

BIODIVERSITY OF *OSCILLATORIA* (NOSTOCOPHYCEAE, CYANOPHYTA) FROM NORTHERN AREAS OF PAKISTAN

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Abstract

Specimens of the blue-green algal genus *Oscillatoria* Vaucher have been collected from various freshwater habitats in the districts of Gujranwala, Jauharabad, Jhang, Kasur Pasrur, Sargodha, Sialkot, Lahore and Sheikhupura, from the province of the Punjab and from Utrod River and Kalam (Swat) in the province of N.W.F.P. as well as from Muzaffarabad, Neelum Valley and Chenari in Azad Kashmir during different seasons of 1996-2000. They were taxonomically investigated and found to belong to 45 species.

Introduction

Oscillatoria Vaucher is a commonly occurring blue-green alga (Oscillatoriaceae, Nostocales, Nostocophyceae; *vide* Shameel, 2001). A few studies of this genus have been made from Pakistan from taxonomic point of view (Farzana & Nizamuddin, 1979; Masud-ul-Hasan, 1980; Farid *et al.*, 1981; Masud-ul-Hasan & Zeb-un-Nisa, 1986; Masud-ul-Hasan & Batool, 1987; Masud-ul-Hasan & Younus, 1989) as well as from the viewpoint of its occurrence (Shameel & Butt, 1984; Jahangir *et al.*, 2000, 2001; Leghari *et al.*, 2000, 2001, 2002; Mahar *et al.*, 2000), but no detailed taxonomic investigation has been 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.*, 2004a,b,c). The present work is a continuation of this study which describes the biodiversity of *Oscillatoria* growing in the northern areas of Pakistan.

Materials and Methods

Collections were made from various freshwater habitats of the districts of Attock, Gujranwala, Jhang, Jhelum, Khushab, Lahore, Sargodha, Sheikhupura and Sialkot in the province of the Punjab and from Kalam (Swat) in the province of N.W.F.P. and from Chenari, Muzaffarabad and Neelum Valley in Azad Kashmir during 1996-2000. The methods used for the collection and studies of the materials were the same as described previously (Naz *et al.*, 2004a). The specimens were taxonomically determined with the help of standard literature (Gomont, 1892; Forti, 1907; Tilden, 1910; Frémy, 1929; Geitler, 1932; Desikachary, 1959; Starmach, 1966).

Results and Discussion

On the basis of their morphological and cytological characteristics the following 45 species of *Oscillatoria* which were found to grow in the northern regions of Pakistan have been identified.

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Oscillatoria Vaucher

Trichomes single or forming a flat or spongy, free-swimming thallus; sheath absent, rarely present with a more or less very delicate configuration; filaments motile mostly by a creeping movement causing rotation on the longitudinal axis; end of trichomes distinctly marked, pointed, bent like a sickle or coiled more or less like a screw; hormogones formed by the division of the trichome. It is represented by the following species in the northern areas of Pakistan and Azad Kashmir, which may be distinguished as follows:

1. Cells smaller in length than breadth 2
Cells longer in length than breadth 3
2. Trichomes constricted 4
Trichomes unconstricted 5
3. Trichomes yellow coloured 6
Trichomes blue-green 7
4. Trichomes straight, capitate 8
Trichomes spirally coiled, not capitate 9
5. Trichomes straight 10
Trichomes bent or spirally coiled 11
6. Trichomes attenuated *O. laetevirens* (24)
Trichomes not attenuated 12
7. Apices of trichomes spirally coiled 13
Apices not so coiled, only bent 14
8. Trichomes constricted *O. sancta* (38)
Trichomes unconstricted *O. vizagapatensis* (44)
9. Trichomes slightly attenuated *O. peronata* (31)
Trichomes not attenuated *O. ornata* (30)
10. End cell with a thickened outer wall *O. limosa* (25)
End cell without a thickened outer wall 15
11. End cell rounded *O. curviceps* (14)
End cell slightly capitate *O. princeps* (32)
12. Trichomes less than 3 µm broad *O. subtilissima* (40)
Trichomes more than 3 µm broad 16
13. Trichomes capitate 17
Trichomes not capitate 18
14. Apices distinctly attenuated 19
Apices not distinctly attenuated 20
15. Trichomes up to 4 µm broad *O. subbrevis* (39)
Trichomes more than 4 µm broad *O. obscura* (28)
16. Cells up to 2 µm long *O. chilkinsis* (10)
Cells more than 2 µm long *O. chlorina* (11)
17. Cells as long as broad *O. martini* (27)
Cells longer than broad *O. willei* (45)
18. Cells not constricted at cross-walls *O. terebriformis* (42)
Cells constricted at cross-walls *O. boryana* (7)
19. End cells capitate *O. amoena* (2)
End cells not capitate 21

20. Trichomes constricted at cross-walls	22
Trichomes not so constricted	23
21. End cells conical, attenuated	24
End cells rounded	<i>O. tanganylikae</i> (41)
22. Trichomes more than 8 µm broad	<i>O. chalybea</i> (9)
Trichomes less than 5 µm broad	25
23. Trichomes less than 5 µm broad	<i>O. jasorvensis</i> (22)
Trichomes more than 5 µm broad	26
24. Cells ½ as long as broad	<i>O. okeni</i> (29)
Cells longer	27
25. Trichomes up to 3 µm broad	<i>O. foreau</i> (18)
Trichomes more than 3 µm broad	<i>O. proteus</i> (33)
26. Trichomes constricted at cross-walls	28
Trichomes not constricted at cross-walls	29
27. Cells more or less as long as broad	30
Cells 3-5 times as long as broad	<i>O. claricentrosa</i> (12)
28. Trichomes 6-10 µm broad	31
Trichomes less than 6 µm broad	32
29. Trichomes up to 1 µm broad	<i>O. angusta</i> (6)
Trichomes broader	33
30. Trichomes more than 5 µm broad	<i>O. cortiana</i> (13)
Trichomes less than 5 µm broad	<i>O. formosa</i> (19)
31. Trichomes up to 10 µm broad	<i>O. tenuis</i> (43)
Trichomes up to 6 µm broad	<i>O. raoi</i> (36)
32. Trichomes 1 µm broad	<i>O. fremyi</i> (17)
Trichomes broader	34
33. Trichomes up to 2 µm broad	35
Trichomes broader	36
34. Trichomes up to 2 µm broad	37
Trichomes broader	<i>O. hamelii</i> (21)
35. Cells 2-4 times as long as broader	<i>O. quadripunctulata</i> (35)
Cells some what longer than broad	<i>O. pseudogeminata</i> (34)
36. Trichomes 6-8 µm long	<i>O. anguina</i> (5)
Trichomes lesser	38
37. Cells 1-2 times as long as broad	<i>O. amphigranulata</i> (4)
Cells more than 2 times as long as broad	<i>O. limnetica</i> (26)
38. Trichomes up to 3 µm broad	39
Trichomes broader	40
39. Cells more than 4 µm long	<i>O. amphibia</i> (3)
Cells less than 4 µm long	<i>O. geitleriana</i> (20)
40. End cells capitate	<i>O. rubescence</i> (37)
End cells not capitate	41
41. Trichomes up to 3 µm broad	<i>O. earlei</i> (15)
Trichomes up to 10 µm broad	42

42. Cells up to $\frac{1}{2}$ as long as broad *O. brevis* (8)
 Cells longer 43
 43. Cross-walls unconstricted 44
 Cross-walls distinctly constricted *O. lacustris* (23)
 44. Cells 6-7 μm broad *O. fracta* (16)
 Cells less than 6 μm broad *O. acuta* (1)

1. *O. acuta* Bruhl et Biswas ex Geitler

(Bruhl & Biswas, 1923: 3; Geitler, 1932: 978; Desikachary, 1959: 240;
 Masud-ul-Hasan & Zeb-un-Nisa, 1986: 234)

General characters: Trichomes either solitary or a number of them parallel to one other, aggregated into bundles of moderate size, hardly brittle, not constricted at the cross walls, 3.7-7.0 μm broad, 32-93 μm long; filaments usually quite straight, narrow, non-capitate, non calyptrate, apex often abruptly bent aside; cells 1.8-6.0 μm long, 1.6-6.0 μm broad; cell contents blue-green, finely granular (Fig. 1).

Geographical distribution: India: Calcutta (Biswas, 1926, 1934); Pakistan.

Localities: Lahore: Abu-Bakkar Colony, Nasir Bagh; Gujranwala District: Chendali; Sialkot District: Sambrall; Pasrur: Mutaike-Raypootan Village; Azad Kashmir: Muzaffarabad;

Remarks: Collections were made in different months of the years 1977 and 1998, such as January, March, April, September and December. Its abundant growth occurred during September as compared to other months of the year because in this month temperature and light intensity remain favourable for its growth and it also rains heavily. When seasonal temperature decreases gradually, its growth rate declines.

