

TAXONOMIC STUDY OF ANABAINA BORY (NOSTOCOPHYCEAE, CYANOPHYTA) FROM NORTHERN AREAS OF PAKISTAN

SABEEN NAZ, MASUD-UL-HASAN¹ AND MUSTAFA SHAMEEL

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

Abstract

Specimens of the blue-green alga, *Anabaina* Bory de Saint-Vincent (= *Anabaena* Bory) have been collected from various freshwater habitats in the districts of Gujranwala, Jauharabad, Khushab, Lahore, Sheikhupura, Sialkot from the province of the Punjab and from Kalam (Swat) in the province of NWFP at different seasons of the year. They were taxonomically investigated and found to belong to 16 species.

Introduction

Anabaina Bory de Saint-Vincent is a commonly occurring blue-green alga (Nostocaceae, Nostocales, Nostocophyceae; *fide* Shameel, 2001). This generic name is usually spelled *Anabaena*, an orthographic variant used by Bornet & Flahault (1888) and conserved against *Anabaena* A. Jussieu 1824 in the Euphorbiaceae (Silva *et al.*, 1996). A few studies of this genus have been made from Pakistan, from taxonomic point of view (Farzana & Nizamuddin, 1979; Masud-ul-Hasan, 1980; Masud-ul-Hasan & Yunus, 1987) as well as from the viewpoint of its occurrence (Shameel & Butt, 1984; Jahangir *et al.*, 2000; Leghari *et al.*, 2000; Mahar *et al.*, 2000), but no detailed taxonomic investigation was made so far. A huge collection of blue-green algae was made from various districts of the Punjab, certain areas of NWFP and Azad Kashmir (Naz *et al.*, 2003) and detailed taxonomic study was carried out (Naz *et al.*, 2004). The present work is a continuation of that study, which describes the taxonomy of *Anabaina* growing in the northern areas of Pakistan.

Materials and Methods

Collections were made from various freshwater habitats of the districts of Gujranwala, Jauharabad, Khushab, Lahore, Sheikhupura, Sialkot in the province of the Punjab and from Kalam (Swat) in the province of NWFP during 1996-2000. The methods used for the collection and studies of the materials were the same as described previously (Naz *et al.*, 2004). The specimens were taxonomically determined with the help of standard literature (Rabenhorst, 1932; Desikachary, 1959; Watanabe, 1971).

Results and Discussion

On the basis of their morphological and cytological characteristics the following 16 species of *Anabaina* have been identified, which were found to grow in the northern regions of Pakistan.

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

Anabaina Bory de Saint-Vincent
(Bornet & Flahault, 1888: 224; Desikachary, 1959: 391)

Trichomes uniformly broad throughout, apices alone somewhat attenuated; sheath absent or more or less diffuent, forming a free, torn or floccose or soft mucilaginous thallus; heterocysts generally intercalary; cells quadrate, cylindrical or barrel shaped; spores occurring singly or in chains, formed contiguous to the heterocysts or away from it; akinetes spherical, cylindrical or ellipsoidal. Species may be distinguished as follows:

1. Akinetes spherical 2
Akinetes not spherical 3
2. Akinetes bordering upon heterocysts 4
Akinetes away from heterocysts 5
3. Akinetes cylindrical 6
Akinetes ellipsoidal 7
4. Trichomes straight *A. sphaerica* (13)
Trichomes spirally coiled *A. spiroides* (16)
5. Akinetes occasionally next to terminal heterocyst *A. oryzae* (11)
Akinetes always remote from heterocysts 8
6. Akinetes bordering upon heterocysts *A. oscillarioides* (12)
Akinetes away from heterocysts *A. laxa* (8)
7. Akinetes contiguous to heterocysts 9
Akinetes remote from heterocysts 10
8. Trichomes 2-5 μ m broad 11
Trichomes 5-6 μ m broad *A. fertilissima* (5)
9. Many trichomes in a common sheath 12
Single trichome in a sheath 13
10. Cells as long as broad 14
Cells longer than broad *A. variabilis* (15)
11. Trichomes mostly contorted, moniliform *A. anomala* (2)
Trichomes mostly curved, not coiled *A. inaequalis* (6)
12. Akinetes occurring singly *A. ambigua* (1)
Akinetes in series of 4 or 5 *A. vaginicola* (14)
13. Akinetes on one side of heterocysts *A. aphanizomenoides* (3)
Akinetes on both sides of heterocysts 15
14. Trichomes regularly coiled *A. ballyganglii* (4)
Trichomes not so coiled *A. naviculoides* (9)
15. Cells quadrate or cylindrical *A. orientalis* (10)
Cells always barrel shaped *A. iyengarii* (7)

