Phenotype diversity of the cyanoprokaryotic genus *Cylindrospermopsis* (Nostocales); review 2002.

Přehled (fenotypová diversita) cyanoprokaryotního rodu *Cylindrospermopsis* (Nostocales); stav v roce 2002.

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Abstract

The cyanobacterial/cyanoprokaryotic nostocalean planktic genus *Cylindrospermopsis* (type species = *C. raciborskii*) was originally described as *Anabaena* by WOŁOSZYŃSKA (1912), later included in the genus *Anabaenopsis* (terminal heterocytes) by ELENKIN (1923), and at last separated as a special genus by SEENAYYA & SUBBA RAJU (1972) in respect to special trichome morphology and a special strategy of trichome development. It has a pantropical distribution. Eight new species were described recently, mainly from tropical freshwater planktic habitats. *C. raciborskii* has tendency to invade intensely temperate zones, where it forms heavy water-blooms, particularly in warmer regions. The intense production of toxic compounds was detected in this species, which classifies it among important and ecologically remarkable cyanobacteria requiring careful studies. The present paper yields a short current literary review of phenotype diversity of this genus, as a background to the further investigation. This study was supported by the grants EU-"MIDI-CHIP" no. EVK2-1999-00213, K6005114 and A6005380.

History

The type species of the cyanobacterial planktic nostocalean genus *Cylindrospermopsis* (*C. raciborskii*) was originally described as *Anabaena* by WOŁOSZYŃSKA (1912) from lakes in Java, Indonesia (**Fig. 1**). Later on, this species was transferred by ELENKIN (1923) in the genus *Anabaenopsis* (described by MILLER 1923) respecting the formation of terminal heterocytes. Under this generic name other related taxa indicating the wide diversity of this cyanobacterial type were described (TAYLOR 1932, GEITLER & RUTTNER 1935, SZALAI 1942, PRESCOTT & ANDREWS 1955, KOGAN 1956, CLAUS 1961, OBUCHOVA & KOSENKO 1964, HAMAR 1977). Similar populations were

described also as members of related genera, e.g., *Aphanizomenon kaufmannii* SCHMIDLE in BRUNNTHALER (1914) from Egypt (river Nile) and *Cylindrospermum doryphorum* BRUHL & BISWAS (1922) from India. This whole cluster of taxa (**Fig. 2**) is presented in various extends in all the following manuals, usually under the generic name *Anabaenopsis* or under original generic and specific names (e.g., in GEITLER 1932, HUBER-PESTALOZZI 1938, DESIKACHARY 1959, STARMACH 1966, KONDRATEVA 1968). The current synonymics was reviewed by DROUET (1978; under *Anabaenopsis*).

In 1972, SEENAYYA & SUBBA RAJU separated the genus *Cylindrospermopsis* (with only one species *C. raciborskii*) from *Anabaenopsis*, respecting the special trichome morphology and a special heterocyte and trichome development as important generic characters. Asymmetrical division of cells before the heterocyte formation in both genera *Anabaenopsis* and *Cylindrospermopsis* is principally similar (SINGH 1962); however, whereas heterocytes arise primarily metamerically in twins in *Anabaenopsis*, the heterocytes in *Cylindrospermopsis* develop solitary after the asymmetrical division from primarily terminal cells (**Fig. 3**). The validity of the genus *Cylindrospermopsis* was supported by 16S rRNA sequencing (WILSON & al. 2000, RUDI & al. 1997, SCHEMBRI & al. 2001, CASTENHOLZ 2001, International Data Bank 2002) (**Fig. 4**). Several other *Cylindrospermopsis* species mainly from tropical or warm temperate freshwater biotopes were recognized and described in the last years (KOMÁREK & KLING 1991, WATANABE 1995, KOMÁRKOVÁ-LEGNEROVÁ & TAVERA 1996, KOMÁREK & KOMÁRKOVÁ-LEGNEROVÁ 2002, COUTÉ & al. 2003, CRONBERG & KOMÁREK 2003); in majority of them the authors found wide distribution and variability. Recent morphological details of this genus were published in KOMÁREK & ANAGNOSTIDIS (1989), KOMÁRKOVÁ (1998), KOMÁREK (2002) and COUTÉ & al. (2003).

Morphological description of the genus

Filaments free-floating, solitary, straight, bent or screw-like coiled, in several species narrowed towards ends, without sheaths. Trichomes isopolar (heteropolar only in trichomes with only one heterocyte), subsymmetrical, with or without constrictions at cross-walls. Cells are cylindrical or barrel-shaped, usually distinctly longer than wide, pale blue-green, yellowish or olive-green, facultatively with aerotopes; end cells are conical or bluntly or sharply pointed. Heterocytes only terminal, oval, ovoid or conical, sometimes slightly curved and drop-like, unipored; they develop after ± asymmetrical division of the end cells, usually asynchronously at both ends of the trichome. Akinetes are ellipsoidal or cylindrical, in coiled specimens usually slightly curved, developing usually slightly distant from heterocytes, rarely adjacent to apical heterocytes. Reproduction by trichome fragmentation and by akinetes. – Nine species are

recently accepted (**Fig. 3**), but more morphotypes can be recognise in future (comp. **Fig. 2**).

Distribution

Cylindrospermopsis is primarily a tropical genus. The type species, "*Anabaena*" (= *Cylindrospermopsis*) *raciborskii*, was found and described in 1912 from Indonesia (Java), and this species was later recorded under various names from almost all tropical regions, from India (BRUHL & BISWAS 1922, DESIKACHARY 1959, SINGH 1962, HORTOBÁGYI 1969, SEENAYYA & SUBA RAJU 1972), Philippines (TAYLOR 1932, BEHRE 1956: fa. *maior* and fa. *minor*), Egypt (BRUNNTHALER 1914), Japan (NEGORO 1953), Brazil (CRONBERG 1978, BRANCO & SENNA 1991, SANT'ANNA 1991, BOUVY & al. 2000), Cuba (KOMÁREK 1984), Australia (HAWKINS & al. 1985, BAKER & FABBRO 1995), etc. Recently, numerous data exist about heavy water blooms of the pantropical *Cylindrospermopsis raciborskii* from the whole tropical Asia, Africa, Australia, central and South America and from numerous Oceanic Islands. Moreover, the 7 new common *Cylindrospermopsis* species described in the period of 1990-2003, almost all spread in different areas of tropical regions, prove the diversification ability and ecological potential of this genus.

