

TAXONOMIC STUDY OF CHROOCOPHYCEAE (CYANOPHYTA) FROM NORTHERN AREAS OF PAKISTAN

SABEEN NAZ, MASUD-UL-HASAN¹ AND MUSTAFA SHAMEEL

*Department of Botany,
University of Karachi, Karachi-75270, Pakistan*

Abstract

Forty-six species of planktonic, edaphic, epipsammic, epioikotic, epilithic and epiphytic blue-green algae belonging to the class Chroocophyceae have been collected from various freshwater habitats in the Districts of Attock, Gujranwala, Jhang, Jhelum, Khushab, Lahore, Sargodha, Sheikhupura and Sialkot of the province of the Punjab, from Bahrain and Kalam (Swat) in the province of N.W.F.P. as well as from Chenari, Muzaffarabad and Neelum Valley in Azad Kashmir during different seasons from March 1996 to August 2000. They were taxonomically investigated and found to belong to two orders, three families and eleven genera. *Johannesbaptistia* and *Stichosiphon* were represented by a single species, *Aphanothece*, *Gleothece* and *Synechocystis* by two, *Synechococcus* by three, *Aphanocapsa* by four, *Microcystis* by six and *Chroococcus* and *Merismopedia* by eight species. *Gloeocapsa* exhibited the largest diversity with ten species.

Introduction

The blue-green algae are distributed world-wide, being primitive organisms known since pre-cambrian period. They are pioneers of the bare areas and play an important role in nitrogen fixation from the atmosphere. Being amphibious they live on moist land as well as in water. A few studies have been made on the freshwater cyanophytes of Karachi (Farzana & Nizamuddin, 1979; Shameel & Butt, 1984), other areas of Sindh (Leghari & Arbani, 1983, 1984; Leghari *et al.*, 2000, 2001) and N.W.F.P. (Faridi, 1970, 1971, 1974,a,b). Ghose (1919, 1924) was the first phycologist to start the systematic study of blue-green algae from the area around Lahore and reported 59 species, including 9 new species and 3 new varieties. Randhawa (1936) mainly worked on Chlorophyta but added 23 species of blue-green algae to the list of this region. Twenty-five species of blue-green algae growing in the culture of rice fields of Kashmir were isolated by Khan (1957) and 95 species were reported by Ali & Sandhu (1972) from Punjab. Masud-ul-Hasan (1978a,b, 1980) has reported some freshwater green algae including Cyanophyta which were collected from ponds around Lahore. It seems that much attention was not paid on the study of blue-green algae of the Punjab and Azad Kashmir. Therefore, primarily a general survey was made in this connection (Naz *et al.*, 2003), and the present report gives an account of the taxonomy of Chroocophyceae (Cyanophyta), collected from the northern areas of Pakistan.

Materials and Methods

Pakistan is situated in the south-east Asia (Fig. 1). Its northern areas were explored for the occurrence of blue-green algae. Several surveys were made to collect algae from various freshwater habitats viz. rain pools, temporary ponds, permanent water reservoirs,

¹Ilyas Street, Shahgoharabad, P.O. Bagbanpura, Lahore, Pakistan.

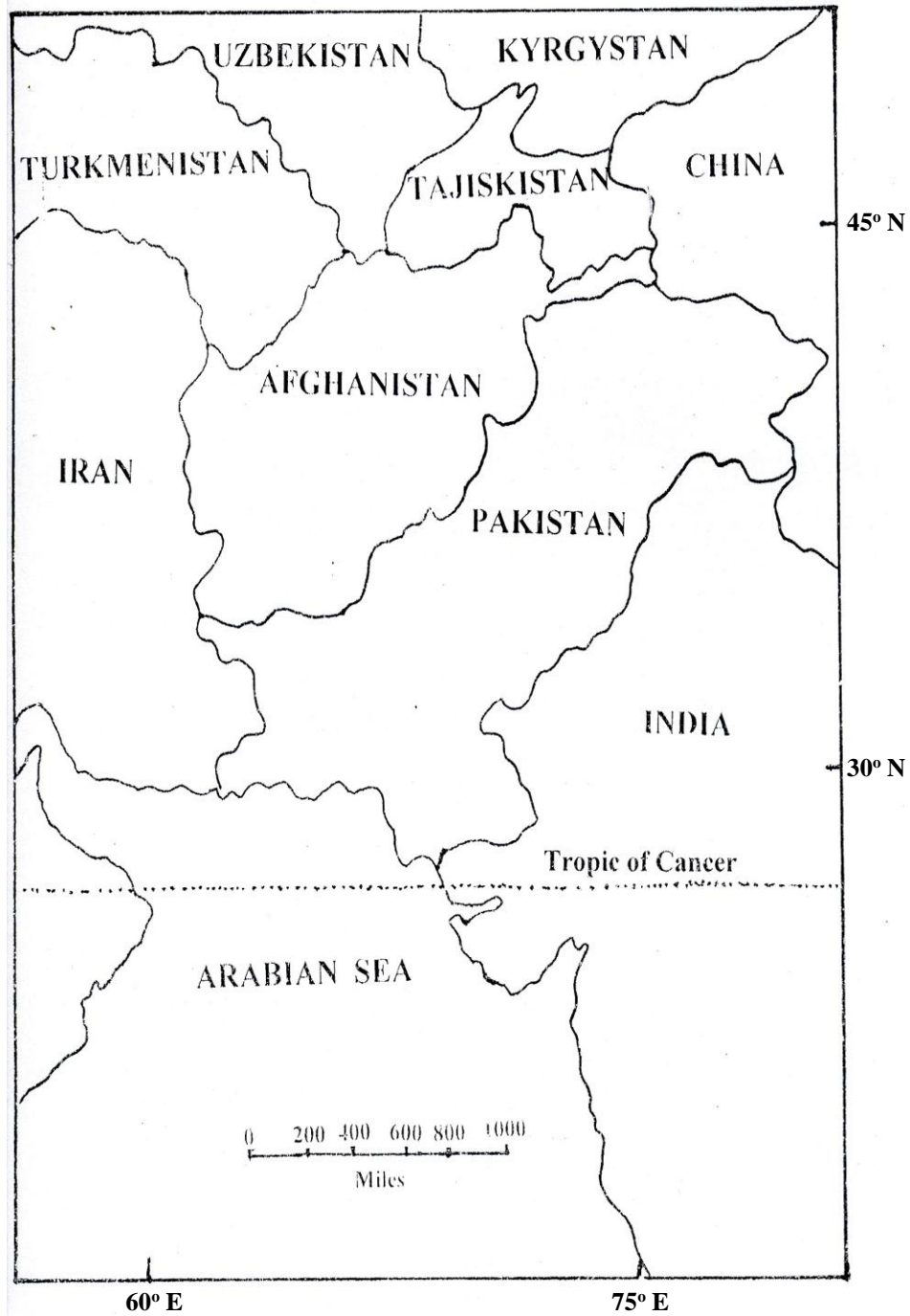


Fig. 1. Map showing geographical position of Pakistan.

rivers, rivulets, brooks, brooklets, rice fields, canals, irrigation channels, lakes and tanks from the Districts of Attock, Gujranwala, Jhang, Jhelum, Khushab, Lahore, Sargodha, Sheikhpura and Sialkot in the province of the Punjab; from Bahrain and Kalam (Swat) in the province of N.W.F.P. as well as from Chenari, Muzaffarabad and Neelum Valley in Azad Kashmir at different seasons during March 1996 to August 2000 (Fig. 2). Wherever possible, the temperature and pH of water at the place of collection were recorded. The material collected in the field was brought to the laboratory and preserved in 3-5 % formalin solution to which a little glycerine was added. For studying the material under microscope, semi-permanent preparations in glycerine were made and sealed with enamel paint. Sketches were prepared with the help of camera lucida and various dimensions were measured with the help of calibrated ocular micrometer. The blue-green species were taxonomically determined after reference to Forti (1907), Tilden (1910), Ghose (1919, 1924), Frémy (1929), Geitler (1932), Randhawa (1936), Rao (1936, 1937), Desikachary (1959), Starmach (1966) and others.

Results

On the basis of their morphological and cytological characteristics, the blue-green algae were identified up to species level. The following 46 identified species are systematically arranged according to the recently proposed classification (Shameel, 2001).

CLASS CHROOCOPHYCEAE

Unicellular, palmelloid or colonial forms.

Order Chroococcales

Cells loosely bounded into gelatinous, irregular colony; reproduction by cell division or endospores; no exospores, nannocytes present.

Family Chroococcaceae

Cells mostly spherical, ellipsoidal, cylindrical, seldom spindle shaped, single or forming colonies; membrane thick, mucilaginous, often lamellated, with an overall formation of amorphous, mucilaginous mass; colony shapeless, spherical, ellipsoidal, tubular or hemispherical; cell division in two or three directions, in elongate cells often only in one direction, cells of many generations in a single parent sheath; multiplication by division, sometimes through nannocytes, spores with firm membrane present in some genera, also planococci. Following genera were collected which may be distinguished as follows:

1. Cells single or a few together 2
 Cells many in a colony 3
2. Cells spherical 4
 Cells elongate 5
3. Cells without any definite arrangement 6
 Cells with definite arrangement in colony *Merisopmedia*

