were slightly better, as they occurred at two different localities. Some of these genera were also found to be poorly distributed at other places (Tiffany 1928, Wichman 1937, Palik 1950, Hoek 1963, Faridi & Haq 1972).
5. SEASONAL DIVERSITY

Collections of green algae were attempted throughout the year. They were found to grow practically in all the four seasons, but the largest number of their collections was made in spring season (Table IV), when 31.6 % of them have been obtained (Fig. 146). Their frequency of occurrence remained almost the same during summer and winter, which was 24.6 and 26.3 % respectively. They were found in smallest number in autumn, indicating a frequency of 17.5 % only. It appeared that they started growing in winter, thrived luxuriantly and reached to a maximum growth during spring, then they declined and began to disappear during autumn. Similar observations have been made about the occurrence of freshwater green algae at several other places as well (West 1904, Pascher 1925, Prescott 1962, John et al. 2005). They usually exhibit a bloom in their occurrence during spring (Round 1981, Wehr & Sheath 2003).

In the present collection, the seasonally resistant most common genera were *Stigeoclonium* and *Ulothrix* from the class Ulvophyceae, *Oedogonium, Spirogyra* and *Zygnema* among Zygnemophyceae and *Pithophora* under the class Siphonocladophyceae, which were found to grow in all the four seasons of the year. These genera were also of common occurrence of other places as well (Hirn 1900, Fritsch 1903, Heering 1914, Cholnoky 1932, Czurda 1932, Islam 1963, Khan & Faridi 1977, Faridi et al. 1982). It was interesting to observe that *Binuclearia, Cylindrocapsa, Geminella* and *Hallasia* were only collected during spring season, *Heterothrichopsis* was only found in summer, *Chaetophora* and *Chara* occurred only during autumn, while *Aphanochaete, Botrydium* and *Sphaeroplea* thrived only in winter. Species of all these genera could not be collected.
during other seasons, they appeared to be of very restricted occurrence and reflected a clear seasonality. Some of these genera have previously been observed to exhibit a restricted seasonal occurrence in our areas (Faridi 1955, Faridi & Haq 1972, Sarim 1991, Langangen & Leghari 2001) as well as in other areas (Wittrock 1887, Hazen 1902, Fritsch 1929, Palik 1950, Krause 1997). The remaining genera were found in certain seasons of the year but remained absent during others.

6. CONCLUDING REMARKS

The above-mentioned conclusions require verifications of the different statements made on the obtained data, which are unfortunately quite small from the required point of view. This is only possible when a sufficiently large amount of data has been obtained by the repeated investigations and researches. Collection of such a huge data is not possible in a small research work like this. In the present study, a preliminary attempt was made to simply present the obtained taxonomic data. As a result of which, the emerging picture about algal floristics of the north-eastern region of Pakistan still remains very faint and blurred. The main reason is that certain districts of the Punjab have been left unexplored in this study and several places in the N. W. F. P. and Azad Kashmir could not be investigated due to difficulties in visiting these areas. After the great tragedy of earthquake, it was extremely difficult to explore in Azad Kashmir.

Only after investigating various freshwater habitats of all the concerned areas of the Punjab, N. W. F. P. and Azad Kashmir a clear picture will emerge about the characteristics of the algal flora of the north-eastern region of Pakistan. It may be
clarified and intensified by further researches. There are several other groups of freshwater algae, especially the microalgae, which are yet to be taxonomically exploited and explored from these areas. Anyhow, the present study will give an impulse and may create initiative and stimulus for such researches and simultaneously will act as a guideline for future research in this direction.
Fig. 142. Diversity of classes exhibited by the collected material.

1 = Ulvophyceae (20.1 %), 3 = Siphonocladaophyceae (5 %),
2 = Zygnemophyceae (65.5 %), 4 = Charophyceae (1.4 %)
5 = Vaucheriophyceae (3.6 %).
1 = Ulotrichales (9.4 %), 5 = Coleochaetales (2.9 %), 9 = Sphaeropleales (0.7 %),
2 = Prasiolales (0.7 %), 6 = Oedogoniales (20.1 %), 10 = Charales (1.4 %),
3 = Microsporales (3.6 %), 7 = Zygnemales (45.3 %), 11 = Tribonematales (1.4 %),
4 = Chaetophrales (3.6 %), 8 = Cladophorales (5.8 %), 12 = Botrydiales (0.7 %),
13 = Vaucheriales (5 %).

Fig 143. Diversity of orders shown by the collected material.
1 = Planktonic (75.5 %), 3 = Epioikotic (1.4 %),
2 = Edaphic (3.6 %), 4 = Epilithic (3.6 %),
5 = Epiphytic (15.8 %).

**Fig. 144.** Diversity of habitats presented by the collected material.
Fig. 145. Diversity of localities displayed by the collected material.
Fig. 146. Seasonal diversity exhibited by the collected material.

1 = Spring (31.6%), 3 = Autumn (17.5%),
2 = Summer (24.6%), 4 = Winter (26.3%).
Table 1
Occurrence of green, stonewort and yellow-green algae in different areas of north-eastern region of Pakistan and Azad Kashmir.

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1 = Attock, 2 = Gujranwala, 3 = Jauharabad, 4 = Jhang, 5 = Kasur, 6 = Lahore, 7 = Pasroor, 8 = Sargodha, 9 = Sheikhupura, 10 = Sialkot, 11 = Swat, 12 = AzadKashmir, + = Present, - = Absent.
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Species diversity of green, stonewort and yellow-green algae in different areas of north-eastern region of Pakistan and Azad Kashmir.

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1= Attock, 2= Gujranwala, 3= Jauharabad, 4= Jhang, 5= Kasur, 6= Lahore, 7= Pasroor, 8= Sargodha, 9= Sheikhupura, 10= Sialkot, 11= Swat, 12= Azad Kashmir, -= Absent, T =Total species.
### Table III

Habitat diversity exhibited by the species of green, stonewort and yellow-green algae of the Punjab, N. W. F. P. and Azad Kashmir.

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Table IV
Seasonal diversity shown by the species of green, stonewort and yellow-green algae of the Punjab, N. W. F. P. and Azad Kashmir.

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<th>Winter</th>
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<td>Algal taxa</td>
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VI. ACKNOWLEDGEMENTS

I wish to express my deepest sense of gratitude and utmost thank to my supervisor Dr. Mustafa Shameel Honourary Professor, Department of Botany, Federal Urdu University of Arts, Science & Technology, Gulshan-e-Iqbal Campus, Karachi and Eminent Professor (HEC), Department of Botany, University of Karachi for his keen interest, inspiration, sustained and perfect guidance throughout the course of this study. He has critically read and corrected the manuscript several times and taken personal interest in the preparation of this thesis.

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I am thankful to Prof. Dr. Shakeel Ahmed Khan, Director, MAH Qadri Biological Research Center, University of Karachi for providing all the necessary facilities in Room No. 18 (Phycology & Phycochemistry Lab.), where taxonomic studies were conducted. An enormous amount of taxonomic literature of Prof. Dr. Mohammed
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VII. LITERATURE CITED


Fjerdingstad, E. 1965 Taxonomy and saprobic valency of benthic phytomicro-organisms. 


Kirchner, O. 1878. Kryptogamenflora von Schlesein. Breslau.


Appendix I

PUBLISHED PAPERS
zarinaali2006@yahoo.com
TAXONOMIC STUDY OF VAUCHERIOPHYTA SHAMEEL FROM CERTAIN AREAS OF THE PUNJAB AND NWFP, PAKISTAN

A. Zarina, Masud-ul-Hasan & Mustafa Shameel

ABSTRACT
Ten species of yellow-green algae were collected from certain areas in the provinces of the Punjab and NWFP (Pakistan) during January-December 2004. They were taxonomically investigated and found to belong to three genera, three families and three orders of the class Vaucheriophyceae Shameel (phylum Vaucheriophyta).

INTRODUCTION
After the classical pioneering work of Randhawa (1936) several studies have been made on the taxonomy of green algae from provinces of the Punjab (Masud-ul-Hasan 1978a, b, 1980, Masud-ul-Hasan & Batool 1987, Masud-ul-Hasan & Yunus 1989, Shahida et al. 2005) and N.W.F.P. (Faridi 1955, 1971, 1978, Faridi et al. 1981, Hussain & Faridi 1977). Some of these works also included descriptions on certain yellow-green algae. Present study is an attempt to present a detailed investigation on the taxonomy of algal species belonging to the phylum Vaucheriophyta, collected from various areas of the above mentioned provinces of Pakistan.

MATERIALS & METHODS
Collections were made from different freshwater habitats in the provinces of the Punjab and N.W.F.P. (Pakistan) during January and December 2004. The specimens were obtained by hand-picking and preserved in 5% formalin solution. They were stained in iodine solution, temporarily mounted in glycerine and examined under microscope. Various cellular parts were measured with the help of ocular micrometer and drawings made by camera lucida. Specimens were identified with the help of authentic literature (West 1904, Venkataraman 1961, Prescott 1962, Nizamuddin & Gerloff 1982, Masud-ul-Hasan & Batool 1987, Masud-ul-Hasan & Yunus 1989). The voucher specimens are kept in the Phycology & Phycochemistry Lab., MAH Qadri Biological Research Centre, University of Karachi.

RESULTS & DISCUSSION
Ten species of the yellow-green algae belonging to three genera, three families and three orders of the class Vaucheriophyceae Shameel 2001: 243 and the phylum Vaucheriophyta Shameel 2001: 243 (vide Shameel 2001) were identified. Their taxonomic enumerations are given below:

Order Tribonematales
The filaments are unbranched, uniseriate and composed of more or less cylindrical cells. There is basal-distal differentiation in young filaments, which are attached by a stipe and an adhesive disc. In nearly all forms, the two-piece construction of the cell-wall is clearly evident, the junction of the piece occurring at the mid region of the cell, when the filaments fragment, the cells
dissociate at the planes of junction with the result that H-pieces are formed. There are two to several parietal disc-like chromatophores.

**Family Tribonemataceae**

Same characters as described above. This family included the following genus.

**Tribonema** Derbès et Solier 1856

Filaments unbranched, uniseriate; cells uniformly cylindrical or slightly barrel-shaped. Cell-wall consists of slightly two equal halves, when filament becomes dissociated H-pieces can be detected, and the end of filaments appear as a cylinder. Chromatophores discoid shaped, light yellow-green, two to several in the cell, without pyrenoid. Reproduction is by fragmentation and by heterokont zoospores. Zoospores are liberated by separation of H-pieces. Sexual reproduction is isogamous, statospores and aplanospores are also formed. This genus is cosmopolitan in distribution. The following two species of this genus were collected, which may be distinguished as follows:

1. Vegetative cells small, up to 6 μm in diameter. . . . . . . . . . . . . T. bombycinum (1)
2. Vegetative cells large, more than 8 μm in diameter. . . . . . . . . . . . T. pyrenigerum (2)

1. **T. bombycinum** (Agardh) Derbès et Solier 1856

**Basionym:** Convera bombycina Agardh


**Morphological characters:** Filaments simple, unbranched, pale in colour (Fig 1).

**Cytological features:** Vegetative cells 3-6 μm in diameter and 10-36 μm long, cylindrical and rectangular in shape; chromatophores numerous; cell-wall composed of the section which adjoins and overlaps in the mid region. Terminal cells thus show H-shaped section. Lateral walls may be somewhat convex; plastids pale-green, parietal discs or folded plates.

**Reproductive structures:** In the present collection reproductive organs were not seen.

**Locality:** Gujranwala District: Nandipur (19-2-2004).

**Geographical distribution:** World wide.

**Remarks:** It was collected during February (winter season) of 2004, from freshwater ponds. It was found in vegetative as well as reproductive forms.

2. **T. pyrenigerum** Pascher

**Morphological characters:** Filaments simple, unbranched, pale in colour (Fig. 2).

**Cytological features:** Vegetative cells 8-11 μm in diameter and 25-27 μm long, cylindrical; chromatophores numerous; cell-wall composed of section which adjoins and overlaps in the mid region; terminal cell thus shows H-shaped section.