Another indication of development and vitality of *Cylindrospermopsis* is the invasive pressure of *C. raciborskii* into temperate zones, and the formation of different morphotypes in different parts of its wide geographic area. Already KOGAN (1956), OBUCHOVA & KOSENKO (1964) and PROŠKINA-LAVRENKO & MAKAROVA (1968) described several species from central Asia (Turkmenistan, Kazakhstan, Caspic Sea), which all belong to the vicinity of *C. raciborskii*, but their stability and relations are unclear (**Fig. 2**). In 1955, PRESCOTT & ANDREWS described one probably *Cylindrospermopsis* species from Kansas (Wooster Lake) in North America (*Anabaenopsis seriata*). Later, since the studies of HILL (1970, from Minnesotta lakes), several north American localities of *Cylindrospermopsis* are known, particularly from southern states of USA and Mexico. The first European record of *C. raciborskii* (sub *Anabaenopsis*) was published probably by SKUJA (1937) from the lake Kastoria in Greece (**Tab. 6B**). In 1942, SZALAI registered the first population of *Cylindrospermopsis* from Hungary (*Anabaenopsis raciborskii* var. *longiscellula*; **Fig. 2H**). Further populations from Pannonian district were registered by HAMAR (1977), JEEJI BAI & al. (1977), SCHMIDT (1977), HORECKÁ & KOMÁREK (1979), PADIŠÁK (1991, 1997) and others. *C. raciborskii* forms now common regular populations in the lowland of Danube river. KONDRATEVA (1968) recorded localities from southern Ukraine (Odessa district, basin of Danube river) and AKSENOVA (1974) from the river Don. Further records are known from lakes in Danube delta (KAŠTOVSKÝ, orig. data). The species collected also from Slovakia and

Moravian part of the Czech Republic by HINDÁK (1988), and from Austria by CLAUS (1961; "*Anabaenopsis woloszynskae*"; **Fig. 2G**) DOKULIL & MAYER (1996), and DOKULIL & TEUBNER (2000). In 2002 there were reported localities also from Germany (NIXDORF and MISCHKE, pers. comm.). The next European localities are known from Italy (VENTURA pers. comm.), and from central and southern France (COUTÉ & al. 1997, 2003) (**Fig. 5**).

Diversity and variability

The morphological variability of *Cylindrospermopsis* is wide, as results from changes, recognized during the life cycles (KOMÁRKOVÁ & al. 1999), from diversity of populations of most common species (*C. raciborskii*, but also *C. cuspis* and *C. africana*; SINGH 1962, HORECKÁ & KOMÁREK 1979, KOMÁREK 1984, HINDÁK 1988, FABBRO & al. 1996, and many others), and from the common infrageneric variability (**Fig. 2, Tab. 1-2**). The wide variation in straight and coiled filaments follows already from the first description of WOŁOSZYŃSKA (1912) (**Fig. 1**).

The coiling is commonly considered as particularly variable, non-taxonomic character. In spite of it, few species were characterized by mainly straight or coiled trichomes. From this point of view, the most problematic are the separating features between *C. raciborskii* and *C. philippinensis*. The coiling itself can hardly be the diacritical feature between the mentioned species, because also the populations with completely coiled filaments appear in *C. raciborskii* (BAKER & FABBRO 1999). The differences between these types must be revised in future; however, the existence of *C. philippinensis* could be supported by other characters than coiling (**Tab. 1**). Both coiled and ± straight filaments occur in majority of morphospecies, and the revision of the stability of other morphological characters is therefore important (**Tab. 2**). The main studies of this phenomenon are included in papers of BOOKER & WALSBY (1979), KOMÁREK (1984), KOMÁRKOVÁ-LEGNEROVÁ & TAVERA (1996), KOMÁRKOVÁ (1998), SAKER & al. (1999), MCGREGOR & FABBRO (2000), CRONBERG & KOMÁREK (2003), etc.

Other changes in morphology can arise under stress conditions (high conductivity, lack of nutrients, etc; FABBRO & al. 1996, KOMÁRKOVÁ & al. 1999, MCGREGOR & FABBRO 2000); such populations are characterized mostly by irregularly undulated filaments (KOMÁRKOVÁ & al. 1999). However, COUTÉ & al. (2003) described similar stable type with flexuous trichomes, as a special species from southern France. The variability and stability of characters in various *Cylindrospermopsis*-types is not well known yet.

Ecology

All *Cylindrospermopsis* species are known from plankton of freshwater eutrophic reservoirs in tropical, subtropical or temperate regions (in summer), where they form sometimes water-blooms. In tropics, the appearance is often connected with nitrogen limitation of phytoplankton. With increasing data about distribution and importance appeared a necessity of detailed autecological studies of *C. raciborskii*. We select several important ecological articles for information: BAXTER (1996), BORMANS (1999), DOKULIL & MAYER (1996), FABBRO & DUIVENVOORDEN (1996), PADISÁK (1991, 1999, 2002), PRÉSING & al. (1996), KOMÁRKOVÁ & al. (1999), GORZÓ (1987), VÖRÖS (1995).

Significance

As a water-bloom forming species, *Cylindrospermopsis* (particularly *C. raciborskii*) belongs to important dominant cyanobacterial plankters of eutrophic reservoirs in all tropical regions, and recently also in temperate zone. Majority of populations produce cyanotoxins (cylindrospermopsin), which insert this genus among the most important cyanobacterial types in the present water management. Already wide literature exists about toxicity of *Cylindrospermopsis* (see special papers); we list here only the basic titles (in an alphabetic order): BAKER (1996), CARMICHAEL & al. (2001), CHISWELL & al. (1999), CHORUS & BARTRAM (1999), EAGLESHAM & al. (1999), FALCONER (1996), FALCONER & al. (1999), FRANCIS (1878), HAWKINS & al. (1985), LAGOS & al. (1997, 1999), MCGREGOR & EVERDING (1998), OHTANI & al. (1992), SEAWRIGHT & al. (1999), SAKER & EAGLESHAM (1999), SCHEMBRI & al. (2001), SENOGLES & al. (2000), SHAW & al. (1999, 2000), SKULBERG & al. (1993), THOMAS & al. (1998), VÖRÖS (1995) and many others. The review of phenotype diversity and further study of *Cylindrospermopsis* in nature is most requested, as the existence of all the described species should be verified. Vice versa, *Cylindrospermopsis* is very plastic, and new types can be recognised. Basic images for such a studies are given in this paper.

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Fig. 1. Original drawings of „*Anabaena* (*Anabaenopsis*) *raciborskii*" by WOŁOSZYŃSKA (1912), with two distinct morphotypes: **a** – with coiled trichomes without constrictions at the cross walls and with longer cells, **b** – with more or less straight trichomes, with shorter cells and usually with constrictions at the cross walls.