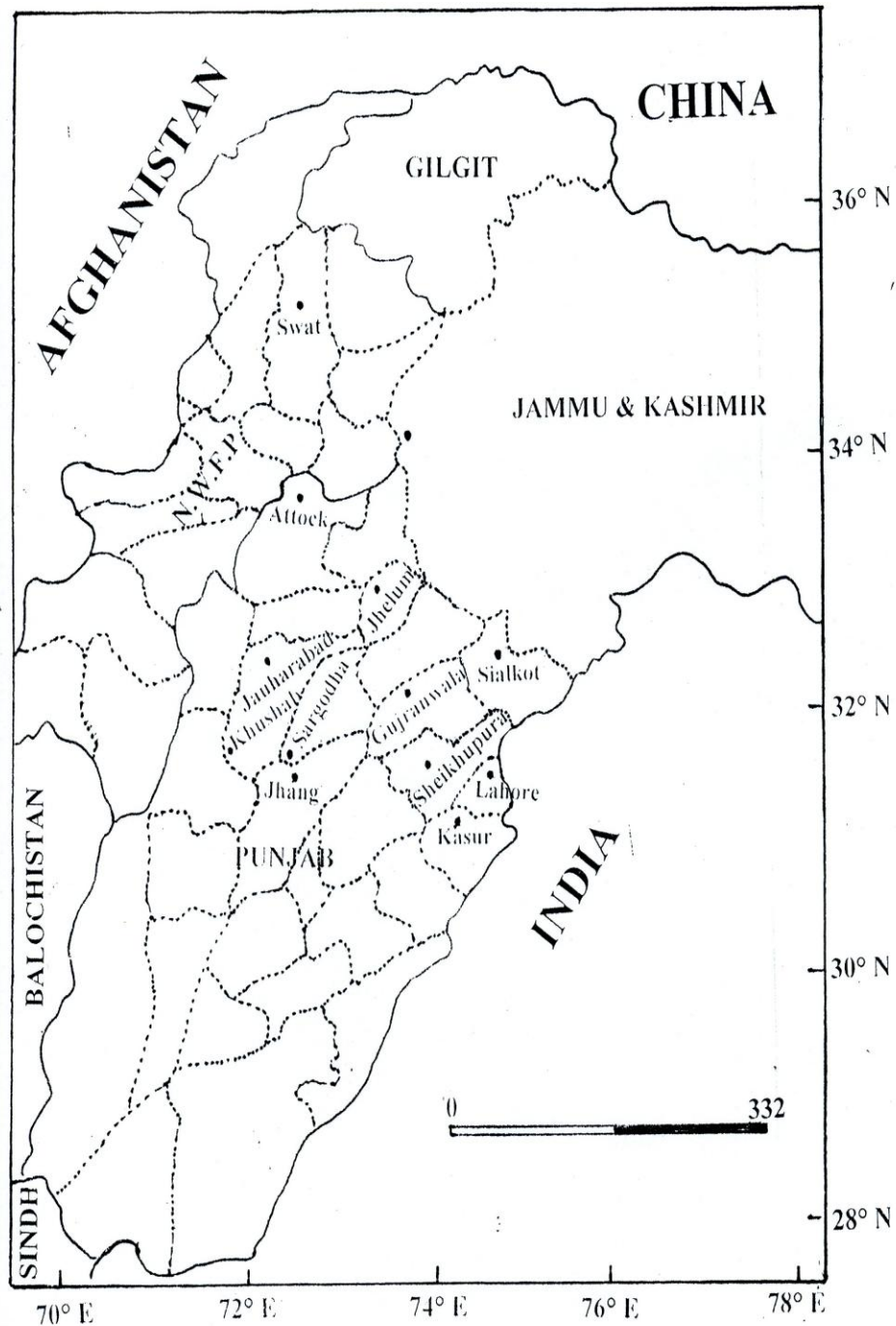


Fig. 2. Map indicating localities of collection.

4. Without individual mucilage envelope *Synechocystis*
 With a distinct envelope 7
5. With a firm vesicular sheath *Gloeotheca*
 Without such sheath *Synechococcus*
6. Cells packed into microscopic colonies *Microcystis*
 Cells loosely arranged 8
7. Sheath vesicular *Gloeocapsa*
 Sheath not vesicular *Chroococcus*
8. Cells spherical *Ahanocapsa*
 Cells ellipsoidal to cylindrical *Aphanothece*

***Aphanocapsa* Nägeli**

Cells spherical or nearly so, many, loosely arranged without an order, forming a gelatinous mass, formless, often a few cm in diam.; mucilage homogenous, colourless, cells often with a thin more or less gelatinized individual sheath; division in two (or various) directions, often two, four and sometimes many within a common mucilaginous envelope of the parent cells; nannocytes present in some species, formed by repeated division. Following species were collected which may be distinguished as follows:

1. Cells more than 5 μm in diameter 2
 Cells less than 5 μm in diameter 3
2. Cells more than 8 μm in diameter *A. crassa*
 Cells 5-8 μm in diameter *A. roeseana*
3. Cells more than 3 μm in diameter *A. pulchra*
 Cells 2-3 μm in diameter *A. virescens*

***A. crassa* Ghose**

(Ghose, 1927b: 239; Desikachary, 1959:136)

General characters: Colonies gelatinous, brownish; cells generally single, globose, 9 μm thick and brownish green (Fig. 3a).

Geographical distribution: Myanmar, Pakistan.

Local distribution: Sheikhpura District: rice fields near Sheikhanwala.

Remarks: Recorded for the first time from Pakistan. Collections were made from rice fields during August 2000. It occurred in massive quantity.

***A. pulchra* (Kützinger) Rabenhorst**

(Forti, 1907: 73, Frémy, 1929: 22, 1933: 14, Geitler, 1932: 155; Venkataraman, 1958: 317; Desikachary, 1959: 132; Masud-ul-Hassan & Batool, 1987: 346)

General characters: Thallus gelatinous, homogenous and hyaline, covered with mucilage, blue green, tuberculate, attached or free; cells spherical or sub-spherical or some what elongate, 2.5 – 4.5 (-4.7) μm in diameter, loosely arranged, single or in pairs, pale blue-green; individual sheath of cell indistinct, planktonic in tanks and lakes; cell content bluish green, minutely granulated (Fig. 3b).

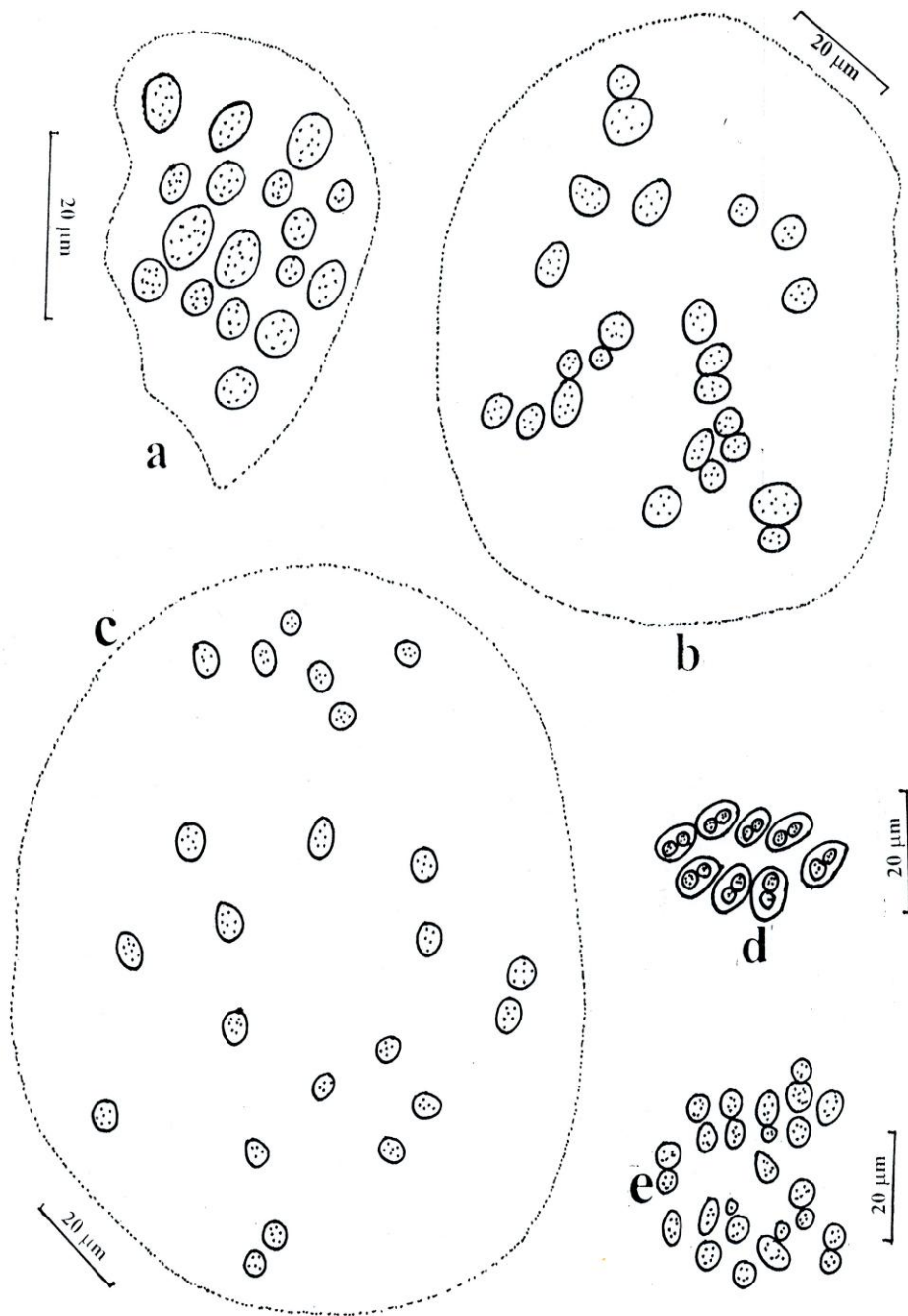


Fig. 3. a. *Aphanocapsa crassa*, b. *A. pulchra*, c. *A. roseana*, d. *A. virescens*; e. *Aphanothece castagnei*.

Geographical distribution: USA, Europe, India: Dadar near Mumbai (Hof & Frémy, 1932), Benaras (Rao, 1937); Sri Lanka: Anuradhapura, Kalawewatank and lake Cantelai (Crow, 1923b); Pakistan.

Local distribution: Azad Kashmir: Neelum Valley; Lahore: Mahmood Booti, rice fields of Batapur, paddy fields near Wagha border; Attock and Sargodha Districts.

Remarks: The collection was carried out in different months of 1999. In summer and rainy season it occurred in massive quantity and the cell size was large but in winter season cells were found in small size and also in low quantity.

A. roseana de Bary
(Forti, 1907: 72; Geitler, 1932: 157; Desikachary, 1959: 131;
Gupta & Kumar, 1968: 487)

General characters: Thallus irregularly spherical, brownish green, often gelatinous, up to 30 cm; cells 6-8 μm in diameter, nearly oval, pale blue-green; mucilage sheath homogenous (Fig. 3c).

Geographical distribution: India: Shembaganur near Madurai (Frémy, 1942); Pakistan.

Local distribution: Pasroor and Sialkot Districts: Adamkey Village.

Remarks: The collection was carried out during May and June 1996 from rice cultivated areas and the nearby roadside puddles. It occurred in free floating state as well as in massive quantity.

A. virescens (Hassall) Rabenhorst
(Tilden, 1910: 29)

General characters: Cells sub-spherical or somewhat elongated, 2.0-2.5 μm in diameter, often in pair, sometime single; division in the two directions, often two within a common mucilaginous envelope of the parent cell; mucilage homogenous, colourless (Fig. 3d).

Geographical distribution: India, Sri Lanka, Pakistan.

Local distribution: Azad Kashmir: Neelum Valley.

Remarks: It has been reported for the first time from Pakistan, being collected during December 1998.

Aphanothece Nägeli

Cells ellipsoidal to cylindrical, straight or slightly bent, many in a more or less shapeless, expanded thallus; mucilage homogenous, occasionally with lamellated individual envelope which often gelatinize; division transverse; nannocytes present. Following two species could be collected, which may be distinguished as follows:

1. Cells more than 2 μm broad *A. castagnei*
2. Cells up to 2 μm broad *A. saxicola*

A. castagnei (Brébisson) Rabenhorst

(Forti, 1907: 81; Tilden, 1910: 31; Geitler, 1932: 171; Frémy, 1933: 19;
Desikachary, 1959: 140; Watanabe *et al.*, 1979: 69)

General characters: Thallus gelatinous, without any definite shape, shining and blue green in colour; cells cylindrical 1-3 μm broad and 5-7 μm long; sheath colourless (Fig. 3e).

Geographical distribution: Myanmar: Maymyo Islands (Ghose, 1927b), Rangoon (Skuja, 1949); India: Madurai (Frémy, 1942), Mumbai (Gonzalves & Joshi, 1943), Singaperumal Koil, Vandalur and Kodaikanal; Pakistan.

Local distribution: Sheikupura District: rice fields near Rana-Bhatti Village.