1. *A. ambigua* C. B. Rao
(Rao, 1937a: 101; Desikachary, 1959: 400)

General characters: Many trichomes enclosed in a common mucilagenous sheath which is usually firm, hyaline, with smooth outline; trichomes straight or bent, usually slightly tapering at the ends, with end cell having rounded apices, usually 250-360 μ m long, sometimes longer; cells barrel shaped with deep construction at the joints, septa

indistinct, 4.9-8.0 μm broad, 3.5-6.0 μm long; cell contents deep blue-green and granular; heterocysts usually ellipsoidal, sometimes cylindrical with rounded ends, 8.0-10.9 μm broad and 10-16.2 μm long; akinetes ellipsoidal, contiguous to heterocysts, occurring singly (Fig. 1).

Geographical distribution: India: Benaras (Rao, 1937a), Bihar, Allahabad (Mitra, 1951); Pakistan.

Local distribution: Lahore: fountain of Shalimar Garden; Sheikhupura District: Sattarwala Village.

Remarks: This species has been recorded for the first time from Pakistan. Specimens were collected from two different localities: from rice fields in summer and from water falls during winter 1998. In the latter season it occurred in limited quantity, having small size due to rapidly flowing water, low light intensity, low pH and low temperature of water as compared to those collected from rice field during August 1998.

2. *A. anomala* Fritsch

(Fritsch, 1949: 146; Desikachary, 1959: 398; Patel & Mahajan, 1984: 88)

General characters: Thallus thin, gelatinous, blue-green; trichomes densely or irregularly aggregated, more or less contorted, moniliform; apical cell rounded or sub conical, apex obtuse; cells generally 2-5 μm broad, as long as broad, spherical or barrel shaped, sometime up to 1½ times as long as broad; heterocysts rare, commonly single, intercalary, spherical, 3-8 μm broad, 2-15 μm long; exospores thick and endospores thin; akinetes spherical, away from heterocysts (Fig. 2).

Geographical distribution: India: Faridpur, Bengal (Fritsch, 1949); Pakistan.

Local distribution: Lahore: rice fields between Batapur and Wagha, Race Course at Bhaseen Village, Muridkey and Narang Mandi; Jauharabad.

Remarks: It was collected from different places during summer and winter seasons of 1997. Morphological differences were seen within species due to different localities and seasonal temperature. Species was found in vegetative condition as well as in low quantity during winter season, because green algae were present in dominant condition. It occurred during summer in massive quantity due to favourable temperature and optimum light intensity.

3. *A. aphanizomenoides* Forti

(Rabenhorst, 1932: 875; Desikachary, 1959: 405)

General characters: Single trichome in a sheath, straight or variously bent; cells disc to barrel shaped or spherical, 3.5-5.5 μm broad, 2.0-5.5 μm long; heterocysts subspherical to oblong or quadrate, 4.2-6.2 μm broad, terminal or intercalary; akinetes ellipsoidal, contiguous to heterocysts, on its one side only (Fig 3).

