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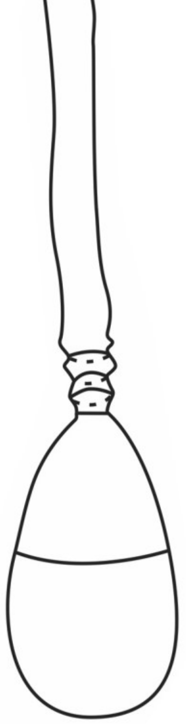
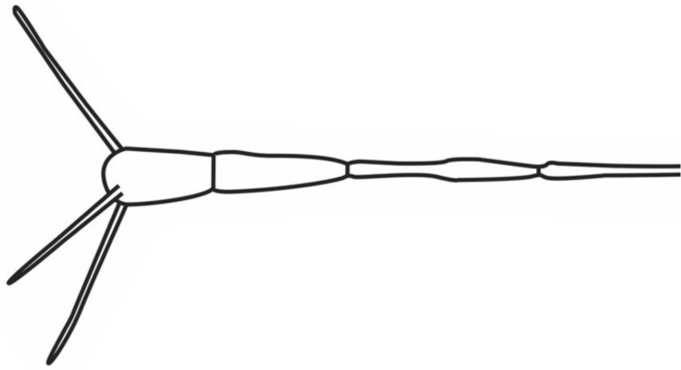
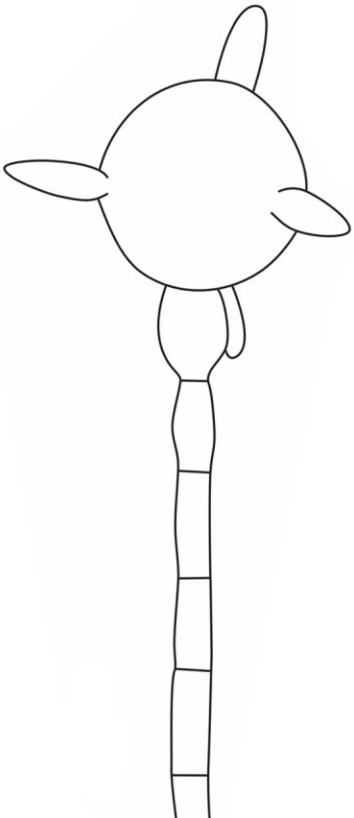
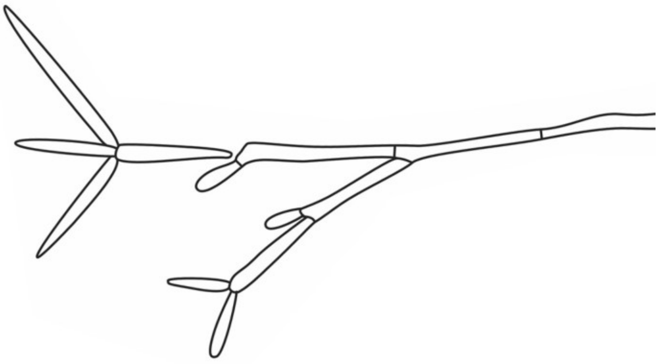




Hifomicetos aquáticos associados a folhas de *Calophyllum brasiliense* em riachos da bacia do Rio de Contas





Feira de Santana - Bahia
2017

UNIVERSIDADE ESTADUAL DE FEIRA DE SANTANA

DEPARTAMENTO DE CIÊNCIAS BIOLÓGICAS

PROGRAMA DE PÓS-GRADUAÇÃO EM BOTÂNICA

Hifomicetos aquáticos associados a folhas de *Calophyllum brasiliense* em riachos da bacia do Rio de Contas

PATRÍCIA OLIVEIRA FIUZA

Tese apresentada ao Programa de Pós-Graduação em Botânica da Universidade Estadual de Feira de Santana como parte dos requisitos para a obtenção do título de *Doutora em Botânica*.

ORIENTADOR: PROF. DR. LUÍS FERNANDO PASCHOLATI GUSMÃO (UEFS)

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2017

Aos meus pais e irmãos,dedico.

"Ouve o barulho do rio, meu filho
Deixa esse som te embalar
As folhas que caem no rio, meu filho
Terminam nas águas do mar
Quando amanhã por acaso faltar
Uma alegria no seu coração
Lembra do som dessas águas de lá
Faz desse rio a sua oração
Lembra, meu filho, passou, passará
Essa certeza, a ciência nos dá
Que vai chover quando o sol se cansar
Para que flores não falte"

Marisa Monte

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O doutorado tem o período de quatro anos que parecem o dobro devido à intensidade dos acontecimentos. São anos de erros, acertos e muita aprendizagem que serão lembrados por toda a vida. Por isto, é importante agradecer aos que estiveram presentes durante esta etapa.

Primeiramente a Deus por toda a força de levantar todos os dias e poder enfrentar os desafios que estariam por vir;

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Introdução e Metodologia Geral

1.INTRODUÇÃO GERAL

Ecossistemas aquáticos de água doce são definidos como sistemas que apresentam salinidade média menor que de 0,5 partes por milhão e incluem habitats lênticos (lagos, lagoas, pântanos e represas) e lóticos (rios e riachos) (Thomas 1996, Moss 2008). Estes habitats abrigam uma grande diversidade de organismos que participam de processos complexos importantes, que contribuem para a manutenção da dinâmica e do equilíbrio desses ecossistemas (Covich 2009) sendo um dos processos mais importantes neste contexto a decomposição.

A decomposição é um processo chave para a ciclagem de nutrientes nos ecossistemas aquáticos que compreendem a transferência de energia e interações tróficas (Suberkropp 1992). Os fungos desempenham um papel importante na decomposição de substratos alóctones, provenientes da vegetação ripária, que entram nos rios e riachos (Sridhar et al. 2011; Ferreira et al. 2014). Dentre os fungos, os hifomicetos aquáticos constituem o principal grupo, pois participam da ciclagem de carbono, liberação de energia e fluxo de nutrientes em ecossistemas de água doce aumentando a palatabilidade dos detritos foliares para os invertebrados aquáticos (Gulis et al., 2006).

Os hifomicetos aquáticos representam a fase assexual dos filos Ascomycota e Basidiomycota (Shearer et al. 2007). De acordo com Goh (1997) estes fungos são subdivididos em três grupos ecológicos: fungos ingoldianos, aeroaquáticos e fungos aquáticos lignícolas, aqui tratados como hifomicetos aquáticos facultativos (Descals & Moralejo 2001).

Os fungos ingoldianos são considerados os verdadeiros fungos aquáticos devido a sua dependência da água para reprodução e principalmente a adaptação de seus conídios para dispersão nos ecossistemas aquáticos. Estes fungos colonizam folhas, galhos e cascas da serapilheira submersa e produzem conídios que são liberados na água e são prontamente levados em espumas (Webster & Descals 1981). Os conídios de fungos ingoldianos apresentam formas únicas de sigmoides a multiradiadas, o que é um fator determinante na sua identificação (Descals 2005). Estes fungos são encontrados em ecossistemas lóticos de águas limpas e claras, mas também há relatos de sua presença em ambientes lênticos ou eutrofizados (Schoenlein-Crusius et al. 2015).

Os fungos aeroaquáticos colonizam substratos submersos e a esporulação só ocorre quando o micélio entra em contato com o ar (Fisher 1977). Os conídios de hifomicetos aeroaquáticos são tridimensionais, helicoidais e clatróides, o que facilita a flutuação na água (Voglmayr 1997, 2004). Foram inicialmente relatados em ecossistemas lênticos (Goh 1997), mas também podem ser registrados em ambientes lóticos (Chuaseeharonnachai et al. 2013).

Os hifomicetos aquáticos facultativos são fungos demateáceos que podem esporular acima ou abaixo d'água, mas perdem a adaptação específica para dispersão nos ecossistemas aquáticos; eles representam um grupo contínuo aos hifomicetos terrestres com esporos que apresentam frequentemente paredes espessas (Descals and Moralejo, 2001). Estes hifomicetos aquáticos são também denominados de lignícolas aquáticos devido a grande quantidade de trabalhos com substratos lignícolas submersos (Hyde et al. 2015), apesar de apresentarem uma grande diversidade em folhas submersas (Castañeda et al. 2016).

Os hifomicetos aquáticos assim como os quitridiomicetos podem estar presentes durante estágios de sucessão de folhas submersas (Schoenlein-Crusius & Milanez 1998). Sucessão é a mudança direcional de composição, abundância e padrão espacial de táxons presentes nas comunidades (Frankland 1992). Existem três estágios de sucessão nas comunidades: pioneiro, maduro e empobrecido (Yanna et al. 2002). O estágio pioneiro é caracterizado pela baixa diversidade e poucos táxons com alta abundância; enquanto o estágio maduro apresenta alta diversidade e vários táxons com picos de abundância; e o estágio empobrecido é caracterizado pelo declínio da diversidade e poucos táxons com alta abundância (Dix & Webster 1995, Yanna et al. 2002).

A diversidade, esporulação e atividade de hifomicetos aquáticos podem ser influenciadas por algumas variáveis ambientais que atuam em habitats lóticos como a temperatura da água, concentração de oxigênio, turbulência, pH (Webster 1975, Hissy et al. 1992, Chauvet & Suberkroop 1998, Rajashekhar & Kaveriappa 2000, Medeiros et al. 2009) e a concentração de nutrientes inorgânicos dissolvidos que tem sido bastante investigada nos últimos anos (Ferreira et al. 2015). A vegetação ripária também é um dos fatores imprescindíveis que afeta a comunidade dos hifomicetos aquáticos uma vez que os substratos decompostos são provenientes desta vegetação (Gulis 2001).

Calophyllum brasiliense Cambess é uma das principais espécies vegetais constituintes da vegetação ripária da bacia do Rio de Contas, sendo encontrada desde a nascente até a foz. Além disso, especialmente na Chapada Diamantina, onde a área de estudo é incluída, a espécie só ocorre na margem dos rios até 10 m (Funch, comunicação pessoal). A Chapada Diamantina tem apresentado uma grande diversidade de fungos conidiais (Cruz et al. 2007), mas estudos com hifomicetos aquáticos são escassos.

Em estudos ecológicos de hifomicetos aquáticos várias técnicas têm sido empregadas desde os trabalhos de Nilsson na Suécia (Shearer & Lane 1983, Ghate & Sridhar 2015a). Técnicas que utilizam agitadores orbitais ou câmaras aeradas (bubble chambers) apresentam comunidades com predominância de fungos ingoldianos (Bärlocher 2005, Graça et al. 2016); enquanto técnicas de câmara úmida demonstram comunidades com predominância de hifomicetos aquáticos facultativos (Hyde et al. 2015).

Estudos com hifomicetos aquáticos no Brasil são registrados em diversos biomas tais como: Amazônia (Fiuza et al. 2015), Caatinga (Barbosa et al. 2013, Silva et al. 2014, Fiuza & Gusmão 2013), Cerrado (Schoenlein-Crusius 2002) e Mata Atlântica (Schoenlein-Crusius et al. 2016). Entretanto, estes trabalhos ainda são muito escassos uma vez que menos de 20% da grande rede hidrográfica brasileira foi investigada. Sendo assim, estudos de hifomicetos aquáticos são imprescindíveis para se conhecer a diversidade destes fungos e a dinâmica de suas comunidades.

A fim de se expandir o conhecimento de hifomicetos aquáticos foi realizada a investigação de folhas submersas de *C. brasiliense* em três riachos da bacia do rio de Contas (Rio de Contas, Patricinho e Patricio) utilizando as metodologias de incubações submersas, e câmaras úmidas, com os seguintes objetivos: (*i*) identificar ao nível de genérico ou específico todas as espécies hifomicetos aquáticos encontradas (*ii*) descrever e ilustrar as espécies de hifomicetos aquáticos que constituam novos registros e espécies (*iii*) analisar a riqueza, diversidade, abundância e similaridade das comunidades de hifomicetos aquáticos nos riachos estudados (*iv*) verificar quais as variáveis ambientais interferem na ocorrência de hifomicetos aquáticos e (*v*) detectar possíveis padrões de sucessão na estrutura das comunidades de hifomicetos aquáticos.

2.METODOLOGIA GERAL

2.1 Área de estudo

Os riachos estudados estão localizados na Serra da Tromba, município de Piatã, Bahia (incluído no PPBio- Semiárido, área Abaíra-Itaetê). A Serra da Tromba compõe a borda Ocidental da Chapada Diamantina (região setentrional da Cadeia do Espinhaço), que está inserida no bioma Caatinga e apresenta vários tipos vegetacionais: Cerrado, Campo rupestre, Caatinga e Mata atlântica (Juncá et al. 2005). Nessa serra várias nascentes do rio de Contas são encontradas (Chiapetti & Chiapetti 2011).

O estudo foi realizado em três riachos da bacia do Rio de Contas: o riacho do rio Contas, Patricinho e Patrício (estes dois últimos são afluentes do Rio de Contas) (Tabela 1) (Figuras 1, 2). Os riachos estão inseridos na área de vegetação do campo rupestre (Chagas, comunicação pessoal). O clima é do tipo semiárido, apresentando época chuvosa de novembro a fevereiro (Chiapetti 2009, Paula et al. 2010).

A bacia hidrográfica do rio de Contas pertence à região hidrográfica do Atlântico Leste e está localizada na porção centro-sul do estado da Bahia, sendo considerada a maior bacia inteiramente baiana com área de drenagem de 55.334 km², o que corresponde a pouco mais de 10% do território baiano (Chiapetti 2009).

Tabela 1. Coordenadas e altitude dos riachos estudados na Bacia do Rio de Contas-BA.

	Contas	**Patricinho**	**Patricio**
Coordenadas	13° 07' 31,7" S. 41° 50' 10,5" W	13° 05' 46,4" S. 41° 50' 56,5" W	13° 05' 11,7"S. 41° 51' 13,1"W
Altitude (m)	1332	1320	1272

2.2 *Calophyllum brasiliense* Cambess

Calophyllum brasiliense vulgarmente denominada como Guanandi, Landim ou Jacareúba, pertence à família *Calophyllaceae* (APG III 2009). Destaca-se pela madeira de boa qualidade muito utilizada na indústria madeireira; as flores são melíferas sendo importantes na apicultura e também apresenta substâncias bioativas que combatem a dor, processos infecciosos e úlceras (Figueiredo 1979). A espécie possui ampla distribuição geográfica se estendendo deste a latitude 18º N (Porto Rico) a 28º 10´S (Brasil, Santa Catarina) (Mendonça 2006). *Calophyllum brasiliense* é típica de vegetação ripária sendo encontrada principalmente em solos encharcados o que favorece o reflorestamento de locais com bastante umidade nos solos. A espécie está presente ao longo da vegetação ripária do Rio de Contas da nascente à foz.

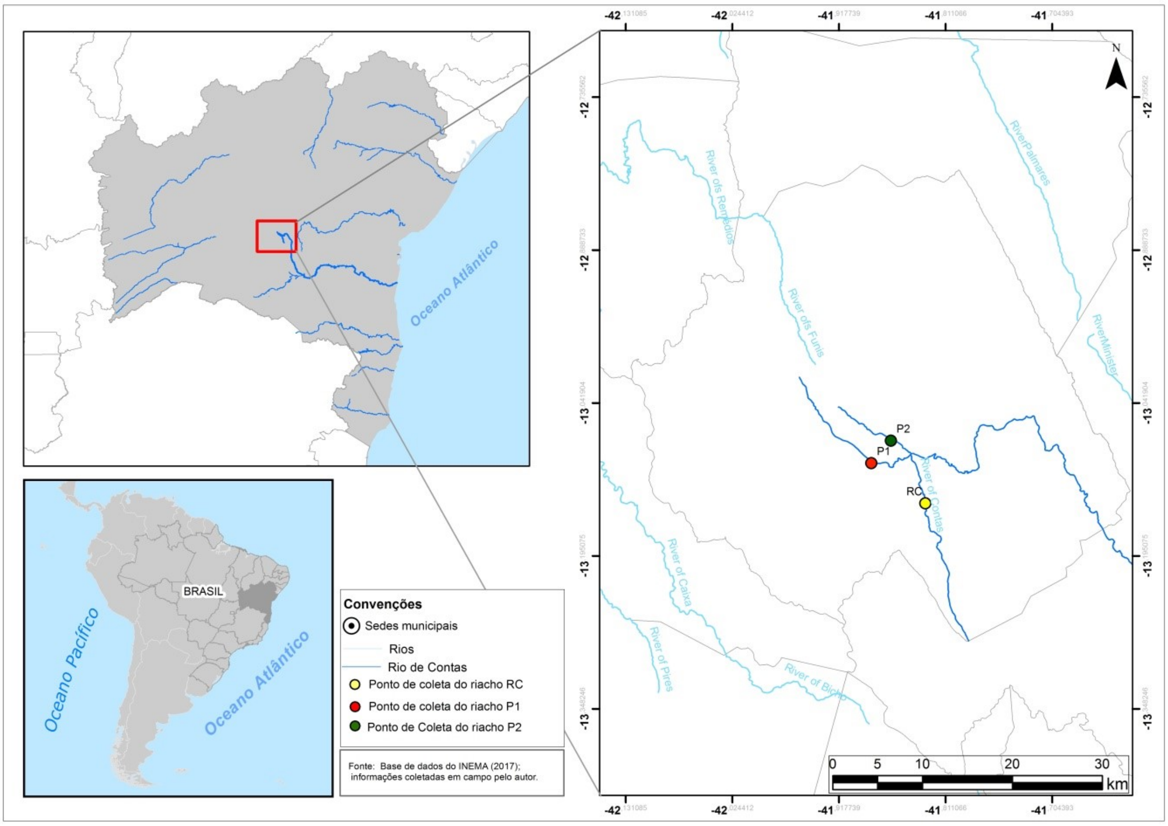

Figura 1. Mapa da área de estudo na Serra da Tromba, Piatã, Bahia, evidenciando os locais de coleta nos riachos: rio de Contas, Patricinho e Patricio (RC, P1 e P2, respectivamente).

2.3 Expedições e métodos de coleta

Em outubro de 2013 e maio de 2014 foram realizadas duas expedições para Serra da Tromba para a coleta de folhas verdes de *Calophyllum brasiliense* na vegetação ripária do rio de Contas para dois experimentos. O experimento 1 (E1) foi realizado de novembro de 2013 a maio 2014 e o experimento 2 (E2) de julho de 2014 a janeiro de 2015, com duração de oito meses cada (4 coletas para cada experimento). Para ambos os experimentos, cinco folhas foram colocadas em cada “litter bag” de malha fina (30 x 30 cm, 0,5 mm, tamanho da malha) (Figura 3), que foram em seguida submersos nos riachos do rio de Contas, Patricio e Patricinho (24 “litter bags” por riacho para cada experimento) e amarrados com fios de nylon a árvores da vegetação ciliar (Figura 4).

Posteriormente, a cada dois meses foram coletados seis sacos de ”litter bags” de cada riacho (6 ”litter bags” x 3 riachos x 4 datas de coleta x 2 experimentos, totalizando 144 sacos e 720 folhas). As amostras foram colocadas em sacos de plástico e transportadas em um isopor com gelo para o laboratório de Micologia (LAMIC) da Universidade Estadual de Feira de Santana. Nas expedições foram também mensuradas variáveis ambientais (temperatura, pH

Figura 2. Visão geral dos riachos estudados; a-b. riacho do rio de Contas, c-d. riacho Patricinho, e-f. riacho Patricio.

e oxigênio dissolvido e velocidade da água) e 1L de água dos riachos para realização de análise da concentração total de fósforo e nitrogênio. As variáveis ambientais (temperatura da água, pH e oxigênio dissolvido) foram medidas com equipamento portátil (HORIBA U-50) e a velocidade da água com o fluxômetro (GLOBAL WATER FP111). A precipitação foi obtida a partir do Instituto Nacional de Metereologia (INMET).

Figura 3. Folhas de *Calophyllum brasiliense*; a. folhas verdes coletadas, b. folhas separadas, c. folhas em "litter bags", d."litter bags" submersos.

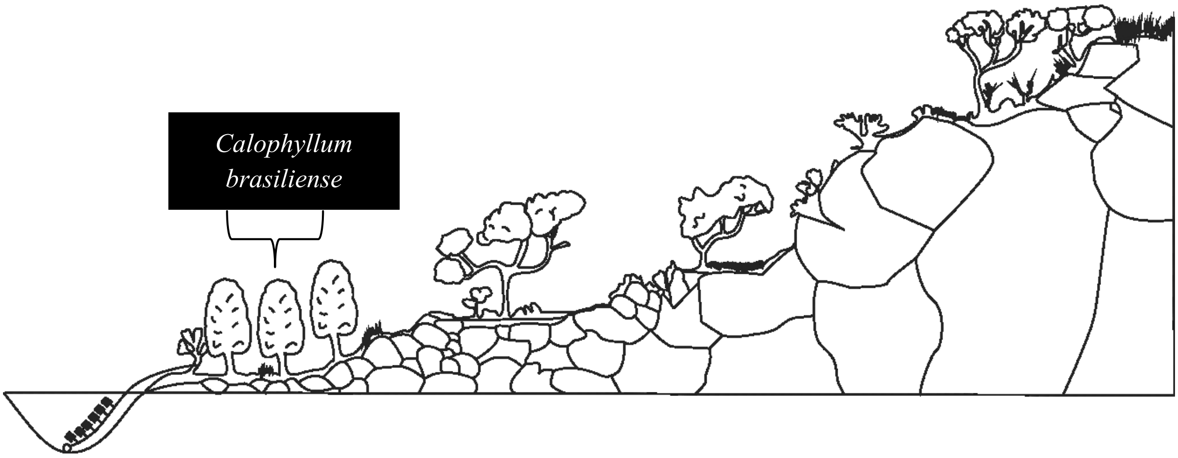

Figura 4. Diagrama de perfil do riacho de Contas demonstrando os "litter bags" unidos pelo fio de nylon preso a uma árvore da vegetação ripária (Adaptado de Cavalcante, EMBRAPA 2007).

No LAMIC as amostras foram processadas de acordo com as metodologias de Bärlocher (2005) e Castañeda-Ruiz et al. (2016).

Bärlocher (2005) incubações submersas: As folhas contidas em três “litter bags” de cada riacho e coleta foram lavadas e discos de 12 mm diam. foram cortados com furador de rolhas. Os discos foram incubados por 48 horas a 18-20ºC no agitador (100rpm) em frascos de Erlenmeyer 100 mL contendo 30 mL de água destilada para induzir a esporulação. Foram analisados três frascos de Erlenmeyer contendo 20 discos de folhas por riacho em cada coleta, totalizando 60 discos de folha por riacho e coleta. As amostras de cada Erlenmeyer foram armazenadas em tubos de Falcon e posteriormente a suspensão de esporos foi filtrada em filtros de membrana (5 µm) e os filtros foram montados em lâminas com azul de algodão e ácido láctico. Os discos de folhas também foram montados em lâminas e examinados sob o microscópio (Olympus BX51). Todos os esporos dos filtros e lâminas com discos de folhas foram contados (Figura 5).

Castañeda-Ruiz et al. (2016): As folhas contidas nos outros três “litter bags”, de cada riacho e coleta, foram lavadas em água corrente por 30 minutos e colocadas em placas de Petri com papel umedecido (câmaras úmidas). As câmaras úmidas foram incubadas em isopor com água destilada e glicerol por 30 dias. Neste período as estruturas dos fungos detectadas em estereomicroscópio foram montadas em lâminas com ácido láctico, seladas com esmalte incolor e posteriormente os fungos foram identificados (Figura 6). Os espécimes isolados de cada folha foram contados como um indivíduo cada.

As identificações foram realizadas no LAMIC e no Laboratório de Microbiologia do Departamento de Biologia na Coastal Carolina University, Estado Unidos. Posteriormente as lâminas foram depositadas no Herbário da Universidade Estadual de Feira de Santana (HUEFS). Alguns fungos foram isolados em cultura pura e depositados na Coleção de Cultura de Microorganismos da Bahia (CCMB).

As amostras de água dos riachos foram analisadas de acordo a metodologia proposta por Koroleff (1976), no Laboratório de Microbiologia Ambiental da Universidade Federal da Bahia (UFBA).

2.4 Ilustrações

As ilustrações foram realizadas em câmara-clara e fotomicrografias no microscópio (Olympus BX51).

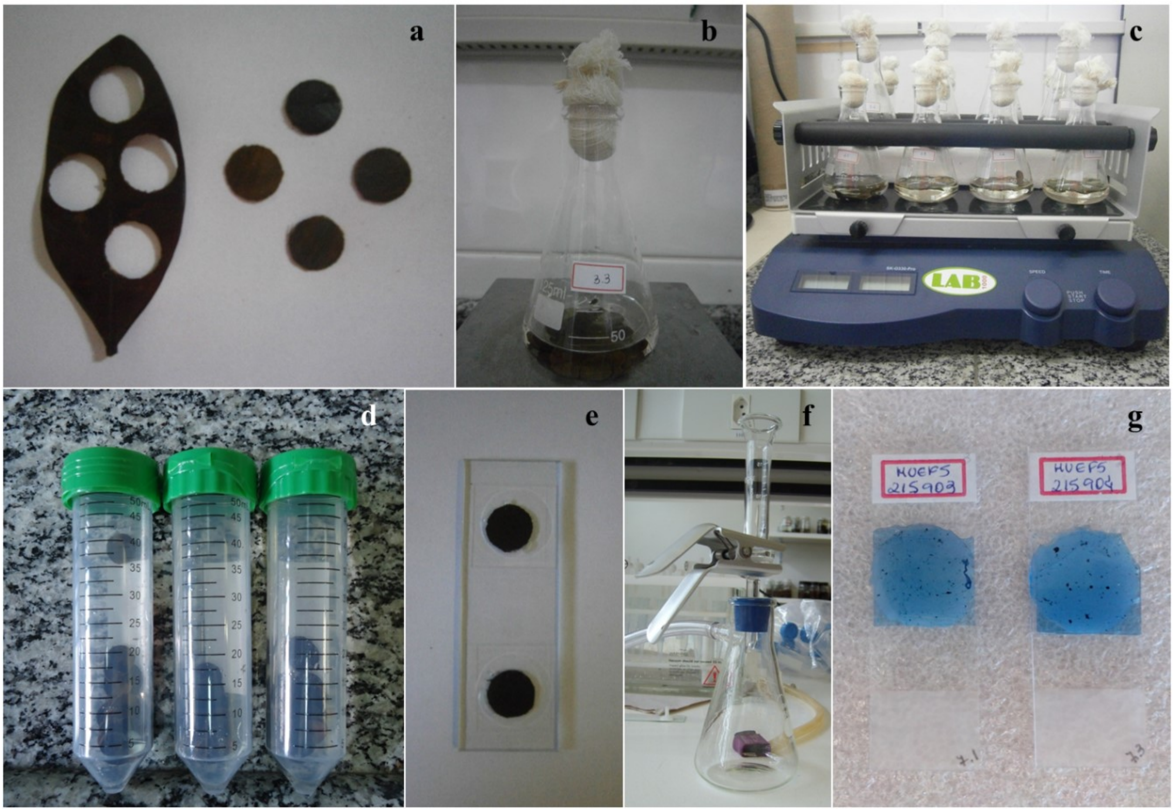

Figura 5. Metodologia de Bärlocher (2005); a. Folhas cortadas em discos, b. Frasco de Erlenmeyer contendo água destilada e discos de folhas, c. Frascos de Erlenmeyer em shaker, d. Tubos de Falcon com amostras de discos de folhas, e. Lâminas com discos de folhas, f. Filtração, g. Lâminas com filtros corados com azul de algodão.

2.5 Análise de dados ecológicos

A diversidade das comunidades de hifomicetos aquáticos associadas à folhas de *C. brasiliense* dos riachos foi avaliada usando o índice de diversidade de Simpson e Equitabilidade (Magurran 1988). Chao 1 foi utilizado para estimar o número de táxons esperados nas comunidades (Chao 1984). Abundância relativa foi expressa em porcentagem do total de conídios pela somatória de todos os conídios de táxons acessados na metodologia de incubações submersas (Ghate & Sridhar 2015b). Abundância relativa para câmara úmida foi calculada da seguinte forma: Abundância relativa= n (100/N), onde n= número de indivíduos por espécie, N= número total de indivíduos na amostra. ANOVA foi realizada para avaliar os efeitos dos riachos, experimentos e datas de coleta sobre as taxas de esporulação. Os dados foram transformados em log para se atender ao pressuposto de normalidade dos resíduos da ANOVA.

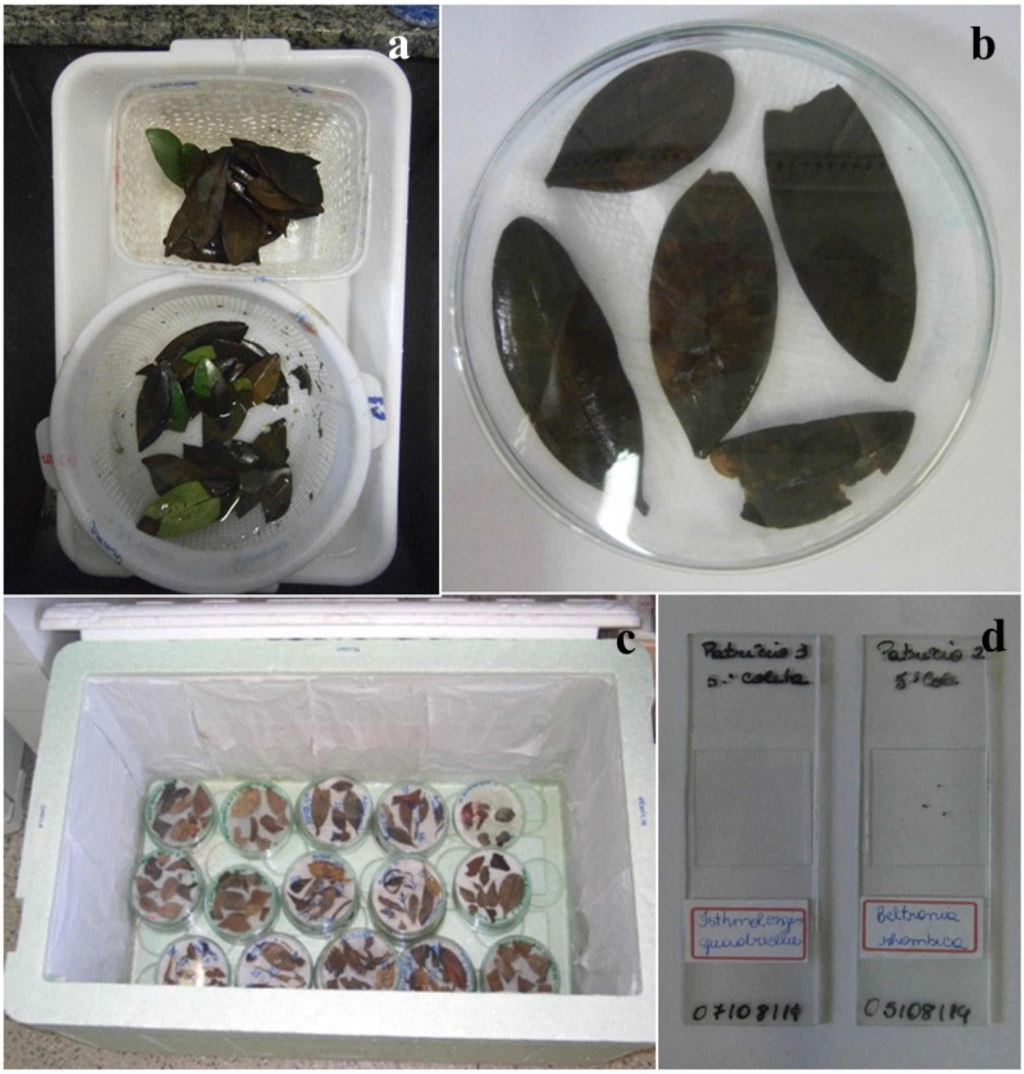

Figura 6. Metodologia de Castañeda et al. (2016); a. Lavagem em água corrente, b. Câmara-úmida com folhas, c. Câmaras-úmidas acondicionadas em isopor, d. Lâminas semi-permanentes.

Análise de porcentagem de similaridade (SIMPER) foi realizada para identificar os táxons mais influentes que contribuíram para dissimilaridade entre riachos. ANOSIM foi realizada para verificar diferenças/dissimilaridades de comunidades nos riachos (Clarke 1993). O NMDS (Método de escalonamento multidimensional não métrico) foi utilizado para verificar se concentração de nutrientes dissolvidos e variáveis ambientais estavam relacionados (temperatura, pH, oxigênio dissolvido e velocidade da água) às comunidades de fungos, utilizando a matriz de dissimilaridade de Bray-curtis (Clarke 1993).

A sucessão de fungos foi avaliada através da constância de espécies. Foram utilizadas as seguintes classes de constância: táxon acidental ($C \leq 25\%$), táxon acessório ($25\% < C \leq 50\%$) e táxon constante ($C > 50\%$). Para comparar as metodologias foi realizada a análise de agrupamento UPGMA, baseada na matriz de similaridade de Dice, para verificar a similaridade e grupos de comunidades.

As análises foram conduzidas no programa Past 3.14 software (Hammer et al. 2013) e Primer 5.2.6 software (Clarke & Gorley 2006).

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Capítulo I

Fungos ingoldianos do Brasil: alguns novos registros e uma revisão incluindo um checklist e uma chave

Os fungos ingoldianos possuem distribuição mundial, mas a maioria das espécies tem sido descrita em regiões temperadas. No Brasil os estudos com fungos ingoldianos foram iniciados nos anos 80, no bioma Mata Atlântica, em São Paulo. Posteriormente os estudos se estenderam para outros biomas tais como Cerrado, Caatinga e Amazônia. O objetivo deste estudo é aperfeiçoar nosso entendimento de ocorrência e distribuição de fungos ingoldianos no Brasil. Nós incluímos e discutimos novos registrados para o Brasil associados a folhas submersas de *Calophyllum brasiliense* e providenciamos um checklist, chave e ilustrações para todas as espécies de fungos ingoldianos registrados no Brasil, assim como mapas de distribuição. *Flagellospora stricta* é um novo registro para as Américas; *Dendrosporomyces prolifer* e *Geniculospora inflata* para o Neotrópico; *Pyramidospora casuarinae* e *Triscelophorus monosporus* são novos registros para a Caatinga. Com a adição das espécies associadas a folhas submersas de *C. brasiliense*, um total de 85 táxons de fungos ingoldianos são agora registrados no Brasil. Dezenove táxons são registrados na Amazônia, 53 para a Mata Atlântica, 39 para a Caatinga e 21 para o Cerrado.

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Ingoldian fungi of Brazil: some new records and a review including a checklist and a key

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Abstract

Ingoldian fungi have a worldwide distribution, but the most species have been described from temperate regions. In Brazil, the studies of Ingoldian fungi started in the 1980's in the Atlantic Forest, the state of São Paulo. Later studies extended to other biomes such as the Cerrado, Caatinga and Amazon. The aim of this study is to improve our understanding of the occurrence and distribution of Ingoldian fungi in Brazil. Here, we include and discuss several new records for Brazil associated with submerged leaves of *Calophyllum brasiliense* and provide a checklist, a key and illustrations for all species of the Ingoldian fungi recorded from Brazil, as well as distribution maps. *Flagellospora stricta* is a new record to the Americas; *Dendrosporomyces prolifer* and *Geniculospora inflata* to the Neotropics; *Pyramidospora casuarinae* and *Triscelophorus monosporus* are new records to the Caatinga. With the new additions of species associated with submerged leaves of *C. brasiliense,* a total of 85 taxa of Ingoldian fungi are now recorded in Brazil. Nineteen taxa are reported from the Amazon, 53 from the Atlantic Forest, 39 from the Caatinga and 21 from the Cerrado.

Key-words: aquatic hyphomycetes, biodiversity, tropical

Introduction

Ingoldian fungi are asexual stages of ascomycetes or basidiomycetes (Shearer *et al.* 2007) adapted to aquatic environments. They are identified mainly based on the morphological features of conidia that are often quite unique: branched, sigmoid, tetraradiate, or multiradiate. Earlier studies based on anamorph-teleomorph connections (Webster 1992) and more recent molecular data (Belliveau & Bärlocher 2005, Baschien *et al.* 2006) have shown that Ingoldian fungi are polyphyletic. The majority of species analyzed have affinity with the Leotiomycetes (Helotiales), while some species are closely related to Dothideomycetes (Dothideales and Pleosporales), Orbiliomycetes (Orbiliales) or Sordariomycetes (Hypocreales) (Belliveau & Bärlocher 2005, Baschien *et al.* 2006, 2013, Campbell *et al.* 2009, Shearer *et al.* 2014); very few species are of basidiomycetous affinity. Ingoldian fungi have worldwide distribution (Jones & Pang 2012) but the highest number of species has been described from temperate regions (Silva & Briedis 2011).

Aquatic fungi are essential in the decomposition of submerged plant litter and are the key players in aquatic ecosystems facilitating the transfer of energy and nutrients to higher tropic levels (Gessner *et al.* 2007). Ingoldian fungi demonstrate the production of a wide variety of enzymes with cellulolytic, pectinolytic and proteolytic activity (Shearer 1992). Some of these fungi have been also reported to produce antimicrobial secondary metabolites (Gulis & Stephanovich 1999, Arya & Sati 2011).

De Wildeman described three genera of Ingoldian fungi in the 1890: *Clavariopsis* De Wild. (1895: 200), *Lemonniera* De Wild. (1894: 147) and *Tetracladium* De Wild. (1893: 39) (De Wildeman 1893, 1894, 1895). The group received more attention in 1942, with the Ingold's study that named the group "aquatic hyphomycetes" and listed 16 species, seven new genera, 11 new species and two new combinations (Ingold 1942). C.T. Ingold collected and published extensively on the Ingoldian fungi from temperate and tropical regions and inspired more interest in this group (Ingold 1949, 1958a, 1959, Hudson & Ingold 1960).

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Nilsson (1962a) began the studies of Ingoldian fungi in South America collecting from rivers in Venezuela and described two new genera: *Angulospora* Sv. Nilsson (1962: 354) and *Pyramidospora* Sv. Nilsson (1962: 358). Later reports came from Argentina, Brazil, Chile, Colombia, Ecuador, Peru and Venezuela (Gamundi *et al.* 1977, Burgos & Riffart 1982, Schoenlein-Crusius & Milanez 1989, Matsushima 1993, Luna-Fontalvo 2009, Silva & Briedis 2016). Matsushima (1993) described a new species, *Triscelophorus curviramifer* Matsush. (1993: 70) and proposed a new combination *T. deficiens* (Matsush.) Matsush. (1993: 70) from Peru.

In Brazil, the studies of Ingoldian fungi started in the 1980's on submerged leaves of *Ficus microcarpa* L.f. (1782: 442) in the Atlantic Forest, the state of São Paulo (Schoenlein-Crusius & Milanez 1989). Later studies extended to other biomes such as the Cerrado, Caatinga and Amazon (Schoenlein-Crusius 2002, Fiuza & Gusmão 2013a, Fiuza *et al.* 2015). Schoenlein-Crusius & Grandi (2003) reviewed the diversity of aquatic hyphomycetes in South America and reported 31 taxa of Ingoldian fungi from Brazil.

The aim of this study is to improve our understanding of the occurrence and distribution of Ingoldian fungi in Brazil. Here, we include and discuss several new records for Brazil associated with submerged leaves of *Calophyllum brasiliense* Cambess. in Saint-Hilaire (1825: 320) and provide a checklist, a key and illustrations for all species of the Ingoldian fungi recorded from Brazil, as well as distribution maps.

Materials and Methods

Study area

From November 2013 to January 2015, we made eight expeditions to "Serra da Tromba", located in the Chapada Diamantina, a semiarid region in northeastern Brazil. Submerged leaves of *C. brasiliense* were collected from three streams in the Contas river basin after several weeks of decomposition in litter bags. The samples were taken to the Laboratory of Mycology (LAMIC) in plastic bags, and processed according to Castañeda Ruiz *et al.* (2016) and Bärlocher (2005).

Sampling methods

Castañeda Ruiz *et al.* (2016): The samples were washed and placed in Petri dishes (moist chambers) incubated in a polystyrene box with sterile water plus glycerol for 30 days. Fungal structures were mounted on slides with lactic acid and sealed with nail polish. Some fungi were also isolated into pure culture.

Bärlocher (2005): Leaf samples were washed and 12-mm diam discs cut with a cork borer. The discs were incubated for 48 hours at 18–20ºC on a shaker (100rpm) in 100-mL Erlenmeyer flasks containing 30 mL of sterile distilled water to induce sporulation. The spore suspensions were filtered through membrane filters (5 µm pore size), and the filters were then mounted on slides with cotton blue in lactic acid. The leaf discs were also mounted on slides and examined under compound microscope. The specimens are deposited in the Herbarium of "Universidade Estadual de Feira de Santana" (HUEFS).

Venn diagram showing the distribution of Ingoldian fungi among different biomes was made using software available at Bioinformatics & Evolutionary Genomics (2016) site.

Results

In the present study in the Caatinga, we found 15 taxa of Ingoldian fungi from 12 genera (Table 1) associated with submerged leaves of *Calophyllum brasiliense*. *Flagellospora stricta* Sv. Nilsson (1962b:82) is a new record to the Americas; *Dendrosporomyces prolifer* Nawawi, J. Webster & R.A. Davey (1977: 59) and *Geniculospora inflata* (Ingold) Sv. Nilsson ex Marvanová & Sv. Nilsson (1971: 532) to the Neotropics; *Pyramidospora casuarinae* Sv. Nilsson (1962a: 359) and *Triscelophorus monosporus* Ingold (1943: 152) are new records to the Caatinga. All new records are discussed in details in the Taxonomy section below.

With these additions, a total of 85 taxa of Ingoldian fungi are now reported from Brazil (Table 2). Of those, 19 taxa are known from the Amazon, 53 from the Atlantic Forest, 39 from the Caatinga and 21 from the Cerrado (Fig. 1). All species of Ingoldian fungi that has been found in Brazil are illustrated in Figs. 2–7. In addition, a key to all taxa and maps showing study sites and distribution are provided (Figs. 8–9).

TABLE 1. Taxa of Ingoldian fungi associated with *Calophyllum brasiliense* in this study.