Remarks: The soil of Sheikupura is of semi-arid type, with rainfall occurring mostly in summer season, which is hot and temperature may rise up to 48 °C. Collections were made mainly from roadside puddles of the Village during summer 1997.

A. saxicola Nägeli

(Forti, 1907: 81; Tilden, 1910: 30; Frémy, 1929: 28; Geitler, 1932: 169;
Desikachary, 1959: 138; Starmach, 1966: 95)

General characters: Thallus mucilaginous, colourless or yellowish; cells cylindrical, 1.0-2.5 μm broad and 2-3 times as long as broad (3.8-5.8 μm), single or in pairs, seldom many embeded in a common mucilagenous envelope, pale blue-green (Fig. 4a).

Geographical distribution: Myanmar; India: Benaras (Rao, 1936), Shembaganur near Madurai (Frémy, 1942), Allahabad (Mitra, 1951); Pakistan.

Local distribution: Kasur District: Keothe, Sheikupura District: rice fields near Rana-Bhatti Village.

Remarks: It has been recorded for the first time from Pakistan, being collected during June 1997. The visited area was mostly water logged or had toxic water of tanneries.

Chroococcus Nägeli

Cells spherical, subspherical or hemispherical, divided in small groups of 2-4 individuals, sometimes 8-16, rarely single, in a gelatinous or mucous matrix; sheath of individual cells distinct, firm, generally lamellated, in some cases homogenous, persistently or irregularly broken; reproduction by the cell division and fragmentation of colonies; division of cells in three directions; nannocytes occasionally formed. Following species have been collected which may be distinguished as follows:

1. Cells single or up to 8 together 2
Cells forming a large thallus 3
2. Sheath lamellated 4
Sheath not lamellated 5

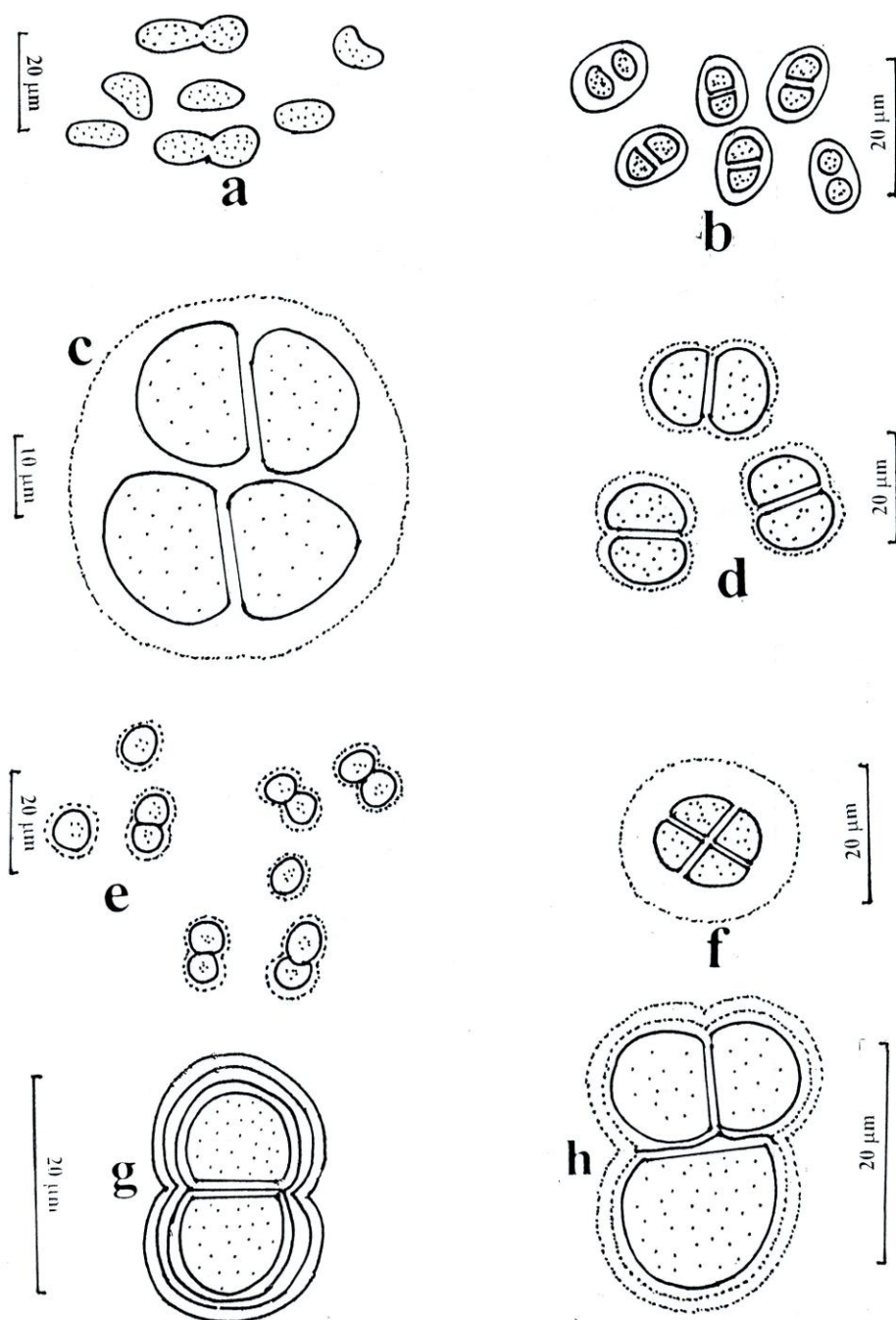


Fig. 4. a. *Aphanothece saxicola*; b. *A. Chroococcus cohaerens*, c. *C. gomontii*, d. *C. hansgirgii*, e. *C. minor*, f. *C. minutus*, g. *C. tenax*, h. *C. turgidus*.

3. Sheath lamellated *C. varius*
 Sheath unlamellated *C. cohaerens*
4. Lamellae of the sheath distinct *C. turgidus*
 Lamellae of the sheath indistinct *C. tenax*
5. Cells without sheath up to 4 μm broad *C. minor*
 Cells without sheath more than 4 μm broad 6
6. Cells without sheath less than 7 μm broad *C. minutus*
 Cells without sheath more than 7 μm broad 7
7. Cells without sheath 7-9 μm broad *C. gomontii*
 Cells without sheath 8-12 μm broad *C. hansgirgii*

C. cohaerens (Brébisson) Nägeli

(Forti, 1907: 21; Tilden, 1910: 9; Frémy, 1929: 44; Geitler, 1932: 235;
 Desikachary, 1959: 111)

General characters: Thallus slimy, dark green; cells single or up to 2-8 in groups, without envelope, 2-5 μm in diameter, with sheath 2.7-4.7 μm in diameter; colony 7-9 μm ; sheath thin, colourless, unlamellated (Fig. 4b).

Geographical distribution: Myanmar: Rangoon (Skuja, 1949); Maldives: Malay (Biswas, 1929); India; Pakistan.

Local distribution: Azad Kashmir: Neelam Valley; Lahore: fountain of zoo, drain near the tube-well house, Ravi Park.

Remarks: Recorded for the first time from Pakistan, being collected during June and August 1998 from Punjab. It was also collected from Azad Kashmir during December 1997. It was found in stagnant water pools and drainage water, with the pH nearly 7.5. During summer season it was found in massive quantity as compared to winter season.

C. gomontii (Kützing) Nygaard

(Geitler, 1932: 240; Desikachary, 1959: 105)

General characters: Colony with 2-4 cells in a common mucilagenous sheath; cells 7-9 μm broad and 11-14 μm long; sheath colourless, unlamellated, 22-25 x 15-20 μm (Fig. 4c).

Geographical distribution: Malaysia: Malaya; Pakistan.

Local distribution: Gujranwala District: Roadside ponds from Sallar Village near Kamonkey.

Remarks: It has been reported for the first time from Pakistan. It occurred in planktonic state in temporary ponds. The water was highly polluted due to dissolved organic matter. It was collected during December 1999.

C. hansgirii Schmidle

(Forti, 1907: 7; Desikachary, 1959: 105)

General characters: Cells single or two together, spherical or oblong, 12-15 μm broad, 18-20 μm long; sheath thin, hyaline; cell contents homogenous, blue green (Fig. 4d).

Geographical distribution: India: Poona; Pakistan.

Local distribution: Azad Kashmir: Neelam Valley; Lahore: rice fields along Burki Road.

Remarks: It is reported for the first time from Pakistan. It was collected in free floating state during winter season of 1997 from slow running water at Azad Kashmir in low quantity, mixed with many other planktonic algae. It was also collected from rice fields of Lahore during October 1999 but in large quantity.

C. minor (Kützinger) Nägeli

(Forti, 1907: 23; Tilden, 1910: 9, Setchell, 1926: 61; Frémy, 1929: 45; Geitler, 1932: 240; Desikachary, 1959: 105; Gupta & Kumar, 1968: 486)

General characters: Thallus slimy, gelatinous, dirty blue green or olive green; cells sub-spherical or oblong, 2-4 μm in diameter, single or in a group of 2-4, sheath colourless, unlamellated, very thin, hardly visible (Fig. 4e).

Geographical distribution: Myanmar: Elephant Point (Theobald, 1883), Kyauktaga, Pegu District (West & West, 1907), Rangoon (Skuja, 1949); North India (Turner, 1892); Pakistan.

Local distribution: Lahore: rice fields near Wagha, Chah Miran.

Remarks: The collection was carried out from different areas of Lahore during summer season of 1997. The pH of water in the rice fields, where from algae were collected, was slightly alkaline (8.0). In different localities depending on their ecological conditions, this species occurred singly, in pair or in groups of 2-4 cells.

C. minutus (Kützinger) Nägeli

(Forti, 1907: 14; Tilden, 1910: 7; Frémy, 1929: 39; Desikachary, 1959: 103; Ardre, 1970: 14; Gupta, 1972: 483)

General characters: Cells spherical or oblong, single or in a group of 2-4, light blue-green, cells with sheath 5-15.5 μm in diameter and without sheath 3.5-14 μm in diameter; colonies 5-28 x 13-31 μm , colourless colonies planktonic among other algae (Fig. 4f).

Geographical distribution: Myanmar: Rangoon and Mandalay (Skuja, 1949); India: Benaras (Rao, 1937), Muzaffarpur, Gorakhpur and Basti (Singh, 1939), Shembaganur (Frémy, 1942), Allahabad (Mittra, 1951), Calcutta (Bruhl & Biswas, 1923); Pakistan.

Local distribution: Sialkot: Head Marala, Adamkey Village; Sheikhpura District: Waghray Village; Kasur District: Raja Jung Village; Lahore: Nasir Bagh, rice fields along Burki Road, Jinnah garden; Gujranwala District: Kamonkey; N.W.F.P.: Swat (Kalam).

Remarks: It has been collected during summer and winter rainy seasons of 1998. Cells were found singly or in groups. It occurred in planktonic state in stagnant water ponds. Size of colonies differed due to the change of temperature, localities and ecological conditions.

C. tenax (Kirchner) Hieronymus
(Geitler, 1932: 231; Desikachary, 1959: 103)

General characters: Cells mostly in groups of 2, 4, 8 or 16, blue green, with sheath 10-26 µm in diameter and without sheath 14-17.5 in diameter; sheath colourless, very thick. Cells distinctly lamellated, 3-4 lamellae found in each cell (Fig. 4g).