2. *O. amoena* (Kützinger) Gomont

(Forti, 1907: 175; Tilden, 1910: 77; Frémy, 1929: 220; Geitler, 1932: 969;
 Desikachary, 1959: 230; Starmach, 1966: 353; Gupta, 1975: 29; Islam, 1976: 70)

General characters: Thallus more or less blue-green; trichomes straight, slightly curved, constricted at the septa, end gradually attenuated; cells 2.0-4.2 μm long, 5-14 μm wide, dull blue-green; septa plane; end cell capitate, broadly conical with calyptra; necridia present (Fig. 2).

Geographical distribution: Myanmar, India, Pakistan.

Localities: Sialkot: Saeedianwali Village; Lahore: Bhani Village.

Remarks: It has been reported for the first time from Pakistan. It was collected from two different habitats in the months of May and July 2000: moist soil surface and in free floating condition. From moist soil habitat it was found mixed with *O. sancta*. In stagnant water it was found in free floating state forming scum. It appears that it changes its nature of occurrence depending upon habitat conditions.

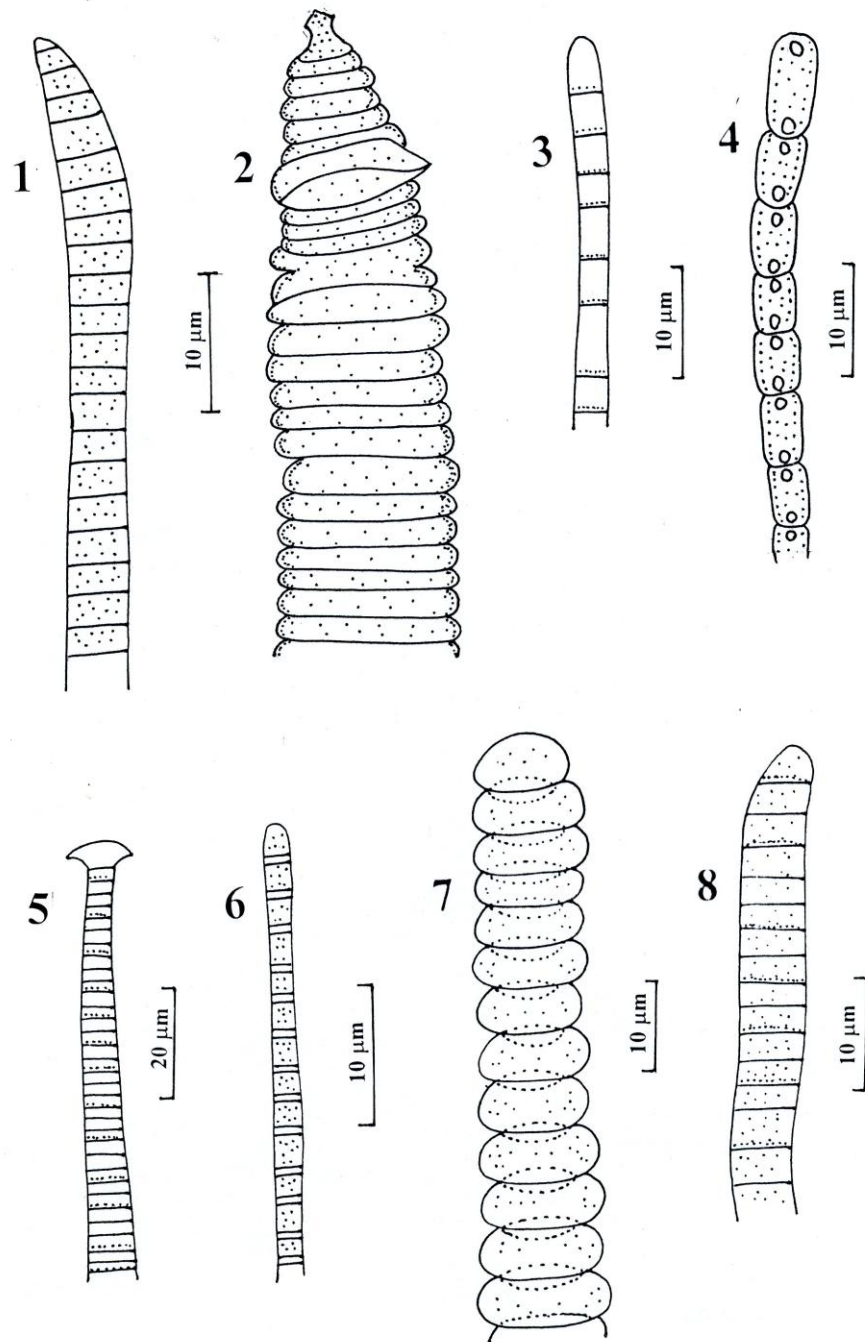


Fig. 1. *Oscillatoria acuta*, 2. *O. amoena*, 3. *O. amphibia*, 4. *O. amphigranulata*, 5. *O. anguina*, 6. *O. angusta*, 7. *O. boryana*, 8. *O. brevis*.

3. *O. amphibia* Agardh ex Gomont

(Gomont, 1892: 221; Forti, 1907: 169; Tilden, 1910: 73; Frémy, 1929: 213; Feldmann, 1937: 164; Desikachary, 1959: 229; Starmach, 1966: 344)

General characters: Thallus blue-green; trichomes straight, apices not attenuated, not capitate, cross-walls unstricted; cells 1-2 μm broad, blue-green; cells 2-3 times longer than broad, 3.0-4.5 μm long; end cells rounded, calyptra absent (Fig. 3).

Geographical distribution: India: Berhampur, Burdwan, Faridpur, Jessore (Bruhl & Biswas, 1922), Calcutta salt lakes (Biswas, 1926), Assam (Bruhl & Biswas, 1926); Pakistan.

Locality: Lahore: Punjab University's old campus.

Remarks: Its collection was made from the wet soil and its damp surface during summer season of 1999, where it occurred in massive quantity as a soil binding alga, forming scum over soil surface.

4. *O. amphigranulata* van Goor

(Geitler, 1932: 964; Desikachary, 1959: 226; Starmach, 1966: 342)

General characters: Trichomes straight, distinctly constricted at the cross-walls, 2.0-2.8 μm broad; ends not attenuated, not capitate; cells 4.2-7.0 μm long, as broad or up to twice as long, with two gas vacuoles at the septa, pale blue-green; end cells rounded, calyptra absent (Fig. 4).

Geographical distribution: India, Pakistan.

Locality: Kasur District: Galwedah.

Remarks: It was collected from stagnant ponds in free floating state during December 1999. Due to low temperature it occurred in low quantity, while green algae were present in dominant condition.

5. *O. anguina* (Bory) Gomont

(Forti, 1907: 159; Tilden, 1910: 68; Geitler, 1932: 948; Desikachary, 1959: 210; Starmach, 1966: 327; Nizamuddin & Gerloff, 1982: 140)

General characters: Thallus dark blue-green; trichomes straight and distinctly attenuated, having convex and expanded cap or calyptra at the end; cells 2.3-4.3 μm long, 5.6-7.6 μm broad; sheath thin; contents granulated (Fig. 5).

Geographical distribution: India: Andhra (Rao, 1938a), Orissa (Rao, 1937b), Bihar (Rao, 1939); Sri Lanka (Lemmermann, 1907); Pakistan.

Locality: Lahore: Chungi Village.

Remarks: It was collected from stagnant water pool during April 1998. It occurred in free floating state being mixed with *Spirogyra* spp. Due to low temperature and other unfavourable conditions it was found in low quantity.

6. *O. angusta* Koppe

(Koppe, 1924: 641; Geitler, 1932: 965; Desikachary, 1959: 227; Starmach, 1966: 347)

General characters: Trichomes colourless, 1.2-1.4 μm broad, not constricted at the cross-walls, straight; end cells rounded; cells 3.5-4.0 μm long, without gas vacuoles (Fig. 6).

Geographical distribution: India: Madras; Pakistan.

Locality: Sialkot District: Bhopalwal Village.

Remarks: Collection was carried out from temporary puddles during summer season of 1997. It occurred in free floating state and mixed with *Oscillatoria frémyi*. Due to favourable environmental conditions it was found in large quantity, both in vegetative condition as well as in reproductive state.

7. *O. boryana* Bory ex Gomont

(Gomont, 1892: 234; Forti, 1907: 188; Tilden, 1910: 83; Frémy, 1929: 227; Geitler, 1932: 954; Desikachary, 1959: 218; Starmach, 1966: 349)

General characters: Trichomes straight, constricted at cross walls, 8-10 μm broad, sometimes slightly granulated at the cross-walls; cells 4-6 μm long; end cells rounded, not capitate (Fig. 7).

Geographical distribution: India: Orissa (Rao, 1938b), Travancore (Parukutty, 1940), Patna (Rao, 1939), Delhi (Rao, 1940); Pakistan.

Locality: Gujranwala: Menhas.

Remarks: Collection was made from roadside pond during winter season of 1998. Due to low temperature it occurred only in vegetative state. Probably it survives in winter season with low growth rate.

