SYSTEMATICS OF CHROOCOCUS FROM PAKISTAN

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Abstract

The present paper reports taxonomic enumeration of genus Chroococcus belonging to the Chroococcaceae family from the Kallar Kahar Lake, Chakwal, Pakistan. In all, 18 species have been recorded from the study area. Of them, 5 species viz., C. microscopicus, C. planctonicus, C. polyedriformis, C. subtilissimus and C. vacuolatus are new records for Pakistan and South Asia. Their taxonomic description and geographic distribution is provided and discussed in this paper.

Key words: Chroococcus, Brackish water, Microalgae, Cyanobacteria, Kallar Kahar Lake, Geographic distribution.

Introduction

The Coccoid genus Chroococcus Nageli belongs to phylum cyanobacteria, the most primitive group of organisms recorded in the Precambrian (Abed et al., 2014; Cuzman et al., 2010; Lee, 2008), containing 149 species (http://www.algaebase.org). It poses simple cell structure (Gama et al., 2014) which can colonize bare areas, live on land and in water (Budel, 2010; Pridmore & Etheredge, 2010), produce extracellular polymeric substances (Song et al., 2015) and are not able to fix nitrogen, are important as food, feed, fuel, fertilizer, medicine and combating pollution (Jeyachitra et al., 2013), similar to diatoms (Munir et al., 2013). Besides, the species of C. dispersus also show antimicrobial activity (Ghasemi et al., 2007) and contain more than two hundred type II restriction endonucleases (Lyra et al., 2000).

There is great morphological diversity among the members of family Chroococcaceae. Their diversity and occurrence in the ponds, puddles, water channels from all provinces of Pakistan was studied (Ghose, 1919, 1924; Faridi, 1970, 1971; Ali & Sandhu, 1972; Masud-ul-Hassan, 1978a; b; Farzana & Nizamuddin, 1979; Leghari & Arbani, 1983, 1984; Shameel & Butt 1984; Leghari et al., 2000, 2001; Naz et al., 2003, 2004; Janjua et al., 2009). However, members of Chroococcaceae were investigated rarely from the Pakistani lakes, including Manchar Lake (Mahar et al., 2009), Keenjhar Lake (Lashari et al., 2014), Sonhoro, Mehro Pateji and Cholari Lakes (Leghari et al. 2000). All previous endeavors altogether have reported approximately 41 species of Chroococcus while this work contributes five new records to the existing list and also presents their geographical distribution.

Materials and Methods

The Kallar Kahar Lake (located between 32° 46’ 30.31” North, 72° 42’ 23.80” East in the District Chakwal, Punjab, Pakistan) was thoroughly explored in different seasons for the collection of Chroococcus species. Seven sites were selected to collect algal samples from surface water as well as from different substrates present in the Lake. The opaque plastic bottles were used for sample collection, labeled and preserved with 3% formalin (Munir et al., 2013). Each sample was homogenized using Homogenizer and one drop of sample was taken and placed on the glass slide, covered with glass cover slip and observed under Leica DMLB microscope®. Various objectives were used for the magnification of images. Microphotographs were captured at 100X objective and 10X eyepiece. The algal taxa were identified using algal floristic materials (Desikatchery, 1959; Prescott, 1962; Komarek & Angnositidis, 1999).

Results and Discussion

Taxonomic evaluation of the collected material indicated the presence of 18 species of Chroococcus. Their taxonomic descriptions and systematic treatment is as follows:

Chroococcus Nageli 1849

Single or colony of 2-32 cells, free floating or attached to various substrates, with a common mucilage, hyaline or colored; ovate, spherical or hemispherical; each cell has an individual envelope; cell content granular; vacuole absent.

1. C. varius A. Braun in Rabenhorst 1861, (Plate 1: Fig. P)

Source of identification: Komarek & Angnositidis, 1999, p. 293, Plate 1: Fig. 387

General characters: Cell diameter 2.7 µm; colonized with single cell or group of 2-4 cells with individual lamellate or homogenate envelope; cell pale blue green. Colonies microscopic or large, macroscopic, slimy or gelatinous, colorless and dirty olive-green or brownish.

Habitat/ Occurrence: It was collected from the Lake growing as metaphyton during October 2011.