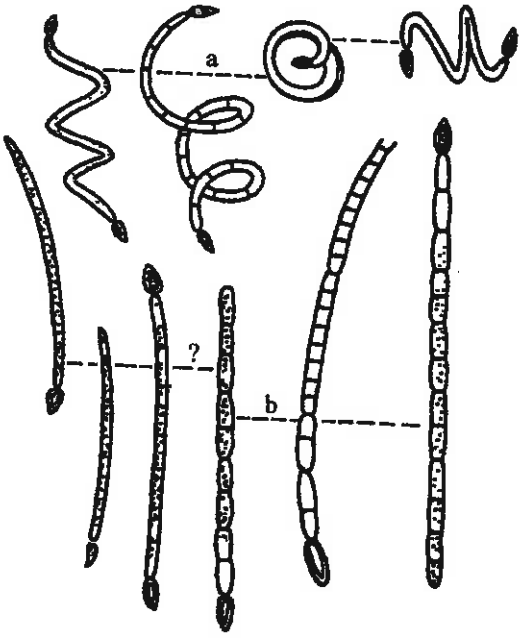


Fig. 2. Main *Cylindrospermopsis*-like taxa, described in the period 1914 to 1980: **A.** *Anabaenopsis koganii* OBUCHOVA et KOSENKO 1964 (**a** – after SINGH 1962, **b** – after KOGAN 1956). – **B.** *Anabaenopsis wustericum* OBUCHOVA et KOSENKO 1964 (**a** – after OBUCHOVA & KOSENKO 1964, **b** – after PRESCOTT & ANDREWS 1955). – **C.** *Anabaenopsis maksimilianii* OBUCHOVA et KOSENKO 1964 (after OBUCHOVA & KOSENKO 1964). – **D.** *Anabaenopsis seriata* PRESCOTT et ANDREWS 1955 (after PRESCOTT & ANDREWS 1955). – **E.** *Cylindrospermum* (?) *kaufmannii* (SCHMIDLE) HUBER-PESTALOZZI 1938 (after BRUNNTHALER 1914). – **F.** *Cylindrospermum doryphorum* BRUHL et BISWAS 1922 (after BRUHL & BISWAS 1922). – **G.** *Anabaenopsis raciborskii* (*A. woloszynskae*) sensu CLAUS 1961 (after CLAUS 1961). – **H.** *Anabaenopsis raciborskii* var. *longiscellula* SZALAI 1942 (after SZALAI 1942). – From HUBER-PESTALOZZI (1938), SZALAI (1942), DESIKACHARY (1959), STARMACH (1966), and KONDRATEVA (1968).

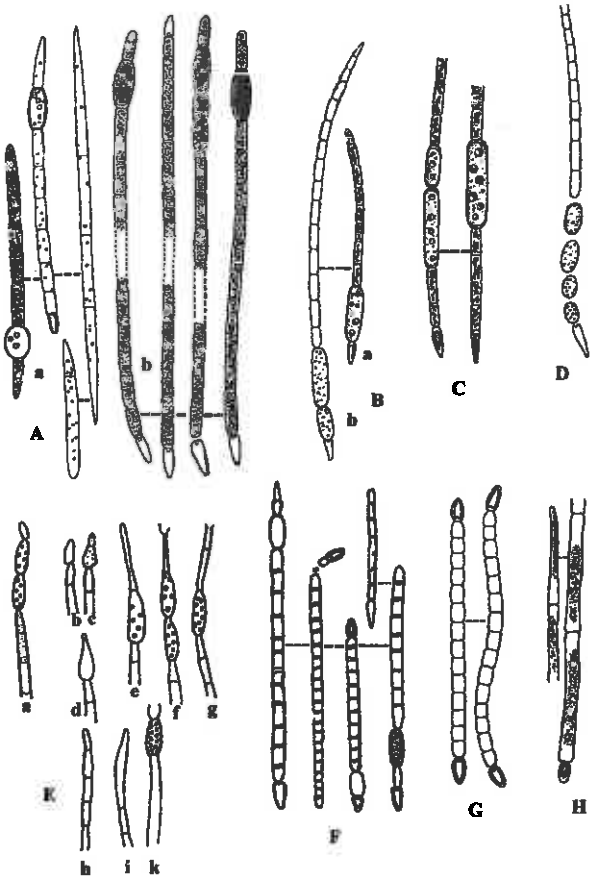
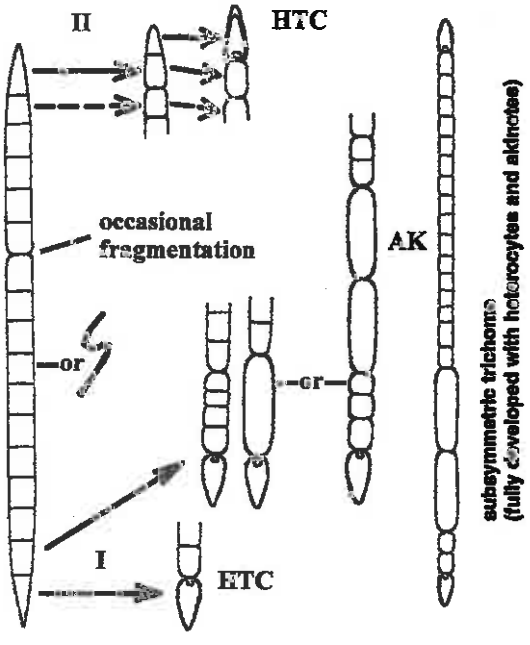


Fig. 3. Generic characters of *Cylindrospermopsis* (after KOMÁRKOVÁ 1998), and list of recently accepted species.



1. *C. africana* ..... Tab. 4
2. *C. cuspis* ..... Tab. 5
3a. *C. raciborskii* (selected drawings) ..... Tab. 6
3b. *C. raciborskii* (morphological variability) ..... Tab. 7
4. *C. sinuosa* ..... Tab. 8
5. *C. curvispora* ..... Tab. 9
6a. *C. philippinensis* (concepts of different authors) .... Tab. 10
6b. *C. philippinensis* (concept of recent authors) ..... Tab. 11
7. *C. taverae* ..... Tab. 12
8. *C. catemaco* ..... Tab. 13
9. *C. helicoidea* ..... Tab. 14

Fig. 4. Example of molecular evaluation (part of a distance tree) of heterocytous cyanobacterial genera according to SAITOU & NEI (1987) and VAN DE PEER & al. (1993); from CASTENHOLZ (2001). Important genera for our review are marked by arrows.

