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Fresh Water Cyanophyceae Algae from Tirumala Hills

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Abstract: Present investigation fresh water algae from Tirumala hills identified 39 species of Cyanophyceae. Identified cyanophycean algae belong to the genus Aphanocapsa (2), Merismopedia (1), Coelosphaerium (1), Chamaesiphon (1), Spirulina (3), Microcystis (1), Aphanothece (8), Chroococcus (5), Borzia (2), Arthrospira (1), Lyngbya (4), Oscillatoria (2), Phormidium (1), Scytonema (1), Calothrix (1), Gloeotrichia(1), Anabaena (2), Cylindrospermum (1) and Nostoc (1). Among them 23 species are new Andhra Pradesh and 2 species are new India.

Keywords: investigation, species, species

INTRODUCTION

The Tirumala hills are Hindu deity and holy place of lord venkateshwara, which is one of the richest temple in India and distributed in 10.33 sq miles geographical area of Chittoor district, Andhra Pradesh. It is located 3,200 feet above the sea level and exists in latitude and longitude of 13.6500 N and 79.42 E. Tirumala hills otherwise known as the Seshachalam range of Eastern Ghats including seven hills namely Sesadri, Neeladri, Garudari, Anjanadri, Narayanadri and Venkatadri. The Tirumala hills are one of the hotspots in India.

Seshachalam hill ranges well established with permanent and temporary water bodies and rainfall was highly received in summer compared to winter and average annual rainfall and temperature is 841mm and 24.1 ℃. Tirumala hills have the tropical climate with Southern Tropical dry deciduous forest. The climate and water resource in Tirumala hills provides the luxuriant growth of evergreen Angiosperms, Gymnosperm plants, lower group plants Pteridophyte, Bryophytes, Algae and habit for different animals. The Tirumala hills have the rare, endangered, vulnerable and endemic plants.

Algae are ubiquitous because they live in all most all habitats, but the majority distributed in the aquatic environment both fresh and marine water. However, algae occur in terrestrial and unusual habitats like within the other plants, animals, hot springs, snowfields, desert sand rocks.

Algae are used as a food, flavouring agent, jelly and ice cream preparations in many countries. And also used food for animals and fishes. Agar, alginates, Iodine, funnoria and funorin, carrageeine and diatomite were commercially synthesized by many industries from algae. Bioactive compounds, secondary metabolites and Volatile compounds extracted from the algae. Algae have the great importance in ecological and economical contest. Hence the availability of systematic details, diversity and distribution is essentially for advance research work.

MATERIALS AND METHODS

Several field trips were made to collection sites in Tirumala hills in different seasons. Every collection was given a field number and colour of the alga material are noted. Algae were temporally collected in Ziplock covers and kept in ice box to prevent deterioration. Temporary slides were prepared with water mounts and with Lugol's solution or Aniline blue, slides were sealed with DPX.

Samples were observed under CHi 20 Olympus bright field binocular micro scope. Organisms were observed under 4X, 10X, 40X and 100X, Size and colour was noted down. Rough sketches were made and characters were described in a separate note book. Photographs were taken with Sony and Olympus camera. Algae were identified based on key characters by using Algal floras, monographs and available research articles from journals (Alan J. Brook and David B. Brook (2010), Gardner, N.L. (1927), Rabenhorst, L. (1865), Unger, F. (1854), Meyen, F.J.F. (1839), Gomont, M. (1892 '1893')., Geitler, L. (1932)., West, W. & West, G.S. (1902), Kützing, F.T. (1846), Chu, H.J. (1991), Komárková-Legnerová, J. & Tavera, R. (1996), Elenkin, A.A. (1938), Lemmermann, E. (1898) , Lemmermann, E. (1904)., Lemmermann, E. (1907), Rabenhorst, L. (1863), Komárková-Legnerová, J. & Cronberg, G. (1994), Komárek, J. (1995), Nägeli, C. (1849), Chatterjee, S. & Keshri, J.P. (2005), Gomont, M. (1892 '1893'), De Toni, G. (1936), Frémy and Abbé P. (1930 '1929'), Richter, P.G. (1894), Brunnthaler, J. (1903), Komárek, J. (2013), Bornet, É. & Flahault, C. (1886 '1888') and compared information and photographs with Algae base (Guiry and Guiry(2019).

RESULTS

The Investigations fresh water algae in Tirumala hills reported about 39 taxa of micro algae belong to the Class Cyanophyceae.

Systematic enumeration

P.C. Silva (1986) classification followed for Systematic enumeration of identified fresh water algae from Tirumala hills, Chittoor district, AndhraPradeh.

1. *Aphanocapsa intertexta* N.L.Gardner 1927, Plate: I, Fig: 1.

Colony irregular in shape, cells embedded in the gelatinous, hyaline, inconspicuous to conspicuous sheath. Cell spherical to ovoid in shape, 2.8 to 3 µm in diameter, lightly granulated and blue green color.

Collection number: Gogarbam Theertham, 004.

Distribution: First report from Andhra Pradesh.

2. *Aphanocapsa pulchra* (Kützing) Rabenhorst 1865, Plate: I, Fig:2

Colony ovate to globose in shape, cell are blue green in color,4.2 µm in diameter, Spherical shape andblue green color. Cell loosely and evenly dispersed in the mucilage.

Collection number: Gogarbam Theertham, 014.

Distribution: First report from Andhra Pradesh.