Geographical distribution: India: Madras (Ganapathi, 1940); Pakistan.

Local distribution: Sheikhpura District: Near Sheikhanwala; Azad Kashmir: moist rocks at Muzaffarabad; Lahore: fountain of zoo.

Remarks: Collections were made during spring, summer and winter seasons of 1999. It was found in stagnant water pools and on moist rock surface. The pH of water was 7.5.

C. turgidus (Kützinger) Nägeli
(Forti, 1907: 12, Setchell, 1926: 61; Frémy, 1929: 36; Geitler, 1932: 228;
Desikachary, 1959: 101; Gupta & Kumar, 1968: 487)

General characters: Cells spherical or ellipsoidal, single or in groups of 2-4, blue green or light green, without sheath 5-29 µm broad, with sheath 12.5-44 µm broad; sheath colourless or bluish green not distinctly lamellated; colonies 10-24 x 5-2 µm; cell diameter 20-20.5 µm; endospores small (Fig. 4h).

Geographical distribution: Myanmar: Rangoon (Skuja, 1949); India: Mumbai (Schmidle, 1900, Gonzalves & Joshi, 1946), Faridpur and Berhampur (Bruhl & Biswas 1922), Calcutta (Bruhl & Biswas, 1923, 1926; Benerji, 1936), Hyderabad, Benaras (Rao, 1937); Sri Lanka: Hanaragodha (West & West, 1902); Pakistan: Lahore (Ghose, 1919, 1924).

Local distribution: Lahore: near Awan Village, Hadiara Village, near Wagha, fountain of zoo; Azad Kashmir: Neelum Valley; Gujranwala District: Chandalay; Kasur District.

Remarks: It was found in groups of 2 or 4 cells from different localities. It was mainly collected from ponds and puddles but some collection were also made from gently flowing portion of the fountain. Slight morphological differences were found within species. It occurred in summer, winter and autumn seasons of 1997. Maximum growth was found during summer with very low growth during winter.

C. varius A. Braun

(Forti, 1907: 21; Tilden, 1910: 7; Geitler, 1932: 236; Desikachary, 1959: 107)

General characters: Thallus gelatinous, brownish and dirty olive green; cells globular, single or in a group of 2-4, seldom in small groups, irregularly arranged, without sheath 3-4 μm in diameter, with sheath 6-8 μm in diameter; sheath purple, apparently thick, indistinctly lamellated (Fig. 5a).

Geographical distribution: Myanmar; Mandalay, Rangoon (Ghose, 1927b; Skuja, 1949); India: Benaras (Rao, 1937); Pakistan.

Local distribution: Lahore: fountain of zoo; Azad Kashmir: Neelum Valley.

Remarks: The collection was carried out during beginning to the late summer of 1997 from two different places. During early summer it was collected from slow running water in attached condition, and in the late summer it was obtained in planktonic state from fountain water locality.

Gloeocapsa Kützing

Cells spherical, 2-8 in colonies, seldom many, with a number of concentric spherical envelopes; colonies single or many together forming an expanded mass; individual sheath lamellated or unlamellated, cell division very regularly in three directions, cells in large colonies often with secondary colonies, arranged irregularly, occasionally with nannocytes, resembling *Aphanocapsa* stage; spores with firm thick walls often formed in a number of species. Following species have been collected, which may be distinguished as follows:

1. Sheath colourless 2
 Sheath coloured 3
2. Sheath lamellated 4
 Sheath not lamellated 5
3. Sheath yellow to brown 6
 Sheath red to orange *G. magma*
4. Cells with sheath more than 7 μm broad *G. turgidus*
 Cells with sheath less than 7 μm broad 7
5. Thallus with calcium impregnation *G. calcarea*
 Thallus without such impregnation 8
6. Sheath lamellated *G. pleurocapsoides*
 Sheath unlamellated *G. kuetzingiana*
7. Cells without sheath 3-5 μm broad *G. polydermatica*
 Cells without sheath 2-4 μm broad 9
8. Cells without sheath up to 3 μm broad *G. aeruginosa*
 Cells without sheath up to 5 μm broad *G. livida*
9. Thallus light green in colour *G. montana*
 Thallus dirty olive-green in colour *G. varius*

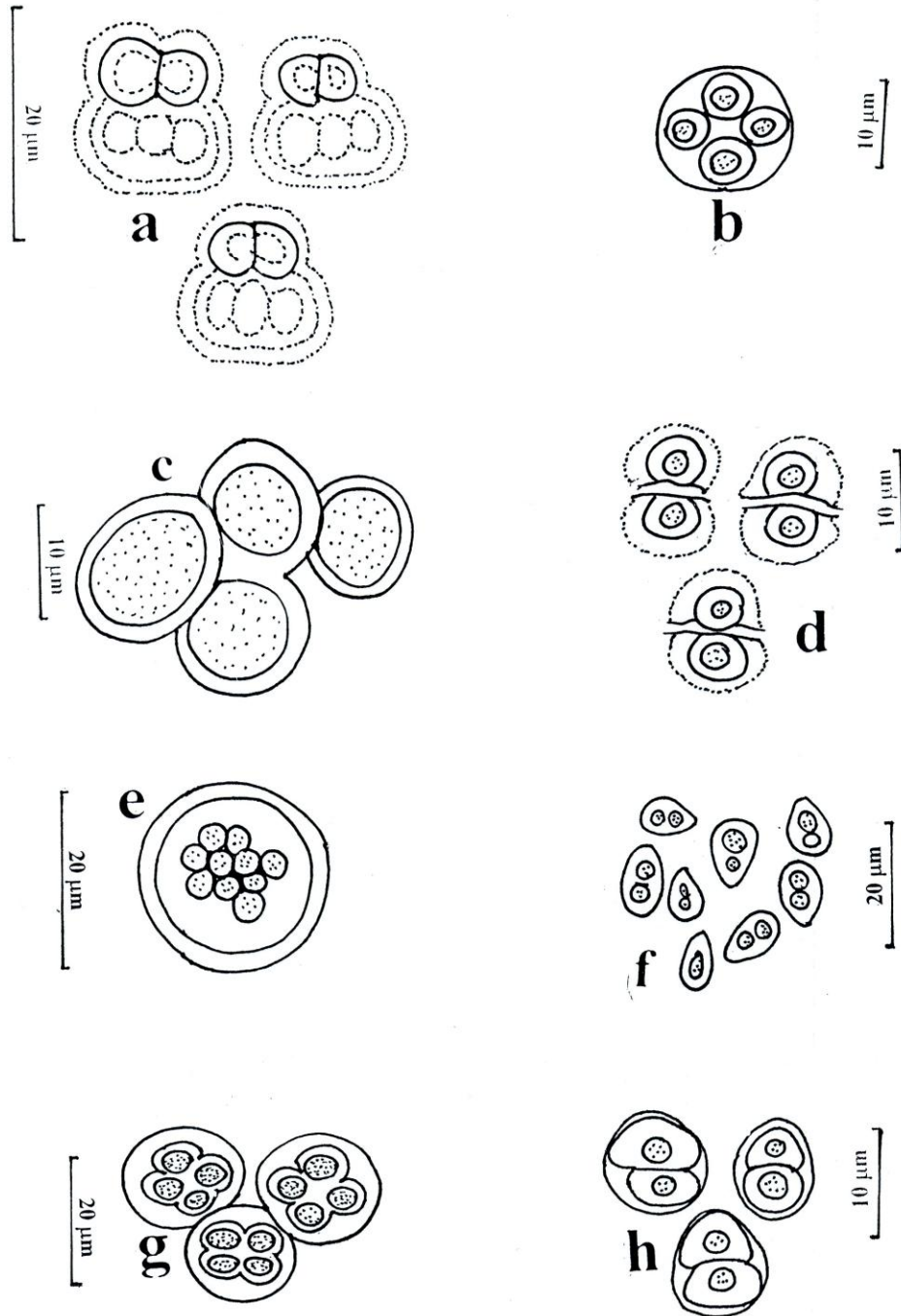


Fig. 5. a. *Chroococcus varius*; b. *Gloeocapsa aeruginosa*, c. *G. calcarea*, d. *G. gelatinosa*, e. *G. kuetzingiana*, f. *G. livida*, g. *G. magma*, h. *C. Montana*.

G. aeruginosa (Carmichael) Nägeli
(Forti, 1907: 55; Desikachary, 1959: 115)

General characters: Thallus crustaceous, granulose, mucilaginous; two-celled colonies; cells spherical, with sheath 4-5 μm broad, without sheath 2-3 μm broad; sheath colourless, unlamellated; cell content blue green (Fig. 5b).

Geographical distribution: India: Berkuda Island, Chilka lake, Orissa (Biswas, 1924), Calcutta (Biswas, 1926), Hyderabad (Deccan), River Hooghly (Biswas 1942); Pakistan.

Local distribution: Lahore: Manawan Village, Shahgoharabad.

Remarks: It was found in extremely hot as well as rainy season of 1998, growing in massive quantity on damp rocks. The collections were made from two different stagnant water localities.

G. calcarea Tilden
(Forti, 1907: 40; Geitler, 1932: 187; Desikachary, 1959: 115)

General characters: Thallus with calcium incrustation; cells with or without individual sheath, 8-9 μm in diameter; blue green, colonies 23.7-25.7 μm in diameter with 4-13 cells (Fig. 5c).

Geographical distribution: India: Madras (Ganapathi, 1940); Pakistan.

Local distribution: Lahore: Hadiara Village.

Remarks: It was collected during July 1996 in free floating and large sized colonies.

G. gelatinosa Kützinger
(Forti, 1907: 54, Frémy, 1929: 47; Geitler, 1932: 187; Desikachary, 1959: 114)

General characters: Colonies mostly two celled; cells without sheath about 2.5 μm and with sheath 7.2 μm in diameter; colonies blue green, about 25 μm in diameter; sheath colourless, seemingly thin, when old lamellated (Fig. 5d).

Geographical distribution: Myanmar: Kaisering Island (Ghose, 1927c); India: Calcutta (Banerji, 1936); Pakistan.

Local distribution: Lahore: Jinnah Garden.

Remarks: It has been recorded for the first time from Pakistan. Its specimens were collected from fountain of Jinnah Garden during April 1996. The temperature was 25.5°C and pH about 7.5.

G. kuetzingiana Nägeli

(Forti, 1907: 47; Geitler, 1932: 194; Desikachry, 1959: 118; Starmach, 1966: 113)

General characters: Thallus thin, soft, brown in colour; cells without sheath, 2-3 μm and with sheath 4-5 μm in diameter, blue green in colour; sheath yellow or brown, not lamellated (Fig. 5e).

Geographical distribution: India: Madras; Pakistan.

Local distribution: Sheikhpura District: rice fields near Sheikhanwala.

Remarks: It is being reported for the first time from Pakistan. The collection was made from the rice fields near Sheikhanwala in summer and rainy season of 1998.

G. livida (Carmichael) Kützing

(Forti, 1907: 56; Desikachary, 1959: 116)

General characters: Thallus mucilaginous, hyaline, blue green in colour; cells small, rounded or elliptical, with sheath 4-6 μm broad, without sheath 2.5-4.5 μm broad; colonies 17.5-25 μm in size; sheath light blue, hyaline; contents blue green (Fig. 5f).