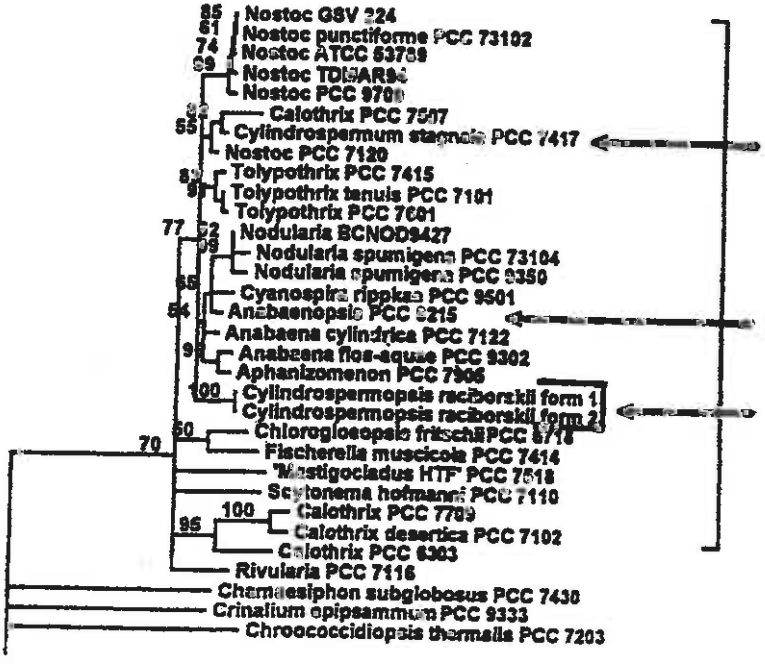
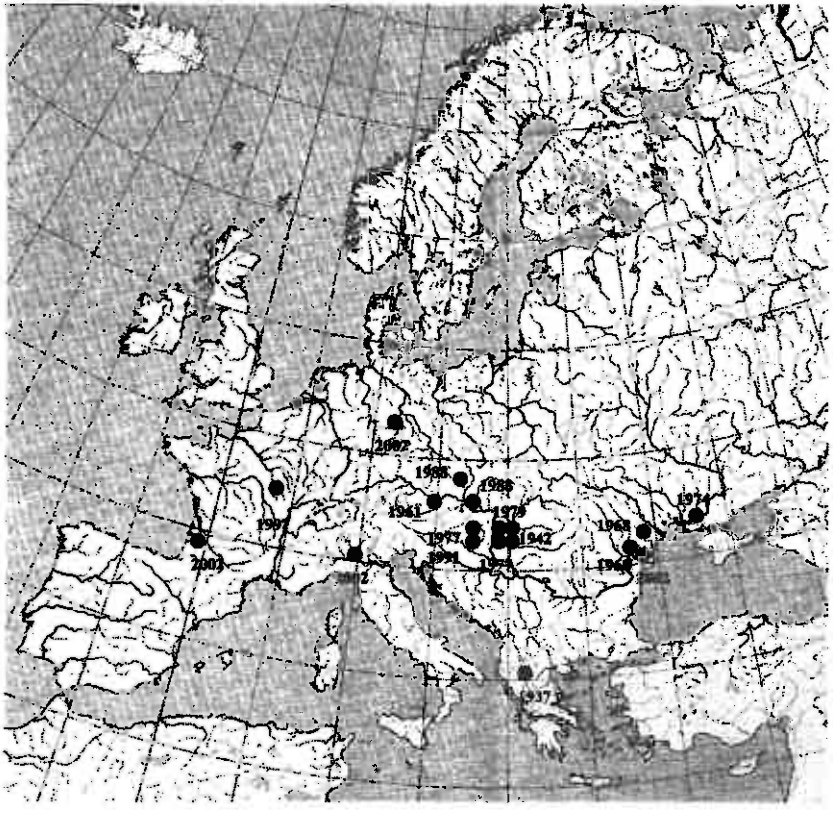


Fig. 5. Invasion of *C. raciborskii* in Europe. Main selected records.



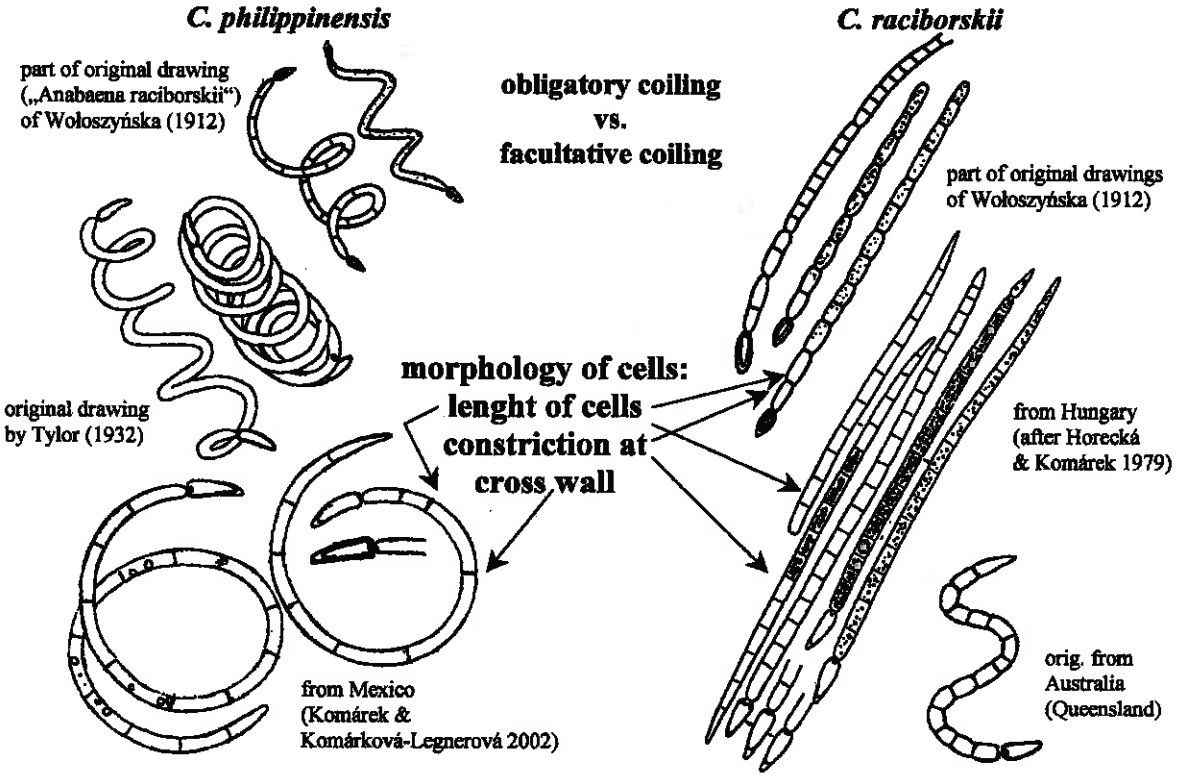


Table 1. Possible phenotype differences between *C. philippinensis* vs. *C. raciborskii*.

	straight or bent	flexuous or screw-like	coiled	known akinetes
				
C. africana				+
C. cuspis				
C. raciborskii Australian populations				+
C. sinuosa				+
C. curvispora				+
C. philippinensis				+
C. taverae				
C. catemaco				
C. helicoidea				

usual occurrence (whole populations)

occasionally common in populations

rare occurrence in populations of other type

solitary occurrence in populations of other type (exceptionally)

Table 2.
Occurrence of straight and coiled morphotypes in various *Cylindrospermopsis* species; presence of akinetes

Table 3. Key to the identification of accepted species.