3. ***Merismopedia punctata Meyen* 1839, Plate: I, Fig:3.**
   32 celled colony, rectangular shape, compact group of 4 individual cells. Cells 4 µm in diameter, homogenous and blue green color**.**
   Collection number: Talakona, 006.
   Distribution reported in Andhra Pradesh.
4. ***Coelosphaerium naegelianum* Unger 1854, Plate: I, Fig: 4.**
   Lobed colony, cell was ellipsoid arranged into dense peripheral layer in colonial mucilage, cells 3.2 µm in width and 5.2 µm in length.
   Collection number: Papavinasam,0012.
   Distribution: First report from Andhra Pradesh.
5. ***Chamaesiphon incrustans* Grunow in Rabenhorst 1865, Plate: I, Fig: 5.**

   Cell are attached to the filamentous algae, cylindrical in shape, straight or somewhat curved, 6 µm width, 20 µm length.

   Collection number: Gogarbam Theertham, 0001.

   Distribution: First report from India.

6. ***Spirulina major*Kützing ex Gomont 1892, Plate: I, Fig: 6.**
   Trichomes loosely spirlled, blue green in colour, 1.7 µm *in diameter, spiral distance 2.8* µm *and spiral width 2.7* µm.

   Collection number: AkashaGanga Waterfalls, 0026

   Distribution: First report from Andhra Pradesh.

7. ***Spirulina maxima* (*Setchell & N.L.Gardner*) *Geitler* 1932, Plate: I, Fig: 7.**
   Trichomes devoid of sheath, highly blue green, regularly coiled, cells invisible, terminal cell rounded. Trichome 3.75µm broad, coiling 10 µm broad**.**
   Collection number: Vakulamatha Cheruvu, 012.
   Distribution not recorded in Andhra Pradesh.
8. ***Spirulina princeps West & G.S.West* 1902, Plate: I, Fig: 6.**
   Trichomes loosely and closely spiraled, straight or bent, 5 µm in diameter, blue green, slightly granular, spiral are 11.8 µm width and distance between the spirals about 9.5 µm.
   Collection number: Vakulamatha Cheruvu 001, Occurred in bundles
   Distribution: Karagam Lake, Srikakulam, Andhra Pradesh.
9. ***Microcystis aeruginosa* (Kützing) Kützing 1846, Plate: II, Fig: 9.**
   Colony irregularly lobed, clathrate with numerous spherical cell in gelatinous matrix, cells 3.8µm, blue green colour, colony mucilage hyaline and homogenous.
   Collection number: Talakona, 011.
   Distribution reported in Andhra Pradesh.
10. ***Aphanothece clathrata* West & G.S.West 1906, Plate: II, Fig: 10.**
    Colonies are irregular in shape and clathrate have the large perforations. Cells elongate elliptical in shape and straight, dispersed in transparent mucilage. Cell 4 to 6 µm in length and 0.8 µm width.
    Collection number: Papavinasam 02 and Akasha Ganga waterfalls 0005.
    Distribution: First report from Andhra Pradesh.

11. ***Aphanothece comasii*** **Komárková-Legnerová & R.Tavera 1996, Plate: II, Fig: 11.**
Colony spherical in shape, cells compactly distributed in the central part of the homogenous sheath. Sheath is colorless but boundary visible, cell oval in shape, 2.8 µm width and 3.5-4.0 µm in length.
Collection number: Common in all places, except in Talakona.
Distribution not recorded from India.

12. ***Aphanothece elabens*** **(Brébisson ex Meneghini) Elenkin 1938, Plate: II, Fig: 12.**
Colonies consist of sub colonies bonded by the general mucilage, mucilage colorless. Cells oval in shape, 4.5 µm long and 2.5 µm width.
Collection number: Gogarbam Theertham0007.
Distribution: First report from Andhra Pradesh.

13. ***Aphanothece gelatinosa*** **(Hennings) Lemmermann 1907, Plate: II, Fig: 13.**
Cells are compactly arranged in the globular shape colony. Cell ovate in shape, 4 µm in width, 4.5 µm length and blue green to brown in colour.
Collection number: Papavinasam 004.
Distribution: First report from Andhra Pradesh.

14. ***Aphanothece microspora*** **(Meneghini) Rabenhorst 1863, Plate: II, Fig: 14.**
Cylindrical shaped with round ends cell loosely arranged in the gelatinous mucilage. Cells solitary, 2.4 µm in width, 8.9 µm in length, olive green or yellow green in color.
Collection number: Gogarbam Theertham 0008.
Distribution: First report from Andhra Pradesh.

15. ***Aphanothece smithii*** **Komárková-Legnerová & Cronberg 1994, Plate: II, Fig: 15.**
Cells loosely, irregularly arranged in the spherical shaped colony mucilage. Mucilage colorless, diffluent margin, cell oval to cylindrical shape with round ends, 1.8 µm width, 2.9 µm length.
Collection number: Vakulamatha Cheruvu007.
Distribution: First report from Andhra Pradesh.

16. ***Aphanothece stagnina*** **(Sprengel) A.Braun in Rabenhorst 1863, Plate: II, Fig: 16.**
Colonies are ovate in shape, bright green color, cell are evenly distributed through the colony, sheath diffluent. Cell 4-6.8 µm width and 5-8 µm length.
Collection number: Gogarbam Theertham0018.
Distribution reported in Andhra Pradesh.

17. ***Aphanothece variabilis*** **(Schiller) Komárek 1995, Plate: II, Fig: 17.**
Colony elongated kidney shape with 2-3 sub colonies, bounded by their own sheath. Cells compactly arranged, broad oval in shape with round ends, 2 µm width and 4 µmlength.
Collection number: Vakulamatha Cheruvu 0004.
Distribution: First report from Andhra Pradesh.