Taxa	**Moist chambers (after Castañeda-Ruiz *et al.* 2016)**	**Submerged incubations (after Bärlocher 2005)**
***Anguillospora filiformis* Greath.**		**x**
***A. longissima* (Sacc. & P. Syd.) Ingold**		**x**
***Condylospora gigantea* Nawawi & Kuthub.**		**x**
***Dendrosporium lobatum* Plakidas & Edgerton ex J.L. Crane**	**x**	**x**
***Dendrosporomyces prolifer* Nawawi, J. Webster & R.A. Davey**	**x**	**x**
***Filosporella* sp.**	**x**	**x**
***Flagellospora curvula* Ingold**		**x**
***F. stricta* Sv. Nilsson**		**x**
***Geniculospora inflata* (Ingold) Sv. Nilsson ex Marvanová & Sv. Nilsson**	**x**	
***Ingoldiella hamata* D.E. Shaw**	**x**	
***Lunulospora curvula* Ingold**		**x**
***Pyramidospora casuarinae* Sv. Nilsson**		**x**
***Scutisporus brunneus* K. Ando & Tubaki**		**x**
***Triscelophorus acuminatus* Nawawi**	**x**	**x**
***T. monosporus* Ingold**		**x**

TABLE 2. Taxa of Ingoldian fungi recorded from Brazil.

Taxa	**Substrate**	**Biome**	**Reference**	**Ilustration from**
***Alatospora acuminata* Ingold**	Submerged leaf litter	Atlantic Forest	Malosso (1999)	Ingold (1942); Fiuza & Gusmão (2013a); Fiuza *et al.* (2015)
	Foam	Caatinga	Fiuza & Gusmão (2013a)	
	Foam	Amazon	Fiuza *et al.* (2015)	
***Anguillospora crassa* Ingold**	Submerged leaf litter	Atlantic Forest	Schoenlein-Crusius & Milanez (1990a , 1990b), Schoenlein-Crusius *et al.* (2009, 2014, 2015a, 2015b, 2016)	Ingold (1958b)
	Submerged leaves of *Alchornea triplinervia* Spreng. M. Arg.	Atlantic Forest	Schoenlein-Crusius & Milanez (1998a, 1998b)	
	Submerged leaves of *Tibouchina pulchra* (Cham.) Cogn	Atlantic Forest	Moreira (2006), Schoenlein-Crusius *et al.* (2015b, 2016)	
	Submerged leaves of *Protium heptaphyllum* Marchand and *Lafoensia pacari* A.St.-Hil.	Atlantic Forest	Rosa *et al.* (2009)	
	Submerged leaves of *Caesalpinia echinata* Lam.	Atlantic Forest	Moreira (2011), Schoenlein-Crusius *et al.* (2015b)	
	Submerged leaf litter	Cerrado	Malosso (1999), Schoenlein-Crusius (2002)	
***A. filiformis* Greath.**	Submerged leaves of *Protium heptaphyllum* Marchand and *Lafoensia pacari* A.St.-Hil.	Atlantic Forest	Rosa *et al.* (2009)	Present study
	Submerged leaf litter	Atlantic Forest	Schoenlein-Crusius *et al.* (2009)	
	Submerged leaf litter	Caatinga	Sales *et al.* (2014)	
	Submerged leaves of *Calophyllum brasiliense* Cambess	Caatinga	Present study	
***A. furtiva* J. Webster & Descals**	Submerged leaf litter	Caatinga	Sales *et al.* (2014)	Descals *et al.* (1998)
***A. longissima* (Sacc. & P. Syd.) Ingold**	Foam	Caatinga	Fiuza & Gusmão (2013a)	Present study
	Submerged leaf litter	Amazon	Fiuza *et al.* (2015)	
	Submerged leaf litter	Cerrado	Malosso (1999), Schoenlein-Crusius (2002)	

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TABLE 2. (Continued)

Taxa	Substrate	Biome	Reference	Ilustration from
***A. longissima* (Sacc. & P. Syd.) Ingold**	Submerged leaf litter	Atlantic Forest	Malosso (1999), Schoenlein-Crusius *et al.* (2009), Schoenlein-Crusius *et al.* (2014, 2015a, 2015b)	
	Submerged leaves of *Caesalpinia echinata* Lam. and *Campomanesia phaea* (O. Berg.) Landrum	Atlantic Forest	Moreira (2011), Schoenlein-Crusius *et al.* (2015b)	
	Submerged leaves of *Calophyllum brasiliense* Cambess	Caatinga	Present study	
	Submerged leaf litter	Caatinga	Sales *et al.* (2014)	
	Submerged leaf litter of *Ficus microcarpa* L. f.	Atlantic Forest	Schoenlein-Crusius & Milanez (1989, 1990a, b), Schoenlein-Crusius *et al.* (2015b)	
	Submerged leaves of *Quercus robur* L.	Atlantic Forest	Schoenlein-Crusius *et al.* (1992)	
	Submerged leaves of *Tibouchina pulchra* (Cham.) Cogn.	Atlantic Forest	Schoenlein-Crusius *et al.* (2016)	
***Anguillospora* sp.**	Submerged leaves of *Alchornea triplinervia* Spreng. M. Arg., *Ficus microcarpa* L. f. and *Quercus robur* L.	Atlantic Forest	Schoenlein-Crusius *et al.* (1992)	
	Submerged leaf litter	Atlantic Forest	Malosso (1999), Schoenlein-Crusius *et al.* (2014, 2015b)	
	Submerged leaves of *Tibouchina pulchra* (Cham.) Cogn.	Atlantic Forest	Moreira (2006)	
	Submerged leaves of *Caesalpinia echinata* Lam. and *Campomanesia phaea* (O. Berg.) Landrum	Atlantic Forest	Moreira (2011)	
***Aquanectria penicillioides* (Ingold) L. Lombard & Crous**	Submerged leaf litter	Cerrado	Schoenlein-Crusius (2002)	Ingold (1944)
	Submerged leaf litter	Atlantic Forest	Schoenlein-Crusius *et al.* (2015a, 2015b)	
***A. submersa* (H.J. Huds.) L. Lombard & Crous**	Submerged leaf litter	Cerrado	Malosso (1999)	Hudson (1961)
	Submerged leaves of *Protium heptaphyllum* Marchand and *Lafoensia pacari* A.St.-Hil.	Atlantic Forest	Rosa *et al.* (2009)	
***Articulospora tetracladia* Ingold**	Submerged leaf litter	Atlantic Forest	Malosso (1999)	Ingold (1942); Fiuza & Gusmão (2013a)
	Submerged leaves of *Protium heptaphyllum* Marchand and *Lafoensia pacari* A.St.-Hil.	Atlantic Forest	Rosa *et al.* (2009)	
	Foam	Caatinga	Fiuza & Gusmão (2013a)	
	Foam	Amazon	Fiuza *et al.* (2015)	
***Articulospora* sp.**	Submerged leaf litter	Atlantic Forest	Schoenlein-Crusius *et al.* (2009)	
***Brachiosphaera tropicalis* Nawawi**	Foam	Caatinga	Fiuza & Gusmão (2013a)	Descals *et al.* (1976); Fiuza & Gusmão (2013a)
	Submerged bark	Caatinga	Barbosa *et al.* (2013)	
	Submerged leaf litter	Amazon	Monteiro (2014)	
***Campylospora brasiliensis* L. B. Moro & Schoenl.-Crus.**	Submerged leaf litter	Atlantic Forest	Moro *et al.* (2015)	Moro *et al.* (2015)

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TABLE 2. (Continued)

Taxa	Substrate	Biome	Reference	Ilustration from
C. chaetocladia **Ranzoni**	Foam	Caatinga	Fiuza & Gusmão (2013b)	Fiuza & Gusmão (2013b); Ranzoni (1953)
	Submerged leaf litter	Cerrado	Schoenlein-Crusius (2002)	
	Submerged leaf litter	Atlantic Forest	Schoenlein-Crusius *et al.* (2015b, 2016)	
	Submerged leaves of *Protium heptaphyllum* Marchand and *Lafoensia pacari* A.St.-Hil.	Atlantic Forest	Rosa *et al.* (2009)	
C. filicladia **Nawawi**	Foam	Caatinga	Fiuza & Gusmão (2013b)	Fiuza & Gusmão (2013b)
C. parvula **Kuzuha**	Foam	Caatinga	Fiuza & Gusmão (2013b)	Fiuza & Gusmão (2013b)
	Submerged leaf litter	Cerrado	Malosso (1999)	
Campylospora **sp.**	Foam	Caatinga	Fiuza & Gusmão (2013b)	
Clavariopsis aquatica **De Wild.**	Submerged leaf litter	Atlantic Forest	Schoenlein-Crusius & Milanez (1990a and 1990b)	De Wildeman (1895)
	Submerged leaf litter	Cerrado	Malosso (1999)	
	Submerged leaves of *Protium heptaphyllum* Marchand and *Lafoensia pacari* A.St.-Hil.	Atlantic Forest	Rosa *et al.* (2009)	
Condylospora flexuosa **Nawawi & Kuthub.**	Foam	Amazon	Fiuza *et al.* (2015)	Fiuza *et al.* (2015)
C. gigantea **Nawawi & Kuthub.**	Foam	Caatinga	Fiuza & Gusmão (2013a)	Present study
	Foam	Amazon	Fiuza *et al.* (2015)	
	Submerged leaves of *Calophyllum brasiliense* Cambess	Caatinga	Present study	
C. spumigena **Nawawi**	Foam	Amazon	Fiuza *et al.* (2015)	Fiuza *et al.* (2015)
Condylospora **sp.**	Foam	Caatinga	Fiuza & Gusmão (2013a)	Fiuza & Gusmão (2013a)
	Foam	Amazon	Fiuza *et al.* (2015)	
Culicidospora aquatica **R.H. Petersen**	Submerged leaves of *Protium heptaphyllum* Marchand and *Lafoensia pacari* A.St.-Hil.	Atlantic Forest	Rosa *et al.* (2009)	Petersen (1960)
C. gravida **R.H. Petersen**	Foam	Caatinga	Fiuza & Gusmão (2013a)	Fiuza & Gusmão (2013a)
Dactylella microaquatica **Tubaki**	Submerged leaf litter	Atlantic Forest	Malosso (1999), Schoenlein-Crusius *et al.* (2015b)	Tubaki (1957)
	Submerged leaf litter	Cerrado	Malosso (1999)	
Dendrospora erecta **Ingold**	Submerged leaf litter	Atlantic Forest	Schoenlein-Crusius *et al.* (2009, 2015b)	Ingold (1943)
	Submerged leaves of *Tibouchina pulchra* (Cham.) Cogn.	Atlantic Forest	Schoenlein-Crusius *et al.* (2016)	
Dendrospora **sp.**	Submerged leaves of *Alchornea triplinervia* Spreng. M. Arg. and *Ficus microcarpa* L. f.	Atlantic Forest	Schoenlein-Crusius *et al.* (1992)	
	Submerged leaf litter	Atlantic Forest	Schoenlein-Crusius *et al.* (2014)	

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TABLE 2. (Continued)

Taxa	Substrate	Biome	Reference	Ilustration from
Dendrosporium lobatum **Plakidas & Edgerton ex J.L. Crane**	Foam	Amazon	Fiuza *et al.* (2015)	Fiuza & Gusmão (2013a); Fiuza *et al.* (2015)
	Soil	Atlantic Forest	Cavalcanti & Milanez (2007)	
	Submerged leaf litter	Caatinga	Fiuza & Gusmão (2013a)	
	Submerged leaves of *Calophyllum brasiliense* Cambess	Caatinga	Present study	
Dendrosporomyces prolifer **Nawawi, J. Webster & R.A. Davey**	Submerged leaves of *Calophyllum brasiliense* Cambess	Caatinga	Present study	Present study
D. splendens **(Nawawi) Nawawi & J. Webster**	Leaves of *Alchornea triplinervia* (Spreng.)Mull. Arg.	Atlantic Forest	Grandi (1998)	Nawawi (1973)
	Leaves of *Euterpe edulis* Mart.	Atlantic Forest	Grandi (1999)	
Dwayaangam **sp. as** ***Dwayaangam cornuta*** **in Fiuza et al. (2015)**	Foam	Amazon	Fiuza *et al.* (2015)	
Filosporella versimorpha **Marvanová, P.J. Fisher, Aimer & B.C. Segedin as** ***Anguillospora pseudolongissima*** **in Fiuza & Gusmão (2013a)**	Foam	Caatinga	Fiuza & Gusmão (2013a)	Ranzoni (1953), Fiuza & Gusmão (2013a)
Filosporella **sp.**	Submerged leaves of *Calophyllum brasiliense* Cambess	Caatinga	Present study	
Flabellocladia tetracladia **(Nawawi) Nawawi**	Foam	Caatinga	Fiuza & Gusmão (2013a)	Fiuza & Gusmão (2013a)
Flabellospora crassa **Alas.**	Submerged leaf litter	Atlantic Forest	Schoenlein-Crusius & Milanez (1990a and 1990b), Schoenlein-Crusius *et al.* (2009, 2015a, 2015b)	Alasoadura (1968a)
	Submerged leaf litter	Cerrado	Schoenlein-Crusius (2002)	
F. multiradiata **Nawawi**	Submerged leaf litter	Amazon	Monteiro (2014)	Monteiro (2014)
F. verticillata **Alas.**	Foam	Caatinga	Fiuza & Gusmão (2013a)	Fiuza & Gusmão (2013a)
	Submerged leaf litter	Atlantic Forest	Schoenlein-Crusius *et al.* (2016)	
Flagellospora curvula **Ingold**	Foam	Caatinga	Fiuza & Gusmão (2013a)	Present study
	Foam	Amazon	Fiuza *et al.* (2015)	
	Submerged leaf litter	Atlantic Forest	Malosso (1999), Schoenlein-Crusius *et al.* (2009, 2015a, 2015b	
	Submerged leaf litter	Cerrado	Malosso (1999)	
	Submerged leaf litter	Caatinga	Sales *et al.* (2014)	
	Submerged leaves of *Calophyllum brasiliense* Cambess	Caatinga	Present study	
	Submerged leaves of *Protium heptaphyllum* Marchand and *Lafoensia pacari* A.St.-Hil.	Atlantic Forest	Rosa *et al.* (2009)	
Flagellospora **sp.**	Submerged leaf litter	Atlantic Forest	Schoenlein-Crusius *et al.* (2014, 2016)	

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TABLE 2. (Continued)

Taxa	Substrate	Biome	Reference	Illustration from
F. stricta **Sv. Nilsson**	Submerged leaves of *Calophyllum brasiliense* Cambess	Caatinga	Present study	Present study
Geniculospora inflata **(Ingold) Sv. Nilsson ex Marvanová & Sv. Nilsson**	Submerged leaves of *Calophyllum brasiliense* Cambess	Caatinga	Present study	Present study
Heliscella stellata **(Ingold & Cox) Marvanová**	Submerged leaf litter	Cerrado	Malosso (1999)	Ingold & Cox (1957)
Heliscus **sp.**	Submerged leaves of *Tibouchina pulchra* (Cham.) Cogn.	Atlantic Forest	Moreira (2006)	
Ingoldiella hamata **D.E. Shaw**	Foam	Amazon	Fiuza *et al.* (2015)	Fiuza *et al.* (2015)
	Submerged bark and petiole	Caatinga	Barbosa *et al.* (2013)	
	Submerged leaf litter	Cerrado	Schoenlein-Crusius (2002)	
	Submerged leaf litter	Amazon	Monteiro (2014)	
	Submerged leaf litter	Caatinga	Silva *et al.* (2014)	
	Submerged leaves of *Calophyllum brasiliense* Cambess	Caatinga	Present study	
Isthmotricladia **sp.**	Submerged leaves of *Quercus robur* L.	Atlantic Forest	Schoenlein-Crusius *et al.* (1990)	
Jaculispora submersa **H.J. Huds. & Ingold**	Foam	Caatinga	Fiuza & Gusmão (2013a)	Fiuza & Gusmão (2013a)
Lemonniera alabamensis **R.C. Sinclair & Morgan-Jones**	Foam	Caatinga	Fiuza & Gusmão (2013a)	Fiuza & Gusmão (2013a)
L. aquatica **De Wild.**	Foam	Amazon	Fiuza *et al.* (2015)	Fiuza *et al.* (2015)
	Submerged leaf litter	Atlantic Forest	Malosso (1999), Schoenlein-Crusius *et al.* (2009, 2015b)	
	Submerged leaf litter	Cerrado	Schoenlein-Crusius (2002)	
	Submerged leaves of *Ficus microcarpa* L. f.	Atlantic Forest	Schoenlein-Crusius & Milanez (1989, 1990a)	
	Submerged leaves of *Protium heptaphyllum* Marchand and *Lafoensia pacari* A.St.-Hil.	Atlantic Forest	Rosa *et al.* (2009)	
	Submerged leaves of *Quercus robur* L.	Atlantic Forest	Schoenlein-Crusius *et al.* (1990, 1992)	
	Submerged leaves of *Tibouchina pulchra* (Cham.) Cogn. and submerged leaf litter	Atlantic Forest	Schoenlein-Crusius *et al.* (2016)	
L. pseudofloscula **Dyko**	Foam	Caatinga	Fiuza & Gusmão (2013a)	Fiuza & Gusmão (2013a)
Lemonniera **sp.**	Submerged leaf litter	Cerrado	Attili & Tauk-Tornisiello (1994)	
Lunulospora curvula **Ingold**	Foam	Caatinga	Fiuza & Gusmão (2013a)	Fiuza & Gusmão (2013a)
	Submerged leaf litter	Cerrado	Malosso (1999), Schoenlein-Crusius (2002)	
	Submerged leaf litter	Atlantic Forest	Malosso (1999), Schoenlein-Crusius *et al.* (2009, 2014, 2015a, 2016)	
	Submerged leaf litter	Caatinga	Sales *et al.* (2014)	
	Submerged leaf litter and *Campomanesia phaea* (O. Berg.) Landrum	Atlantic Forest	Moreira (2011), Schoenlein-Crusius *et al.* (2015b)	

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TABLE 2. (Continued)

Taxa	Substrate	Biome	Reference	Illustration from
Lunulospora curvula **Ingold**	Submerged leaves of *Alchornea triplinervia* Spreng. M. Arg., *Ficus microcarpa* L. f., *Quercus robur* L. and submerged leaf litter	Atlantic Forest	Schoenlein-Crusius & Milanez (1990a, 1990b, 1998b)	
	Submerged leaves of *Calophyllum brasiliense* Cambess	Caatinga	Present study	
	Submerged leaves of *Protium heptaphyllum* Marchand and *Lafoensia pacari* A.St.-Hil.	Atlantic Forest	Rosa *et al.* (2009)	
	Submerged leaves of *Tibouchina pulchra* (Cham.) Cogn.	Atlantic Forest	Schoenlein-Crusius *et al.* (2016)	
L. cymbiformis **Miura**	Submerged leaf litter	Cerrado	Malosso (1999), Schoenlein-Crusius (2002)	Marvanová (1997)
	Submerged leaf litter	Atlantic Forest	Schoenlein-Crusius *et al.* (2009, 2015a, 2015b)	
Lunulospora **sp.**	Submerged leaves of *Ficus microcarpa* L. f.	Atlantic Forest	Schoenlein-Crusius & Milanez (1989)	
	Submerged leaf litter	Atlantic Forest	Schoenlein-Crusius *et al.* (2015a)	
Margaritispora aquatica **Ingold**	Submerged leaf litter	Atlantic Forest	Schoenlein-Crusius *et al.* (2009, 2014, 2015a, 2015b)	Ingold (1942)
	Submerged leaves of *Tibouchina pulchra* (Cham.) Cogn. and submerged leaf litter	Atlantic Forest	Schoenlein-Crusius *et al.* (2016)	
Margaritispora **sp.**	Submerged leaves of *Alchornea triplinervia* Spreng. M. Arg., *Ficus microcarpa* L. f. and *Quercus robur* L.	Atlantic Forest	Schoenlein-Crusius *et al.* (1992)	
	Submerged leaves of *Tibouchina pulchra* (Cham.) Cogn.	Atlantic Forest	Schoenlein-Crusius *et al.* (2016)	
Mycocentrospora acerina **(R. Hartig) Deighton**	Submerged leaf litter	Atlantic Forest	Schoenlein-Crusius *et al.* (2009)	Gulis *et al.* (2005)
	Submerged leaf litter	Caatinga	Sales *et al.* (2014)	
	Submerged leaf litter	Cerrado	Malosso (1999)	
Mycofalcella calcarata **Marvanová, Om-Kalth. & J. Webster**	Submerged leaf litter	Caatinga	Sales *et al.* (2014)	Marvanová *et al.* (1993)
Naiadella fluitans **Marvanová & Bandoni**	Submerged leaf litter	Atlantic Forest	Schoenlein-Crusius *et al.* (2015b)	Marvanová & Bandoni (1987)
Pyramidospora casuarinae **Sv. Nilsson**	Submerged leaf litter	Atlantic Forest	Schoenlein-Crusius *et al.* (2009)	Present study
	Submerged leaves of *Caesalpinia echinata* Lam. and *Campomanesia phaea* (O. Berg.) Landrum	Atlantic Forest	Moreira (2011), Schoenlein-Crusius *et al.* (2015b)	
	Submerged leaves of *Tibouchina pulchra* (Cham.) Cogn. and submerged leaf litter	Atlantic Forest	Schoenlein-Crusius *et al.* (2016)	
	Submerged leaves of *Calophyllum brasiliense* Cambess	Caatinga	Present study	
P. densa **Alas.**	Submerged leaves of *Caesalpinia echinata* Lam. and *Campomanesia phaea* (O. Berg.) Landrum	Atlantic Forest	Moreira (2011)	Alasoadura (1968b)
P. quadricelullaris **M.S. Oliveira, Malosso & R.F. Castañeda**	Submerged leaf litter	Atlantic Forest	Oliveira *et al.* 2015	Oliveira *et al.* (2015)
P. robusta **Moreira & Schoenlein-Crusius**	Submerged leaves of *Caesalpinia echinata* Lam. and *Campomanesia phaea* (O. Berg.) Landrum	Atlantic Forest	Moreira & Schoenlein-Crusius (2012)	Moreira & Schoenlein-Crusius (2012)
Pyramidospora **sp.**	Submerged leaves of *Protium heptaphyllum* Marchand and *Lafoensia pacari* A.St.-Hil.	Atlantic Forest	Rosa *et al.* (2009)	

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TABLE 2. (Continued)

Taxa	Substrate	Biome	Reference	Ilustration from
***Pyramidospora* sp.**	Submerged leaves of *Caesalpinia echinata* Lam. and *Campomanesia phaea* (O. Berg.) Landrum	Atlantic Forest	Moreira (2011)	
	Submerged leaves of *Tibouchina pulchra* (Cham.) Cogn.	Atlantic Forest	Schoenlein-Crusius *et al.* (2016)	
***Scutisporus brunneus* K. Ando & Tubaki**	Foam	Caatinga	Fiuza & Gusmão (2013a)	Present study
	Foam	Amazon	Fiuza *et al.* (2015)	
	Submerged leaves of *Calophyllum brasiliense* Cambess	Caatinga	Present study	
	Submerged petiole	Caatinga	Barbosa *et al.* (2013)	
***Tetrachaetum elegans* Ingold**	Submerged leaf litter	Cerrado	Schoenlein-Crusius (2002)	Ingold (1942)
	Submerged leaf litter	Atlantic Forest	Schoenlein-Crusius *et al.* (2009, 2014, 2015b)	
	Submerged leaf litter and submerged leaves of *Ficus microcarpa* L. f.	Atlantic Forest	Schoenlein-Crusius *et al.* (2015b)	
	Submerged leaves of *Alchornea triplinervia* Spreng. M. Arg.	Atlantic Forest	Schoenlein-Crusius & Milanez (1998a, 1998b)	
	Submerged leaves of *Alchornea triplinervia* Spreng. M. Arg., *Ficus microcarpa* L. f., *Tibouchina pulchra* (Cham.) Cogn. and *Quercus robur* L.	Atlantic Forest	Schoenlein-Crusius & Milanez (1990a and 1990b); Schoenlein-Crusius *et al.* (2016)	
***Tetracladium breve* A. Roldán**	Submerged leaf litter	Caatinga	Fiuza & Gusmão (2013a)	Fiuza & Gusmão (2013a)
***T. marchalianum* De Wild.**	Submerged leaves of *Protium heptaphyllum* Marchand and *Lafoensia pacari* A.St.-Hil.	Atlantic Forest	Rosa *et al.* (2009)	Ingold (1942)
	Submerged leaf litter	Atlantic Forest	Schoenlein-Crusius *et al.* (2014, 2015b)	
***T. maxiliiforme* (Rostr.) Ingold**	Submerged leaf litter	Atlantic Forest	Schoenlein-Crusius *et al.* (2015b)	Ingold (1942)
***T. nainitalense* Sati & P. Arya**	Foam	Caatinga	Fiuza & Gusmão (2013a)	Fiuza & Gusmão (2013a)
***T. setigerum* (Grove) Ingold**	Submerged leaf litter	Atlantic Forest	Schoenlein-Crusius *et al.* (2009, 2014, 2015b)	Ingold (1942)
***Tricladium angulatum* Ingold**	Submerged leaves of *Tibouchina pulchra* (Cham.) Cogn.	Atlantic Forest	Schoenlein-Crusius *et al.* (2016)	Ingold (1942)
***T. attenuatum* S.H. Iqbal as *T. fallax* in Fiuza & Gusmão (2013a)**	Foam	Caatinga	Fiuza & Gusmão (2013a)	Fiuza & Gusmão (2013a)
***T. chaetocladium* Ingold**	Submerged leaves of *Protium heptaphyllum* Marchand and *Lafoensia pacari* A.St.-Hil.	Atlantic Forest	Rosa *et al.* (2009)	Ingold (1974)
***T. curvisporum* Descals**	Foam	Amazon	Fiuza *et al.* (2015)	Fiuza *et al.* (2015)
***T. gracile* Ingold**	Submerged leaf litter	Cerrado	Schoenlein-Crusius (2002)	Ingold (1944)
***T. splendens* Ingold**	Submerged leaf litter	Atlantic Forest	Schoenlein-Crusius *et al.* (2009)	Ingold (1942)
***Trinacrium incurvum* Matsush.**	Foam	Caatinga	Fiuza & Gusmão (2013a)	Fiuza & Gusmão (2013a)
***Triscelophorus acuminatus* Nawawi**	Foam	Caatinga	Fiuza & Gusmão (2013a)	Present study
	Foam	Amazon	Fiuza *et al.* (2015)	
	Submerged leaf litter	Atlantic Forest	Schoenlein-Crusius *et al.* (2014, 2015a)	

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TABLE 2. (Continued)

Taxa	Substrate	Biome	Reference	Ilustration from
***Triscelophorus acuminatus* Nawawi**	Submerged leaf litter	Amazon	Monteiro (2014)	
	Submerged leaf litter and submerged leaves of *Caesalpinia echinata* Lam. and *Campomanesia phaea* (O. Berg.) Landrum	Atlantic Forest	Moreira & Schoenlein-Crusius (2012); Schoenlein-Crusius *et al.* (2015b)	
	Submerged leaves and bark	Caatinga	Silva *et al.* (2014)	
	Submerged leaves of *Calophyllum brasiliense* Cambess	Caatinga	Present study	
	Submerged leaves of *Tibouchina pulchra* (Cham.) Cogn. and submerged leaf litter	Atlantic Forest	Schoenlein-Crusius *et al.* (2016)	
***T. curviramifer* Matsush.**	Foam	Amazon	Fiuza *et al.* (2015)	Fiuza *et al.* (2015)
	Leaves of *Manilkara maxima* Penn. and *Parinari alvimii* Prance	Atlantic Forest	Magalhães *et al.* (2011)	
	Submerged leaf litter	Atlantic Forest	Schoenlein-Crusius *et al.* (2016)	
***T. deficiens* (Matsush.) Matsush.**	Leaf litter	Caatinga	Cruz *et al.* (2007)	Fiuza *et al.* (2015)
	Leaves of *Manilkara maxima* Penn. e *Parinari alvimii* Prance	Atlantic Forest	Magalhães *et al.* (2011)	
	Foam	Amazon	Fiuza *et al.* (2015)	
***T. magnificus* Petersen**	Submerged leaves of *Quercus robur* L.	Atlantic Forest	Schoenlein-Crusius *et al.* (1990)	Petersen (1962)
	Submerged leaf litter	Atlantic Forest	Schoenlein-Crusius *et al.* (2015b)	
***T. monosporus* Ingold**	Submerged leaf litter	Cerrado	Malosso (1999); Schoenlein-Crusius (2002)	Present study
	Submerged leaf litter	Atlantic Forest	Malosso (1999); Schoenlein-Crusius & Milanez (1990a ,1990b) Schoenlein-Crusius *et al.* (2014, 2015b)	
	Submerged leaf litter and submerged leaves of *Caesalpinia echinata* Lam. and *Campomanesia phaea* (O. Berg.) Landrum	Atlantic Forest	Moreira (2011), Schoenlein-Crusius *et al.* (2015b)	
	Submerged leaves of *Quercus robur* L.	Atlantic Forest	Schoenlein-Crusius & Milanez (1990a , 1990b)	
	Submerged leaves of *Alchornea triplinervia* Spreng. M. Arg.	Atlantic Forest	Schoenlein-Crusius & Milanez (1998a, 1998b)	
	Submerged leaves of *Calophyllum brasiliense* Cambess	Caatinga	Present study	
	Submerged leaves of *Ficus microcarpa* L. f.	Atlantic Forest	Schoenlein-Crusius *et al.* (1990, 1992)	
	Submerged leaves of *Tibouchina pulchra* (Cham.) Cogn. and submerged leaf litter	Atlantic Forest	Schoenlein-Crusius *et al.* (2016)	
***Triscelophorus* sp.**	Submerged leaf litter	Atlantic Forest	Malosso (1999), Schoenlein-Crusius *et al.* (2016)	
	Submerged leaf litter	Cerrado	Malosso (1999)	
	Submerged leaves of *Caesalpinia echinata* Lam. and *Campomanesia phaea* (O. Berg.) Landrum	Atlantic Forest	Moreira (2011)	
***Trisulcosporium acerinum* H.J. Huds. & B. Sutton**	Submerged leaves of *Alchornea triplinervia* Spreng. M. Arg.	Atlantic Forest	Schoenlein-Crusius *et al.* (1992)	Fiuza & Gusmão (2013a)
	Foam	Caatinga	Fiuza & Gusmão (2013a)	

...continued on the next page

TABLE 2. (Continued)

Taxa	Substrate	Biome	Reference	Illustration from
Varicosporium elodeae **W. Kegel**	Submerged leaf litter	Atlantic Forest	Schoenlein-Crusius *et al.* (2009, 2015a)	Ingold (1942)
	Submerged leaf litter and submerged leaves of *Caesalpinia echinata* Lam.	Atlantic Forest	Moreira (2011), Schoenlein Crusius *et al.* (2015b)	
	Submerged leaves of *Tibouchina pulchra* (Cham.) Cogn. and submerged leaf litter	Atlantic Forest	Schoenlein-Crusius *et al.* (2016)	
Varicosporium **sp.**	Submerged leaves of *Tibouchina pulchra* (Cham.) Cogn.	Atlantic Forest	Schoenlein-Crusius *et al.* (2016)	

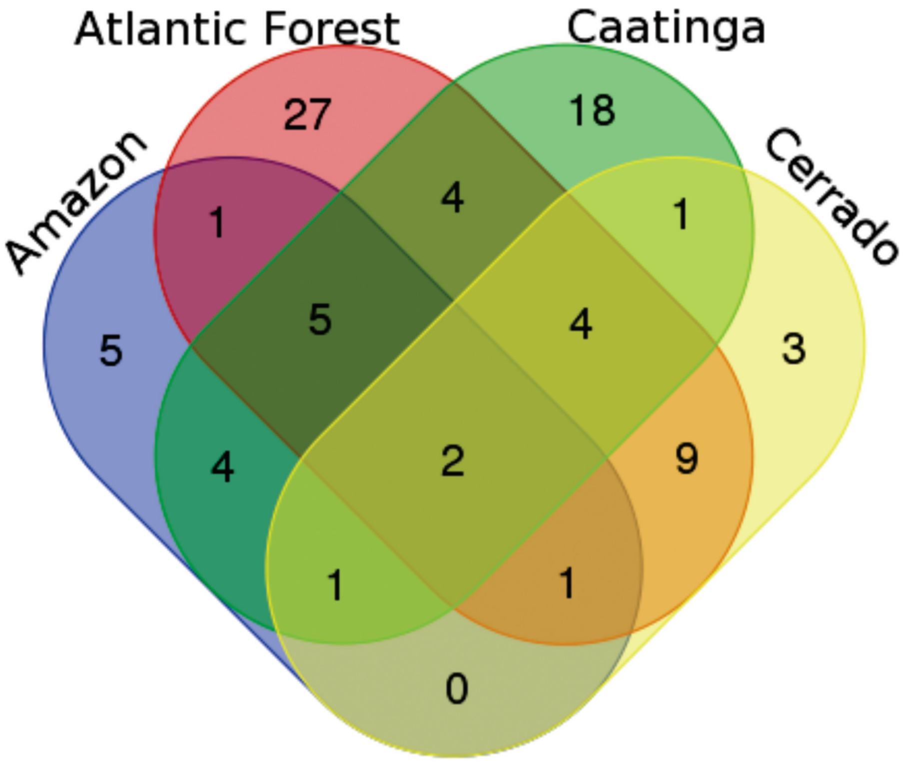

FIGURE 1. Venn diagram showing the number of Ingoldian taxa found in the different biomes in Brazil.

Taxonomy

Dendrosporomyces prolifer Nawawi, J. Webster & R.A. Davey, Trans. Br. mycol. Soc. 68: 59, 1977.
(Fig. 4A)

Material examined:—BRAZIL. Bahia: Piatã, Chapada Diamantina, on submerged leaves of *Calophyllum brasiliense* (*Calophyllaceae*), 10 November 2013, *P.O. Fiuza s.n* (HUEFS 215692); BRAZIL. Bahia: Piatã, Chapada Diamantina, on submerged leaves of *Calophyllum brasiliense* (*Calophyllaceae*), 07 September 2014, *P.O. Fiuza s.n* (HUEFS 215706).

Conidiophores not observed. Conidia hyaline, consisting of cylindrical, curved main axis with 7–10 primary branches. Main axis not constricted at septa, 14–20 septate, 150–440 × 7–10 µm; primary branches cylindrical, 4–17 septate, 198–335 × 8–10 µm, constricted at base, rounded at the apex; secondary branches cylindrical, 3–13 septate, 62–323 × 8–10 µm; branches constricted at base, rounded at the apex.

Geographical distribution:—India (Sridhar *et al.* 1992); Malaysia (Nawawi *et al.* 1977); USA (V. Gulis, unpublished).

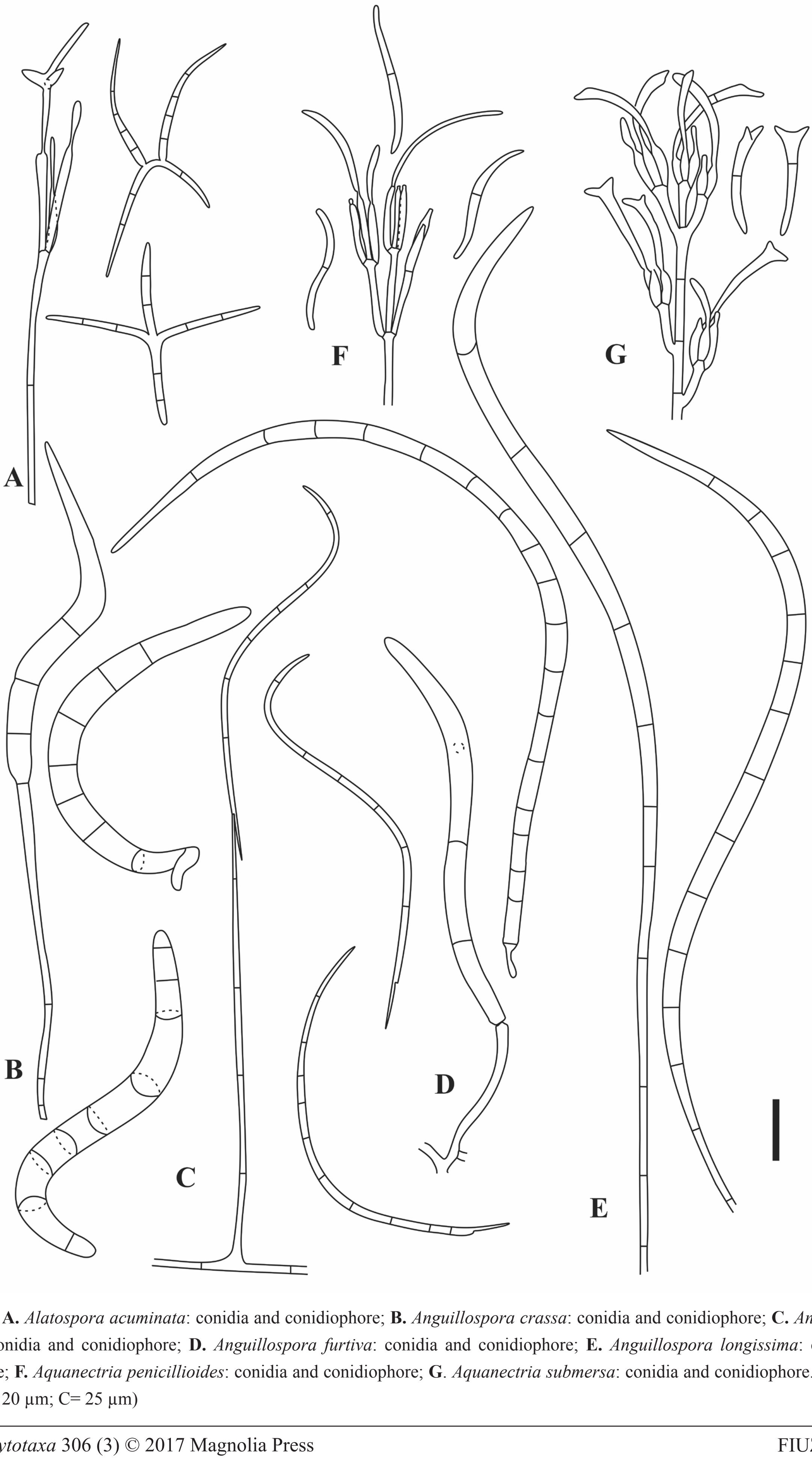

FIGURE 2. A. *Alatospora acuminata*: conidia and conidiophore; **B.** *Anguillospora crassa*: conidia and conidiophore; **C.** *Anguillospora filiformis*: conidia and conidiophore; **D.** *Anguillospora furtiva*: conidia and conidiophore; **E.** *Anguillospora longissima*: conidia and conidiophore; **F.** *Aquanectria penicillioides*: conidia and conidiophore; **G**. *Aquanectria submersa*: conidia and conidiophore. (Scale bar: A–B, D–G= 20 µm; C= 25 µm)

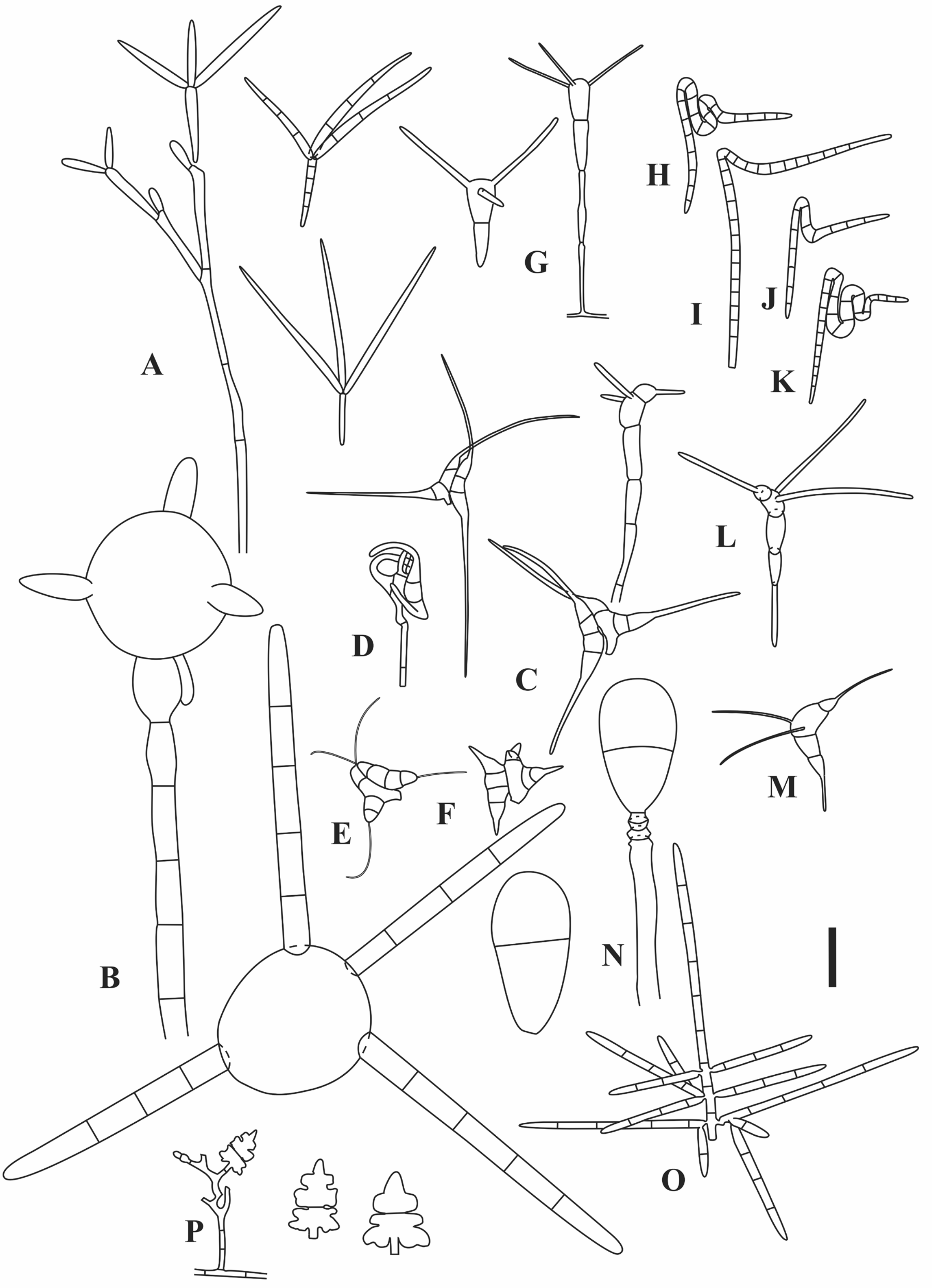

FIGURE 3. A. *Articulospora tetracladia*: conidia and conidiophore; **B.** *Brachiosphaera tropicalis:* conidia and conidiophore; **C.** *Campylospora brasiliensis:* conidium; **D.** *Campylospora chaetocladia:* conidia and conidiophore; **E.** *Campylospora filicladia*: conidium; **F.** *Campylospora parvula*: conidium; **G.** *Clavariopsis aquatica*: conidia and conidiophore; **H.** *Condylospora flexuosa*: conidium; **I.** *Condylospora gigantea*: conidium; **J.** *Condylospora spumigena*: conidium; **K.** *Condylospora* sp.; conidium; **L.** *Culicidospora aquatica*: conidia and conidiophore; **M.** *Culicidospora gravida:* conidium; **N.** *Dactylella microaquatica*: conidia and conidiophore; **O.** *Dendrospora erecta*: conidium; **P.** *Dendrosporium lobatum*: conidia and conidiophore. (Scale bar: A–B, H–M= 20 µm; C–F= 25 µm; G = 60 µm; N= 5 µm; O= 50 µm; P= 10 µm)

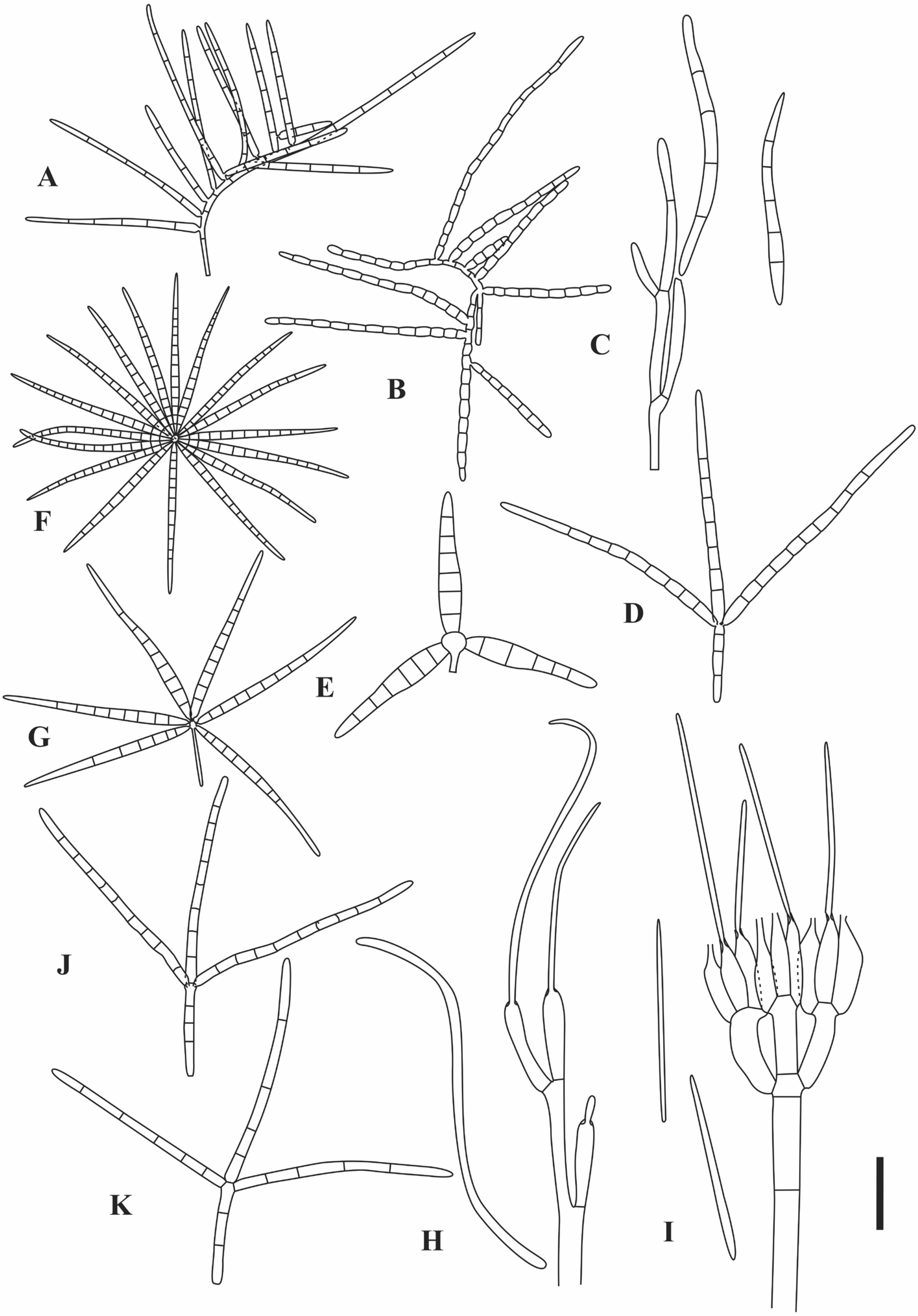

FIGURE 4. A. *Dendrosporomyces prolifer*: conidium; **B.** *Dendrosporomyces splendens*: conidium; **C.** *Filosporella versimorpha*: conidiophore and conidia; **D.** *Flabellocladia tetracladia*: conidium; **E.** *Flabellospora crassa*: conidium; **F.** *Flabellospora multiradiata*: conidium; **G.** *Flabellospora verticillata*: conidium; **H.** *Flagellospora curvula*: conidia, conidiophore and conidiogenous cells; **I.** *Flagellospora stricta*: conidia, conidiophore and conidiogenous cells; **J–K.** *Geniculospora inflata*: conidia. (Scale bar: A–B= 80 µm; C, E, G–H= 25 µm; D, J–K= 30 µm; F= 50 µm; I=10 µm)

Notes:—*Dendrosporomyces* is composed by two species: *D. prolifer* (type species) and *D. splendens* (Nawawi) Nawawi & J. Webster (Nawawi & Webster 1982). The genus is characterized by holoblastic, branched, hyaline conidia, consisting of a main axis bearing primary and secondary branches (Nawawi *et al.* 1977) and dolipore septa (Nawawi 1985a). *Dendrosporomyces prolifer* differs from *D. splendens* by having somewhat smaller, profusely branched conidia (Marvanová 1997). *Dendrosporomyces splendens* has been previously reported from Brazil on submerged leaves of *Euterpe edulis* Mart. (1824: 33) and *Alchornea triplinervia* (Spreng.) Mull. Arg. in Candolle (1866: 909) from the Atlantic Forest, the state of São Paulo (Grandi 1998, 1999). It is the first record of *D. prolifer* from Brazil.