8. *O. brevis* (Kützing) Gomont

(Gomont, 1892: 229; Forti, 1907: 180; Tilden, 1910: 79; Setchell, 1926: 62; Frémy, 1929: 223; 1934: 125; Geitler, 1932: 977; Desikachary, 1959: 241; Starmach, 1966: 327)

General characters: Thallus very thin, expanded; trichomes blue-green, not constricted at the septa; ends briefly attenuated, more or less bent, not capitate, 4.5-5.0 μm broad; cells shorter than broad, 2.0-3.5 μm long, not granulated at septa; end cells obtuse, conical; calyptra absent (Fig. 8).

Geographical distribution: India: Calcutta (Martens, 1871), Bihar (Rao, 1939), New Delhi (Rao, 1940); Pakistan: Lahore (Masud-ul-Hasan, 1980).

Locality: Lahore: Nasir Bagh.

Remarks: It was collected from wet soil surface during October 1997. During this month temperature started decreasing, it was found in low quantity along with other soil binding algae.

9. *O. chalybea* (Mertens) Gomont

(Gomont, 1892: 232; Tilden, 1910: 82; Forti, 1907: 185; Frémy, 1929: 224; 1934: 127; Geitler, 1932: 956; Desikachary, 1959: 218; Starmach, 1966: 339)

General characters: Thallus dark blue-green; trichomes nearly straight, constricted at cross walls, attenuated at the apex and bent, living trichomes show forward and rotatory movement, 3-12 µm broad; cells, 1/2 - 1/3 times as long as broad or nearly quadrate (4.5-5.5 µm broad), 2-8 µm long, septa not granulated; end cells obtuse, not capitate, without calyptra; gas vacuoles present (Fig. 9).

Geographical distribution: India: Calcutta (Biswas, 1926), Andhra (Rao, 1938a), Orissa (Rao, 1938b); Sri Lanka: Malaya (Biswas, 1929); Pakistan.

Localities: Lahore: Punjab University's old campus, Narang Mandi, fountain of Shahi Qila, Mahmood Booti; Sialkot District: Sambrial.

Remarks: Its collection was done from different localities in the months of January, September and October 1997 and 1998. It occurred in different habitats such as stagnant water, fountain water and moist soil surface. Its massive growth was observed in rice fields as compared to other localities due to suitable ecological conditions. It appears that this species has a special tendency to survive in different habitats in different seasons with different growth rates.

10. *O. chilensis* Biswas

(Biswas, 1932: 186; Desikachary, 1959: 215)

General characters: Thallus yellowish blue-green; trichomes 2.5-5.0 µm in diameter, undulated, somewhat curved, slightly constricted at cross walls; apex of trichomes shortly tapering; apical cell narrow, obtusely rounded, not pointed, capitate; cells shorter than broad, 2-4 µm long, 4-6 µm broad; transverse septa not granulated; cell contents homogenous, pale blue-green (Fig. 10).

Geographical distribution: Sweden; India: Orissa (Biswas, 1932); Pakistan.

Localities: Lahore: Wagha Border area, Government College University; Sialkot: Bhopalwall Village; N.W.F.P. Utrod River (Swat Valley).

Remarks: It has been reported for the first time from Pakistan. The specimens were collected from soil surface and stagnant water ponds during spring, summer and winter seasons of 1997 and 1998. Its massive growth was observed during summer as compared to other seasons of the year. The pH in most of the cases was near about 8.0.

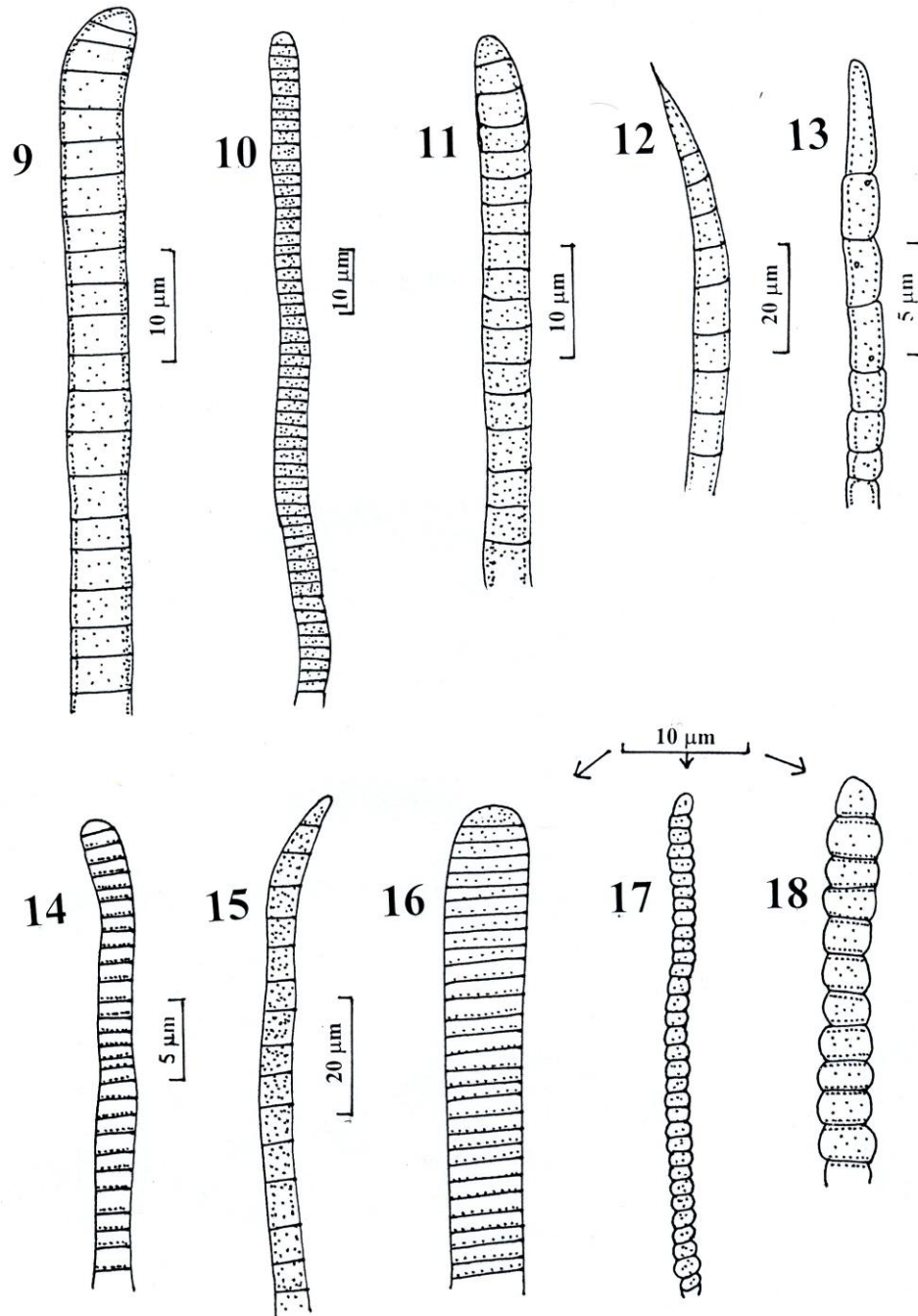


Fig. 9. *Oscillatoria chalybea*, 10. *O. chilensis*, 11. *O. chlorina*, 12. *O. claricentrosa*, 13. *O. cortiana*, 14. *O. curviceps*, 15. *O. earlei*, 16. *O. fracta*, 17. *O. fremyi*, 18. *O. foreaui*.

11. *O. chlorina* Kützting ex Gomont

(Gomont, 1892: 223; Forti, 1907: 172; Tilden, 1910: 75; Frémy, 1929: 215; Geitler, 1932: 951; Desikachary, 1959: 215; Vasishta, 1960: 588; Starmach, 1966: 332; Faridi *et al.*, 1981: 156)

General characters: Thallus very thin, yellowish green, unconstricted at cross walls; trichomes slightly curved or straight, 4-8 µm broad; gas vacuoles absent; cells shorter than broad, or quadrate, 5-7 µm broad, 2.0-8.5 µm long; cross walls not granulated; calyptra absent (Fig. 11).

Geographical distribution: Myanmar: Kamayut (Skuja 1949); India: Assam (Bruhl & Biswas, 1926), Allahabad (Gupta, 1956); Sri Lanka (Crow, 1923); Pakistan.

Localities: Lahore: Nasir Bagh, Mahmood Booti, Bund Road; Sialkot: Punawal; N.W.F.P. Kalam (Swat).

Remarks: The collection work was done from river side ponds, wet soil surface, stagnant water pools and rice fields during 1998 and 1999. Only once it could be collected during winter but was usually found in summer season. It occurred in free floating, epiphytic and epiedaphic conditions, showing its variability of habitat preference. Its massive growth was observed in stagnant water of rice fields. Some morphological changes were found among inhabitants of different localities.