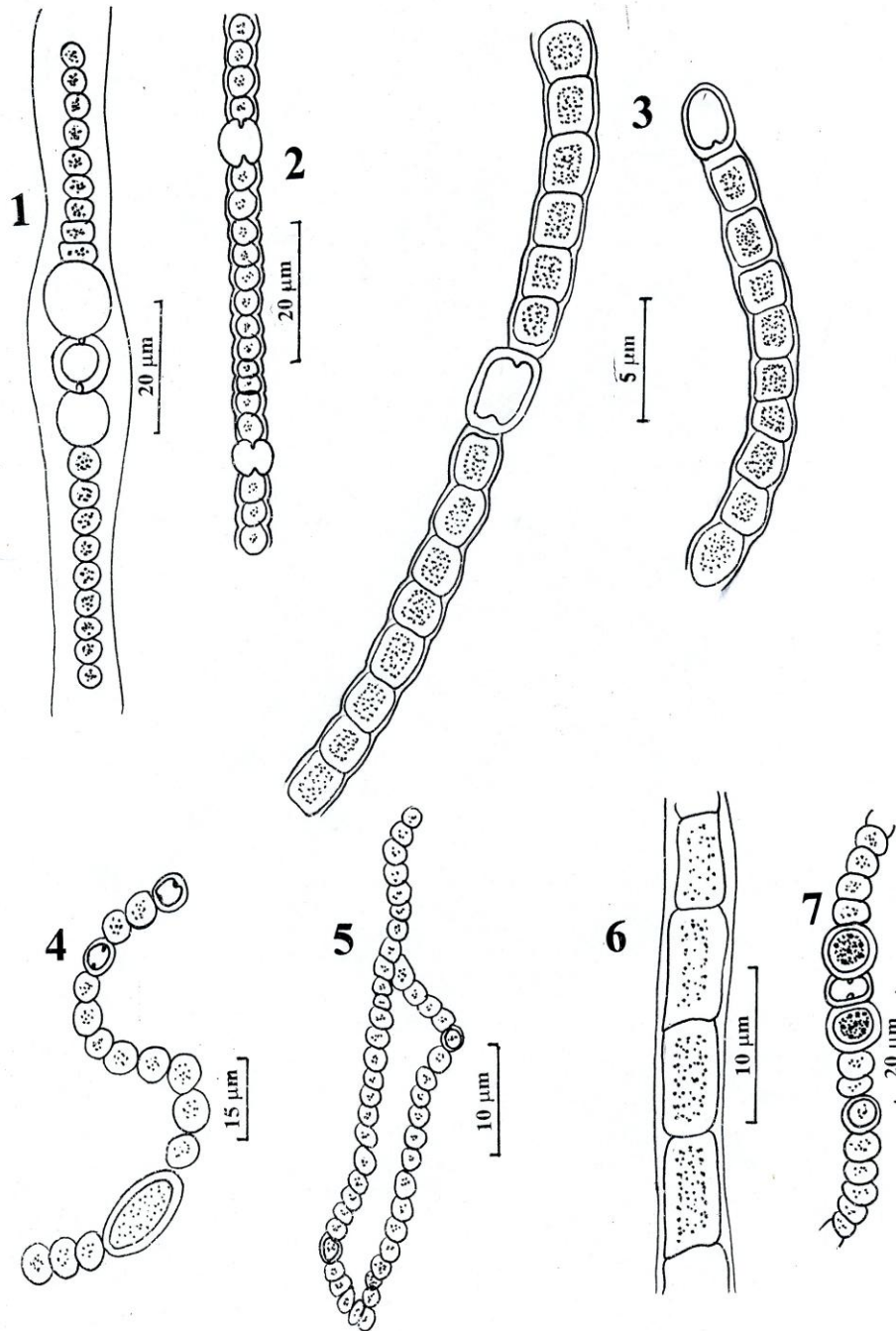


Fig. 1-7. *Anabaina* species: 1. *A. ambigua*, 2. *A. anomala*, 3. *A. aphanozomenoides*, 4. *A. ballyganglii*, 5. *A. fertilissima*, 6. *A. inaequalis*, 7. *A. iyengarii*.

