

New aerophytic morphospecies of Cyanobacteria from tropical forest fragments in northwestern São Paulo state, Brazil

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RESUMO – (Novas morfoespécies aerofíticas de Cyanobacteria de fragmentos de floresta tropical na região noroeste do Estado de São Paulo, Brasil). Algas e cianobactérias podem colonizar uma grande variedade de ambientes terrestres e a composição florística das comunidades desses habitats é praticamente desconhecida. Durante o estudo das algas e cianobactérias aerofíticas de fragmentos florestais na região noroeste do estado de São Paulo, seis populações de cianobactérias não puderam ser identificadas em nível específico e, após estudos morfológicos e métricos, revelaram-se novos morfotipos para a Ciência. Quatro desses pertencem ao gênero *Aphanothece* (*A. excentrica*, *A. coacervata*, *A. densa* e *A. vaginata*), um a *Phormidium* (*P. arboricola*) e um a *Hapalosiphon* (*H. santannae*). Este estudo apresenta a descrição, comparação e proposição das novas morfoespécies e contribui com o conhecimento da diversidade do grupo.

Palavras-chave: Cyanobacteria aerofíticas, floresta estacional semidecidual, novas morfoespécies

ABSTRACT – (New aerophytic morphospecies of Cyanobacteria from tropical forest fragments in northwestern São Paulo state, Brazil). Algae and Cyanobacteria can colonize a wide variety of terrestrial environments and the assemblages from aerophytic habitats are very poorly known. During the survey of aerophytic algal and cyanobacterial communities in forest fragments in northwestern São Paulo state, six cyanobacteria populations could not be identified at species level and, after morphological and metrical analysis, proved to be new morphotypes to Science. Four belong to the genus *Aphanothece* (*A. excentrica*, *A. coacervata*, *A. densa* and *A. vaginata*), one to *Phormidium* (*P. arboricola*) and one to *Hapalosiphon* (*H. santannae*). This study presents the description, comparison and proposition of the new morphospecies and improves taxonomic knowledge of the diversity of the group.

Key words: Aerophytic Cyanobacteria, new morphospecies, seasonal semideciduous forest

Introduction

Algae and cyanobacteria can colonize a wide variety of terrestrial environments, including rocks (Büdel *et al.* 2002), soil (Evans & Johansen 1999), walls (Rindi & Guiry 2004) and tree trunks (Hoffmann 1989). Cyanobacteria are especially common in terrestrial environments and have important ecological functions in the ecosystem, acting to retain silt and clay and adding large amounts of organic carbon and nitrogen to the soil (De 1939; Fletcher & Martin 1948; Allen 1956; Singh 1961; Whitton 2000), among other properties. However, despite their ecological relevance, taxonomic studies on this group are scarce in the world and most of these focus mainly on edaphic organisms (Johansen 1993; Flechtner *et al.* 1998; Tirkey & Adhikary 2006).

Taxonomic knowledge concerning cyanobacteria from terrestrial habitats in Brazil is very limited. Studies regarding the edaphic community from Rio de Janeiro and São Paulo states were presented by Oliveira (1976) and Oliveira *et al.* (1980). Azevedo (1991), in a study of the edaphic cyanobacterial community of the São Paulo Botanical Garden, found 24 specific taxa distributed in nine families and described a new species of *Lyngbyopsis*.

Some surveys provide additional information on cyanobacteria from other terrestrial habitats. The

study carried out by Sant'Anna (1984) investigated the cyanobacterial flora associated with bryophytes in Campina Grande (Minas Gerais) and recorded 23 species from five different families. Sant'Anna *et al.* (1991a) described a new species of *Gloeothece* from "Gruta-que-chora" at Sununga beach (Ubatuba, São Paulo). In addition, the aerophytic cyanobacterial flora of the same locality was surveyed by Sant'Anna *et al.* (1991b) and resulted in the identification of 41 specific taxa from 11 families, including two new species of *Calothrix*. Büdel *et al.* (2002) carried out an investigation on the cyanobacteria from inselbergs in the Atlantic forest (eastern Brazil) and found 16 species.

Recent data on aerophytic cyanobacterial flora indicate that knowledge of diversity in the Brazilian territory is still underestimated (e.g., Branco *et al.* 2009). In addition, new aerophytic morphospecies have been described for different regions of São Paulo state comprising three new *Symplocastrum* (Branco *et al.* 2006a), one new *Cyanoarbor* (Branco *et al.* 2006b) and three new *Nostoc* (Sant'Anna *et al.* 2007), showing how taxonomic accounts are needed.