Flagellospora stricta Sv. Nilsson, Bot. Notiser 115: 82, 1962. (Fig. 4I)

Material examined:—BRAZIL. Bahia: Piatã, Chapada Diamantina, on submerged leaves of *Calophyllum brasiliense* (*Calophyllaceae*)*,* 10 November 2013, *P.O. Fiuza s.n* (HUEFS 215892).

Conidiophores branched, septate, hyaline, 40–60 × 4.5–5 µm. Conidiogenous cells phialidic, clavate, terminal, hyaline, 8–15 × 3–4.5µm. Conidia filiform, straight, aseptate, hyaline, 20–50 × 1–1.5 µm.

Geographical distribution:—Poland (Orłowska *et al.* 2004); Sweden (Nilsson 1962b, 1964).

Notes:—*Flagellospora stricta* is distinguished from other species of *Flagellospora* by having straight conidia (Nilsson 1962b). In Brazil, one species of *Flagellospora—F. curvula* (Ingold 1942: 404)—has been recorded from the Atlantic Forest on mixed submerged leaves (Schoenlein-Crusius *et al.* 2009), from the Caatinga in foam (Fiuza & Gusmão 2013a) and from the Amazon in foam (Fiuza *et al.* 2015). It is the first record of *Flagellospora stricta* for the Americas.

Geniculospora inflata (Ingold) Sv. Nilsson ex Marvanová & Sv. Nilsson, Trans. Br. mycol. Soc. 57: 532, 1971.
(Figs. 4 J–K)

Material examined:—BRAZIL. Bahia: Piatã, Chapada Diamantina, on submerged leaves of *Calophyllum brasiliense* (*Calophyllaceae*)*,* 18 December 2014, *P.O. Fiuza s.n* (HUEFS 215970).

Conidiophores simple, septate, hyaline, 40–45 × 3–5 µm. Conidia tetraradiate, hyaline, consisting of a cylindrical geniculate main axis and 2 lateral branches attached at the point of main axis inflection. Main axis 108–176 × 4.5–5 µm, somewhat inflated at the point of branch attachment, branches slightly constricted at base, 70–131 × 4.5–6 µm, elements septate.

Geographical distribution:—Austria (Marvanová & Gulis 2000); Canada (Sokolski *et al.* 2006); England (Ingold 1944); França (Fabre 1998); Greenland (Engblom *et al.* 1986); Hungary (Gönczöl & Révay 2011); India (Sridhar *et al.* 1992); Pakistan (Iqbal 1997); Portugal (Pascoal *et al.* 2005); Spain (Casado *et al.* 2015); USA (Suberkropp & Wallace 1992).

Notes:—*Geniculospora* is represented by two well known species: *G. grandis* Greath. ex Nolan (1972: 1173) and *G. inflata* (type species). *G. intermedia* (R.H. Petersen) Sv. Nilsson ex Marvanová & Sv. Nilsson (1971: 532) (Nolan 1972) is probably conspecific with *G. inflata*. The genus is characterized by hyaline, tetraradiate conidia with characteristically geniculate main axis, from the middle of which two other branches arise at the same level (Nilsson 1964). *Geniculospora grandis* displays nearly concurrent development of 3 elements, so the conidium can be interpreted as having 3 terminal arms originating from a relatively short stalk (main axis); conidia of *G. grandis* are also considerably larger than in *G. inflata* (Greathead 1961). *Geniculospora inflata* is a new record to the Neotropics.

Pyramidospora casuarinae Sv. Nilsson, Svensk bot. Tidskr. 56: 359, 1962.
(Fig. 5M)

Material examined:—BRAZIL. Bahia: Piatã, Chapada Diamantina, on submerged leaves of *Calophyllum brasiliense* (*Calophyllaceae*)*,* 10 November 2013, *P.O. Fiuza s.n* (HUEFS 216621).

Conidiophores simple, septate, hyaline 20–45 × 3–4.5 µm. Conidiogenous cells monophialidic, terminal, hyaline. Conidia multicellular (3–9 cells), with oblong cells arranged in a regular or irregular way, 3–4 cells each develop from the basal cell as well as from the top cell; conidia span 15–22 × 14–18 µm, each cell 5.3–7.5 × 4.5–6 µm.

Geographical distribution:—Brazil (Schoenlein-Crusius *et al.* 2009); Cuba (Marvanová & Marvan 1969); France (Jabiol *et al.* 2013); India (Sridhar & Kaveriappa 1992); Italy (Rodino *et al.* 2003); Pakistan (Bareen & Iqbal 1994); Poland (Czeczuga *et al.* 2007); Puerto Rico (Caballero 1983); Sweden (Nilsson 1964); Venezuela (Nilsson 1962a).

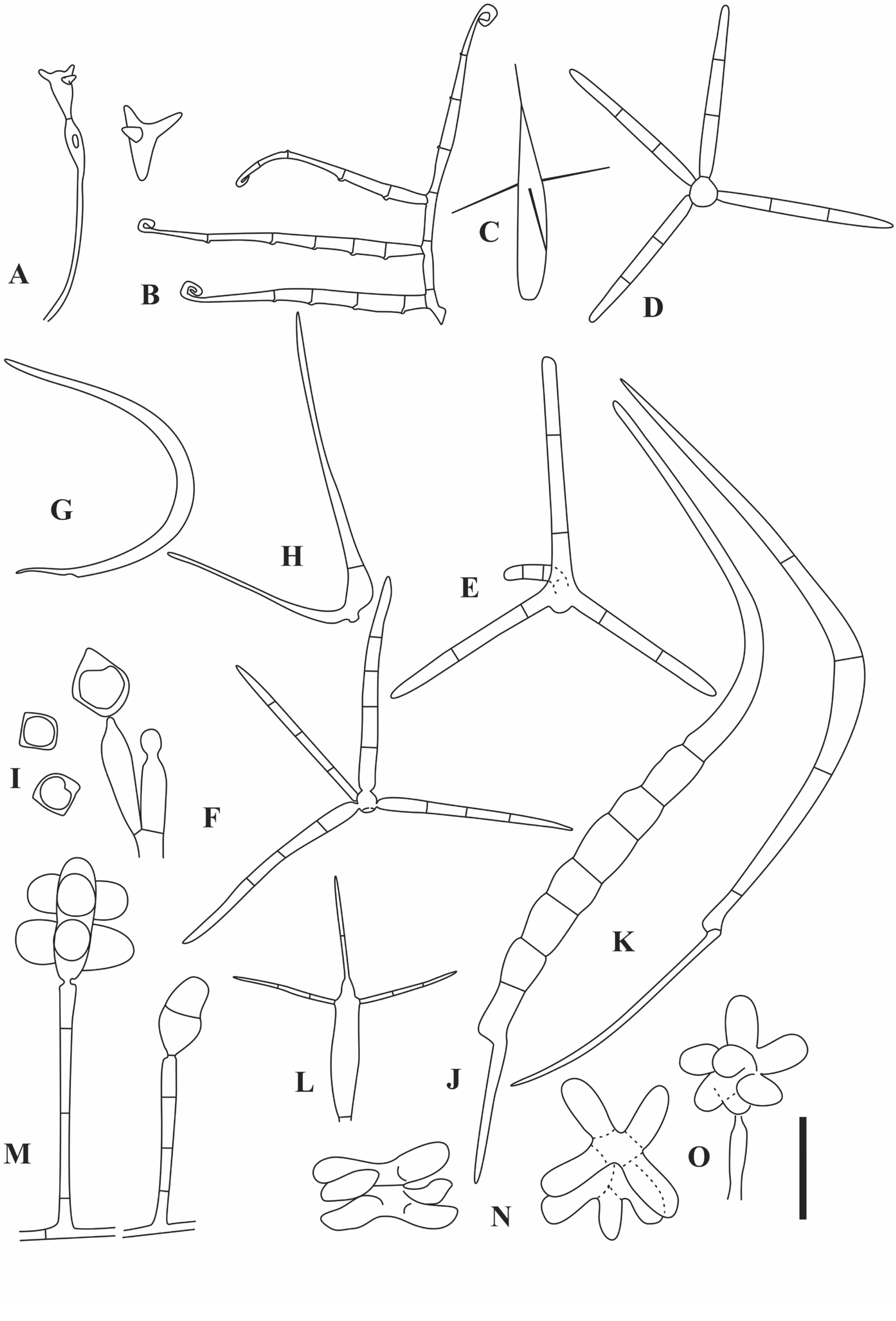

FIGURE 5. A. *Heliscella stellata*: conidia and conidiophore; **B.** *Ingoldiella hamata*: conidium; **C.** *Jaculispora submersa*: conidium; **D.** *Lemonniera alabamensis*: conidium; **E.** *Lemonniera aquatica*: conidium; **F.** *Lemonniera pseudofloscula*: conidium; **G.** *Lunulospora curvula*: conidium; **H.** *Lunulospora cymbiformis*: conidium; **I.** *Margaritispora aquatica*: conidia and conidiophore; **J.** *Mycocentrospora acerina*: conidium; **K.** *Mycofalcella calcarata*: conidium; **L.** *Naiadella fluitans*: conidium; **M.** *Pyramidospora casuarinae*: conidia and conidiophores; **N–O.** *Pyramidospora densa*: conidia and conidiophore. (Scale bar: A,C–O= 20 µm; B= 40 µm)

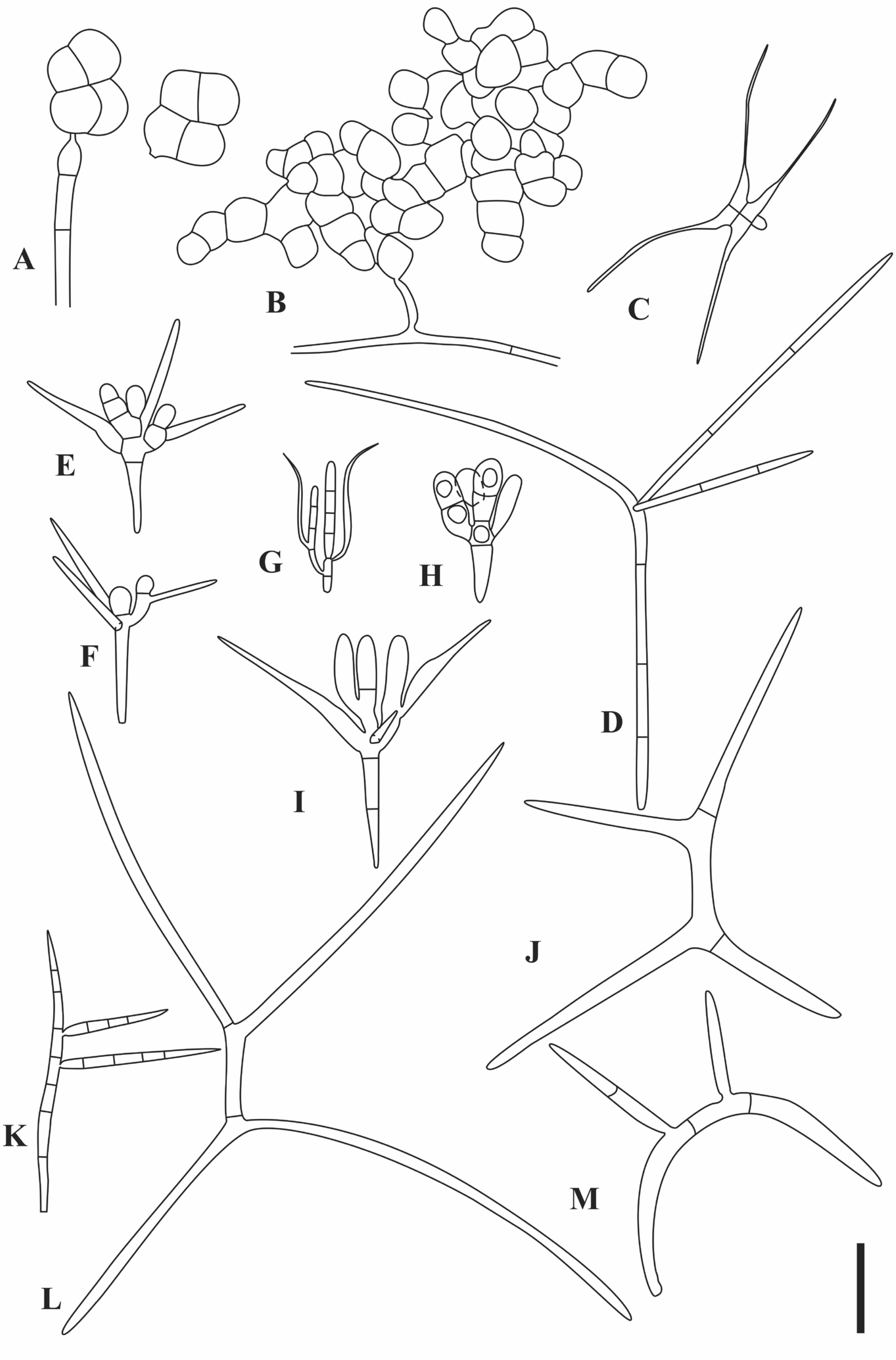

FIGURE 6. A. *Pyramidospora quadricelullaris*: conidia and conidiophore; **B.** *Pyramidospora robusta*: conidium and conidiophore; **C.** *Scutisporus brunneus*: conidium; **D.** *Tetrachaetum elegans*: conidium; **E.** *Tetracladium breve*: conidium; **F.** *Tetracladium marchalianum*: conidium; **G.** *Tetracladium maxiliiforme*: conidium; **H.** *Tetracladium nainitalense*: conidium; **I.** *Tetracladium setigerum*: conidium; **J.** *Tricladium angulatum*: conidium; **K.** *Tricladium attenuatum:* conidium; **L.** *Tricladium chaetocladium*: conidium; **M.** *Tricladium curvisporum*: conidium. (Scale bar: A–E, G–M= 20 µm; F= 40 µm)

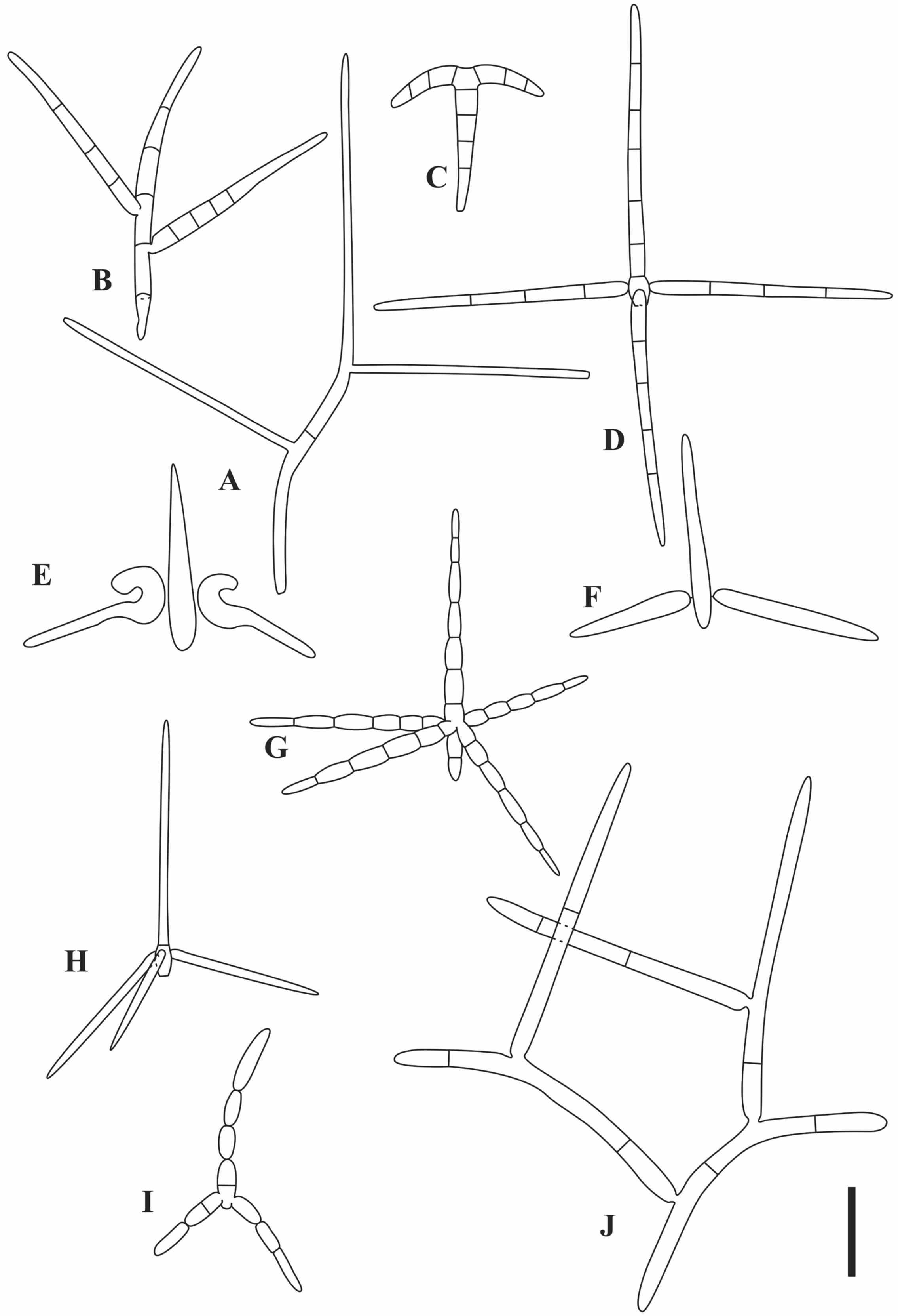

FIGURE 7. A. *Tricladium gracile*: conidium; **B.** *Tricladium splendens*: conidium; **C.** *Trinacrium incurvum*: conidium; **D.** *Triscelophorus acuminatus*: conidium; **E.** *Triscelophorus curviramifer*: conidium; **F.** *Triscelophorus deficiens*: conidium; **G.** *Triscelophorus magnificus*: conidium; **H.** *Triscelophorus monosporus*: conidium; **I.** *Trisulcosporium acerinum*: conidium; **J.** *Varicosporium elodeae*: conidium. (Scale bar: A–B, D, G–J= 20 µm; C= 25 µm; E–F= 10 µm)

Notes:—*Pyramidospora* was erected with *P. casuarinae* as a type species, and it currently comprises nine species (Oliveira *et al.* 2015). *Pyramidospora casuarinae* is easily distinguished from other species of the genus by conidia having a pyramidal shape, 3–4 cells produced as outgrowths from the original basal cell and from the top cell (Nilsson 1962a). In Brazil, three species of *Pyramidospora* were recorded: *P. casuarinae* from the Atlantic Forest on submerged leaves (Schoenlein-Crusius *et al.* 2009), *P. robusta* C.G. Moreira & Schoenl.-Crus. (2012: 523) from the Atlantic Forest on submerged leaves of *Caesalpinia echinata* Lam. (1785: 461) and *Campomanesia phaea* (O. Berg.) Landrum (1984: 241) (Moreira & Schoenlein-Crusius 2012) and *P. quadricellularis* M.S. Oliveira, Malosso & R.F. Castañeda-Ruiz (2015: 973) on submerged leaves from the Atlantic Forest (Oliveira *et al.* 2015). *Pyramidospora casuarinae* is a new record to the Caatinga.

Triscelophorus monosporus Ingold, Trans. Br. Mycol. Soc. 26:152, 1943.
(Fig. 7H)

Material examined:—BRAZIL. Bahia: Piatã, Chapada Diamantina, on submerged leaves of *Calophyllum brasiliense* (*Calophyllaceae*)*,* 10 July 2014, *P.O. Fiuza s.n* (HUEFS 215907).

Conidia tetraradiate, hyaline, comprised by the main axis and three branches attached to its basal cell, main axis 1-septate, tapering toward the apex, not constricted at the septum, apical cell 45–60 × 3.5–4 µm; doliiform basal cell with truncated base, 5–7 × 4.5–5 µm; branches cylindrical, slightly constricted at the base, aseptate, 37–45 × 2.5–3 µm.

Geographical distribution:—Cosmopolitan.

Notes:—*Triscelophorus monosporus* is the type of the genus composed by eight species (Matsushima 1993). The conidia of *T. monosporus* are similar to *T. acuminatus* Nawawi (1975: 346), both have a slightly tapering main axis with doliiform basal cell, but in the latter, the axis is multiseptate, while in *T. monosporus* it is typically 1-septate (rarely with no septum). In Brazil, five species of *Triscelophorus* (Table 2) have been recorded, including *T. monosporus* from the state of São Paulo. *Triscelophorus monosporus* is a new record to the Caatinga.

Key to species of Ingoldian fungi from Brazil

1.	Conidia not branched	2
-	Conidia branched	19
2.	Conidia filiform, long-fusoid, scolecoid or lunate	3
-	Conidia flattened, obovoid or tetrahedral	17
3.	Conidia aseptate	4
-	Conidia septate	6
4.	Conidia lunate with submedian scar, 100–130 × 2.5–5 µm	*Lunulospora curvula* (Fig. 5G)
-	Conidia without submedian scar	5
5.	Conidia gently curved, falcate or sigmoid	*Flagellospora curvula* (Fig. 4H)
-	Conidia straight	*Flagellospora stricta* (Fig. 4I)
6.	Conidia with excentric basal extension	7
-	Conidia without excentric basal extension	9
7.	Conidia less than 5 µm in width	*Anguillospora filiformis* (Fig. 2C)
-	Conidia more than 5 µm in width	8
8.	Conidia often with the median cell somewhat larger, scar distinct, truncated, 87–188 × 6–13 µm	*Mycofalcella calcarata* (Fig. 5K)
-	Conidia sometimes fuscous, 150–200 × 6–15 µm	*Mycocentrospora acerina* (Fig. 5J)
9.	Conidia with 0–2 septa	10
-	Conidia with more than 2 septa	11
10.	Conidia with submedian scar and often inflated in the lower third	*Lunulospora cymbiformis* (Fig. 5H)
-	Conidia without submedian scar, 0–2-septate	*Aquanectria penicillioides* (Fig. 2F)
11.	Conidia bent abruptly at >90° angle	12
-	Conidia gently curved	14
12.	Conidia kinked 1–2 times	13
-	Conidia kinked 3 or more times	*Condylospora flexuosa* (Fig. 3H)
13.	Conidia, 12–15-septate	*Condylospora spumigena* (Fig. 3J)
-	Conidia larger, 22–27 septate	*Condylospora gigantea* (Fig. 3I)
14.	Conidia more than 10 µm wide	*Anguillospora crassa* (Fig. 2B)
-	Conidia less than 10 µm wide	15
15.	Conidia with base truncated or with subulate extension 4–23 septate, 50–590 × 3–9.5 µm (schizolytic secession)	16
-	Conidia mostly with basal frill or remnants of separating cell (rhexolytic secession), 7–20 septate, 105–345 × 3–5 µm	*Anguillospora longissima* (Fig. 2E)

16. Conidia 10–23 septate, 60–590 × 4.5–9.5 µm.. *Anguillospora furtiva* (Fig. 2D)
- Conidia 4–6 septate, 53–90 × 3–5 µm.. *Filosporella versimorpha* (Fig. 4C)
17. Conidia obovoid, 1-septate, 10–13 × 6.5–8 µm.. *Dactylella microaquatica* (Fig. 3N)
- Conidia not obovoid..18
18. Conidia tetrahedral to subspherical, 10–13 diam.. *Margaritispora aquatica* (Fig. 5I)
- Conidia flattened, triangular, three-lobed, with a pedicellate base.. *Dendrosporium lobatum* (Fig. 3P)
19. Conidia multiradiate, tetraradiate, T or Y shaped..20
- Conidia of other, more complex, shapes..46
20. Conidia multiradiate..21
- Conidia tetraradiate, T or Y shaped..22
21. Conidia with more than 9 branches.. *Flabellospora multiradiata* (Fig. 4F)
- Conidia with less than 9 branches.. *Flabellospora verticillata* (Fig. 4G)
22. Conidia tetraradiate..23
- Conidia T or Y shaped..51
23. Very large conidia with globose to pyramidal central body and four branches.. *Brachiosphaera tropicalis* (Fig. 3B)
- Conidia of another shape..24
24. Conidia with clamps.. *Ingoldiella hamata* (Fig. 5B)
- Conidia without clamps..25
25. Main axis with base dolliform, obpyriform or obclavate..26
- Main axis of another shape..30
26. Main axis with basal cell doliiform or obclavate and 3–5 branches..27
- Main axis with basal cell obpyriform or obclavate and two branches..29
27. Main axis with 3–5 branches, elements constricted at each septum.. *Triscelophorus magnificus* (Fig. 7G)
- Conidial elements are not constricted at each septum..28
28. Conidia multiseptate, with three branches.. *Triscelophorus acuminatus* (Fig. 7D)
- Conidia 0–1 septate, with three branches.. *Triscelophorus monosporus* (Fig. 7H)
29. Conidia with strongly curved branches.. *Triscelophorus curviramifer* (Fig. 7E)
- Conidia with branches not curved.. *Triscelophorus deficiens* (Fig. 7F)
30. Conidia with a central body and four branches..31
- Main axis cylindrical, clavate, fusiform, straight or curved..32
31. Spherical central body 5–6.3 µm diam., no constrictions at branch insertions.. *Lemonniera alabamensis* (Fig. 5D)
- Spherical central body 4–5 µm diam., branches strongly constricted at the point of insertion.. *Lemonniera pseudofloscula* (Fig. 5F)
32. Elongated main axis with typically two branches arising at different levels..33
- Conidia of different shape..38
33. Main axis and lateral branches are markedly attenuated, main axis 46.5–69 × 2.3 µm.. *Tricladium attenuatum* (Fig. 6K)
- Main axis and lateral branches are not markedly attenuated..34
34. Main axis is bent at lateral branch insertions, branches are not constricted at the base..35
- Main axis is not bent at lateral branch insertions, branches constricted at the base..36
35. Branches tape distinctly toward the apex.. *Tricladium angulatum* (Fig. 6J)
- Branches thinner than main axis, of uniform width.. *Tricladium gracile* (Fig. 7A)
36. Main axis fusiform, 60–120 × 6–7 µm, 3–6 septate, 30–80 × 6–7 µm.. *Tricladium splendens* (Fig. 7B)
- Main axis not fusiform..37
37. Main axis with 2–3 branches, strongly curved, 28–45 × 1.5–3 µm.. *Tricladium curvisporum* (Fig. 6M)
- Main axis with 2 branches, curved, 150–200 × 3–4 µm.. *Tricladium chaetocladium* (Fig. 6L)
38. Conidia with two divergent branches attached at the same level near the middle of the main axis..39
- Conidia with 3–5 branches..41
39. Main axis slightly swollen and bent at branch insertion, resulting in conidia appearing as if having a main axis and 3 apical branches.. *Geniculospora inflata* (Fig. 4 J–K)
- Main axis not swollen at branch insertion..40
40. Branches 23–53 × 1.5–2.5 µm.. *Alatospora acuminata* (Fig. 2A)
- Branches 120–150 × 2–4 µm.. *Tetrachaetum elegans* (Fig. 6D)
41. Cylindrical axis..42
- Obconic or clavate axis..44
42. Conidia with three branches not constricted at the insertions, attached at the base of the main axis.. *Lemonniera aquatica* (Fig. 5E)
- Conidia with three branches constricted or slightly constricted at the insertions..43
43. Main axis 23–37.5 × 1.5–3 µm, branches 33–90 × 1.5–3 µm.. *Articulospora tetracladia* (Fig. 3A)
- Main axis 30–60 × 3.5 µm, branches 90–110 × 5–7 µm.. *Flabellocladia tetracladia* (Fig. 4D)
44. Conidia with 3–5 branches, main axis sometimes inconspicuous.. *Flabellospora crassa* (Fig. 4E)
- Conidia of other shape..45
45. Main axis clavate, 1-septate, branches 50–70 µm long.. *Clavariopsis aquatica* (Fig. 3G)
- Clavate to obconic axis, aseptate, elements ca. 10 µm long.. *Heliscella stellata* (Fig. 5A)
46. Conidia with cylindrical main axis and >3 lateral branches or with asymmetrical main axis consisting of inflated cells..47
- Conidia papilioniform, or with acicular branches, or with oblong or digitiform elements..58
47. Conidia with cylindrical main axis..48
- Conidia with asymmetrical main axis..53

48. Conidia with multiple branches developing on one side of the axis .... *Varicosporium elodeae* (Fig. 7J)
- Conidia with multiple branches not developing just on one side of the axis 49
49. Lateral branches arise in pars or in whorls of three from near the base of the straight main axis ...... *Dendrospora erecta* (Fig. 3O)
- Lateral branches do not arise in pars or in whorls of three from near the base of the main axis, main axis curved to hook-shaped 50
50. Conidia with a main axis having more than 7 primary lateral branches .... *Dendrosporomyces prolifer* (Fig. 4A)
- Conidia with a main axis having less than 7 primary lateral branches .... *Dendrosporomyces splendens* (Fig. 4B)
51. Conidia T-shaped, main axis slightly club-shaped, branches curved, 18.5–20 µm long.......... *Trinacrium incurvum* (Fig. 7C)
- Conidia of different shape 52
52. Conidia with two branches attached close to the base of the axis, septate and strongly constricted at the septa .... *Trisulcosporium acerinum* (Fig. 7I)
- Conidia Y-shaped, with a single short subapical branch 4–8.5 µm long.......... *Aquanectria submersa* (Fig. 2G)
53. Asymmetrical main axis with two lateral branches produced by subapical cell 54
- Conidia with strongly curved main axis of deltoid and allantoid cells; overall appearance of four diverging branches.......... 55
54. Main axis 100–200 µm long.......... *Culicidospora aquatica* (Fig. 3L)
- Main axis 35–50 µm long.......... *Culicidospora gravida* (Fig. 3M)
55. Branches less than 13 µm long.......... *Campylospora parvula* (Fig. 3F)
- Branches more than 13 µm long.......... 56
56. Branches 0.5–0.7 µm wide .... *Campylospora filicladia* (Fig. 3E)
- Branches more than 1 µm wide.......... 57
57. Branches more than 30µm long.......... *Campylospora chaetocladia* (Fig. 3D)
- Branches less than 30 µm long.......... *Campylospora brasiliensis* (Fig. 3C)
58. Conidia with navicular main axis.......... 59
- Conidia papilioniform, with digitiform elements, or with oblong cells.......... 60
59. Conidia with schizolytic secession.......... *Jaculispora submersa* (Fig. 5C)
- Conidia with rhexolytic secession.......... *Naiadella fluitans* (Fig. 5L)
60. Conidia papilioniform, with four cells and branches attached to each cell of the main body.......... *Scutisporus brunneus* (Fig. 6C)
- Conidia with digitiform elements or oblong cells 61
61. Cells of conidia tightly arranged to form a pyramid-like compact structure 62
- Main axis with digitiform, ellipsoid and acicular elements 65
62. Main axis composed of two cells with 8–13 lateral branches.......... *Pyramidospora robusta* (Fig. 6B)
- Conidia with 2–8 branches 63
63. Conidia with 6–8 branches, spanning 29–37 µm .... *Pyramidospora densa* (Fig. 5 N-O)
- Conidia composed of globose or oblong cells.......... 64
64. Conidia composed of four globose cells .... *Pyramidospora quadricellularis* (Fig. 6A)
- Conidia composed of 3–5 rounded cells .... *Pyramidospora casuarinae* (Fig. 5M)
65. Main obconic axis with two digitiform and an ellipsoid element .... *Tetracladium nainitalense* (Fig. 6H)
- Main axis with 2–3 acicular branches 66
66. Main axis with two acicular branches .... *Tetracladium maxilliformis* (Fig. 6G)
- Main axis with three acicular branches 67
67. Main axis with two ellipsoid elements 3–6 µm wide.......... *Tetracladium marchalianum* (Fig. 6F)
- Main axis with 3 digitiform elements.......... 68
68. Digitiform elements 10–13.5 × 3.5 µm and acicular branches 12–35 × 2–3.5 µm.......... *Tetracladium breve* (Fig. 6E)
- Digitiform elements 12–15 × 3–9 µm and acicular branches 20–40 × 3 µm.......... *Tetracladium setigerum* (Fig. 6I)

Discussion

Ingoldian fungi comprise about 320 species distributed worldwide. In Brazil, 85 taxa have been recorded from four out of six Brazilian biomes: Atlantic Forest (53 taxa), Caatinga (39 taxa), Cerrado (21 taxa) and Amazon (19 taxa) (Fig. 1). The Atlantic Forest currently shows the highest diversity, which could be explained by both the number and the length of studies. Indeed, it had the highest number of studies (18, with 15 of them in the state of São Paulo), and they originated more than 27 years ago. On the other hand, the Caatinga had only five studies distributed in four states during just five years; the Cerrado biome was addressed in two studies (all in São Paulo state) since 1999; and the Ingoldian fungi from the Amazon were sampled in two studies (two states) only starting from 2014 (Figs. 8–9). Pampa and Pantanal biomes have not yet been sampled for the Ingoldian fungi (Fig. 8). Bärlocher & Boddy (2015) argue that freshwater wetlands may be the hotspots of fungal diversity. Taking into account that the Pantanal biome is one of the largest continuous wetland habitats on the planet (MMA 2016), mycological expeditions to this area are critically needed.

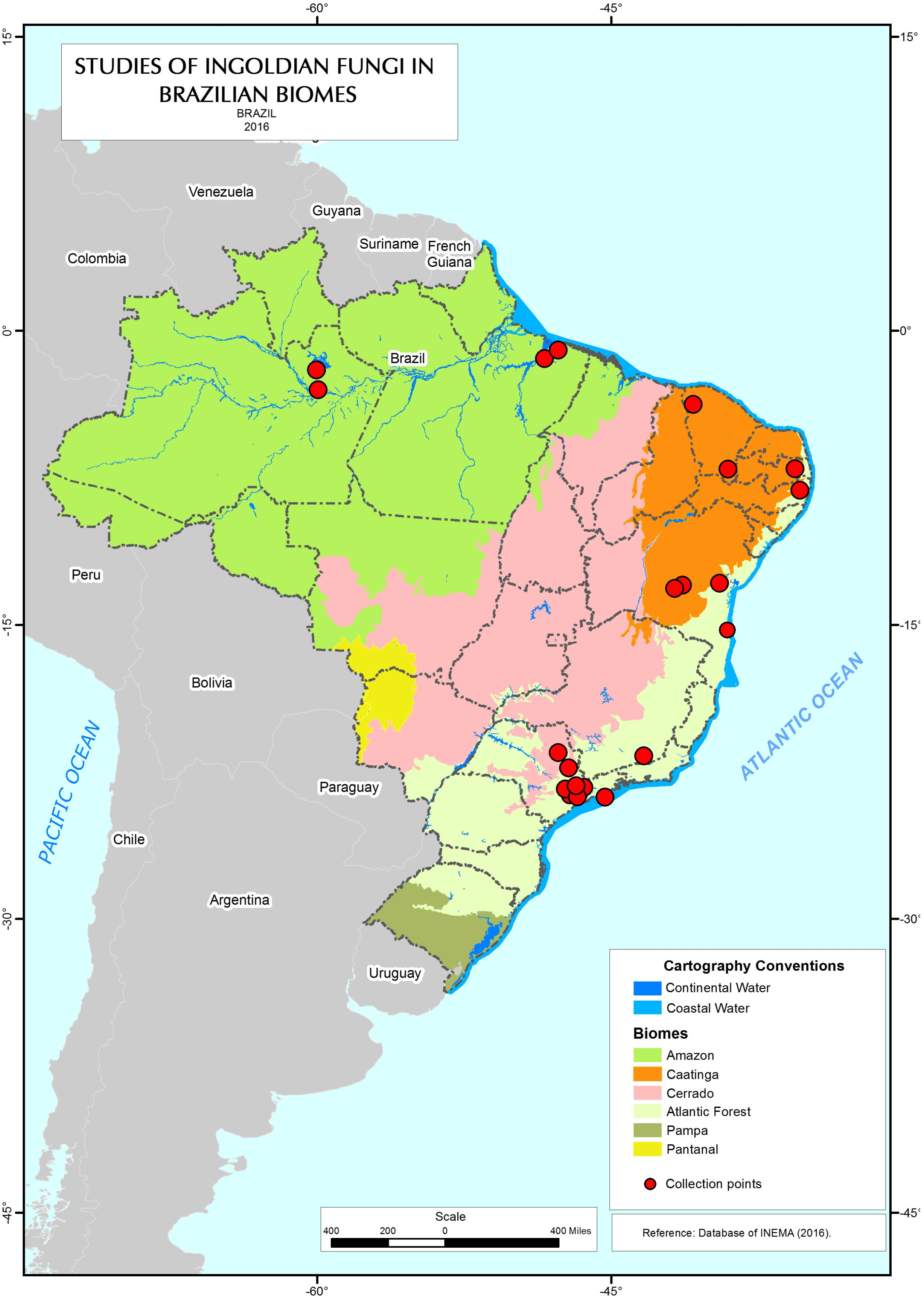

FIGURE 8. Distribution of collection sites of Ingoldian fungi in Brazil.