**Reproductive structures:** In the collected material reproductive structures were not observed.

**Locality:** Lahore District: Nishtar colony (20-7-2004).

**Geographical distribution:** World wide.

**Remarks:** The observed specimens were collected during rainy season of 2004, from a pond.

**Order Botrydiales**

Thalli globose or cylindrical, siphonaceous, multinuculeate with colourless rhizoids; discoid chromatophores; cell-wall thick and tough.
Family Botrydiaceae

Same characteristics as described for the order. Following genus has been collected which is characterized as follows:


**Botrydium Wallroth 1815**

Conoecytic thallus, aerial vesicular portion may be 1-2 μm in diameter, in most cases globose or may be cylindrical; tough wall and a thin layer of cytoplasm containing many nuclei and chromatophores; rhizoidal portion colourless which penetrates in the soil. Only following species could be collected:
3. *B. granulatum* (Linnaeus) Greville 1830


Morphological characters: Multinucleate, globose or pyriform, visible to naked eye. On wet soil with considerable quantity, anchored to the soil with colourless, branched rhizoidal system, diameter 1.5-24.0 μm (Fig. 3).

Reproductive structures: Reproductive structures were not observed.


Remarks: Collection was made in the month of February 2004. It was raining heavily during this month and many stagnant ponds were formed which provided favourable condition for its growth.

Order Vaucheriales

They are all filamentous or saccate, have many discoid chloroplasts within a reticulate cytoplasm and accumulate food as oil. Asexual reproduction is by aplanospores or zoospores, whereas sexual reproduction is isogamous, anisogamous or oogamous.

Family Vaucheriaceae

Multinucleate, coenocytic filaments, possessing above mentioned characters. It included the following genus.

*Vaucheria* De Candolle 1803

It is much branched, filamentous coenocytic form. The thallus consists of a mat of these filaments, some of which are vegetative and others reproductive, forming green, velvety expanse. Food reserve is oil. Sexual reproduction is oogamous, thalli are mostly monoecious. Sex organs are either sessile on the main filament or located at the end of special branches. The oogonium is round or oval, has a wall with a wide pore when mature, and is cut off from the stalk or main filament by a cross wall. The antheridium is cut off by a cross wall from the stalk or main filament. Following species were collected which may be distinguished as follows:

1. Filaments less than 50 μm broad………………………………………2
2. Filaments more than 50 μm broad……………………………………..3
2. Oogonium one on each fruiting branch………………………………..4
3. Oogonium more than one on fruiting branches………………………5
3. Oogonia and antheridia borne on the same filament……………….6
   Oogonia and antheridia borne on different filaments……………….6
4. Oogonium up to 65 μm broad………………………………………V. longata (9)
   Oogonium more than 65 μm broad……………………………………V. terrestris (10)
5. Oogonia up to 2 on a branch………………………………………V. hamata (8)
   Oogonia more than 2 on a branch……………………………………V. debaryana (6)
6. Reproductive organs sessile……………………………………V. bursata (5)
   Reproductive organs pedicellate……………………………………….V. discoidea (7)

4. *V. amphibia* Randhawa 1939


Morphological characters: Filaments branched, 52-58 μm broad (Fig. 4a).

Reproductive structures: Oogonia and antheridia on the same filament, oogonia spherical, 70-91 μm in diameter (Fig. 4b); oosporangiosomes completely filling the oogonium, dark in colour; antheridium terminal, coiled, 26-39 μm broad (Fig. 4a).

Localities: Gujranwala District: Dand Valley (11-12-2004); Lahore District: Nasir Bagh (22-12-2004).
Geographical distribution: Pakistan.

Remarks: Collections were made from two different localities of the Punjab during December 2004. It was found in road-side ponds in free floating state as well as on moist soil.

5. V. burzata (O. F. Müller 1788) C. A. Agardh 1811

Basionym: Conerva burzata O. F. Müller 1788.

Taxonomic synonym: Vaucheria sessilis (Vaucher 1803) De Candolle 1805.


Morphological characters: Filaments 50-60 μm broad (Fig. 5).

Cytological features: Vegetative cells 50-55 μm broad.

Reproductive structures: Oogonia occur singly, mostly sessile, ovate or oblong ovate. 75-76 μm broad and 85-87 μm long; beak short, parallel to the filament; antheridium behind a single oogonium on a short slightly curved pedicel, hooked to circuminate, 18-19 μm broad; oosporic fill the oogonium, 49-50 μm broad and 61-63 μm long; dark spotted oospore membrane, three layered; zoosporangia aroid, elavate, terminal or on a branch.

Locality: Pasrur District; Mutaike Raypootan Village (3-4-2004).

Type locality: Bad Meinberg, Southwest of Hannover, Germany.

Geographical distribution: USA, Europe, Japan, India: Varanasi, Kolkata, Delhi, Lucknow; Australia (Venkataraman 1961).

Remarks: The collections were made from a village of Pasrur District during 2004. It was found growing at the surface of moist soil as well as in free floating state.

6. V. deburayana Woronin 1880


Morphological characters: Filaments 27-44 μm broad (Fig. 6).

Reproductive structures: Monoecious, oogonia 1-3, oval or spherical; with a short, straight, terminal beak; shortly stalked; 45-60 μm broad and 50-70 μm long, situated under the antheridium. Oosporic 44-48 μm broad and 48-50 μm long; oospore membrane three layered; antheridium straight, broader than stalk, opening by 1-4 lateral pores.

Locality: NWFP: Attock two miles east of Khairabad (12-1-2004).

Geographical distribution: USA, China and Europe.

Remarks: It was collected from slow running water stream of a bridge near Attock during winter season of 2004. The specimens were found in free floating state in massive quantity. It occurred only in reproductive form.

7. V. discoida Taft 1937


Morphological characters: Filaments 110-170 μm broad.

Reproductive structures: Monoecious, oogonia (3-4) 6-16 usually 8, ovoid to oblong, more or less oblique, pedicellate, borne at the periphery of a disc-like expansion of the short lateral branches (Fig. 7a), 71-73 μm disc, sometimes terminal on the main filament (Fig. 7b), mature oosporic not observed; antheridium single, circuminate on a pedicel above the disc, 34-44 μm broad (Fig. 7c).

Locality: Sialkot District: Sambharal (6-4-2004).

Geographical distribution: USA, previously reported from Peshawar by Faridi & Hussain (1977).

Remarks: The collection was carried out during April 2004 from stagnant water ponds. It occurred in free floating state, only in reproductive form.
8. *V. hamata* Walz 1866


**Morphological characters:** Filaments 36.5-38.5 μm broad (Fig 8).

**Reproductive structures:** Monoecious, oogonia 1-2, ovoid to convexo-concave, borne on the shorter division of an apparently forking branch; the longer branch recurved bearing the hooked or circinate antheridia or an oogonium on each division; oogonia 50-52 μm broad and 50-75 μm long; oospore membrane four layered; antheridium in a plane at an angle to that of the oogonium, 12-14 μm broad; aplanosporangia terminal, clavate.

**Locality:** Pasur District: Mutaiker Raypootan Village (4-3-2004).

**Geographical distribution:** USA, France, China, India: Fuzabad (Venkataraman 1961).

**Remarks:** The collections were made during March 2004. It was found on moist soil surface and water pools of a village in free floating state.

9. *V. longata* Blum 1953


**Morphological characters:** Filaments 43-45 μm broad (Fig. 9).

**Cytological features:** Cell-walls of the old filaments very thick and lamellated.

**Reproductive features:** Monoecious, oogonia and antheridia borne on stalk of special fruiting branches; each fruiting branch bearing one oogonium and one to three antheridia; oogonia globose to sub-ovoid, 62-65 μm broad and 70-74 μm long, borne at the end of a short pedicel at the base of the antheridal pedicel; oospores 54-56 μm broad and 57-59 μm long, membrane thin; antheridia circinate with a single terminal pore, narrowing towards the tip, 17-19 μm broad.

**Locality:** Jhang District: Kot Ameer Shah (15-04-2004).

**Geographical distribution:** Previously reported from Sweden, Germany and USA.

**Remarks:** Collection was made during March 2004, where it was found growing on moist surface of the soil in large quantity.

10. *V. terrestris* Lyngbye *emend.* Walz 1866


**Morphological characters:** Filaments 43-50 μm broad (Fig. 10).

**Reproductive structures:** Monoecious, oogonia single on each fruiting branch, 90-95 μm broad and 108-110 μm long, planeconvex, 60-65 μm broad and 80-85 μm long; oospores membrane four layered; antheridium by the side of oogonium, 10-16 μm broad.

**Locality:** Lahore District: Sharifpura Village (16-7-2004).

**Geographical distribution:** France, Greenland, China, India and Australia.

**Remarks:** Collection was made during August 2004, from a village near border area. During rainy season many ponds were created, where it occurred in large quantity. It appeared that high temperature and water pH were suitable for its growth. It was found in free floating state.

**REFERENCES**


TAXONOMIC STUDY OF THE ORDER ULOTIRICHALES (CHLOROPHYTA) FROM NORTH-EASTERN AREAS OF PAKISTAN

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Abstract

Thirteen species belonging to the genera Binuclearia, Geminella, Heteroohrichopsis, Ulothrix and Uronema were collected from various freshwater habitats in Gujranwala, Jauharabad, Kasur, Lahore, Pasrur, Sheikhupura and Sialkot districts of the Punjab; Bahrain, Kalan and Urood river in Swat (NWFP) and Neelum Valley of Azad Kashmir during March 2003-July 2005. They were taxonomically determined and have been described for the first time from these areas.

Introduction

Ulothrix, the typical genus of the order Ulotrichales was reported for the first time from Pakistan by Shameel (1963) and reaffirmed by Faridi (1971). Later on, a detailed taxonomic study of this genus was made from Swat (Shameel, 1978, 1984) and other areas of Pakistan (Faridi et al., 1982). No investigation was ever made on the other genera of this order. A detailed taxonomic study was, therefore, carried out on all the genera of the order Ulotrichales collected from NWFP and the Punjab Province of Pakistan and certain areas of Azad Kashmir, which is presented herein.

Materials and Methods

Collections were made from various freshwater habitats in Gujranwala, Jauharabad, Kasur, Lahore, Pasrur, Sheikhupura and Sialkot districts of the Punjab; Bahrain, Kalan and Urood River in Swat (NWFP) and Neelum Valley of Azad Kashmir during March 2003-July 2005. The collected material was taxonomically investigated as described earlier (Zarina et al., 2005). Specimens were identified with the help of authentic literature (West, 1904; Heering, 1914; Tiffany & Britton, 1952; Mattox & Bold; Prescott, 1962; Ramanathan, 1964; Pankow, 1971; Abbott & Hollenberg, 1976; Shameel, 1978; Faridi et al., 1982). The voucher specimens are kept in the Phycology & Phycochemistry Lab., MAH Qadri Biological Research Centre, University of Karachi, where the research work was carried out.

