The Lichenologist **45**(5): 627–634 (2013)
doi:10.1017/S0024282913000303

Two new species of *Roccellaceae* (Ascomycota: *Arthoniales*) from Brazil, with the description of the new genus *Sergipea*

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Abstract: The new lichen genus *Sergipea* M. Cáceres, Ertz & Aptroot is described in the *Roccellaceae*, based on the new species *Sergipea aurata* M. Cáceres, Ertz & Aptroot from NE Brazil. The species was found in a remnant of Atlantic transition forest in Sergipe. It is similar in many respects to species of the genus *Enterographa*, but it is characterized by bright orange stromata, due to the presence of an anthraquinone, and a thallus with a somewhat byssoid hypothallus. Phylogenetically it is close to the genera *Dichosporidium* and *Erythrodecton*. The phylogenetic position of the generic type of *Dichosporidium* confirms the close relationship of the genus to *Erythrodecton* in the basal branch of the *Roccellaceae*. A new species of *Enterographa* is also described from NE Brazil. *Enterographa rotundata* E. L. Lima, M. Cáceres & Aptroot has solitary, round apothecia, which is unusual in this genus with mainly elongated apothecia or punctiform apothecia arranged in lines. It was found in Caatinga forest in Pernambuco.

Key words: Atlantic rainforest, Catinga, corticolous, *Dichosporidium*, *Enterographa*, *Erythrodecton*, lichens, Pernambuco, Sergipe

Accepted for publication 31 *March* 2013

Introduction

The *Roccellaceae* are a predominantly tropical group of lichens. The basal branch in the phylogeny contains the core group of *Enterographa* [including its type, *E. crassa* (DC.) Fée], as well as *Erythrodecto*n (Ertz & Tehler 2011). The genus *Enterographa* Fée is a predominantly tropical group of crustose *Roccellaceae* comprising *c.* 50 species (Sparrius 2004; Ertz *et al.* 2005; Sparrius *et al.* 2006; Sparrius & Aptroot 2007; Jagadeesh Ram *et al.* 2008; Lücking 2008; Sparrius & Björk 2008; Ertz 2009*a*, *b*; Seaward & Aptroot 2009; Yeshitela *et al.* 2009; Sipman 2011). Phylogenetic studies have shown the genus to be polyphyletic (Ertz *et al.* 2009), and two species that were accepted in the genus by Sparrius (2004) were shown to fall into a different clade than the type species of *Enterographa*, *E. crassa* (DC.) Fée. These were transferred to the genera *Opegrapha* Ach. (Ertz *et al.* 2009) and *Fulvophyton* Ertz & Tehler (Ertz & Tehler 2011). It is likely that the many species remaining in the genus still do not form a monophyletic group.

The Atlantic rainforests and the Caatinga forests in NE Brazil are rich in lichen species but still incompletely explored (Cáceres 2007; Menezes *et al.* 2011; Lima *et al.* 2013). The *Arthoniales*, including the *Roccellaceae*, is one of the three dominant crustose lichen groups on bark in NE Brazil, and crustose *Roccellaceae* are common and sometimes abundant (Cáceres *et al.* 2007, 2008).

During ecological studies focusing on epiphytic crustose lichens in NE Brazil, an *Enterographa*-like lichen was found with

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TABLE 1. *Specimens and DNA sequences used in this study, with their respective voucher information. GenBank accession numbers* ***in bold*** *refer to sequences (3) generated by this project. All other sequences (17 GenBank accession numbers) were obtained directly from GenBank.*