Geographical distribution: India: Shembaganur (Frémy, 1942); Pakistan.

Local distribution: Azad Kashmir: Neelum Valley; Lahore: tube well hose near Burki Road.

Remarks: The collection was made during December 1998 from Neelum Valley and from Lahore during September 1999 in planktonic state and in large quantity.

G. magma (Brébisson) Kützing

(Forti, 1907: 35; Frémy, 1929: 50; Geitler, 1932: 198; Desikachary, 1959: 120)

General characters: Colonies spherical or irregularly arranged, 30-60 μm in diameter; cells colourless or angular, 3-7 μm in diameter, blue green; mostly with a thin optical cell with sheath, 7.5 to 16 μm long, 10 to 11 μm broad; dull reddish brown sheath, thin, firm, often with one or more broader sheath enclosed within 2 μm thick coloured outermost layer (Fig. 5g).

Geographical distribution: Myanmar: Rangoon (Skuja, 1949); India: Madras (Ganapathi, 1940); Pakistan.

Local distribution: Azad Kashmir: Neelum Valley.

Remarks: It is being reported for the first time from Pakistan. Collection has been made from stagnant water ponds during winter season of 1998.

G. montana Kützing

(Forti, 1907: 50; Desikachary, 1959: 123; Starmach, 1966: 120)

General characters: Thallus amorphous, broad, mucilaginous, light green in colour; cells spherical or ellipsoidal, with sheath 4-6 μm broad and without sheath 2-4 μm broad; occurring singly or together in a colony, which is 13-15 μm broad; sheath lamellated, colourless, outer lamellae having diffluent contents, more or less opaque, homogenous, finely, granular, pale blue green (Fig. 5h).

Geographical distribution: India: Assam, Calcutta, Bengal (Banerji, 1936); Pakistan.

Local distribution: Lahore: fountain of zoo.

Remarks: It is being reported for the first time from Pakistan. It was collected in August 2000, during which the water temperature was about 37.2°C and pH 7.5.

G. pleurocapsoides Novacek

(Skuja, 1949: 17; Desikachary, 1959: 118)

General characters: Colony small, irregular, brown in colour; cells pale blue green, homogenous, granular, 10-11 μm broad, cells closely arranged in the colony; sheath thin, firm yellowish brown in colour and 2-3 μm thick, lamellated, 3-4 lamellae present in each cell (Fig. 6a).

Geographical distribution: Myanmar: Rangoon; Pakistan.

Local distribution: Sheikhpura District: wall of discharge box of a tube well.

Remarks: It is being reported for the first time from Pakistan. Collections were made during April 1998, it was not found in massive quantity.

G. polydermatica Kützing

(Forti, 1907: 51; Geitler, 1932: 185; Desikachary, 1959: 114)

General characters: Thallus mucilaginous, compact; cell spherical, without sheath 3.0-4.5 μm diameter, blue green; sheath colourless, very thick, almost as thick as protoplast, very distinctly visible, many times lamellated (Fig. 6b).

Geographical distribution: India: Dawna Hills (Carter, 1926); Pakistan: Lahore (Ghose, 1919).

Local distribution: Lahore: fountain of zoo.

Remarks: It was collected during summer from fountain water, having temperature 37.2°C and pH 7.5 during 1996. It occurred in a group of two cells in the flowing water.

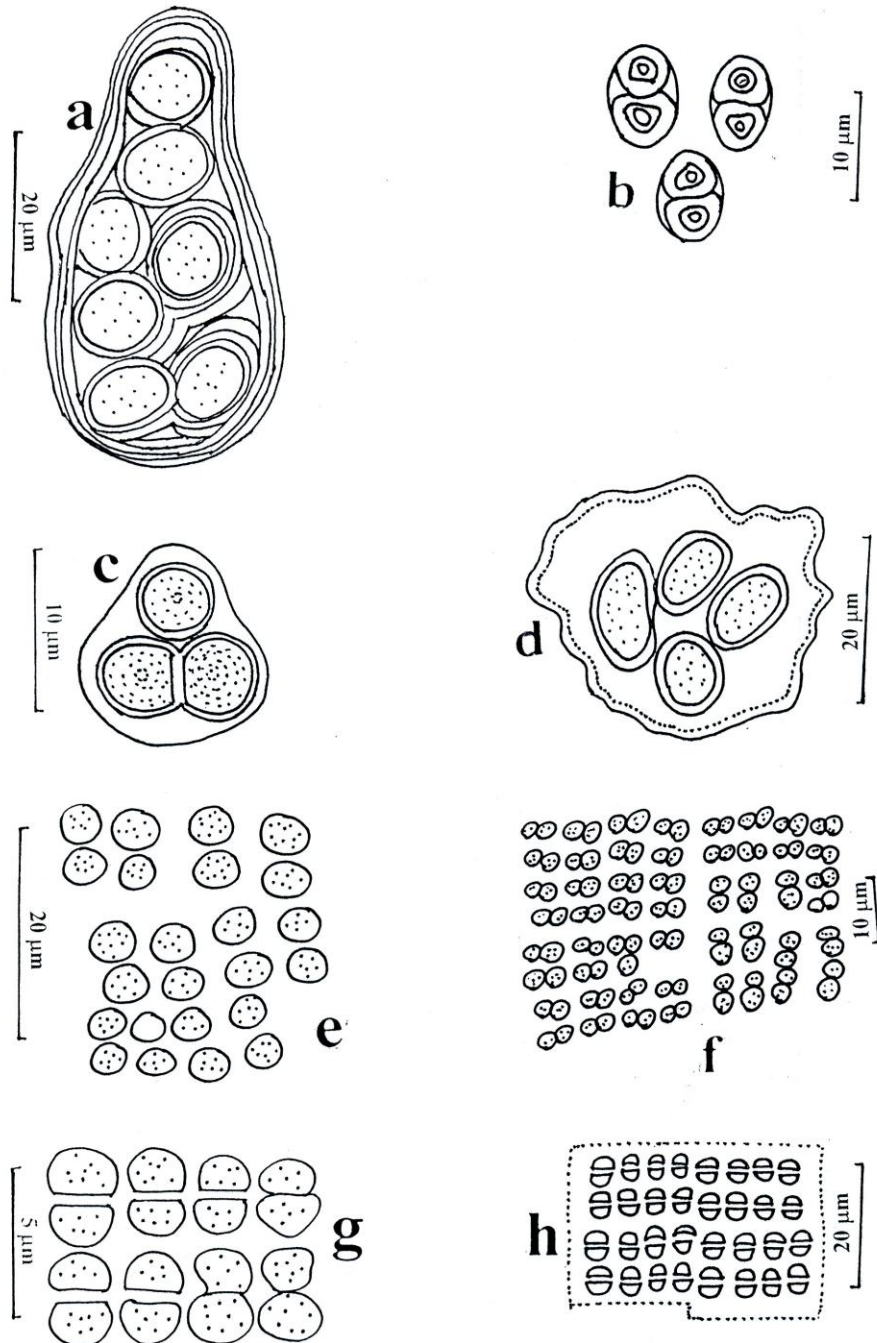


Fig. 6. a. *Gloeocapsa pleurocapsoides*, b. *G. polydermatica*, c. *G. varius*; d. *Gloeothoece samoensis*; e. *Mersimopedia aeruginea*, f. *M. convoluta*, g. *M. elegans*, h. *M. glauca*.

G. varius Hollerbach

General characters: Thallus gelatinous, dirty olive green; cells globular, 2-4 together, cells without sheath 2-4 μm and with sheath 4-8 μm in diameter; sheath thick, distinctly lamellated, colourless (Fig. 6c).

Geographical distribution: Myanmar: Rangoon (Ghose, 1927a); India: Benaras (Rao, 1937); Pakistan.

Local distribution: Lahore: near Wagha.

Remarks: Collection was made during July 1999 from rice fields near Wagha Border. It occurred in massive quantity in planktonic state.

Gloeotheca Nägeli

Cells cylindrical to ellipsoidal, straight or bent, not attenuated at the ends, but broadly rounded, in small colonies or forming large thallus, division of cells at right angles to the longitudinal axis, sometimes daughter cells divide in all the three directions; sheath structure and colony structure same as in *Gloeocapsa*; nannocytes present. The following one species could be collected:

G. samoensis Wille

(Geitler, 1932: 219; Desikachary, 1959: 128)

General characters: Cells ellipsoidal, without sheath 3.5-5.5 μm broad and 7-9 μm long, cells blue green in colour. Colonies nearly round and contain 4 cells is a common envelope, which is colourless, unlamellated (Fig. 6d).

Geographical distribution: India: Kunnakudi, Madras; Pakistan.

Local distribution: Sheikhpura District: walls of discharge box of the tube well.

Remarks: The collection work was done during April 1997 in vegetative stage from the wall of discharge box of tube well, which was sometimes in running and sometimes in stop position for a definite time period.

Merismopedia Meyen

Cells 4-16 (or more) in tubular colonies arranged in a homogenous mucilage, generally in fours, arranged in a single plane, free floating, cells globose, oblong before cell division, sub spherical after division; contents blue-green, rarely violaceous or reddish, multiplication by division in two directions perpendicular to the plane of the colony. Following species have been collected, which may be distinguished as follows:

- | | |
|--|---------------------|
| 1. Thallus convoluted | <i>M. convoluta</i> |
| Thallus not convoluted | 2 |
| 2. Gas vacuoles present | <i>M. marsonii</i> |
| Gas vacuoles absent | 3 |
| 3. Cells less than 4 μm broad | 4 |
| Cells more than 4 μm broad | 5 |

- | | |
|-------------------------------------|----------------------|
| 4. Cells less than 1 µm broad | <i>M. minima</i> |
| Cells more than 1 µm broad | 6 |
| 5. Cells 5 µm broad or more | 7 |
| Cells less than 5 µm broad | <i>M. glauca</i> |
| 6. Cells less than 2 µm broad | <i>M. tenuissima</i> |
| Cells more than 2 µm broad | <i>M. punctata</i> |
| 7. Cells 5 µm broad | <i>M. aeruginea</i> |
| Cells broader | <i>M. elegans</i> |

***M. aeruginea* Brébisson**

(Forti, 1907: 107; Frémy, 1929: 13; Desikachary, 1959: 156)

General characters: Thallus more or less limited, colonies 35 µm in diameter, each colony contains 4-64 cells, cells spherical and 4-5 µm broad, contents blue green (Fig. 6e).

Geographical distribution: Myanmar: Irrawady River near Bhamo (West & West, 1902); Pakistan.

Local distribution: Sheikhpura District: near Sattarwala.

Remarks: The collections were made during April 1997 from bank of a canal. 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.

***M. convoluta* Brébisson**

(Forti, 1907: 108; Geitler, 1932: 262; Frémy, 1933: 8; Desikachary, 1959: 152;
Nizamuddin & Gerloff, 1982:138; Masud-ul-Hasan & Yunus, 1989: 100)

General characters: Cells spherical, 3.5-4 µm broad; leaf like convolute colonies, olive green in colour (Fig. 6f).

Geographical distribution: India: Calcutta (Biswas, 1942); Pakistan.

Local distribution: Lahore: Bhani Village.