1a Trichomes strictly cylindrical and mainly straight (very rarely arcuated or slightly screw like coiled), only the apical cell conical or pointed **2**
1b Trichomes straight, arcuated, screw-like or spirally coiled; if straight, slightly narrowed to ends **3**

2a Heterocytes ovoid or elliproidal, rounded; terminal cell rounded ..... *C. africana*
2b Heterocytes drop-like, pointed; terminal cells conical ..... *C. cuspis*

3a Trichomes mainly straight or flexuous, rarely bent or screw-like coiled **4**
3b Trichomes screw-like or spirally coiled, very rarely ± straight or bent **5**

4a Trichomes mainly straight or slightly arcuated, very rarely flexuous or screw-like coiled; heterocytes oval or ovoid, rounded at the end; cells 2.5-12(16) x 1.7-4 µm .. *C. raciborskii*
4b Trichomes obligatory flexuous; heterocytes drop-like, ± pointed at the end; cells 5-10 x 1.5-2 µm ..... *C. sinuosa*

5a Trichomes mainly in wide and low coiles ("circular" in outline) **6**
5b Trichomes distinctly screw-like coiled, sometimes very densely **7**

6a Cells 3.5-7 x 3.2-3.8 µm, trichomes slightly constricted at cross walls; akinetes usually in twos, rarely solitary, sausage-like arranged in the "center" of coiled trichomes .... *C. curvispora*
6b Cells (3.6)6-18(22) x (1.5)1.9-5 µm, trichomes unconstricted or very slightly constricted at cross-walls; akinetes occur rarely, usually solitary, rarely in twos, cylindrical and arcuated, joined to heterocytes in the trichome axis ..... *C. philippinensis*

7a Trichomes mainly screw-like coiled, very rarely straight, constricted at cross-walls; cells almost isodiametric up to 2-times longer than wide ..... *C. taverae*
7b Trichomes screw-like coiled or (rarely) irregularly flexuous, unconstricted at cross-walls; cells always more than 2-times longer than wide **8**

8a Trichomes freely screw-like coiled, pointed at the ends, 0.8-1.6 µm wide, elongated heterocytes in axes of trichomes, mainly only at one end of a trichome ..... *C. catemaco*
8b Trichomes usually densely coiled, rarely irregularly flexuous, rounded at the ends, 2-2.5 µm wide, umainly oval or ovoid, declined from the trichome axis, often at both ends of a trichome ..... *C. helicoidea*

Table 4.

Cylindrospermopsis africana **KOMÁREK et KLING, Algolog. Stud. 61: 38, 1991.**

Trichomes: cylindrical, mainly ± straight, very rarely screw-like coiled, in different populations constricted or unconstricted at cross walls.
Cells: cylindrical, 4.2-22.4 x 1 – 2.5 µm.
Apical cells: cylindrical and ± rounded.
Heterocytes: oval, ovoid or drop-like, rounded at the end.
Akinetes: rare, cylindrical with rounded ends, 8-15 x 2.5-4 µm.
Distribution: East and southern Africa.

A – after KOMÁREK & KLING (1991)
B – after CRONBERG & KOMÁREK (2003)

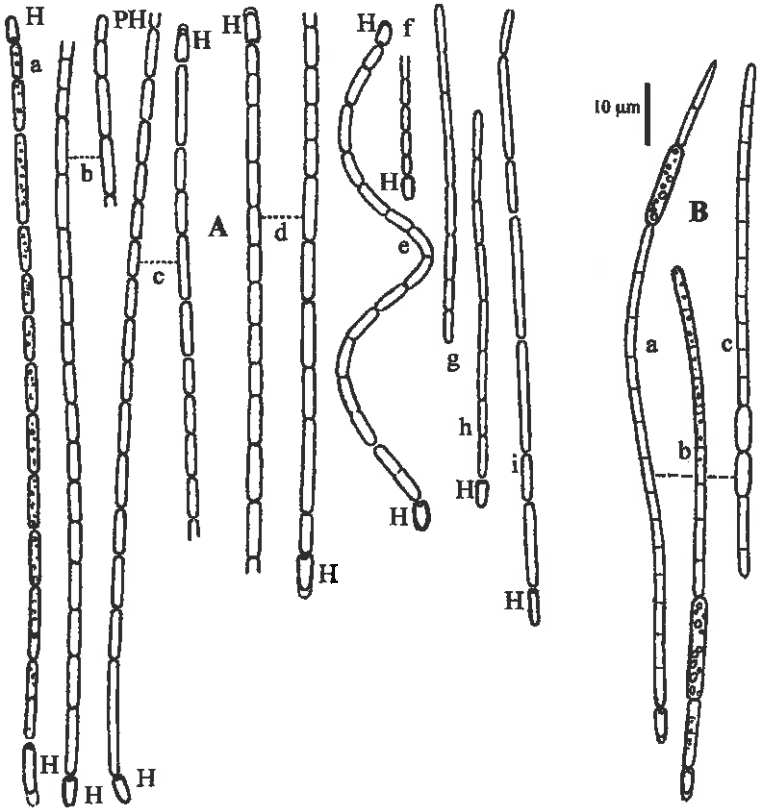


Table 5.

Cylindrospermopsis cuspis **KOMÁREK et KLING, Algolog. Stud. 61: 38, 1991.**

Trichomes: cylindrical, mainly ± straight, rarely slightly flexuous or irregularly screw-like coiled (Brazilian populations), slightly constricted at cross-walls.
Cells: cylindrical, 4.2-19.5 x 0.8-1.2 (-2.1 in Brazil).
Apical cells: cylindrical to narrowed and pointed et ends.
Heterocytes: drop-like to narrow-conical, pointed.
Akinetes: unknown
Distribution: trop. E Africa (large lakes), central America (Mexico, USA-Florida), Brazil.

A – after KOMÁREK & KLING (1991)
B – specimens from E Brazil (orig.)

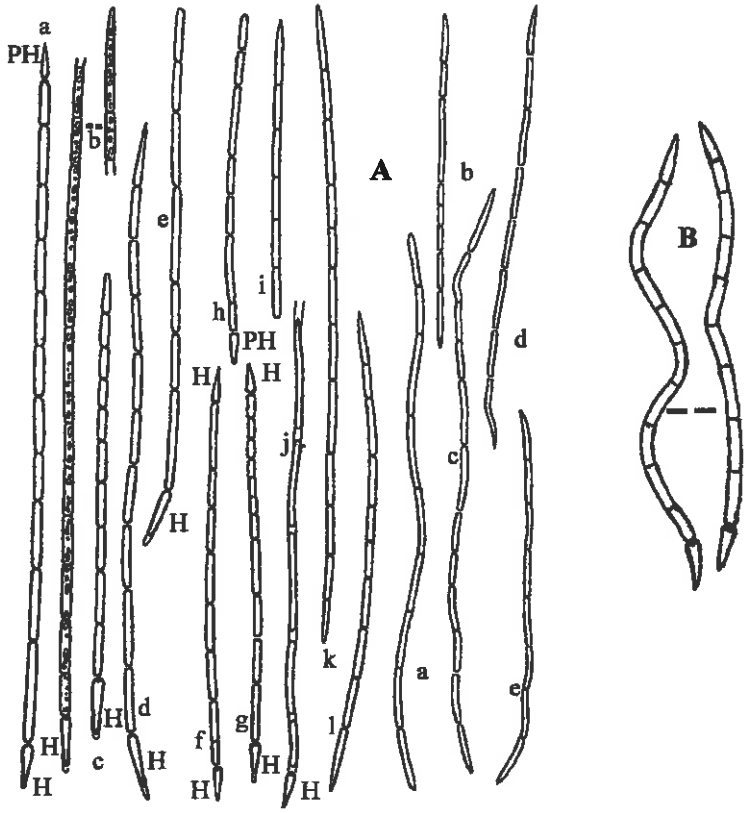
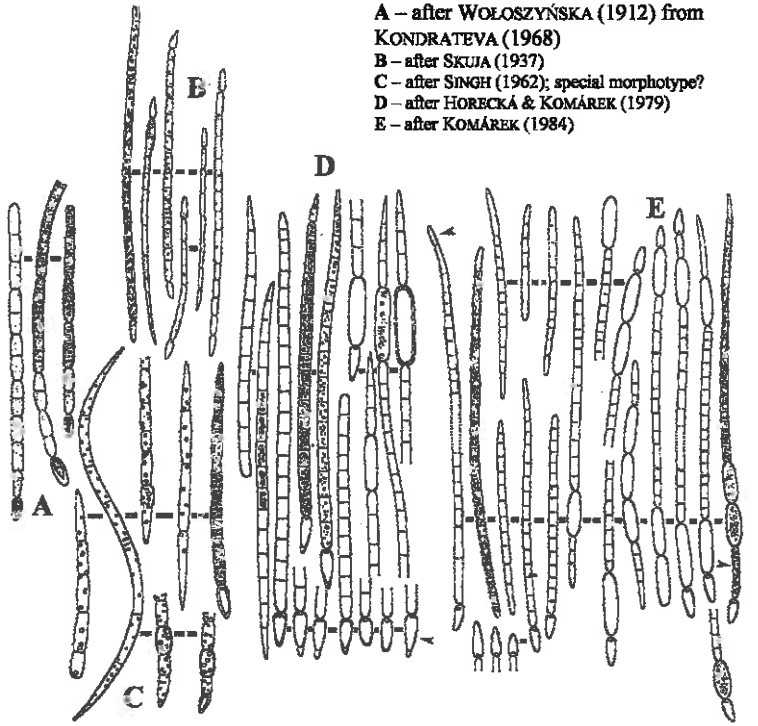