This work is part of a more comprehensive study on aerophytic algal and cyanobacterial communities from forest fragments in northwestern São Paulo state. During this survey, six new cyanobacterial morphospecies were recorded and are now presented.

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Material and methods

Sampling was carried out between March and May, 2007, in seasonal semideciduous forest fragments occurring in northwestern São Paulo state (Tab. 1).

Detailed description of collection, preservation and study can be found in Lemes-da-Silva *et al.* (2010). In short, visible growths of algae, cyanobacteria and bryophytes were collected from randomly selected tree bark. The dried material was taken to the laboratory, rehydrated and analyzed under stereoscope microscope and light microscope. For each population found, at least 20 observations of each qualitative or quantitative taxonomic characteristic were made.

The taxa found were described according to the patterns adopted for each group and the following abbreviations were used for species description in text and tables: diam. (diameter) and L/D (cell length/diameter ratio).

The classification system used was that of Hoffmann *et al.* (2005); holotypes are deposited in the SJRP Herbarium (IBILCE/UNESP – São José do Rio Preto, São Paulo, Brazil).

Results and discussion

Six new morphospecies of cyanobacteria, belonging to the orders Chroococcales (*Aphanothece excentrica*, *A. coacervata*, *A. densa* and *A. vaginata*), Oscillatoriales (*Phormidium arboricola*) and Nostocales (*Hapalosiphon santannae*) were found.

Chroococcales

Key for identification of the new *Aphanothece* morphospecies:

- | | |
|--|-------------------------|
| 1. Cells over 6.0 µm diam. | 3. <i>A. excentrica</i> |
| 1. Cells up to 6.0 µm diam. | 2 |
| 2. Cells up to 3.2 µm diam. | 1. <i>A. coacervata</i> |
| 2. Cells over 3.2 µm diam. | 3 |
| 3. Cells densely aggregated in the centre of the colony, blue-green, colonial margin wide, colonial mucilage yellowish brown | 2. <i>A. densa</i> |
| 3. Aggregated cells, distributed over the whole colony, usually violet, colonial margin narrow, colonial mucilage hyaline, rarely reddish | 4. <i>A. vaginata</i> |

cell-length metrics (Tab. 2). However, *A. saxicola* usually forms macroscopic and amorphous colonies and typical cells are smaller in diameter (1.0-2.3 µm – Komárek & Anagnostidis 1998).

Aphanothece densa N.M. Lemes-da-Silva *et al.* sp. nov.
(Fig. 1C-D)

Diagnosis: Coloniae microscopicae, sphaericae, cum dense dispositis cellulis in centrum coloniae; coloniae cum vagina luteo-castenea; cellulae 4.0-7.0 µm longae, 4.0-5.0 µm latae, 1.0-1.7 longiores quam latiores, contentu caerulescenti.

Locus classicus: ad corticem arborum, Municipium Sales, Provincia Sanctus Paulus, Brasilia.

Typus: BRAZIL. São Paulo: Votuporanga, 26/IV/2007, N. M. Lemes-da-Silva (SJRP 28276).

Etymology: The specific epithet refers to cells agglomerated in the center of the colony.

Aphanothece coacervata N.M. Lemes-da-Silva *et al.* sp. nov.
(Fig. 1A-B)

Diagnosis: Coloniae microscopicae, sphaericae vel cylindrica, cum dense dispositis cellulis; cellulae 3.2-4.8 µm longae, (1.6-)2.4-3.2 µm latae, (1.1-)1.2-1.7(-2.0) longiores quam latiores, contentu olivaceo vel castaneo.

Locus classicus: ad corticem arborum, Municipium Votuporanga, Provincia Sanctus Paulus, Brasilia.

Typus: BRAZIL. São Paulo: Votuporanga, 26/IV/2007, N. M. Lemes-da-Silva (SJRP 28278).

Etymology: The specific epithet refers to cell arrangement, which is densely aggregated in the whole colony.

Colonies microscopic, spherical or cylindrical; cells densely arranged, distributed throughout the whole colony; colonial sheath hyaline, margin well delimited; cells cylindrical, 3.2-4.8 µm long, (1.6-)2.4-3.2 µm diam., L/D (1.1-)1.2 to 1.7(-2.0); cell content homogeneous, light green to brownish.