Geographical distribution: India, Pakistan.

Local distribution: Lahore.

Remarks: Collection was made from road-side ponds during the month of September 1999, where it occurred in free floating state. During rainy season many temporary ponds were created, where it was found in large quantity because high temperature and water pH were suitable for its growth.

4. *A. ballyganglii* Banerji

(Banerji, 1938: 98; Desikachary, 1959: 409; Farzana & Nizamuddin, 1979: 249)

General characters: Trichomes fragile (breaking into pieces in a day of two), circinate or spirally coiled in 1-8 spirals, never straight, forming a thick green stratum on the surface of pond or settled on sand or mud on the bank of the pond; cells spherical, 5-8 µm broad, as long as broad, blue-green or brownish green; cell contents granular, gas vacuoles present; heterocysts present, spherical and of the same size as cells, with homogenous blue-green contents, occur singly, 5-8 µm in diameter or smaller; spores only rarely seen, occur singly, ellipsoidal, 10-12 x 18-20 µm, remote from heterocysts, wall thick smooth, contents homogenous, blue-green; akinetes ellipsoidal, remote from heterocysts (Fig. 4).

Geographical distribution: India: Calcutta (Banerji, 1938); Pakistan

Local distribution: Lahore: Mahmood Booti.

Remarks: Collection was made in the month of October 1998. It occurred in massive quantity in planktonic form mixed with *Microcystis aeruginosa*. It was raining heavily during this month and many stagnant ponds were formed which provided favourable condition for its growth.

5. *A. fertilissima* C. B. Rao

(Rao, 1937b: 363; Desikachary, 1959: 398; Farzana & Nizamuddin, 1979: 249; Patel & Mahajan, 1984: 90)

General characters: Trichomes single, straight or bent, blue-green with almost rounded end cells, up to 350 µm long, 5.0-5.6 µm broad; cells almost barrel-shaped, 8.8 µm long; heterocysts almost spherical, 3.2-8.8 µm long, 4.8-8.4 µm broad; spores occur singly, not adjoining the wall of heterocyst, almost spherical, with a smooth hyaline outer wall, 3.2-8.8 µm long, 4.8-8.0 µm broad; akinetes spherical, away from heterocysts (Fig. 5).

Geographical distribution: U.S.A., India: Assam (Parukutty, 1939), Bihar, Mumbai (Gonzalves & Joshi, 1946); Pakistan.

Local distribution: Lahore: rice fields near Cross Mor, fountain at Minar-e-Pakistan; Gujranwala District: Nandipur; Jauharabad; N.W.F.P: Kalam (Swat).

Remarks: Collections were made in different months of the year from various habitats. A large growth rate was observed during August 1996 due to high light intensity and temperature. During February and April 1997 temperature remained moderate, therefore less growth appeared. Higher growth was found in stagnant water as compared to other localities, such as running water, fountain water etc.

6. *A. inaequalis* (Kützinger) Bornet *et* Flahault

(Bornet & Flahault, 1888: 231; Forti, 1907: 446; Tilden, 1910: 191; Frémy, 1929: 365; Rabenhorst, 1932: 896; Watanabe, 1971: 274; Masud-ul-Hasan, 1980: 71)

General characters: Trichomes blue green, straight or mostly curved (not spirally coiled), free floating; sheath thin; cells cylindrical, constricted at septa, 3-4 µm broad, 6-8 µm long; heterocysts usually on both ends of trichomes, rarely at only one end, cylindrically elliptic, 6-7 µm broad, 9-11 µm long; spores found only in some trichomes mostly lacking, when present next to heterocyst, cylindrical, slightly thick walled, 4-5 µm broad, 8-11 µm long, wall yellowish brown; akinetes spherical, away from heterocysts (Fig. 6).

Geographical distribution: Pakistan.

Local distribution: Lahore.

Remarks: The collection work was carried out during winter season of 1998, specimens were found mixed with *Cylindrospermum* spp. It occurred in vegetative state and in low quantity. It appears that winter season is not favourable for its growth, during this season green algae were found in large quantity.