Table 6.

Cylindrospermopsis raciborskii **(WOŁOSZYŃSKA) SEENAYYA et SUBBA RAJU in DESIKACHARY ed., Taxon. Blue-green Algae, Madras, p. 55, 1972.**

Synonyms: *Anabaena raciborskii* WOŁOSZYŃSKA, Bull. Int. Acad. Sci. Cracovie, Ser. B, 6: 684, 1912 (basionym).
Anabaenopsis raciborskii (WOŁOSZYŃSKA) ELENKIN, Not. syst. Inst. crypt. Horti bot. Petropolit. 2(1-2): 73-75. 1923.

Trichomes: cylindrical, tapering to the ends, straight, slightly bent, less frequently irregularly screw-like coiled (esp. Australian populations), irregularly and indistinctly constricted at cross walls.
Cells: cylindrical to slightly barrel-shaped, 2.5-12(16) x (1.7)2-4 µm.
Apical cells: conically narrowed and rounded.
Heterocytes: drop-like, with rounded-pointed ends.
Akinetes: cylindrical-oval, (7)8.5-18(22) x (2.4)3-5(5.5)µm.
Distribution: pantropical, warmer regions of temperate zones, often forming water blooms.



A – after WOŁOSZYŃSKA (1912) from KONDRATEVA (1968)
B – after SKUJA (1937)
C – after SINGH (1962); special morphotype?
D – after HORECKÁ & KOMÁREK (1979)
E – after KOMÁREK (1984)

Table 7. *Cylindrospermopsis raciborskii*, morphological variability; A – populations and B – life cycle from Southern Brazil after KOMÁRKOVÁ & al. (1999), C – Australian populations, from BAKER & FABBRO(1999).

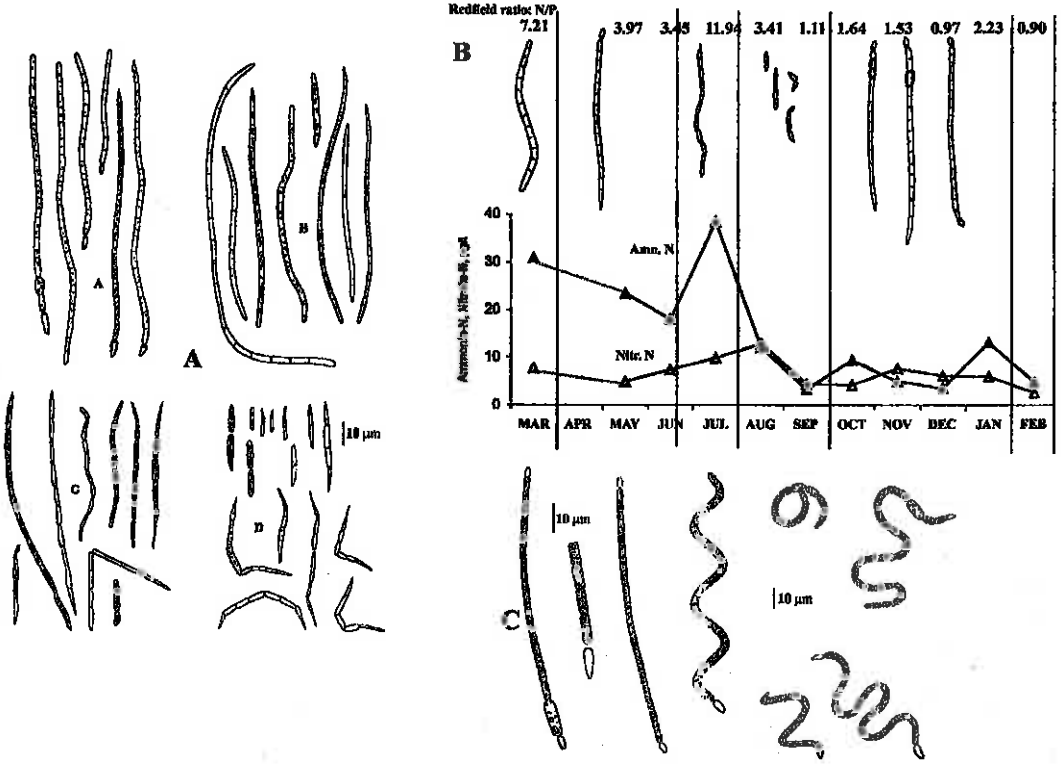


Table 8.

Cylindrospermopsis sinuosa **COUTÉ et al., Algological Studies 111: in press, 2003.**

Trichomes: ± cylindrical, irregularly flexuous, unconstricted or very indistinctly constricted at cross-walls.
Cells: cylindrical, 5-10 x 1.5-2 µm
Apical cells: slightly attenuated, without aerotopes, rounded at the end.
Heterocytes: drop-like, pointed at the end.
Akinetes: cylindrical to oval with irregular sides, 8.5-15 x 2.5-5 µm.
Distribution: SW France.

A – after COUTÉ et al. (2003).