Occurrence: S3.

Comments: The species most similar to *Aphanothece coacervata* is *A. saxicola* Nägeli, since they have close

Colonies microscopic, spherical; cells densely agglomerated in the center of the colony; colonial sheath yellowish brown, margin well delimited and wide; cells cylindrical, 4.0-7.0 µm long, 4.0-5.0 µm diam., L/D 1.0 to 1.7; cell content homogeneous, blue-green.

Occurrence: L2, L5, S2, S1.

Comments: *Aphanothece pallida* (Kützing) Rabenhorst and *A. variabilis* (Schiller) Komárek are the closest taxa to *A. densa* (Tab. 3). Komárek & Anagnostidis (1998) commented that *A. pallida* is found in aerophytic environments (soil and wet walls), showing wide geographic distribution; however its cells are longer ((5.6-)7.5-10.5(-16.0) µm) and densely arranged at the colony margin (usually with individual sheaths).

According to Komárek & Anagnostidis (1998), *A. variabilis* presents densely agglomerated cells, as well as *A. densa*; however they are distinguishable by the longer cells (4.2-10.0 µm) and habitat (marshes and reservoirs) of

Table 1. Locality and total area of forest remnants where the new morphospecies were found. (L - large area, S - small area).

Remnant	Municipality	Latitude (S)	Longitude (W)	Area (ha)
L1	Novo Horizonte	21°31'15"	49°17'41"	635.0
L2	Sales	21°24'17"	49°30'01"	1,799.6
L3	Planalto	21°00'05"	49°58'26"	207.5
L4	União Paulista	20°55'16"	49°55'34"	230.4
L5	São João da Iracema	20°28'25"	50°17'36"	1,656.2
L9	Matão	21°37'14"	48°32'14"	2,189.6
S1	Vicentópolis	20°55'34"	50°20'55"	128.2
S2	Ida Iolanda	20°44'34"	49°55'45"	66.8
S3	Votuporanga	20°30'52"	50°05'12"	112.6
S4	Turmalina	20°00'13"	50°26'02"	108.3

Table 2. Comparison of morphometric and ecological characteristics of *Aphanothece saxicola* and *Aphanothece coacervata* (according to Komárek & Anagnostidis 1998).

	<i>A. saxicola</i>	<i>A. coacervata</i>
Colonies	macroscopic, amorphous	microscopic, spherical or cylindrical
Sheath	colorless or yellow-brownish	hyaline, margin delimited
Cell diam. (µm)	1.0-2.3	(1.6-)2.4-3.2
Cell length (µm)	(1.5-)2.4-4.5(-6.0?)	3.2-4.8
Individual sheath	indistinct, colorless	absent
Cells distribution in the colony	more or less densely arranged, throughout the whole colony	densely arranged, throughout the whole colony
Ecology	terrestrial – temperate region	terrestrial (epiphyte) – tropical region, Brazil

Table 3. Comparison of morphometric and ecological characteristics of *Aphanothece pallida*, *A. variabilis* and *Aphanothece densa* (according to Komárek & Anagnostidis 1998).

	<i>A. pallida</i>	<i>A. variabilis</i>	<i>A. densa</i>
Colonies	micro or macroscopic, amorphous	irregular	microscopic, spherical
Sheath	fine, diffluent, greenish, blue-green or brown when older	colorless, margin delimited	brown yellowish, margin delimited and wide
Cell diam. (µm)	(3.2-)5.0-8.0	2.5-7.0	4.0-5.0
Cell length (µm)	(5.6-)7.5-10.5 (-16.0)	4.2-10.0	4.0-7.0
Cells distribution in the colony	loosely (in the colonial center) to densely arranged	densely arranged, in the center of the colony	densely arranged, in the center of the colony
Ecology	terrestrial - cosmopolitan	swamps - pantropical	terrestrial (epiphyte) - tropical region, Brazil

the former species. Cell arrangement in *A. densa* is similar to genus *Asterocapsa*, but individual sheath with wart-like process is a diagnostic characteristic in *Asterocapsa* and they are absent in *A. densa*.