7. *A. iyengarii* Bharadwaja

(Bharadwaja, 1935: 105; Desikachary, 1959: 406; Vasishta, 1960: 585; Watanabe 1971: 265; Patel & Mahajan, 1984: 90)

General characters: Thallus thin, free floating, pale blue-green; single trichome in a sheath, straight or irregularly curved, 3-5 µm broad; end cells conical with rounded apices; other cells barrel-shaped, as long as broad, or slightly shorter or longer than broad, 3-5 µm long; heterocysts spherical, 4-6 µm broad, 6-8 µm long; spores ellipsoidal, with rounded ends, 7-9 µm broad, 10-12 µm long, with a smooth, hyaline outer wall; akinetes ellipsoidal, contiguous to heterocysts, on both sides (Fig. 7).

Geographical distribution: India: Benaras (Bharadwaja, 1935), Allahabad (Gupta, 1956); Pakistan.

Local distribution: Lahore: Muridke, Narang Mundi, Haadiara Village, Thokar Nayaz Baig; Sheikhupura District: Moranwala Village; Jauharabad

Remarks: Collections were made from various areas of the Punjab and some morphological changes were observed within different specimens. Those collected from rice fields, occurred in large quantity. Rice is cultivated in summer season and blue-green

algae usually prefer intense sunlight and high temperature for their growth, and such conditions are available in the rice fields, that is why cyanophytes occur in abundance. It also occurred in winter season of 1999 but in a limited quantity due to unfavourable conditions.

8. *A. laxa* (Rabenhorst) A. Braun *in* Bornet *et* Flahault
(Bornet & Flahault, 1888: 120; Tilden, 1910: 192; Desikachary, 1959: 413;
Starmach, 1966: 512; Patel & Mahajan, 1984: 90)

General characters: Thallus free floating, blue-green; trichomes 3.0-3.5 μm broad, straight, embedded in mucilagenous sheath; cells spherical or barrel shaped, 3.0-3.5 μm broad; spores barrel shaped when present, 7.0 μm in diameter; akinetes cylindrical, away from heterocysts (Fig. 8).

Geographical distribution: Myanmar: Rangoon (Ghose, 1926); India: Allahabad (Gupta, 1956); Sri Lanka (Crow, 1923); Pakistan: Lahore.

Local distribution: Lahore: Awan Village.

Remarks: The collection was made during rainy season of summer 2000. It was found in massive amount in water bloom. The temperature, locality and pH of water were favourable for its growth.

9. *A. naviculoides* Fritsch
(Fritsch, 1949: 138; Desikachary, 1959: 410)

General characters: Thallus thin, gelatinous, blue-green; trichomes elongate, slightly coiled, moniliform, apices acuminate; cells 3.5-4.0 μm broad, as long as broad; apical cell obtuse, conical; heterocysts rarely present; spores usually present, 5.0-5.25 μm in diameter; akinetes ellipsoidal, remote from heterocysts (Fig. 9).

Geographical distribution: India: Faridpur, Bengal (Fritsch, 1949); Pakistan.

Local distribution: Lahore: Mahmood Booti.

Remarks: This species occurred in summer season of 2000, during which temperature, light intensity and water quality were suitable for its growth.

10. *A. orientalis* Dixit
(Dixit, 1936: 101; Desikachary, 1959: 405; Patel & Mahajan, 1984: 90)

General characters: Single trichome in a sheath, straight or curved, 3-4 μm broad; cells quadrate or cylindrical, rarely slightly barrel-shaped; end cell conical with rounded apex; heterocysts single, intercalary, 4.9-6.6 μm ; akinetes ellipsoidal, contiguous to heterocysts, on their both sides (Fig. 10).

Geographical distribution: India: Vajreshwari (Desikachary, 1959).