Results

Thirteen species of 5 genera belonging to the phylum Chlorophyta, class Ulvophyceae, order Ulotrichales, family Ulotrichaceae (Shameel, 2001) have been identified. Their taxonomic enumerations are given below:
Family Ulotrichaceae

It includes all the unbranched filamentous genera, in which the cells are uninucleate having a single girdle-shaped chloroplast with the cell-wall not composed of overlapping H-pieces. Almost all of them are known to produce bi- or quadriflagellate zoospores. Sexual reproduction is known only in few genera, and in all cases it is isogamous with a union of biflagellate gametes. The present collection included the following 5 genera, which may be distinguished as follows:

1. Filaments in sheath, cells cylindrical ........................................... *Geminella*
   Filaments without sheath, cells not cylindrical ........................................... 2
2. Filaments not attached by holdfast ........................................... *Heterothricopsis*
   Filaments attached by a holdfast ..................................................... 3
3. Apical cell pointed ........................................................................... *Uronema*
   Apical cell not pointed ........................................................................... 4
4. Protoplast in one section ................................................................. *Ulothrix*
   Protoplast in two sections ................................................................... *Binuclearia*

*Binuclearia* Wittrock 1887: 4

It contains simple filamentous forms, consisting of simple cells united in linear series. There is no broad gelatinous sheath. When young the filaments are attached by a mucilaginous disc, the basal cell is not specialized but the terminal cell has a cellulose cap, other cells are cylindrical. Cell-wall is thick, lamellated; the transverse septa are stratified. The protoplast is concentrated in two small portions separated from each other. Each protoplast contains a nucleus and a laminate, girdle-shaped chloroplast, shiny; volutin granules are present at the end of the protoplast. Chloroplast has one marginal pyrenoid, food reserves are starch and volutin. The transverse septa are thick and stratified in older cells, separating the protoplast. Vegetative reproduction is by fragmentation, asexual reproduction is by thick-walled akinetes or quadriflagellate zoospores formed singly in each cell. Only following species were collected:

1. *B. tectorum* (Kützing) Bererex ex Wichmann 1937
   (Ramanathan, 1964: 60)

*Basionym:* *Gloeotilla tectorum* Kützing.
*Morphological characters:* Filaments uniseriate, unbranched, with cylindrical cells (Fig. 1).
*Cytological features:* Cells 11-12 µm broad, 23-24 µm long; chloroplast parietal, plate like, with a conspicuous pyrenoid.
*Reproductive structures:* Reproduction by akinetes, quadriflagellate zoospores.
*Locality:* Lahore District: Dinanath (1-8-2004).
*Habitat:* The collection was made from rice fields, where it occurred in free-floating state in massive quantity.
Geminella Turpin 1828: 329 emend. Lagerheim 1883

It comprises of uniseriate filaments, mostly free floating, rarely sessile. The filaments are enclosed by a mucilaginous envelope varying in its relative width, but always hyaline and homogenous. The cells are cylindrical, ellipsoidal or oblong, mostly separated by mucilage and scarceely adherent to each other. They contain a laminate chloroplast, partially filling the cell, pyrenoid may or may not be present. Reproduction is by fragmentation, aplanospores, akinetes, and sometimes swarmers are produced. Only following species could be collected:

2. *G. ordinata* (W. et G. S. West) Heering 1914: 14

Basionym: *Hormospora ordinata* W. et West G. S. West.

**Morphological characters:** Unbranched filamentous algae, surrounded by a mucilaginous sheath (Fig. 2).

**Cytological features:** Cells arranged in a row with equidistant intervening spaces, inside a gelatinous sheath; cells 4-6 µm broad and 7-9 µm long; chloroplast parietal, laminate and have one pyrenoid.

**Reproductive structures:** Reproduction by fragmentation, aplanospores, akinetes.

**Locality:** Sheikhpur District: Sattarwala (15-5-2004).

**Geographical distribution:** Previously reported from Europe, Asia, America and South-Africa.

**Habitat:** The collections were obtained from stagnant water ponds.

**Heterothricopsis** Iyengar et Kanthamma 1941: 105

It includes unbranched filamentous forms made up of a few cells, placed in a row. Each cell contains a single nucleus and one or 2-4 parietal plate-like chloroplasts with one or more pyrenoids in each. In very young cell there is only one chloroplast, but as the cells become older the number of chloroplast increases to 2, 4 or 8. The cell-wall is thin and uniform, reproduction is by fragmentation. Asexual reproduction takes place by aplanospores, no zygospore or gamete has been observed. In the present collection only following species could be collected:

3. *H. viridis* Iyengar et Kanthamma 1941: 105
(Ramanathan, 1964: 97)

**Synonym:** *Ulotrichopsis viridis* Iyengar et Kanthamma 1940: 167.

**Morphological characters:** Filaments unbranched and 4-celled (Fig. 3).

**Cytological features:** Cells 6-8 µm broad and 14-16 µm long; chloroplasts 2-4 with a pyrenoid in each.

**Reproductive structures:** Reproduction by aplanospores.

**Locality:** Sheikhpur District: Aliwala (30-8-2004).

**Geographical distribution:** Previously known from India.

**Habitat:** The specimens were collected from stagnant water channels.
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_Ulothrix_ Kützing 1833: 517

It is made up of simple unbranched filaments of undefined length, special holdfast cells may be found at the base of filaments. Growth of filament diffused by cell division (holdfast does not divide). Chloroplast is single, girdle shaped, parietal band, partly or fully encircling the protoplast, pyrenoid one or more in each cell. A small nucleus is present, generally placed internally to the chloroplast. Vegetative multiplication is by fragmentation, asexual reproduction is by zoospores of two types _i.e._, biflagellated microzoospores and quadriflagellated macrozoospores, which are formed in all cells except basal cells. Sexual reproduction is by isogamy. The following six species of this genus were collected, which may be distinguished as follows:

1. Each cell contains one pyrenoid .................................................. 2
   Each cell contains more than one pyrenoids .................................. 3

2. Cell-wall thick, without mucilage ........................................... _U._ *aequalis*
   Cell-wall thin and somewhat mucilaginous ................................... _U._ *tenella*

3. Cells contain 6 pyrenoids ..................................................... _U._ *flaccia*
   Cells contain less than 6 pyrenoids ........................................ 4

4. Cells more than 11 μm in breadth .......................................... _U._ *tenuissima*
   Cells less than 11 μm in breadth ........................................... 5

5. Cells 7-8 μm in breadth ...................................................... _U._ *cylindrica*
   Cells 9-11 μm in breadth ................................................... _U._ *moniliformis*

4. _U._ *aequalis* Kützing 1845: 197


**Morphological characters:** Filament very long, composed of cylindrical cells (Fig. 4).

**Cytological features:** Cells cylindrical, 15-17 μm broad; cell-wall somewhat thickened; chloroplast broad, girdle shaped, covering more than half the wall surface; containing one pyrenoid.

**Reproductive structures:** Asexual reproduction by quadriflagellated macrozoospores and aplanospores, biflagellated or quadriflagellated microzoospores also present.

**Locality:** Lahore District; fountain of zoo (3-8-2003).

**Geographical distribution:** Previously reported from Europe, America, New Zealand and Asia.

**Habitat:** It was collected from fountain of zoo, where the temperature was 37.2 °C and pH about 7.5.

5. _U._ *cylindrica* Prescott 1944: 349

(Prescott, 1962: 96; Ramanathan, 1964: 36)

**Morphological characters:** Filaments unbranched, long, curved and lightly entangled (Fig. 5).

**Cytological features:** Cells elongate, cylindrical, 7-8 μm in width and 25-26 μm long; cell-wall thin and not constricted at joints; chloroplast a broad band nearly equal to the cell in length and covering ¾ of the wall circumference; pyrenoids 2-5.

**Reproductive structures:** Reproduction by fragmentation and zoospores.

**Locality:** Pasroor District; Mutak-Raypoontan Village (4-3-2003).
Geographical distribution: America, India (Ramanathan, 1964).
Habitat: It was collected from standing water.

6. U. flacca (Dillwyn) Thuret in Le Jolis 1863: 56
(Ramanathan, 1964: 43; Abbott & Holllenberg, 1976: 55)

Basionym: Conoera flacca Dillwyn 1805 [1802-1809].
Morphological characters: Filament bright to dark-green, entangled often in large skeins (Fig. 6).
Cytological features: Cells are cylindrical, 34-35 μm in diameter; each cell with six pyrenoids.
Reproductive structures: Reproduction by fragmentation and zoospores.
Type locality: Swansea, Glamorgan, Wales.
Geographical distribution: Previously reported from Europe, Asia, Australia, New Zealand, America.
Habitat: Collected from slow running water.

7. U. moniliformis Kützing 1849
(Ramanathan, 1964: 40)

Morphological characters: Filaments light or yellow-green, clearly constricted at the cross walls (Fig.7).
Cytological features: Cells 9-11 μm broad and 12-14 μm long (cells 6.9 μm in diameter). Chloroplast on one side of the cell, rarely forming a girdle, usually with one or two but sometimes more pyrenoids.
Reproductive structures: Reproduction by akinets or by quadriflagellate zoospores.
Locality: Kasur District: 23 km away from Kasur (15-6-2005), Sheikhupura District: near Sheikh Hanwala (30-8-2003).
Geographical distribution: Cosmopolitan in distribution; previously reported from USA, Europe, Africa, India, New Zealand.
Habitat: The specimens were collected from roadside puddles.

8. U. tenerima (Kützing) Kützing 1843

Basionym: Conoera tenerima Kützing 1833.
Morphological characters: Filaments attached or free floating, mucilaginous (Fig. 8).
Cytological features: Cells 8.0-9.5 μm broad and 4.0-5.5 μm long; cell-wall thin, somewhat mucilaginous; chloroplast girdle shaped; encircling more than half the width of the cell, with one pyrenoid.
Reproductive structures: Reproduction by fragmentation and zoospores.
Locality: Gujranwala District: Nandipur (7-12-2003); Jauharabad District: (25-4-2004); Lahore District: Hunjarwala field (16-8-2004), near Washa Boarder (25-12-2004); Sheikhupura District: Mureedk and Narang Mundi (12-9-2004).
Geographical distribution: Previously reported from Europe, America, New Zealand, Central India (Ramanathan, 1964), Sri Lanka, Myanmar and also from Lahore (Randhawa, 1948).
Habitat: It occurred in canal side ponds and stagnant water pools.

Remarks: It was collected from five different places of the Punjab during spring, summer and winter. Slight morphological changes like size differences were observed in the specimens obtained from different places due to various ecological conditions. The massive growth of this species was found in rice fields.

9. U. tenassima Kützing 1833: 517
(Heering, 1914: 32; Prescott, 1962: 97; Ramanathan, 1964: 34; Shameel, 1978: 381; Faridi et al., 1982: 186)

Morphological characters: Filament long, composed of cylindrical cells (Fig. 9).

Cytological features: Cells mostly 16-18 μm in breadth, 3-5 μm in length and 14-30 μm thick; chloroplast a broad band with two or more pyrenoids.

Reproductive structures: Zoospores formed in somewhat swollen cells.

Localities: Lahore District: fountain of zoo (3-8-2004); Sheikhupura District: near Sheikhupura (28-2-2004); Azad Kashmir: Neelum Valley (15-12-2004).

Geographical distribution: Previously reported from Europe, America, New Zealand, India, Myanmar, Pakistan.

Remarks: The collection work was carried out during beginning to the late summer from three different places. During early summer it was collected from cold water ponds, and in late summer it was obtained from fountain water locality and from road side puddles.

10. U. variabilis (Kützing) Kützing 1849: 349

Basionym: Hornidium variabile Kützing.

Morphological characters: Filaments long, slender and entangled, forming cottony masses rarely with a pointed basal cell (Fig. 10).

Cytological features: Cells 7 μm broad, 10-12 μm longer, cylindrical; chloroplast a parietal folded plate, not filling more than half the circumference of the cell, appearing as a plate covering one side of the cell.

Reproductive structures: Reproductive organs were not observed.


Habitat: Patches of soil with algal growth have been collected, as it occurred on wet soil surface in massive quantity. It was in soil binding habitat.


Basionym: Conerva zona Weber et Mohr 1804.

Synonym: Ulothrix shameeli Faridi in Faridi et al., 1982: 184.

Morphological characters: Filament long, stout, variable in diameter, attached in earlier stages, later free with cylindrical cell (Fig. 11).