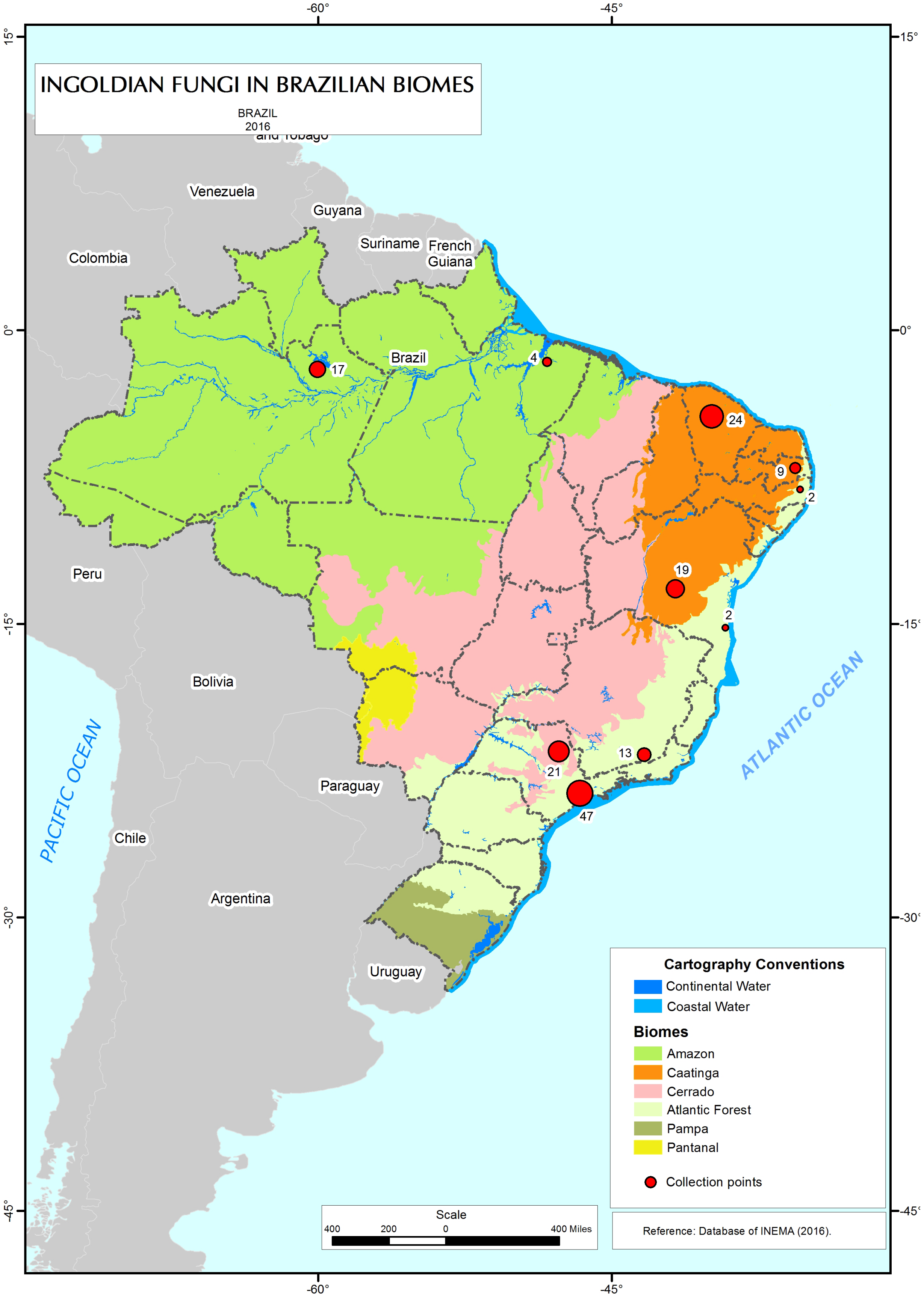

FIGURE 9. Taxa richness of Ingoldian fungi at different sites in Brazilian biomes. The size of the symbol corresponds to the number of taxa recorded from a particular site.

In the Atlantic Forest and the Cerrado, the Ingoldian fungi have been recorded from incubated submerged leaves or randomly collected leaf litter (Schoenlein-Crusius & Grandi 2003, Schoenlein-Crusius *et al.* 2009), while during the studies in the Caatinga and the Amazon, these fungi have been recorded from foam samples or incubated submerged leaves, leaf petioles and bark (Fiuza & Gusmão 2013a, Fiuza *et al.* 2015). The differences in the techniques employed may have contributed to the ability to detect certain species of the Ingoldian fungi. For example, litter bag approach often employing leaf litter of a single type may negatively affect our ability to detect species with pronounced substrate specificities compared to studies relying on randomly collected naturally occurring mixtures of leaves from multiple tree species. While examining foam can quickly provide a reasonable snapshot of community structure based on spores of Ingoldian fungi in transport, this approach complicates fungal isolation into pure culture that may be sometimes necessary for reliable identification.

Among 85 taxa of Ingoldian fungi recorded from Brazil, 27 are unique to the Atlantic Forest, 18 to the Caatinga, 5 to the Amazon and 3 to the Cerrado (Fig. 1). This can be explained by the unequal number of studies on Ingoldian fungi in these biomes as well as by biogeography (Figs. 8–9). However, some common species, such as *Anguillospora longissima* (Sacc. & P. Syd.) Ingold (1942: 402) and *Flagellospora curvula* are reported from all Brazilian biomes with relatively high frequency (Table 2). These are cosmopolitan species that were previously often reported from other countries in both temperate and tropical climates (Shearer 1992, Sridhar *et al.* 2010, Sudheep & Sridhar 2011).

The present study that focused on the submerged leaves of *C. brasiliense* yielded three new records to Brazil and two new records to the Caatinga. *Dendrosporomyces prolifer* has been confirmed to have tropical to subtropical distribution, while *Flagellospora stricta* and *Geniculospora inflata* have been recorded just in the temperate regions until now.

Studies of the Ingoldian fungi in the Atlantic Forest have been conducted primarily in the urban areas (Schoenlein-Crusius *et al.* 2015b), where some water bodies experience eutrophication (Schoenlein-Crusius & Milanez 1989, Schoenlein-Crusius *et al.* 2009). Nevertheless, some species reported from these impacted sites are also found in relatively pristine streams e.g. *Anguillospora longissima, A. filiformis* Greath. (1961: 202) and *Flagellospora curvula* (Fiuza & Gusmão 2013a, Fiuza *et al.* 2015). On the other hand, *Naiadella fluitans* Marvanová & Bandoni (1987: 579) has been recorded just from Brazilian urban areas (Shoenlein-Crusius *et al.* 2015b).

Brazil has many species of Ingoldian fungi that are also reported from other tropical countries such as Malaysia (Nawawi 1985b) and Puerto Rico (Santos-Flores & Betancout-López 1997), and tropical to subtropical areas of India (Sridhar *et al.* 1992, Sudheep & Sridhar 2013). These countries share genera like *Condylospora* Nawawi (1976: 363)*, Flabellospora* Alas. (1968a: 415)*, Flabellocladia* Nawawi (1985c: 174)*, Ingoldiella* D.E. Shaw (1972: 258) and *Jaculispora* H.J. Huds. & Ingold (1960: 475), which are not common in temperate zones.

The studies of the Ingoldian fungi in Brazil in the last 13 years (after Schoenlein-Crusius & Grandi 2003) added 54 taxa to the list, which now contains 85 taxa. This demonstrates a drastic shift in our understanding of the diversity of the Ingoldian fungi in Brazil. However, there are still huge gaps in our data from many regions and totally unexplored biomes (Fig. 8), requiring further studies on the biodiversity of the Ingoldian fungi and their potential application in biotechnology.

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Capítulo II

Hifomicetos raros em ecossistemas de água doce da Chapada Diamantina, Bahia, Brasil

Fungos aquáticos associados à serapilheira constituem um grupo relativamente desconhecido que inclui geralmente estágios assexuais de Ascomycota e Basidiomycota que são adaptados a ecossistemas aquáticos. Eles são imprescindíveis atuando em processos fundamentais nos ecossistemas, incluindo decomposição de matéria orgânica submersa. O objetivo deste trabalho foi realizar um estudo taxonômico de hifomicetos aeroaquáticos e outros fungos associados à material da serrapilheira submersa na Chapada Diamantina, Bahia, Brasil e providenciar descrições, comentários e ilustrações, incluindo distribuição geográfica mundial para novos registros e espécies raras. *Dactylaria fusifera*, *Helicoon myosuroides*, *Pseudaegerita websteri, Spadicoides subsphaerica* e *Verticicladus subiculifer* são registrados pela primeira vez após descrição original; *Pseudaegerita viridis* é um novo registro para as Américas, *Spirosphaera carici-graminis* é um novo registro para América do Sul e *Ardhachandra aequilatera* é um novo registro para os ecossistemas aquáticos.

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Rare hyphomycetes from freshwater environments from Chapada Diamantina, Bahia, Brazil

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With 3 figures

Abstract: Aquatic litter-associated fungi are a relatively understudied group that includes mostly asexual stages of Ascomycota and Basidiomycota which are adapted to aquatic environment. They are important players in fundamental ecosystem-level processes, including decomposition of submerged organic matter. The aim of this work was to carry out a taxonomic survey of aero-aquatic hyphomycetes and other fungi associated with submerged decaying plant litter in Chapada Diamantina, Bahia, Brazil and provide descriptions, comments and illustrations, including worldwide geographical distribution for new records and rare species. *Dactylaria fusifera*, *Helicoon myosuroides*, *Pseudaegerita websteri*, *Spadicoides subsphaerica* and *Verticicladus subiculifer* are reported for the first time after the original descriptions; *Pseudaegerita viridis* is a new record for the Americas, *Spirosphaera carici-graminis* is a new record for South America and *Ardhachandra aequilatera* is a new record for the aquatic environments.

Key words: Aquatic hyphomycetes, Chapada Diamantina, taxonomy, tropical.

Introduction

Freshwater fungi are capable of completing the entire or part of their life cycle in aquatic ecosystems where they colonize a wide variety of substrates (Thomas 1996). They may be saprophytic, mutualistic, parasitic or endophytic and have a worldwide distribution (Jones & Pang 2012, Chauvet et al. 2015). Shearer et al. (2007) compiled literature data on fungi recorded from aquatic ecosystems (both freshwater and marine) and reported the total of 3047 taxa, with the Ascomycota (including asexual ascomycetes) being the

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most diverse (1527 spp.), followed by Chytridiomycota (576 spp.), Ingoldian fungi (290 spp., that include species with affinity to asco- or basidiomycetes) and Basidiomycota (21 spp.). Recently, Jones & Pang (2012) compiled data on freshwater fungi from the tropics and recorded 660 species of asexual ascomycetes (including Ingoldian fungi and species lacking specific adaptations for water dispersal), 548–650 ascomycetes and 214 trichomycetes.

Freshwater hyphomycetes are asexual stages of ascomycetes and basidiomycetes that are adapted to growth, reproduction and dispersal in freshwater ecosystems. They can be separated into three ecological groups. (1) Ingoldian fungi (also known as aquatic hyphomycetes) regularly sporulate underwater and form tetraradiate, multiradiate, variously branched or sigmoid conidia (Descals 2005, Gulis et al. 2005). (2) Aero-aquatic hyphomycetes mainly occur in stagnant waters, growing vegetatively on submerged substrates but sporulating only when the substrate gets in contact with air or conidiophores pierce through the water surface (Fisher 1977); they produce conidia with three-dimensional, helicoid or clathroid morphology that often trap air and float on the water surface (Michaelides & Kendrick 1982). (3) "Facultative aquatic" (Goh & Hyde 1996a, Descals & Moralejo 2001) hyphomycetes represent a heterogeneous group of fungi that often, though not always, form thick-walled dematiaceous conidia and are often associated with submerged woody substrates (i.e. lignicolous). Even though they can sporulate under submerged conditions, their conidia often lack specific morphological adaptations to water dispersal typical for Ingoldian fungi and aero-aquatic hyphomycetes.

The term "aero-aquatic" was originally proposed by van Beverwijk (1951) who referred to helicosporous genera studied by Linder (1929) and ecologically similar genera like *Candelabrum* and *Papulaspora* [nowadays *Beverwykella pulmonaria* (Beverw.) Tubaki] (van Beverwijk 1954). Later studies of aero-aquatic fungi led to discoveries of many new species from Asia, Australia, Europe, North, Central and South America (e.g. Webster & Davey 1980, Abdullah et al. 1986, Matsushima 1993, Abdullah et al. 1996, 1997, Castañeda-Ruiz & Gams 1997, Voglmayr 1997a, Voglmayr & Fisher 1997, Voglmayr & Krisai-Greilhuber 1997, Marvanová & Bärlocher 1998, Hyde & Goh 1998, Voglmayr 1998, Chang 2001, Voglmayr & Delgado-Rodríguez 2001, Voglmayr 2004, Abdullah et al. 2005, Voglmayr & Yule 2006). In Brazil, relatively few studies of aero-aquatic fungi have been carried out. However, recently, several new species have been described (Monteiro & Gusmão 2013, Monteiro et al. 2014a, Moro et al. 2015a) and new records of rare species have been published (Barbosa & Gusmão 2011, Monteiro 2014).

Facultative aquatic fungi were studied in Brazil more extensively than aero-aquatic fungi. In general, a higher number of species from this group has been recorded (Barbosa et al. 2013, Silva et al. 2014, Monteiro 2014) and multiple new species have been described from the Brazilian semiarid region and Brazilian Amazon (Silva & Gusmão 2013, Monteiro & Gusmão 2014, Monteiro et al. 2014b, Fiuza et al. 2015a).

This study aimed to carry out a taxonomic survey of aero-aquatic and facultative aquatic hyphomycetes in Chapada Diamantina, Bahia, Brazil and provide descriptions, comments and illustrations, including data on worldwide geographical distribution for new records and rare species.

Materials and methods

From November 2013 to January 2015 we made eight expeditions to “Serra da Tromba”, located in the Chapada Diamantina, a semiarid region in northeastern Brazil. Submerged leaves of *Calophyllum brasiliense* Cambess and submerged wood, twigs and tree barks from unidentified hosts were collected from three streams in the Contas river basin. The samples were taken to the Laboratory of Mycology (LAMIC) in plastic bags, processed according to Castañeda-Ruiz (2005), incubated at room temperature (~24°C) with natural light conditions during one month and examined periodically under a dissecting microscope for the presence of reproductive structures. Some fungi were also isolated into potato dextrose agar, corn meal agar and malt extract agar and incubated at ~24°C. In those cases that isolates did not show sporulation on the agar, fragments of the pure culture isolates were submerged in a Petri dish with sterile distilled water until reproductive structures appeared. Measurements of reproductive structures and identification of specimens were performed using a compound microscope (Olympus BX51). The specimens were deposited in the Herbarium of "Universidade Estadual de Feira de Santana" (HUEFS).

Results

Fifty six taxa of freshwater hyphomycetes have been identified in this study, eight of them are rare. *Dactylaria fusifera*, *Helicoon myosuroides*, *Pseudaegerita websteri*, *Spadicoides subsphaerica* and *Verticicladus subiculifer* are reported for the first time after their original descriptions; *Pseudaegerita viridis* is a new record for the Americas, *Spirosphaera carici-graminis* is a new record for South America and *Ardhachandra aequilatera* is a new record for the aquatic environments.

Taxonomy

Aero-aquatic hyphomycetes

Beverwykella clathrata Voglmayr, Mycol. Res. 107(2): 239, 2003. Fig. 1A–B

Conidiophores macronematous, mononematous, unbranched, 1–2-septate, straight to flexuous, 39–45 × 3–3.5 µm, brown. Condiogenous cells monoblastic, integrated, terminal. Conidia oval to rectangular, lenticular, with a dichotomous branching system, clathrate layer formed by the eight outermost branches produced by internal branches, edges rounded, conidia brown, 40–57 µm diam.

Material examined: Brazil. Bahia: Piatã, Chapada Diamantina, on submerged leaves of *Calophyllum brasiliense,* 30.X.2014, P.O.Fiuza (HUEFS 215942).

Geographical distribution: Brazil (Monteiro 2014) and USA (Voglmayr & Delgado-Rodríguez 2003).

Beverwykella clathrata is close to *B. cerebriformis* based on the ontogeny, size and shape of conidia (Voglmayr & Delgado-Rodríguez 2003). However, *B. cerebriformis* displays an outermost cell layer sealed by tightly appressed cells, while *B. clathrata* has a clathrate outermost cell layer (Voglmayr & Delgado-Rodríguez 2003). The material examined in this study is in agreement with the original description. This species was recorded several times on submerged leaves and twigs in Brazilian Amazon (Monteiro 2014, SpeciesLink 2016) and also in São Paulo (Moro et al. 2015a); it is the first record for the Brazilian semiarid region.

Helicoon myosuroides Voglmayr, Mycol. Res. 101(3): 337, 1997. Fig. 1C–E

Conidiophores macronematous, mononematous, unbranched, flexuous, 30–66 × 3–4 µm, brown. Condiogenous cells monoblastic, integrated, terminal. Conidia helicoid, doliiform, cup-shaped, 27–30 µm diam., 12–18 µm long. Conidial filament septate, 4.5–6 µm wide in the middle of the conidium, gradually tapering towards the distal end (3 µm), coiled 4–6 times, brown.

Material examined: Brazil. Bahia: Piatã, Chapada Diamantina, on submerged leaves of *Calophyllum brasiliense*, 19.V.2014, P.O.Fiuza (HUEFS 215947). Bahia: Piatã, Chapada Diamantina, on submerged leaves of *C. brasiliense*, 10.II.2015, P.O.Fiuza (HUEFS 215948).

Geographical distribution: Austria (Voglmayr 1997a) and Brazil (new record).

Helicoon was proposed by Morgan in 1892, and nowadays it is represented by 17 species (Seifert et al. 2011). The main diagnostic character is the spiral coil of the conidial filament that forms an elongated ellipsoidal body (Morgan 1892) in combination with conidium production directly on a conidiophore. *Helicoon myosuroides* is very close to *H. pluriseptatum* Berverw. but the latter has larger conidia (Voglmayr 1997a); furthermore, *H. pluriseptatum* has a conidial filament that is loosely coiled and not significantly tapering at the end (Voglmayr 1997a). The material examined in this study agrees well with the protologue. *Helicoon myosuroides* is reported for the first time after it was originally described from Austria.

Nidulispora quadrifida Nawawi & Kuthub., Mycotaxon 36 (2): 330, 1990. Fig. 3C

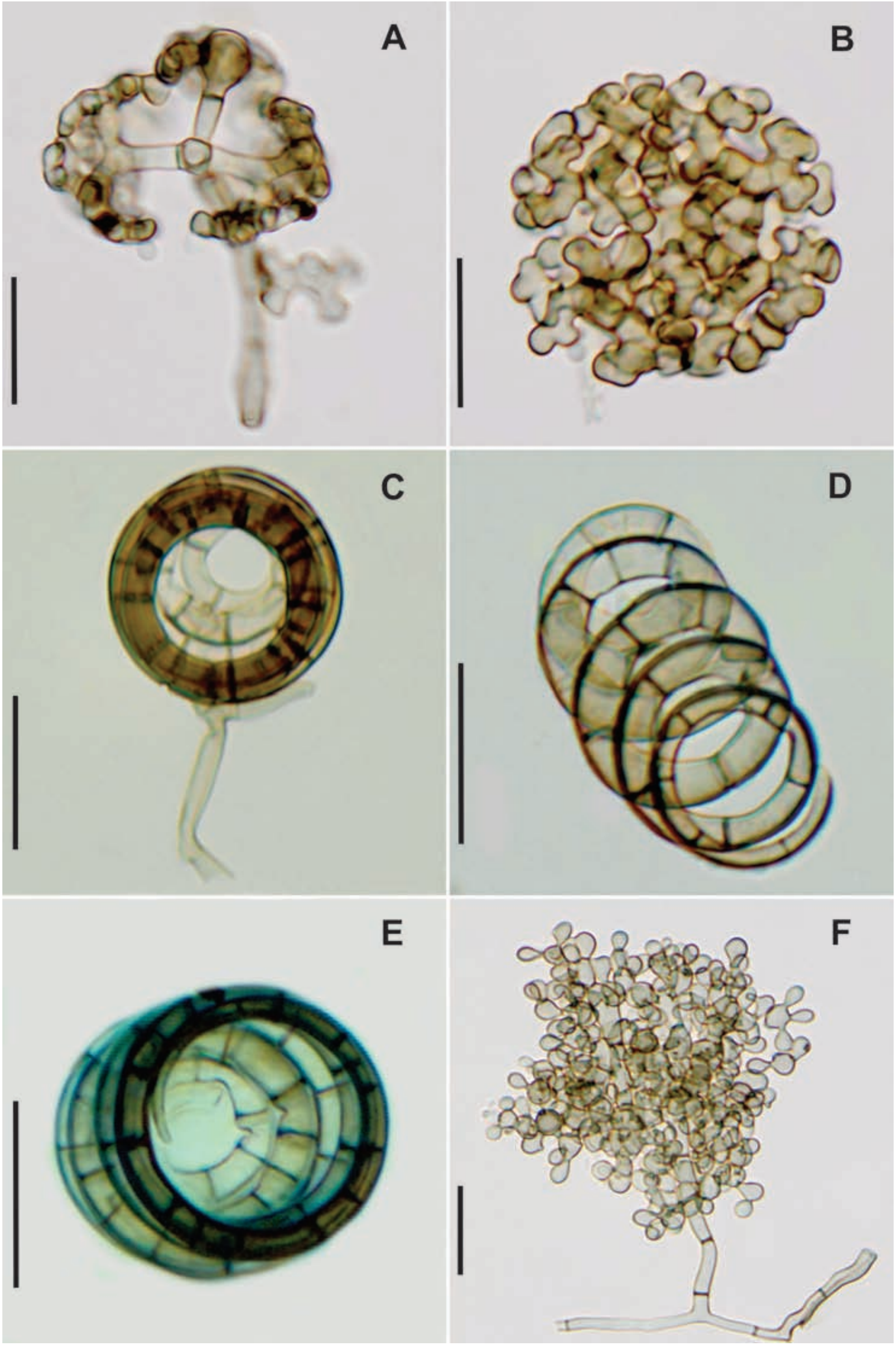
Conidia crateriform, solitary, dry, with several dichotomously branched, curved, ascending arms, attenuated at the tips, with 6–7(9) eusepta each, ascending from several basal cells and encircling a hollow, air-filled space, light brown, becoming paler at the apex, 45–65(70) × 30–45 µm.

Material Examined: Brazil. Bahia: Piatã, Chapada Diamantina, on submerged wood, 08.VII.2014, T.Cantillo (HUEFS 216614).

Geographical distribution: Brazil (Monteiro 2014) and Malaysia (Nawawi & Kuthubutheen 1990).

Nidulispora is a monotypic genus (Seifert et al. 2011). Until recently, this fungus was known only from the original description from Peninsular Malaysia (Nawawi & Kuthubutheen 1990, Kirk 2016). This is the second record from Brazil, following the recent finding on submerged leaves from Utinga State Park, Pará (Monteiro 2014). The peculiar arrangement of the arms forms a hollow space which traps air and allows conidia to float on the water surface, a common feature of aero-aquatic fungi.

Fig. 1. A–B. *Beverwykella clathrata*. A. Conidiophore and detail of conidial development. B. Conidium. C–E. *Helicoon myosuroides*. C. Conidiophore and conidium. D–E. Conidia. F. *Pseudaegerita viridis*. Conidiophore and conidium. Scale bars: A–E = 20 µm, F = 60 µm.


A
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E
F

Pseudaegerita viridis (Bayl.-Ell.) Abdullah & J.Webster, Trans. Br. Mycol. Soc. 80: 247, 1983. Fig. 1F

Conidiophores macronematous, mononematous, unbranched, 2–3-septate, light green in colour, 3–5 µm wide, up to 100 µm long. Conidia subglobose, 180–565 µm diam., olivaceous to dark green, composed of a highly branched system of torulose or subglobose cells, 5–7 µm diam., each successively budding out 1–3 (4) daughter cells, with empty spaces between them that trap air. The conidia disarticulate easily when mounted on slides. Colonies on potato dextrose agar up to 90 mm diam. in 7 days. Mycelium mostly immersed, rarely superficial, hyphae septate, olivaceous green, colony reverse blackish green. Conidia forming solitary or in groups, white at first, dark green with age. Phialidic state observed.

Material examined: Brazil. Bahia: Piatã, Chapada Diamantina, on submerged wood, 17.VII.2014, T.Cantillo (HUEFS 216602); Bahia: Piatã, Chapada Diamantina, on submerged bark tree, 09.I.2015, T.Cantillo (HUEFS 216603).

Geographical distribution: Brazil (new record), Hungary (Gönczöl & Révay 2003), New Zealand (Cooper 2005), Poland (Czeczuga & Orlowska 1996) and United Kingdom (Abdullah & Webster 1983).

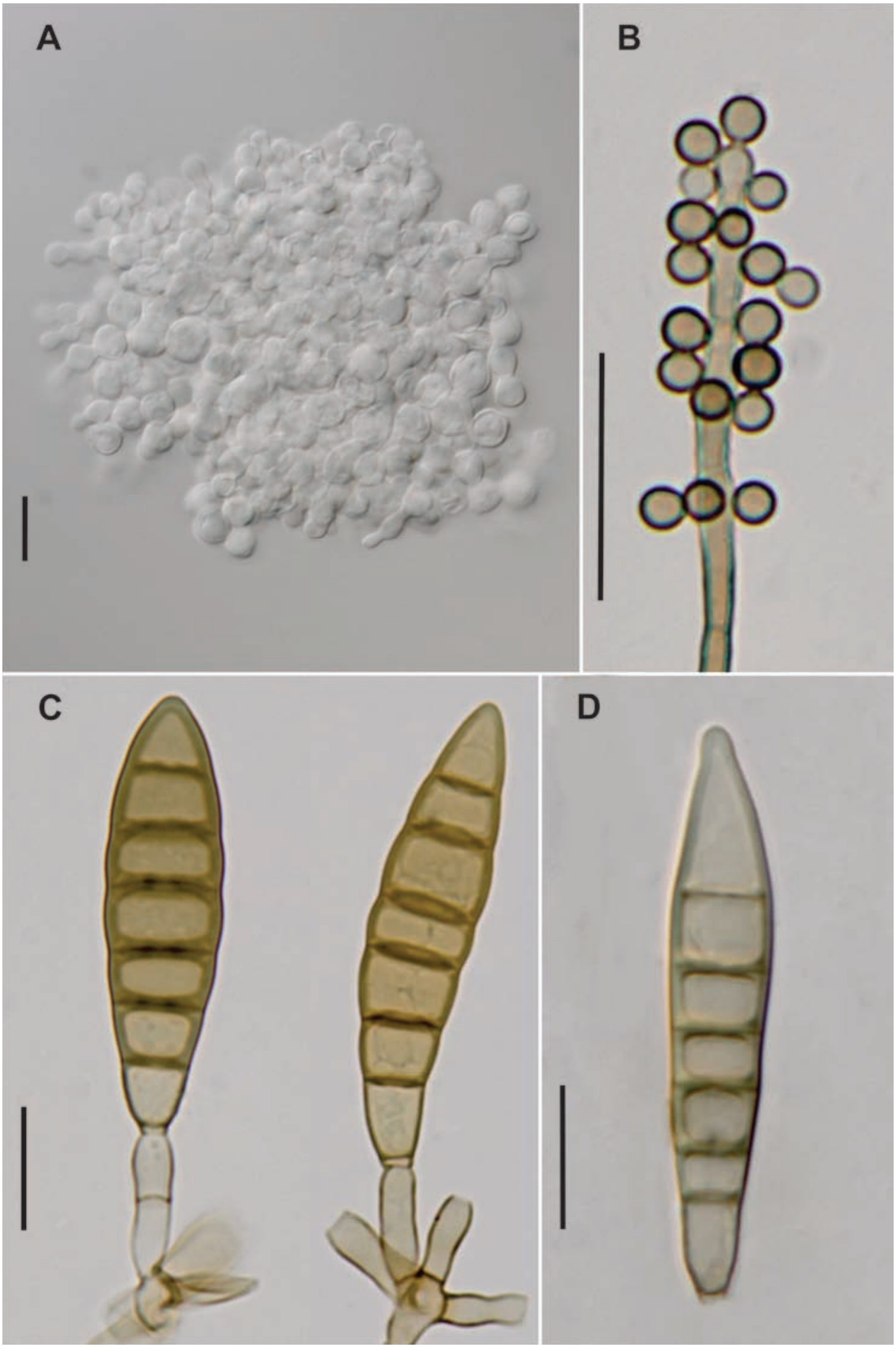
Pseudaegerita is represented by eight species (Seifert et al. 2011). *Psedaegerita viridis* is, by far, the most commonly found species of the genus (Cooper 2005) and one of the most common species of aero-aquatic hyphomycetes in Britain (Abdullah & Webster 1983) with 42 records in the Fungal Records Database of Britain and Ireland (FRDBI) (Kirk & Cooper 2009). It has been found on decaying twigs and wood of different plants deposited on the banks of rivers, streams and stagnant water bodies (Abdullah & Webster 1983). It has also been reported from water-filled tree holes in Hungary (Gönczöl & Révay 2003). The examined material is in agreement with the original description. Only in culture, the Brazilian material also develops a phialidic state, whereas it was reported from culture as well as from the natural substrate by Abdullah and Webster (1983).This is the first record from the Americas and from the tropical region.

Pseudaegerita websteri Abdullah, Gené & Guarro, Mycol Res. 109(5): 593, 2005. Fig. 2A

Conidiophores macronematous, mononematous, unbranched, 1–2-septate, hyaline, 3.5–5 µm wide, up to 25 µm long. Conidia globose to subglobose, 52.5–105 µm diam., hyaline, composed of a branched system of globose cells, 3–4.5 µm diam., each successively budding out 1–4 daughter cells, with empty spaces between them that trap air. The conidia disarticulate easily when mounted on slides.

Material examined: Brazil. Bahia: Piatã, Chapada Diamantina, on submerged leaves of *Calophyllum brasiliense*, 08.I.2015, P.O.Fiuza (HUEFS 215946).

Fig. 2. A. *Pseudaegerita websteri*. Conidium. B. *Spadicoides subsphaerica*. Conidiogenous cells and conidia. C–D. *Verticicladus subiculifer*. C. Conidiophores and conidia from natural substrate. D. Conidium from culture. Scale bars: A = 15 µm, B = 20 µm, C–D = 10 µm.


A
B
C
D

Geographical distribution: Brazil (new record) and Spain (Abdullah et al. 2005).

Pseudaegerita websteri is easily distinguished from other species in the genus by forming white conidia on natural substrate and short conidiophores. This species is close to *P. corticalis* but the latter has larger and pigmented conidia (Abdullah et al. 2005). The material examined is in agreement with the original description. This is only the second record of *P. websteri* and the first from the tropics.

Spirosphaera carici-graminis Voglmayr, Can. J. Bot. 75(10): 1772, 1997. Fig. 3A–B

Conidiophores semimacronematous, mononematous, unbranched, septate, hyaline, 10–30 × 3–6 µm. Condiogenous cells monoblastic, integrated, terminal. Conidia globose to subglobose, hyaline, 51–120 µm diam. Conidial filaments constricted at septa, 3–6 µm wide. Colonies in 0.1% malt extract agar up to 22 mm diam. in 30 days. Mycelium mostly immersed, hyphae septate, hyaline, colony white to cream. Conidia forming solitary or in groups, white.

Material examined: Brazil. Bahia: Piatã, Chapada Diamantina, on submerged leaves of *Calophyllum brasiliense*, 19.V.2014, P.O.Fiuza (HUEFS 215949). Bahia: Piatã, Chapada Diamantina, on submerged leaves of *C. brasiliense*, 07.VIII.2014, P.O.Fiuza (HUEFS 215950). Bahia: Piatã, Chapada Diamantina, on submerged leaves of *C. brasiliense*, 01.X.2014, P.O.Fiuza (HUEFS 215951). Bahia: Piatã, Chapada Diamantina, on submerged leaves of *C. brasiliense*, 19.XII.2014, P.O.Fiuza (HUEFS 215952). Bahia: Piatã, Chapada Diamantina, on submerged leaves of *C. brasiliense*, 10.II.2015, P.O.Fiuza (HUEFS 215953). Bahia: Piatã, Chapada Diamantina, on submerged tree bark, 19.V.2014, T.Cantillo (HUEFS 216610).

Geographical distribution: Austria, Netherlands and USA (Voglmayr 1997b) and Brazil (new record).

Spirosphaera was erected by van Beverwijk in 1953 based on *S. floriformis*. The genus includes nine species (Voglmayr 2004). *Spirosphaera carici-graminis* differs from other species of the genus by its strongly constricted hyaline conidial filaments and cells that can give rise to up to two daughter filaments, while only one daughter filament is formed in other species (Voglmayr 1997b). *Spirosphaera carici-graminis* is usually recorded in association with monocotyledonous plant remains (Voglmayr 1997b), but in this study, it is reported from decaying leaves of a dicotyledonous tree and bark material of an unidentified host. In the present study the species just showed sporulation when the media with fungi were put in contact with water. This is the first record for the Neotropics.

Additional records of aero-aquatic hyphomycetes

Cancellidium applanatum Tubaki, Trans. Mycol. Soc. Japan 16(4): 358, 1975.

Material examined: Brazil. Bahia: Piatã, Chapada Diamantina, on submerged twigs, 15.I.2015, T.Cantillo. (HUEFS 216616).

Candelabrum brocchiatum Tubaki, Trans. Mycol. Soc. Japan 16(2): 134, 1975.

Material examined: Brazil. Bahia: Piatã, Chapada Diamantina, on submerged leaves, 12.VII.2014, J.S.Monteiro (HUEFS 216617).

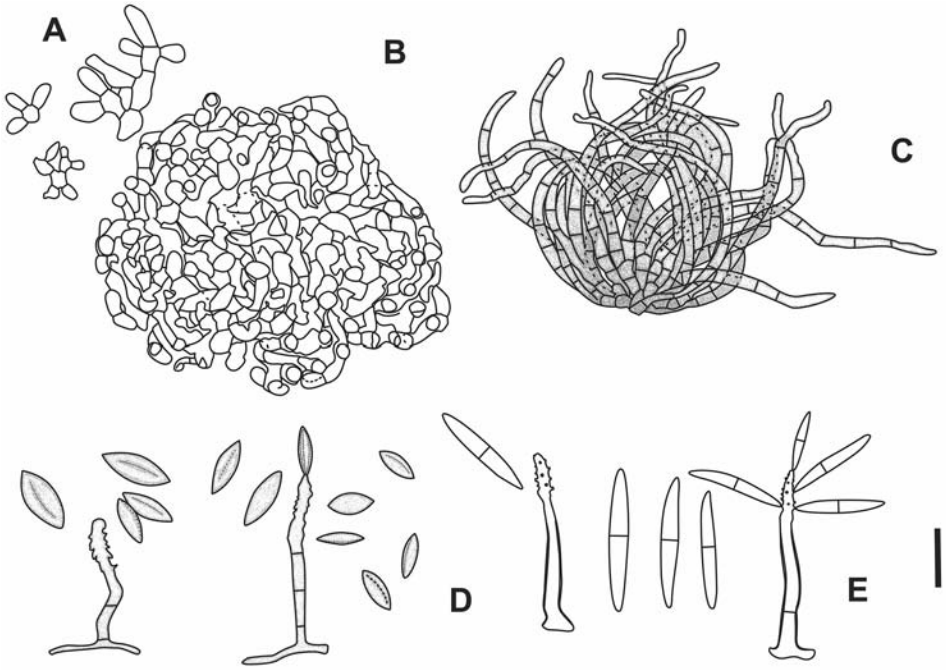


Fig. 3. A–B. *Spirosphaera carici-graminis*. A. Branching filaments. B. Conidium. C. *Nidulispora quadrifida*. Conidium. D. *Ardhachandra aequilatera*. Conidiophores and conidia. E. *Dactylaria fusifera*. Conidiophores and conidia. Scale bars: A–B, E = 20 µm, C–D = 15 µm.

Candelabrum microsporum R.F.Castañeda & W.B.Kendr., Univ. Waterloo Biol. Ser. 35: 16, 1991.

Material examined: Brazil. Bahia: Piatã, Chapada Diamantina, on submerged leaves of *Calophyllum brasiliense*, 12.VI.2014, P.O.Fiuza (HUEFS 215943).

Fusticeps laevisporus Matsush., Matsush. Mycol. Mem. 7: 52, 1993.

Material examined: Brazil. Bahia: Piatã, Chapada Diamantina, on submerged leaves of *Calophyllum brasiliense*, 18.III.2014, P.O.Fiuza (HUEFS 216618). Bahia: Piatã, Chapada Diamantina, on submerged leaves of *C. brasiliense*, 03.II.2015, P.O.Fiuza (HUEFS 216619).

Inesiosporium longispirale (R.F.Castañeda) R.F.Castañeda & W.Gams, *Nova Hedwigia* 64(3-4): 486, 1997.

Material examined: Brazil. Bahia: Piatã, Chapada Diamantina, on submerged leaves, 10.IV.2014, J.S.Monteiro (HUEFS 216620).

"Facultative aquatic" hyphomycetes associated with submerged decaying plant litter

Ardhachandra aequilatera Matsush., Matsush. Mycol. Mem. 5: 3, 1987. Fig. 3D

Conidiophores macronematous, mononematous, unbranched, 1–3-septate, straight to flexuous, 28.5–65 × 3–6 µm, pale brown. Condiogenous cells holoblastic, denticulate, sympodial, pale brown. Conidia fusiform in front view, lenticular in lateral view, guttulate, pale brown, 13.5–16.5 × 4.5–6 µm.

Material examined: Brazil. Bahia: Piatã, Chapada Diamantina, on submerged leaves of *Calophyllum brasiliense*, 08.VII.2014, P.O.Fiuza (HUEFS 215941).

Geographical distribution: Brazil (new record), Cuba (Matsushima 1987) and Taiwan (Matsushima 1987).

Ardhachandra was erected by Subramanian and Sudha in 1978 with the type species *A. selenoides*. The genus is represented by six species (Mel'nik 2012) with conidia selenoid, fusiform or lenticular, produced singly and successively by conidiogenous cells with prominent denticles (Subramanian & Sudha 1978). *Ardhachandra aequilatera* is easily distinguished from the type species that forms selenoid conidia (Subramanian & Sudha 1978). *Ardhachandra prolatofusiformis* J.L.Chen & Tzean is close to *A. aequilatera* but has longer conidia which are asymmetrical (unequal-sided) in front view (Chen & Tzean 1995). Two species of *Ardhachandra* were recorded in Brazil: *A. critastospora* (Matsush.) Subram. & Sudha was found associated with leaves of *Tibouchina pulchra* (Cham.) Cogn. in the state of São Paulo (Grandi & Gusmão 2002) and leaves of *Clusia melchiorii* Gleason in Bahia (Barbosa et al. 2009); *A. selenoides* (de Hoog) Subram. & Sudha was recorded from leaves of *C. melchiorii* and unidentified litter in Bahia (Barbosa et al. 2009, Marques et al. 2008). This is the first record of *A. aequilatera* from the aquatic environment and for the Americas.

Dactylaria fusifera (Berk. & M.A.Curtis) de Hoog, Stud. Mycol. 26: 17, 1985. Fig. 3E

Conidiophores macronematous, mononematous, unbranched, aseptate, rarely 1-septate, erect, subhyaline, with swollen foot, 22–40 × 5–7.5 µm. Condiogenous cells polyblastic, denticulate, sympodial, 20–27.5 × 4–5 µm. Conidia cylindrical to fusiform, 1-septate, hyaline, 32.5–42 × 4–5 µm. Colonies on corn meal agar up to 40 mm diam. in 15 days. Mycelium mostly immersed, rarely superficial, hyphae septate, brown, colony dark brown.

Material examined: Brazil. Bahia: Piatã, Chapada Diamantina, on submerged leaves of *Calophyllum brasiliense*, 24.IV.2014, P.O.Fiuza (HUEFS 215944). Brazil. Bahia: Piatã, Chapada Diamantina, on submerged leaves of *C. brasiliense*, 05.X.2014, P.O.Fiuza (HUEFS 215945).

Geographical distribution: Brazil (new record) and USA (Berkeley 1875).

Dactylaria consist of 90 species (Seifert et al. 2011). The defining characteristics of the genus are conidiogenous cells with multiple cylindrical apical denticles (de Hoog 1985). *Dactylaria fusifera* is closest to *D. candidula* (Höhn.) G.C.Bhatt & W.B.Kendr., but the latter has fusiform conidia with constricted septa. The specimens found in this study match the description provided by de Hoog (1985), which is based on Berkeley's material. This is a new record for the Neotropics and the first report after the original description.

Spadicoides subsphaerica D.W.Li, *Mycotaxon* 111: 258, 2010. Fig. 2B

Conidiophores macronematous, mononematous, unbranched, straight, septate, erect, smooth, brown, 62–115 × 3.5–4.5 µm. Condiogenous cells polytretic, terminal and intercalary, integrated, minute pores clearly visible. Conidia subglobose, globose, or broadly ellipsoidal, aseptate, brown to dark brown, smooth, thick-walled, with an occasionally visible, slightly protuberant pore at the base, 4–4.5 × 3–3.5(4) µm.

Material examined: Brazil, Bahia: Piatã, Chapada Diamantina, on submerged wood, 3.V.2014, T.Cantillo (HUEFS 216612).

Geographical distribution: Brazil (new record) and USA (Li 2010).

Spadicoides was introduced with *S. bina* (Corda) S.Hughes as the type species and is very similar to the genus *Diplococcium* Grove, with the only difference being that in *Diplococcium* the conidia are produced in short chains (Goh & Hyde 1996b). Among other species of the genus with single-celled conidia, *Spadicoides subsphaerica* is characterized by small conidia (3.3–5.4 × 3.2–4.3 µm), subspherical or ellipsoidal, smooth, brown to dark brown. The Brazilian specimen had slightly larger conidiophores and conidia compared to the specimen from the U.S.