12. *O. claricentrosa* Gardner

(Gardner, 1927: 37; Geitler, 1932: 971; Desikachary, 1959: 231; Vasishta, 1960: 588)

General characters: Trichomes nearly straight, 1.6-2.6 µm broad, curved near the end, 2.6-4.5 µm broad, sharply attenuated at the ends, pointed, slightly constricted at the joints; cells 1.6-3.6 µm broad, 5.6-7.6 µm long (Fig.12).

Geographical distribution: India: Madhubani, Bihar (Rao, 1939); Pakistan.

Localities: Lahore: Dial Village, Salamatpura Village.

Remarks: It was found to grow in the months of April and September 1997. During April it showed low growth as compared to September. In September temperature remains high and it rains, that is why it occurred in massive quantity producing bloom.

13. *O. cortiana* Meneghini ex Gomont

(Desikachary, 1959: 233; Tilden, 1910: 81; Masud-ul-Hasan & Yunus, 1989: 103)

General characters: Thallus dull blue-green, trichomes straight, slightly constricted at the joints, 3.5-5.5 µm broad, gradually tapering at the ends, sometimes bent, not capitate, blue-green; cells as long as broad or longer or shorter than broad, 3-8 µm long; septa not granulated; end cell obtuse, without calyptra; gas vacuoles observed (Fig. 13).

Geographical distribution: India; Bengal; Pakistan.

Locality: Lahore: Paddy fields along Defence Road.

Remarks: It was collected during late summer season of 1996 from rice field area. It was obtained in planktonic state. The rice field area appeared most suitable for its growth because environmental condition of this place are most suitable.

14. *O. curviceps* Agardh ex Gomont
(Gomont, 1892: 213; Forti, 1907: 157; Tilden, 1910: 67; Geitler, 1932: 947;
Frémy, 1933: 117; Desikachary, 1959: 209; Starmach, 1966: 323;
Gupta, 1972: 484; Faridi *et al.*, 1981: 156)

General characters: Thallus light or dark blue-green; trichomes more or less wavy, slightly attenuated, not constricted at the cross walls, 10-17 μm broad; cells 1/3-1/6 as long as broad, 8.9-10.9 μm broad, 2-5 μm long; cross wall sometimes granulated; end cells flat, rounded, not capitate (Fig. 14).

Geographical distribution: India: Orissa; Sri Lanka: Gregory and Colombo lakes (Lemmermann, 1907); Pakistan.

Localities: Lahore: Mari Village, Mahmood Booti, Muridkey and Narang Mandi; Kasur District: Galwedah; Azad Kashmir: Nelum Valley;

Remarks: It was collected both in summer and winter seasons of 1999 occurring mostly in stagnant water, once it was also found in bloom condition in free floating state. It occurred in temporary ponds formed by the collection of tannery water and rain water. Its maximum growth was observed in rice fields and medium growth in ponds. Its minimum growth was found in the month of February. It appears that high temperature is favourable for its growth.

15. *O. earlei* Gardner
(Gardner, 1927: 36; Geitler, 1932: 976; Desikachary, 1959: 238)

General characters: Trichomes short, straight, bent at the ends, tip attenuated, 2-4 μm broad, not constricted at the cross walls; cells quadrate, 6-8 μm long; ends prominently pointed (Fig. 15).

Geographical distribution: India: Madras; Pakistan.

Locality: Sheikhupura District: Ali Wala.

Remarks: Collection has been made from stagnant water ponds during May 1997. It occurred in free floating conditions in vegetative as well as reproductive stages and also in massive quantity. The summer season appears favourable for its growth.

16. *O. fracta* Carlson
(Venkataraman, 1957: 473; Desikachary, 1959: 619)

General characters: Trichomes solitary, more or less straight, not attenuated, cross walls unconstricted; cells 6-7 μm broad, 1/3 to 1/5 as long as broad; septa dim, usually not granulated but sometimes granulated; end cells flat, rounded (Fig. 16).

Geographical distribution: India: Kanya Kumari (Venkataraman, 1957); Pakistan.

Locality: Lahore: Nasir Bagh.

Remarks: It was collected from moist soil surface during October 1996, especially where decaying organic matter was in abundance. It occurred in massive quantity.

17. *O. fremyii* J de Toni

(Lemmermann, 1910: 112; Geitler, 1932: 963; Desikachary, 1959: 225)

General characters: Trichomes single, straight; cells 1.0-1.5 µm broad, 1-1.5 µm long, constricted at cross walls; apical cell rounded, blue-green (Fig. 17).

Geographical distribution: Myanmar: Rangoon (Skuja, 1949), Keli Valley near Aravan Kadu; Pakistan.

Localities: Sialkot District: Bhopalwall Village; Lahore: fountain of Shahi Qila.

Remarks: Collection has been made from fountain water and temporary ponds during March and May 1998. It has been reported for the first time from Pakistan. It occurred in massive quantity in stagnant water as compared to fountain water. The rapidly flowing and heavily aerated fountain water was not favourable for its growth.

18. *O. foreauii* Frémy

(Frémy, 1942: 23; Desikachary, 1959: 219; Faridi *et al.*, 1981: 156)

General characters: Trichomes sparse, elongated, suberect, sub-filiform, distinctly constricted at cross walls, 3.5-4.0 µm broad; apex not capitate, not attenuated; cells 2-3 µm long, protoplast granular, septa commonly distinct, rarely inconspicuous; apical cells obtuse rounded, calyptra absent (Fig. 18).

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

Locality: Lahore: Punjab University's old campus.

Remarks: It was found in summer season of 1996 in soil binding habitat. It occurred in massive quantity.

19. *O. formosa* Bory ex Gomont

(Gomont, 1892: 230; Forti, 1907: 182; Tilden, 1910: 80; Setchell, 1926: 62; Frémy, 1929: 225; 1933: 126; Geitler, 1932: 970; Desikachary, 1959: 232; Starmach, 1966: 364)

General characters: Trichomes straight or flexuous, not tapering at the end; septa conspicuously constricted, 4-6 µm broad, apex neither capitate nor calyptrate, obtusely conical; cells almost subquadrate to quadrate, 2.0-4.0 µm long; cell contents bright blue-green, granular (Fig. 19).

Geographical distribution: Myanmar: Kyauktan, Rangoon (Skuja, 1949); India: Madras (Frémy, 1942), Cuttack (Rao, 1938b), Allahabad (Gupta, 1956); Pakistan.

Locality: Lahore: Nasir Bagh.