18. ***Chroococcus dispersus*** **(Keissler) Lemmermann 1904, Plate: III, Fig: 18.**
Cell 4-4.8 µm dimeter, pale blue green, homogenous, spreaded irregularly in the center of the colony.
Collection number: Vakulamatha Cheruvu, 016.
Distribution: First report from Andhra Pradesh.

19. ***Chroococcus limneticus*** **Lemmermann 1898 Plate: III, Fig: 19.**

Spherical shaped 4 cells evenly arranged in the ovate colony. They are 2 cells in one group withindistinct individual cell sheath and general mucilaginous colonial sheath, 21.6 µm in diameter, bright blue green color.

Collection number: Vakulamatha Cheruvu, 0016-0019.

Distribution: First report from Andhra Pradesh.

20. *Chroococcus minutus* (Kützing) Nägeli 1849 Plate: III, Fig: 20.

2 celled colony, small, ovoid in shape, margin firm. Cells 10 µm in diameter, blue green in color, homogenous, hemispherical in shape.

Collection number: Gogarbam Theertham,0028.

Distributed reported in Andhra Pradesh.

21. *Chroococcus pallidus* Nägeli 1849 Plate: III, Fig: 21.

4 cells are arranged in to pair with their own sheath and surrounded by the gelatinous, colorless mucilage sheath. Cells sub spherical shape, 11 µm long, 10 µmwidth and yellowcolor.

Collection number: Talakona, 029-030.

Distributed reported in Andhra Pradesh.

22. *Chroococcus turgidus* (Kützing) Nägeli 1849 Plate: III, Fig: 22.

2-4 celled colony, hemi spherical shape with wide colonial envelop. Cells blue green colour, granular, 30 µm length, 50 µm width up to sheath, enclosed by individual envelop**.**

Collection number: Gogarbam Theertham, 022-026.

Distributed recorded in Andhra Pradesh.

23. *Borzia indica Chatterjee* & Keshri 2005 Plate: III, Fig: 23.

7 celled trichrome, blue green color without sheath and constricted in the cross walls, 15 µm broad, 9 µm long and barrel shape with round end cells.

Collection number: Papavinasam, 030,16.

Distribution: First report from Andhra Pradesh.

24. *Borzia trilocularis Cohn* ex Gomont 1892 Plate: III, Fig: 24.

The trichomes solitary,18 µm long, composed of 8 cells without sheath and constricted in cross walls, Cells 6 µm long and 7 µm wide.

Collection number: Gogarbam Theertham, 001-004.

Distribution: First report from Andhra Pradesh.

25. *Arthrospira jenneri* Stizenberger ex Gomont 1892, Plate: III, Fig: 25.

Trichomes loosely coiled, gregarious, 7.2 µm in width, 5 µm long, spirals 10.8 µm width, distance spirals 12 µm.

Collection number: Vakulamatha cheruvu, 0012.

Distribution: First report from Andhra Pradesh.

26. *Lyngbya aestuarii* Liebman ex Gomont 1892, Plate: III, Fig: 26.

Cells 22 µm width, 5 µm length, sheath thickened, firm and lamellose. Trichome apiece conical shape, truncate.

Collection number: Akasha Ganga water falls, 006.

Distributed reported in Andhra Pradesh.

***27. Lyngbya major* Meneghini ex Gomont 1892, Plate: IV, Fig: 27.**

Filaments were long, straight, dark-green colour caespitose bundles, sheath thick colorless, lamellated, cells 16.4 broad, 50 long, not constricted at the cross walls and end cells rounded with a slightly thick end membrane.

Collection number: Akasha Ganga water falls, common in all collection.

Distribution: First report from Andhra Pradesh.

28. *Lyngbya majuscula* Harvey ex Gomont 1892, Plate: IV, Fig: 28.

Trichomes long, yellow brown in color and sheath colour less, lamellated, Cells 7.9 µmin length, 48 µm width and rotund calyptra absent.

Collection number: Vakulamatha cheruvu, 016-021.

Distributed reported in Andhra Pradesh.

29. *Lyngbya martensiana* Meneghini ex Gomont 1892, Plate: IV, Fig: 29.

Trichome caespitose, usually in blue green but when dried violet in colour, long and sheath colourless. Cells 1.75 µm long, 8.4 µm width and end cell round in shape without calyptra.

Collection number: Akasha Ganga water falls, 014-018.

Distribution reported in Andhra Pradesh.

30. *Oscillatoria limosa* C.Agardh ex Gomont 1892, Plate: IV, Fig: 30.

Filament dark blue in color, solitary, straight, apical cell rotund, outermembrane thickened without calyptra, Cell18 µm width and 5 µm long and granular.

Collection number: Akasha Ganga water falls, 014-018.

Distribution reported in Andhra Pradesh.

31. *Oscillatoria sancta* Kützing ex Gomont 1892, Plate: IV, Fig: 31.

The filaments gray green color, straight, apical cell with calyptraand outer membrane thickened, cells 20 µm width, 5 µm long and granular.

Collection number: Vakulamatha cheruvu, 06-11.

Distribution reported in Andhra Pradesh.

32. *Phormidium subfuscum* Kützing ex Gomont 1892, Plate: IV, Fig: 32.

Trichome olive green color, agglutinated, short with round calyptra. Cell 11 µm in wide, 3 µm long, granular.

Collection number: Akasha Ganga water falls, 09.

Distribution: First report from Andhra Pradesh.

33. *Scytonema crispum* Bornet ex De Toni 1907, Plate: IV, Fig: 33.