Aphanothece excentrica N.M. Lemes-da-Silva *et al.* sp. nov.
(Fig. 1E-F)

Diagnosis: Coloniae microscopicae, sphaericae, cum dense dispositis cellulis; cellulae 7.2-8.8(-10.8) µm longae, (5.6-)6.4-7.2(-8.0) µm latae, (1.1-)1.2-1.4(-1.5) longiores quam latiores, contentu granuloso, olivaceo vel griseo;

cellulae cum vagina granulata, ferruginea et asymetrica.

Locus classicus: ad corticem arborum, Municipium Votuporanga, Provincia Sanctus Paulus, Brasilia.

Typus: BRAZIL. São Paulo: Votuporanga, 26/IV/2007, N. M. Lemes-da-Silva (SJRP 28279).

Etymology: The specific epithet refers to individual sheath in some cells which is asymmetrical, out of cell center, i.e., eccentric.

Colonies microscopic, spherical; cells densely arranged, distributed throughout the whole colony; colonial sheath hyaline, margin well delimited; cells cylindrical, 7.2-8.8(-

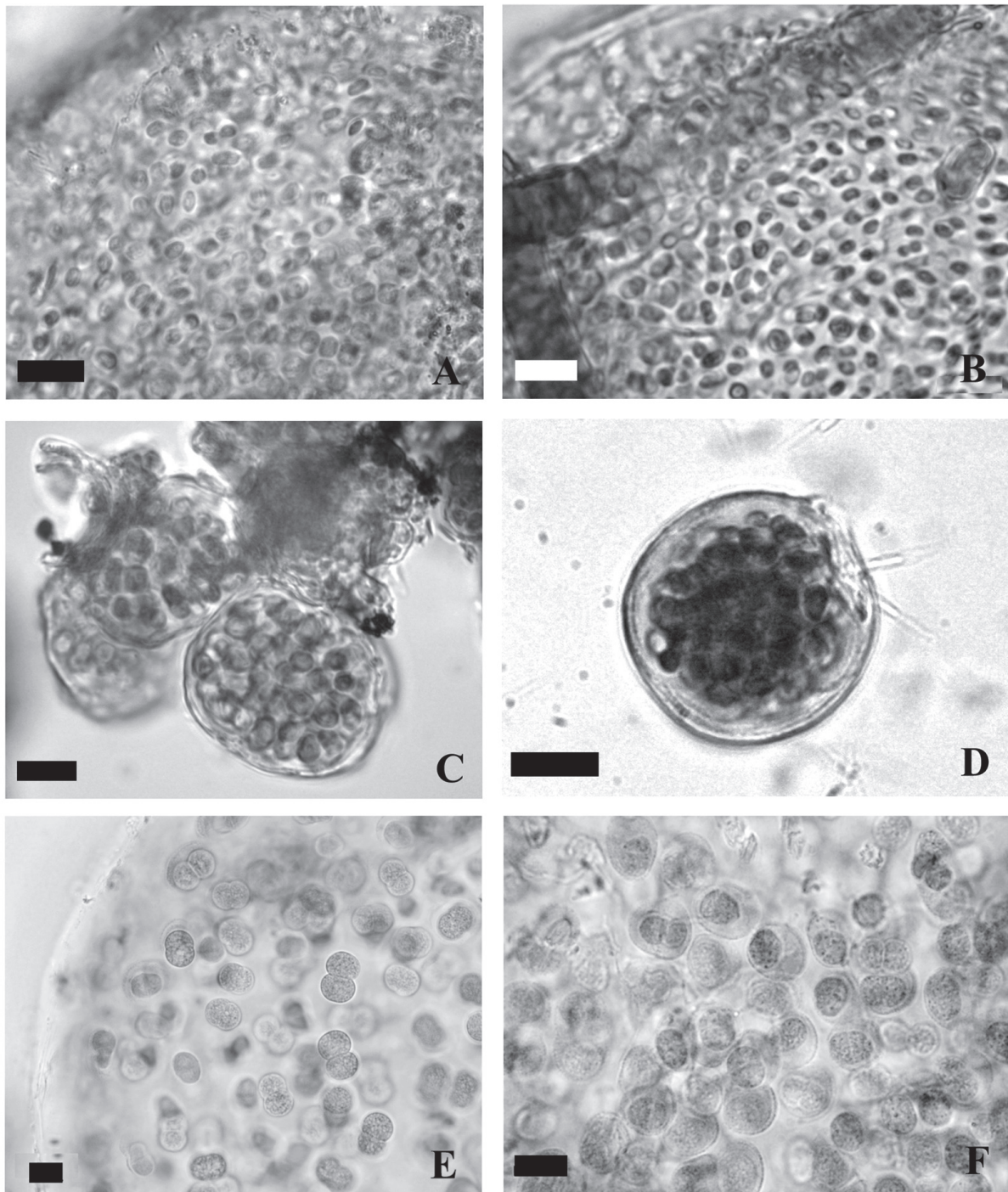


Figure 1. A-B. *Aphanothece coacervata*. C-D. *A. densa*. E-F. *A. excentrica*. Scale bars = 10 μ m.

10.8 μ m long, (5.6-)6.4-7.2(-8.0) μ m diam., L/D (1.1-)1.2 to 1.4(-1.5); cell content granular, green or grayish green; some cells with individual, reddish, asymmetrical, granular sheath.

Occurrence: S3.

Comments: This population presents metrics similar to *Aphanothece pallida* (Kützing) Rabenhorst (Tab. 4), however the cells are distributed along the colony margin and each one is surrounded by an individual

concentrically lamellate sheath in the latter, while in *A. excentrica* the individual sheath is asymmetrical and granular, when present. An additional morphological incompatibility between the two taxa is the presence of greenish to brownish sheath in *A. pallida* and colorless in *A. excentrica*. The two species are also ecologically distinguishable since *A. pallida* is typically a soil-and-wet-walls inhabitant and *A. excentrica* was found on tree

Table 4. Comparison of morphometric and ecological characteristics of *Aphanothece pallida* and *Aphanothece excentrica* (according to Komárek & Anagnostidis 1998).

	<i>A. pallida</i>	<i>A. excentrica</i>
Colonies	micro or macroscopic, amorphous	microscopic, spherical