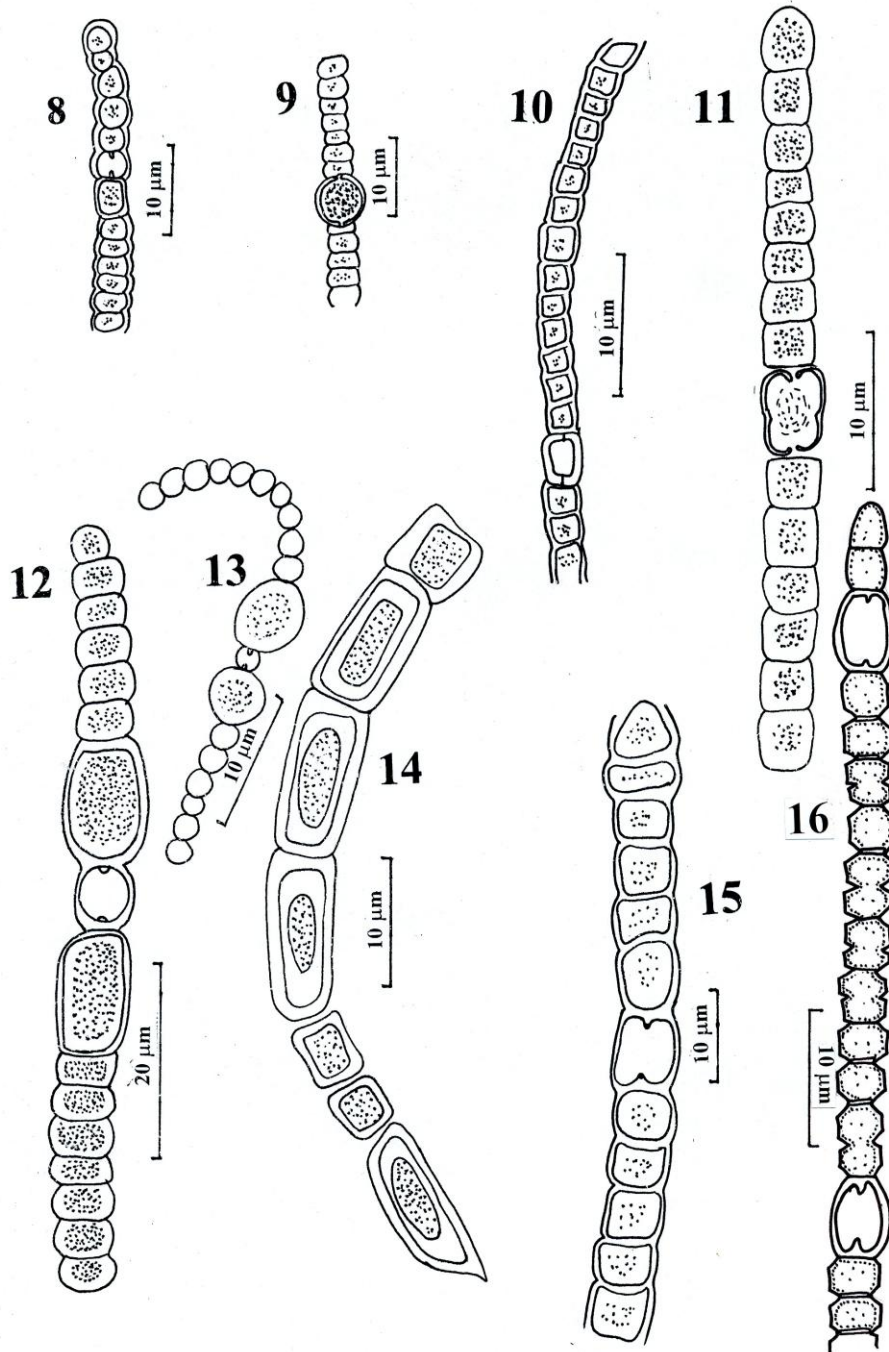


Fig. 8-15. *Anabaina* species: 8. *A. laxa*, 9. *A. naviculoides*, 10. *A. orientalis*, 11. *A. oryzae*, 12. *A. oscillarioides*, 13. *A. sphaerica*, 14. *A. vaginicola*, 15. *A. variabilis*, 16. *A. spiroides*.