Cytological features: Cells varying in width and length, length generally smaller than width, cell 27-48 μm broad and 30-53 μm long; chloroplast band shaped, broad, covering
only the median region of the cell and containing more than one pyrenoids, often several; end cell rounded. **Reproductive structures:** In the present collection reproductive structures were not seen. **Localities:** Gujranwala District: Nandipur (19-2-2004), N.W.F.P.: Swat, Urod River (19-2-2004); Azad Kashmir; Neelum Valley (15-12-2004). **Geographical distribution:** Worldwide occurrence, previously recorded from various parts of India: Mumbai, Assam, Bengal and Pakistan: Swat. **Habitat:** Collections were made along the canal side ponds and slow running water of river. **Remarks:** Specimens of the present collection differed in the structure of their apical cell and holdfast from *Ulothrix zonata* var. *faridii* (=*Ulothrix shaneei*), which was described earlier from Swat (Shameel, 1978, 1984; Faridi et al., 1982)

**Uronema Lagerheim 1887: 517**

The characteristic feature of this genus is the terminal cell of the filaments which is often tapering to an acuminate tip. It comprises of simple, unbranched filaments, mostly attached by a narrow basal cell or disc. The following two species of this genus were collected, which may be distinguished as follows:

1. Cells less than 12 µm broad, 1-3 pyrenoids .......................... *U. confervicolum*
2. Cells more than 12 µm broad, 2-3 pyrenoids .......................... *U. gigas*

**12. U. confervicolum** Lagerheim 1887: 518

(West, 1904: 80; Mattos & Bold, 1962: 29; Ramanathan, 1964: 50; Faridi et al., 1982: 183)

**Synonym:** *Ulothrix confervicola* (Lagerheim) Mattos & Bold 1962: 29.

**Morphological characters:** Filaments many celled, straight, long, attached by a disc formed by basal cell (Fig. 12).

**Cytological features:** Cells 4-8 µm broad and 5.6-21.0 µm long; basal cell 5-6 µm broad, 15-16 µm long; terminal cell pointed, 15-20 µm long; cells cylindrical; chloroplast extending the full length of the cell, parietal, encircling the protoplast and containing 1-3 pyrenoids.

**Reproductive structures:** Aplanospores and zoosporas not observed.

**Locality:** Sialkot District: Darganwali Village (25-6-2005).

**Geographical distribution:** Previously reported from America, Europe, Africa and India (Ramanathan, 1964).

**Habitat:** It was collected being attached at the margins of puddles mixed with *Microra ergula* Hazen.

**13. U. gigas** Vischer 1933

(Ramanathan, 1964: 53)

**Morphological characters:** Filaments a few mm long, unbranched, constricted at intervals (Fig. 13).

**Cytological features:** Cells 13-14 µm broad and 10-11 µm long; pyrenoids 2-3 in each cell; terminal cell elongated.

**Locality:** N.W.F.P.: Swat, Kalam, Urod River (13-8-2004).

**Geographical distribution:** Previously reported from Europe: Switzerland.

**Habitat:** Collection work was carried out from the river side.
Discussion

Taxonomy of the order Ulotrichales is in a chaotic condition. Contrary to the classical view, Forest (1945) amalgamated the genera Chlorohormidium, Stichococcus and Uronema with Ulothrix. Mattox & Bold (1962) put Ulothrix and Uronema together but retained others as separate genera, and this view was later supported by Faridi et al., (1982). In his synoptical study on Ulotrichales, Ramanathan (1964) followed the classical view and maintained all the genera as separate entities. Chlorohormidium may be distinguished from other genera by lacking a pronounced holdfast and producing biflagellate zoospores (Fott, 1960) similarly Stichococcus is also easily distinguishable from other genera (Faridi et al., 1982). Uronema has pointed apical end, while Ulothrix possesses an apical cell with prominently broad end. Therefore, in the present investigation the classical view has been followed.

References


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TAXONOMIC STUDY OF THE CLASS SIPHONOCladophyceae
SHAMEEL FROM NORTH-EASTERN AREAS OF PAKISTAN

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Abstract

Eight species of the coenocytic green algae belonging to the genera Cladophora, Pithophora, Rhizoclonium and Sphaeroplea were collected from various freshwater habitats in Kasur, Lahore, Sheikhupura and Sialkot districts of the Punjab, Attock (NWFP) and Neelum Valley of Azad Kashmir during January 2004 - April 2005. They were taxonomically determined and found to belong to the orders Cladophorales and Sphaeropleales. They have been described for the first time from these areas.

Introduction

After the sad demise of Prof. M. A. F. Faridi and the retirement of Prof. Masud-ul-Hasan no study was conducted on the algal flora of the north-eastern areas of Pakistan, therefore, the present research program was made. As a result of that, starting from December 2003 a large collection of grass green, yellow green and stonewort algae was made from freshwater habitats of various districts of the Punjab, certain areas of NWFP and Azad Kashmir. They were taxonomically determined and systematically described (Zarina et al., 2005a, b). This is a continuation of that research program. Several Bryopsis species were found to produce stephanokontic zoospores and to serve as gametophyte of a Derbesia (Rietema, 1969, 1970, 1971a, b), therefore, it appeared more plausible to place Bryopsis in the Derbesiaceae instead of its own family Bryopsidaceae. As a result of that all higher typified taxa lost their existence. Therefore, the name Bryopsidophyceae has been replaced by a new name Siphonocladophyceae by Shameel (2001). Eight species belonging to this class have been investigated and described here.

Materials and Methods

The specimens were collected from various freshwater habitats in Kasur, Lahore, Sheikhupura and Sialkot districts of the Punjab and Attock in NWFP provinces of Pakistan as well as from Azad Kashmir during January 2004 - April 2005. They were taxonomically investigated as described earlier (Zarina et al., 2005a). The collected material was identified with the help of authentic literature (West, 1904; Prescott, 1962; Faridi, 1971; Pankow, 1971; Nizamuddin & Begum 1973; Nizamuddin & Gerloff, 1982; Kornmann & Sahling, 1983; Womersley, 1984; Masud-ul-Hasan & Batoel 1987). The voucher specimens are kept in the Phycology & Phycochemistry Lab., M. A. H. Qadri Biological Research Centre, University of Karachi, where this research work was conducted.
Results and Discussion

Eight species of the coenocytic green algae belonging to the phylum Chlorophyta, Class Siphonocladothyceae, orders Cladophorales and Sphaeropleales have been identified (fide Shaneel, 2001). Their taxonomic enumerations are given below:

Class Siphonocladothyceae Shaneel 2001: 242

Green macroalgae, thallus coenocytic, siphonaceous, filamentous or thalloid.

Order Cladophorales

Multinucleate forms with thick walled cylindrical cells, united end to end in simple or branched filaments. The chloroplast is a parietal, net like or fragmated or reticulate sheet, encircling the protoplast and with a pyrenoid at many intersections of the reticulum. Filaments coarse and wiry, mostly unattached and branched. Branching, when occurs is irregular, no arbuscular plane of growth. Some species with short rhizoidal branches. Reproductive organs open by fissures or simple pores. Asexual reproduction is by means of quadriflagellate zoospores and aplanospores, sexual reproduction is iso- and aniso-gamous. Following genera were collected which may be distinguished as follows:

1. Filaments with akinetes ................................................. Pithophora
   Filaments without akinetes ......................................... 2
2. Branches smaller .......................................................... Rhizoclonium
   Branches larger .......................................................... Cladophora

Cladophora Kützing 1843: 262, nom. cons.

Large, sometimes coarse tufts of branching filaments, composed of long and multinucleate cells. The chloroplast is characteristicely a reticulate cylinder, sometimes dissociated to form a network of small, discoid chloroplasts. All thalli begin as attached, but only some remain permanently so. Following two species were collected which may be distinguished as follows:

1. Filaments trichotomously branched ....................................... C. aegagropila (1)
   Filaments dichotomously branched ..................................... C. crispata (2)

   1. C. aegagropila (Linnaeus) Rabenhorst 1868: 343

Basionym: Conerva aegagropila Linnaeus 1753.
Morphological characters: Thalli considerably branched and bushy in form; ultimate branches not differing greatly in size from the main ones; branching appear to be trichotomous by avagination (Fig. 1).
Cytological features: Cells of any branch may be swollen at the apex; cell width usually 45-90 μm.
Reproductive structures: Reproductive organs were not observed.
Localities: Lahore District: Mahmood Booti (2-7-2004); Sheikhpura District: paddy fields near Mureedke and Narang Mundi (20-9-2004); Azad Kashmir: Neelum Valley (20-3-2004, 5-4-2005).

Type locality: Lakes in Sweden.

Geographical distribution: Sweden, Libya, China, Sri Lanka, Australia.

Remarks: The collections were carried out from three different areas during spring and summer. In Lahore it was obtained in summer season. The pH of water in the rice fields of Sheikhpura, wherefrom algae were collected, was slightly alkaline (8.0). In Azad Kashmir it was obtained during the months of March and April from stagnant water ponds. Slight cytological differences (specially in cell width) were observed among specimens collected from different habitats.

2. C. crispata (Roth) Kützing 1843: 264
   (West, 1904: 105; Prescott, 1962: 137)

Basionym: Conerva crispata Roth 1797.

Morphological characters: Branches diverging conspicuously at wide angles, giving the impression of dichotomy, no glomerate fascicles formed (Fig. 2).

Cytological features: Cells generally cylindrical, width 49-51 µm or more.

Reproductive structures: In the present collection reproductive organs were not observed.


Remarks: It occurred in slow running water of streams throughout the area of collection. During this study it was found only in vegetative form and not in reproductive phase.

Pithophora Wittrock 1877: 48

The side branches are almost at right angle to the main filament. There seems to be a tendency for the first cross wall in a branch to form at some distance above its junction. The main character is the presence of conspicuous akinetes, which occupy various cells, sometimes alternating with vegetative cells. Following two species were collected which may be distinguished as follows:

1. Akinetes rectangular, up to 125 µm broad .................. P. cleveana (3)
2. Akinetes polymorphic, more than 125 µm broad ............ P. oedogonia (4)

3. P. cleveana Wittrock

Morphological characters: Branches emerging below septum of main filament (Fig. 3).

Cytological features: Cells 5-6 times longer than broad.

Reproductive structures: Akinetes intercalary, 120-125 µm broad, almost rectangular in shape (Fig. 4).

Locality: Lahore District: Mahmood Booti (2-7-2004).

Geographical distribution: U.S.A., Germany.
Remarks: The collection work was carried out in summer season from a village of the border area of Lahore. During this season border area shows rich growth of green alga as compared to other areas of Lahore, because it is totally a cultivated area of rice and other grain crops. Therefore, this alga was found in large quantity. The collected specimens were found in reproductive condition.

   (West, 1904: 107; Prescott, 1962: 137)

Basionym: *Confervidae oedogonia* Montagne 1850.

Morphological characters: Filaments rarely branched and consistently cask-shaped; width of filaments 46-82 μm and length 200-925 μm; three orders of branching (Figs. 5, 6).

Cytological features: Vegetative cells 60 μm broad and 600-630 μm long (cells many times longer than broad); chloroplast reticulate, embedded with pyrenoids.

Reproductive structures: Akinetes intercalary, about 77-192 μm broad and 162-300 μm long, variously shaped: e.g., spherical (Fig. 7), rectangular (Fig. 9), cylindrical (Fig. 8), barrel-shaped but never consistently hexagonal.

Localities: Kasur District: Al-Feroze Town (28-1-2004); Lahore District: Mahmood Booti (2-7-2005); Sheikhupura District: between Mureedk and Narang Mundi (12-9-2004); Sialkot District: near main G.T. Road (25-5-2004).


Remarks: Specimens were collected from four different localities of the Punjab during different months of summer, winter and spring seasons. They were obtained from paddy fields in spring and other water sources during summer and winter. Morphological and reproductive variations were observed within specimens collected from different localities under various temperatures. It occurred in massive quantity in rice fields.

*Rhizoclonium* Kützing 1843: 261

Filaments contain both branched and unbranched forms. The branching is almost at right angle and the first cross wall of the branches is formed away from the junction. However, a transition of branches may be observed through short unicellular side stump to multicellular branches of indefinite length. The uniseriate filaments possess occasional or numerous, short, septate or non-septate, colourless branches. The number of nuclei per cell ranges from 1-4. Chloroplast is a reticulate plate or a pattern of small chloroplasts. Asexual reproduction is by means of biflagellate zoospores which in some species also possess unequal flagella. Following three species have been collected which may be distinguished as follows:

1. Filaments unbranched ...................................................... *R. hieroglyphicum* (6)
   Filaments branched ..................................................... 2

2. Thallus mostly branched ............................................... *R. fontanum* (5)
   Thallus rarely branched .............................................. *R. inplexum* (7)
5. *R. fontanum* Kützing 1843: 261
(Prescott, 1962: 142)

**Morphological characters:** Branched filaments with long cells; branches of one order arise in between the two adjoining cells at right angle to the parent filament; cross walls laid down at some distance from it (Fig. 10).