Sheath	thin, diffuent, greenish, blue-green or brown when older	hyaline, margin delimited
Cell diam. (µm)	(3.2-)5.0-8.0	(5.6-)6.4-7.2(-8.0)
Cell long (µm)	(5.6-)7.5-10.5(-16.0)	7.2-8.8(-10.8)
Individual sheath	concentrically lamellate, yellow-brown	asymmetrical, granular, reddish
Cells distribution in the colony	loosely (in the colonial center) to densely arranged	densely arranged, throughout the whole colony
Ecology	terrestrial edaphic - cosmopolitan	terrestrial (epiphyte) - tropical region, Brazil

trunks. This morphospecies of *Aphanothece* shares some characteristics with the genus *Asterocapsa*, mainly the colored granular individual sheaths in some cells, but *Asterocapsa* shows solitary cells or grouped with few cells and the colony sheath presents wart-like projections of different lengths.

Aphanothece vaginata N.M. Lemes-da-Silva *et al.* sp. nov. (Fig. 2A-B)

Diagnosis: Coloniae microscopicae, sphaericae vel cylindricae, cum dense dispositis cellulis; coloniae cum vagina hyalina usque ferruginea; cellulae (4.8-)5.6-7.2(-8.0) µm longae, (3.2-)4.0-4.8(-6.0) µm latae, 1.2-1.6 longiores quam latiores, contentu olivaceo usque violeo.

Locus classicus: ad corticem arborum, Municipium Votuporanga, Provincia Sanctus Paulus, Brasilia.

Typus: BRAZIL. São Paulo: Votuporanga, 26/IV/2007, N. M. Lemes-da-Silva (SJRP 28280).

Etymology: The specific epithet refers to colonial sheath with well-delimited margin.

Colonies microscopic, spherical to cylindrical, cells densely arranged, distributed throughout the whole colony; colonial sheath hyaline, rarely reddish, margin well-delimited; cells cylindrical, (4.8-)5.6-7.2(-8.0) µm long, (3.2-)4.0-4.8(-6.0) µm diam., L/D 1.2 to 1.6; cell content homogeneous, green to violet.

Occurrence: S3.

Comments: *Aphanothece vaginata* is close to *A. castagnei* (Brébisson) Rabenhorst (Tab. 5). According to Komárek & Anagnostidis (1998), colonies of *A. castagnei* are macroscopic and irregularly spherical to amorphous and the cells, with individual lamellate and yellowish brown envelopes, are distributed along the colony margin, differing from *A. vaginata*.