Trichomes gray brown wooly mats, seldom branches, straight. Cells disc shaped, 30 µm width, 3 µm long.

Collection number: Papavinasam, 0009-0016.

Distribution: First report from Andhra Pradesh.

34. *Calothrix atricha* Frémy 1930

Trichomes clusters 3, heterocyst is basal cell, spherical in shape, 9 µm diameter, blunt apical cell. Vegetative cells 7.6 µm in width, 1.8 µm long.

Collection number: Vakulamatha cheruvu, 01-05.

Distribution: First report from Andhra Pradesh.

35. *Gloeotrichia echinulata* P.G.Richter 1894, Plate: V, Fig: 35.

Spherical shaped gelatinous colour with many sheathed trichomes from common center. Cells barrel shaped, 8-10.5 µm in width, heterocyst spherical and 10 µm in diameter**.**
Collection number: Talakona, 022.
Distribution: First report from Andhra Pradesh.

36. *Anabaena planctonica* Brunnthaler 1903, Plate: V, Fig: 36.

Filaments solitary, enveloped with gelatinous sheath, barrel or spherical shaped cells, 10 µm in wide, 9 µm long, heterocyst spherical about 11 um in diameter.
Collection number: Talakona, 0026.
Distribution: First report from Andhra Pradesh.

37. *Anabaena wisconsinensis* Prescott 1944, Plate: V, Fig: 37.

Trichomes solitary, slightly flexuous without envelop, cell cylindrical shape, 4 µm in wide, 10 µm long, oval shape heterocyst about 4.2 in diameter.
Collection number: Vakulamatha cheruvu, 018.
Distribution: First report from Andhra Pradesh.

38. *Cylindrospermum majus* Kützing ex Bornet & Flahault 1888, Plate: V, Fig: 38.

Cells short cylindrical in shape, 2.7 um to 3.5 µm width, 7.4 µm long. Heterocyst sub quadrate-ovate, 3 um width, 4 um long.
Collection number: Vakulamatha cheruvu, 011.
Distribution reported in Andhra Pradesh.

39. *Nostoc verrucosum* Vaucher ex Bornet & Flahault 1886, Plate: V, Fig: 39.

Trichome brown colour, densely occur in the colonial mucilage, radiating with individual sheath distinct, cells compressed spherical or disc shape, 3 µm width, 3-4 µm long, heterocyst spherical in shape, 6 um diameter.

Collection number: Talakona,011-016.

Distribution reported in Andhra Pradesh.

Discussion

Algae are the primary producer in the water ecosystem, they have importance in food chain. The present study reveals the importance about systematics of our surrounding biodiversity, for their conservation and utilization earlier than extinct or even known to the world. Algae occur wide range of habitats like aquatic, terrestrial and adopted to extreme environment based on the nutrient availability and environmental factors.

The study area Tirumala hills belong to the Tirupati-cuddapa- Nallamali hills (Nayer 1996), which is one of the micro centres of the endemic plant of India. Tirupati-cuddapa- Nallamali hills are part of Eastern Ghats. The study reported 39 Species of Cyanophyceae collected from the 5place of Tirumala hills, preserved, identified and illustrated.

The Survey and documentation of freshwater algae in the present investigation yielded 39 species belong to the 19 genera. The availability of algae species varies from one season to the other season. The algae species were highly collected in the after rainy season. All ponds are dried in summer but small amount of water available in the dams and reservoir.

The diversity of algae in the Tirumala hills varies from one to other region due to presence of nutrient availably, nature of water and environmental factors**.** *Lyngbya and Phormidium sps*

abundant in the Akasha Ganga, which indicated that the water was organically polluted. Species diversity ofalgae observed in the Gogarbam reservoir area due to the presence of light and nutrients availability. Comprehensive data of freshwater algae of Andhra Pradesh is not available yet. Hence the present attempt gains importance and generate interest on potential utilization, sustainable management of algal wealth.

Conclusion

Diversity of biological organisms is one of the important natural resources to any nation in economic and social development. Algae inhabiting all kinds of water bodies are the main primary producers playing a greater role in ecosystems and indicate the nature of water. Present investigation yielded 39 species of *Cyanophyceae*.

They belong to genus Aphanocapsa (2), Merismopedia (1), Coelosphaerium (1), Chamaesiphon (1), Spirulina (3), Microcystis (1), Aphanothece (8), Chroococcus (5), Borzia (2), Arthrospira (1), Lyngbya (4), Oscillatoria (2), Phormidium (1), Scytonema (1), Calothrix (1), Gloeotrichia(1), Anabaena (2), Cylindrospermum (1) and Nostoc (1). Among them 23 species are new Andhra Pradesh and 2 species are new India. New to India species are *Chamaesiphon incrustans* and *Aphanothece comasii*.