Name	Voucher	Substratum	mtSSU GenBank number
Chiodecton natalense	Zambia, *D. Ertz* 6576 (BR)	bark	EU704051
Dendrographa leucophaea	California, *L. Sparrius* 7999 (DUKE)	bark	AY548811
Dichosporidium boschianum	Fiji, *T. Lumbsch* 19815a (F)	?	GU327692
D. nigrocinctum 1	Guadeloupe, *D. Ertz* 15377 (BR)	bark	**KC820664**
D. nigrocinctum 2	Guadeloupe, *D. Ertz* 15923 (BR)	bark	**KC820665**
Enterographa crassa 1	France, *D. Ertz* 5041 (BR)	bark	EU704056
E. crassa 2	France, *D. Ertz* 7554 (BR)	bark	EU747080
E. crassa 3	Belgium, *D. Ertz* 7561 (BR)	bark	EU747081
E. crassa 4	Luxembourg; *D. Ertz* 7621 (BR)	bark	EU747082
E. hutchinsiae 1	Belgium, *D. Ertz* 10064 (BR)	rock	EU747083
E. hutchinsiae 2	Belgium, *D. Ertz* 10066 (BR)	bark	EU704057
E. zonata 1	Belgium, *N. Vigneron* 104 (BR)	bark	EU704081
E. zonata 2	Belgium, *D. Ertz* 9230 (BR)	rock	EU747084
Erythrodecton granulatum	Gabon, *D. Ertz* 9908 (BR)	bark	EU704058
Lecanactis abietina	Belgium, *D. Ertz* 5068 (DUKE)	bark	AY548813
Opegrapha rufescens	Belgium, *N. Vigneron* 75 (BR)	bark	EU704074
O. vulgata	Belgium, *D. Ertz* 7564 (BR)	bark	EU704080
Roccella fuciformis	Tenerife, *P. Diederich* 15572 (DUKE)	rock	EU704082
Schismatomma pericleum	*A. Tehler* 7701 (S)	bark	AY571390
Sergipea aurata	Brazil, *M. E. S. Cáceres & K. A. Jesus* 12539 (ISE)	bark	**KC820666**

bright orange stromata, due to the presence of an anthraquinone. It was found in a remnant of Atlantic transition forest in Sergipe. It was clear that it was an undescribed species, but as this would be the first *Enterographa* with anthraquinones, it was sequenced to ascertain that it really belongs to the genus *Enterographa*. However, it clustered with strong support in the sister group of the well-supported core group of *Enterographa*, together with species of *Dichosporidium* and *Erythrodecton*. Although it shares some characters with *Erythrodecton* in particular (the presence of an anthraquinone), it differs in several respects from both genera, markedly by the firm, not byssoid thallus, the absence of ascoma carbonization, and the ascospore type. Therefore, this new species is described here in the new genus *Sergipea*.

Also, a new species of the genus *Enterographa* was found as part of the ecological studies. *Enterographa rotundata* has solitary round apothecia, which is unusual in this genus with mainly elongated apothecia or punctiform apothecia arranged in lines. It was found in the Vale do Catimbau National Park, a Caatinga forest reserve, in Pernambuco State.

Material and Methods

Identification and descriptive work was carried out in Itabaiana, Universidade Federal de Sergipe, using a Leica EZ4 stereomicroscope and a Leica DM500 compound microscope, and also in Soest using an Olympus SZX7 stereomicroscope and an Olympus BX50 compound microscope with interference contrast, connected to a Nikon Coolpix digital camera. Sections were mounted in tap water, on which all measurements were also taken. The specimens from this study are preserved in ISE. The chemistry of the type specimens was investigated by thin-layer chromatography (TLC) using solvent A (Orange *et al.* 2001).

The mtSSU of the holotype of *Sergipea aurata* and of two specimens of *Dichosporidium nigrocinctum* (Ehrenb.) G. Thor were sequenced, using primers mrSSU1 and mrSSU3R (Zoller *et al.* 1999) and following the procedures cited by Ertz *et al.* (2009). For the phylogenetic analyses, 17 sequences were retrieved from GenBank in addition to our own sequences (Table 1). The outgroup species, *Opegrapha vulgata* Ach., was chosen based on Ertz & Tehler (2011).

The mtSSU sequences were aligned manually to the existing alignment of Ertz *et al.* (2009) using MacClade 4.05 (Maddison & Maddison 2002). Ambiguously aligned regions and introns representing a total of 727 bp (mainly due to an intron in the sequence of *Roccella fuciformis*) were delimited manually and excluded from the analyses.

Maximum Parsimony (MP) analysis was performed in PAUP*4.0b10 (Swofford 2002) on the mtSSU matrix of 735 unambiguously aligned characters, including 251 variable characters of which 195 are parsimony-informative. Heuristic searches were used with 1000 random addition sequence replicates, MaxTrees set to autoincrease, tree-bisection-reconnection (TBR) branch swapping, MulTrees option in effect and gaps treated as missing data. The MP analysis yielded four most parsimonious trees (448 steps) with topological differences present only in the clade *Lecanactis-Chiodecton*. Bootstrap values (MP-bs) were obtained from 1000 replicates with three random addition sequences (all other parameters identical to the original MP search).