**Cytological features:** Cells cylindrical but uneven lateral walls.

**Reproductive structures:** In present collection reproductive structure were not observed.

**Locality:** Sialkot District: Sambaral (6-4-2004).

**Geographical distribution:** U.S.A.

**Remarks:** Collection was made from stagnant water ponds during the month of April, where it occurred in free floating state. Although, the pH of water, light intensity and temperature of this area were suitable for its growth, but it was found only in vegetative form.

(Børjesen, 1901: 254; West, 1904: 103; Prescott, 1962: 142; Pankow, 1971: 111; Faridi et al., 1981: 156; Ghazala et al., 2005: 74)

**Basionym:** *Conferva hieroglyphica* C. A. Agardh 1827.

**Morphological characters:** Unbranched long filaments with long cells, tips of the filament rounded (Fig. 11).

**Cytological features:** Vegetative cells 23-112 μm broad and 102-663 μm long; chloroplast reticulate or broken; pyrenoids many (Fig. 12).

**Reproductive structures:** Asexual reproduction by zoospores, 50-65 μm broad and 150-275 μm long (Fig. 13).

**Locality:** Kasur District: Hawaiylan Village (22-12-2004); Sheikhupura District: near Rana Bhatti (2-4-2004); Sialkot District: Adamkay Village (25-5-2004).

**Type locality:** Cave near Carlsbad, Karlovy Vary, Czech Rep.


**Remarks:** The collection was carried out in different months of 2004. It occurred in drainage and temporary pond water. The water was highly polluted in irrigation channels. In different localities it was found sometimes in low and sometimes in high quantity.

7. *R. implexum* (Dillwyn) Kützing 1845: 206

**Basionym:** *Conferva implexa* Dillwyn 1809 [1802-1809].

**Synonym:** *Rhizoclonium Kochianum* Kützing 1845: 206.

**Morphological characters:** Rarely branching filaments with long cells (Fig. 14).

**Cytological features:** Cells 44-46 μm broad and 180-375 μm long; chloroplast reticulate.

**Reproductive structures:** In the present collection reproductive structures were not observed.

**Locality:** Kasur District: Lulyani Village (6-1-2004).

**Syntype localities:** North Sea, Germany; Dubrovnik, Croatia.
Geographical distribution: U.S.A., Germany, Croatia, Pakistan, Australia.
Remarks: It was collected from stagnant water ponds of Lulyani Village during January. The temperature of water was about 6 °C. The specimens were only found in vegetative condition.

Order Sphaeropleales

Protoplasm segregated into bands by vacuoles, the following genus was collected.

*Sphaeroplea* C. A. Agardh 1824: 76

Free floating filaments of long cylindrical multinucleate units, with thickened cross walls. The cells are divided into protoplasmic sections by large vacuoles. Chloroplasts numerous, ovate, narrow, ring-like which vary in shape with age and so grouped as to form up to 30 parietal bands or zones within each cell. Sexual reproduction oogamous, non motile eggs and antherozoids produced in unmodified vegetative cells in the same or in separate filaments. Zygospores are red, with thick decorated walls. Only the following species could be collected:

8. *S. annulina* (Roth) C. A. Agardh 1824

Racronym: *Convera annulina* Roth 1806.
Morphological characters: Unbranched filaments (Figs. 15, 16).
Cytological features: Long cylindrical cells united into unbranched filament; recognizable in vegetative condition because of numerous septation of cytoplasm with vacuoles between them, giving a sort of ladder effect in the cell; end walls unevenly thickened, side walls relatively thin; cells length 470-480 μm and width 35-40 μm.
Reproductive structures: Sexual reproduction oogamous; zygospore wall is not smooth, but decorated with spines.
Remarks: The collection work was carried out during winter season of 2004, specimens were found mixed with different free floating algae. It occurred in vegetative as well as reproductive condition. During this season, temperature, pH of water and light intensity were favourable for its growth.

Acknowledgement

The services rendered by Mr. Muhammad Wahaj Zafar, Computer Operator Technician, Dendrochronology Lab., Botany Dept., Fed. Urdu Univ., Gulshan-e-Iqbal Campus in literature search through internet are gratefully acknowledged.

References

TAXONOMIC STUDY OF THE SIPHONOCALDOPHYCEAE FROM PAKISTAN


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DIVERSITY OF THE GENUS OEDOGONIUM (ZYGONEMOPHYCEAE SHAMEEL) FROM NORTH-EASTERN AREAS OF PAKISTAN

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ABSTRACT

Twenty-six species of Oedogonium Link (Chlorophyta) have been collected from various freshwater habitats in Attock and Swat of NWFP and Jauharabad, Kasur, Lahore, Sargodha and Sheikhpura districts of the Punjab Province of Pakistan during January 2004-April 2005. They were taxonomically investigated and described for the first time from their area of collection. It was observed that most of the species start growing in spring. They thrive luxuriantly in mid and late summer and disappear in autumn. Only few of them survive in winter and grow very well.

INTRODUCTION


MATERIALS & METHODS

Algal specimens were collected by hand-picking from various freshwater habitats in Attock and Swat of NWFP and Jauharabad, Kasur, Lahore, Sargodha and Sheikhpura districts of the Punjab Province of Pakistan during January 2004-April 2005. Being preserved in 5% formalin solution they were brought to the laboratory at Karachi and taxonomically investigated as described earlier (Zarina et al. 2005a). The specimens were identified with the help of authentic literature (Bærgesen 1901, Tiffany 1930, Prescott 1962). The voucher specimens are kept in the Phycolgy & Phycochemistry Lab., MAH Qadri Biological Research Centre, University of Karachi, where this research work was conducted.

RESULTS & DISCUSSION

Twenty-six species of the cap-forming green genus Oedogonium (Phylum Chlorophyta, class Zygonomophyceae Shameel 2001: 242 order Oedogoniales, family Oedogoniaceae; fide Shameel 2001) have been identified. It was observed that most of the species appear in spring. They thrive luxuriantly in mid and late summer and start disappearing in autumn. Only few of them grow in winter. Their taxonomic enumerations are given below:
**Oedogonium Link 1920**

Unbranched filaments, slightly broader at anterior ends or almost cylindrical; thalli attached by means of basal holdfast; cells uninucleate, with one or more ring like caps immediately below cross walls; reticulate chloroplast with many embedded pyrenoids; thalli monoecious or dioecious, macrandrous or nannandrous having small male filaments; swimmers stephanokontic; oogonium with a slit or pore for the entry of sperms; oospores may be globose, elipsoid, oblong or ovoid; oospore wall may be smooth, spiny, scrobiculate, ribbed or striated. In a recently proposed new classification of algae this genus has been placed under the class Zygnemophyceae due to its peculiarity of cap-cell formation during cell-division (Shameel 2001). This new concept of the class Zygnemophyceae has also been validated (Shameel 2006). The following species of this genus were collected, which may be distinguished as follows:

<table>
<thead>
<tr>
<th>Step</th>
<th>Description/Condition</th>
<th>Species Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Terminal cell pointed</td>
<td><strong>O. curtum (3)</strong></td>
</tr>
<tr>
<td></td>
<td>Terminal cell not pointed</td>
<td><strong>O. pachydermum (15)</strong></td>
</tr>
<tr>
<td>2.</td>
<td>Terminal cell sharply pointed</td>
<td><strong>O. suecicum (23)</strong></td>
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<tr>
<td></td>
<td>Terminal cell spiny</td>
<td><strong>O. exsperale (5)</strong></td>
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<tr>
<td>3.</td>
<td>Suffultory cell prominent</td>
<td><strong>O. sociale (22)</strong></td>
</tr>
<tr>
<td></td>
<td>Suffultory cell not prominent</td>
<td><strong>O. foveolatum (6)</strong></td>
</tr>
<tr>
<td>4.</td>
<td>Pore superior</td>
<td><strong>O. urbicum (25)</strong></td>
</tr>
<tr>
<td></td>
<td>Pore nearly median</td>
<td><strong>O. argenteus (1)</strong></td>
</tr>
<tr>
<td>5.</td>
<td>Oogonial wall dentate</td>
<td><strong>O. granda (8)</strong></td>
</tr>
<tr>
<td></td>
<td>Oogonial wall smooth</td>
<td><strong>O. pachydermum (15)</strong></td>
</tr>
<tr>
<td>6.</td>
<td>Oogonial wall striated</td>
<td><strong>O. pachydermum (15)</strong></td>
</tr>
<tr>
<td></td>
<td>Oogonial wall not striated</td>
<td><strong>O. pachydermum (15)</strong></td>
</tr>
<tr>
<td>7.</td>
<td>Pore median</td>
<td><strong>O. obsoletum (14)</strong></td>
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<td></td>
<td>Pore apical</td>
<td><strong>O. obsoletum (14)</strong></td>
</tr>
<tr>
<td>8.</td>
<td>Oogonium up to 41 µm long</td>
<td><strong>O. urbicum (25)</strong></td>
</tr>
<tr>
<td></td>
<td>Oogonium more than 41 µm long</td>
<td><strong>O. pachydermum (15)</strong></td>
</tr>
<tr>
<td>9.</td>
<td>Oospores completely filling the oogonia</td>
<td><strong>O. urbicum (25)</strong></td>
</tr>
<tr>
<td></td>
<td>Oospores not completely filling the oogonia</td>
<td><strong>O. pachydermum (15)</strong></td>
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<tr>
<td>10.</td>
<td>Antheridium up to 7 µm broad</td>
<td><strong>O. urbicum (25)</strong></td>
</tr>
<tr>
<td></td>
<td>Antheridium more than 7 µm broad</td>
<td><strong>O. pachydermum (15)</strong></td>
</tr>
<tr>
<td>11.</td>
<td>Thalli monoecious</td>
<td><strong>O. pachydermum (15)</strong></td>
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<tr>
<td></td>
<td>Thalli dioecious</td>
<td><strong>O. pachydermum (15)</strong></td>
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<tr>
<td>12.</td>
<td>Thalli monoecious</td>
<td><strong>O. pachydermum (15)</strong></td>
</tr>
<tr>
<td></td>
<td>Thalli dioecious</td>
<td><strong>O. pachydermum (15)</strong></td>
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<tr>
<td>13.</td>
<td>Epiphyte on <em>Pithophora</em></td>
<td><strong>O. pachydermum (15)</strong></td>
</tr>
<tr>
<td></td>
<td>Not epiphyte on <em>Pithophora</em></td>
<td><strong>O. pachydermum (15)</strong></td>
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<tr>
<td>14.</td>
<td>Basal cell slightly swollen</td>
<td><strong>O. pachydermum (15)</strong></td>
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<tr>
<td></td>
<td>Basal cell not swollen</td>
<td><strong>O. pachydermum (15)</strong></td>
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<tr>
<td>15.</td>
<td>Vegetative cell less than 14 µm broad</td>
<td><strong>O. pachydermum (15)</strong></td>
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<tr>
<td></td>
<td>Vegetative cell more than 14 µm broad</td>
<td><strong>O. pachydermum (15)</strong></td>
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<tr>
<td>16.</td>
<td>Vegetative cells more than 82 µm long</td>
<td><strong>O. pachydermum (15)</strong></td>
</tr>
<tr>
<td></td>
<td>Vegetative cells less than 82 µm long</td>
<td><strong>O. pachydermum (15)</strong></td>
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<tr>
<td>17.</td>
<td>Vegetative cell up to 8 µm broad</td>
<td><strong>O. pachydermum (15)</strong></td>
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<tr>
<td></td>
<td>Vegetative cell more than 8 µm broad</td>
<td><strong>O. pachydermum (15)</strong></td>
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<tr>
<td>18.</td>
<td>Oogonium up to 38 µm long</td>
<td><strong>O. pachydermum (15)</strong></td>
</tr>
<tr>
<td></td>
<td>Oogonium more than 38 µm long</td>
<td><strong>O. pachydermum (15)</strong></td>
</tr>
</tbody>
</table>
Diversity of the genus *Oedogonium* from Pakistan.