Local distribution: Lahore: rice fields near Chungi Village.

Remarks: The specimens were collected in bloom composition during the month of August 1999, clinging to the surface of water, in large quantity. The pH of water was about 8 *i.e.* slightly alkaline. It appeared that high temperature, rice field locality and rainy season were the most suitable conditions for their growth.

11. *A. oryzae* Fritsch

(Fritsch, 1949: 135; Desikachary, 1959: 396; Gupta & Kumar, 1968: 487; Patel & Mahajan, 1984: 91)

General characters: Thallus soft, green, gelatinous, membranous; trichomes short, densely aggregated; cells 2.5-3.0 µm broad, barrel shaped; heterocysts intercalary, sometimes terminal, broader than vegetative cells, 3.5-4.0 µm broad, 5.5-6.0 µm long; akinetes spherical, away from intercalary heterocysts, occasionally next to terminal heterocyst (Fig. 11).

Geographical distribution: India: Faridpur, Bengal (Fritsch, 1949); Pakistan.

Local distribution: Sheikhupura District: Muridke, Narang Mandi.

Remarks: Although specimens were collected from two different areas of Lahore at the end of summer season (September 1998), no morphological differences were found among them. Both the specimens were collected from rice field localities, when temperature was high, pH of water nearly 8.0 *i.e.* slightly alkaline and water remained stagnant. Such conditions were favourable, therefore, it occurred abundantly and cells were found in vegetative as well as in reproductive state.

12. *A. oscillarioides* Bory ex Bornet *et* Flahault

(Bornet & Flahault, 1888: 233; Forti, 1907: 451; Tilden, 1910: 192; Desikachary, 1959: 417; Vasishta 1960: 585; Starmach 1966: 479; Masud-ul-Hasan, 1980: 72; Nizamuddin & Gerloff, 1982: 139)

General characters: Thallus gelatinous with thin sheath, dark green, attached on submerged grass leaves; trichomes almost straight or irregularly curved, 3-6 µm broad; cells rounded as long as broad, septa slightly constricted, vegetative cell 4-6 µm long, 3-5 µm broad; fluorescent gas vacuoles; heterocysts spherical or oval, 5-8 µm broad, 6-14 µm long; spores long, cylindrical, single or 2-3, on both sides of the heterocysts, 5-11 µm broad and 6-24 µm long; akinetes cylindrical, yellowish brown, bordering upon heterocysts (Fig. 12).

Geographical distribution: Myanmar: Rangoon (Skuja, 1949); India: Sadiyar (Carter, 1926), Mumbai (Gonzalves & Joshi 1946); Pakistan.

Local distribution: Lahore: on submerged dead grass leaves; Sheikhupura District: Sheikhwanala; Gujranwala District: Chak Hida, Nandipur; Sialkot District: Head Marala.

Remarks: Specimens have been collected from different areas of the Punjab during the months of February 1997 and December 1998. They were obtained from stagnant water ponds where they occurred in epiphytic and free floating state. The water was slightly alkaline (pH 8), its turbidity varied at different localities. During winter season it occurred as epiphyte on green algae in low quantity, and in summer season it was found in planktonic state in large quantity. High temperature appeared favourable for its growth.

13. *A. sphaerica* Bornet *et* Flahault

(Bornet & Flahault, 1888: 228; Forti, 1907: 440; Tilden, 1910: 188; Frémy, 1929: 361; Rabenhorst, 1932: 878; Desikachary, 1959: 393; Starmach, 1966: 482; Gupta, 1972: 484; Patel & Mahajan, 1984: 91; Masud-ul-Hasan & Yunus, 1989: 104)

General characters: Thallus floccose, blue-green; trichomes moniliform, straight, arranged parallel with a distinct mucilaginous sheath; cells spherical or short, barrel-shaped; end cell rounded; heterocysts sub-spherical, 6-10 µm broad, 10-12 µm long; spores on one or on both sides of heterocysts, sub-spherical to oval, 10-13 µm long, 8-11 µm broad, one to few together; akinetes spherical, yellowish brown, bordering upon heterocysts (Fig. 13).