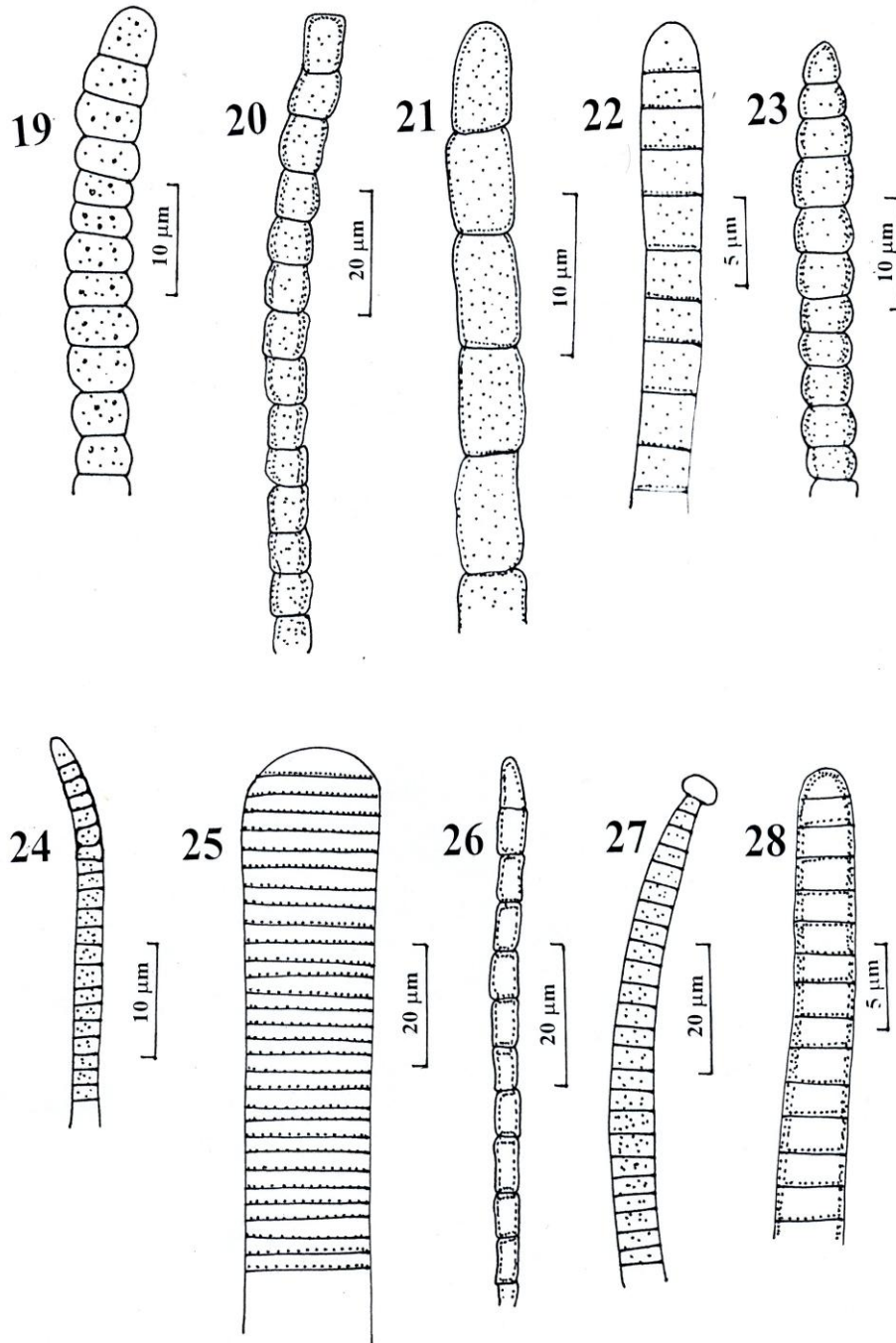


Fig. 19. *Oscillatoria formosa*, 20. *O. geitleriana*, 21. *O. hamelii*, 22. *O. jasorvensis*, 23. *O. lacustris*, 24. *O. laetevirens*, 25. *O. limosa*, 26. *O. limnetica*, 27. *O. martini*, 28. *O. obscura*.

Remarks: It was collected from moist soil surface during late summer of 1997 as soil binding alga. It exhibited massive growth at soil surface as compared to varying depths of the soil. High temperature appears to be favourable for its growth.

20. *O. geitleriana* Elenkin

(Frémy, 1929: 216; Geitler, 1932: 967; Elenkin, 1949: 1288; Desikachary, 1959: 230)

General characters: Trichomes single, long, flexible, green, 2.5-2.8 µm broad, not constricted at the cross walls; ends erect, not attenuated, sub-capitate; cells 1 ½ times longer than broad, 3.5-4.2 µm long, septa not granulated; end cells with a convex, distinctly thick membrane (Fig. 20).

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

Locality: Kasur District: Hawailyan.

Remarks: The collection work has been carried out in stagnant water ponds during winter season of 1999. This species occurred in small quantity due to unfavourable temperature conditions.

21. *O. hamelii* Frémy

(Frémy, 1929: 218; Geitler, 1932: 964; Desikachary, 1959: 225; Starmach, 1966: 347)

General characters: Trichomes single, flexible, regularly undulated, not constricted at the cross walls, 4-5 µm broad; tip rounded, not capitate; cells 2.0-2.5 µm long, not granulated at the cross walls; calyptra absent (Fig. 21).

Geographical distribution: Myanmar: Rangoon (Skuja, 1949); India: Andhra State (Rao, 1938a); Pakistan.

Locality: Sialkot District: Bhopalwall Village.

Remarks: It has been reported for the first time from Pakistan, showing massive growth in summer season of 2000. It was collected from temporary ponds with other species of *Oscillatoria* in free floating condition on the surface of water, where bottom of the pond was polluted due to some organic matter and pH was slightly high. It appears that this species may occur in polluted water in free floating state.

22. *O. jasorvensis* Vouk

(Vouk, 1920: 133; Geitler, 1932: 962; Desikachary, 1959: 221; Starmach, 1966: 332; Gupta, 1972: 483)

General characters: Thallus yellowish blue-green; trichomes not straight (slightly irregularly curved), 3-4 µm broad, not attenuated, not capitate; cells as long as broad or longer; end cell obtuse conical, without calyptra (Fig. 22).

Geographical distribution: Myanmar: Rangoon (Skuja, 1949); India: Mumbai; Pakistan.

Locality: Lahore: Shahgoharabad.

Remarks: It was collected during July 1996 in massive quantity. It occurred on moist soil surface as a soil binding alga.

23. *O. lacustris* (Klebahn) Geitler
(Geitler, 1932: 955; Desikachary, 1959: 246; Starmach, 1966: 337)

General characters: Thallus free floating; trichomes straight, distinctly constricted at cross walls, 4-5 µm broad, not tapering towards apices; cells compressed, globose, sometimes semiquadratic or little shorter than broad; cells 3.0-3.5 µm long; end cell acute, rounded (Fig. 23).

Geographical distribution: Europe, Africa, Pakistan.

Locality: Lahore: Government College University.

Remarks: The specimens were collected from soil surface during June 1996. It occurred in vegetative and reproductive stages showing high growth rate.

24. *O. laetevirens* (Crouan) Gomont
(Gomont, 1892: 226; Forti, 1907: 177; Tilden, 1910: 78; Geitler, 1932: 949;
Frémy, 1933: 126; Desikachary, 1959: 213; Starmach, 1966: 350)

General characters: Thallus thin, green; trichomes yellowish green, curved at the end, fragile, septa slightly constricted, 3-5 µm broad; apices attenuated; cells not capitate, bent, conical, without calyptra (Fig. 24).

Geographical distribution: Myanmar: Rangoon (Skuja, 1949); India: Calcutta (Biswas, 1926, 1934); Pakistan.

Locality: Lahore: Punjab University's old campus.

Remarks: The collection has been done from wet soil surface of Punjab University during the month of October 1998. It occurred in massive quantity in soil binding habitat. Such algae growing at the surface, as well as at varying depths, together with other organisms may have a profound influence on the biology of soil.

25. *O. limosa* Agardh ex Gomont
(Gomont, 1892: 210; Turner, 1892: 13; Forti, 1907: 154; Tilden, 1910: 65;
Frémy, 1929: 212, 1933: 117; Geitler, 1932: 944; Desikachary, 1959: 206;
Starmach, 1966: 326; Farzana & Nizamuddin, 1979: 252; Faridi *et al.*, 1981: 156;
Masud-ul-Hasan & Zeb-un-Nisa, 1986: 233; Masud-ul-Hasan & Batool, 1987: 347;
Masud-ul-Hasan & Yunus, 1989: 103)

General characters: Thallus dark blue-green; trichomes more or less straight, not constricted at the cross walls, 11-20 µm broad (more commonly 13-16 µm broad); septa

granulated; cells flat, rounded with a slightly thickened membrane $1/3 - 1/6$ as long as broad, $1.5-5.0\ \mu\text{m}$ long, $2.5-13.0\ \mu\text{m}$ broad (Fig. 25).

Geographical distribution: Malaysia: Kuala Lumpur, Malaya (Biswas, 1929); Myanmar: Royal Lakes, Rangoon and Tanuggyi Canal, Maymyo and Myoingam (Ghose, 1927a; Skuja, 1949); India: Central India (Turner, 1892), Hyderabad, Berhampur in Orissa (Rao, 1938b); Pakistan.

Localities: Jauharabad District; Jhang District: Trimmu Head Works; Sargodha District: Saim Nala; Kasur District: Galwedha; Lahore: Muridkey and Narang Mandi; Azad Kashmir: Neelum Valley, Chenari;

Remarks: The collection work was made in different seasons of 1998-1999 from different localities. It occurred in free floating state in stagnant water ponds, roadside puddles, rice fields etc, being associated with other algae. It was found growing in summer, winter, autumn and spring seasons. During summer it showed a massive growth in rice field locality, but minimum growth was observed in winter season. It appears that this species can survive in different seasons with different growth rates.

26. *O. limnetica* Lemmermann

(Forti, 1907; Frémy, 1929: 220, 1933: 123; Geitler, 1932: 963; Desikachary, 1959: 226; Starmach, 1966: 346; Masud-ul-Hasan & Zeb-un-Nisa, 1986: 233)

General characters: Thallus blue-green; trichomes straight or slightly bent, constricted at the cross walls, pale blue-green, $1-2\ \mu\text{m}$ broad; filaments not attenuated, not capitate; cells $1.5\ \mu\text{m}$ broad, $3-11\ \mu\text{m}$ long, usually $2\frac{1}{2} - 6$ times as long as broad (Fig. 26).

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

Localities: Lahore: Muridkey and Narang Mandi; Azad Kashmir: Chenari.

Remarks: The collections were made from two different localities during April and September 1999. It occurred in slow running water at Chenari during April in limited quantity. Other specimens were collected from rice field locality during September in large amount, showing some morphological differences. It appears that rice field is favourable for its growth as compared to the running water.

27. *O. martini* Frémy

(Frémy, 1929: 230; Geitler, 1932: 935; Desikachary, 1959: 216; Islam, 1976: 70; Masud-ul-Hasan & Zeb-un-Nisa, 1986: 232)

General characters: Trichomes single, clearly attenuated, loosely spirally coiled, slightly curved; tip capitate, not constricted at the cross walls; filaments $5-7\ \mu\text{m}$ broad, septa not granulated; cells $5-7\ \mu\text{m}$ broad, $1-5\ \mu\text{m}$ long (Fig. 27).