19. Pore remiform....................................................... *O. rufescens* (21)
   Pore not remiform............................................. 21

20. Oogonium pyriform.................................................. *O. pyriforme* (20)
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21. Vegetative cell irregularly swollen.................................. *O. nanum* (13)
   Vegetative cell not irregularly swollen.......................... 23

22. Vegetative cells up to 35 μm long................................... *O. vaucheri* (26)
   Vegetative cells more than 35 μm long............................... 24

23. Vegetative cell up to 76 μm long.................................. *O. indicum* (9)
   Vegetative cell up to 62 μm long.................................. 25

24. Oospores ellipsiodo-ovoid.......................................... *O. pseudobosci* (19)
   Oospores globose................................................... *O. tyrolicum* (24)

25. Vegetative cell up to 13 μm broad.................................. *O. inerme* (10)
   Vegetative cell more than 13 μm broad.............................. *O. plagiostomum* (17)

1. *O. argenteum* Hirn 1900

Morphological characters: Dioecious, unbranched filaments.
Cytological features: Vegetative cells 16-18 μm broad and 80-160 μm long (Fig. 1).
Reproductive structures: Macronuclear; oogonium one, globose, 39-41 μm long; oogonal pore superior; outer layer of oospore wall scrobiculate (Fig. 2). In observed specimens antheridia were not seen.
Locality: NWFP: Swat, between Bahrain and Kalam (12-8-2004).
Geographical distribution: Previously reported from Brazil and USA: Michigan
Remarks: Collection was made during summer from a slow running water channel.

2. *O. cardiacum* (Hassall 1845) Wittrock 1871

Basionym: *Vesticulifera cardifica* Hassall 1845
Morphological characters: Only germpling were seen, attached by a basal cell (Fig. 3).
Cytological features: Basal cell slightly swollen; other cells cylindrical, 27-29 μm broad and 68-70 μm long; upper cell with minute tip.
Reproductive structures: In the present material reproductive organs were not observed.
Locality: Lahore District: Mureedke (8-3-2004).
Geographical distribution: USA, Canada, Paraguay, England, Denmark, Sweden, Finland, France, Germany, Switzerland and Australia.
Remarks: The collection was carried out during spring. It was obtained from roadside ponds, epiphytic upon *Azolla pinnata* R. Br.

3. *O. curtum* Wittrock et Lundell in Wittrock 1870

Morphological characters: Monococious, unbranched filaments.
Cytological features: Terminal cells elongated (Fig. 4); vegetative cells 10-11 μm broad and 70-80 μm long.
Reproductive structures: Macronuclear thalli, oogonium globose, 40-41 μm broad and 47-48 μm long (Fig. 5); pore superior; oogonal wall smooth; antheridia 1-4, division horizontal.
Geographical distribution: Finland, Germany, Latvia, Sweden
Remarks: The collection was made during summer, from slow running water.
8. *O. grande* Kützing 1845


**Morphological characters:** Dioecious, unbranched filaments.

**Cytological features:** Vegetative cells 26–27 μm broad and 82–84 μm long (Fig. 14).

**Reproductive structures:** Macrandrous thalli; oogonium 1–5, sub-ovoid, 44–46 μm broad and 82–
84 μm long (Fig. 15); oospores of the same form as oogonium, completely filling or not (Fig. 13);
spore wall smooth; male filament not seen.

**Locality:** Kasur District: Al-Feroze Town (9-12-2004).

**Geographical distribution:** USA: California, Mississippi, Ohio, Pennsylvania; Sweden,
Switzerland and Australia.

**Remarks:** The collection was carried out from temporary ponds of the village during winter.

9. *O. indicum* Hirn 1900

**Reference:** Tiffany 1930: 139.

**Morphological characters:** Dioecious, unbranched filaments (Fig. 16).

**Cytological features:** Vegetative cells 25–27 μm broad and 57–76 μm long.

**Reproductive structures:** Nannandrous; oogonium 1–2, 49–51 μm broad and 57–64 μm long,
depressed-globose or depressed-ovovoid-globose (Fig. 17); oospores depressed-globose,
completely filling oogonium; spore wall smooth.

**Locality:** Kasur District: Kot Mela Ram (28-1-2004).

**Geographical distribution:** Previously reported from India.

**Remarks:** The material was obtained from temporary ponds of the village in winter.

10. *O. inerme* Hirn 1900

**Reference:** Tiffany 1930: 166.

**Morphological characters:** Dioecious, unbranched filaments.

**Cytological features:** Vegetative cells 11–13 μm broad.

**Reproductive structures:** Macrandrous thalli; oogonium one, 30–32 μm broad and 33–35 μm
long; oospores not filling the oogonium (Fig. 18); spore wall smooth and 23–25 μm broad and 25–
27 μm long; male filament with antheridium not observed.

**Locality:** Sheikhupura District: Sattarwala Village (15-8-2004).

**Geographical distribution:** Previously reported from France and India.

**Remarks:** The collections were made during summer from paddy fields. The soil at the place
of collection was made up of silt, clay and large portion of sand with pH 8.0. The specimens were
found only in the vegetative stage.

11. *O. irregulare* Wittrock 1871


**Morphological characters:** Dioecious and unbranched filaments.

**Cytological features:** Vegetative cells 19–21 μm broad and 62–64 μm long.

**Reproductive Structures:** Oogonium 1, globose, 39–40 μm broad and 41–43 μm long; oospores
globose, completely filling the oogonium; spore wall smooth; oospores 38 μm long and 37 μm
broad (Fig. 19).

**Locality:** Sargodha District: Sargodha (22-4-2005).
Geographical distribution: Previously reported from Denmark, Sweden, Canada, USA: Michigan, Illinois, Ohio, Florida; India, Myanmar.
Remarks: Collection has been made from slow running water channels during spring. It was obtained in free floating state.

12. O. laeve Wittrock 1875

Morphological characters: Monoecious, unbranched filaments (Fig. 20).
Cytological features: Vegetative cells 13-14 μm broad and 27-28 μm long.
Reproductive structures: Macandrous thalli; oogonium one, globose, pore superior; oogonial wall smooth; antheridia in series 4-6, 6-7 μm broad and 10-11 μm long; oosores 23-24 μm broad and 27-28 μm long (Fig. 21).
Geographical distribution: Previously reported from France, USA; Michigan, Illinois.
Remarks: Collection of the material was made from slow running water of the river during summer in large quantity.

13. O. nanum Wittrock 1875

Morphological characters: Dioecious, unbranched filaments.
Cytological features: Vegetative cells often irregularly swollen, 6-10 μm broad and 30-33 μm long (Fig. 22).
Reproductive structures: Macandrous thalli; oogonium 1-3, ovoid to broadly ellipsoidal, 24-26 μm broad and 32-34 μm long; oospores ovoid to globose-ellipsoidal, usually filling the oogonium; spore wall smooth; antheridia were not observed.
Geographical distribution: Previously reported from India and USA: Iowa.
Remarks: The specimens were collected during winter. They were obtained from stagnant water ponds along with Pithophora spp.

14. O. obsoletum Wittrock 1874

Morphological characters: Monoecious, unbranched filaments.
Cytological features: Vegetative cells 13-14 μm broad and 64-65 μm long (Fig. 23).
Reproductive structures: Macandrous thalli; oogonium one, sub-globose, 34-35 μm broad and 44-45 μm long pore a little above median; oospores not completely filling the oogonia (Fig. 24); spore wall smooth; antheridia not seen.
Locality: NWFP: Swat, between Bahrain and Kalam (12-8-2004).
Geographical distribution: Previously reported from England, Sweden, USA; Pennsylvania.
Remarks: It was found to grow in slow running water channel during summer.

15. O. pachydermatum Wittrock et Lundell 1871

Morphological characters: Unbranched filaments (Fig. 26).
Cytological features: Terminal cell spiny (Fig. 25); vegetative cells 23-24 μm broad and 99-100 μm long (Fig. 27).
Reproductive structures: In this collection no reproductive structures were observed.
Geographical distribution: Previously reported from Finland and Sweden.
Remarks: The collection was made only in vegetative stage from the paddy fields near Hunjaval during autumn.
Diversity of the genus *Oedogonium* from Pakistan.

16. *O. pithophorae* Wittrock 1878

**Reference:** Tiffany 1930: 112.

**Morphological characters:** Monoecious, unbranched filaments (Fig. 28).

**Cytological features:** Basal cell elongated; vegetative cells 9-11 μm broad and 19-32 μm long.

**Reproductive structures:** In the present collection reproductive structures were not observed.

**Localities:** Lahore District: Mahmood Booti (2-7-2004); Sheikhupura District: between Muree and Narang Mundi (12-9-2004).

**Geographical distribution:** Previously reported from west of India (Tiffany 1930) and West Indies.

**Remarks:** It was collected from two different areas of the Punjab during summer and autumn seasons in association with *Pithophora* spp. The massive growth of this species was found in paddy fields.

17. *O. plagiotomum* Wittrock ex Hrn 1875


**Morphological characters:** Dioecious, unbranched filaments.

**Cytological features:** Vegetative cells 21-23 μm broad and 57-59 μm long.

**Reproductive structures:** Macrandrous thallus; oogonium obovoid, 41-43 μm broad and 49-51 μm long; oospores sub-globose, filling entire oogonium (Fig. 29); spore wall smooth; spores 40-42 μm broad and 47-48 μm long; antheridial filaments were not observed.

**Localities:** Sheikhupura District: between Muree and Narang Mundi (20-9-2004), near Nain Sukh Village (28-2-2004).

**Geographical distribution:** Previously reported from India, South Africa, Sweden and USA.

**Remarks:** The collections were made during winter and autumn seasons in free floating state from slow running water present in paddy fields, from two different places of the Punjab.

18. *O. plasioporum* Wittrock 1875

**References:** Tiffany 1930: 70, Prescott 1962: 180.

**Morphological characters:** Monoecious, unbranched filaments.

**Cytological features:** Vegetative cells 13-14 μm broad and 51-52 μm long (Fig. 30).

**Reproductive structures:** Macrandrous thallus; oogonium one, globose, 34-35 μm broad and 37-38 μm long; pore a little above median, oospores 30-31 μm broad and 34-35 μm long (Fig. 31); antheridia 6-8 μm broad and 11-12 μm long.

**Locality:** NWFP: Swat, Kalam (12-8-2004).

**Geographical distribution:** Previously reported from Rumania; Finland; Sweden; USA: Pennsylvania, New Jersey, California; Canada; Columbia.

**Remarks:** Collection of the material was carried out during summer. It was found to grow in the slow running water pools.

19. *O. pseudoboscii* Hrn 1895


**Morphological characters:** Unbranched, monoecious filaments.

**Cytological features:** Vegetative cells 18-20 μm broad and 138-140 μm long.

**Reproductive structures:** Oogonium 1, ellipsoid, 62-64 μm broad and 101-103 μm long (Fig. 32); oospores ellipsoid-ovoid; lower part of oogonium inflated; spore wall smooth; oospores 56-58 μm broad and 87-89 μm long.

**Locality:** Sargodha District: Sargodha (22-4-2005).

**Geographical distribution:** Previously reported from Russia.

**Remarks:** The specimens were collected during spring from a slow running water channel. They were found in free floating state and growing in massive quantity, because the environmental conditions like pH and temperature of water were suitable for their growth.
20. *O. pyriforme* Wittrock ex Hirn 1875


**Morphological characters:** Monoecious, unbranched filaments.

**Cytological features:** Vegetative cells 14-18 μm broad and 39-49 μm long (Fig. 33).

**Reproductive structures:** Macronemous thalli; oogonium occurs singly, 39-41 μm long and 44-46 μm broad, operculate (Fig. 34); pore above the median; oospores pyriform, not completely filling the oogonia, 35.5-37.5 μm in diameter; spore wall smooth; antheridia two, 10-12 μm broad and 8-12 μm long; sperm in each antheridium two, division horizontal.

Localities: Lahore District: Salamatpura near border area (2-4-2004); NWFP: Swat, Usla and Utrod River in Kalam (13-8-2004).