Remarks: The collection was made from stagnant water ponds in bloom composition during 1997.

***M. elegans* A. Braun**

(Forti, 1907: 104; Frémy, 1929: 13, 1933: 7; Geitler, 1932: 265; Desikachary, 1957: 156;
Nizamuddin & Gerloff, 1982: 138)

General characters: Colonies small or big, 4, 8 or 16 celled; cells spherical or oblong, more or less closely arranged, 4.2-6.2 µm broad, 7.2-9.2 µm long; light blue green. Found mixed with other algae (Fig. 6g).

Geographical distribution: India: Calcutta (Biswas, 1942); Pakistan.

Local distribution: Lahore: rice fields along Burki Road.

Remarks: The collection has been made from stagnant water of rice fields during September 1997, in large quantity. It has been recorded for the first time from Pakistan.

M. glauca (Ehrenberg) Nägeli

(Turner, 1892: 12; Forti, 1907: 105; Frémy, 1929: 13, 1933: 7; Geitler, 1932: 264; Feldmaun, 1937: 145; Desikachary, 1959: 155; Starmach, 1966: 71; Ardre, 1970: 14; Nizamuddin & Gerloff, 1982: 138; Masud-ul-Hasan & Zeb-un-Nisa, 1986: 230)

General characters: Colonies small with 16-64 cells, rarely more, 30-31 µm long, 31-44 µm broad; cells 3-6 µm broad, 3-5 µm long, oval or spherical, closely arranged, pale blue green (Fig. 6f).

Geographical distribution: Myanmar: Rangoon (Skuja, 1949); India: Mumbai (Beck & Zahlbruckner, 1897), North India (Turner, 1892), Calcutta (Banerji, 1936), Madras (Ganapathi, 1940); Sri Lanka: Perediniya, Pandure (West & West, 1907), Anuradhapura, Newarawewa, Bentole (Crow, 1923b); Pakistan.

Local distribution: Azad Kashmir: Chenari; Neelum Valley; Lahore: Ghulam Colony.

Remarks: Collections have been made from Azad Kashmir and Lahore during spring, summer and winter seasons of 1997. In specimens collected during winter and spring from Azad Kashmir, the cells were found in small size as compared to those obtained from Lahore during summer.

M. marssonii Lemmermann

(Forti, 1907: 107, Frémy, 1929: 15; Geitler, 1932: 265; Desikachary, 1959: 154; Starmach, 1966: 71)

General characters: Cells spherical, 1-2 µm broad; colony rectangular with 128 cells, planktonic (Fig. 7a).

Geographical distribution: India: Madras; Pakistan.

Local distribution: Azad Kashmir: Neelum Valley.

Remarks: Collection work was done during December 1999. It occurred in planktonic condition.

M. minima Beck

(Forti, 1907: 108; Geitler, 1932: 263; Desikachary, 1959: 154)

General characters: Cells pale blue-green, 4 to many in small colonies; width with sheath 10-12 µm, free floating; individual cell 1.65 µm wide (Fig. 7b).

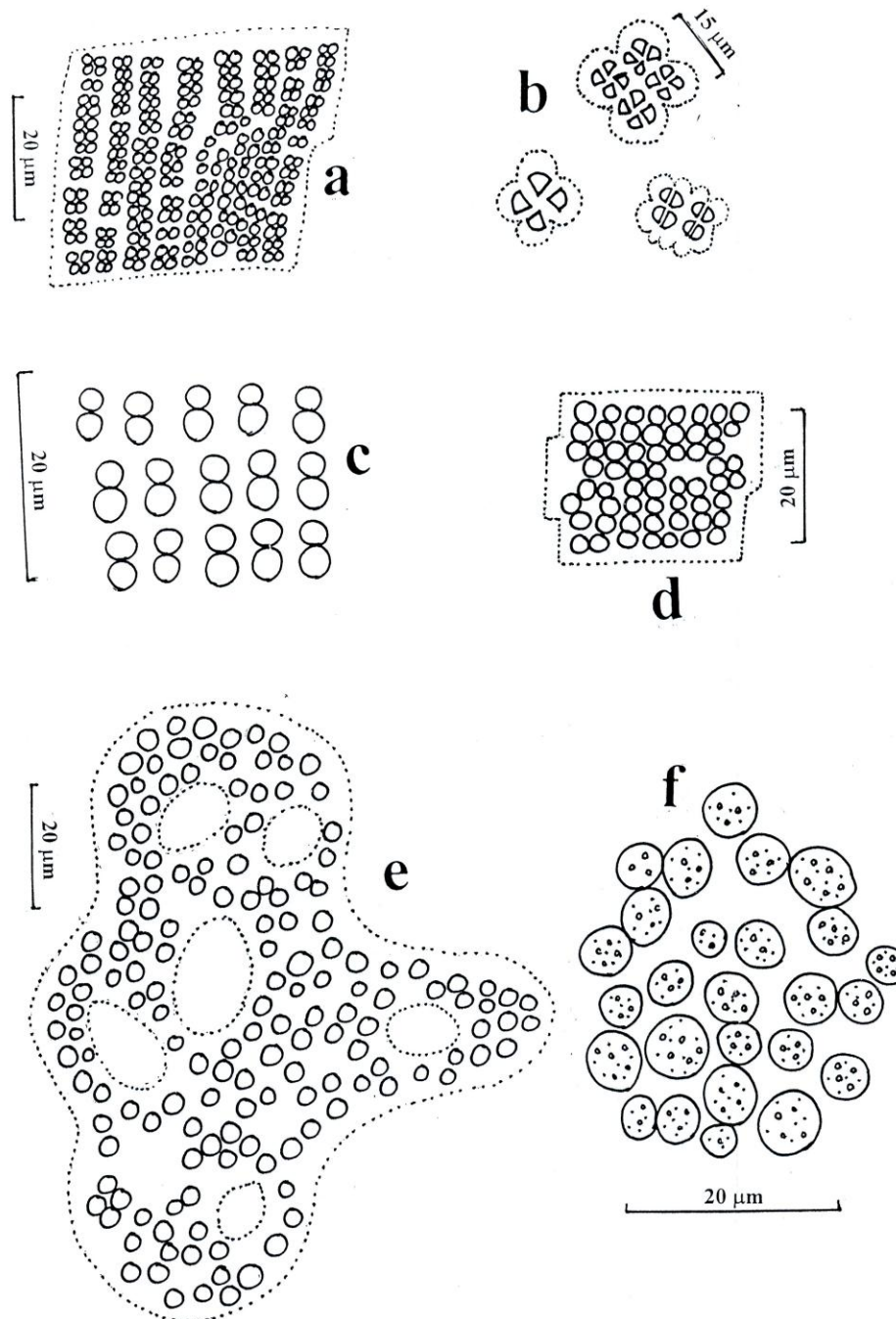


Fig. 7. a. *Merismopedia marssonii*, b. *M. minima*, c. *M. punctata*, d. *M. tenuissima*; e. *Microcystis aeruginosa*, f. *M. flosaquae*.

Geographical distribution: Myanmar (Skuja, 1949); India: Benaras (Rao, 1936), Ellore (Rao, 1938a); Pakistan.

Local distribution: Lahore: rice fields in Ghulam Colony (Chungi).

Remarks: The collection was made during June 1996. It occurred in vegetative as well as in reproductive phases in rice field area, the pH of water was about 8.

M. punctata Meyen

(Forti, 1907: 106; Frémy, 1929: 12; Geitler, 1932: 263; Desikachary, 1959: 155)

General characters: Colonies small, 4-64 cells, 34-68 μm broad, cells not closely packed; cells spherical or sub-spherical, 2-4 μm broad, length 3.0-5.5 μm , blue-green, planktonic; grow mixed with other algae (Fig. 7c).

Geographical distribution: India: Pandure (Crow, 1923a,b), Delhi (Rao, 1940), Madras (Ganapathi, 1940), Punjab, Chamba State (Singh, 1941); Pakistan.

Local distribution: Sheikhpura District: bank of the canal near Satarwala; Gujranwala District: Nandipur; Pasrur: Bakhatpura Village; Lahore: rice fields along Burki Road; Azad Kashmir: Neelum Valley.

Remarks: It was collected from different areas of the Panjab (plain areas) and Azad Kashmir (mountainous area). Collection work was carried out in Azad Kashmir during December 1996 and February 1997, where it occurred in low quantity and in free floating state. In specimens collected from different areas of the Punjab especially those growing during summer 1996, the cell size was large and growth rate was also high.

M. tenuissima Lemmermann

(Forti, 1907: 108; Frémy, 1929: 11, 1933: 6; Geitler, 1932: 263; Desikachary, 1959: 154; Starmach, 1966: 70)

General characters: Cells pale blue-green, closely packed in colonies of 16, 32, 48 up to 100 cells, sub-spherical, 1.0-3.3 μm broad (Fig. 7d).

Geographical distribution: India: Benaras (Rao, 1937), Berhampur (Rao, 1938b), and Delhi (Rao, 1940); Pakistan.

Local distribution: Lahore: from rice fields in Ghulam Colony (chungi); Azad Kashmir: stagnant pond of Neelum Valley.

Remarks: Collections have been made during July and December 1997. In Azad Kashmir it was collected in free floating state during winter season, where it occurred in large sized colonies and individual cells were also large as compared to those collected in summer from Lahore producing water bloom.

Microcystis Kützing

Cells spherical or elongated, many in spherical, ellipsoidal or irregularly overlapping or net-like colony, free swimming, often with attached daughter colonies; cells in homogenous, colourless, often diffuent mucilage, individual envelope absent; cells mostly very densely arranged, cell-division in all directions, generally transverse in elongate cells; gas-vacuoles often present; nannocytes sometimes present. Following species have been collected, which may be distinguished as follows:

1. Cells more than 7 µm broad *M. robusta*
Cells less than 7 µm broad 2
2. Cells with gas vacuoles 3
Cells without gas vacuoles *M. pulverea*
3. Margins of colonial mucilage thick *M. viridis*
Margins of colonial mucilage diffuent 4
4. Colonies many times longer than broad *M. pseudofilamentosa*
Colonies not many times longer than broad 5
5. Colony clathrate *M. aeruginosa*
Colony not clathrate *M. flosaquae*

M. aeruginosa Kützing

(Crow, 1923a: 61; Frémy, 1929: 18, 1933: 10; Desikachary, 1959: 93; Vasishta, 1960: 582; Starmach, 1966: 78; Gupta, 1972: 483; Nizamuddin & Gerloff, 1982: 138)

General characters: Colony when young spherical or irregular, when old clathrate, mucilage hyaline; cells 5-7 µm in diameter spherical with gas vacuoles; planktonic in pond on water surface (Fig 7e).

Geographical distribution: Myanmar: Kolodyne valley in Arracan (Martens, 1871, Theobald, 1883), Rangoon (Ghose, 1926, 1927a); Malaya: Kuala Lumpur (Biswas, 1929); India: Calcutta (Biswas, 1926), Benaras (Bharadwaja, 1935), Hyderabad; Sri Lanka: Colombo Lake (Lemmermann, 1907), Balawewa tank (Crow, 1923a,b); Pakistan: Lahore (Ghose, 1919, 1924; Randhawa, 1936).

Local distribution: Lahore: Mahmood Booti, Shahinabad, Narang Mundi.