Geographical distribution: Spain (Cuzman et al., 2010: 92), China (Liu, 2008), India (Samad & Adhiakary, 2008: 97), Nepal (Rai et al., 2010: 337) and Pakistan (Barkatullah et al., 2013: 331; Naz et al., 2004: 256; Husna et al., 2005: 146; Leghari et al., 2005: 155).
Key to species

1a. Colonies macroscopic:
2a. Envelop indistinctly lamellate or homogeneous ....................................................... 1. C. varius
2b. Envelop not lamellate:
31. Cells in 2-8-celled groups ......................................................................................... 2. C. cohaerens
3b. Cells in 2-4-celled groups;
41. Envelopes narrow, sometimes diffuent ................................................................. 3. C. limneticus
4b. Envelopes firm, delimitated ......................................................................................... 4. C. lithophilus
1b. Colonies microscopic:
5a. Cells 2-4 in colony:
6a. Diameter 13-27 µm .................................................................................................. 5. C. westii
6b. Diameter 0.8-1 µm .................................................................................................... 6. C. subtilissimus
7a. Cells spherical or slightly elongate, or hemispherical ................................................ 7. C. planctonicus
7b. Cells triangular or variable in shape ........................................................................... 8. C. polyedriformis
8a. Cells blue green ........................................................................................................... 9. C. schizodermaticus
8b. Cells pale blue-green ................................................................................................. 10. C. minor
5b. Cells 4-16-32 in colony:
9a. Cells irregularly, sparsely or almost densely arranged .............................................. 11. C. dispersus
9b. Cells more or less regularly arranged ........................................................................ 12. C. minimus
10a. Aerotope present one large, more or less central ...................................................... 13. C. vacuolatus
10b. Aerotope absent ........................................................................................................ 14. C. microsphericus
11a. Cells arrangement in cubic or sarcinoid clusters ...................................................... 15. C. prescottii
11b. Cells arrangement typical chroococcoid ................................................................. 16. C. thermalis
12a. Cell solitary or in microscopic colony, more or less spherical or oval ................. 17. C. minutus
12b. Cells rarely solitary, spherical or widely oval ......................................................... 18. C. turgidus

2. C. cohaerens (Brebisson) Nageli 1849, (Plate 1: Fig. C)

Source of Identification: Komarek & Anagnostidis, 1999, P. 294, Plate 1: Fig. 385
Synonym: Chroococcus bituminosus (Bory) Hansgirg 1892
General characters: Cell length 1.7µm, diameter 2.5 µm; cells hemispherical, in 2-8-celled groups or forming micro- or macroscopic colonies, which are gelatinous, amorphous, dirty green; mucilage colorless; envelope not lamellate.

Habitat/ Occurrence: Specimen was collected from water surface in January 2011.

Geographical distribution: Britain (John et al., 2011), Romania (Caraus, 2012: 524), China (Chu & Tiffany, 1951: 712), Pakistan (Hussain et al., 1984: 82; Anjum et al., 1986: 120; Sarim et al., 1998: 118; Naz et al., 2004: 256; Husna et al., 2005: 144; Leghari et al., 2006: 34); Bangladesh (Hasan, 2012: 186) and India (Nandan & Ahuja, 2010)

3. C. limneticus Lemmermann 1898, (Plate 1: Fig. K)

Source of Identification: Komarek & Anagnostidis, 1999, P. 291, Plate 1: Fig. 382

General characters: Cell diameter 5.9 µm; cells spherical or hemispherical; envelop not laminate, narrow sometimes diffused and indistinct. Colonies free floating, mucilaginous, spherical or irregular with 2-4 cells.

Habitat/ Occurrence: This species was collected from the lake as metaphyton during spring and summer seasons.

Geographical distribution: Portugal (Figueiredo et al., 2006: 149); Egypt (El-Karim, 2008: 347), Turkey (Verol & Sen, 2014), Pakistan (Barkatullah et al., 2013: 331; Mehwish & Aliya, 2005: 118; Leghari et al., 2005: 39; Leghari et al., 2005: 155; Leghari et al., 2006: 34; Hussain et al., 2008: 150; Anjum et al., 1986: 120), India (Nandan & Ahuja, 2010: 133), Nepal (Rai et al., 2010: 337) and Sri Lanka (Silva et al., 2013: 96).