Geographical distribution: Previously reported from Canada, Columbia, India and Australia: Tasmania.

Remarks: It has been collected during spring and summer seasons from Punjab and from NWFP. It was found to grow on rock surfaces along the river and also in roadside puddles of the villages.

21. *O. rufescens* Wittrock 1871


**Morphological characters:** Dioecious, unbranched filaments.

**Cytological features:** Vegetative cells 8-11 µm broad and 23-34 µm long.

**Reproductive structures:** Macrandrous thalli; oogonium 1-3, obovoid or depressed-obovoid, globose, reniform, 21-22 µm broad and 22-23 µm long (Fig. 35); pore median; oospores globose or depressed-globose, filling oogonium or so, 20-21 µm in diameter; spore wall smooth.

**Localities:** Lahore District: Hunjarwal (16-8-2004); Jauharabad District: near Jauharabad (25-4-2004); NWFP: Attock (12-1-2004).

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Geographical distribution: Previously reported from USA: Ohio, Sweden, Denmark, France, Austria, England, Germany, Latvia, South Africa, Southern Tibet.

Remarks: It occurred in stagnant water ponds mixed with other free floating algae during winter and spring seasons, and also found in Hunjarwal paddy fields during late summer.

22. *O. sociale* Wittrock 1882

Morphological characteristics: Dioecious, unbranched filaments.
Cytological features: Terminal cell rounded; cell-wall smooth; vegetative cells 13-16 μm broad and 35-82 μm long (Fig. 36).
Reproductive structures: Macrandrous thalli; oogonium one, sub-globose, with median pore (Fig. 37); 33-36 μm broad and 40-43 μm long; oospores globose, almost filling the oogonia; spore wall smooth; oospores 31-32 μm broad and 31-33 μm long.
Localities: Lahore District: between Bund Road and Mureedke (17-3-2004); Sargodha District: Sargodha (22-4-2005); Sheikhupura District: between Mureedke and Narang Mundi (20-9-2004); NWFP: Swat, Kalam (12-8-2004).
Geographical distribution: Previously reported from USA, Austria, Sweden, Latvia, Germany, Myanmar, India, Tibet, Australia (Tiffany 1930).
Remarks: It was collected from three different places during spring, summer and autumn seasons. Slight morphological differences were seen within the collected specimens from different localities probably due to temperature differences. Higher growth was found in paddy fields as compared to other localities such as slow running water of the river where they occurred as epiphyte on *Spirogyra* spp.

23. *O. succicum* Wittrock 1874

Morphological characteristics: Dioecious, unbranched filaments.
Cytological features: Basal cell elongated (Fig. 38); vegetative cells 10-12 μm broad and 75-78 μm long.
Reproductive structures: Macrandrous thalli; oogonium occurs singly, with or without suffrulyer cell, sub-globose (Fig. 39); pore slightly above median; oospores globose, nearly filling the oogonium, 26-28 μm broad and 30-31 μm long; oogonial wall echinate; antheridia 3-5 in a series, each with single sperm; sperm 10-11 μm broad and 10-11 μm long.
Geographical distribution: Previously reported from Canada, USA, Austria, Denmark, Germany, Finland, France, Latvia, Iceland, Norway, Sweden, South Africa and Australia.
Remarks: It occurred in slow running water of the river and was collected during summer.

24. *O. tyrolicum* Wittrock 1875

Morphological characteristics: Monoecious, unbranched filaments.
Cytological features: Vegetative cells, 10-15 μm broad and 60-65 μm long (Fig. 40).
Reproductive structures: Macrandrous thalli; oogonium one, ellipsoid, pore superior (not clear); oospores globose, not filling the oogonium (Fig. 41); oogonial wall smooth, antheridia not seen.
Locality: NWFP: Swat, between Bahrain and Kalam (12-8-2004).
Geographical distribution: Austria, England, Sweden, USA: Massachusetts, Iowa.
Remarks: Collection work was carried out during summer. It occurred in the free floating state in slow running water of the river.

25. *O. urbicum* Wittrock 1874

Morphological characteristics: Monoecious, unbranched filaments.
Cytological features: Vegetative cells 13-14 μm broad and 78-79 μm long (Fig. 42).
Reproductive structures: Macrandrous thalli; oogonium one, ellipsoid-globose, 37-39 μm broad and 40-41 μm long (Fig. 43); pore above median; oogonial wall smooth; antheridia 6-7 μm broad and 13-14 μm long; sperm two, division horizontal.

Locality: NWFP: Swat, between Bahrain and Kalam (12-8-2004).

Geographical Distribution: Previously reported from USA, France, Germany and Sweden.

Remarks: The material was obtained during summer in the free floating condition from the river.

26. O. vaucheri (Le Clerc 1817) A. Braun 1855


Basionym: Prolifera vaucheri Le Clerc 1817.

Morphological characters: Monocious, unbranched filaments.

Cytological features: Vegetative cells 20-21 μm broad and 34-35 μm long (Fig. 44).

Reproductive structures: Macrandrous thalli; oogonium one, obovoid to globose, 37-40 μm broad and 44-46 μm long, with superior pore (Fig. 45); oogonial wall smooth; antheridia 1-4, 6-7 μm broad and 15-17 μm long; sperm two, division horizontal.


Geographical Distribution: Previously reported from USA, France, Germany, Denmark, India, Italy, Sweden and Switzerland.

Remarks: The collection was made during summer, where it occurred in the free floating state in river water.

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TAXONOMIC STUDIES OF THE GENUS ZYGEMEA FROM NORTH-EASTERN AREAS OF PAKISTAN

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Abstract

Ten species of Zygema C. A. Agardh (Zygennophasaceae, Chlorophyta) were collected during December 2003-December 2004 from different freshwater habitats of Gujranwala, Kasur, Lahore, Sheikhupura, Sialkot and Pasrur districts of the Punjab, Attock and Swat in N.W. F. P. of Pakistan and Neelum Valley of Azad Kashmir. They were taxonomically determined and have been described for the first time from these areas. Their reproduction was observed to occur mostly in winter and spring. They were usually found abundant in permanent water habitats.

Introduction

The occurrence of Zygema C. A. Agardh in Pakistan and Kashmir was reported earlier by Faridi (1971). Later on, Khan & Faridi (1977) carried out its detailed taxonomic investigation and reported 14 species from Peshawar Valley (N.W. F.P.) of Pakistan including a new species, Z. pakistanica Khan et Faridi. Since then no composite study was made on this genus from any other area of Pakistan. During a research program, which started in December 2003, a large collection of green algae was made from freshwater habitats of various districts of the Punjab, certain areas of N. W. F. P. and Azad Kashmir (Zarina et al., 2005a, b, 2006). In this program 10 species of Zygema (Zygennaceae, Zygennales, Zygennophasaceae Shameel, Chlorophyta; fide Shameel, 2001, 2006) have been collected and taxonomically determined. All of them were found to be different from those described by Khan & Faridi (1977).

Materials and Methods

Collections were made during December 2003-December 2004 from different freshwater habitats of Gujranwala, Kasur, Lahore, Sheikhupura, Sialkot and Pasrur districts of the Punjab, Attock and Swat in N.W. F. P. of Pakistan and Neelum Valley of Azad Kashmir. They were taxonomically investigated as described earlier (Zarina et al., 2005a) and were identified with the help of authentic literature (West, 1904; Transeau, 1951; Randhawa, 1959; Prescott, 1962). The voucher specimens are kept in the Phycology & Phycochemistry Lab., MAH Qadri Biological Research Centre, University of Karachi.

Results and Discussion

In the present collection 10 species have been identified. They are taxonomically described for the first time from their area of collection. They were usually abundant in permanent water habitat and were observed to reproduce mostly in winter and spring. Their taxonomic enumerations are as follows:

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Zygnema C. A. Agardh 1824

Filaments unbranched, up to 10 mm long; with short, cylindric, uninucleate cells; each cell with two stellate chloroplasts, with a central prominent pyrenoid; sometimes chloroplast connected by a cytoplasmic isthmus; single nucleus lying in between the two chloroplasts; reproduction scalariform or chain conjugation; zygospores mostly spherical; mesosporium may be smooth or variously ornamented; parthenospores (aplanospores) may also be formed. The collected species may be distinguished as follows:

1. Vegetative cells less than 38 μm broad ................................................................. 2
   Vegetative cells more than 38 μm broad ................................................................. 3
2. Conjugation only scalariform .............................................................................. 4
   Conjugation both lateral and scalariform ................................................................ 5
3. Vegetative cells up to 60 μm long ............................................................ Z. kashmirense (7)
   Vegetative cells more than 60 μm long ............................................................... Z. czurdae (2)
4. Vegetative cells up to 35 μm long ............................................................ Z. khanna (8)
   Vegetative cells more than 35 μm long ............................................................... 6
5. Vegetative cells up to 52 μm long ............................................................ Z. insigne (6)
   Vegetative cells more than 52 μm long ............................................................... 7
6. Zygospores more than 34 μm broad ............................................................ Z. normani (9)
   Zygospores up to 34 μm broad .............................................................................. 8
7. Zygospores up to 39 μm long ............................................................. Z. gangeticum (4)
   Zygospores more than 39 μm long .................................................................... Z. fanicum (3)
8. Zygospores more than 37 μm long ............................................................ Z. cyaneum (1)
   Zygospores up to 37 μm long .............................................................................. 9
9. Vegetative cells 43 μm long ............................................................ Z. suberuclatum (10)
   Vegetative cells 70 μm long .............................................................................. Z. himalayense (5)

1. Z. cyaneum Czurda 1932: 127
   (Czurda, 1932: 127; Transeau, 1951: 38; Randhawa, 1959: 246)

Cytological features: Vegetative cells 30-32 μm broad and 55-60 μm long.
Reproductive structures: Conjugation scalariform, zygospores in one of the
gametangia; receptive gametangia cylindric; zygospores globose, 30-34 μm broad and
38-45 μm long; wide, median spore wall thick and smooth (Fig. 1).
Geographical distribution: U.S.A., India.
Remarks: It was collected in free floating state during spring season. It was found in
slow running water of stagnant ponds at Azad Kashmir in low quantity.

2. Z. czurdae Randhawa 1936: 239
   (Transeau, 1951: 27; Randhawa, 1959: 217; Ghazala et al., 2004: 336)

Cytological features: Vegetative cells 32-38 μm broad and 132-136 μm long;
chloroplasts showing tiny protuberances (Fig. 2).
Reproductive structures: In the present specimens reproductive stages were not found.
Geographical distribution: India.
Remarks: The collection was carried out during summer. It was obtained in planktonic
state from slow running water of stagnant ponds somewhere in between Bahrain and
Kalam.
3. *Z. fanicum* Li 1934: 212
(Transeau, 1951: 35; Randhawa, 1959: 239)

Cytological features: Vegetative cells 30-34 μm broad and 51-69 μm long; cells contain stellate chloroplasts with several long lobes (Fig. 3).

Reproductive structures: Conjugation scalariform (Fig. 4) and lateral (Fig. 5); receptive gametangia slightly enlarged; zygospores globose, 44-45 μm in diameter; mesosporium yellow and sharply pitted, pits 2-3 μm apart; aplanospores globose 33-35 μm broad and 36-38 μm long (Fig. 6).

Localities: Sheikhupura District: near Sheikhamwala (15-3-2004); Azad Kashmir: Neelum Valley (5-4-2004).

Geographical distribution: China: Hupeh, Kiangsi, Anhwei, Szechwan, Shantung (Transeau, 1951); India.

Remarks: Collection was made from stagnant water ponds and roadside puddles during spring where specimens occurred in free floating state and also mixed with other planktonic algae.

(Transeau, 1951: 43; Randhawa, 1959: 216; Masud-ul-Hasan, 1978b: 93)

Cytological features: Vegetative cells 17-25 μm broad and 50-65 μm long (Fig. 7).

Reproductive structures: Conjugation scalariform and lateral; zygospores formed in conjugation tubes and extending into gametangia; zygospores globose to ovoid, 32-39 μm broad and 30-46 μm long; median spore wall yellow-brown and smooth (Fig. 8).