Remarks: It was collected from three different places during summer 1997 and 1998 in association with different algal genera like *Oscillatoria*, *Anabaina* etc. Slight morphological changes were found due to different ecological conditions. The massive growth of this species was found in rice fields of Narang Mandi.

M. flosaquae (Wittrock) Kirchner

(Forti, 1907: 86; Tilden, 1910: 35; Crow, 1923a: 61; Frémy, 1929: 19; Geitler, 1932: 138; Desikachary, 1959: 94; Masud-ul-Hasan, 1980: 77)

General characters: Colonies roughly spherical, somewhat elongate, not clathrate, with indistinct colonial mucilage; cells 4-7 µm in diameter, spherical with gas vacuoles, planktonic in lakes, tanks and ponds, often as a water bloom (Fig. 7f).

Geographical distribution: Myanmar (Skuja, 1949); India: Mumbai (Gonzalves & Joshi, 1946), Calcutta (Banerji, 1936; Biswas, 1942), Madras (Frémy, 1942; Ganapathi, 1940); Sri Lanka: (Crow, 1923a,b); Pakistan.

Local distribution: Lahore: Awan Village; Sheikhpura District: near Coat Noor Shah Village.

Remarks: The collections were made during March and September 1996 in free floating state as well as in water bloom composition. The specimens collected in March were in free floating state with large cell size and in low quantity. Those obtained in September were in water bloom condition, with small cell size and in massive quantity.

M. pseudofilamentosa Crow

(Crow, 1923a: 64; Geitler, 1932: 138; Desikachary, 1959: 94)

General characters: Colonies of varying size and shape, rounded colonies small in size and elongated colonies large in size, broken through or reticulate, widened or narrow at places, margins of colonial mucilage indistinct; cells 5-7 µm in diameter with gas vacuoles, cells compactly arranged (Fig. 8a).

Geographical distribution: India: Calcutta (Banerji, 1936), Madras; Sri Lanka: Anuradhapura (Crow, 1923a,b); Pakistan.

Local distribution: Lahore: Mahmood Booti.

Remarks: It was collected during October 1999 which occurred in bloom composition in massive quantity.

M. pulverea (Wood) Forte

(Forti, 1907: 92; Tilden, 1910: 35; Crow, 1923a: 66; Geitler, 1932: 143; Desikachary, 1959: 96)

General characters: Colonies rounded to ellipsoidal, often many together, limits of colonial mucilage distinct; cells spherical or ellipsoidal, closely arranged; 2-4 µm broad, blue-green, without gas vacuoles (Fig. 8b).

Geographical distribution: Myanmar: Travancore (Parukutty, 1940), Rangoon (Skuja, 1949); Sri Lanka: Colombo, Dambella (Crow, 1923a,b); Pakistan.

Local distribution: Sialkot District: Head Marala; Lahore.

Remarks: It is being reported for the first time from Pakistan. The specimens were collected during the months of July and September 1999. It occurred in massive quantity and in planktonic state.

M. robusta (Clark) Nygaard

(Geitler, 1932: 135; Desikachary, 1959: 85)

General characters: Colonies round, later irregularly elongate and clathrate; sheath distinct, later gelatinising; cells 6-11 µm diameter, spherical, without vacuoles (Fig. 8c).

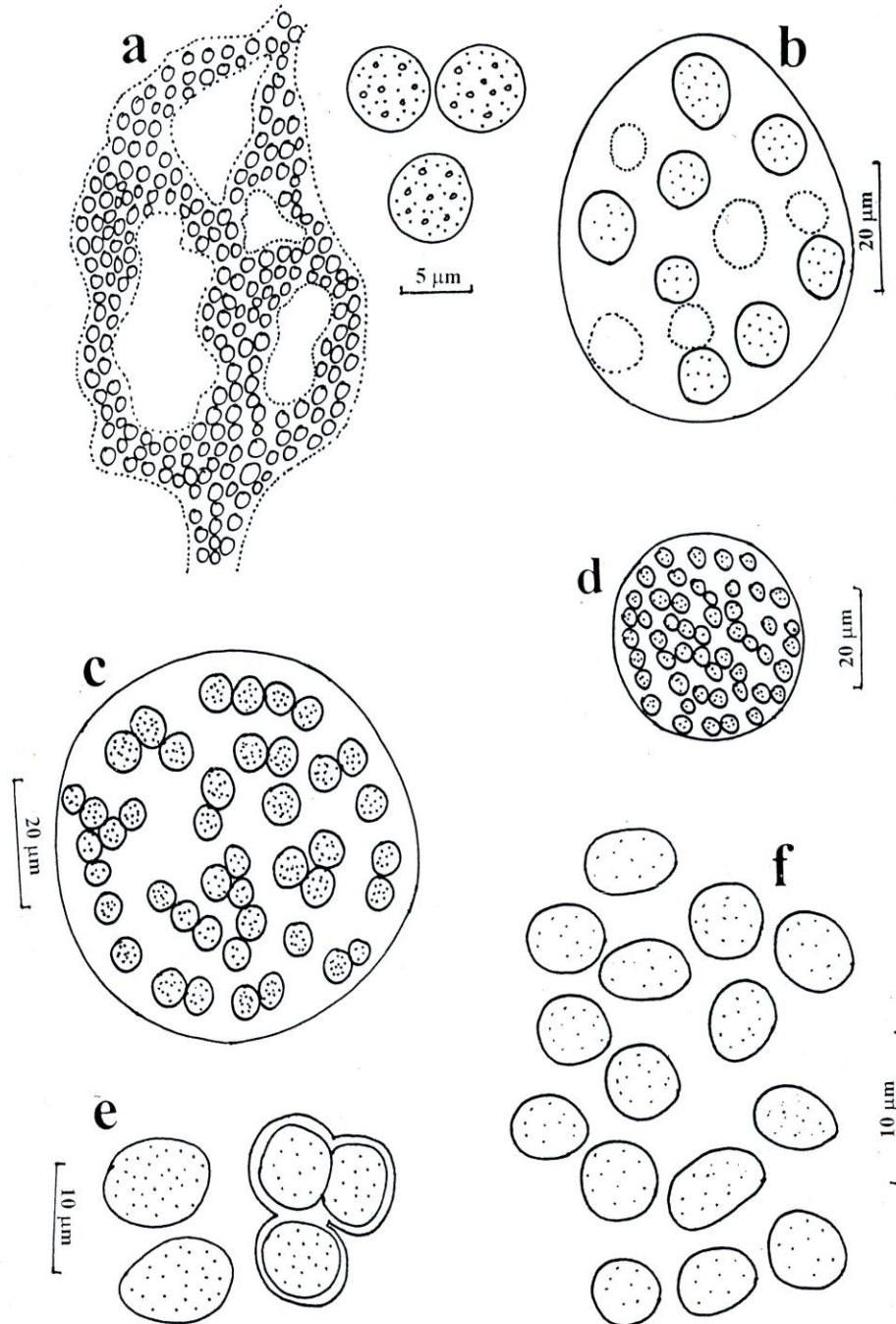


Fig. 8. a. *Microcystis pseudofilamentosa*, b. *M. pulverea*, c. *M. robusta*, d. *M. viridis*; e. *Synechococcus aeruginosus*, f. *S. cedrorum*.

Geographical distribution: India: Calcutta (Biswas, 1927; Banerji, 1936), Madras (Ganapathi, 1940), Malayan lakes (Nygaard, 1926); Pakistan.

Local distribution: Lahore: Mureedkey and Narang Mandi rice fields; Kasur District: Village Raja Jung.

Remarks: Collections were made during August and December 1999. Specimens collected during August (rainy season) were in massive quantity as well as in reproductive state, and those obtained during December were in free floating, vegetative state and in low quantity.

M. viridis (A. Braun) Lemmermann

(Forti, 1907: 90; Lemmermann, 1910: 74; Crow, 1923a: 65; Frémy, 1929: 15, 1933: 10; Geitler, 1932: 135; Desikachary, 1959: 87; Starmach, 1966: 83)

General characters: Colonies spherical, surrounded by mucilaginous sheath, margin of colonial mucilage definite and highly refractive; cells 2-3 µm in diameter, spherical, with gas vacuoles (Fig. 8d).

Geographical distribution: Myanmar: Rangoon (Skuja, 1949); India: Calcutta (Banerji, 1936); Sri Lanka: Tank Nuwarawewa at Anuradhapura (Crow, 1923a,b); Pakistan.

Local distribution: Sheikhupura District: bank of the canal near Satarwala.

Remarks: It was collected during March 1997 from canal in free floating state.

Synechococcus Nägeli

Cells oblong, cylindrical or ellipsoidal, erect, seldom slightly bent with rounded apices, single or in colonies of 2, rarely in fours; mucilage envelope absent or a very thin and narrow one present; division transverse. The following three species were collected, which may be distinguished as follows:

1. Cells more than 5 µm broad *S. aeruginosus*
Cells less than 5 µm broad 2
2. Cells cylindrical *S. elongatus*
Cells ellipsoidal *S. cedrorum*

S. aeruginosus Nägeli

(Forti, 1907: 27; Geitler, 1932: 274; Desikachary, 1959: 143; Starmach, 1966: 58)

General characters: Cells cylindrical, 5.5-6.0 µm broad, 9-11 µm long, single rarely in group, blue-green in colour (Fig. 8e).

Geographical distribution: Myanmar: Thyttonk and Hpet-wan-Choung (Theobald, 1883); Pakistan.

Local distribution: Lahore: Burki Road.

Remarks: It has been reported for the first time from Pakistan. It occurred in soil binding habitat during September 1997.

S. cedrorum Sauvageau

(Forti, 1907: 26; Geitler, 1932: 273; Desikachary, 1959: 144)

General characters: Cells cylindrical, elongate, ellipsoidal, single or two together, 2-6.8 μm broad and 4-10 μm long; content homogenous and light blue-green in colour (Fig. 8f).

Geographical distribution: India: Travancore (Parukutty, 1940); Pakistan.

Local distribution: Sheikhpura District: near Ali Wala; Lahore: Burki Road.

Remarks: It was recorded for the first time from Pakistan. The collection was made during September 1997 from rice fields, where it occurred in massive growth and free floating condition.

S. elongatus Nägeli

(Forti, 1907: 27; Geitler, 1932: 273; Desikachary, 1959: 143; Starmach, 1966: 56).

General characters: Cells cylindrical, 2 μm broad and 4.5 μm long, content homogenous and light blue-green in colour (Fig. 9a).

Geographical distribution: India: Travancore (Parukutty, 1940); Pakistan.

Local distribution: Sheikhpura District: near Ali Wala.

Remarks: It was recorded for the first time from Pakistan. The collection was made during September 1997 from rice fields, where it occurred in free floating and massive quantity.

Synechocystis Sauvageau

Cells spherical, single or two together after division, or rarely in colonies of a few cells, without distinguishable mucilage envelope. The following two species could be collected, which may be distinguished as follows:

1. Cells less than 4 μm in diameter *S. pevalekii*
Cells more than 4 μm in diameter *S. aquatilis*

S. aquatilis Sauvageau

(Forti, 1907: 26; Geitler, 1932: 270; Desikachary, 1959: 144;
Zaib-un-Nisa *et al.*, 2000: 62)

General characters: Thallus green and amorphous; cells spherical; mostly single, 3.5-6.0 μm broad, blue-green, sheath absent (Fig. 9b).