Acknowledgment

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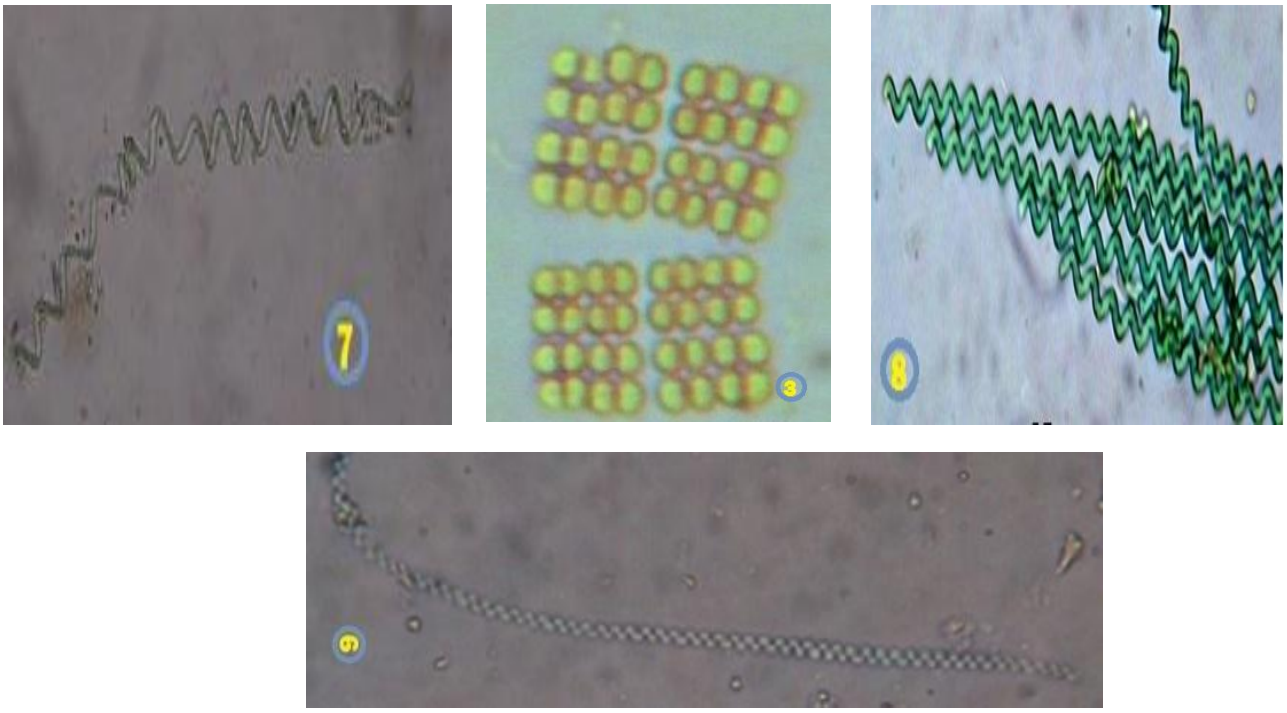
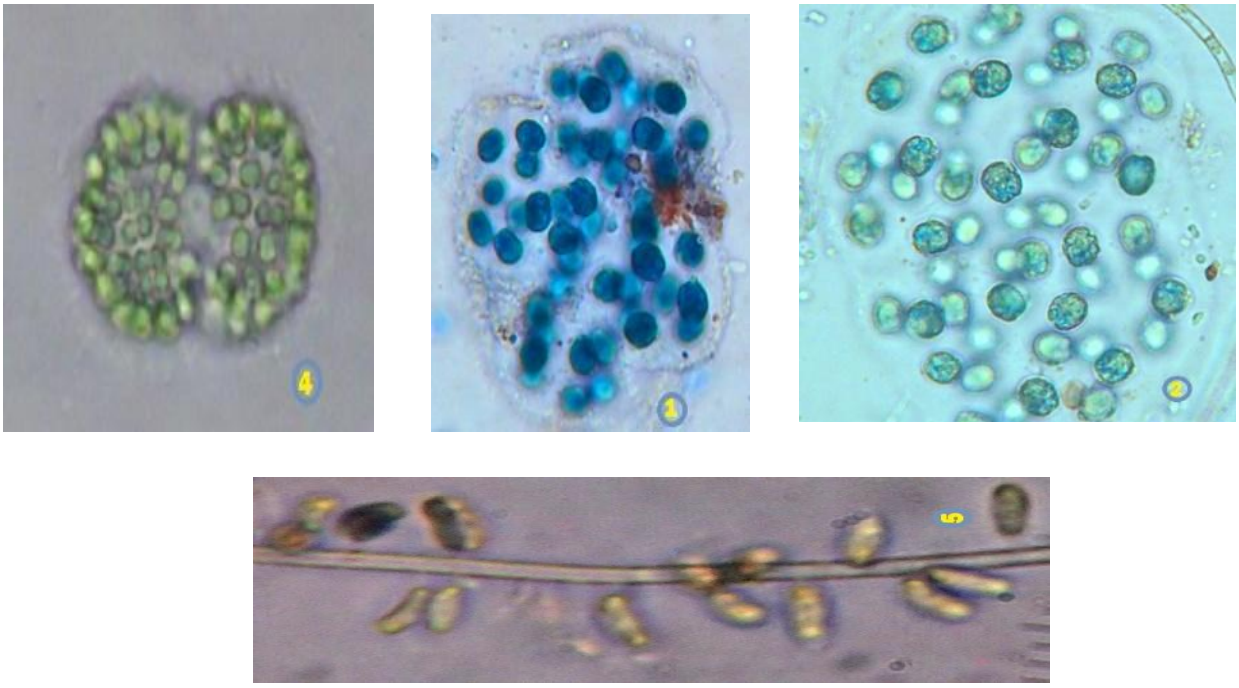
Identified fresh water Cyanophyceae from Tirumala hills