Localities: Kasur District: Kamal Chisti Village (22-12-2003); Sialkot District: Jumkay Village (25-5-2004).


Remarks: Although specimens were collected from two different areas of the Punjab in summer and winter seasons, slight size differences were found among them. In Sialkot it was found in temporary puddles near residential areas. The temperature was high, pH of water was nearly 8.0 i.e. slightly alkaline and water remained stagnant. Such conditions were favourable, therefore, it occurred abundantly as compared to those found in Kasur. In both areas it was found in vegetative as well as in reproductive states.

5. *Z. himalayense* Randhawa 1940: 129
(Transeau, 1951: 23; Randhawa, 1959: 218)

Cytological features: Vegetative cells 20.4-22.4 μm broad and 68-70 μm long and have two stellate chloroplasts, which are connected by a cytoplasmic isthmus (Fig. 9).

Reproductive structures: Conjugation scalariform; zygospores bluish-green in colour, 35-37 μm long and 64-66 μm in diameter (Fig. 9).

Locality: Sheikhupura District: near Sheikhamwala (15-3-2004).

Geographical distribution: India: at the elevation of 5,750 feet in the Himalaya mountains (Transeau, 1951).

Remarks: Collections were made during spring. It was found in roadside puddles of Sheikhupura, where pH of water was 7.5 i.e. slightly alkaline.


*Basionym:* *Tyndaridea insignis* Hassall.

**Cytological features:** Vegetative cells 22-56 μm broad and 26-52 μm long (Fig. 10).

**Reproductive structures:** Conjugation scalariform (Fig. 11) and lateral (Fig. 12); two empty gametangia alternate with two zygospores in one of the gametangium, receptive gametangia cylindrical and enlarged; zygospores globose to sub-globose, 29-31 μm broad and 30-35 μm long; median spore wall yellow-brown and smooth; aplanospores ovoid, 22-24 μm broad and 32-34 μm long, otherwise like zygospores (Fig. 13).

**Localities:** Gujranwala District: Nandipur (4-4-2004); Lahore District: Batapur (27-9-2004), Salamatpara (11-3-2004); Sialkot District: (25-5-2004), Ravi-Marala link Submaral Road (6-4-2004); N.W.F.P.: Attock: (12-1-2004); Azad Kashmir: Neelum Valley (5-4-2004).

**Geographical distribution:** U.S.A., South America, Europe, China, Sikkim, India, Australia (Randhawa, 1959).

**Remarks:** The collection work was carried out in different areas of the Punjab, N.W.F.P. and Azad Kashmir during spring, summer and winter seasons. It was mainly obtained from rice fields, tube well houses near border areas, ponds and puddles, but some collections were also made from gently flowing portion of streams along the road side. It was found in vegetative as well as reproductive state, mixed with other free floating algae. Slight cytological differences were found among the same species.


(Randhawa, 1959: 235)

**Cytological features:** Vegetative cells 39-41 μm broad and 57-60 μm long (Fig. 14).

**Reproductive structures:** Specimens were found only in vegetative state.

**Locality:** N.W.F.P.: Swat; Kalam (13-8-2004).

**Geographical distribution:** Kashmir: Srinagar (Randhawa, 1959).

**Remarks:** The species occurred in summer season of 2004, in flowing water of Kalam River during which temperature, light intensity, water quantity and pH conditions were suitable for its growth.


(Transeau, 1951: 44; Randhawa, 1959: 255)

**Cytological features:** Vegetative cells 23-25 μm broad and 33-35 μm long; with two stellate chloroplasts, which are connected by a cytoplasmic isthmus (Fig. 15).

**Reproductive structures:** Conjugation scalariform; aplanospores 22-24 μm broad and 43-45 μm long (Fig. 16).

**Locality:** Sheikhpura District: near Sheikhanwala (15-3-2004).

**Geographical distribution:** Myanmar; near Rangoon.

**Remarks:** Collections were made during spring season. It was found in stagnant water ponds along the roadside puddles, where the pH of water was 7.5.
(Transeau, 1951: 34; Randhawa, 1959: 237; Shahida *et al.*, 2005: 112)

**Cytological features:** Vegetative cells 24-28 μm broad and 30-73 μm long (Fig. 17).

**Reproductive structures:** Conjugation scalariform; zygospores in one of the gametangia greatly inflated on conjugation side; zygospores globose or sub-globose, 36-46 μm broad and 35-45 μm long; median spore wall yellow-brown, scrobiculate; pits 3-4 μm in diameter 2.5-4 μm apart (Fig. 18).

**Locality:** Kasur District: Galwedah (9-12-2004), Raja Jung Village (21-12-2004).

**Geographical distribution:** U.S.A.: Oklahoma (Transeau, 1951), India.

**Remarks:** The collections were carried out from two different stagnant water ponds at two different areas of Kasur during winter seasons. Slight cytological and reproductive differences were noticed among these specimens, probably because they occurred in different ecological conditions.

10. *Z. subcruciatum* Transeau 1934: 212
(Transeau, 1951: 34; Randhawa, 1959: 236)

**Cytological features:** Vegetative cells 25-26 μm broad and 42-43 μm long (Fig. 19).

**Reproductive structures:** Conjugation scalariform; zygospores in one of the gametangia (Fig. 19); receptive gametangia cylindrical or enlarged, mostly on the inner side; zygospores globose to ovoid, 24-33 μm broad and 31-37 μm long; median spore wall brown, finally scrobiculate (Fig. 20).

**Locality:** Pasur District: Kot Libajuva Village (4-3-2004).

**Geographical distribution:** U.S.A. Oklahoma, Texas, Arkansas, Louisiana, Illinois, Ohio (Transeau, 1951); Sweden, Norway, France, China (Randhawa, 1959).

**Remarks:** The collection was carried out during spring, from surface of large ponds as free floating masses. It was found in vegetative as well as reproductive stages.

**References**


TAXONOMIC STUDY OF THE GENUS ZYGNEMA FROM PAKISTAN


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OCCURRENCE OF THE GENUS CHARA (CHAROPHYTA) IN SHEIKHUPURA DISTRICT OF PAKISTAN

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Abstract

Two species of the stonewort algae, Chara Linnaeus have been collected during September 2004 from an area between Murree and Narang Mundi in Sheikhupura District of the Punjab Province of Pakistan. They were taxonomically investigated and determined as C. aspera Detharding ex Wildenow and C. globularis Thuillier. They are being described for the first time from their area of collection.

Introduction

Chara Linnaeus has been observed to grow in all the four provinces of Pakistan (Grove, 1923; Faridi, 1955, 1956; Pal et al., 1962; Sarim, 1991; Aisha & Shameel, 1995; Leghari et al., 1999, 2000, 2001, 2002, 2003, 2005; Jahangir et al., 2000; Langangen & Leghari, 2001; Shameel, 2002, 2005, Ghazala et al., 2004). During these studies, it was collected from different freshwater and brackish water habitats. A large survey for the collection of green algae was started in December 2003 from various areas of NWFP and Punjab, during which some species of Chara were obtained. They were taxonomically determined and described for the first time from their area of collection. This is an addition to the Charophyta flora of Pakistan.

Materials and Methods

The specimens were collected by hand-picking from road-side puddles between Murree and Narang Mundi in the Sheikhupura District of the Punjab Province of Pakistan during September 2004. They were preserved in 5% formalin solution, brought to the laboratory at Karachi University and investigated as described previously (Zarina et al., 2005, 2006). The material was identified with the help of authentic literature (Bergesen, 1901; Prescott, 1962; Imahori, 1964; Wood, 1965; Pankow, 1971; Krause, 1997). The voucher specimens are kept in the Phycology & Phycochemistry Lab., MAH Qadir Biological Research Centre, University of Karachi, where this research work was carried out.

Results and Discussion

Two species of the stonewort genus Chara (phylum Charophyta, class Charophyceae, order Charales, family Characeae; fide Shameel, 2001) have been identified. Their taxonomic enumerations are as follows:
**Chara Linnaeus 1753: 1156**

Stem and branchlets corticate or ecorticate; stipulodes present, though sometimes rudimentary; branchlets of 4 or more segments; bract cells 4 or more at the node; nucules and globules produced one above the other from periphery of branchlet nodes, globule below the nucule, oospore terete. This genus is chiefly distinguished from the other allied genera by relative position of its sex organs. The nature of the cortex, whether haplostichous, diplostichous or tripllostichous and the stipulodes, whether in a single or double row are characters used for its further division. The following two species were collected which may be distinguished as follows:

1. Stem slender, 375-500 µm in diameter ......................... C. aspera (1)
   Stem stout, 1,000-1,400 µm in diameter ......................... C. globularis (2)

**1. C. aspera** Detharding ex Wildenow 1809: 298


**Morphological characters:** Thallus monocious, up to 15 cm long, incrusted with lime (Fig. 1); stem slender, 375-500 µm in diameter; internode as long or twice as long as the branchlets; stipulodes in a double whorl, those of the upper whorl tough, short, better developed than those of the usually rudimentary, lower whorl; branchlets 7-8 in whorl, usually curved, composed of 8-11 segments of which the upper 1-3 are ecorticate, the other diplostichous, corticate; bracteoles somewhat longer than the oogonium.

**Anatomical features:** Stem cortex tripllostichous, primary cortical cells broader than the secondary ones; spine cells usually minute, papiliform; bract cells 5-7, anterior pair only developed, anterior ones 0.5-1 time the length of oogonium.

**Reproductive structures:** Antheridia and oogonia together at the three lower branchlets; node solitary; antheridia 350-560 µm in diameter; oogonia 750-1,000 µm long, 500-700 µm wide (Fig. 2); spiral cells showing 14-15 convolutions, coronula 100-240 µm high, 180-260 µm wide at the base; individual cells convent; oospore black, 625-670 µm long, 340-550 µm wide with 12-14 thin ridges, terminating in basal claws.

**Locality:** Sheikhupura District: between Mureedke and Narang Mundi (12-9-2004).

**Geographical distribution:** India: Varanasi (U.P.); Pakistan: Lahore, Nurpur (Pal et al., 1962).

**Remarks:** The collection was made during autumn from paddy fields. The ecological conditions were not favourable for its growth, therefore, it occurred in low quantity.
2. *C. globularis* Thuillier 1799: 472
Krause, 1997: 87; Langangen & Leghari, 2001: 78)

Taxonomic synonymy: *Chara fragilis* Desvaux *in* Loiseleur-Deslongchamps 1810; *C. fragilis* var. *subverrucosa* A. Braun; *C. leptoasperma* A. Braun.

Morphological characters: Thallus monocious, incrusted, up to 60 cm high (Fig. 3); stem stout, 1,000-1,400 μm in diameter; internodes 1-2 times the length of the branchlets; irregular, multicellular bulbls sometime present; stipules in double whorls, rudimentary, greatly reduced and inconspicuous branchlets, 7-8 in a whorl, straight, very long, consisting of 8-11 segments of which the upper 1-3 are ectocarpate; bracteoles somewhat developed, shorter than or as long as the oogonium.

Anatomical features: Cortex tripliostichous, regular; cells of primary and secondary series of equal width; spine cells rudimentary, visible only in very young internodes; cortical cells of branchlets twice as numerous as the bract cell; bract cells usually 7, varying in length, equal or somewhat shorter than the oogonium; only one anterior pair developed, posterior cell rudiments at fertile nodes, at sterile nodes frequently absent.

Reproductive structures: Antheridia and oogonia solitary (Fig. 4), at the lowest branchlet nodes (Fig. 4); antheridia 300-450 μm in diameter; oogonia 800-1,100 μm long, and 350-450 μm wide, 11-14 well pronounced ridges prolong downward (Fig. 5).


Geographical distribution: India, Pakistan: Lahore (Pal et al., 1962).

Remarks: Material was collected during autumn from rice fields. It occurred in limited quantity due to the unfavourable conditions, but was found in vegetative as well as reproductive states.

References


GENUS CHARA (CHAROPHYTA) IN SHEIKHUPURA, PAKISTAN


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