Verticicladus subiculifer Matsush., Matsush. *Mycol. Mem.* 9: 29, 1996. Fig. 2C–D

Conidiophores micronematous, mononematous, branched, straight, smooth, brown, 15–45 × 3–4 µm, 0–3-septate. Condiogenous cells monoblastic, terminal, integrated, doliiform, brown, 6–10 × 3–4 µm. Conidia fusiform, 4–6 distoseptate, brown, 37.5–40.5 × 6–7.5 µm. Colonies on 2% malt extract agar up to 42 mm diam. in 15 days. Mycelium mostly immersed, rarely superficial, hyphae septate, brown, colony dark brown to black.

Material examined: Brazil. Bahia: Piatã, Chapada Diamantina, on submerged leaves of *Calophyllum brasiliense*, 12.XI.2013, P.O.Fiuza (HUEFS 215955). Bahia: Piatã, Chapada Diamantina, on submerged leaves of *C. brasiliense*, 16.I.2014, P.O.Fiuza (HUEFS 215956). Bahia: Piatã, Chapada Diamantina, on submerged leaves of *C. brasiliense*, 14.III.2014, P.O.Fiuza (HUEFS 215957). Bahia: Piatã, Chapada Diamantina, on submerged leaves of *C. brasiliense*, 30.VI.2014, P.O.Fiuza (HUEFS 215958). Bahia: Piatã, Chapada Diamantina, on submerged leaves of *C. brasiliense*, 26.I.2015, P.O.Fiuza (HUEFS 215959).

Geographical distribution: Brazil (new record) and South Africa (Matsushima 1996).

Verticicladus was erected by Matsushima in 1993. The genus includes three species: *V. amazonensis* Matsush., *V. hainanensis* M.T.Guo & Z.F.Yu and *V. subculifer* (Guo et al. 2015). *Verticicladus* is characterized by short conidiophores, verticillate conidiogenous cells and rhexolytic secession of cylindrical to fusiform phragmoconidia (Matsushima 1993). *Verticicladus subiculifer* is close to *V. amazonensis* but the conidiogenous cells of *V. subiculifer* are doliiform with more pronounced apical constriction than in *V. amazonensis*. *Verticicladus subiculifer* was originally described from terrestrial decaying leaves of *Podocarpus* sp., while in the present study it was recorded from submerged decaying leaves; *V. amazonensis* and *V. hainanensis* were also reported from aquatic habitats (Matsushima 1993, Guo et al. 2015). In the present study, some cultures of *V. subculifer* isolated on 2% malt extract agar showed faster sporulation under submerged conditions than without submergence. *Verticicladus subculifer* is a new record to the Americas.

Discussion

Freshwater hyphomycetes are successful colonizers of submerged decaying leaves of a variety of deciduous dicotyledonous trees (Goh & Hyde 1996a). They are important players in fundamental ecosystem-level processes, including decomposition of submerged organic matter. Of the three ecological groups that are involved in decomposition in freshwaters (Ingoldian fungi, aero-aquatic and facultative aquatic fungi) only two were addressed in this study (aero-aquatic and facultative aquatic fungi).

The first aero-aquatic hyphomycete recorded in Brazil was *Peyronelina glomerulata* P.J.Fisher, J.Webster & D.F.Kane in the state of Paraiba from a soil sample (Batista et al. 1970). Subsequent studies focused on freshwaters greatly expanded our knowledge on the biodiversity and distribution of aero-aquatic hyphomycetes in Brazilian biomes of Caatinga, Amazon and the Atlantic Forest (Barbosa et al. 2013, Monteiro & Gusmão 2013, Moro et al. 2015a). Nowadays, 19 species of aero-aquatic hyphomycetes are recorded from Brazil, 15 from Amazon (Monteiro 2014), six from Caatinga (Batista et al. 1970, Barbosa & Gusmão 2011) and seven from Atlantic Forest (Magalhães et al. 2011, Moro et al. 2015a). The present study yielded four new records for Brazil and seven species were reported for the first time from Caatinga. *Beverwykella clathrata*, *Cancellidium applanatum*, *Candelabrum brocchiatum* and *Inesiosporium longispirale* (observed in the present study) are now recorded in all three Brazilian biomes. *Cancellidium applanatum* and *Candelabrum brocchiatum* are broadly distributed worldwide, with the first one displaying mainly tropical distribution (Shaw 1994, Chuaseeharonnachai et al. 2013, Farr & Rossman 2016).

Facultative aquatic hyphomycetes have been studied in Brazil to greater extent than aero-aquatic ones, with a total of 338 species reported, 213 from Amazon (Monteiro 2014), 174 from Caatinga (Barbosa & Gusmão 2011, Silva & Gusmão 2013, Silva et al. 2014, Fiuza et al. 2015a, Fiuza et al. 2015b) and 39 from the Atlantic Forest (Schoenlein-Crusius & Grandi 2003, Schoenlein-Crusius et al. 2014, Schoenlein-Crusius et al. 2015, Moro et al. 2015b). In the present study, all new records are rare species (i.e. reported just once or twice worldwide), which suggests that more interesting or rare species could be recorded with the help of focused inventory programs in relatively understudied biomes.

Biodiversity inventories are important to increase our knowledge on the distribution of fungal species worldwide, especially for relatively understudied groups such as freshwater hyphomycetes and in less explored tropical regions. Furthermore, biodiversity studies and genetic barcoding can provide valuable information for ecological studies and environmental conservation programs.

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Capítulo III

Fungos conidiais do bioma Caatinga do Brasil: Uma nova espécie de *Selenosporella* em folhas submersas

Selenosporella minima sp. nov., coletada em folhas submersas de *Calophyllum brasiliense* na região semiárida brasileira, é descrita e ilustrada. A nova espécie é diagnosticada por conidióforos com ramificações verticiladas e conídios naviculares a acerosos.

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Conidial fungi from the semiarid Caatinga biome of Brazil: a new species of *Selenosporella* from submerged leaves

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Abstract — *Selenosporella minima* sp. nov., collected on submerged leaves of *Calophyllum brasiliense* in the Brazilian semiarid region, is described and illustrated. It is distinguished by verticillate branched conidiophores and navicular to acerose conidia.

Key words — asexual fungi, taxonomy, freshwater

Introduction

Selenosporella G. Arnaud ex MacGarvie comprises twelve species. Descriptions, illustrations, and a key to *Selenosporella* species has been provided by Castañeda-Ruiz et al. (2009), who divided the genus into two groups: i) with conidiogenous cells discrete and arranged in verticils and ii) with conidiogenous cells integrated and not arranged in verticils.

Most *Selenosporella* species have been described from litter or wood (Seifert et al. 2011), except for *Selenosporella aristata* Kuthub. & Nawawi, which was described from submerged leaves (Kuthubutheen & Nawawi 1988). An interesting *Selenosporella* specimen recently found on decaying submerged leaves of *Calophyllum brasiliense* is described here as new.

Materials & methods

During several expeditions between November 2013 and May 2014 through Serra da Tromba in the semiarid region of northeastern Brazil, samples of submerged leaves of *Calophyllum brasiliense* were stored in plastic bags, taken to the laboratory, and treated according to Castañeda-Ruiz (2005). Mounts were prepared in PVL (polyvinyl alcohol, lactic acid, and phenol) and measurements made at a magnification of ×1000. Microphotographs were obtained with an Olympus microscope (model BX51) with bright field and Nomarski interference optics. The holotype is deposited in the Herbarium of Universidade Estadual de Feira de Santana, Bahia, Brazil (HUEFS).

Taxonomy

Selenosporella minima Fiuza, Gusmão & R.F. Castañeda, **sp. nov.** FIGS 1, 2

IF 550802

Differs from *Selenosporella cymbiformis* by single, verticillate branched conidiophores.

TYPE: Brazil, Bahia, Piatã, Serra da Tromba, 13°05′S 41°50′W, on submerged leaves of *Calophyllum brasiliense* Cambess. (*Calophyllaceae*), 1-V-2014, coll. P.O. Fiuza (**Holotype**: HUEFS 210422).

ETYMOLOGY: Latin, *minima*, meaning small, refers to conidial size.

COLONIES on the natural substrate effuse, hairy, brown. Mycelium mostly immersed, composed of septate, branched, brown hyphae. CONIDIOPHORES distinct, single, erect, straight, verticillate branched, 2–5-septate, smooth, dark brown, 60–100 × 4–5 µm. CONIDIOGENOUS CELLS holoblastic, denticulate, sympodially elongated, discrete, brown to pale brown. Conidial secession schizolytic. CONIDIA solitary, navicular to acerose, unicellular, smooth, hyaline, 3.5–5 × 1 µm.

NOTE: *Selenosporella cymbiformis* B. Sutton is similar to *S. minima* in conidial shape and size, but *S. cymbiformis* has single or loosely synnematous, unbranched or irregularly branched, 35–55 × 3–4 µm, dark to medium brown conidiophores (Sutton 1973).

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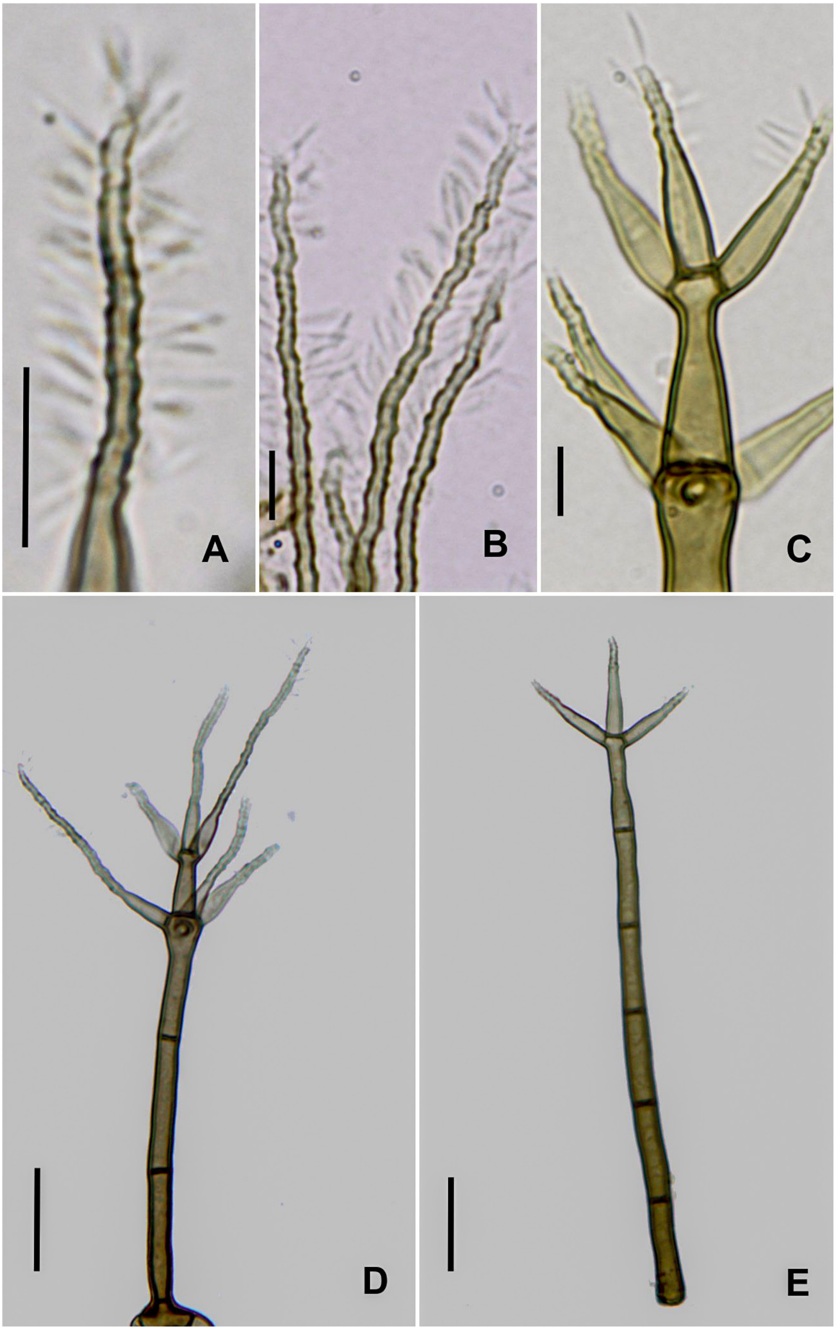
FIG. 1. *Selenosporella minima* (ex holotype, HUEFS 210422): A, B. Conidiogenous cells and conidia; C. Conidiophore, conidiogenous cells and conidia; D, E. Conidiophores. Scale bars: A = 10 µm; B, C = 5 µm; D, E= 20 µm.


A
B
C
D
E

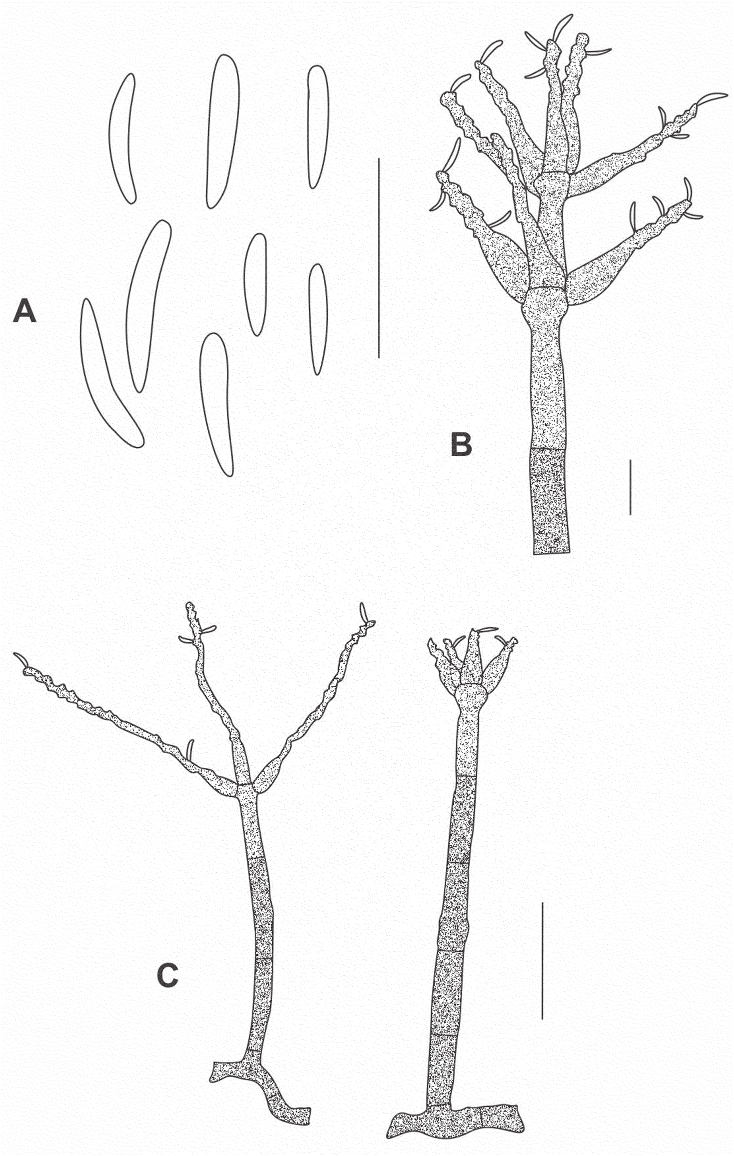


Fig 2. *Selenosporella minima* (ex holotype, HUEFS 210422):
A. Conidia; B. Conidiogenous cells and conidia; C. Conidiophores.
Scale bars: A, B = 5 µm; C = 20 µm.

IndexFungorum and MycoBank websites. Dr. Lorelei Norvell's editorial review and Dr. Shaun Pennycook's nomenclature review are greatly appreciated.

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Capítulo IV

Synchaetomella aquatica sp. nov. em folhas submersas do Brasil

Synchaetomella aquatica sp. nov., um novo microfungo coletado em folhas submersas de *Calophyllum brasiliense* é descrito e ilustrado. A nova espécie é distinta por células conidiogênicas em sinema, conidioma determinado, células conidiogênicas monofialídicas, evidentes e conídios terminais, solitários, falcados, unicelulares e hialinos.

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Synchaetomella aquatica sp. nov. from submerged leaves from Brazil

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Abstract — *Synchaetomella aquatica*, a new microfungus collected on the submerged decaying leaves of *Calophyllum brasiliense*, is described and illustrated. It is distinguished by conidiogenous cells that are synnematal, determinate conidiomata, monophialidic, discrete, and terminal and solitary falcate unicellular hyaline conidia.

Key words — asexual fungi, systematics, freshwater fungi

Introduction

During the studies of saprobic conidial fungi colonizing submerged leaves of *Calophyllum brasiliense* in the Brazilian semiarid Caatinga biome, an interesting fungus belonging to the genus *Synchaetomella* was collected. Critical morphological observation of the specimen revealed it to be an undescribed species, which we describe here as *S. aquatica*.

Materials & methods

During several expeditions between November 2013 to May 2014 through "Serra da Tromba" in the semiarid region northeastern Brazil, samples of submerged leaves of *Calophyllum brasiliense* were stored in litter bags, taken to the laboratory, and processed according to Castañeda Ruiz (2005). Mounts were prepared in PVL (polyvinyl alcohol and lactic acid) and measurements were made at a magnification of ×1000. Micrographs were obtained with an Olympus microscope (model BX51) with bright field and Nomarski interference optics. The type specimen of the new species is deposited in the Herbarium of "Universidade Estadual de Feira de Santana" (HUEFS).

Taxonomy

Synchaetomella aquatica Fiuza, Gusmão & R.F. Castañeda, **sp. nov.** FIGS 1, 2

MYCOBANK MB812900

> Differs from all other *Synchaetomella* spp. by its exclusively terminal conidiogenous cells.
>
> TYPE: Brazil, Bahia, Piatã, Chapada Diamantina, Serra da Tromba, 13°07′S 41°50′W, on decaying submerged leaves of *Calophyllum brasiliense* Cambess. (*Calophyllaceae*), 11.XI.2013, coll. P.O. Fiuza (**Holotype**, HUEFS 209015).
>
> ETYMOLOGY: Latin, *aquatica*, referred to its growing in water.

On the natural substratum mycelium partly immersed and partly superficial. Hyphae septate, branched, smooth, pale brown, 2–3 µm diam. CONIDIOMATA synnematal, determinate, scattered, erect, cylindrical, dark brown, 60–150 µm tall, 25–30 µm wide. STIPE composed of parallel hyphal filaments (conidiophores), multi-septate, straight, cylindrical, closely packed at the base and slightly loosely and branched towards the apex, brown below, brown or pale brown above, smooth, 1.5–3 µm diam. CONIDIOGENOUS CELLS monophialidic, discrete, terminal, determinate, brown to pale brown, 15–45 × 1.5–2.5 µm with a narrow, slightly obscure, sub-cupulate collarette with a distinct, very narrow periclinal channel, 1–2.5 µm deep. CONIDIA solitary, acrogenous, falcate, unicellular, 8–18 × 1.5–2 µm, smooth, hyaline, accumulating in a white mucilaginous mass.

NOTE: Decock et al. (2005) introduced the synnematous genus *Synchaetomella* Decock & Seifert, typified by *S. lunatospora* Decock et al. and characterized by phialidic, terminal and intercalary conidiogenous cells and falcate, 0–1-septate, hyaline conidia. The second species, *S. acerina* (Seifert & Louis-Seize 2012), also has intercalary and terminal conidiogenous cells, but the conidia are unicellular, allantoid to ellipsoidal. *Synchaetomella aquatica* is clearly differentiated by the terminal subulate conidiogenous cells.

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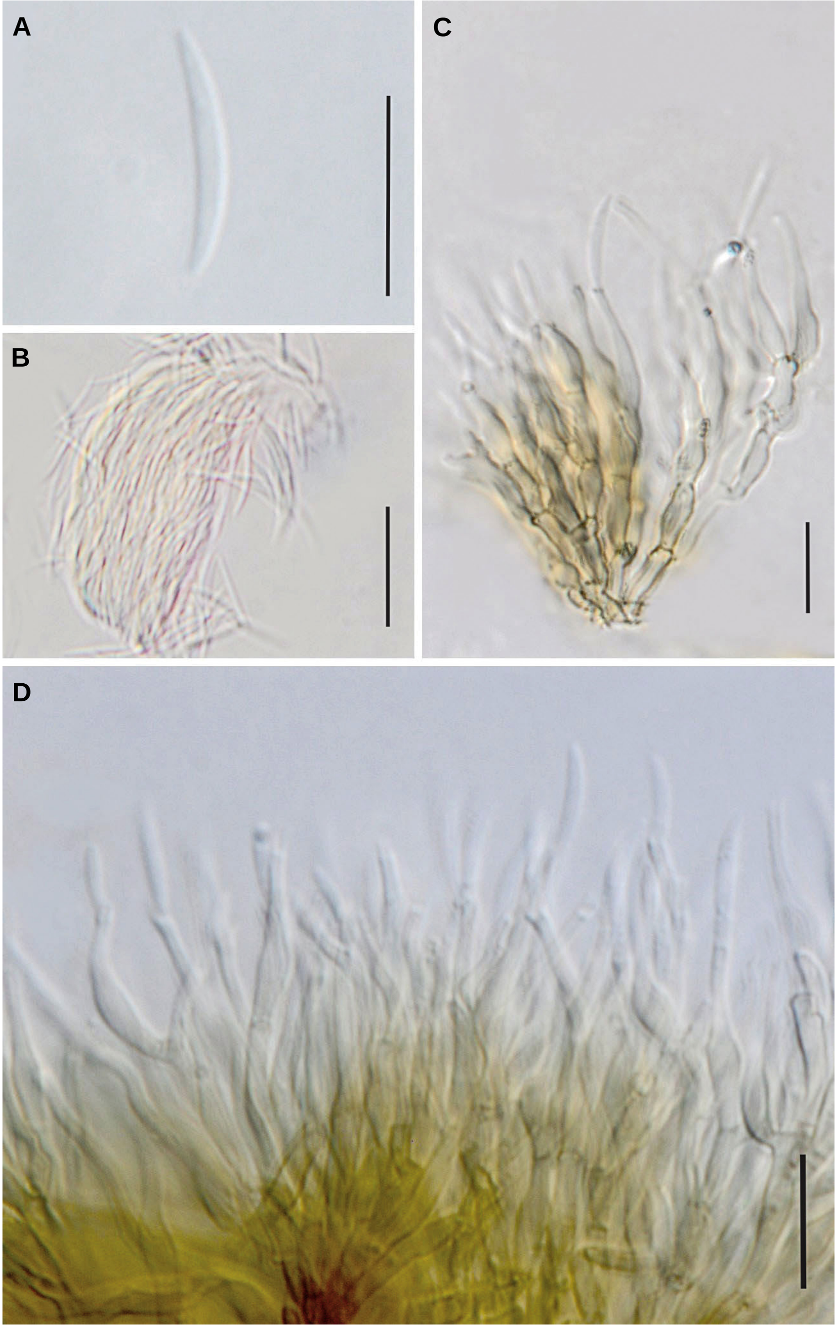
FIG. 1. *Synchaetomella aquatica* (ex holotype HUEFS 209015). A, B. conidia; C, D. conidiogenous cells and conidia. Scale bars: A, C, D = 10 µm, B = 20 µm.


A
B
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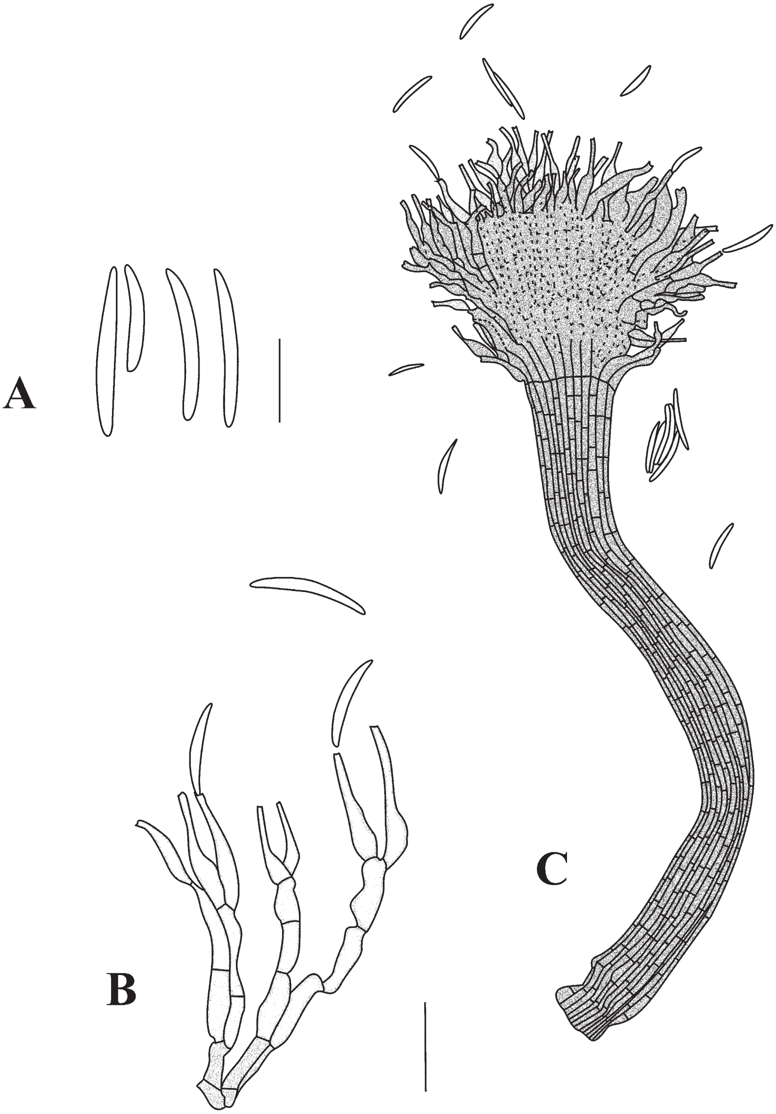

Fig 2. *Synchaetomella aquatica* (ex holotype HUEFS 209015).
A. conidia; B. conidiogenous cells and conidia; C. synnema.
Scale bars: A, B = 10 µm; C = 25 µm.

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Capítulo V

Mirandina uncinata sp. nov. em folhas submersas do Brasil

Uma nova espécie, *Mirandina uncinata*, coletada em folhas submersas de *Calophyllum brasiliense* na região semiárida brasileira é descrita e ilustrada. *Mirandina uncinata* é caracterizada por células conidiogênicas poliblásticas, integradas, terminais, extensão simpodial e conídios cilíndrico-fusiformes, uncinados em direção em ápice, 5-7 septados e castanho-claros.

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Mirandina uncinata sp. nov. from submerged leaves from Brazil

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Abstract — A new species, *Mirandina uncinata*, collected on submerged leaves of *Calophyllum brasiliense* in the Brazilian semiarid region, is described and illustrated. *Mirandina uncinata* is characterized by polyblastic, integrated, terminal, sympodially extended conidiogenous cells and cylindrical-fusiform, uncinate toward the apex, 5–7-septate, pale brown conidia.

Key words — freshwater fungi, conidial fungi, taxonomy

Introduction

An undescribed *Mirandina* species was collected during an investigation of conidial fungi associated with submerged decaying leaves of *Calophyllum brasiliense* in a riparian forest of Chapada Diamantina in Brazil's semiarid region. It is described here as new.

Materials & methods

Samples of submerged leaves of *C. brasiliense* were collected in Piatã, Bahia State, from November 2013 to January 2015. The material was placed in plastic bags and taken to the laboratory and processed according to Castañeda-Ruiz (2005). The samples were washed, placed in Petri dish moist chambers, and stored in a polystyrene box with sterile water plus glycerol for 30 days. Slide mounts were prepared in PVL (polyvinyl alcohol and lactic acid) and measurements were made at a magnification of ×1000. Microphotographs were obtained with an Olympus microscope (model BX51) equipped with bright field and Nomarski interference optics. The specimens and

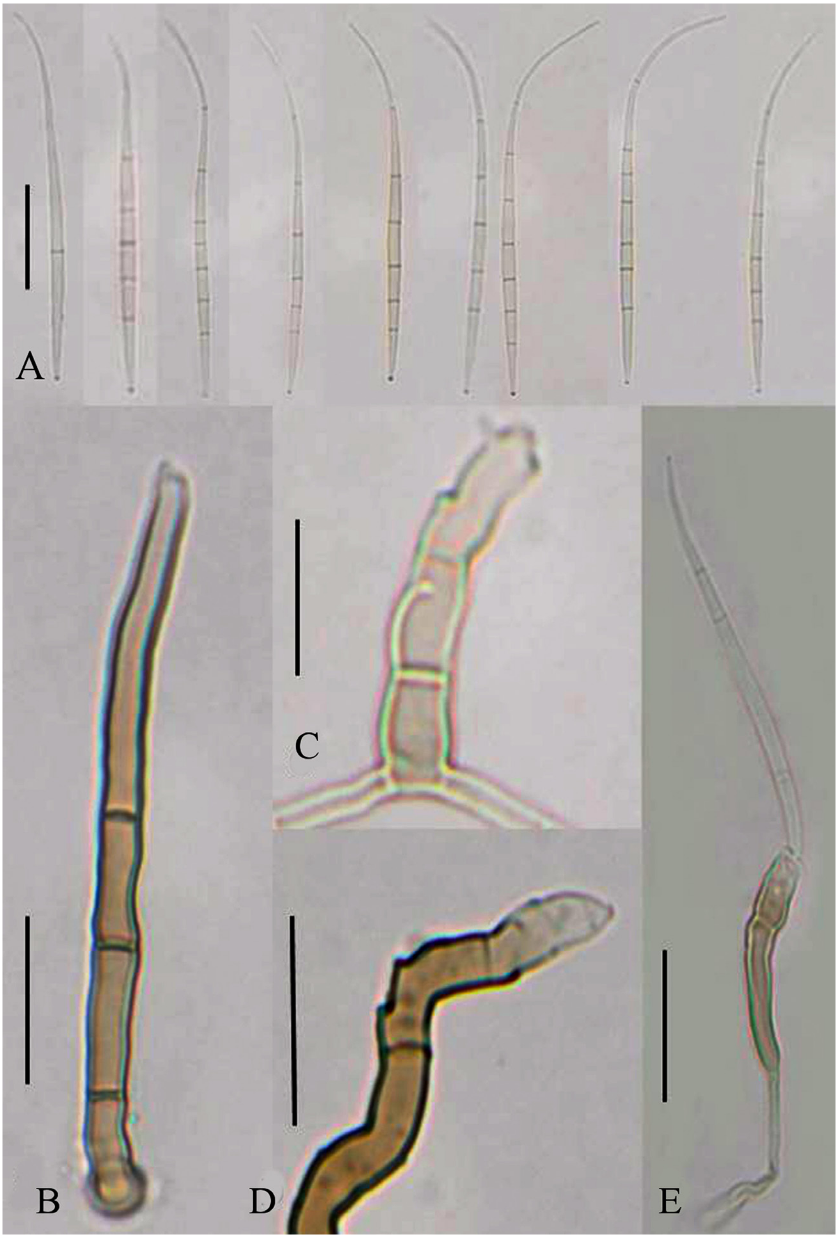

Fig. 1. *Mirandina uncinata* (ex HUEFS 216003). A. Conidia; B–D. Conidiophores and conidiogenous cells; E. Conidiophore and conidium. Bars: A, B, D, E = 20 µm; C = 10 µm.

holotype are deposited in the Herbarium of Universidade Estadual de Feira de Santana, Brazil (HUEFS).

Taxonomy

Mirandina uncinata Fiuza, J.S. Monteiro, R.F. Castañeda & Gusmão, **sp. nov.** Fig. 1

MycoBank MB813056

Differs from *Mirandina flagelliformis* by cylindrical-fusiform, pale brown conidia that are mostly 5–7-septate and uncinate toward the apex.

Type: Brazil, Bahia, Piatã, Serra da Tromba, 13°07′S 41°50′W, on submerged decaying leaves of *Calophyllum brasiliense* Cambess. (*Clusiaceae*), 21. XI. 2014, coll. P.O. Fiuza (**Holotype**: HUEFS 216003).

Etymology: Latin, *uncinata*, referring to the hooked conidia.

Colonies on the natural substratum effuse, hairy, hypophyllous, brown. Mycelium mostly immersed in the substrate. Conidiophores distinct, single, unbranched, cylindrical, straight to geniculate toward the apex, 2–7-septate, brown at the base becoming paler to the apex, smooth, 20–100 × 3–5 µm. Conidial secession schizolytic. Conidiogenous cells polyblastic, integrated, mostly terminal, sometimes intercalary, indeterminate, sympodially elongated, slightly denticulate, brown to pale brown, 20–25 × 3–4 µm, slightly cicatrized at the loci. Conidia solitary, cylindrical-fusiform, attenuate, truncate at the base, rostrate, uncinate toward the apex, (1–)5–7(–11)-septate, pale brown, smooth, 40–95 × 2–4.5 µm.

Additional specimens examined: **BRAZIL, Pará**, Belém, Ilha do Combu, 1°29 S 48°25 W, on submerged decaying twig 29 X. 2011, coll. J.S. Monteiro (HUEFS 216005); Parque Estadual de Utinga, 1°25 S 48°27 W, on submerged decaying twig, 30 VII. 2012, coll. J.S. Monteiro (HUEFS 216004).

Note: The genus *Mirandina* G. Arnaud ex Matsush., typified by *M. corticola,* is characterized by distinct, unbranched, brown conidiophores and polyblastic, denticulate, integrated, sympodial elongated conidiogenous cells. The conidia are cylindrical, fusiform to obclavate, unicellular or septate, hyaline, and subhyaline (Kirk 1986). Ten species have been accepted in *Mirandina* (Castañeda-Ruiz & Kendrick 1991, Castañeda-Ruiz et al. 1997, de Hoog 1985, Kirk 1986, Matsushima 1975, 1980, 1987; Matsushima & Matsushima 1996, Paulus et al. 2003, Ma et al. 2015). *Mirandina uncinata* resembles *M. flagelliformis* Matsush., which differs by its narrowly obclavate hyaline conidia that are flagelliform toward the apex and slightly constricted at the septa (Matsushima 1987, Matsushima & Matsushima 1996).

Acknowledgments

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Capítulo VI

Dictyotrichocladium aquaticum gen. & sp. nov. e *Minimelanolocus aquatilis* sp. nov. em água doce na região semiárida brasileira

Dictyotrichocladium aquaticum gen. & sp. nov. e *Minimelanolocus aquatilis* sp. nov. são descritos e ilustrados de espécimes coletados respectivamente de folhas submersas de *Calophyllum brasiliense* e galhos submersos de plantas não identificadas na região semiárida brasileira. *Dictyotrichocladium aquaticum* é distinto por conidióforos macronematosos ou micronematosos e células conidiogênicas monoblásticas e terminais que produzem conídios solitários, piriformes, cilíndricos, clavados, turbinados a vermiformes, curvados a sigmóides, distoseptados, negros ou escuro pigmentados que usualmente não secedem e permanecem presos após a maturação. *Minimelanolocus aquatilis* é caracterizado por conídios obclavados, 3-5 euseptos, verruculosos e castanho-claros.

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Dictyotrichocladium aquaticum **gen. & sp. nov. and** ***Minimelanolocus aquatilis*** **sp. nov. from freshwater from Brazilian semiarid region**

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ABSTRACT — *Dictyotrichocladium aquaticum* gen. & sp. nov. and *Minimelanolocus aquatilis* sp. nov. are described and illustrated from specimens collected respectively on submerged decaying leaves of *Calophyllum brasiliense* and decaying twigs of unidentified plant in the Brazilian semiarid region. *Dictyotrichocladium aquaticum* is distinguished by macronematous, sometimes micronematous conidiophores, and monoblastic, terminal conidiogenous cells that produce solitary, long pyriform, cylindrical, long clavate, turbinate to vermiform, curved or sigmoid, dictyoseptate, black or dark pigmented conidia that usually do not secede and remain attached after maturation. *Minimelanolocus aquatilis* is characterized by obclavate, 3–5-euseptate, verruculose, pale brown conidia.

KEY WORDS – aquatic fungi, Caatinga, taxonomy, tropics.

Introduction

Freshwater hyphomycetes are essential to recycle the complex organic matter in aquatic environments (Jones & Pang 2012), and make part or entire life cycle in water (Thomas 1996). Goh & Hyde (1996) introduced three groups of freshwater hyphomycetes: the Ingoldian fungi, the aero-aquatic hyphomycetes and the facultative aquatic hyphomycetes. The present study focused on facultative aquatic hyphomycetes which includes hyaline and dematiaceous genera, and produce conidia that are mainly unmodified by aquatic environment (Goh & Hyde 1996; Shearer et al. 2007).

In Brazil, the first taxonomic research on facultative aquatic hyphomycetes occurred in the Brazilian semiarid region, Caatinga, and was followed by explorations in Amazon and Atlantic Forest (Barbosa & Gusmão 2011; Barbosa et al. 2011, 2013; Silva & Gusmão 2013; Monteiro & Gusmão 2014; Moro et al. 2015; Fiuza et al. 2015a,b, 2016a,b). These studies reveal a high biodiversity of facultative aquatic hyphomycetes and a large number of new species for Brazil.

During studies on freshwater hyphomycetes associated with submerged decaying leaves of *Calophyllum brasiliense* Cambess. (*Calophyllaceae*) and twigs in the Brazilian semiarid region, a new genus, *Dictyotrichocladium*, and an interesting species of *Minimelanolocus* R.F. Castañeda & Heredia (Castañeda-Ruiz et al. 2001) were found. Their conidial morphology differ from other genera or species, and are proposed here as new to science.

Materials & methods

From November 2013 to August 2015, expeditions were made in "Serra da Tromba" (Chapada Diamantina) and "Serra da Fumaça" (Pindobaçú state of Bahia). Both areas belong to the semiarid region in northeastern Brazil. In "Serra da Tromba", submerged decaying leaves of *Calophyllum brasiliense* were collected from three streams in the Contas river basin, taken to the Laboratory of Mycology (LAMIC) in plastic bags, and processed as described by Bärlocher (2005). Leaf samples of *C. brasiliense* were washed, and 12-mm diam discs were cut with a cork borer. The discs were incubated for 48 hours at 18-20ºC on a shaker (100rpm) in 100-mL Erlenmeyer flasks containing 30 mL of sterile distilled water to induce sporulation. The spore suspensions were filtered through membrane filters (5 µm pore size), and the filters were then mounted on slides with cotton blue in lactic acid. The leaf discs were mounted on slides with acid lactic and examined under compound microscope. In “Serra da Fumaça”, submerged twigs were collected from some streams, taken to the Laboratory of Mycology (LAMIC) in plastic bags, and processed as described by Castañeda-Ruiz et al. (2016). The twigs were washed and placed in Petri dishes (moist chambers) incubated in a polystyrene box with sterile water plus glycerol for 30 days. The slides were mounted using resin PVL (polyvinyl alcohol, lactic acid and phenol). Measurements of reproductive structures and identification of specimens were performed using a compound microscope (Olympus BX51). The specimens were deposited in the Herbarium of “Universidade Estadual de Feira de Santana” (HUEFS).

Taxonomy

Dictyotrichocladium Fiuza, Gusmão & R.F. Castañeda, **gen. nov.**

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Differs from *Trichocladium* by its long clavate, turbinate to vermiform, curved or sigmoid, dictyoseptate conidia.

TYPE SPECIES: *Dictyotrichocladium aquaticum* Fiuza et al.

ETYMOLOGY: Greek, *Dictyo-,* meaning conidia with one or more transversal and longitudinal and/or oblique septa; Latin, -*trichocladium*, referring to the hyphomycete genus *Trichocladium.*

CONIDIOPHORES micronematous or macronematous, unbranched, septate, brown. CONIDIOGENOUS CELLS monoblastic, integrated, terminal, pale brown to brown. CONIDIAL SECESSION schizolytic. CONIDIA solitary, long pyriform, cylindrical, long clavate, turbinate to vermiform, curved or sigmoid, dictyoseptate, brown to dark brown.

NOTES – *Dictyotrichocladium* is similar to *Trichocladium* Harz, but the latter differs by its didymo or phragmoconidia (Hughes 1952). Several other genera including *Acrodictys* M.B. Ellis, *Cirrenalia* Meyers & R.T. Moore, *Paradictyoarthrinium* Matsush. and *Thyrostroma* Höhn. have conidia similar to *Dictyotrichocladium*. However, *Acrodictys* produce cylindrical, pyriform, obovoid or ovoid and straight conidia (Zhao et al. 2011). *Cirrenalia* is close to *Dictyotrichocladium* in conidial shape, but differs by its helicoids, phragmoconidia (Zhao & Liu 2005). In *Paradictyoarthrinium*, the conidiophores are slightly constricted at the septa or monilioid, and conidiogenous cells are lateral or intercalary (Matsushima 1996; Seifert et al. 2011). *Thyrostroma* has stromatic, sporodochial conidiomata, and its conidiogenous cells are indeterminate with several enteroblastic percurrent generations (Höhnel 1911). *Dictyodesmium* S. Hughes and *Dictyorostrella* U. Braun also have dictyoseptate conidia, but both genera have stromatic, sporodochial conidiomata (Seifert et al. 2011).

Dictyotrichocladium aquaticum Fiuza, Gusmão & R.F. Castañeda, **sp. nov.** FIG. 1

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Differs from *Trichocladium* spp. by long clavate to vermiform, curved or sigmoid, dictyoseptate conidia.

TYPE: Brazil, Bahia: Piatã, Chapada Diamantina, 13°05'S 41°51'W, alt. 1272 m, on submerged decaying leaves of *Calophyllum brasiliense* Cambess. (*Calophyllaceae*), 05.June 2015, coll: P.O. Fiuza (**Holotype**, HUEFS 215954).

ETYMOLOGY: Latin, *aquaticum,* referring to the aquatic environment where the species grows.

COLONIES on natural substrate effuse, brown to dark brown. Mycelium superficial and immersed, composed of slightly branched, septate, smooth, pale brown to brown hyphae, 2–4.5 µm wide. CONIDIOPHORES micronematous or macronematous, single, erect, straight or flexuous, unbranched, 2–8-septate, smooth, 20–80 × 6–7.5 µm, brown. CONIDIOGENOUS CELLS monoblastic, integrated, terminal, smooth, 6–10 × 7–9 µm, pale brown to brown. CONIDIAL SECESSION schizolytic. CONIDIA solitary, long pyriform, cylindrical, long clavate, turbinate to vermiform, curved or sigmoid, dictyoseptate, smooth, 30–140 × 18–37.5 µm, brown to dark brown, dry.

Minimelanolocus aquatilis L.B. Conc., M.F.O. Marques, Gusmão & R.F. Castañeda, **sp. nov.** FIG. 2

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Differs from *Minimelanolocus limpidus* by smaller conidiophores and verruculose conidia.