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

Localities: Sialkot District: Ravi Marala link, Motra; Azad Kashmir: Chenari.

Remarks: Collections were made from stagnant water pools and slow running water during January and April 1997. It was found growing in a small quantity at Chenari in slow running water in the month of January but in massive quantity at Sialkot in stagnant water in the month of April. Slight morphological differences were observed in specimens from two localities. It appeared that high temperature and stagnant water locality are favourable for its growth.

28. *O. obscura* Bruhl *et* Biswas

(Bruhl & Biswas, 1922: 6; Geitler, 1932: 945; Desikachary, 1959: 207)

General characters: Trichomes straight, blue-green, free floating, dispersed, septa distinct, not constricted at cross walls; cells 4-5 µm broad, 1.5-2.3 µm or 1/3 – 1/4 µm as long as broad; gas vacuoles present, cross walls granulated; apical cells rounded (Fig. 28).

Geographical distribution: India: Orissa (Bruhl & Biswas, 1922; Rao, 1938), Benaras (Rao 1937b), Travancore (Parukutty, 1940); Pakistan.

Localities: Pasrur: Pakarwal Village; Lahore: Government College University.

Remarks: The collection was made from roadside puddles and ponds during March and June 1999. It was found in free floating state. During June it occurred in massive quantity due to high temperature as compared to March. It appears that summer season is favourable for its growth rather than other seasons of the year.

29. *O. okeni* Agardh *ex* Gomont

(Gomont, 1892: 232; Forti, 1907: 185; Tilden, 1910: 81; Frémy, 1929: 227, 1933: 127; Geitler, 1932: 969; Desikachary, 1959: 231; Starmach, 1966: 363; Gupta & Kumar, 1968: 487; Masud-ul-Hasan & Zeb-un-Nisa, 1986: 232)

General characters: Trichomes straight, slightly constricted at cross walls, at the end gradually attenuated; cells 7-9 µm broad, 3-4 µm long, at the end gradually attenuated, slightly bent; end cells 8-9 µm long and triangular (Fig. 29).

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

Localities: Sialkot: Sambrial; Azad Kashmir: Muzaffarabad.

Remarks: It has been collected during April 2000. It occurred in small quantity in stagnant water under bridge of Neelum River, Azad Kashmir. It was also collected in massive quantity from stagnant water pools during September 2000 because temperature and light intensity were high and favourable for its growth.

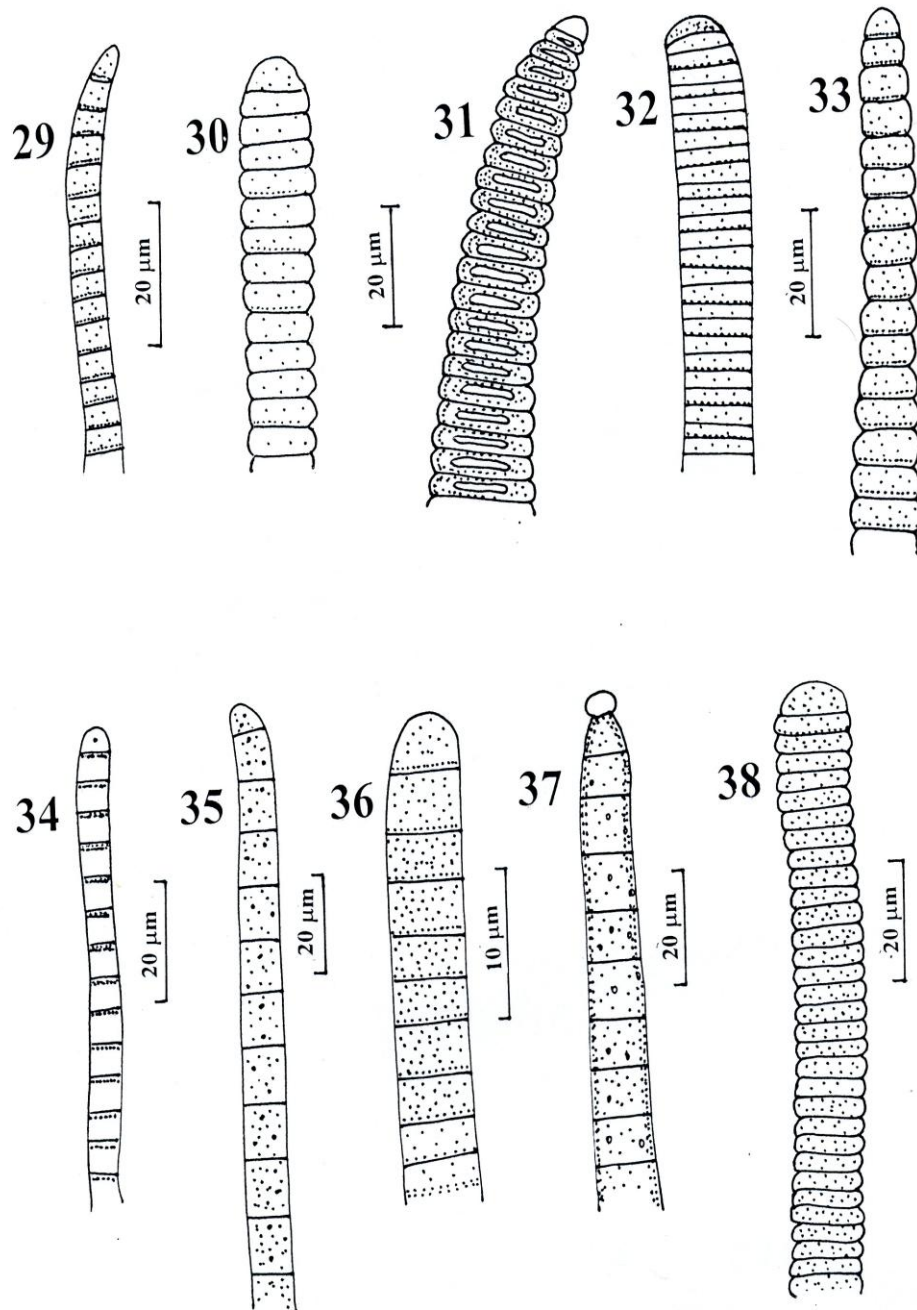


Fig. 29. *Oscillatoria okeni*, 30. *O. ornata*, 31. *O. perornata*, 32. *O. princeps*, 33. *O. proteus*, 34. *O. pseudogeminata*, 35. *O. quadripunctulata*, 36. *O. raoi*, 37. *O. rubescens*, 38. *O. sancta*.

30. *O. ornata* Kützinger ex Gomont

(Gomont, 1892: 214; Forti, 1907: 158; Tilden, 1910: 67; Frémy 1929: 212; Geitler, 1932: 944; Desikachary, 1959: 206; Venkatarman, 1957: 319; Starmach, 1966: 322)

General characters: Thallus dark blue-green; trichomes straight, uniform in thickness, 9.0-12.6 µm broad, constricted at the cross walls, granulated; cells shorter than broad, 3-5.6 long; end cells convex, without calyptra, not capitate (Fig. 30).

Geographical distribution: India: Mysore; Pakistan.

Localities: Lahore: Shahi Qila, Handoo Village; Jauharabad.

Remarks: The collections were made from stagnant water pools and fountain water in the months of February, June and October 1999. It was found during summer season in large quantity in vegetative as well as reproductive phases especially in stagnant water. It also occurred in abundance in gently flowing portion of the fountain in vegetative but rarely in reproductive condition. Specimens were also collected during winter season but in low quantity. It appeared that temperature plays the most important role in the growth of this alga.

31. *O. perornata* Skuja

(Skuja, 1949: 47; Desikachary, 1959: 205; Masud-ul-Hasan & Yunus, 1989: 103)

General characters: Trichomes erect, flexuous, occur singly, apices slightly curved, constricted at the cross walls, 11-15 µm broad; cells commonly 1/2 - 1/5 as long as broad or 2.5-6.6 µm long, 8-9 µm broad; contents granular, septa more or less granulated; end cells depressed, hemispherical, calyptra absent (Fig. 31).

Geographical distribution: Myanmar: Rangoon, Kamayut (Skuja, 1949); Pakistan.

Localities: Jauharabad; Lahore: Copaira Village, Mureedke and Narang Mandi.

Remarks: The specimens were collected during summer and winter seasons of 1998 from rice fields and stagnant ponds in free floating state. It occurred in rice fields in massive quantity during summer season. Some morphological differences were found within the species. Although, cold climate is unfavourable for its growth but it may survive in winter season.

32. *O. princeps* Vaucher ex Gomont

(Gomont, 1892b: 206; Forti, 1907: 150; Tilden, 1910: 62; Setchell, 1926: 62; Frémy, 1929: 208; Geitler, 1932: 947; Desikachary, 1959: 210; Starmach, 1966: 323; Masud-ul-Hasan & Zeb-un-Nisa, 1986: 232; Anagnostidis & Komárek, 1988: 363)

General characters: Trichomes blue-green or brownish, mostly straight, slightly bent at the apices, not constricted at the cross walls, 27-29 µm broad; cells 2.3-7.0 µm long, 12-28 µm broad; end cells flatly rounded, with slightly thickened membrane (Fig. 32).