Some species of *Aphanothece* described in this study were found in the same forest fragment but they are clearly separated and recognizable on the basis of their morphology and metrics (Tab. 6).

Phormidium arboricola N.M. Lemes-da-Silva *et al.* sp. nov. (Fig. 2C-D)

Diagnosis: Fila flexuosa, (8.0-)10.0-12.0 µm latae; vaginae hyalinae usque casteneae; trichomatibus abusque constrictis, (7.0-)9.0-10.0 µm latae; articulis (6.0-)8.0-10.0 µm longis, 0.6-1.0(-1.42) longiores quam latiores; cellula apicalis rotundata conica.

Locus classicus: ad corticem arborum, Municipium São João da Iracema, Provincia Sanctus Paulus, Brasilia.

Typus: BRAZIL. São Paulo: São João da Iracema, 25/IV/2007, N. M. Lemes-da-Silva (SJRP 28277).

Etymology: The specific epithet refers to typical habitat (on tree bark) where organisms of this species are found.

Filaments isolated or forming small aggregates of entangled filaments; filaments slightly waved, (8.0-)10.0-12.0 µm diam.; sheath thin, hyaline to brown, homogeneous; trichomes not constricted, (7.0-) 9.0-10.0 µm diam.; cells cylindrical, (6.0-)8.0-10.0 µm long, L/D 0.6 to 1.0(-1.42); apical cell conical-rounded; cell content homogeneous, grayish green.

Occurrence: L1, L2, L4, L5, L9, S2, S3, S4.

Comments: *Phormidium corbieri* (Frémy) Anagnostidis & Komárek and *P. ornatum* (Kützing ex Gomont) Anagnostidis & Komárek are the species most similar to the Brazilian populations (Tab. 7). They have cell diameter similar to that of *Phormidium arboricola*, however both species are found in periphyton of European environments, significantly differing from the studied populations.

Phormidium usteri Schmidle has been recorded for Brazilian soils (Komárek & Anagnostidis 2005), but trichome diameter is narrower (3.0-4.0 µm). The aerophytic *Phormidium rubroterricola* Gardner and *P. jadinianum* Gomont present smaller cell diameter, while *P. durum* Gardner is distinguishable from *P. arboricola* by having greater trichome diameter.

Hapalosiphon santannae N.M. Lemes-da-Silva *et al.* sp. nov. (Fig. 2E-F)

Diagnosis: Fila agglutinata, fasciculi erecti; fila primaria et secundaria dimensionibus similaria, 16.0-20.0

Table 5. Comparison of morphometric and ecological characteristics of *Aphanothece castagnei* and *Aphanothece vaginata* (according to Komárek & Anagnostidis 1998).

	<i>A. castagnei</i>	<i>A. vaginata</i>
Colonies	macroscopic, spherical to amorphous	microscopic, spherical or cylindrical
Sheath	brown	hyaline to reddish, margin delimited
Cell diam. (µm)	(2.0-)3.0-4.8(-5.5)	(3.2-)4.0-4.8(-6.0)
Cell length (µm)	(3.8-)4.0-8.0	(4.8-)5.6-7.2(-8.0)
Individual sheath	lamellate, yellowish brown	absent
Cells distribution in the colony	more or less densely arranged, throughout the whole colony	densely arranged, throughout the whole colony
Ecology	terrestrial - temperate region	terrestrial (epiphyte) – tropical region, Brazil

Table 6. Comparison of morphometric characteristics of the *Aphanothece* found species.

	<i>A. coacervata</i>	<i>A. densa</i>	<i>A. excentrica</i>	<i>A. vaginata</i>
Colonies	spherical or cylindrical	spherical	spherical	Spherical or cylindrical
Sheath	hyaline, margin delimited	brown yellowish, margin delimited and wide	hyaline, margin delimited	hyaline to reddish, margin delimited
Cell color	green to brown	blue-green	green to greyish	green to violet
Cell diam. (µm)	(1.6-)2.4-3.2	4.0-5.0	(5.6-)6.4-7.2(-8.0)	(3.2-)4.0-4.8(-6.0)
Cell length (µm)	3.2-4.8	4.0-7.0	7.2-8.8(-10.8)	(4.8-)5.6-7.2(-8.0)
L/D	(1.1-)1.25 to 1.67(-2.0)	1.0 to 1.75	(1.1-)1.25 to 1.37(-1.5)	1.2 to 1.6
Individual sheath	absent	absent	asymmetrical, granular, reddish	absent
Cells distribution in the colony	densely arranged, throughout the whole colony	densely arranged, in the center of the colony	densely arranged, throughout the whole colony	densely arranged, throughout the whole colony

Table 7. Morphometric and ecological characteristics of *Phormidium arboricola* and the closest species (according to Komárek & Anagnostidis 2005).