TYPE: Brazil, Bahia: Pindobaçú, Serra da Fumaça, 10°38'S 40°22'W, alt. 865 m, on submerged decaying twigs of unidentified plant, 08. August 2015, coll: L.B. Conceição (**Holotype**, HUEFS 216640).

ETYMOLOGY: Latin, *aquatilis*, refers to its capacity or ability to live in water.

COLONIES on natural substrate effuse, hairy, brown. Mycelium superficial and immersed, composed of slightly branched, septate, smooth, brown hyphae, 2–4 µm wide. CONIDIOPHORES macronematous, mononematous, single or caespitose, erect, straight or flexuous, unbranched, 1–5-septate, think-walled, smooth, 43–78 × 5–10 µm, brown to pale brown at the apex. CONIDIOGENOUS CELLS polyblastic, integrated, terminal, indeterminate, with several sympodial extensions, 20–42 × 5–7 µm, brown to pale brown. CONIDIAL SECESSION schizolytic. CONIDIA solitary, acropleurogenous, dry, 3–5-euseptate, obclavate, verruculose, 21–30 × 5–8 µm, pale brown to subhyaline, with small dark scar at the truncate base, 1.5–2 µm wide.

NOTES – *Minimelanolocus* currently comprises 29 species (Castañeda-Ruiz et al. 2001; Heredia et al. 2014; Liu et al. 2015; Hyde et al. 2016), most of them were found as a saprobe on decaying leaves, rotten wood, dead branches and bamboo under terrestrial environment, and only five species have been reported from aquatic habitats (Liu et al. 2015; Hyde et al. 2016). *Minimelanolocus aquatilis* is superficially similar to *M. limpidus* Heredia et al., but the latter are from terrestrial environment, and has smooth, longer conidia (27–48 long), and longer and wider conidiophores (140–358 × 18–23 µm) with more septa (10–17) (Heredia et al. 2014).

Discussion

Facultative aquatic hyphomycetes have been recorded in Brazil since 2011 (Barbosa et al. 2013). Thus far, 339 species are distributed in Amazon, Caatinga and Atlantic Forest (Fiuza et al. 2016a,b), of these 25 are new species: 15 to Amazon, 1 to Atlantic Forest and 9 to Caatinga (Barbosa et al. 2011, 2013; Silva & Gusmão 2013; Monteiro & Gusmão 2014; Fiuza et al. 2015a,b, 2016a; Moro et al. 2015; Conceição et al. 2016; Monteiro et al. 2016), and a new genus: *Dictyoaquaphila* J.S. Monteiro et al., collected on submerged wood of Amazon and Caatinga (Monteiro et al. 2016). The present study yielded one new species, *Minimelanolocus aquatilis* and a new genus, *Dictyotrichocladium*, to Caatinga. Therefore, taxonomy studies are essential to knowledge of diversity of fungi, subsequently contributing to conservation works.

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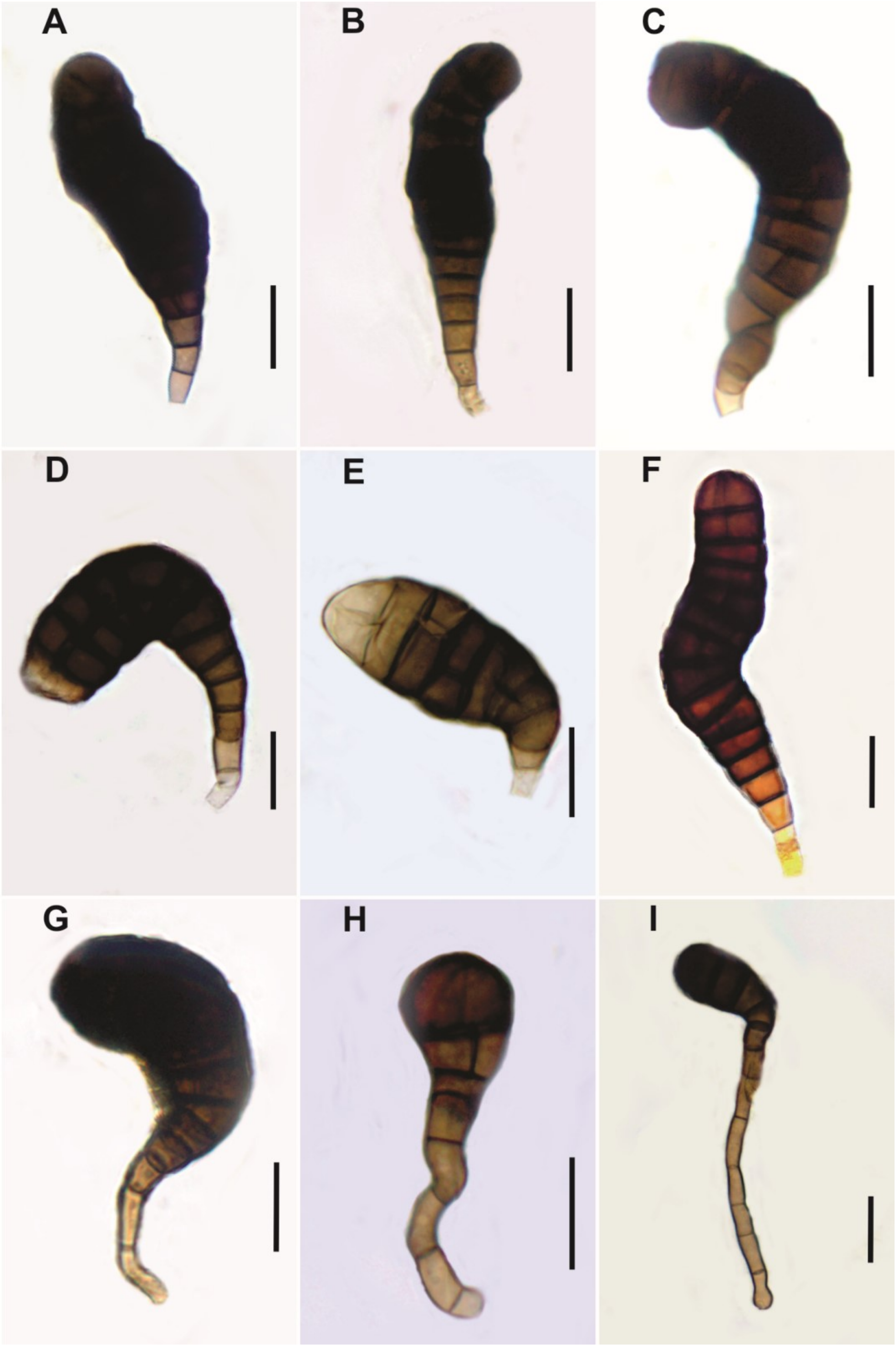

FIG. 1. *Dictyotrichocladium aquaticum* (holotype HUEFS 215954). A–F. Conidia; G–I. Conidiophores, conidiogenous cells and conidia. Scale bars: A–I = 20 µm.

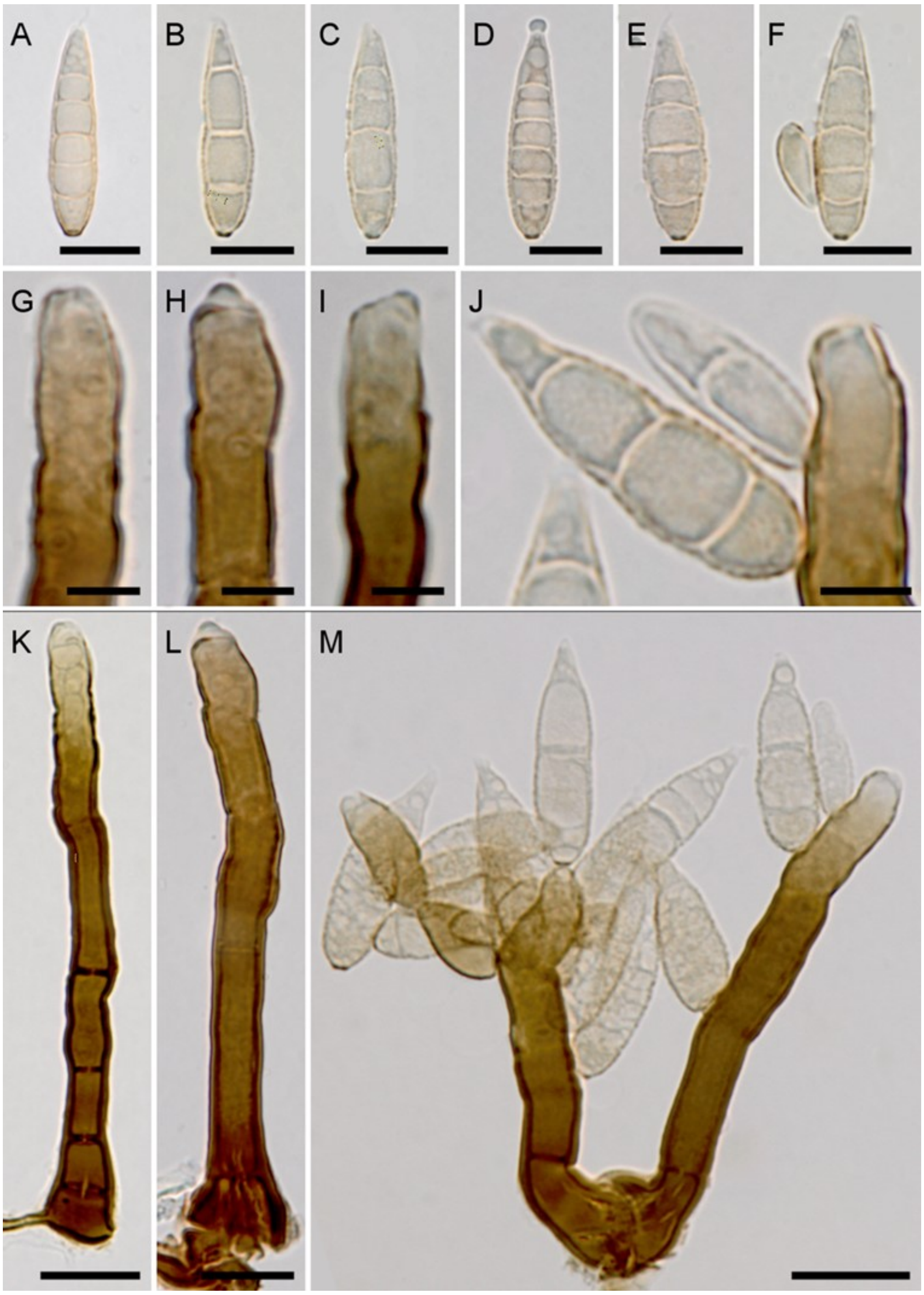

FIG. 2. *Minimelanolocus aquatilis* (holotype, HUEFS 216640). A–F. Conidia; G–I. Conidiogenous cells; J. Conidiogenous cell and conidia; K, L. Conidiophores; M. Conidiophores, conidiogenous cells and conidia. Scale bars: A–F, K–M = 10 µm; G–J= 5 µm.

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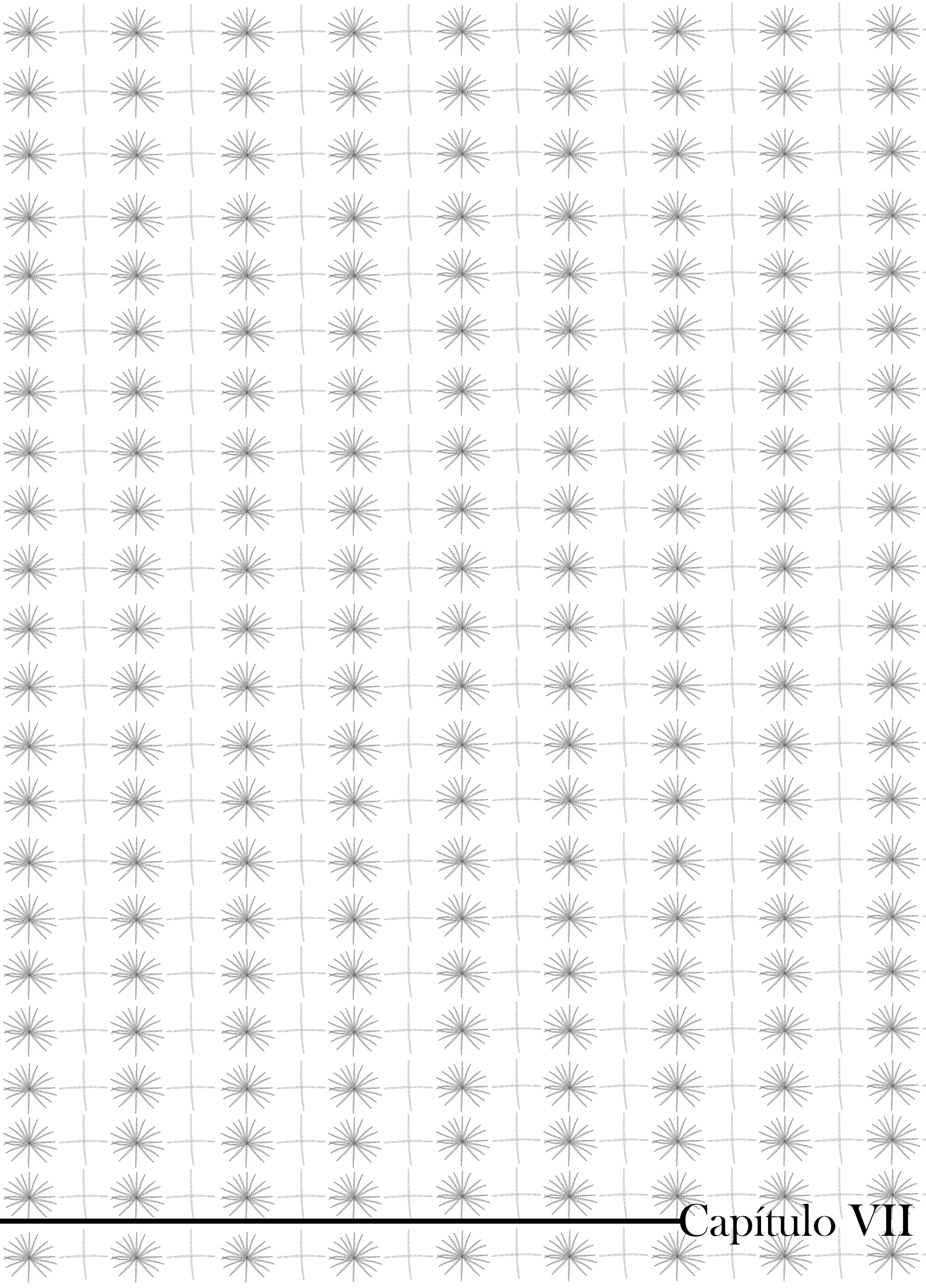

Capítulo VII

Diversidade de hifomicetos aquáticos associados à folhas de *Calophyllum brasiliense* em riachos da região semiárida brasileira

O presente estudo teve como foco os hifomicetos aquáticos associados a folhas submersas de *Calophyllum brasiliense* em três riachos da região semiárida do nordeste brasileiro (Bacia do Rio Contas, Piatã, Bahia). As folhas de *C. brasiliense* foram colocadas em "litter bags" e submergidas nos riachos em duas ocasiões (estação seca e chuvosa). Utilizaram-se dois métodos complementares para coleta de hifomicetos aquáticos: incubações submersas e incubação em câmaras úmidas. Nossos objetivos foram: (*i*) analisar e comparar a estrutura de comunidades fúngicas nos riachos experimentais utilizando ambos os métodos; (*ii*) avaliar se as variáveis ambientais têm influenciado a diversidade e esporulação de comunidades fúngicas e (*iii*) detectar possíveis padrões de sucessão na estrutura das comunidades de hifomicetos aquáticos. Sessenta e nove táxons de hifomicetos aquáticos foram observados. As maiores taxas de esporulação (incubações submersas) foram observadas durante a estação chuvosa. A alta entrada de folhas nos riachos, as alterações na concentração de oxigênio e a velocidade da água afetaram as comunidades de hifomicetos aquáticos associadas à serapilheira submersa. As análises também mostraram diferenças claras entre comunidades fúngicas recuperadas de incubações submersas versus câmaras úmidas. Este estudo permite compreender melhor as comunidades de hifomicetos aquáticos nos riachos do semiárido do Brasil e os fatores ambientais que controlam a estrutura dessas comunidades, o que é especialmente importante, uma vez que os estudos ecológicos de fungos aquáticos no Brasil e nas regiões tropicais em geral ainda são escassos.

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Diversity of freshwater hyphomycetes associated with leaf litter of *Calophyllum brasiliense* in streams of the semiarid region of Brazil

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Abstract

The present study focused on freshwater hyphomycetes associated with submerged leaves of *Calophyllum brasiliense* in three streams in the semiarid region of northeastern Brazil (River Contas basin, Piatã, Bahia). Leaves of *C. brasiliense* were enclosed in litter bags and deployed into streams on two occasions (dry and wet season). Samples of submerged leaf litter were collected every two months (November 2013 to January 2015). Two complementary methods were used: incubation of leaf litter under submerged condition on an orbital shaker and incubation in moist chambers. We aimed to (*i*) analyze and compare the structure of fungal communities in the experimental streams using both methods; (*ii*) evaluate which environmental variables have influenced the diversity and sporulation of fungal communities and (*iii*) detect possible successional patterns in the structure of freshwater hyphomycete communities. Sixty-nine taxa of freshwater hyphomycetes were observed. The highest sporulation rates (submerged incubations) have been observed during the wet season. The high input of leaves, changes in oxygen concentration and water velocity affected the communities of freshwater hyphomycetes associated with submerged leaf litter. We also found differences between fungal communities recovered from submerged incubations vs. moist chambers. This study improves our understanding of the freshwater hyphomycete communities in streams of the semiarid regions of Brazil and the environmental variables that control the structure of these communities, which is especially important since ecological studies of aquatic fungi in Brazil and the tropical regions in general are still uncommon.

1. Introduction

In aquatic ecosystems successional studies of fungal communities have been conducted on both submerged wood (Ho et al., 2002) and leaves (Gessner et al., 1993; Schoenlein-Crusius and Milanez, 1998; Newman et al., 2015). On submerged leaves, both chytridiomycetes and zygomycetes can be detected, but the fungal communities are dominated by freshwater hyphomycetes (Schoenlein-Crusius and Milanez, 1989; Gessner et al., 1993).

According to Yanna et al. (2002) and Gessner et al. (1993) there are three stages of succession: pioneer, mature and impoverished later stage of communities. Pioneer stage is characterized by low diversity and a few taxa with high abundance (Dix and Webster, 1995); the mature stage shows the highest taxa richness and evenness (Yanna et al., 2002); and the impoverished stage is characterized by the decline of fungal diversity and just a few codominant taxa (Yanna et al., 2002; Gessner et al., 1993).

Freshwater hyphomycetes include diverse aquatic fungi found in continental aquatic ecosystems that, as a group, have a worldwide distribution (Shearer et al., 2007). Freshwater hyphomycetes encompass three ecological groups that have been studied for decades (Hyde et al., 2015). The most famous group is called Ingoldian fungi in honor of Dr. Ingold for his pioneering contribution to their studies (Descals et al., 1977) and represents the true aquatic hyphomycetes due to their unique adaptations to aquatic environments, mostly streams and rivers. The aero-aquatic hyphomycetes display mycelial growth on submerged substrates, however, even though sporulation typically does not occur underwater, the conidia demonstrate adaptations to water dispersal (Fisher, 1977). Species of facultative aquatic hyphomycetes can sporulate below or above water but typically lack specific adaptation for water dispersal; they represent a continuous group with terrestrial hyphomycetes with conidia often showing thick walls, i.e. being dematiaceous (Descals and Moralejo, 2001).

Freshwater hyphomycetes play an important role in decomposition of allochthonous plant litter entering rivers and streams from the riparian zone (Sridhar et al., 2010; Ferreira et al., 2014). Fungi mediate carbon, energy and nutrient flow in freshwater ecosystems including the increase in the quality of decomposing leaf detritus which makes it more palatable and nutritious food source to aquatic invertebrate consumers (Gulis et al., 2006).

The structure of freshwater hyphomycete communities can be assessed by a variety of techniques that are aimed to induce sporulation: incubation of submerged plant material on a shaker or in bubble chambers simulating stream conditions or, if fungi produce spores in air, moist chamber incubation (Graça et al., 2016). Submerged incubation of plant material, mainly leaves, yields a large number of Ingoldian fungi or aquatic hyphomycetes (Chan et al., 2000; Ghate and Sridhar, 2016), while incubation of leaf litter or wood in moist chambers reveals mainly facultative aquatic hyphomycetes (Sridhar et al., 2010; Barbosa et al., 2013), that are quite diverse in the Neotropics (Castañeda et al., 2016).

Several studies have indicated that environmental variables, such as water temperature, oxygen concentration, turbulence and pH, may influence the diversity, activity and sporulation of freshwater hyphomycetes (Webster, 1975; Hissy et al., 1992; Chauvet and Suberkroop, 1998; Rajashekhar and Kaveriappa, 2000; Medeiros et al., 2009).The effects of dissolved inorganic nutrients (nitrogen and phosphorus), which are often elevated in rivers affected by human activity have recently received considerable attention (Gulis and Suberkropp, 2003; Gulis et al., 2008; Ferreira et al., 2015; Kominoski et al., 2015).

Another important factor affecting aquatic fungal communities is the diversity of plant litter and riparian vegetation (Gulis, 2001; Chauvet et al., 2016). *Calophyllum brasiliense* was chosen due to its high abundance and ecological importance in the riparian corridors in Chapada Diamantina including the River Contas (Funch, personal communication).

In this study, we investigated the freshwater hyphomycetes communities associated with submerged decomposing leaves of *Calophyllum brasiliense* Cambess in three streams of the River Contas basin using two complementary methods: submerged and moist chamber incubations. We aimed to (*i*) analyze and compare the structure of fungal communities in the experimental streams using both methods; (*ii*) evaluate if environmental variables (water temperature, pH, dissolved oxygen, water velocity and concentration of nitrogen and phosphorus) have influenced the diversity and sporulation of fungal communities and (*iii*) detect possible successional patterns in the structure of freshwater hyphomycete communities.

2. Materials and Methods

2.1 Study area

The present study was conducted in three streams of the River Contas basin: Rio de Contas (RC), Patricinho (P1) and Patricio (P2) (RC: 13° 07' 31.7" S, 41° 50' 10.5" W; P1: 13° 05' 46.4" S, 41° 50' 56.5" W; P2: 13° 05' 11.7"S, 41° 51' 13.1"W), located in Piatã, “Serra da Tromba”, Chapada Diamantina, semiarid region in northeastern Brazil (Table 1). The RC has predominantly grassland vegetation, some trees, shrubs and lianas in the riparian corridor; it does not have closed canopy or exposed stones. P1 has similar riparian vegetation but has less grassland vegetation. P2 has even more trees, nearly closed canopy and exposed stones. “Serra da Tromba” is included in the Caatinga biome and the area around the experimental streams shows rupestrian grassland vegetation (Chagas, personal communication) (Table S1).

The rainfall in the study area was atypical, somewhat higher than historical means during December to April period (2013-2015), and the collections made from January 2014 to May 2014 and in January 2015 were categorized as "wet season" while the rest of the samples were considered as "dry season" (Fig. 1). The rainfall data was obtained from the "Instituto Nacional de Metereologia" (INMET).

2.2 Sampling and laboratory analyses

In October 2013 and May 2014, we visited the study area to collect green leaves of *Calophyllum brasiliense* from the riparian forest for our two experiments. Experiment 1 (E1) was carried out from November 2013 to May 2014 and Experiment 2 (E2) from July 2014 to January 2015, approximately eight-month duration each to allow sufficient leaf litter decomposition and fungal succession. For both experiments, five leaves were enclosed in each fine-mesh litter bag (30 x 30 cm, 0.5 mm mesh size) which were then deployed in streams by tying with nylon line to trees or other riparian vegetation. Every two months, we collected six litter bags from each stream (6 litter bags x 3 streams x 4 collection dates x 2 experiments for the total of 144 bags and 720 leaves). Litter bags were placed in plastic bags and transported to the Laboratory of Mycology (LAMIC), Universidade Estadual de Feira de Santana in a cooler. At each sampling date, we also collected water samples (1 L) that were later analyzed for total nitrogen and phosphorus according to Koroleff (1976). Environmental variables (water temperature, pH and dissolved oxygen) were measured in the field on each sampling date with portable equipment (HORIBA U-50) and the water velocity with the flow meter (GLOBAL WATER FP111 flow probe).

In the laboratory, leaf litter samples were processed using two methodological approaches: (1) to induce sporulation of freshwater fungi under submerged conditions and (2) incubation in moist chambers.

Sporulation under submerged conditions, following Bärlocher (2005): on each sampling date, leaves from three litter bags per stream were rinsed and twenty 12-mm diam discs were cut with a cork borer from each litter bag. These discs were incubated for 48 hours at 18-20ºC on a shaker (100 rpm) in 100-mL Erlenmeyer flasks containing 30 mL of sterile distilled water to induce fungal sporulation. Spore suspensions were filtered through membrane filters (5 µm pore size, Millipore), and the filters were then mounted on slides with cotton blue in lactic acid. In addition, the leaf discs were also mounted on slides and examined under compound microscope. All spores on filters and slides with leaf discs were identified and counted.

Incubation in moist chambers following Castañeda-Ruiz et al. (2016): leaf litter samples (from three litter bags per stream) were rinsed, placed in Petri dishes (moist chambers) and incubated in a polystyrene box with sterile water plus glycerol for 30 days. Fungal structures were mounted on slides with lactic acid and sealed with nail polish.

2.3 Data analysis

Litter-associated fungal communities from experimental streams were evaluated using Simpson diversity index and evenness (Magurran, 1988). Chao 1 was used to estimate the number of taxa expected in the communities (Chao, 1984). While analyzing the relative importance of individual taxa in the communities, the relative abundance was expressed as a percentage of total conidia produced by all taxa in submerged incubations (Ghate and Sridhar, 2015); for the moist chambers, the relative abundance was calculated as: Relative abundance= n (100/N), where n= number of individuals by species, N= total number of individuals in sample. Analysis of variance (ANOVA) was performed to test for the effects of stream, experiment and collection day on fungal sporulation rate. Similarity percentage analysis (SIMPER) was performed to identify the most influential taxa that contributed to the dissimilarity of fungal communities among streams. ANOSIM permutation test (Analysis of Similarity) was also performed to assess the dissimilarities of communities among streams (Clarke, 1993). Non-metric Multidimensional Scaling method (NMDS) was used to analyze the effects of environmental variables (dissolved nutrient concentrations, oxygen, pH, temperature and water velocity) on communities of fungi, using Bray-Curtis dissimilarity matrix (Clarke, 1993). The distribution of fungi on stages of succession was evaluated through the constancy of species, which was calculated as: $C = p \times 100/P$, (where p= number of collections in which the taxon was present, and P= total number of collections.). We used the following constancy classes: accidental taxon ($C \leq 25\%$), accessory taxon ($25\% < C \leq 50\%$) and constant taxon ($C > 50\%$) (Santos and Cavalcanti, 1995). To compare the methodologies (submerged incubations vs. moist chambers) we performed Unweighthed Pair Group Method with Arithmetic Mean (UPGMA) cluster analysis based on the Dice similarity matrix.

Analyses were conducted in Past software 3.14 (Hammer et al., 2013) and Primer 5.2.6 software (Clarke and Gorley, 2006).

3. Results

3.1. Environmental variables

RC, P1 and P2 are oligotrophic streams (0-0.66 mg/L of total nitrogen, 0-0.09 mg/L of total phosphorus) with moderate to high concentrations of dissolved oxygen

(7.9-9.0 mg/L) and slightly acidic pH (5.2-5.9). P1 had the highest temperatures (17.5-24.5 ºC) while P2 had slightly cooler waters (15.0-20.5 ºC) (Table 1).

3.2. Sporulation rates in submerged incubations

Sporulation rates of freshwater hyphomycetes under submerged incubation conditions (Fig. 2) were significantly higher in E1 than in E2 (ANOVA, $F_{1,60}$=14.1, P=0.0004). In E1, high sporulation rates were found in RC and P2 on date 120, and P1 on date 180, while in E2, the highest peaks in all streams were achieved on date 180 or 240. These patterns generally corresponded to increased precipitation during the wet seasons (Fig. 1). No differences in sporulation rates among streams or collection dates were found (ANOVA, P>0.05).

3.3. Fungal community structure

3.3.1. Submerged incubations

3.3.1.1. Taxa richness and diversity

Twenty-six taxa of freshwater hyphomycetes were recorded from submerged leaves of *C. brasiliense*: one was an aero-aquatic hyphomycete, 13 were Ingoldian fungi and 12 were facultative aquatic hyphomycetes (Table 2, S2-S4). Taxa richness was comparable among streams with 16, 19 and 22 species, while 11 species were shared by all three streams (Table 2). *Dendrosporium lobatum* was recorded only in RC, while *Scutisporus brunneus* was found only in P1, and four species were exclusive to P2. The highest taxa richness was observed during E1 that mostly coincided with the wet season, while fewer species were recorded during E2 (mostly dry season) (Fig. 3, Table 2). Estimates of Chao 1 were close to the actual number of taxa recorded in our samples suggesting an adequate sampling effort. In contrast, diversity estimates (Simpson index) and evenness of spore distribution among taxa were generally higher during the experiment E2 than E1 (Table 2).

3.3.1.2. Succession

The temporal changes in relative abundances of dominant taxa for all streams and both experiments are illustrated in Fig. 4. *Triscelophorus acuminatus* was a dominant or co-dominant species in most cases, with its relative abundance increasing at later stages of decomposition by the end of E2. Morphotype 1 displayed high relative abundance during the middle stages of decomposition (d. 60 and d. 120), especially during the E2 and in P2. *Monotosporella* sp. was the dominant species in P1 during E1 while during the E2 it was mostly recorded during the middle stages of decomposition. Overall, Ingoldian fungi were mostly associated with submerged leaves of *Calophyllum brasiliense* during early to middle stages of succession (until 120 days) in all streams during E1 and in RC in E2 (Tables S2-S4), while they were more abundant during the later successional stages in P1 and P2 during E2. The constancy of fungal taxa in each stream and experiments (Tables S5) shows that during E1 all streams had more constant taxa (2, 5 and 5 in RC, P1 and P2, respectively) that during E2 (3, 4 and 3 taxa), while the number of accessory and accidental species did not show a clear pattern.

3.3.1.3. Dissimilarity of communities and effects of environmental variables

Similarity percentage analysis (SIMPER) shows that *Triscelophorus acuminatus, Monotosporella* sp. and Morphotype 1 contributed the most to the differentiation of fungal communities among streams (Table S6). ANOSIM analysis showed no significant differences in freshwater hyphomycetes communities among streams.

UPGMA cluster and NMDS analyses generally showed separation of streams and experiments based on their fungal communities (Figs. 5, 6). NMDS analysis also allowed to relate fungal communities to environmental variables. Oxygen availability was important in separating fungal communities along coordinate 1 axis, and it was mainly related to the communities found in P1 and P2 during the dry season. The pH helped to separate fungal communities along coordinate 2 axis, mainly due to pH being somewhat higher in P2 vs. RC on most dates. Water velocity was related to communities of RC and P1 in E1 that showed highest abundance.

The UPGMA cluster with samples of both methodologies displays separation of methods (Fig. 5). Moreover there is highest similarity between samples of submerged incubation method (65%).

3.3.2. Moist chambers

3.3.2.1. Taxa richness and diversity

Fifty-six taxa of freshwater hyphomycetes were recorded in moist chambers, of these 6 were aero-aquatic hyphomycetes, 6 were Ingoldian fungi and 44 were facultative aquatic hyphomycetes (Table 3, S7-S9). RC had the highest taxa richness with 41 species, while samples from P1 and P2 yielded 32 and 19 species, respectively. All streams shared 10 taxa, while RC, P1 and P2 had 18, 9 and 3 exclusive taxa, respectively. RC and P2 showed the highest taxa richness during E2 (Table 3), while in P1 it was the same in both experiments. In contrast to submerged incubations, estimates of Chao 1 for all streams and both experiments were considerably higher than the number of taxa actually recorded. Simpson diversity indices were comparable across streams and experiments, while the evenness among taxa was considerably lower in E2 than E1 in RC and P2 (Table 3).

3.3.2.2. Succession

Overall, the highest number of taxa was generally found at later stages of decomposition (d. 240) in all streams and in both experiments (Tables S7-S9). In RC, species of *Thozetella* were co-dominant in E1, being especially important during earlier stages of decomposition (Fig. 7). In P2, *Kionochaeta spissa* and *Chalara alabamensis* were highly important on d. 180 of E1, while the latter was the dominant species on the very last sampling date in E2. *Beltrania rhombica* was an important early colonized in P2 in both experiments, while *Codinea simplex* had high relative abundances in P1 throughout both experiments. Overall, the number of constant taxa varied from 2 to 5 among streams and experiments, while the number of accidental taxa was generally higher during E2 (e.g., up to 24 accidental taxa in RC) than E1 (Table S10).

3.3.2.3. Dissimilarity of communities and effects of environmental variables

SIMPER analysis showed that *Codinaea simplex*, *Triscelophorus acuminatus*, and *Chalara alabamensis* contributed the most to differentiation of fungal communities among streams (Table S11). ANOSIM showed that streams significantly affected the structure of fungal communities (R=0.47, P=0.0001). In contrast to data from submerged incubations, NMDS analysis based on fungal data from moist chambers was not significant and did not provide meaningful ordination (not shown).

4. Discussion

A total of 69 species of freshwater hyphomycetes have been recorded in this study using two methodologies. However, since incubations under submerged conditions and in moist chambers targeted (and yielded) largely different ecological communities of fungi, the observed patterns will be discussed separately.

4.1. Submerged incubations

4.1.1. Taxa richness and diversity

Most species of freshwater hyphomycetes recovered from *C. brasiliense* under submerged conditions are Ingoldian fungi or aquatic hyphomycetes (13 species). This was expected since the methodology of Bärlocher (2005) promotes sporulation of this group. The species richness recorded is somewhat higher than previously reported from submerged leaves in Brazil (Schoenlein-Crusius and Milanez 1989; Schoenlein-Crusius and Milanez 1998; Sales et al. 2014). However, some studies in Neotropical region have indicated a higher number of taxa than recorded in present study, e.g. Bärlocher et al. (2010) that observed 34 taxa of freshwater hyphomycetes in streams of Panamá.

Jabiol et al. (2013) studied aquatic hyphomycete communities along a broad latitudinal gradient and found relatively low diversity in the tropics, which corroborates the earlier observation of Shearer et al. (2007) that aquatic hyphomycetes display the highest diversity in temperate regions. Duarte et al. (2016) reviewing the distribution of aquatic hyphomycetes worldwide came to the same conclusion.

Graça et al. (2016) suggested some explanations of the low diversity of aquatic hyphomycetes in tropical streams. One of those is the relatively low nutrient availability in water, which was also documented in our study. Another factor that may explain the low diversity in tropical streams is the low quality of substrate, such as leaf litter. Many species of plants in tropical regions produce compounds (tannins and phenols) that inhibit the colonization by fungi thus making plant litter recalcitrant and decreasing litter decomposition rates (Canhoto and Graça, 1996; Hoorens et al., 2003; Moretti et al., 2007). *Calophyllum brasiliense* used in this study produces phenolic compounds and calcium oxalate crystals (Junior et al., 2005).

4.1.2. Succession

Most Ingoldian fungi together with some facultative hyphomycetes were found in pioneer or mature stages of succession on decaying leaves of *C. brasiliense*. Earlier studies of succession on submerged leaves of *Ficus microcarpa*, *Quercus robur*, *Alchornea triplinervia*, *Caesalpinia echinata* and *Campomanesia phaea* conducted in the Atlantic forest of Brazil, indicated that Ingoldian fungi typically occur in later stages of succession while facultative aquatic or terrestrial fungi are found during the early phases (Schoenlein-Crusius and Milanez, 1989; Schoenlein-Crusius et al., 1990; Schoenlein-Crusius and Milanez, 1998; Moreira, 2011). Gessner et al. (1993) working with succession of alder leaves in temperate region demonstrated the mature stage of succession as richer.

In our study, we did not find clear cut replacement of species through stages of succession; some taxa were constant from pioneer stages until the end of the study, while a few taxa occurred just in early stages. Gessner et al. (1993) also did not observe clear extinction of species as expected from classical succession studies.

All streams in E1 showed pioneer community with high species richness. The impoverished communities at the later stages of decomposition were in agreement with a pattern suggested by Yanna et al. (2002). In E2, we did not generally observe this pattern probably because of delay in colonization due to the presence of green spots in collected leaves. According to Bärlocher (1991), when the leaching does not occur, the colonization by aquatic hyphomycetes will be delayed.

Beltrania rhombica and *Thozetella havanensis* were observed only in early stages (until 120 days) of succession. According to Hyde et al. (2015) some species found in terrestrial situations cannot survive for a long time under submerged conditions.

4.2. Moist chambers

4.2.1. Taxa richness and diversity

As expected the methodology of moist chambers displays more taxa of facultative aquatic hyphomycetes due the simulation of a terrestrial and humid environment with limited amount of water in method. This kind of methodology also contributes to sporulation of aero-aquatic hyphomycetes, once they are able to produce mycelium in submerged substrates but the sporulation mainly occurs in contact with air (Fisher, 1977). Ingoldian fungi also occur but in a low amount, what was observed in works of Brazilian Caatinga and Amazon (Fiuza et al., 2017).

The most studies of freshwater hyphomycetes using moist chambers are realized with submerged wood (Hyde et al., 2015). They show a highly diversity of facultative aquatic hyphomycetes and some species are similar that we found in present study (Tsui et al., 2001; Kodsueb et al., 2016). Studies of submerged leaves are few but they also have showed a highly diversity and a lot of new taxa (Castañeda-Ruiz et al., 2010, Fiuza et al., 2015, Castañeda et al., 2016). In the current study the richness of freshwater hyphomycetes associated with leaves of *C. brasiliense* is high considering it is from a unique plant species. In Atlantic forest of Brazil Schoenlein-Crusius and Milanez (1998) recorded 50 freshwater hyphomycetes associated with *Alchornea triplinervia*. Kodsueb et al. (2016) in an evergreen forest of Thailand recorded 37 taxa associated with submerged *M. liliifera* wood baits. On the other hand, Tsui et al. (2001) recorded about 115 taxa of freshwater hyphomycetes on wood.

4.2.2. Succession

The results of richness of freshwater hyphomycetes in three stages of succession indicated that in the most experiments the highest richness is found in impoverished stage. It is in disagreement with Dix and Webster (1995) that shows mature stage with highest richness, besides of several species have high level of occurrences.

In communities of saprophytic fungi is usual detected replacement or substitution of species during succession times (Gessner et al., 1993; Rayner and Todd, 1979). The samples of moist chambers display this patron which is evidenced by high number of accessory or rare species in all streams.

Cylindrocladiella infestans often isolated as endophytic or pathogen fungus (Brown and Ferreira, 2000; Evans et al., 2003) occurred in date 60 of all streams in E2, which was displayed in leaves with large green spots when collected. Probably the species was already on leaves when collected from trees and after submersion showed up just in moist chamber, which allows it development. Studies have indicated that endophytic fungi are able to colonize leaves before senescence; they remain dormant until senescence, abscission or damage so they can grow and sporulate as saprophytic (Promputtha et al., 2007; Promputtha et al., 2010).

4.3. Comparison between methodologies

The species shared between submerged incubations and moist chambers suggested a great overlap between both methods (13 taxa). This overlap of species is high due the same species of plant used as bait to both methods. Sridhar et al. (2010) studying aquatic fungi on wood assessed by damp incubation and bubble chamber methodologies had the overlap of just one species.

Simpson diversity index indicated most chambers samples have higher diversity than submerged incubations because of highest dominance displayed in samples of the second method. Moreover, evenness is highest also in moist chamber samples. According Magurran (2004) the higher dominance of species leads to a lesser diversity.

Simpson index gives more weight to more abundant species in the samples being less sensitive to richness of species.

UPGMA results shows separation of methodologies applied. The samples from moist chambers displays lower similarity because of the high number of species recorded. To submerged incubations there are two clusters separating E1 and E2 due the amount of taxa and abundance displayed, in E1 there are most of taxa and highest abundance, while in E2 the amount of taxa and abundance are lowest.

Like in some studies Ingoldian fungi are present also in moist chambers samples, but the activity of them is decreased and the most of them shows shorter conidiophores than in submerged incubations (e.g. *Triscelophorus acuminatus*).

4.4. Sporulation rates, multivariate analyses and effects of environmental variables

In current study was observed that in E1 occurred highest richness, sporulation rates and abundance peaks of few taxa that drove the decomposition. E1 was developed in the end of dry season and all wet season differently of E2, developed most part in dry season. Some studies indicated that in Brazil the litter fall occurs in the end of dry season, due hydrological stress, and beginning of wet season, due physical abrasion and more nutrients carried from riparian zone, there is a higher litter fall on streams (Gonçalves et al., 2014; Rezende et al., 2016). Sales et al. (2014) working in Chapada Diamantina, as the present study, also founded peaks of sporulation during the wet season; moreover there was a greater input of litter leaves in the beginning of the wet season which may provide more food resource to microorganisms. In periods of superabundance of leaves the Ingoldian fungi can colonize quickly these substrates (Bärlocher, 2009). Ghate and Sridhar (2016) studying aquatic hyphomycetes on leaves of palm canopies by bubble chambers also detected highest richness in wet season.

The present study as other studies in tropical areas e.g. India (Sridhar and Sudheep, 2010) shows that in tropical areas there are seasonality influence in dynamics of freshwater hyphomycetes. However, temperate areas displays strongest seasonality mainly in input of leaves, once the litter fall occurs predominantly in autumn, which contribute more to dynamics of this group of fungi (Shearer et al., 2007; Graça et al., 2016).

According Graça et al. (2016) in tropical regions during the wet season the higher input of litter leaves and turbulence may result of some seasonality in abundance and dominance of aquatic hyphomycetes conidia and thus litter decomposition.

In E1 the sporulation rate of stream RC was the highest in d. 60 (faster response after high litter fall), it may be occurred due the type of riparian vegetation predominant grassland and stream without vegetation cover. Ferreira et al. (2006) observed that in streams with *Eucaliptus'* riparian vegetation of Portugal, which shows riparian vegetation more open than in deciduous trees, the sporulation of aquatic hyphomycetes was highest in initial stages. In E2 all streams showed peaks of sporulation rates from time 180 due the latter leaching of leaves what caused a delay in decomposition. The stream RC shows highest sporulation rate soon in time 180, while the stream P2, which has tree canopy more closed, shows high sporulation just in time 240.