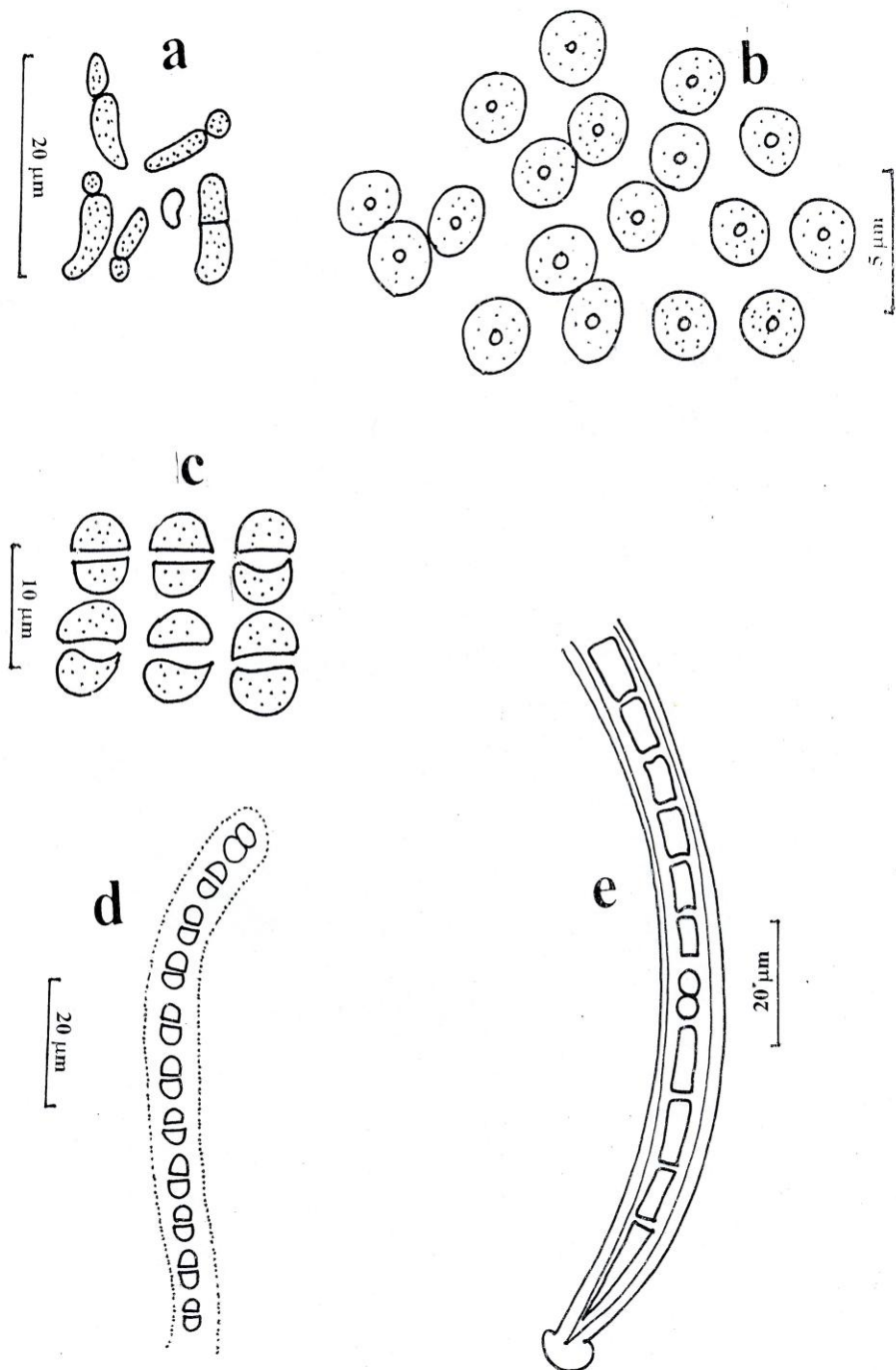


Fig. 9. a. *Synechococcus elongatus*; b. *Synechocystis aquatilis*, c. *S. pevalekii*; d. *Johannesbaptistia pellucida*; e. *Stichosiphon sansibaricus*.

Geographical distribution: India: Benaras (Rao, 1937), Delhi (Rao, 1940); Pakistan.

Local distribution: Lahore: Punjab University's old campus, road side ponds along Burki Road.

Remarks: The collection was made during August and September 1998. It was found on moist soil as well as in free floating state in water.

S. pevalekii Ercegovic
(Geitler, 1932: 269; Desikachary, 1959: 145; Starmach, 1966: 55;
Zaib-un-Nisa *et al.*, 2000: 62)

General characters: Thallus indefinite among other algae; cells spherical, after division hemispherical, 2.5-3.5 µm broad, single or two together, contents blue-green, homogenous (Fig. 9c).

Geographical distribution: India: Beira Lake, Nuwarawewa Tank, Gregory Lake (Holsinger, 1955), Madras; Pakistan.

Local distribution: Lahore: Shahgoharabad.

Remarks: The specimens were collected in summer 1998. It occurred in soil binding habitat in large quantity.

Family Entophysalidaceae

Thallus generally attached, in some cases free floating; cells arranged in erect, radial rows, rarely in irregular rows or groups or without the formation of a typical filament; sometimes with a prominent one-sided development of a sheath forming a mucilaginous filamentous stalk with a cell or groups of cells at the apex; cells spherical or ellipsoidal seldom cylindrical, often in a homogenous mucilage with or without individual sheath; sheath narrow or broad; nannocytes known; spores also present. It included only the following genus:

Johannesbaptistia J. de Toni

Thallus microscopic, linear, elongated, cylindrical, straight, or curved; cells discoid, arranged in a single series, in narrow, cylindrical, hyaline mucilage; division in one plane, transverse to the thallus; propagation by fragmentation into pieces of one to few cells. Only the following species could be collected:

J. pellucida (Dickie) Taylor *et* Drouet
(Drouet & Daily, 1956: 85; Desikachary, 1959: 165; Zaib-un-Nisa *et al.*, 2000: 63)

General characters: Filaments blue-green, thallus compact, slightly curved 6-8 µm broad; trichome blue-green, discoid or spherical, rounded at the apices; filament arranged in series in hyaline mucilage; cells 3-5 µm broad and 1.0-6.4 µm long; mucilage homogenous, sheath firm or diffuent, contents homogenous (Fig. 9d).

Geographical distribution: India: Madras (Iyengar & Desikachary, 1946); Pakistan.

Local distribution: Lahore: Shahgoharabad; Sheikhpura District: stagnant pond near Aliwala.

Remarks: The collections were made from two different localities during 1997. At one place it was found growing at the surface of moist soil having single cells and from other locality it was obtained from stagnant water ponds in groups, alongwith *Oedogonium* spp.

Order Chamaesiphonales

Usually occurring as lithophytes or epiphytes with the thallus showing polarity; reproduction by endospores or exospores.

Family Dermocarpaceae

Unicellular, attached, with a differentiation of base and apex; the entire contents dividing to form endospores or occasionally a basal sterile part first cut off and the rest forming endospores; vegetative division absent; sporangia more or less spherical, ellipsoidal, club-shaped, pyriform or cylindrical with a basal mucilaginous stalk or disc; wall thick, often lamellated, seldom thin or gelatinous; endospores 2 to many, mostly 8-32, formed by division in all directions, seldom in only one direction, liberated by a rupture at the apex of the sporangium, seldom by a total dissolution of the wall. It included only the following genus:

Stichosiphon Geitler

Sporangia when young ellipsoid or pyriform, attached by means of a mucilaginous foot, sometimes growing elongate, then the contents dividing transversely to form a row of endospores; fully grown sporangia elongate, cylindrical or club-shaped with 4-12 or sometimes more endospores lying in a row, liberated by the gelatinisation of the apex of sporangial wall. Only the following species could be collected:

S. sansibaricus (Hieronymus) Drouet *et* Daily
(Drouet & Daily, 1956: 125; Desikachary, 1959: 176)

General characters: Thallus blue-green, olivaceous, solitary, curved, cylindrical, 6-8 µm broad; contents dividing into a series of cylindrical endospores, uniseriate; sheath hyaline, stalk at the base (Fig. 9e).

Geographical distribution: Myanmar: Mandalay, Rangoon (Skuja, 1949); India: Benaras (Rao, 1936), Andhra State (Rao, 1938a), Berhampur in Orissa State (Rao, 1938b), Shembaganur in Madurai (Frémy, 1942), Allahabad (Drouet & Daily, 1956); Pakistan: Lahore (Ghose, 1924; Randhawa, 1936).

Local distribution: Sheikhpura District: Baugharwala.

Remarks: The specimens were collected from stagnant water pool, being attached (epiphytic) on *Oedogonium* spp., during August 1997. It occurred in large quantity in association with green algae.

Discussion

Of a total of 46 species of blue-green algae identified, only one belonged to the order Chamaesiphonales, while rest of them were included under Chroococcales. In the later order, only one species was included under the family Entophysalidaceae, while 44 species belonged to Chroococcaceae, which appeared to dominate the Chroocophyceean flora. Similar observations have been made at the neighbouring areas (Rao, 1940; Frémy, 1942; Drouet & Daily, 1946; Gupta & Kumar, 1968; Thajuddin & Subramanian, 1992). Among the identified 11 genera, *Johannesbaptistia* and *Stichosiphon* were represented by single species, *Aphanothece*, *Gloeothece* and *Synechocystis* by two, *Synechococcus* by three and *Aphanocapsa* by four species. *Microcystis* included six and *Chroococcus* and *Merismopedia* eight species, while *Gloeocapsa* exhibited the largest diversity with 10 species. Greatest species diversity was exhibited in the collections made from Lahore and its neighbouring areas. Several species have been described for the first time from the freshwater environment or the moist soil of Pakistan.

The blue-green algae were found to grow mainly in the summer season but some of them also occurred in winter. Their growth is largely controlled by the seasonal changes of temperature due to which morphological differences were observed within the same species. Those growing in summer were having larger cells and showed massive growth and high rate of reproduction than those surviving in winter. The latter showed smaller cells, stunted growth and poor rate of reproduction. Habitat of rice field, high temperature and heavy rain-fall were most suitable conditions for their growth. Those growing in rapidly flowing water and water-fall were having smaller cell size than those inhabiting stagnant water. Probably it was due to the stress of water movement. Similarly, the algal flora found in the fountain water was different from stagnant water around it, because the fountain water is more oxygenated. Those growing in bloom condition were also having small cells, probably due to over growth and heavy competition with one another. Naturally, ecological conditions play an important role in their growth (Lobban & Harrison, 1997).

The growth of Chroocophyceae was most abundant in the aquatic environment especially in planktonic state than in the terrestrial environment in benthic condition as observed previously (Naz *et al.*, 2003). Some of them occurred as soil binding algae forming a complete layer over a large eroded area, which is later on replaced by higher perennials, thus forming an initial stage in succession. Algae stabilize the surface layer, bind the soil into a non-erosible layer, by resisting the surface of rain-fall, improve infiltration of water, decrease the run-off, produce humus after death and thus increase the soil fertility (Dawes, 1998).

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