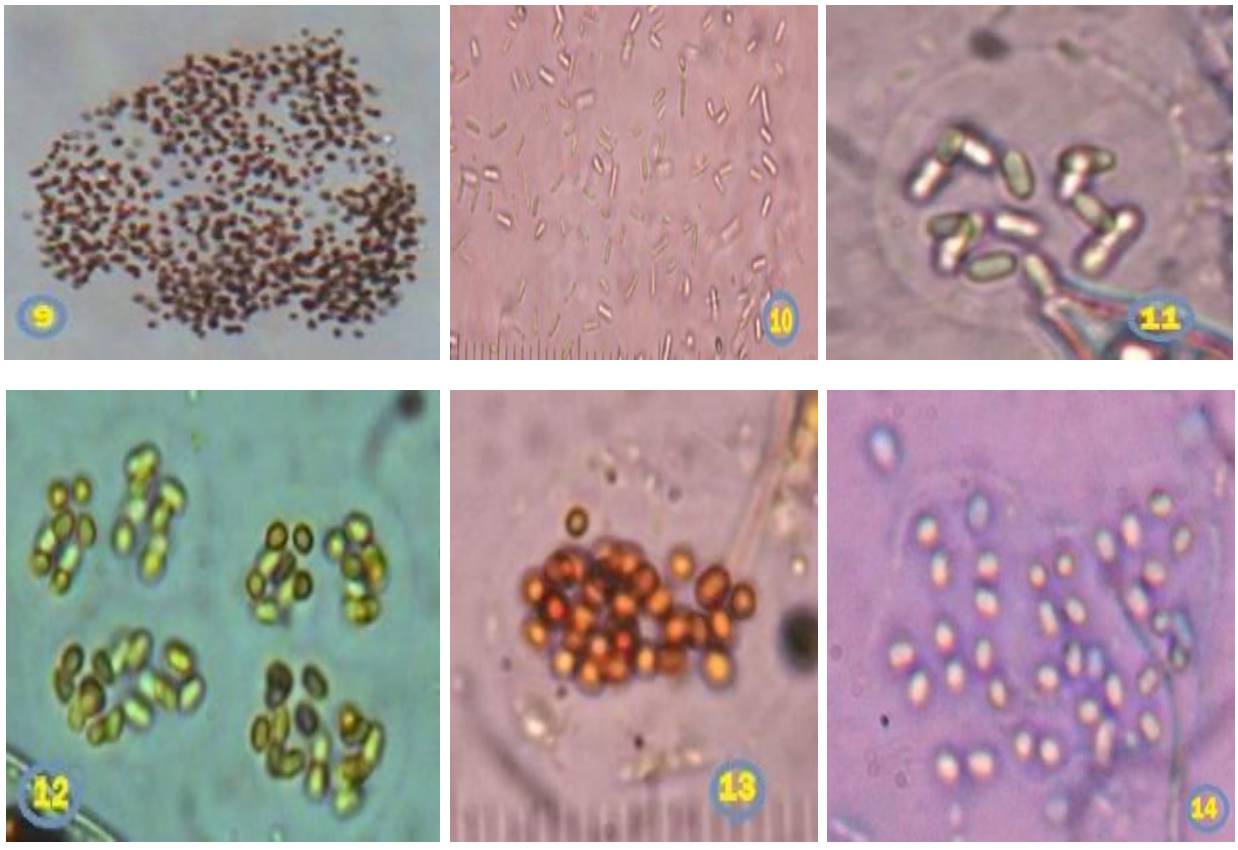
PLATE: I

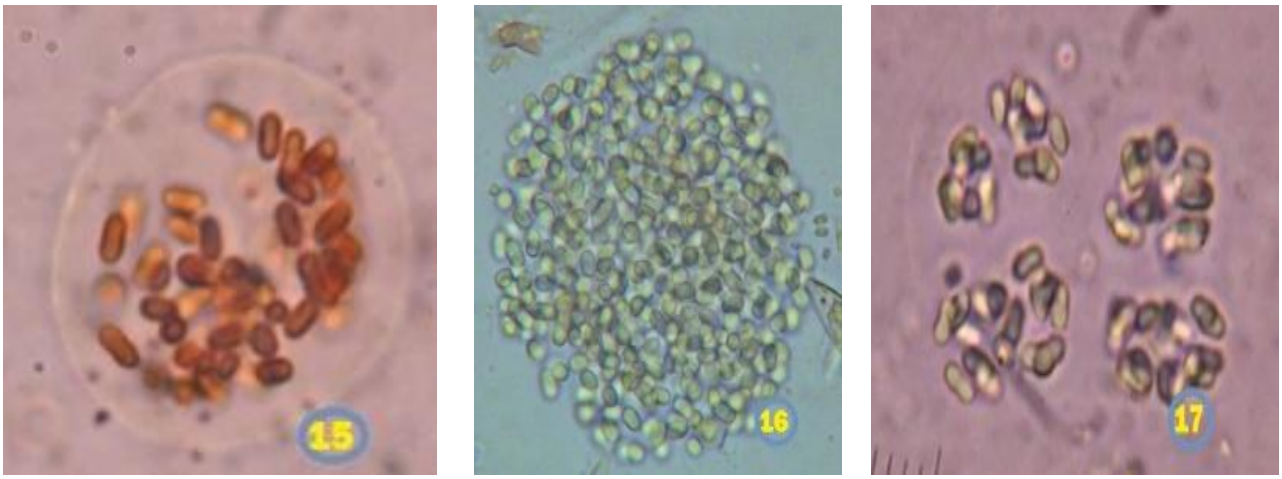




1. *Aphanocapsa intertexta* N.L.Gardner 1927, 2. *Aphanocapsa pulchra* (Kützing) Rabenhorst 1865, 3. *Merismopedia punctata* Meyen 1839, 4. *Coelosphaerium naegelianum* Unger 1854, 5. *Chamaesiphon incrustans* Grunow in Rabenhorst 1865, 6. *Spirulina major* Kützing ex Gomont 1892, 7. *Spirulina maxima* (Setchell & N.L.Gardner) Geitler 1932, 8.*Spirulina princeps* West & G.S.West 1902.