4. C. lithophilus Ercegovc 1925, (Plate 1: Fig. F)

Source of Identification: Komarek & Anagnostidis, 1999, P. 301, Plate 1: Fig. 397
General characters: Cell diameter 5 µm, hemispherical; envelope firm, delimited, thin, not lamellate and colorless; colonies micro or macroscopic, free floating, blue green.

Habitat/ Occurrence: Free floating colonies were collected from the water surface in July 2011.

Geographical distribution: Rome (Bellinzoni et al., 2003: 205), China (Chu & Tiffany, 1951: 712), Pakistan (Munir et al., 2008: 217) and India (Samad & Adhikary, 2008: 97).

5. C. westii Boye-Petersen 1929, (Plate 1: Fig. I)

Source of Identification: Komarek & Anagnostidis, 1999, P. 304, Plate 1: Fig. 403

General characters: Cell diameter 12.9-27 µm; colony with 2-4 cells with individual concentrically lamellate envelope; cell hemispherical, blue green with granular content.

Habitat/ Occurrence: Collected from wet rocks in the Lake in summer.

Geographical distribution: Romania (Caraus, 2012: 18), Oman (Abed et al., 2013: 1438), China (Zhang et al., 2010: 183; 2011: 283) and Pakistan (Leghari et al., 2005: 169).
6. *C. subtilissimus* Skuja 1937, (Plate 1: Fig. Q)

**Source of identification:** Komarek & Anagnostidis, 1999, P. 294, Plate 1: Fig. 386

**General characters:** Cell diameter 0.8 µm; irregular colony of 2-4 closely packed cells, mucilaginous; cells blue green, discoid, spherical or hemispherical; envelope not lamellate.

**Habitat/ Occurrence:** *C. subtilissimus* was collected from the submerged rocks in the Lake.

**Geographical distribution:** Greece (Komarek & Anagnostidis, 1999: 293).

7. *C. planctonicus* Bethge 1935 (Plate 1: Fig. A)

**Source of identification:** Komarek & Anagnostidis, 1999, P. 285, Plate 1: Fig. 372

**General characters:** Cell diameter 4.4 µm, cells in group of 2 or 4, spherical or slightly elongate or hemispherical, round, pale blue green and with aerotopes; individual cell envelop absent.

**Habitat/ Occurrence:** *C. planctonicus* occurred as epiphyte, lithophytes and metaphytone during winter and summer.

**Geographical distribution:** Argentina: (Navarro & Modenutti, 2012: 192), Clipperton Island (Charpy et al., 2010: 777).

8. *C. polyedriformis* Schmidle 1902, (Plate 1: Fig. M)

**Source of identification:** Komarek & Anagnostidis, 1999, P. 309, Plate 1: Fig. 411

**Synonym:** *Chroococcus multicellularis* (Chu) Chu 1952

**General characters:** Cell length 4.2 µm, diameter 2.4 µm; colony microscopic, free floating, cell triangular or variable in shape enclosed in an envelope and blue green.

**Habitat/ Occurrence:** The cells of this Cynoabacterium were collected from lake among other filamentous algae as metaphyton during summer.

**Distribution:** Australia and New Zealand, (Bostock & Holland, 2010: 257), Mexico (Komarek & Novele, 1994: 3).

9. *C. schizodermaticus* W. & G. S. West 1892, (Plate 1: Fig. R)

**Source of identification:** Komarek & Anagnostidis, 1999, P. 290, Plate 1: Fig. 395

**General characters:** Cell diameter 11.4 µm diameter; colony of 2-4 cells, gelatinous; each cell envelope lamellate; cell irregular round, spherical or hemispherical and blue green.

**Habitat/ Occurrence:** During the summer it was collected from the rocks forming a mat.


10. *C. minor* (Kutzing) Nageli 1849, (Plate 1: Fig. E)

**Source of identification:** Komarek & Anagnostidis, 1999, P. 294, Plate 1: Fig. 388

**General characters:** Cell diameter 4.1 µm; colony microscopic 2-4 celled, irregular, mucilaginous wide; Cells spherical or hemispherical and pale blue-green; envelop scarcely visible.