Geographical distribution: Myanmar, India, Sri Lanka, Pakistan.

Localities: Lahore: Nishtar Colony; Jauharabad; Azad Kashmir: Chenari.

Remarks: Its collection was made from rice fields area and stagnant water ponds. Specimens were obtained both in summer and winter seasons of 1999. In summer it occurred in vegetative and reproductive stages but in winter it was found in small quantity and only in vegetative condition. It appears that winter season is not favourable for its growth but it survives in this season only in vegetative state.

33. *O. proteus* Skuja

(Skuja, 1949: 48; Desikachary, 1959: 221; Farzana & Nizamuddin, 1979: 251)

General characters: Trichomes more or less straight, sometimes curved, apices briefly attenuated and slightly bent or curved, 6-7 μm broad, constricted at the cross walls; cells 2-4 μm long, commonly granulated, blue-green; apical cells hemispherical to rounded, conical (Fig. 33).

Geographical distribution: Myanmar: Rangoon, Kamayut (Skuja, 1949); Pakistan.

Locality: Gujranwala District: Machrala Village of Kamonkey.

Remarks: The collections were made from the pond water during December 1997. The ponds were temporary and small, the pH of water was 8 *i.e.* slightly alkaline. It occurred in small quantity in free floating state.

34. *O. pseudogeminata* G Schmid

(Schmid, 1914: 124; Geitler, 1932: 966; Desikachary, 1959: 228)

General characters: Thallus dirty blue-green; trichomes straight or coiled, ends not attenuated; cells 1.3-3.3 μm broad, 2.4-3.4 μm long, usually cells as long as broad or somewhat longer, constricted at cross walls which are thick (double), granulated; end cells rounded, calyptra absent (Fig. 34).

Geographical distribution: Myanmar: Rangoon (Skuja 1949); India: Assam (Biswas, 1934), Benaras (Rao, 1937a), Orissa (Rao, 1938b), Bihar (Rao, 1939); Pakistan.

Localities: Lahore: Jallo More; Sheikhpura District: wall discharge box of tube-well near Sheikhanwala.

Remarks: The collections have been made during winter and spring seasons of 1998. Specimens were collected from stagnant water ponds and wet surface of discharge box of the tube-well. Its dense growth occurred in stagnant water during spring season because temperature was relatively high. Specimens found in gently flowing water at wall of discharge box were in small quantity. It appears that gently flowing water is not favourable for its growth.

35. *O. quadripunctulata* Bruhl *et* Biswas

(Bruhl & Biswas, 1922: 5; Geitler, 1932: 966; Desikachary, 1959: 227; Venkataraman, 1958: 320; Starmach, 1966: 344)

General characters: Trichomes curved or nearly straight, bluish green, unconstricted at cross walls, with thick septa, 2.0-2.5 μm broad, embedded in delicate sheath; cells quadrate or somewhat shorter, 1.5-6.5 μm long, 4.6 μm wide, sometimes almost as long as wide, not constricted at septa; cell contents slightly granular, transverse walls rather obscure or dim (Fig. 35).

Geographical distribution: Malaya: Ampang, Kodaikanal (Biswas, 1929); India: Benaras (Rao, 1937b), Andhra (Rao, 1938a); Pakistan.

Localities: Lahore: Mahmood Booti, Salamatpura Village.

Remarks: The specimens were collected from moist soil surface and roadside puddles during April and September 1999. It occurred both in soil binding habitat and planktonic state. In the latter state it occurred in large quantity.

36. *O. raoi* J de Toni

(Rao, 1936: 172; Desikachary, 1959: 223; Farzana & Nizamuddin, 1979: 253; Masud-ul-Hasan & Yunus, 1989: 103; Masud-ul-Hasan & Zeb-un-Nisa, 1986: 233)

General characters: Thallus thin, firm, pale blue-green; trichomes straight, usually of uniform thickness, only rarely slightly tapering at the ends, without constricted at the joints, 5-8 μm broad; septa indistinct, but with distinct granules closely arranged on either side; cells 2.0-6.5 μm longer, 5-7 μm broad; end cells rounded, rarely conical, not capitate, without any calyptra (Fig. 36).

Geographical distribution: India: Benaras (Rao, 1936), Orissa (Rao, 1938b), Assam (Parukutty, 1940), Delhi (Rao, 1940); Pakistan.

Localities: N.W.F.P. Swat; Lahore: Loharpura Village, Thokar Niaz Baig; Azad Kashmir: Neelum Valley, Chenari.

Remarks: The collections were carried out in slow running water and stagnant water ponds during summer and winter seasons of 1998 and 1999. During summer season remarkable growth occurred in planktonic state especially in rice field locality. During winter season it was found in small quantity, floating in slow running water.

37. *O. rubescens* D.C. *ex* Gomont

(Gomont, 1892: 204; Forti, 1907: 148; Geitler, 1932: 972; Desikachary, 1959: 235)

General characters: Trichomes straight, 6-7 μm broad, not constricted at cross walls; cells 2-3 μm long; end cells capitate; with convex calyptra (Fig. 37).

Geographical distribution: India, Sri Lanka, Pakistan.

Locality: Azad Kashmir: Neelum Valley.

Remarks: The specimens were collected in bloom composition during August 1997 in rice field locality clinging to the surface of water. The pH of water was about 8 *i.e.* slightly alkaline, where it occurred in large quantity.

38. *O. sancta* (Kützinger) Gomont

(Gomont, 1892: 209; Forti, 1907: 153; Tilden, 1910: 64; Frémy, 1929: 211; Geitler, 1932: 943; Desikachary, 1959: 203; Starmach, 1966: 322; Faridi *et al.*, 1981: 156)

General characters: Thallus dark blue; trichomes straight, constricted at the cross walls, end broadly attenuated; cells 1.5-5.6 μm long, 8-13 μm broad, granulated at the cross walls; end cells flattened, hemispherical, slightly capitate, with a thickened membrane (Fig. 38).

Geographical distribution: Myanmar: Rangoon (Skuja, 1949); India: Mumbai (Schmidle, 1900, Gonzalves & Joshi, 1946), Benaras (Rao, 1937), Cuttack (Rao, 1938b); Pakistan.

Localities: Sialkot District: Saediawali Village; Lahore: Bhaseen Village.

Remarks: It was collected from wet soil surface and stagnant water ponds during summer season of 2000. It occurred in soil binding and free floating states in large quantity, showing some morphological differences in specimens collected from different habitats.

39. *O. subbrevis* Schmidle

(Forti, 1907: 208; Frémy, 1929: 208; Geitler, 1932: 949; Desikachary, 1959: 207; Vasishtha, 1960: 588; Starmach, 1966: 328; Masud-ul-Hasan, 1980: 77; Faridi *et al.*, 1981: 156; Masud-ul-Hasan & Yunus, 1989: 103)

General characters: Trichomes free, planktonic, small or long (up to 77 μm) single, 4.5-10 μm broad, nearly straight, not attenuated at the apices; not granulated at the end walls; cells 1.5-3.5 μm long, 4.5-8.2 μm broad; end cells rounded, calyptra absent (Fig. 39).

Geographical distribution: World wide, Myanmar; India: Mumbai, Madras; Pakistan: Lahore (Masud-ul-Hasan, 1980).

Localities: Pasrur: Pakarwall Village; Sialkot District: Head Marala; Lahore: Burki Village, BRB Channel, Nasir Bagh, fountain of zoo; Kasur District: River Ravi; N.W.F.P. Swat; Azad Kashmir: Neelum Valley.

Remarks: The collections have been made from wide areas of the Punjab and Azad Kashmir. Large collections were made during summer season of 1998 from Punjab. But few collections were also made from Azad Kashmir during winter season of 1999. Species was found in different habitats, sometimes it occurred as a soil binding alga, as a component of algal bloom and in planktonic state. It appears that type of locality, temperature, light intensity and other ecofactors may affect its form, kind, distribution and growth.