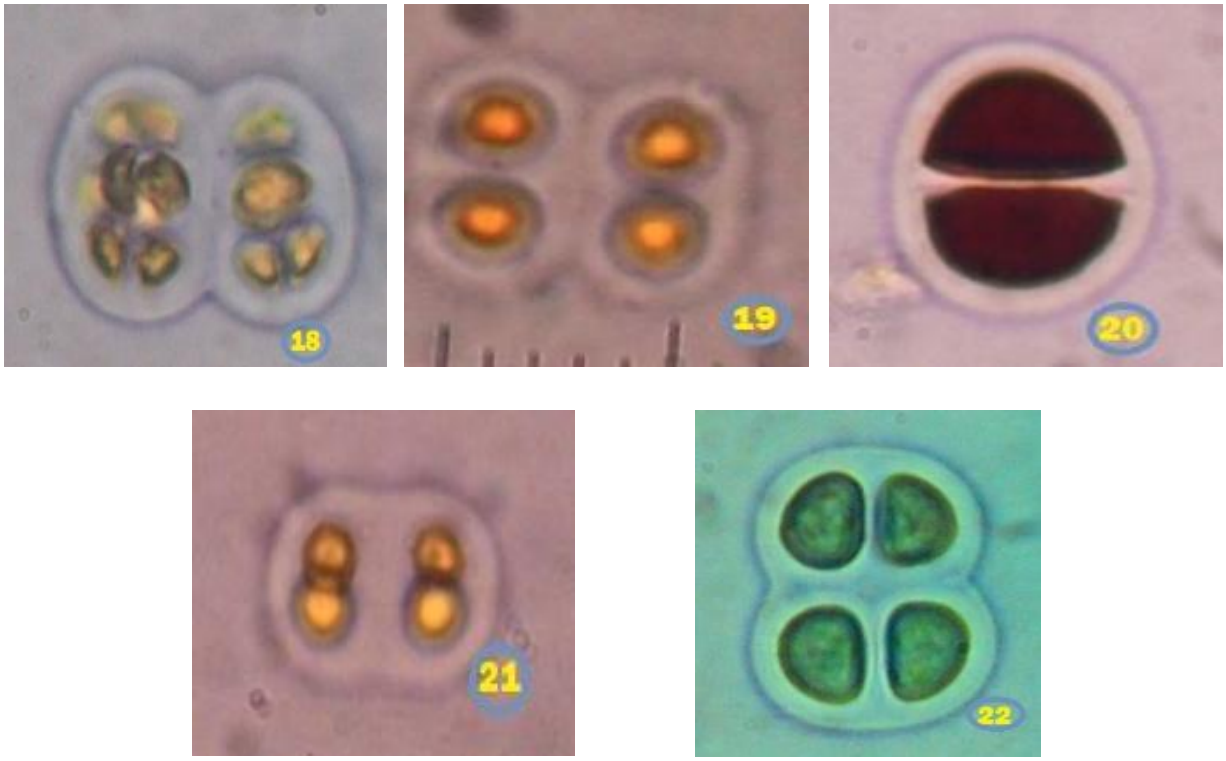
PLATE: II

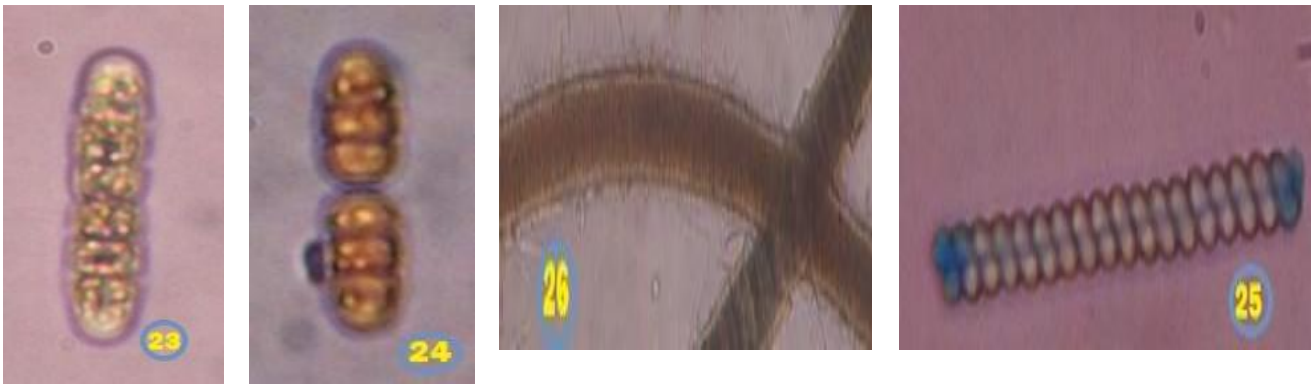




9. *Microcystis aeruginosa* (Kützing) Kützing 1846, 10. *Aphanothece clathrata* West & G.S.West 1906, 11. *Aphanothece comasii* J.Komárková-Legnerová & R.Tavera 1996, 12. *Aphanothece elabens* (Brébisson ex Meneghini) Elenkin 1938, 13. *Aphanothece gelatinosa* (Hennings) Lemmermann 1907, 14. *Aphanothece microspora* (Meneghini) Rabenhorst 1863, 15. *Aphanothece smithii* Komárková-Legnerová & G.Cronberg 1994, 16.*Aphanothece stagnina* (Sprengel) A.Braun in Rabenhorst 1863, 17. *Aphanothece variabilis* (Schiller) Komárek 1995.