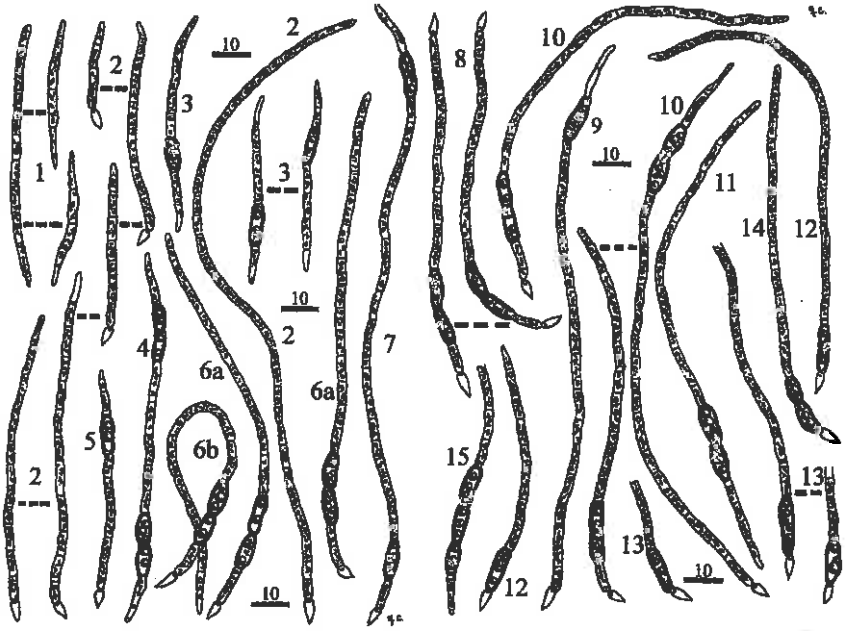


Table 9.

Cylindrospermopsis curvispora **M. WATANABE, Bull. Nat. Sci. Mus. Ser. B, 21(2):48, 1995.**

Synonyms: *Cylindrospermopsis allantoidispora* KOMÁRKOVÁ in AZEVEDO ed., Ann. IV. Lat.-Amer. Phycol. Congr., p. 338, 1998; nomen nudum (populations from Srí Lanka and Africa).

Trichomes: irregulalry spirally coiled (circular in outline), with up to 2(2.5) coils, cylindrical, unconstricted or constricted at cross walls, not attenuated towards ends.
Cells: cylindrical (Japanese populations) to cylindrical-barrel-shaped (populations from Srí Lanka and Africa), 3.5-7 x 3.2-3.8 µm.
Apical cells: ± cylindrical rounded.
Heterocytes: ovoid or oval, sometimes curved, rounded at ends.
Akinetes: cylindrical-kidney-shaped, in the "center" of spirals.
Distribution: described from central Japan, slightly different populations known from Srí Lanka and southern Africa.

A – after M. WATANABE (1995)
B – after CRONBERG & KOMÁREK (2003)

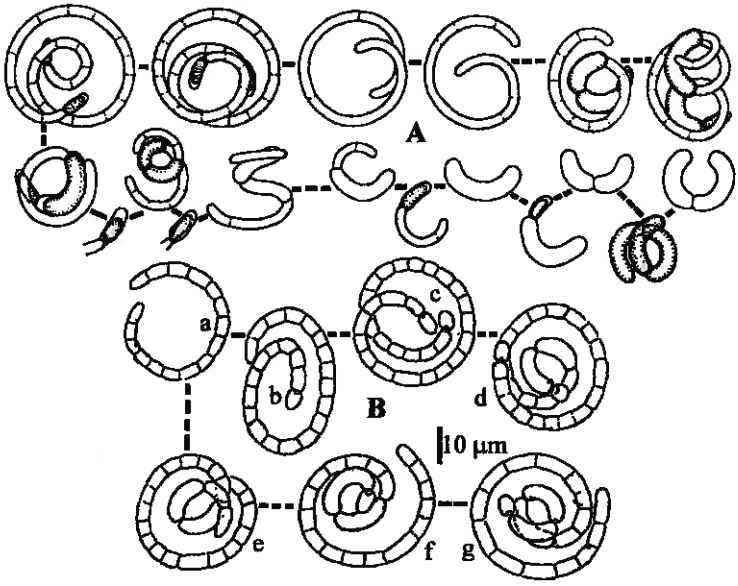


Table 10. *Cylindrospermopsis philippinensis*, concepts of different authors; from KOMÁRKOVÁ (1998): a – after WOŁOSZYŃSKA (1912) as a part of "*Anabaena raciborskii*" from Indonesia, b – original drawing of "*Anabaenopsis philippinensis*" after TAYLOR (1932) from the Philippines, c – after KOMÁREK (1984) from Cuba, d – after KOMÁRKOVÁ-LEGNEROVÁ & TAVERA (1996) from Mexico.

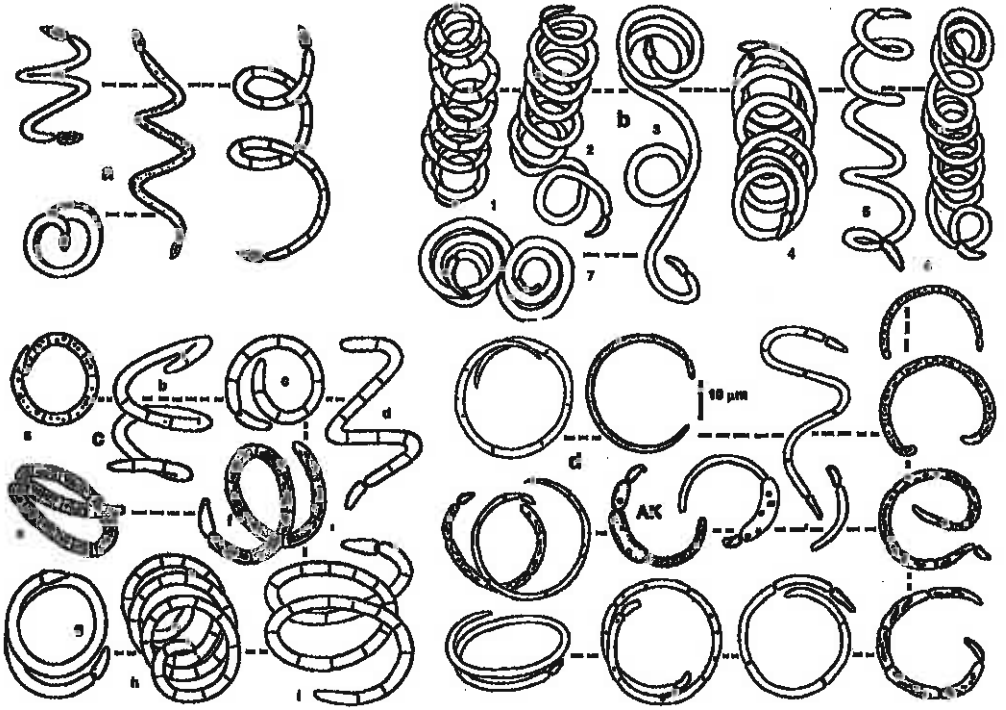


Table 11.

Cylindrospermopsis philippinensis **(TAYLOR) KOMÁREK, Acta Bot. Cubana, 19: 29, 1984.**

Synonyms: *Anabaenopsis philippinensis* TAYLOR, Amer. J. Bot., 19: 462, 1932 (basionym).