In moist chamber methodology was observed that streams RC and P2 showed higher richness in E2 than in E1, meanwhile in stream P1 it was equal in both experiment. This difference of taxa between experiments may be occurred due the differences stages of decomposition of *C. brasiliense* leaves in experiments. In E1 the leaves were already totally leached, what can propitiate the decomposition by a similar mycota. Meanwhile the leaves of E2 showed some green spots what provide a mycota more differentiated, which can decompose since green leaves until leaves more degraded in last time of collection.

According SIMPER analysis *Triscelophorus acuminatus* is the taxa with highest contribution between streams. *Triscelophorus acuminatus* is a cosmopolitan species (Fiuza and Gusmão, 2013), but it shows more frequency in waters more warm (Jabiol et al., 2013). In tropical areas of India Sridhar and Sudheep (2010) observed the high production of spores by *T. acuminatus*, as well as *Anguillospora longissima, Flagellospora curvula, Lunulospora curvula* and *T. monosporus*, also reported in current study but they do not display high contribution. ANOSIM did not show significant dissimilarity in composition and richness of fungal communities between streams.

NMDS (Fig. 6) display an important relationship of communities of first quadrant with concentration of oxygen. In this communities were recorded a highest concentration of oxygen in this streams, but the diversity and abundance of freshwater hyphomycetes conidia were lowest between communities leading in the high similarity mainly the communities of streams P1 and P2 in dry season. However some studies demonstrated that oxygen concentration could affect positively the diversity and sporulation of aquatic hyphomycetes. Medeiros et al. (2009) verified that microcosms with higher oxygen concentration showed more diversity and abundance of spores than microcosms with lower oxygen concentration, consequently decomposition leaves was affected by oxygen concentration.

The highest values of water velocity in NMDS are the abiotic factor that most affected the communities in third quadrant (mainly P1_E1_60 and RC_E1_120). These communities show higher abundances regarding other quadrants indicating that more water velocity can stimulate sporulation. Sanders and Webster (1980) also indicated that flow can stimulate the sporulation. They verified there was a higher production of conidiophores and spores, and the cause of higher production of spores was the turbulence of water.

In present study the most of species are typical of warm waters and according NMDS the temperature did not show a high relation with dissimilarity of communities. Chauvet and Suberkroop (1998) observed that temperature significantly affected the sporulation rate of aquatic hyphomycetes and the number of conidia released was species dependent. Posteriorly Boyero et al. (2016) indicated that microbial breakdown of alder is positively affected by temperature mainly in higher altitudes. Duarte et al. (2013) showed that some species are affected by temperatures regarding activity and growing, some species (e.g. *Lunulospora curvula*) have best development between 21-27ºC and are inhibited at 11ºC and they are usually reported to tropical to subtropical areas; on the other hand, *Articulospora tetracladia* shows best development in low temperatures and low activity and less competitive at 27ºC.

In NMDS pH is the abiotic factor more related to coordinate 2 axis and indicated the separation of two experiments of *Calophyllum brasiliense* leaves realized. Concentration of nutrients (nitrogen and phosphorus) characterized the streams as oligotrophic. In second quadrant the nitrogen concentration was more related to communities, mainly the community of stream P2 in dry season that displayed the highest richness in conditions of lowest nitrogen concentration. But phosphorus concentration was not so related to communities in third quadrant. Ferreira et al. (2015) verified that in the most studies the enrichment of nutrients in streams can affect positively the activity of aquatic hyphomycetes together with invertebrates speeding up decomposition of litter.

The communities of freshwater hyphomycetes in moist chambers show in SIMPER results species which are common also in terrestrial ecosystems, with exception of *Triscelophorus acuminatus*. *Codinaea simplex,* also known as *Dictyochaeta simplex*, is usually found in leaves and twigs of submerged or terrestrial litter and grasses of *Thysanolaena maxima* (Wong and Hyde 2001, Paulus et al. 2006). *Chalara alabamensis* was recorded several times in leaves or lignicolous substrates in terrestrial conditions (Morgan-Jones and Ingram, 1976, Rambelli et al. 2004). ANOSIM analyze indicated significant differences in composition and richness of fungal communities between streams.

NMDS with environmental variables analyzed in this study was not significant using moist chambers samples probably due the conditions which the methodology is developed. In moist chambers the fungi are submitted to stress of water and the environmental variables collected do not influenced so much this community as in submerged incubations. Moist chamber methodology can simulate terrestrial conditions, where the water regime, temperature and humidity can influenced the decomposition (Bärlocher and Boddy, 2015).

5. Conclusions

The data showed in current study ratify that when are used more than one methodology the richness will be higher than just use one methodology. The methodologies select the species that will be observed, submerged incubations allows grown and sporulation of species adapted to aquatic ecosystems and in moist chambers there are species can support the stress of water, the most of them from terrestrial ecosystems. Moreover, was observed that samples in submerged incubations are more sensitive to environmental variables of streams and riparian vegetation than samples of moist chambers.

This study indicated the richness of freshwater hyphomycetes associated with submerged leaves of *C. brasiliense* in three streams of stream Contas basin is lower than in temperate streams. The abundance of conidia displayed significant difference between experiments and in the wet season it was the most abundant. It probably happened due the higher input of litter leaves during beginning of wet season what could provide more food resource to microorganisms and, as indicated by NMDS, the relative high water velocity during this season. The oxygen was the other environmental factor related to communities in dry season that showed more oxygen concentration but that related communities displayed lowest richness and abundance between all communities studied. Regarding succession in fungal communities the submerged incubations showed the most of freshwater hyphomycetes associated with *C. brasiliense* during pioneer and mature stages of succession and in moist chambers the most of hyphomycetes were observed in impoverished stage.

This study improves our understanding of the freshwater hyphomycetes communities in streams of the semiarid regions of Brazil and the environmental variables that control the structure of these communities, which is especially important since ecological studies of aquatic fungi in Brazil and the tropical regions in general are still uncommon.

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Table 1. General characteristics of the studied sites (mean ± SE, n = 8).

	Contas (RC)	**Patricinho (P1)**	**Patricio (P2)**
Coordinates	13° 07' 31.7" S. 41° 50' 10.5" W	13° 05' 46.4" S. 41° 50' 56.5" W	13° 05' 11.7"S. 41° 51' 13.1"W
Altitude (m)	1332	1320	1272
Total nitrogen (mg/L)	0.195 ± 0.056	0.235 ± 0.074	0.231 ± 0.075
Total Phosphorus (mg/L)	0.007 ± 0.002	0.020 ± 0.011	0.020 ± 0.007
Temperature (°C)	19.4 ± 0.4	20.9 ± 0.9	18.1 ± 0.7
pH	5.22 ± 0.17	5.63 ± 0.36	5.92 ± 0.41
Oxygen (mg/L)	7.90 ± 0.70	8.97 ± 1.51	8.23 ± 0.82
Water velocity (m/s)	0.24 ± 0.04	0.06 ± 0.02	0.20 ± 0.05

Table 2. Relative abundances (%) of conidia of freshwater hyphomycetes associated with submerged leaves of *C. brasiliense* in streams RC, P1 and P2 during two experiments (E1 and E2) assessed using submerged incubation technique.

Taxa/ Samples	RC_E1	P1_E1	P2_E1	RC_E2	P1_E2	P2_E2
*Anguillospora filiformis	0.14	0.40	2.87	2.02	1.47	11.00
*A. longissima	1.59	0.92	0.06	0.25	2.95	0.33
**Beltrania rhombica	0.24	0.09	0.57	-	0.25	-
*Condylospora gigantea	-	0.09	0.03	-	-	0.33
**Dactylella ellipsospora	-	-	0.03	-	-	-
*Dendrosporium lobatum	0.02	-	-	-	-	-
*Dendrosporomyces splendens	0.05	-	0.26	-	-	-
**Dictyotrichocladium gen. nov.	-	-	-	-	-	9.00
*Filosporella sp.	-	0.18	-	2.27	1.72	1.33
*Flagellospora curvula	3.47	0.15	1.82	-	-	-
*F. stricta	-	4.92	3.81	-	-	-
**Henicospora coronata	2.89	0.58	5.09	9.34	23.10	15.67
**Isthmolongispora variabilis	-	0.67	0.43	-	0.49	13.33
*Lunulospora curvula	9.35	0.12	0.03	0.25	0.49	0.67
**Monotosporella sp.	0.70	81.93	8.25	24.24	6.39	0.67
**Morphotype 1	9.64	1.13	45.48	30.05	26.29	17.00
**Morphotype 2	-	0.03	21.87	-	-	-
*Pyramidospora casuarinae	-	0.03	3.41	-	-	-
*Scutisporus brunneus	-	0.31	-	-	-	-
***Spirosphaera carici-graminis	-	-	0.06	-	-	-
**Subulispora procurvata	-	-	-	-	-	0.33
**Thozetella havanensis	38.69	-	3.41	-	-	-
*Triscelophorus acuminatus	30.09	8.35	2.53	19.44	34.64	30.00
*T. monosporus	-	0.06	-	11.87	0.49	-
**Verticicladus subiculifer	3.01	0.03	-	0.25	-	0.33
**Xylomyces foliicola	0.12	-	-	-	1.72	-
TOTAL:	100	100	100	100	100	100
No. of taxa	14	18	18	10	12	13
Simpson index	0.74 (0.73-0.74)	0.32 (0.29-0.33)	0.73 (0.71-0.74)	0.78 (0.77-0.80)	0.75 (0.73-0.77)	0.81(0.79-0.83)
Evenness	0.36 (0.35-0.37)	0.12(0.11-0.12)	0.32(0.30-0.33)	0.55(0.51-0.58	0.42(0.38-0.46)	0.50(0.46-0.54)
Chao1	14 (13.5-14.5)	19.5 (16-23)	19(16-22)	13 (11.5-14.5	12(10.5-13.5)	15(10-20)

Note: *Ingoldian fungi; **Facultative aquatic hyphomycetes; ***Aero-aquatic hyphomycete.

Table 3. Relative abundances (%) of freshwater hyphomycetes associated with submerged leaves of *C. brasiliense* in streams RC, P1 and P2 during two experiments (E1 and E2) assessed using moist chamber technique.

Taxa/ Samples	RC_E1	P1_E1	P2_E1	RC_E2	P1_E2	P2_E2
**Anungitopsis triseptata	3.13	1.33	-	2.83	-	-
**A. speciosa	1.56	-	-	-	-	-
**Ardhachandra aequilatera	4.69	-	-	-	-	-
**Beltrania africana	-	4.00	-	-	-	-
**B. rhombica	-	-	2.86	21.70	10.91	11.58
**Beltraniella botryospora	-	-	2.86	-	-	-
**B. fertilis	3.13	-	-	0.94	3.64	-
**B. portoricensis	-	2.67	8.57	-	-	-
***Beverwykella clathrata	-	-	-	-	-	3.16
***Candelabrum microsporum	1.56	-	-	1.89	-	-
**Chalara alabamensis	1.56	2.67	14.29	0.94	-	31.58
**Cladosporium sp.	-	-	-	1.89	-	-
**Codinaea fertilis	-	-	-	2.83	1.82	1.05
**C.simplex	-	20.00	-	0.94	12.73	-
**Corynesporopsis antillana	-	-	-	-	7.27	-
**Cylindrocladiella infestans	-	-	-	0.94	1.82	7.37
**Dactylaria fusifera	-	-	-	0.94	3.64	-
**D. naviculiformis	-	8.00	-	-	-	-
**Dactylella ellipsospora	-	2.67	-	-	-	-
*Dendrosporium lobatum	-	-	-	1.89	-	-
*Dendrosporomyces prolifer	3.13	-	-	-	3.64	-
**Dictyochaeta heteroderae	-	-	-	0.94	-	-
*Filosporella sp.	-	-	-	0.94	-	-
***Fusticeps laevisporus	-	1.33	2.86	-	-	1.05
*Geniculospora inflata	-	-	-	0.94	-	-
***Helicoon myosuroides	1.56	-	-	0.94	-	-
**Hemibeltrania decorosa	-	2.67	-	-	1.82	-
**Henicospora coronata	1.56	6.67	22.86	0.94	5.45	4.21
*Ingoldiella hamata	1.56	-	-	-	-	-
**Isthmolongispora intermedia	1.56	-	-	5.66	-	1.05
**I. rotundata	1.56	2.67	-	1.89	5.45	-
**I. variabilis	1.56	-	5.71	7.55	7.27	20.0

Taxa/ Samples	RC_E1	P1_E1	P2_E1	RC_E2	P1_E2	P2_E2
**_Kionochaeta spissa_	-	1.33	22.86	-	-	7.37
**_Mariannaea elegans_	1.56	-	-	0.94	5.45	-
**_Mirandina uncinata_	-	-	-	0.94	-	-
**Morphotype 1	-	1.33	-	-	-	-
**_Paliphora porosa_	3.13	-	-	-	-	-
**_Phialocephala bactrospora_	-	-	-	0.94	1.82	-
***_Pseudaegerita websteri_	-	-	-	-	1.82	-
**_Roselymyces_ gen. nov.	4.69	-	-	-	-	-
**_Selenosporella curvispora_	-	-	-	0.94	-	-
**_S. minima_	-	4.00	-	-	3.64	-
***_Spirosphaera carici-graminis_	-	10.67	-	15.09	3.64	1.05
**_Subulispora procurvata_	-	-	5.71	-	-	4.21
**_Synchaetomella aquatica_	7.81	1.33	-	2.83	1.82	-
**_Thozetella acerosa_	1.56	-	-	-	-	-
**_T. canadensis_	-	-	-	0.94	-	1.05
**_T. cristata_	10.94	1.33	-	8.49	3.64	1.05
**_T. pinicola_	26.56	1.33	8.57	0.94	10.91	3.16
**_T. queenslandica_	-	-	-	0.94	-	-
**_T. radicata_	-	-	-	1.89	-	1.05
*_Triscelophorus acuminatus_	7.81	17.33	-	5.66	1.82	-
**_Vermiculariopsiella immersa_	-	1.33	-	-	-	-
**_Verticicladus subiculifer_	3.13	5.33	2.86	0.94	-	-
**_Xylomyces foliicola_	4.69	-	-	-	-	-
**_Zygosporium masonii_	-	-	-	0.94	-	-
TOTAL:	100	100	100	100	100	100
No. of taxa	23	21	11	33	21	16
Simpson index	0.89(0.85-0.92)	0.89(0.86-0.92)	0.85(0.80-0.89)	0.90(0.87-0.93)	0.93(0.91-0.94)	0.82(0.78-0.87)
Evenness	0.63(0.52-0.74)	0.64 (0.54-0.74)	0.74(0.62-0.86)	0.52(0.43-0.62)	0.81(0.72-0.90)	0.53(0.43-0.62)
Chao1	32.17(21.62-42.71)	25.67(16-77-34.56)	13(7.5-18.5)	61.5(45.63-77.37)	24(14.97-33.03)	37(26.6-47.4)

Note: *Ingoldian fungi; **Facultative aquatic hyphomycetes; ***Aero-aquatic hyphomycete.

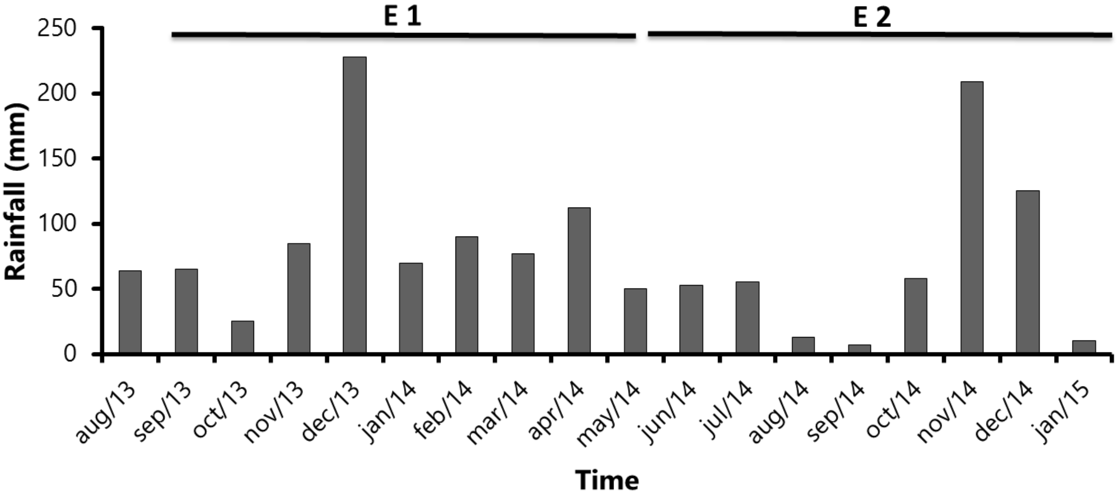

Fig. 1. Rainfall during the study period E1 and E2 indicate the duration of the experiment 1 and 2, respectively.

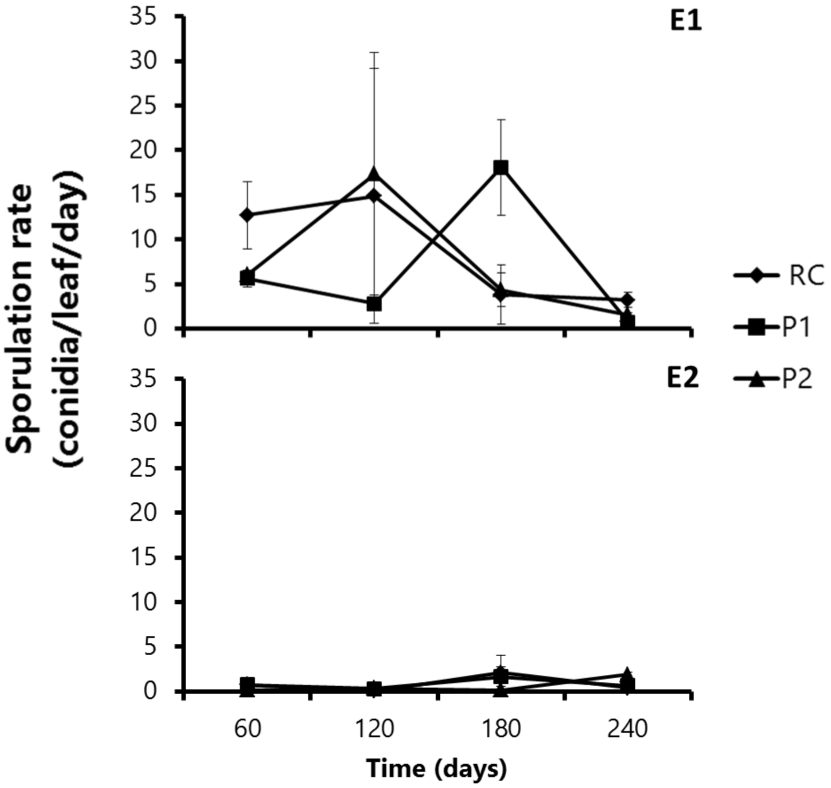

Fig. 2. Sporulation rates of freshwater hyphomycetes under submerged condition from leaf material incubated in three streams during experiment 1 and experiment 2.

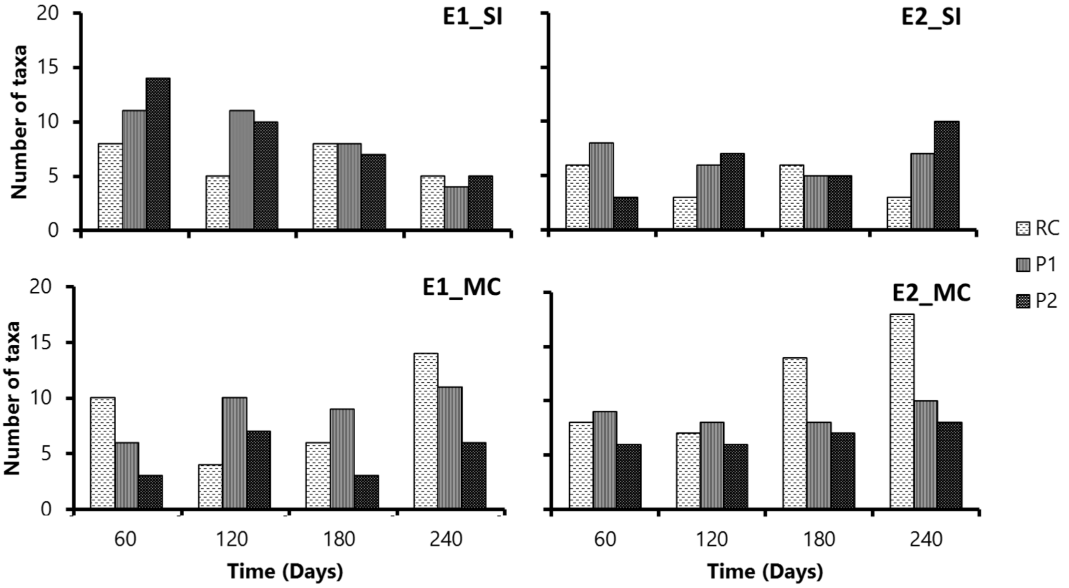

Fig. 3. Number of taxa of freshwater hyphomycetes under submerged condition (SI) and moist chambers (MC) from leaf material incubated in three streams during E1 and E2.

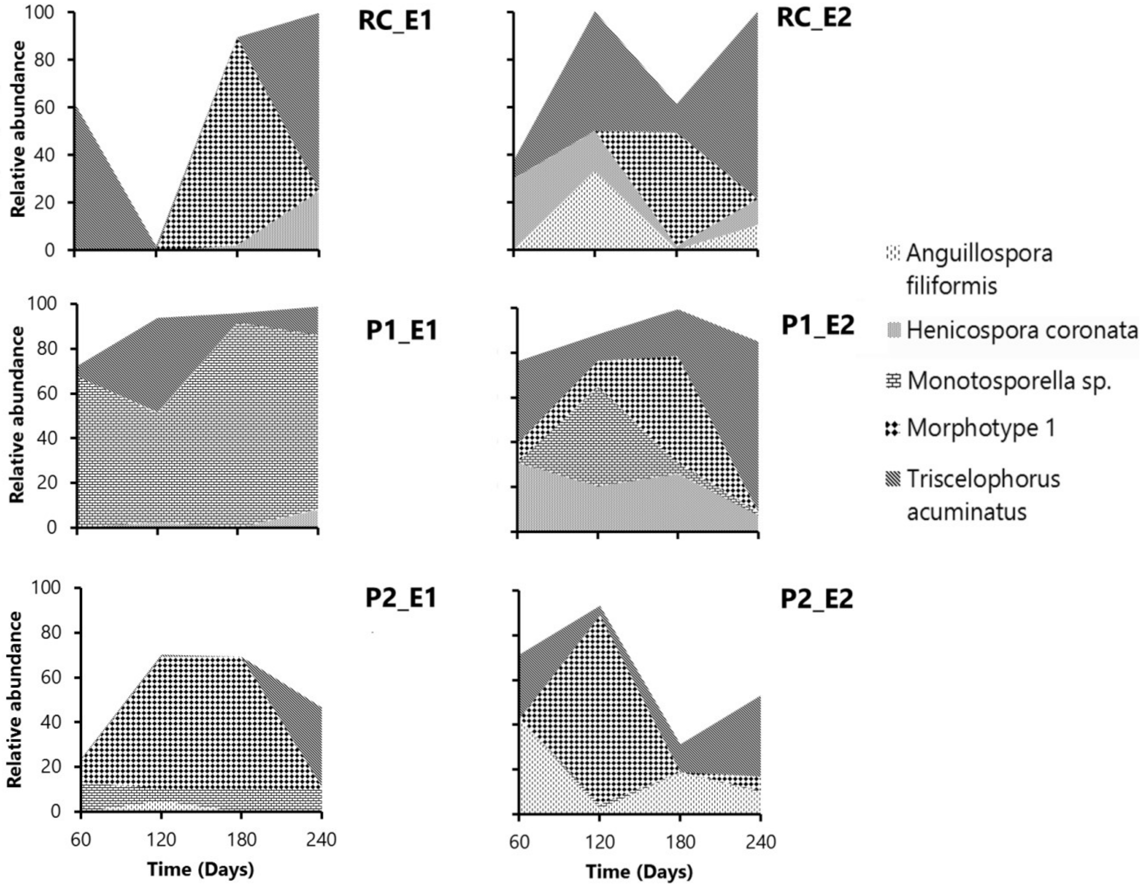

Fig. 4. Relative abundance of taxa more abundant under submerged incubation conditions from leaf material collected in three streams (RC, P1 and P2) in E1 and E2.

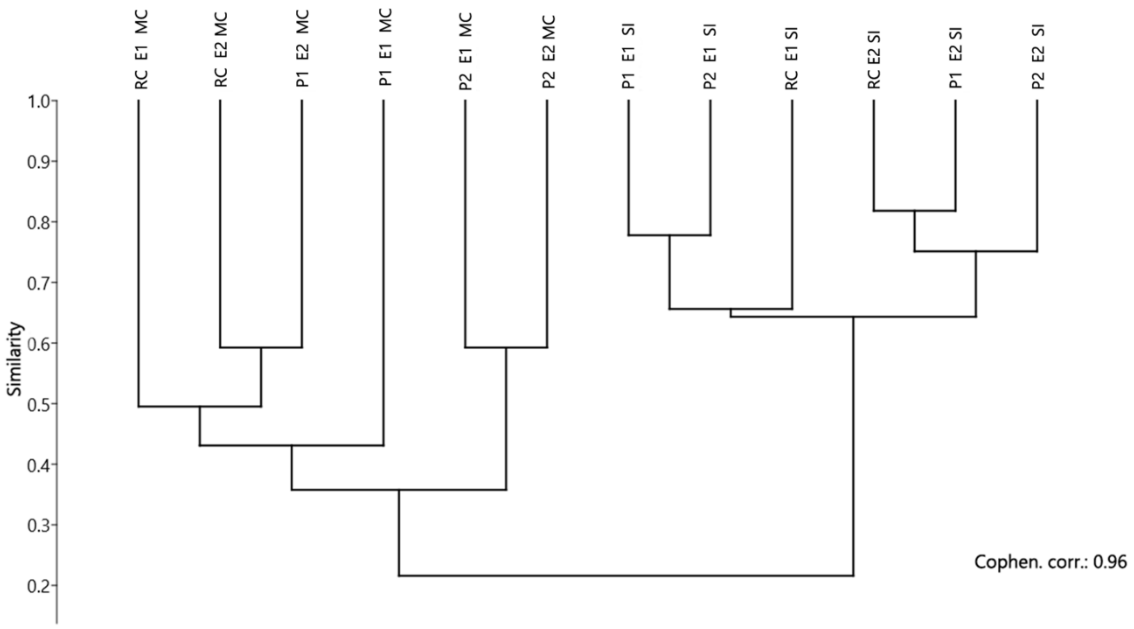

Fig. 5. Results of UPGMA cluster analysis of leaf-associated freshwater hyphomycetes communities from submerged incubations and moist chambers. Treatments are defined by stream (RC, P1 or P2), experiment (E1 or E2) and methodology (SI for submerged incubations and MC for moist chambers).

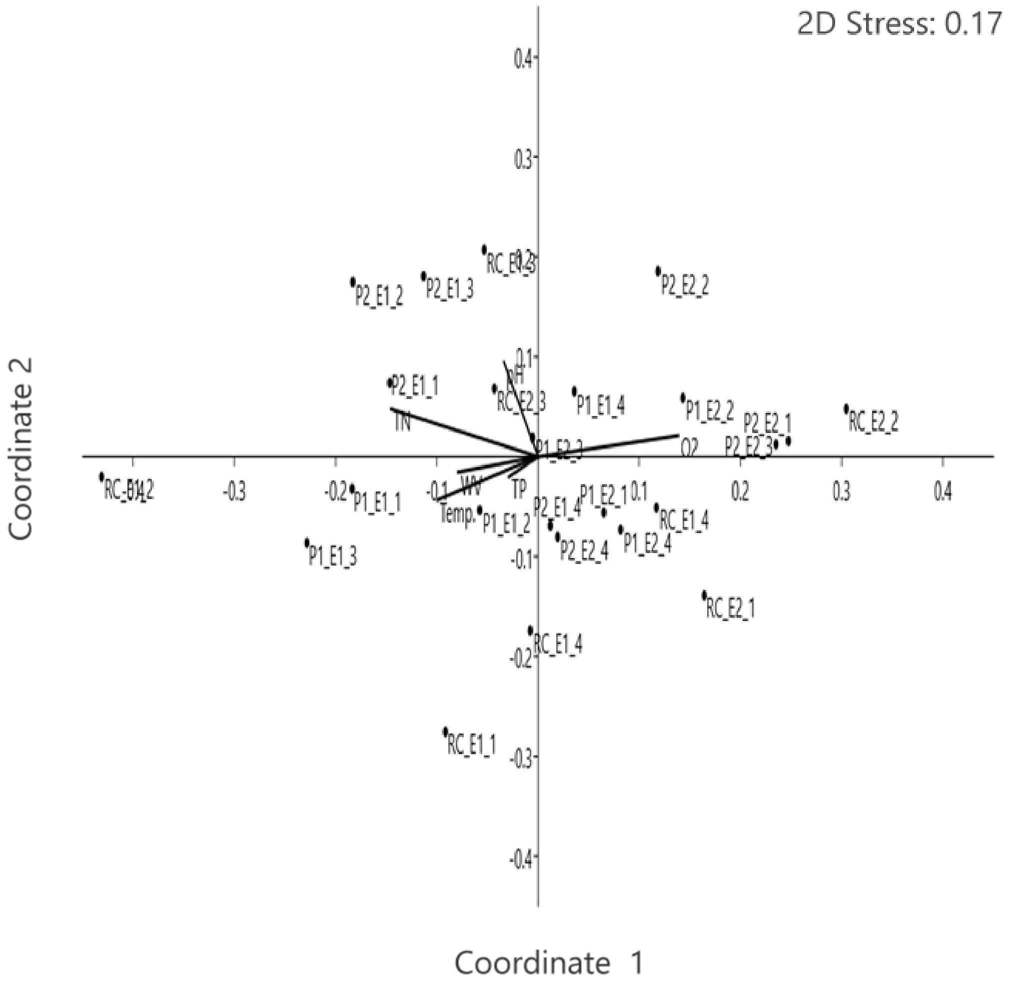

Fig. 6. Results of NMDS analysis showing ordination of leaf-associated freshwater hyphomycete communities from submerged incubations. The effects of environmental factors are also shown (RC, P1 and P2: streams; E1: experiment 1; E2: experiment 2; 1: 60 days; 2: 120 days; 3: 180 days; 4: 240 days).

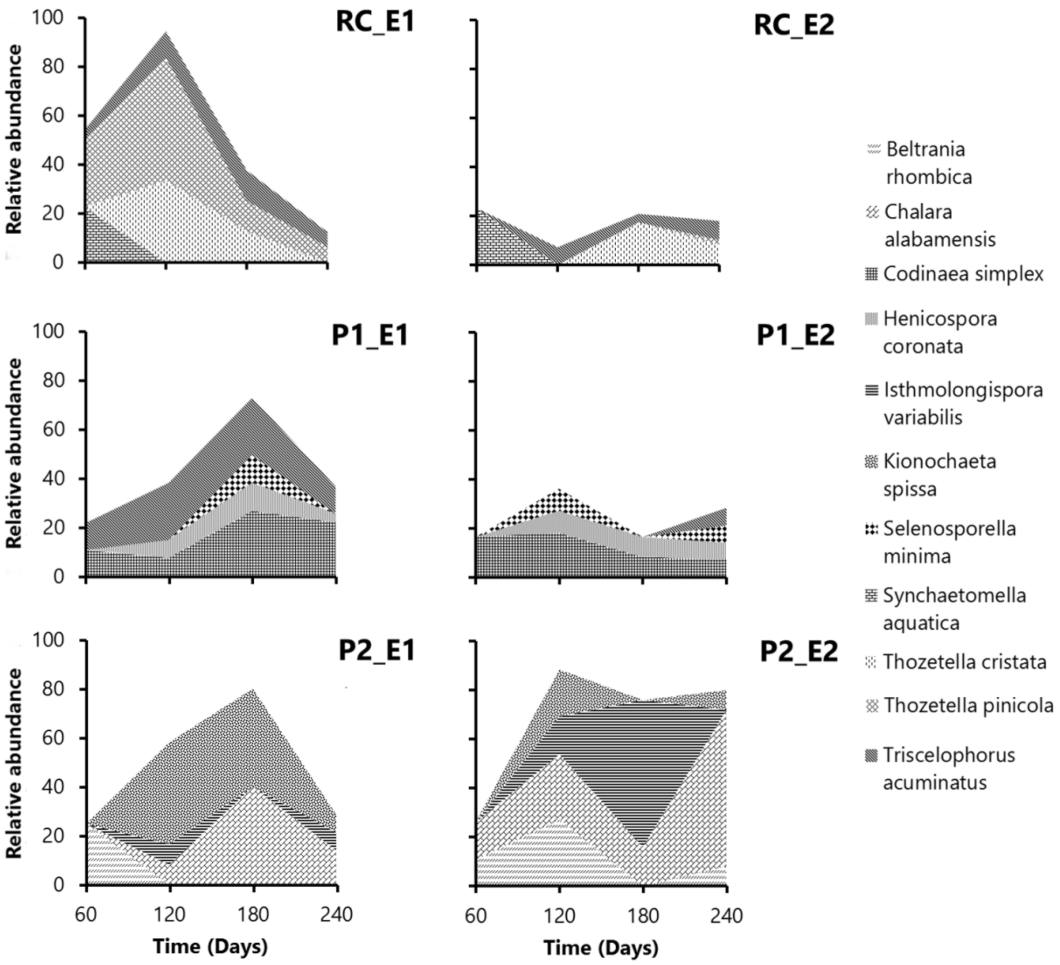

Fig. 7. Relative abundance of taxa more frequent in moist chambers from leaf material collected in three streams (RC, P1 and P2) in E1 and E2.

SUPPLEMENTARY INFORMATION

Table S1. Plant families of riparian vegetation from the study sites.

Families/Rivers	**RC**	**P1**	**P2**
Anacardiaceae			x
Apiaceae	x		
Bromeliaceae		x	x
Bombacaceae			x
Calophyllaceae	x	x	x
Convolvulaceae	x		
Cyperaceae	x	x	x
Dicksoniaceae			x
Eriocaulaceae	x		
Euphorbiaceae	x	x	x
Lamiaceae	x		
Leguminosae	x	x	x
Malpighiaceae		x	
Melastomataceae	x		x
Myrtaceae	x		x
Orchidaceae			x
Poaceae	x	x	x
Rubiaceae	x		x
Rutaceae			x
Simaroubaceae		x	
Turneraceae			x
Xyridaceae	x		

Table S2. Relative abundances (%) of conidia of freshwater hyphomycetes associated with submerged leaves of *C. brasiliense* in stream Rio de Contas (RC) during two experiments (E1 and E2) and four sampling dates (days 60, 120, 180, 240) assessed using submerged incubation technique.

Taxa/ Samples	**E1_ 60**	**E1_ 120**	**E1_ 180**	**E1_ 240**	**E2_ 60**	**E2_ 120**	**E2_ 180**	**E2_ 240**
******Anguillospora filiformis*** Greath.**	-	-	0.9	0.5	-	33.3	0.4	10.6
******A. longissima*** (Sacc. & P. Syd.) Ingold**	4.3	0.1	-	-	1.1	-	-	-
*******Beltrania rhombica*** Penz.**	0.6	-	-	0.3	-	-	-	-
******Dendrosporium lobatum*** Plakidas & Edgerton ex J.L. Crane**	-	-	0.2	-	-	-	-	-
******Dendrosporomyces prolifer*** Nawawi . J. Webster & R.A. Davey**	-	0.1	-	-	-	-	-	-
******Fillosporella*** sp.**	-	-	-	-	9.7	-	-	-
******Flagellospora curvula*** Ingold**	0.2	7.9	-	-	-	-	-	-
*******Henicospora coronata*** B. Sutton & P.M. Kirk**	1.3	-	1.3	24.4	30.1	16.7	1.2	10.6
******Lunulospora curvula*** Ingold**	25.5	-	-	-	1.1	-	-	-
*******Monotosporella*** sp.**	0.7	-	4.2	-	-	-	38.4	-
****Morphotype 1**	-	-	87.1	0.5	-	-	47.6	-
*******Thozetella havanensis*** R.F. Castañeda**	-	90.0	-	-	-	-	-	-
******Triscelophorus acuminatus*** Nawawi**	60.8	2.0	0.2	74.3	7.5	50.0	12.0	78.7
******T. monosporus*** Ingold**	-	-	-	-	50.5	-	-	-

Taxa/ Samples	E1_ 60	E1_ 120	E1_ 180	E1_ 240	E2_ 60	E2_ 120	E2_ 180	E2_ 240
*******Verticicladus subiculifer* **Matsush.**	6.7	-	5.0	-	-	-	0.4	-
*******Xylomyces foliicola* **W.B. Kendr. & R.F. Castañeda**	-	-	1.1	-	-	-	-	-
TOTAL:	100	100	100	100	100	100	100	100
Nº of taxa	8	5	8	5	6	3	6	3
Simpson index	0.56 (0.54-0.58)	0.18 (0.16-0.21)	0.24 (0.18-0.29)	0.39 (0.34-0.43)	0.64 (0.57-0.70)	0.61 (0.5-0.72)	0.61 (0.58-0.6)	0.36 (0.20-0.51)
Evenness	0.38 (0.35-0.39)	0.29 (0.28-0.30)	0.22(0.20-0.25)	0.38 (0.35-0.40)	0.57 (0.48-0.65)	0.91 (0.81-1.02)	0.49 (0.45-0.52)	0.65 (0.50-0.79)
Chao-1	8.5 (7-10)	6 (5.5-6.5)	14 (8.3-19.8)	8 (6.5-9.5)	6.5 (5-8)	6 (3.5-8.5)	9 (7.5-10.5)	3 (2.5-3.5)

Note: *Ingoldian fungi; **Facultative aquatic hyphomycetes; ***Aero-aquatic hyphomycetes.

Table S3. Relative abundances (%) of conidia of freshwater hyphomycetes associated with submerged leaves of *C. brasiliense* in stream Patricinho (P1) during two experiments (E1 and E2) and four sampling dates (days 60, 120, 180, 240) assessed using submerged incubation technique.

Taxa/ Samples	**E1_ 60**	**E1_ 120**	**E1_ 180**	**E1_ 240**	**E2_ 60**	**E2_ 120**	**E2_ 180**	**E2_ 240**
***_Anguillospora filiformis_ Greath.**	0.3	1.2	0.3	-	-	8.8	-	3.8
***_A. longissima_ (Sacc. & P. Syd.) Ingold**	0.6	1.8	0.9	-	11.8	-	-	1.3
****_Beltrania rhombica_ Penz.**	0.4	-	-	-	-	2.9	-	-
***_Condylospora gigantea_ Nawawi & Kuthub.**	0.3	0.3	-	-	-	-	-	-
***_Filosporella_ sp.**	0.3	1.2	-	-	7.5	-	-	-
***_Flagellospora curvula_ Ingold**	-	-	0.2	-	-	-	-	-
***_F. stricta_ Sv. Nilsson**	23.9	-	-	-	-	-	-	-
****_Henicospora coronata_ B. Sutton & P.M. Kirk**	-	2.7	0.1	8.0	31.2	20.6	26.0	7.5
****_Isthmolongispora variabilis_ Matsush.**	0.1	-	1.0	-	1.1	-	0.5	-
***_Lunulospora curvula_ Ingold**	-	1.2	-	-	2.2	-	-	-
****_Monotosporella_ sp.**	67.7	48.5	91.7	78.2	-	44.1	5.0	1.3
****Morphotype 1**	-	0.3	1.7	-	8.6	11.8	47.5	-
****Morphotype 2**	-	0.3	-	-	-	-	-	-
***_Pyramidospora casuarinae_ Sv. Nilsson**	-	0.3	-	-	-	-	-	-
***_Scutisporus brunneus_ K. Ando & Tubaki**	1.5	-	-	-	-	-	-	-

Taxa/ Samples	**E1_ 60**	**E1_ 120**	**E1_ 180**	**E1_ 240**	**E2_ 60**	**E2_ 120**	**E2_ 180**	**E2_ 240**
******Triscelophorus acuminatus*** **Nawawi**	4.6	42.3	4.1	12.6	36.6	11.8	21.0	76.3
******T. monosporus*** **Ingold**	0.3	-	-	-	1.1	-	-	1.3
*******Verticicladus subiculifer*** **Matsush.**	-	-	-	1.1	-	-	-	-
*******Xylomyces foliicola*** **W.B. Kendr. & R.F. Castañeda**	-	-	-	-	-	-	-	8.8
TOTAL:	100	100	100	100	100	100	100	100
Nº of taxa	11	11	8	4	8	6	5	7
Simpson index	0.48 (0.45-0.52)	0.58 (0.56-0.61)	0.16 (0.13-0.18)	0.36 (0.25-0.48)	0.74 (0.70-0.79)	0.73 (0.63-0.82)	0.66 (0.62-0.70)	0.40 (0.30-0.52)
Evenness	0.23 (0.21-0.25)	0.27 (0.24-0.30)	0.19 (0.18-0.19)	0.51 (0.41-0.60)	0.60 (0.51-0.68)	0.75 (0.60-0.90)	0.67 (0.61-0.72)	0.35 (0.27-0.43)
Chao-1	16 (11.14-26)	21.5 (11.17-32)	9 (8-14)	4 (3-5)	9.5 (8-14)	9 (6-12)	5 (5-6)	17 (6-17)

Note: *Ingoldian fungi; **Facultative aquatic hyphomycetes; ***Aero-aquatic hyphomycetes.

Table S4. Relative abundances (%) of conidia of freshwater hyphomycetes associated with submerged leaves of *C. brasiliense* in stream Patricio (P2) during two experiments (E1 and E2) and four sampling dates (days 60, 120, 180, 240) assessed using submerged incubation technique.