	<i>P. corbieri</i>	<i>P. durum</i>	<i>P. jadinianum</i>	<i>P. ornatum</i>	<i>P. rubroterricola</i>	<i>P. usteri</i>	<i>P. arboricola</i>
Filament diam. (µm)							8.0-12.0
Trichome diam. (µm)	9.0-10.0	12.0-14.0	4.0-6.0	(6.0-)9.0-11.5(-15.0)	2.2-2.4	3.0-4.0	7.0-10.0
Cell length (µm)	3.5-4.0		2.0-3.5	2.0-5.5			6.0-10.0
L/D	shorter than wide	isodiametric or 2 times longer than wide		0.2-0.5 times longer than wide	isodiametric	shorter than wide	0.6-1.0
Apical cell	rounded	rounded	elongated or acute-conical	hemispherical	bluntly conical	rounded	conical- rounded
Constriction	not constricted	not constricted	constricted	constricted	not constricted	not constricted	not constricted
Ecology	freshwater - France	aerophytic - Puerto Rico	trunks, soils and streams - tropical region	freshwater, benthic - cosmopolitan	aerophytic - India, Puerto Rico, tropical region Brazil	aerophytic, soil - India, Philippines, tropical region Brazil	aerophytic - trunks, tropical region, Brazil

intercalary or lateral, (8.0-)10.0-12.0 µm long, (12.0-)14.0-16.0 µm diam.

Occurrence: L3.

Comments: *Hapalosiphon fontinalis* (Agardh) Bornet has filament diameter comparable to *Hapalosiphon santannae*, however it is found in aquatic environments and has longer than wide cells (Tab. 8).

In the most extensive survey of true-branched Nostocales carried out in São Paulo state, Silva &

Sant'Anna (1990) found six species of *Hapalosiphon*, all occurring in aquatic environments, except for *H. stuhlmannii* Hieronimus that was also found growing on wet rocky wall and soil, but with different filament diameter ((4.0-)5.9-11.5(-14.3) µm) than *Hapalosiphon santannae*. Azevedo *et al.* (1996) recorded *H. stuhlmannii* in edaphic environment in São Paulo state; however the morphological and metric characteristics differ from those of *Hapalosiphon santannae* (Tab. 8).