**Habitat/ Occurrence:** This metaphyton was collected during January.

**Geographical distribution:** Saudi Arabia (El-Naggar, 1994: 205), Korea (Park, 2012: 10), China (Chu & Tiffany, 1951: 712), India (Mongra, 2013: 926), Nepal (Rai et al., 2010: 337), Pakistan (Barkatullah et al., 2013: 331; Leghari et al., 2005: 39; Leghari et al., 2006: 34) and AJK (Khuhawat et al., 2009: 1910).

11. *C. dispersus* (Keissl.) Lemmermann 1904, (Plate 1: Fig. D)

**Source of identification:** Komarek & Anagnostidis, 1999, P. 286, Plate 1: Fig. 373

**Synonym:** *Chroococcus limneticus* var. subalbus

**Geographical distribution:** Europe, America (Munawar et al., 2009: 1016), China (Shams et al., 2012: 721; Chu and Tiffany, 1951: 712), Egypt (El-Sheekh et al., 2010: 2626), Pakistan (Mehwish & Aliya, 2005: 115; Leghari et al., 2005: 155; Leghari et al., 2006: 34; Mehwish & Aliya, 2006: 150), Bangladesh (Khondker et al., 2006) and Sri Lanka (Pathmalal & Piyasiri, 1995: 33).

12. *C. minimus* (Keissl.) Lemmermann 1904, (Plate 1: Fig. L)

**Source of identification:** Komarek & Anagnostidis, 1999, P. 285, Plate 1: Fig. 371

**Synonym:** *Chroococcus minatus* var. minimus

**Geographical distribution:** Europe, America (Munawar et al., 2009: 1016), China (Chu & Tiffany, 1951: 712), Egypt (El-Sheekh et al., 2010: 2626), Pakistan (Mehwish & Aliya, 2005: 115), Bangladesh (Khondker et al., 2006) and Sri Lanka (Pathmalal & Piyasiri, 1995: 33).

13. *C. vacuolatus* Skuja 1939, (Plate 1: Fig. S)

**Source of identification:** Komarek & Anagnostidis, 1999, P. 285, Plate 1: Fig. 370
Phragmites karka

Habitat/ Occurrence: C. vacuolatus appeared in January as planktonic species in stagnant water along with Phragmites karka.

Geographical distribution:

Habitat/ Occurrence: Romania (Caraus, 2012: 1525). 


14. C. microscopicus Komarkova-Legnerova et Cronberg, (Plate 1: Fig. J)

Source of identification: Komarek & Anagnostidis, 1999, P. 285; Plate 1: Fig. 367

General characters: Colonies microscopic, free floating irregular or spherical, pale blue green; Cell diameter 1 µm; cell spherical or irregular, 2-many cells together, sheath distinct, aerotopes absent; mucilage colorless and delicate.

Habitat/ Occurrence: C. microscopicus was found growing as metaphyton year round in the Lake.


15. C. prescottii Drouet & Daily 1942, (Plate 1: Fig. B)

Source of identification: Komarek & Anagnostidis, 1999, P. 288; Plate 1: Fig. 379

Synonym: Chroococcus gomontii Nygaard sensu auctorum; Eucapsis alpina Sieminska 1967

General characters: Colony microscopic, free floating, irregular, oval to spherical or almost sub spherical; cells enclosed in delimited envelope, often slightly lamellate; cell spherical or hemispherical with granular content, bright blue green, arranged in cubic or sarcinoid clusters; Cell diameter 3.8 µm.

Habitat/ Occurrence: This Cyanobacterium appeared in winter and summer as planktonic species.

Geographical distribution: Argentine (Mataloni & Tell, 1996: 103), Korea (Park, 2012: 10) and Pakistan (Leghari et al., 2009: 157).

16. C. thermalis (Maneghini) Nageli 1849, (Plate 1: Fig. H)

Source of identification: Komarek & Anagnostidis, 1999, P. 303; Plate 1: Fig. 401

Synonym: Chroococcus turgidus sensu auct.; Pleurococcus thermalis Meneghini 1837; Protococcus thermalis (Meneghini) Kützing 1846; Chroococcus turgidus var. thermalis (Meneghini) Rabenhorst ex Hansgirg1892; Chroococcus yellowstonensis Copeland 1936.