Taxa/ Samples	E1_ 60	E1_ 120	E1_ 180	E1_ 240	E2_ 60	E2_ 120	E2_ 180	E2_ 240
******Anguillospora filiformis*** **Greath.**	0.3	4.8	-	-	42.9	2.3	18.8	10.2
******A. longissima*** **(Sacc. & P. Syd.) Ingold**	-	0.1	-	-	-	2.3	-	-
*******Beltrania rhombica*** **Penz.**	0.1	0.9	-	-	-	-	-	-
******Condylospora gigantea*** **Nawawi & Kuthub.**	0.1	-	-	-	-	-	-	0.4
*******Dactylella ellipsospora*** **(Preuss) Grove**	0.1	-	-	-	-	-	-	-
******Dendrosporomyces prolifer*** **Nawawi . J. Webster & R.A. Davey**	1.2	-	-	-	-	-	-	-
*******Dictyotrichocladium*** **sp. nov.**	-	-	-	-	-	-	-	11.9
******Filosporella*** **sp.**	-	-	-	-	-	-	-	1.8
******Flagellospora curvula*** **Ingold**	-	0.1	11.7	-	-	-	-	-
******F. stricta*** **Sv. Nilsson**	18.5	-	-	-	-	-	-	-
*******Henicospora coronata*** **B. Sutton & P.M. Kirk**	6.2	1.3	1.5	52.9	28.6	2.3	50.0	15.0
*******Isthmolongispora variabilis*** **Matsush.**	2.1	-	-	-	-	-	6.3	17.3
******Lunulospora curvula*** **Ingold**	-	-	-	0.5	-	-	12.5	-
*******Monotosporella*** **sp.**	12.8	5.9	10.3	10.7	-	2.3	-	0.4

Taxa/ Samples	**E1_ 60**	**E1_ 120**	**E1_ 180**	**E1_ 240**	**E2_ 60**	**E2_ 120**	**E2_ 180**	**E2_ 240**
****Morphotype 1**	9.8	58.6	58.8	0.5	-	84.1	-	6.2
****Morphotype 2**	16.0	27.1	17.0	-	-	-	-	-
******Pyramidospora casuarinae*** **Sv. Nilsson**	15.6	0.3	-	-	-	-	-	-
********Spirosphaera carici-graminis*** **Voglmayr**	-	-	0.4	-	-	-	-	-
*******Subulispora procurvata*** **Tubaki**	-	-	-	-	-	-	-	0.4
*******Thozetella havanensis*** **R.F. Castañeda**	16.6	-	-	-	-	-	-	-
******Triscelophorus acuminatus*** **Nawawi**	0.6	0.9	0.2	35.3	28.6	4.5	12.5	36.3
*******Verticicladus subiculifer*** **Matsush.**	-	-	-	-	-	2.3	-	-
TOTAL:	100	100	100	100	100	100	100	100
Nº of taxa	14	10	7	5	3	7	5	10
Simpson index	0.86 (0.85-0.86)	0.58 (0.56-0.59)	0.60 (0.56-0.63)	0.58 (0.54-0.62)	0.65 (0.54-0.76)	0.29 (0.16-0.42)	0.68 (0.5-0.86)	0.79 (0.76-0.82)
Evenness	0.56 (0.54-0.56)	0.32 (0.30-0.33)	0.47 (0.41-0.53)	0.54 (0.50-0.59)	0.98 (0.85-1.10)	0.29 (0.21-0.37)	0.77 (0.59-0.96)	0.58 (0.53-0.63)
Chao-1	50 (39.71-60.30)	10.33 (7.33-13.33)	7 (5-9)	6 (5.5-6.5)	6 (3.5-8.5)	12 (6.62-17.38)	6.5 (2.5-10.5)	16 (13-19)

Note: *Ingoldian fungi; **Facultative aquatic hyphomycetes; ***Aero-aquatic hyphomycetes.

Table S5. Constancy in percentage of taxa of freshwater hyphomycetes in two experiments of streams RC. P1 and P2 (E1: Experiment 1. E2: Experiment 2) (samples of submerged incubations).

Taxa/ Samples	**RC_E1**	**RC_E2**	**P1_E1**	**P1_E2**	**P2_E1**	**P2_E2**
***Anguillospora filiformis* Greath.**	50	75	75	50	50	100
***A. longissima* (Sacc. & P. Syd.) Ingold**	50	25	75	50	25	25
***Beltrania rhombica* Penz.**	50	0	25	25	50	0
***Condylospora gigantea* Nawawi & Kuthub.**	0	0	50	0	25	25
***Dactylella ellipsospora* (Preuss) Grove**	0	0	0	0	25	0
***Dendrosporium lobatum* Plakidas & Edgerton ex J.L. Crane**	25	0	0	0	0	0
***Dendrosporomyces prolifer* Nawawi. J. Webster & R.A. Davey**	25	0	0	0	25	0
***Dictyotrichocladium* gen. nov..**	0	0	0	0	0	25
***Filosporella* sp.**	0	25	50	25	0	25
***Flagellospora curvula* Ingold**	50	0	25	0	50	0
***F. stricta* Sv. Nilsson**	0	0	25	0	25	0
***Henicospora coronata* B. Sutton & P.M. Kirk**	75	100	75	100	100	100
***Isthmolongispora variabilis* Matsush.**	0	0	50	50	25	50
***Lunulospora curvula* Ingold**	25	25	25	25	25	25
***Monotosporella* sp.**	50	25	100	75	100	50
Morphotype 1	50	25	50	75	100	50
Morphotype 2	0	0	25	0	75	0
***Pyramidospora casuarinae* Sv. Nilsson**	0	0	25	0	50	0
***Scutisporus brunneus* K. Ando & Tubaki**	0	0	25	0	0	0
***Spirosphaera carici-graminis* Voglmayr**	0	0	0	0	25	0
***Subulispora procurvata* Tubaki**	0	0	0	0	0	25
***Thozetella havanensis* R.F. Castañeda**	25	0	0	0	25	0
***Triscelophorus acuminatus* Nawawi**	100	100	100	100	100	100
***T. monosporus* Ingold**	0	25	25	50	0	0
***Verticicladus subiculifer* Matsush.**	50	25	25	0	0	25
***Xylomyces foliicola* W.B. Kendr. & R.F. Castañeda**	25	0	0	25	0	0

Table S6. Similarity percentage analysis (SIMPER) of freshwater hyphomycete communities associated with submerged leaves of *C. brasiliense* for streams (data from submerged incubations). Overall average dissimilarity: 87.12%.

Taxa	**Av. dissim**	**Contrib. %**	**Cumulative %**	**Mean Stream1**	**Mean Stream2**	**Mean Stream3**
Triscelophorus acuminatus	20.45	23.47	23.47	43.5	13.7	22.8
***Monotosporella* sp.**	19.55	22.44	45.91	23.3	101	6
Morphotype 1	13	14.92	60.83	3.29	79.6	13.5
Henicospora coronata	9.021	10.36	71.19	5.29	4.5	10.9
Morphotype 2	3.473	3.987	75.17	4.83	23.5	3.71
Thozetella havanensis	3.44	3.949	79.12	71.9	0	0
Anguillospora filiformis	3.315	3.806	82.93	0.5	4.96	1.5
Flagellospora stricta	2.7	3.099	86.03	12.3	0	0
Flagellospora curvula	2.013	2.311	88.34	6	0.333	2.54
Lunulospora curvula	1.678	1.927	90.27	16.3	0.167	0.125
Verticicladus subiculifer	1.542	1.77	92.04	4.25	1.04	0.0417
Triscelophorus monosporus	1.228	1.409	93.44	2.08	0	0.0417
Anguillospora longissima	1.199	1.377	94.82	3.42	1.21	0.0417
Pyramidospora casuarinae	1.02	1.17	95.99	4.71	0.333	0
Isthmolongispora variabilis	0.9909	1.137	97.13	0.708	0.917	1.67
***Filosporella* sp.**	0.6893	0.7912	97.92	0.75	0.167	0.167
***Dictyotrichocladium* gen. nov..**	0.5499	0.6312	98.55	0	0	1.13
Xylomyces foliicola	0.3983	0.4573	99.01	0	0.208	0.292
Beltrania rhombica	0.3771	0.4329	99.44	0.542	0.833	0.0417
Dendrosporomyces prolifer	0.1501	0.1723	99.61	0.458	0	0
Scutisporus brunneus	0.1208	0.1387	99.75	0.417	0	0
Dendrosporium lobatum	0.09427	0.1082	99.86	0	0.0417	0
Condylospora gigantea	0.06466	0.07422	99.94	0.125	0.0417	0.0417
Subulispora procurvata	0.0239	0.02743	99.96	0	0	0.0417
Spirosphaera carici-graminis	0.02372	0.02722	99.99	0	0	0.0833
Dactylella ellipsospora	0.008588	0.009858	100	0.0417	0	0

Table S7. Relative abundances (%) of conidia of freshwater hyphomycetes associated with submerged leaves of *C. brasiliense* in stream Rio de Contas (RC) during two experiments (E1 and E2) and four sampling dates (days 60, 120, 180, 240) assessed using moist chamber technique.

Taxa/ Samples	E1_ 60	E1_ 120	E1_ 180	E1_ 240	E2_ 60	E2_ 120	E2_ 180	E2_ 240
***Anungitopsis triseptata* (Matsush.) R.F. Castañeda & W.B. Kendr.	-	-	12.5	6.3	-	-	-	6.0
***A. speciosa* R.F. Castañeda & W.B. Kendr.	4.5	-	-	-	-	-	-	-
***Ardhachandra aequilatera* Matsush.	-	-	-	18.8	-	-	-	-
***Beltrania rhombica* Penz.	-	-	-	-	30.8	50.0	27.6	8.0
***B. fertilis* Heredia, R.M. Arias, M. Reyes & R.F. Castañeda	9.1	-	-	-	-	-	-	2.0
****Candelabrum microsporum* R.F. Castañeda & W.B. Kendr.	-	-	-	6.3	-	-	6.9	-
***Chalara alabamensis* Morgan-Jones & E.G. Ingram	-	-	-	6.3	-	-	-	2.0
***Cladosporium sp.*	-	-	-	-	-	14.3	-	-
***Codinaea fertilis* S. Hughes & W.B. Kendr.	-	-	-	-	-	-	6.9	2.0
***C.simplex* S. Hughes & W.B. Kendr.	-	-	-	-	-	-	3.4	-
***Cylindrocladiella infestans* Boesew.	-	-	-	-	7.7	-	-	-
***Dactylaria fusifera* (Berk. & M.A. Curtis) de Hoog	-	-	-	-	-	7.1	-	-

Taxa/ Samples	**E1_ 60**	**E1_ 120**	**E1_ 180**	**E1_ 240**	**E2_ 60**	**E2_ 120**	**E2_ 180**	**E2_ 240**
***Dendrosporium lobatum* Plakidas & Edgerton ex J.L. Crane**	-	-	-	-	7.7	7.1	-	-0.0
***Dendrosporomyces prolifer* Nawawi, J. Webster & R.A. Davey**	4.5	-	-	6.3	-	-	-	-
****Dictyochaeta heteroderae* (Morgan-Jones) Aramb. & Cabello**	-	-	-	-	-	-	-	2.0
***Filosporella* sp.**	-	-	-	-	-	-	-	2.0
***Geniculospora inflata* (Ingold) Sv. Nilsson ex Marvanová & Sv. Nilsson**	-	-	-	-	-	-	3.4	-
*****Helicoon myosuroides* Voglmayr**	-	-	-	6.3	-	-	-	2.0
****Henicospora coronata* B. Sutton & P.M. Kirk**	4.5	-	-	-	7.7	-	-	-
***Ingoldiella hamata* D.E. Shaw**	4.5	-	-	-	-	-	-	-
****Isthmolongispora intermedia* Matsush.**	-	-	-	6.3	7.7	-	6.9	6.0
****I. rotundata* Matsush.**	-	5.6	-	-	-	-	3.4	2.0
****I. variabilis* Matsush.**	-	-	-	6.3	7.7	-	6.9	10.0
****Mariannaea elegans* G. Arnaud**	-	-	-	6.3	-	-	3.4	-
****Mirandina uncinata* Fiuza, J.S. Monteiro, Gusmão & R.F. Castañeda**	-	-	-	-	-	7.1	-	-

Taxa/ Samples	E1_ 60	E1_ 120	E1_ 180	E1_ 240	E2_ 60	E2_ 120	E2_ 180	E2_ 240
**_Paliphora porosa_ Kuthub.	-	-	25.0	-	-	-	-	-
**_Phialocephala bactrospora_ W.B. Kendr.	-	-	-	-	-	-	3.4	-
**_Roselymyces_ gen. nov.	13.6	-	-	-	-	-	-	-
**_Selenosporella curvispora_ G. Arnaud ex Matsush.	-	-	-	-	-	-	3.4	-
***_Spirosphaera carici-graminis_ Voglmayr	-	-	-	-	7.7	-	-	30.0
**_Synchaetomella aquática_ Fiuza, Gusmão & R.F. Castañeda	22.7	-	-	-	23.1	-	-	-
**_Thozetella acerosa B.C._ Paulus, Gadek & K.D. Hyde	-	-	-	6.3	-	-	-	-
**_T. canadensis_ Nag Raj	-	-	-	-	-	-	-	2.0
**_T. cristata_ Piroz. & Hodges	-	33.3	12.5	-	-	-	17.2	8.0
**_T. pinicola_ S.Y. Yeung, Jeewon & K.D. Hyde	27.3	50.0	12.5	6.3	-	-	-	2.0
**_T. queenslandica_ B.C. Paulus, Gadek & K.D. Hyde	-	-	-	-	-	7.1	-	-
**_T. radicata_ (E.F. Morris) Piroz. & Hodges	-	-	-	-	-	-	-	4.0
*_Triscelophorus acuminatus_ Nawawi	4.5	11.1	12.5	6.3	-	7.1	3.4	8.0

Taxa/ Samples	**E1_ 60**	**E1_ 120**	**E1_ 180**	**E1_ 240**	**E2_ 60**	**E2_ 120**	**E2_ 180**	**E2_ 240**
***Verticicladus subiculifer* Matsush.**	4.5	-	-	6.3	-	-	-	2.0
***Xylomyces foliicola* W.B. Kendr. & R.F. Castañeda**	-	-	25.0	6.3	-	-	-	-
***Zygosporium mansonii* S. Hughes**	-	-	-	-	-	-	3.4	-
TOTAL:	100	100	100	100	100	100	100	100
Nº of taxa	10	4	6	14	8	7	14	18
Simpson index	0.83 (0.78-0.88)	0.63 (0.51-0.73)	0.81 (0.70-0.92)	0.91 (0.85-0.97)	0.81 (0.71-0.92)	0.70 (0.48-0.93)	0.86 (0.79-0.93)	0.86 (0.82-0.91)
Evenness	0.75 (0.63-0.87)	0.76 (0.61-0.91)	0.94 (0.86-1.01)	0.93 (0.83-1.03)	0.82 (0.67-0.97)	0.68 (0.50-0.87)	0.73 (0.58-0.87)	0.64 (0.51-0.76)
Chao-1	17.5 (9.6-25.4)	4 (3.5-4.5)	8 (2-14)	92 (73-111)	23 (14.25-31.75)	12 (5-19)	19.6 (7.78-31.42)	40.5 (29.25-51.75)

Note: *Ingoldian fungi; **Facultative aquatic hyphomycetes; ***Aero-aquatic hyphomycetes.

Table S8. Relative abundances (%) of conidia of freshwater hyphomycetes associated with submerged leaves of *C. brasiliense* in stream Patricinho (P1) during two experiments (E1 and E2) and four sampling dates (days 60, 120, 180, 240) assessed using moist chamber technique.

Taxa/ Samples	**E1_ 60**	**E1_ 120**	**E1_ 180**	**E1_ 240**	**E2_ 60**	**E2_ 120**	**E2_ 180**	**E2_ 240**
*******Anungitopsis triseptata*** **(Matsush.) R.F. Castañeda & W.B. Kendr.**	-	-	-	3.7	-	-	-	-
*******Beltrania africana*** **S. Hughes**	-	-	7.7	3.7	-	-	-	-
*******B. rhombica*** **Penz.**	-	-	-	-	22.2	9.1	8.3	-
*******Beltraniella fertilis*** **Heredia, R.M. Arias, M. Reyes & R.F. Castañeda**	-	-	-	-	11.1	-	-	-
*******B. portoricensis*** **(F. Stevens) Piroz. & S.D. Patil**	-	15.4	-	-	-	-	-	-
*******Chalara alabamensis*** **Morgan-Jones & E.G. Ingram**	-	-	3.8	3.7	-	-	-	-
*******Codinaea fertilis*** **S. Hughes & W.B. Kendr.**	-	-	-	-	-	-	-	7.1
*******C.simplex*** **S. Hughes & W.B. Kendr.**	11.1	7.7	26.9	22.2	16.7	18.2	8.3	7.1
*******Corynesporopsis antillana*** **R.F. Castañeda & W.B. Kendr.**	-	-	-	-	-	9.1	-	21.4
*******Cylindrocladiella infestans*** **Boesew.**	-	-	-	-	5.6	-	-	-
*******Dactylella ellipsospora*** **(Preuss) Grove**	-	-	3.8	3.7	-	-	-	-

Taxa/ Samples	**E1_ 60**	**E1_ 120**	**E1_ 180**	**E1_ 240**	**E2_ 60**	**E2_ 120**	**E2_ 180**	**E2_ 240**
*******Dactylaria fusifera*** **(Berk. & M.A. Curtis) de Hoog**	-	-	-	-	-	-	8.3	7.1
*******D. naviculiformis*** **Matsush.**	22.2	-	7.7	7.4	-	-	-	-
******Dendrosporomyces prolifer*** **Nawawi, J. Webster & R.A. Davey**	-	-	-	-	5.6	9.1	-	-
********Fusticeps laevisporus*** **Matsush.**	-	7.7	-	-	-	-	-	-
*******Hemibeltrania decorosa*** **R.F. Castañeda & W.B. Kendr.**	22.2	-	-	-	-	-	-	7.1
*******Henicospora coronata*** **B. Sutton & P.M. Kirk**	-	7.7	11.5	3.7	-	9.1	8.3	7.1
*******Isthmolongispora rotundata***Matsush.**	-	-	-	7.4	-	-	25.0	-
*******I. variabilis*** **Matsush.**	-	-	-	-	11.1	-	16.7	-
*******Kionochaeta spissa*** **P.M. Kirk & B. Sutton**	-	7.7	-	-	-	-	-	-
*******Mariannae elegans*** **G. Arnaud**	-	-	-	-	-	-	-	21.4
****Morphotype 1**	-	7.7	-	-	-	-	-	-
*******Phialocephala bactrospora*** **W.B. Kendr.**	-	-	-	-	5.6	-	-	-
********Pseudaegerita websteri*** **Abdullah, Gené & Guarro**	-	-	-	-	-	-	8.3	-
*******Selenosporella mínima*** **Fiuza, Gusmão & R.F. Castañeda**	-	-	11.5	-	-	9.1	-	7.1

Taxa/ Samples	**E1_ 60**	**E1_ 120**	**E1_ 180**	**E1_ 240**	**E2_ 60**	**E2_ 120**	**E2_ 180**	**E2_ 240**
******Spirosphaera carici-graminis* Voglmayr**	-	-	-	29.6	-	9.1	-	7.1
*****Synchaetomella aquática* Fiuza, Gusmão & R.F. Castañeda**	11.1	-	-	-	5.6	-	-	-
*****Thozetella. cristata* Piroz. & Hodges**	-	7.7	-	-	-	-	16.7	-
*****T. pinicola* S.Y. Yeung, Jeewon & K.D. Hyde**	-	-	-	3.7	16.7	27.3	-	-
****Triscelophorus acuminatus* Nawawi**	11.1	23.1	23.1	11.1	-	-	-	7.1
*****Vermiculariopsiella immersa* (Desm.) Bender**	-	7.7	-	-	-	-	-	-
*****Verticicladus subiculifer* Matsush.**	22.2	7.7	3.8	-	-	-	-	-
TOTAL:	100	100	100	100	100	100	100	100
Nº of taxa	6	10	9	11	9	8	8	10
Simpson index	0.81 (0.72-0.91)	0.87 (0.82-0.93)	0.83 (0.78-0.88)	0.83 (0.78-0.88)	0.86 (0.79-0.92)	0.84 (0.77-0.91)	0.85 (0.79-0.90)	0.87 (0.80-0.93)
Evenness	0.94 (0.85-1.03)	0.90 (0.83-0.98)	0.79 (0.66-0.92)	0.71 (0.58-0.83)	0.87 (0.75-0.99)	0.89 (0.81-0.98)	0.90 (0.81-0.99)	0.87 (0.77-0.98)
Chao-1	6.75 (0.75-12.75)	24 (12.75-35.25)	10 (5-15)	16 (8.3-23.7)	11 (2.5-19.5)	15.5 (4.12-26.88)	11.33 (2.95-19.71)	38 (26.63-49.38)

Note: *Ingoldian fungi; **Facultative aquatic hyphomycetes; ***Aero-aquatic hyphomycetes.

Table S9. Relative abundances (%) of conidia of freshwater hyphomycetes associated with submerged leaves of *C. brasiliense* in stream Patricio (P2) during two experiments (E1 and E2) and four sampling dates (days 60, 120, 180, 240) assessed using moist chamber technique.

Taxa/ Samples	E1_ 60	E1_ 120	E1_ 180	E1_ 240	E2_ 60	E2_ 120	E2_ 180	E2_ 240
*******Beltrania rhombica*** **Penz.**	25.0	-	-	-	10.5	26.9	-	8.0
*******Beltraniella brotryospora*** **Shirouzu & Tokum.**	-	-	-	7.1	-	-	-	-
*******B. portoricensis*** **(F. Stevens) Piroz. & S.D. Patil**	50.0	8.3	-	-	-	-	-	-
********Beverwykella clathrata*****Voglmayr**	-	-	-	-	-	7.7	-	4.0
*******Chalara alabamensis*** **Morgan-Jones & E.G. Ingram**	-	8.3	40.0	14.3	15.8	26.9	16.0	64.0
*******Codinaea fertilis*** **S. Hughes & W.B. Kendr.**	-	-	-	-	-	-	4.0	-
*******Cylindrocladiella infestans*** **Boesew.**	-	-	-	-	36.8	-	-	-
********Fusticeps laevisporus*** **Matsush.**	-	-	20.0	0.0	-	-	-	4.0
*******Henicospora coronata*** **B. Sutton & P.M. Kirk**	-	8.3	-	50.0	5.3	3.8	8.0	-
*******Isthmolongispora intermedia*****Matsush.**	-	-	-	-	-	-	4.0	-
*******I. variabilis*** **Matsush.**	-	8.3	-	7.1	-	15.4	60.0	-

Taxa/ Samples	E1_ 60	E1_ 120	E1_ 180	E1_ 240	E2_ 60	E2_ 120	E2_ 180	E2_ 240
*******Kionochaeta spissa*** **P.M. Kirk & B. Sutton**	-	41.7	40.0	7.1	-	19.2	-	8.0
********Spirosphaera carici-graminis*** **Voglmayr**	-	-	-	-	-	-	4.0	-
*******Subulispora procurvata*** **Tubaki**	-	-	-	14.3	15.8	-	-	4.0
*******Thozetalla canadenses*** **Nag Raj**	-	-	-	-	-	-	-	4.0
*******T. cristata*** **Piroz. & Hodges**	-	-	-	-	-	-	4.0	-
*******T. pinicola*** **S.Y. Yeung, Jeewon & K.D. Hyde**	25.0	16.7	-	-	15.8	-	-	-
*******T. radicata*** **(E.F. Morris) Piroz. & Hodges**	-	-	-	-	-	-	-	4.0
*******Verticicladus subiculifer*** **Matsush.**	-	8.3	-	-	-	-	-	-
TOTAL:	100	100	100	100	100	100	100	100
Nº of taxa	3	7	3	6	6	6	7	8
Simpson index	0.62 (0.5-0.75)	0.76 (0.69-0.83)	0.64 (0.48-0.8)	0.69 (0.55-0.86)	0.7756 (0.68-0.87)	0.78 (0.72-0.85)	0.60 (0.45-0.75)	0.57 (0.37-0.76)
Evenness	0.94 (0.88-1.0)	0.78 (0.65-0.91)	0.95 (0.88-1.03)	0.72 (0.54-0.90)	0.8542 (0.70-1.01)	0.85 (0.72-0.98)	0.53 (0.37-0.70)	0.47 (0.32-0.62)
Chao-1	3.5 (2.75-4.25)	12 (6.6217.38)	3 (2-4)	7 (3-11)	6 (4-8)	6 (5.5-6.5)	10 (6.5-13.5)	11.33 (4.83-17.83)

Note: *Ingoldian fungi; **Facultative aquatic hyphomycetes; ***Aero-aquatic hyphomycetes.

Table S10. Constancy in percentage of taxa of freshwater hyphomycetes in two experiments of streams RC. P1 and P2 (E1: Experiment 1. E2: Experiment 2) (samples of moist chambers)

Taxa/ Samples	**RC_E1**	**RC_E2**	**P1_E1**	**P1_E2**	**P2_E1**	**P2_E2**
Anungitopsis triseptata	50	25	25	0	0	0
A. speciosa	25	0	0	0	0	0
Ardachandra aequilatera	25	0	0	0	0	0
Beltrania africana	0	0	50	0	0	0
B. rhombica	0	100	0	75	25	75
Beltraniella brotryospora	0	0	0	0	25	0
B. fertilis	25	25	0	25	0	0
B. portoricensis	0	0	25	0	50	0
Bewervikiella chlatrata	0	0	0	0	0	50
Candelabrum microsporum	25	25	0	0	0	0
Chalara alabamensis	25	25	50	0	75	100
Cladosporium sp.	0	25	0	0	0	0
Codineae fertilis	0	50	0	25	0	25
C.simplex	0	25	100	100	0	0
Corinesporopsis antillana	0	0	0	50	0	0
Cylindrocladiella infestans	0	25	0	25	0	25
Dactylella ellipsospora	0	0	50	0	0	0
Dactylaria fusifera	0	25	0	50	0	0
D. naviculiformis	0	0	75	0	0	0
Dendrosporium lobatum	0	50	0	0	0	0
Dendrosporomyces prolifer	50	0	0	50	0	0
Dictyochaeta heteroderae	0	25	0	0	0	0
Filosporella sp.	0	25	0	0	0	0
Fusticeps laevisporus	0	0	25	0	25	25
Geniculospora inflata	0	25	0	0	0	0
Helicoon myosuroides	25	25	0	0	0	0
Hemibeltrania decorosa	0	0	25	25	0	0
Henicospora coronata	25	25	75	75	50	75
Ingoldiella hamata	25	0	0	0	0	0
Isthmolongispora intermedia	25	75	0	0	0	25
I. rotundata	25	50	25	25	0	0
I. variabilis	25	75	0	50	50	50
Kionochaeta spissa	0	0	25	0	75	50
Mariannae elegans	25	25	0	25	0	0
Mirandina uncinata	0	25	0	0	0	0
Morphotype 1	0	0	25	0	0	0
Paliphora porosa	25	0	0	0	0	0
Phialocephala bactrospora	0	25	0	25	0	0
Pseudaegerita websteri	0	0	0	25	0	0
***Roselymyces* gen. nov.**	25	0	0	0	0	0

Taxa/ Samples	**RC_E1**	**RC_E2**	**P1_E1**	**P1_E2**	**P2_E1**	**P2_E2**
Selenosporella curvispora	0	25	0	0	0	0
S. minima	0	0	25	50	0	0
Spirosphaera carici-graminis	0	50	25	50	0	25
Subulispora procurvata	0	0	0	0	25	50
Synchaetomella aquatica	25	25	25	25	0	0
Thozetella acerosa	25	0	0	0	0	25
T. cristata	0	0	25	25	0	25
T. canadensis	0	25	0	0	0	0
T. cristata	50	50	0	0	0	0
T. pinicola	100	25	25	50	50	25
T. queenslandica	0	25	0	0	0	0
T. radicata	0	25	0	0	0	25
Triscelophorus acuminatus	100	75	100	25	0	0
Vermiculariopsiella immersa	0	0	25	0	0	0
Verticicladus subiculifer	50	25	75	0	25	0
Xylomyces foliicola	50	0	0	0	0	0
Zygosporium mansonii	0	25	0	0	0	0

Table S11. Similarity percentage analysis (SIMPER) of freshwater hyphomycete communities associated with submerged leaves of *C. brasiliense* for streams (data from moist chambers). Overall average dissimilarity: 13.91%.

Taxa	**Av. dissim**	**Contrib. %**	**Cumulative %**	**Mean Stream1**	**Mean Stream2**	**Mean Stream3**
Codinaea simplex	0.7003	5.034	5.034	1.88E+09	2.75	2.15E+09
Triscelophorus acuminatus	0.6651	4.781	9.815	2.68E+08	8.05E+08	2.15E+09
Chalara alabamensis	0.6089	4.377	14.19	1.61E+09	1.61E+09	2.68E+08
Henicospora coronata	0.5713	4.107	18.3	1.61E+09	5.37E+08	8.05E+08
Thozetella pinicola	0.5365	3.857	22.16	8.05E+08	1.34E+09	1.34E+09
Isthmolongispora variabilis	0.5286	3.8	25.96	1.07E+09	1.61E+09	1.07E+09
Beltrania rhombica	0.5256	3.778	29.74	1.07E+09	1.34E+09	1.07E+09
Kionochaeta spissa	0.467	3.357	33.09	2.15E+09	1.88E+09	8.05E+08
Thozetella cristata	0.4621	3.322	36.41	1.07E+09	1.61E+09	1.88E+09
Verticicladus subiculifer	0.4538	3.263	39.68	1.34E+09	1.34E+09	1.88E+09
Spirosphaera carici-graminis	0.4095	2.944	42.62	1.61E+09	1.34E+09	1.88E+09
Isthmolongispora intermedia	0.4081	2.934	45.55	1.07E+09	2.15E+09	1.88E+09
Isthmolongispora rotundata	0.3782	2.719	48.27	1.34E+09	1.61E+09	2.15E+09
Anungitopsis triseptata	0.3269	2.35	50.62	1.34E+09	1.88E+09	2.15E+09
Dendrosporomyces prolifer	0.3092	2.223	52.84	1.61E+09	1.61E+09	2.15E+09
Codineae fertilis	0.3057	2.197	55.04	1.61E+09	1.88E+09	1.88E+09
Synchaetomella aquatica	0.3036	2.183	57.22	1.61E+09	1.61E+09	2.15E+09
Selenosporella minima	0.2635	1.894	59.12	2.15E+09	1.34E+09	2.15E+09
Dactylaria naviculiformis	0.2627	1.888	61.01	2.15E+09	1.34E+09	2.15E+09
Subulispora procurvata	0.2612	1.878	62.89	2.15E+09	2.15E+09	1.34E+09
Mariannae elegans	0.249	1.79	64.67	1.61E+09	1.88E+09	2.15E+09
Beltraniella fertilis	0.2486	1.787	66.46	1.61E+09	1.88E+09	2.15E+09
Dactylaria fusifera	0.2393	1.72	68.18	1.88E+09	1.61E+09	2.15E+09
Fusticeps laevisporus	0.2393	1.72	69.9	2.15E+09	1.88E+09	1.61E+09
Beltraniella portoricensis	0.2385	1.715	71.62	2.15E+09	1.88E+09	1.61E+09
Cylindrocladiella infestans	0.2282	1.64	73.26	1.88E+09	1.88E+09	1.88E+09
Helicoon myosuroides	0.1881	1.352	74.61	1.61E+09	2.15E+09	2.15E+09
Candelabrum microsporum	0.1839	1.322	75.93	1.61E+09	2.15E+09	2.15E+09
Dactylella ellipsospora	0.1776	1.276	77.21	2.15E+09	1.61E+09	2.15E+09
Beltrania africana	0.1776	1.276	78.48	2.15E+09	1.61E+09	2.15E+09
Xylomyces foliicola	0.1764	1.268	79.75	1.61E+09	2.15E+09	2.15E+09
Corinesporopsis antillana	0.1757	1.263	81.02	2.15E+09	1.61E+09	2.15E+09
Bewervikiella chlatrata	0.1748	1.256	82.27	2.15E+09	2.15E+09	1.61E+09
Hemibeltrania decorosa	0.1739	1.25	83.52	2.15E+09	1.61E+09	2.15E+09

Conclusões Gerais

CONCLUSÕES GERAIS

- 69 táxons de hifomicetos aquáticos foram registrados na decomposição de folhas de *Calophyllum brasiliense* nos três riachos da bacia do rio de Contas;
- Destes, 15 táxons são fungos ingoldianos, seis são hifomicetos aeroaquáticos e 48 são hifomicetos aquáticos facultativos;
- *Dendrosporomyces prolifer* e *Geniculospora inflata* são novos registros para o Neotrópico;
- *Pyramidospora casuarinae* e *Triscelophorus monosporus* são novos registros para o nordeste;
- Oito espécies são raras:
    - *Flagellospora stricta, Helicoon myosuroides, Pseudaegerita websteri* e *Verticicladus subiculifer* são novos registros para as Américas;
    - *Dactylaria fusifera* e *Spirosphaera carici-graminis* são novos registros para o Neotrópico;
    - *Ardhachandra aequilatera* é um novo registro para a América do Sul;
    - *Beverwykella clathrata* é um novo registro para o nordeste.
- *Dictyotrichocladium* e *Roselymyces* são novos gêneros;
- *Dictyotrichocladium aquaticum, Mirandina uncinata, Roselymyces brasiliensis, Selenosporella minima* e *Synchaetomella aquatica* são novas espécies catalogadas;
- A metodologia de câmara úmida apresentou maior riqueza de táxons e diversidade que a metodologia de incubações submersas;
- Para a metodologia de incubações submersas:
    - Foram observados 16 táxons no riacho do rio de Contas, 19 no riacho Patricinho e 22 no riacho Patricio;

  - As taxas de esporulação e riqueza de fungos foram significativamente mais altas no período chuvoso;
  - *Triscelophorus acuminatus* foi a espécie com maior contribuição para diferenciação das comunidades dos riachos;
  - A análise ANOSIM revelou que não houve diferença significativa entre as comunidades dos riachos;
  - Os resultados do NMDS demonstraram que as comunidades estavam associadas negativamente a concentração de oxigênio e positivamente a velocidade da água;
  - A maioria dos hifomicetos aquáticos foi observada associada a *Calophyllum brasiliense* do estágio pioneiro ao intermediário de sucessão (até 120 dias).
- Para a metodologia de câmaras úmidas:
  - Foram observados 41 táxons no riacho do rio de Contas, 32 no riacho Patricinho e 19 no riacho Patricio;
  - *Codinaea simplex* foi a espécie fúngica com maior contribuição para a dissimilaridades dos riachos;
  - Os resultados do ANOSIM revelaram diferenças significativas entre as comunidades dos riachos;
  - Para o NMDS as amostras de câmara úmida não demonstraram ordenação significativa;
  - A maioria dos hifomicetos aquáticos foi observada associada a *Calophyllum brasiliense* no estágio empobrecido de sucessão (240 dias);
- As duas metodologias utilizadas (incubações submersas e câmaras-úmidas) apresentaram 13 espécies em comum;

- A análise UPGMA demonstrou separação das amostras de incubações submersas e câmaras-úmidas em dois grupos, sendo que as primeiras apresentaram maior similaridade;
- Os três riachos da bacia do rio de Contas estudados apresentam alta riqueza de hifomicetos aquáticos associados à *Calophyllum brasiliense* para o Brasil, contendo espécies inéditas, raras e novos registros para a ciência;
- O presente estudo de hifomicetos aquáticos associados à *C. brasiliense* poderá subsidiar estudos futuros de conservação de *C. brasiliense* e das nascentes da bacia do Rio de Contas.

HIFOMICETOS AQUÁTICOS ASSOCIADOS A FOLHAS DE *CALOPHYLLUM BRASILIENSE* EM RIACHOS DA BACIA DO RIO DE CONTAS

Patrícia Oliveira Fiuza

RESUMO

Os hifomicetos aquáticos constituem o principal grupo de fungos que medeia carbono, energia e fluxo de nutrientes em ecossistemas de água doce aumentando da qualidade da decomposição de detritos foliares. O conhecimento acerca desses fungos no Brasil é escasso, principalmente quanto a sua ecologia, diversidade e padrões de distribuição. Visando expandir o conhecimento de hifomicetos aquáticos no Brasil e analisar a dinâmica de suas comunidades em riachos da Chapada Diamantina, foi realizada uma investigação em folhas submersas de *C. brasiliense* em três riachos na bacia do rio de Contas (Rio de Contas, Patricinho e Patricio). Em outubro de 2013 e maio de 2014 foram realizadas expedições para Serra da Tromba, Piatã, Bahia, para coleta de folhas verdes de *Calophyllum brasiliense,* na vegetação ripária do riacho do rio de Contas, para dois experimentos de decomposição. O experimento 1 (E1) foi realizado de novembro de 2013 a maio 2014 e experimento 2 (E2) de julho de 2014 a janeiro de 2015, com duração de oito meses cada. Para ambos os experimentos, cinco folhas foram colocadas em cada litter bag de malha fina (30 x 30 cm, 0,5 mm tamanho da malha) que foram em seguida submersos em três riachos da bacia do rio de Contas e amarrados com linha de nylon a árvores da vegetação ciliar. A cada dois meses, foram coletados seis sacos de "litter bag" de cada riacho (6 "litter bags" x 3 riachos x 4 datas de coleta x 2 experimentos, totalizando 144 sacos e 720 folhas). As amostras foram colocadas em sacos de plástico e transportadas para o laboratório de Micologia (LAMIC) da Universidade Estadual de Feira de Santana em um isopor com gelo. Nas expedições foram também coletadas variáveis ambientais (temperatura, pH e oxigênio dissolvido e velocidade da água) e 1L de água do riacho para realização de análise da concentração total de fósforo e nitrogênio. As amostras de folhas foram tratadas de acordo com as metodologias de incubação submersa e câmaras úmidas. A identificação de fungos foi realizada no LAMIC e no Laboratório de Microbiologia do Departamento de Biologia na Coastal Carolina University, Estados Unidos. Para análise de dados ecológicos, foram utilizados Simpson e equitabilidade para o cálculo de diversidade; Chao 1 para estimar o número de táxons esperados nas comunidades; ANOVA foi realizada para avaliar os efeitos dos riachos, experimentos e datas de coleta sobre as taxas de esporulação; SIMPER foi utilizado para identificar os táxons mais influentes; ANOSIM para verificar se existiam diferenças entre as comunidades nos riachos; NMDS foi utilizado para demonstrar se houve influência de variáveis ambientais nas comunidades; a constância de espécies foi realizada para avaliar a distribuição dos fungos durante a sucessão e o UPGMA foi realizado para visualizar a similaridade e grupos de amostras de incubações submersas e câmaras úmidas. Os capítulos são divididos em três seções. Na primeira seção são apresentados dois capítulos com taxonomia de novos registros:

(1) apresenta a revisão de fungos ingoldianos para o Brasil, incluindo novos registros associados à *C. brasiliense*, uma chave e ilustrações para todas as espécies encontradas no Brasil e mapas de distribuição geográfica; (2) são apresentadas espécies raras de aeroaquáticos e hifomicetos aquáticos facultativos com descrição, ilustração e distribuição geográfica. A segunda seção é composta por espécies inéditas de hifomicetos aquáticos facultativos associados à *C. brasiliense*: (3) *Selenosporella minima*, (4) *Synchaetomella aquatica*, (5) *Mirandina uncinata*, e (6) *Dyctiotrichocladium aquaticum;* enquanto a terceira e última seção é constituída por um capítulo de ecologia que analisa a dinâmica das comunidades de hifomicetos aquáticos associados à *C. brasiliense* em três riachos da bacia do rio de Contas, utilizando as metodologias de incubação submersa e câmaras úmidas. O capítulo conta com análises de dados ecológicos e tabelas com todos os táxons encontrados em cada metodologia.

Palavras-chave: Biodiversidade, Chapada Diamantina, ecossistemas lóticos, fungos aquáticos, tropical.

FRESHWATER HYPHOMYCETES ASSOCIATED WITH LEAVES OF *CALOPHYLUM BRASILIENSE* IN STREAMS OF RIVER CONTAS BASIN

Patrícia Oliveira Fiuza

ABSTRACT

Freshwater hyphomycetes are the main fungal group that mediates carbon, energy and nutrient flux in freshwater ecosystems, increasing the quality of the decomposition of foliar debris. The knowledge about these fungi in Brazil is scarce, mainly regarding their ecology, diversity and distribution patterns. Aiming to expand the knowledge of aquatic hyphomycetes in Brazil and to analyze the dynamics of their communities in Chapada Diamantina streams, an investigation was carried out on submerged leaves of *C. brasiliense* in three streams in the River Contas basin (Rio de Contas, Patricinho and Patricio). In October 2013 and May 2014, were carried out expeditions to Serra da Tromba, Piatã, Bahia, for the collection of green leaves of *Calophyllum brasiliense*, in the riparian vegetation of the Rio de Contas stream, for two decomposition experiments. Experiment 1 (E1) was carried out from November 2013 to May 2014 and experiment 2 (E2) from July 2014 to January 2015, eight months each. For both experiments, five leaves were placed in each fine mesh litter bag (30 x 30 cm, 0.5 mm mesh size) which were then submerged in three streams of the river Contas basin and tied with nylon thread trees of riparian vegetation. Every two months, six litter bags were collected from each stream (6 litter bags x 3 streams x 4 collection dates x 2 experiments, totalizing 144 bags and 720 leaves). The samples were placed in plastic bags and transported to the Laboratory of Mycology (LAMIC) of the State University of Feira de Santana in a cooler. In the expeditions, environmental variables (temperature, pH and dissolved oxygen and water velocity) and 1L of water of streams were also collected for analysis of the phosphorus and nitrogen total concentration. Leaf samples were treated according to submerged incubation and moist chamber methodologies. Fungus identification was performed at LAMIC and at the Laboratory of Microbiology of the Department of Biology at Coastal Carolina University, USA. For ecological data analysis, Simpson and evenness were used to calculate diversity; Chao 1 was used to estimate the number of taxa expected in the communities; ANOVA was performed to test for the effects of stream, experiment and collection day on fungal sporulation rate; SIMPER was used to identify the most influential taxa; ANOSIM to verify if there were differences between the communities in the streams; NMDS was used to demonstrate if there was influence of environmental variables in the communities; constancy of species was performed to evaluated the distribution of fungi on the succession; and the UPGMA was performed to visualize the similarity and groups of samples of submerged incubations and moist chambers. The chapters are divided into three sections. The first section presents two chapters with taxonomy of new records: (1) review of Ingoldian fungi for Brazil, including new records associated with *C. brasiliense*, a key and illustrations for all species found in Brazil and distribution maps; and (2) are presented rare species of aquatic and facultative aquatic hyphomycetes with description, illustration and geographical distribution. In the second section were described new species of facultative aquatic hyphomycetes associated with *C. brasiliense*: (3) *Selenosporella minima*, (4) *Synchaetomella aquatica*, (5) *Mirandina uncinata*, and (6) *Dyctiotrichocladium aquaticum*; while the third and last section is an ecology chapter that analyzes the dynamics of the aquatic hyphomycetes communities associated with *C. brasiliense* in three streams of the Contas river basin, using submerged incubation and moist chamber methodologies. The chapter has ecological data analyzes and tables with all the taxa found in each methodology.

Key words: Aquatic fungi, biodiversity, Chapada Diamantina, lotic ecosystems, tropical.

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