Trichomes: cylindrical, spirally coiled, slightly tapering towards ends, unconstricted or slightly constricted at cross walls; cells ± 20-25 µm in diameter.
Cells: cylindrical, (3.6)6-18(22) x (1.5)1.9-3(5) µm.
Apical cells: long, narrowed to the ends, pointed-rounded.
Heterocytes: drop-like to conical, pointed-rounded at the ends.
Akinetes: cylindrical, arcuated in the trichome axis, not attenuated.
Distribution: tropical regions; Cuba, Indonesia, Mexico, Philippines.

A – after KOMÁRKOVÁ-LEGNEROVÁ & TAVERA (1996)
B – after KOMÁREK & KOMÁRKOVÁ-LEGNEROVÁ (2002)

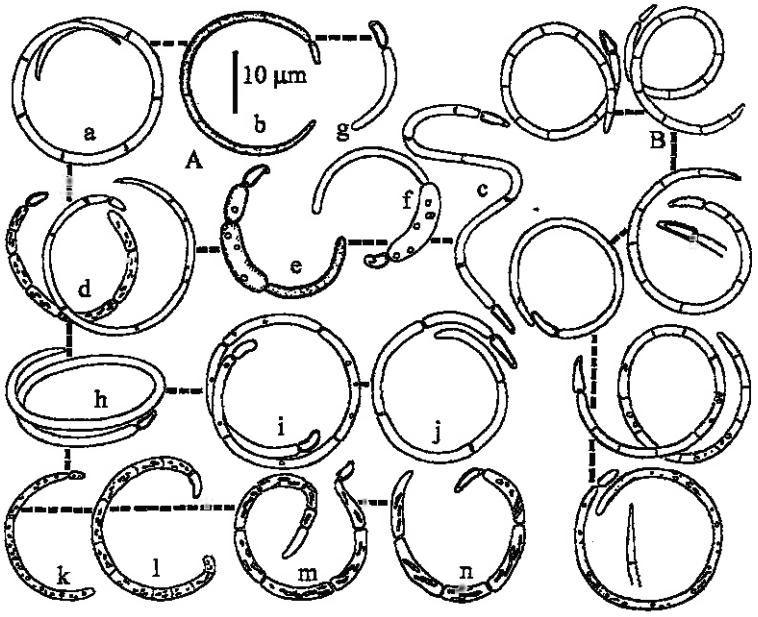


Table 12.

Cylindrospermopsis taverae **KOMÁREK et KOMÁRKOVÁ-LEGNEROVÁ, Preslia (Praha) 74: 229, 2002.**

Trichomes: screw-like coiled, very rarely almost straight, shortly narrowed to the ends, slightly constricted at cross walls.
Cells: cylindrical to barrel-shaped, 2.4-6.9 x 2.7-3.2 μm.
Apical cells: narrowed, conical, rounded.
Heterocytes: drop-like, narrowed and rounded at ends, usually slightly curved.
Akinetes: unknown.
Distribution: eutrophic pools, central Mexico.

after KOMÁREK & KOMÁRKOVÁ-LEGNEROVÁ (2002)

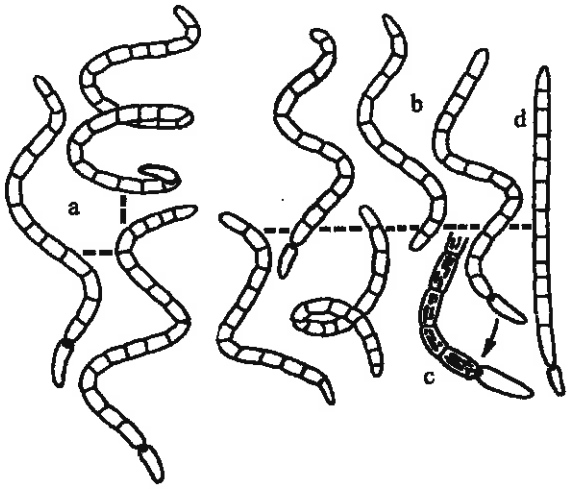


Table 13.

Cylindrospermopsis catemaco **KOMÁRKOVÁ-LEGNEROVÁ et TAVERA, Algolog. Stud 83: 413-414, 1996.**

Trichomes: screw-like coiled, cylindrical, tapering toward ends and pointed.
Cells: cylindrical, 5-10(32) x 0.8-1.2(1.6) µm.
Apical cells: elongated, narrowed, arcuated, pointed at the end.
Heterocytes: drop-like, arcuated, pointed.rounded at the ends.
Akinetes: unknown.
Distribution: lakes in central America (USA – Southern California, Mexico, Belize).

A-C - after KOMÁRKOVÁ-LEGNEROVÁ & TAVERA

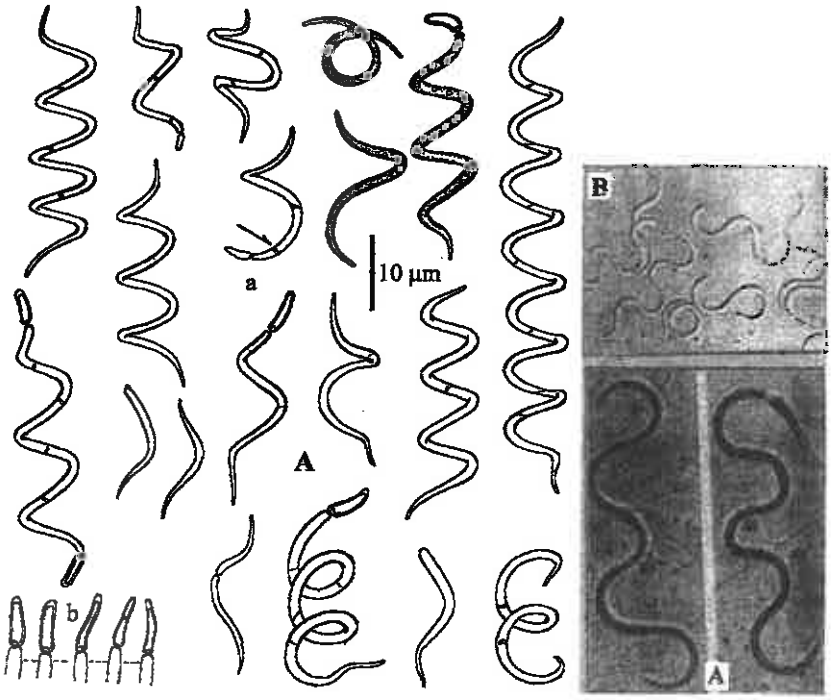


Table 14.

Cylindrospermopsis helicoidea **CRONBERG et KOMÁREK, Nova Hedwigia, in press, 2003.**

Trichomes: densely, less frequently freely screw-like coiled, cylindrical, not constricted at cross walls; coils 7-8 µm in diameter.
Cells: cylindrical, -5 x 1.4-2 µm.
Apical cells: cylindrical, slightly narrowed and rounded.
Heterocytes: oval to drop-like, rounded at the ends, usually declined from the coiled trichome axis.
Akinetes: unknown.
Distribution: in crater lakes of eastern Africa (Uganda).

after CRONBERG & KOMÁREK (2003)