Geographical distribution: India: Mumbai: Calcutta (Banerji, 1938), Madras (Ganapathi, 1940); Pakistan.

Local distribution: Lahore: Mahmood Booti, Bhaseen Village, Chungi.

Remarks: The collection work was carried out in summer season of 1997 from a village of border area of Lahore. During this season border areas show rich growth of blue-green algae as compared to other areas of Lahore because it is totally a cultivated area. This species occurred in water bloom in stagnant water pools.

14. *A. vaginicola* Fritsch *et* Rich

(Desikachary, 1959: 401; Vasishta, 1960: 585; Patel & Mahajan, 1984: 92)

General characters: Many trichomes occurring in a common mucilaginous sheath, more or less parallel; colony with sheath 17-21 µm broad, attached to other plants; trichomes 4.0-4.5 µm broad; cells subquadrate to elongate, cylindrical, apical cell acuminate, conical; heterocysts cylindrical, 4-5 µm broad, 6-10 µm long; spores short, cylindrical or oblong, attached with the heterocysts, 6.5-10 µm broad, 12.0-13.5 µm long; akinetes ellipsoidal, contiguous to heterocysts, occurring in a series of 4 or 5 (Fig. 14).

Geographical distribution: Africa, India, Pakistan.

Local distribution: Lahore: Badshahi Mosque.

Remarks: The collection was made during the month of March 2000 from fountain of historical Mosque. As fountain water was more oxygenated, its algal flora was different from the stagnant water and the present specimens showed a special tendency to be

restricted to the gently flowing water. Its occurred in limited quantity in free floating state, rarely in reproductive condition.

15. *A. variabilis* Kützing *ex* Born *et* Flahault

(Bornet & Flahault, 1888: 226; Forti, 1907: 437; Frémy, 1929: 360; Rabenhorst, 1932: 876; Desikachary, 1959: 410; Starmach, 1966: 480; Watanabe, 1971: 265; Gupta, 1972: 485; Farzana & Nizamuddin, 1979: 248; Patel & Mahajan, 1984: 92)

General characters: Thallus gelatinous, green; trichomes without any sheath, flexuous, 4.5-6.0 μm broad, end conical; cells barrel shaped, gas vacuoles absent, 3.0-5.5 μm broad, longer than broad; heterocysts sub-spherical, 4-5 μm broad; akinetes ellipsoidal, remote from heterocysts (Fig. 15).

Geographical distribution: Myanmar: Rangoon (Ghose, 1926); India: Simla, Thana, Calcutta (Banerji, 1938); Pakistan.

Local distribution: Lahore: Punjab University old campus.

Remarks: Patches of soil with algal growth have been collected from Punjab University in the month of September 1998. This species occurred on wet soil surface, as it was collected in soil binding habitat in massive quantity.

16. *A. spiroides* Klebahn

(Desikachary 1959: 396)

General characters: Thallus free floating, blue green; trichome 4-8 μm broad, straight; cells cylindrical constricted in middle, 4-8 long and 2-6 μm broad; heterocyst 6-9 μm in diameter; immature spore spherical away from heterocyst, 9.0 μm in length and 6.5 μm in breadth (Fig. 16).

Geographical distribution: Myanmar: Rangoon (Ghose 1926, 1927a); Sri Lanka: Colombo (Lemmermann 1907); Pakistan: Lahore (Ghose 1924).

Local distribution: Lahore: Dial Village, Mahmood Booti; Jauharabad.

Remarks: Collections were made during spring and summer season. The specimens were collected from different localities therefore slight morphological differences were found within species.

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