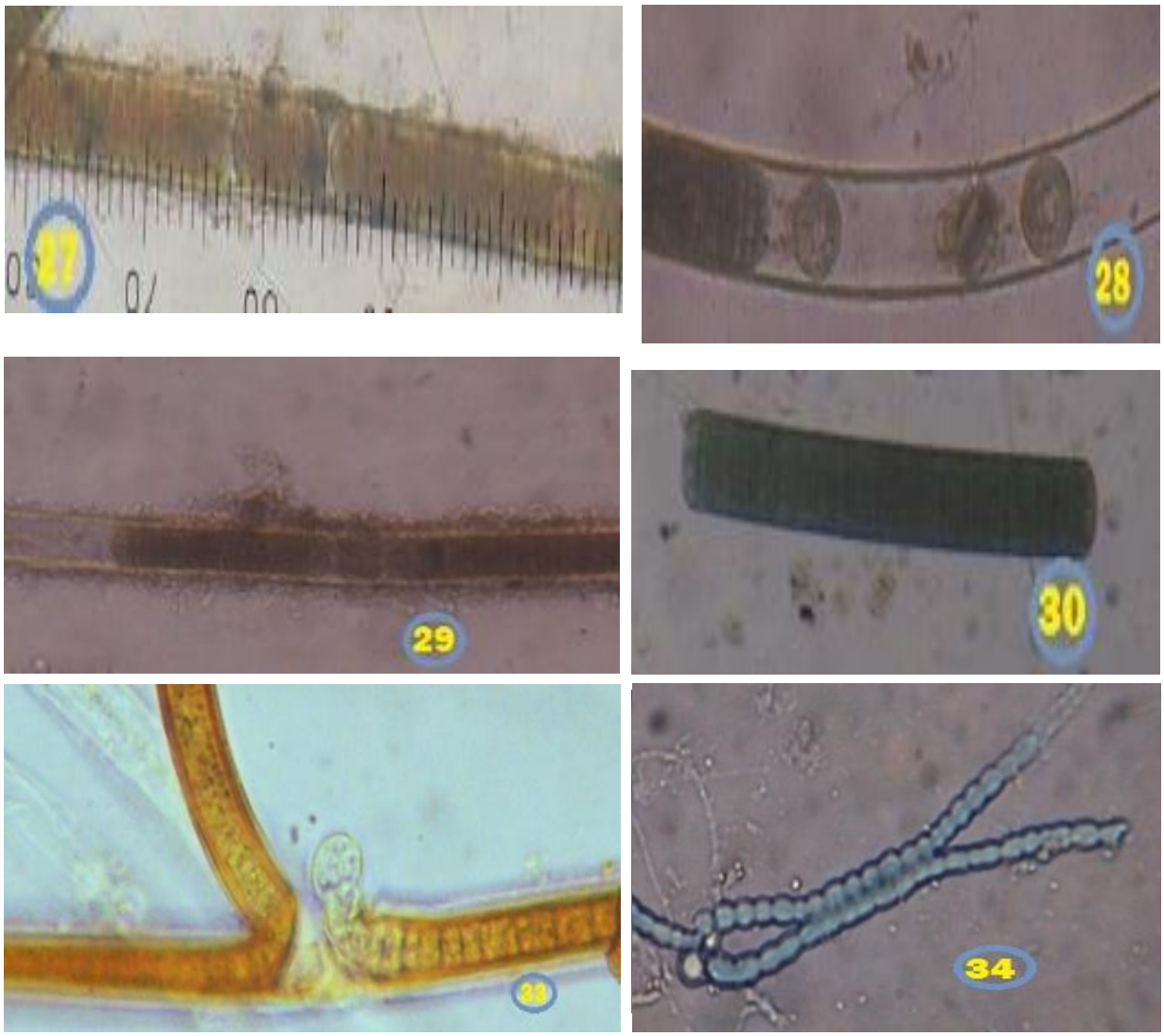
PLATE: III





18. *Chroococcus dispersus* (Keissler) Lemmermann 1904, 19. *Chroococcus limneticus* Lemmermann 1898, 20. *Chroococcus minutus* (Kützing) Nägeli 1849 21. *Chroococcus pallidus* Nägeli 1849, 22. *Chroococcus turgidus* (Kützing) Nägeli 1849, 23. *Borzia indica* Chatterjee & Keshri 2005, 24. *Borzia trilocularis* Cohn ex Gomont 1892, 25. *Arthrospira jenneri* Stizenberger ex Gomont 1892, 26. *Lyngbya aestuarii* Liebman ex Gomont 1892.

PLATE: IV



27. *Lyngbya major* Meneghini ex Gomont 1892, 28. *Lyngbya majuscula* Harvey ex Gomont 1892, 29. *Lyngbya martensiana* Meneghini ex Gomont 1892, 30. *Oscillatoria limosa* C.Agardh ex Gomont 1892, 31. *Oscillatoria sancta* Kützing ex Gomont 1892, 32. *Phormidium subfuscum* Kützing ex Gomont 1892, 33. *Scytonema crispum* Bornet ex De Toni 1907, 34. Calothrix atricha Frémy 1930.

PLATE: V

35. *Gloeotrichia echinulata* P.G.Richter 1894, 36. *Anabaena planctonica* Brunnthaler 1903, 37. *Anabaena wisconsinensis* Prescott 1944, 38. *Cylindrospermum majus* Kützing ex Bornet & Flahault 1888, 39. *Nostoc verrucosum* Vaucher ex Bornet & Flahault 1886

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