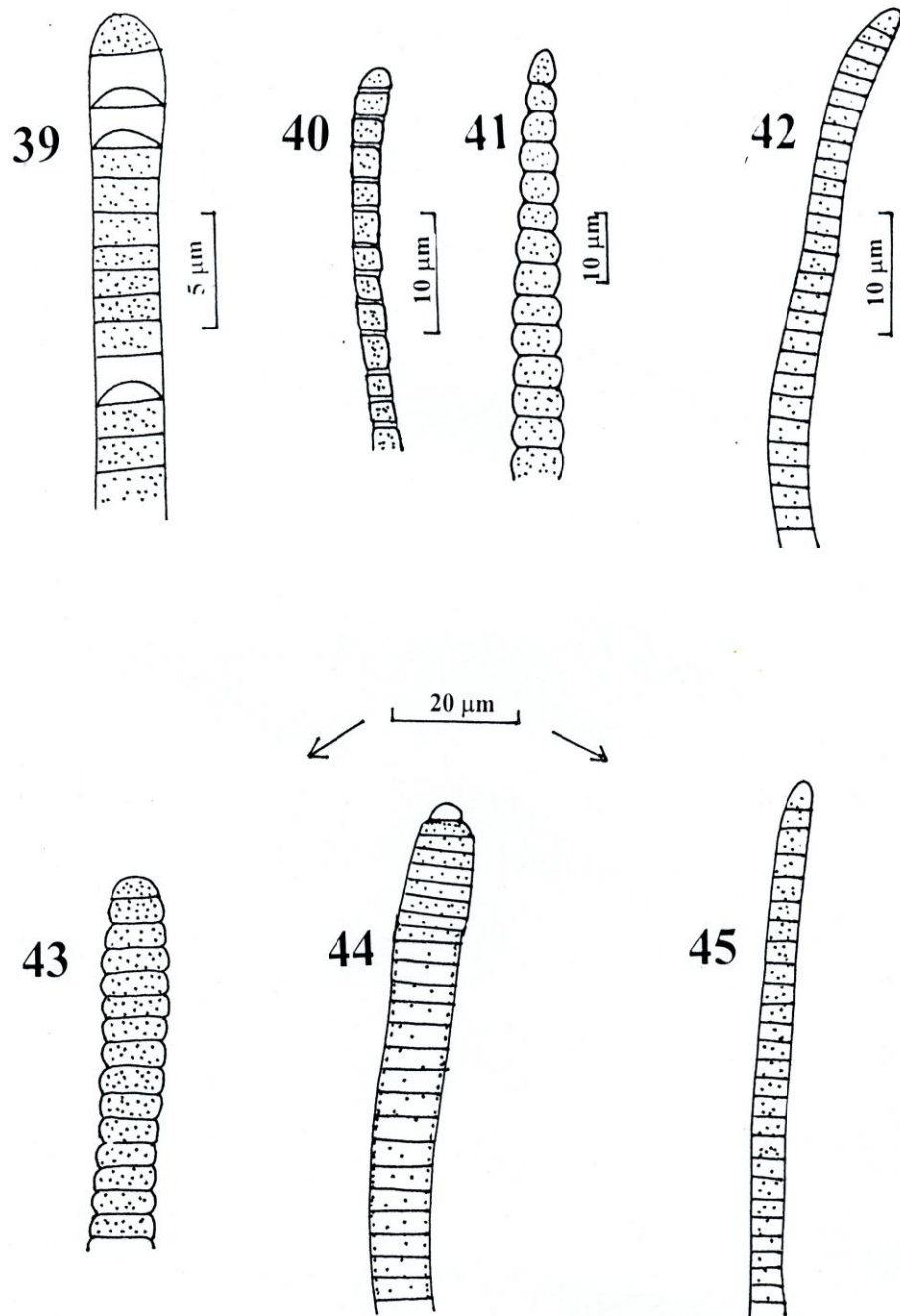


Fig. 39. *Oscillatoria subbrevis*, 40. *O. subtilissima*, 41. *O. tanganyikae*, 42. *O. terebriformis*, 43. *O. tenuis*, 44. *O. vizagapatensis*, 45. *O. willei*.

40. *O. subtilissima* Kützing
(Desikachary, 1959: 215; Starmach, 1966: 328)

General characters: Trichomes single, yellowish green, nearly straight, slightly constricted with thick cross walls, 1-2 µm broad; apex neither capitate nor calyptrate, conical, not attenuated; cells quadrate or longer, 1.5-2.5 µm long; cell contents blue-green, smooth (Fig. 40).

Geographical distribution: India: Orissa (Bruhl & Biswas, 1922; Banerji, 1938); Sri Lanka (Crow, 1923); Pakistan.

Locality: Lahore: Mahmood Booti.

Remarks: It has been collected from wet soil surface during September 1998. It showed massive growth due to heavy rain water, pH of the soil, temperature and sunlight conditions. These factors are favourable for its growth.

41. *O. tanganylikae* GS West
(Frémy, 1929: 224; Geitler, 1932: 971; Desikachary, 1959: 233)

General characters: Thallus yellowish blue-green; trichomes single, gradually tapering at the ends, sometimes not bent, obtuse rounded, septa constricted, 7-8 µm broad; cells quadrate or shorter than broad, 5-7 µm long; calyptra absent; cell contents include fine refractive granules (Fig. 41).

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

Locality: Lahore: Government College University.

Remarks: It was collected from moist soil surface during winter season of 1998 but due to low temperature it was found in small quantity. As soil binding alga it stabilizes the surface layer, binding the soil particles into a non-erosible layer. It resists the force of rain, improves infiltration of water, decreases run off, produces humus after death, and thus increases the soil fertility.

42. *O. terebriformis* Agardh ex Gomont
(Gomont, 1892b: 234; Forti, 1907: 189; Tilden, 1910: 83; Geitler, 1932: 954;
Gupta, 1956: 1; Desikachary, 1959: 217; Starmach, 1966: 348; Gupta, 1972: 484)

General characters: Thallus dull blue; trichomes coiled in a screw like manner, slightly attenuated, septa not constricted, 3-8 µm broad; cells 2.5-7.6 µm long; end cells rounded, not capitate, calyptra absent (Fig. 42).

Geographical distribution: India: Assam (Biswas, 1934), Benaras (Rao, 1936), Orissa (Rao, 1938b), New Delhi (Rao, 1940); Pakistan: Lahore (Ghose, 1919).

Locality: Lahore: Nasir Bagh, Copaira Village.

Remarks: It was collected from moist soil and pond water, the collections were made during summer and winter seasons of 1998. During summer it occurred in large quantity and in different reproductive stages, especially in pond water. During winter season it was found in limited amount.

43. *O. tenuis* Agardh ex Gomont

(Gomont, 1892b; Forti, 1907: 166; Tilden, 1910: 71; Frémy, 1929: 217, 1933: 121; Geitler, 1932: 959; Desikachary, 1959: 222; Starmach, 1966: 338; Islam, 1976: 70; Faridi *et al.*, 1981: 156; Masud-ul-Hasan & Zeb-un-Nisa, 1986: 233; Anagnostidis & Komárek, 1988: 365)

General characters: Thallus blue-green or olive green, straight, fragile, 3-11 µm broad, not attenuated at the apices; cells 1.5-6.0 µm or up to 1/3 as long as broad, 4-5 µm broad; end cells rounded, more or less hemispherical with thickened outer membrane (Fig. 43).

Geographical distribution: Myanmar: Arracan, Akyab (Martens, 1871; Theobald, 1883), Bhomo (West & West, 1907), Rangoon (Ghose, 1927b, Skuja, 1949); India: Faridpur (Bruhl & Biswas, 1922), Hyderabad, Benaras (Rao, 1937), Shembagnur in Madras (Frémy, 1942); Sri Lanka: Pandure (West & West, 1902), Anuradhapura, Tricomalee; Pakistan: Lahore (Ghose, 1919, 1924).

Localities: Lahore: Punjab University's old campus; Sialkot District: Sambrial; Kasur District: Galwedah; Azad Kashmir: Chenari.

Remarks: The collection work has been carried out from slow running and stagnant water ponds during the months of April, June, September and November 1998-99. This species occurred in massive quantity during summer season both in free floating and soil binding habitats. In winter it was collected only in soil binding habitat, as some rain took place a few days before collection.

44. *O. vizagapatensis* CB Rao

(Rao, 1938b: 89; Desikachary, 1959: 205)

General characters: Trichomes straight, pale blue-green, uniformly broad, 9-11 µm broad; cells much shorter than broad, 1.5-2.0 µm long, contents granulated; end cells broadly rounded forming a cup with thickened outer wall (Fig. 44).

Geographical distribution: India: Andhra State (Rao, 1938b); Pakistan.

Locality: Sialkot District: Punnowall Village.

Remarks: It was collected from roadside puddles during April 2000. It occurred in medium vegetative growth because temperature started rising from this month. The water pH was slightly alkaline. The puddles where from collection was made, were temporary in nature and the source of water was rain.

45. *O. willei* Gardner ex Drouet

(Gardner, 1927: 86; Geitler, 1932: 954; Desikachary, 1959: 217; Starmach, 1966: 347)

General characters: Trichomes pale blue-green, bent at the end, not constricted at the cross walls; ends not attenuated, not capitate; cells 1.6-3.5 µm long, 2.5-4.5 µm broad; end cells rounded, tip gradually curved and narrow (Fig. 45).

Geographical distribution: India: UP (Rao, 1937), Orissa (Rao, 1938b), Calcutta (Banerji, 1938); Pakistan.

Locality: Lahore: Lakhodehr.

Remarks: The specimens were collected from roadside puddles during summer of 2000 in free floating state. It was found mixed with other blue-green algae. The summer season appears to be suitable for its growth. Due to rapid reproduction it occurred in massive quantity.

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