General characters: Cell diameter 9.4 µm; colony of 2, 3 or 4 cells with colorless indistinct mucilage; cells round, hemispherical, blue green with granular content, cell arrangement typical chroococcoid.

Habitat/ Occurrence: This species was collected from submerged rocks in July among other cyanobacteria.


17. C. minutus (Kützing) Nageli 1849, (Plate 1: Fig. N, O)

Source of identification: Komarek & Anagnostidis, 1999, P. 297; Plate 1: Fig. 391

Synonym: Protococcus minutus Kützing 1843; Chroococcus virescens Hantzsch in Rabenhorst 1865; Gleocapsa minuta (Kützing) Hollerbatch in Elenkin 1938.

General characters: Cell diameter 9.6 µm; solitary or form microscopic colony; cell spherical, oval or hemispherical, yellow blue green with granular content, enclosed by a wide and distinct margin and granular content.

Habitat/ Occurrence: This species was collected throughout the year in 2011 growing as metaphyton.

Geographical distribution: Spain (Cuzman et al., 2010: 92), Portugal (Figueiredo et al., 2006: 149), Korea (Park, 2012: 10), Saudi Arabia (El-Naggar, 1994: 205), Egypt: (El-Shekh et al., 2010: 2626), Turkey (Verol & Sen, 2014), China (Chu & Tiffany, 1951: 712), India (Choudhary, 2009: 59), Nepal (Rai et al., 2010: 337), Pakistan (Naz et al., 2004: 256; Leghari et al., 2005: 39; Husna et al., 2005: 144; Leghari et al., 2006: 34; Gul et al., 2007: 39; Hussain et al., 2008: 150; Munir et al., 2008: 217) and AJK (Khuwawar et al., 2009: 1910).

18. C. turgidus (Kützing) Nageli 1849 (Plate 1: Fig. G)

Source of identification: Komarek & Anagnostidis, 1999, P. 307; Plate 1: Fig. 407

Synonym: Chroococcus dimidiatus (Kützing) Nageli 1849; Anacystis dimidiata (Kützing) Drouet & Daily 1952; Gleocapsa turgida (Kützing) Hollerbatch in Elenkin 1938, Chroococcus turgidus var. maximus Nygaard 1926.

General characters: Cell diameter 7.3 µm; colony of 2-8 cells, colorless, mucilaginous envelope around each cell or group of cells; individual cell lamellate; cell oval, hemispherical or segment of a sphere; dark blue green with granular content.

Habitat/ Occurrence: It was found as metaphyton with a lot of vegetation in stagnant lake water during summer and autumn months.

Geographical distribution: Europe: Spain (Cuzman et al., 2010: 92), Portugal (Figueiredo et al., 2006: 149); Korea (Park, 2012: 10), Turkey (Verol & Sen, 2014); China (Chu & Tiffany, 1951: 712), India (Mahajan & Mahajan, 1988: 50), Nepal (Rai et al., 2010: 337), Pakistan (Naz et al., 2004: 256; Husna et al., 2005: 146; Mehwish & Aliya, 2005: 118; Leghari et al., 2005a: 39; Leghari et al., 2005b: 155; Leghari et al., 2006: 34; Mehwish & Aliya, 2006: 150; Anjum et al., 1986: 120) and AJK (Khuwawar et al., 2009: 1910).

Plate 1. Microphotographs of *Chroococcus* species recorded from the Kallar Kahar Lake, Chakwal.
Conclusion

The *Chroococcus* species inhabit in fresh, brackish and marine water in tropical and temperate regions across the world due to their broad ecological amplitude and preference for a variety of habitats. This study recorded 18 *Chroococcus* species, including 5 new records viz., *C. microscopicus*, *C. planctonicus*, *C. polyedriformis*, *C. subtilissimus* and *C. vacuolatus* for Pakistan and South Asian countries. Molecular studies are recommended to further ascertain its taxonomic complexities (Afzal et al., 2015).

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Algaebase: http://www.algaebase.org


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