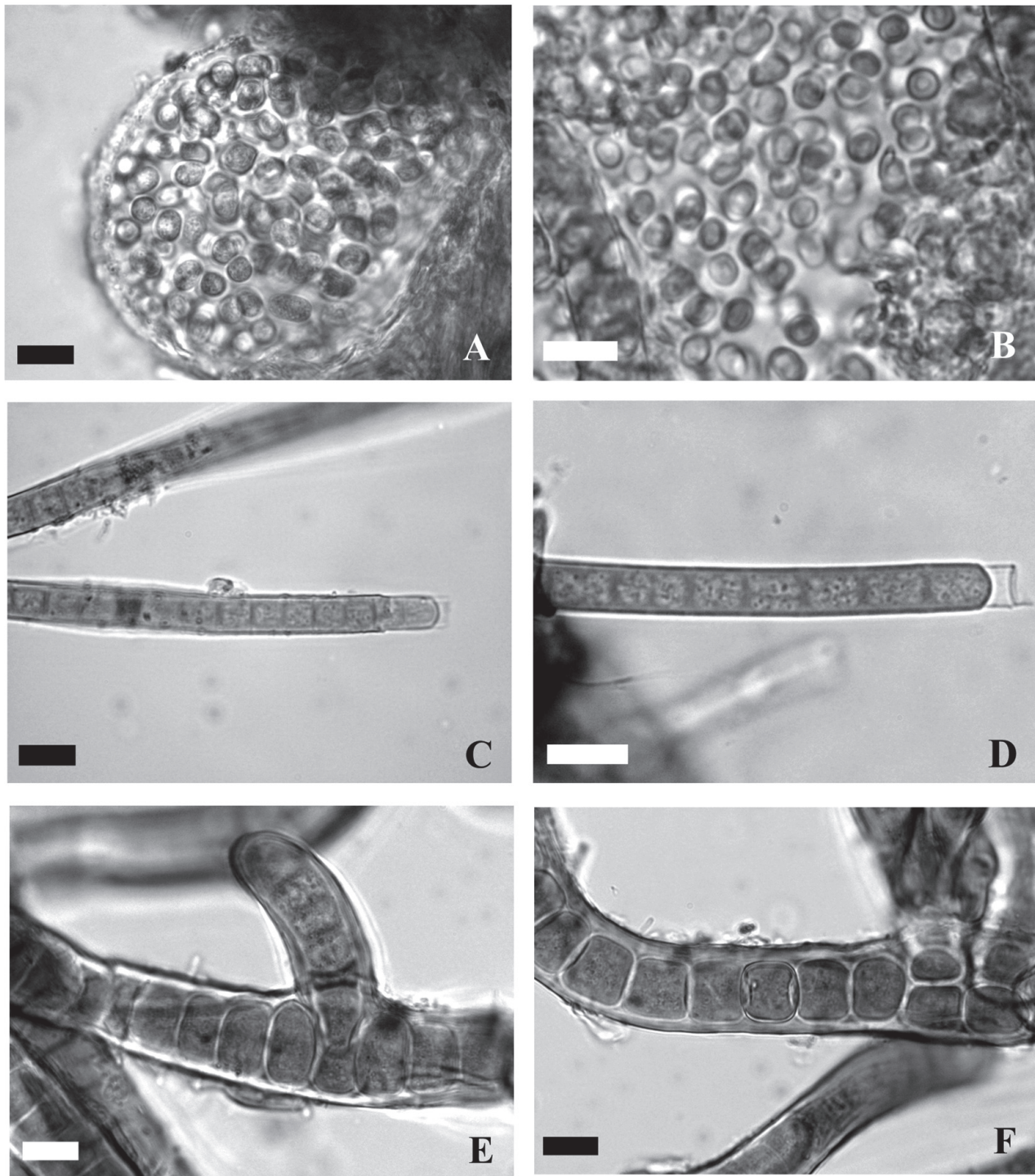


Figure 2. A-B. *Aphanothece vaginata*. C-D. *Phormidium arboricola*. E-F. *Hapalosiphon santannae*. Scale bars = 10 μ m.

The taxonomic knowledge of aerophytic cyanobacterial communities is proved to be insufficient to offer a solid background on biodiversity patterns, especially in tropical regions. Ideally, molecular approaches are recommended to better characterize the species but aerophytic cyanobacteria are difficult organisms to cultivate and, consequently, the characterization of the populations from nature is still an

important step in the recognition of the specific tropical flora and for understanding cyanobacterial diversity in different ecosystems and regions (Komárek & Komárková-Legnerová 2007; Sant'Anna *et al.* 2007). It is hoped that studies dealing with aerophytic cyanobacterial communities are encouraged to provide a good basis for group taxonomy, phylogeny and diversity.

Table 8. Morphometric and ecological characteristics of *Hapalosiphon santannae* and the closest species.

	<i>H. aureus</i> ^{1,3}	<i>H. fontinalis</i> ²	<i>H. stuhlmannii</i> ^{2,3,4}	<i>H. santannae</i>
Plant mass		caespitose	caespitose	Filaments tangle, caespitose
Filament diam.	11.5-12.5µm	12.0-24.0µm	10.0µm	16.0-20.0µm
Lateral branches	long and narrow	narrower than main filament		short/long
Sheath	wide	colorless or yellowish in the oldest portions	fine and colorless	yellow
Cell length (µm)	4.0-8.0			8.0-12.0
L/D		longer than wide	quadratic or shorter	0.6-0.8 times longer than wide
Heterocytes	intercalar, subcylindrical, subquadratic		spherical or bluntly	intercalar and lateral
Ecology	swamps, wet soil – tropical region, Brazil	lentic environment - cosmopolitan	lentic environment - Africa; edaphic, wet walls, aquatic subtropical and tropical regions, Brazil	aerophytic – tropical region, Brazil

¹Frémy (1924), ²Frémy (1930), ³Silva & Sant'Anna (1990), ⁴Azevedo *et al.* (1996).

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