The best-fit model of DNA evolution GTR+G was chosen using the Akaike Information Criterion (AIC), as implemented in Modeltest v. 3.06 (Posada & Crandall 1998). Bayesian analyses were carried out using the Metropolis-coupled Markov chain Monte Carlo method (MCMCMC) in MrBayes v. 3.1.2 (Huelsenbeck & Ronquist 2001; Ronquist & Huelsenbeck 2003) on the CIPRES portal (Miller *et al.* 2010). Analyses were run under the GTR model of nucleotide substitution, including a discrete gamma distribution with six rate categories. Two parallel MCMCMC runs were performed, each using four independent chains and 10 000 000 generations, sampling trees every 1000th generation. TRACER v.1.5 (Rambaut & Drummond 2007) was used to ensure that stationarity was reached by plotting the log-likelihood values of the sample points against generation time. Posterior probabilities (PP) were determined by calculating a majority-rule consensus tree generated from the last 15 002 of the 20 002 trees sampled.

The MP tree did not contradict the Bayesian tree topology for the strongly supported branches, and hence only the majority-rule consensus tree of the Bayesian analysis is shown here with the branch supports of the MP analysis. PP $\geq$ 95% and MP-bs $\geq$ 70% were considered to be significant.

The Species

Sergipea aurata M. Cáceres, Ertz & Aptroot gen. et sp. nov.

MycoBank No.: MB 803755 (genus) & 803756 (species)

Roccellaceae with non-carbonized ascomata immersed in stromata covered with orange anthraquinone, ascospores 7–9-septate, 35–40(–50) × 5–6 μm, narrowly clavate, rather thick-walled with elongated lumina, thallus with lichexanthone, stromata with anthraquinone.

Type: Brazil, Sergipe, Areia Branca, Fonte da Bica, on tree bark, *c.* 400 m alt., 19 May 2012, *M. E. S. Cáceres* & *K. A. Jesus* 12539 (ISE—holotype).

(Fig. 1)

Thallus crustose, cracked, not corticate, dull, pale greenish grey, very thin and closely following the bark surface, patchily interspersed with slightly byssoid hypothallus (visible only at high magnification), surrounded by a brown prothallus line. *Algae* trentepohlioid.

Ascomata not carbonized, *c.* 0·1 mm diam., globose, immersed and visible from above only by the ostiole, 5–25 clustered together in 1–2 mm wide, bright orange stromata. *Excipulum* hyaline, continuous below the hymenium. *Epihymenium* internally with pale brown pigmentation and externally with orange crystals. *Hamathecium* not inspersed, IKI+ blue (amyloid), paraphysoids 1·0–1·5 μm wide, anastomosing and often somewhat curled. *Asci* cylindrico-clavate, 73–89 × 21–27 μm. *Ascospores* 8 per ascus, hyaline, 7–9-septate, narrowly clavate, 35–40(–50) × 5–6 μm, without gelatinous sheath, rather thick-walled with elongated lumina.

Pycnidia not observed.

Chemistry. Thallus partly UV+ yellow, partly UV−, C−, P−, K−, stromata K+ purple. TLC: thallus with lichexanthone, stromata with an unidentified anthraquinone that resembles parietin in Rf-value and KOH-reaction.

Ecology and distribution. On smooth bark of trees in Caatinga forest. Known only from Brazil. It grows together with the equally endemic *Enterographa subquassiaecola* M. Cáceres & Lücking (Cáceres 2007), which is quite common in NE Brazil.

Discussion. As only one species is known in this genus, the description above refers to both the genus and the species (a so-called *descriptio generico-specifica*, ICBN Art. 38), as it would be impossible to discern generic and specific characters at this stage. The thallus and the internal structures, including the internal pigmentation, fit some species in the genus *Enterographa* well. It seems in habitus close to *E. pertusarioides* Sparrius (Sparrius 2004), which however lacks anthraquinones, contains psoromic acid and has 3-septate ascospores of a much smaller size. *Sergipea*

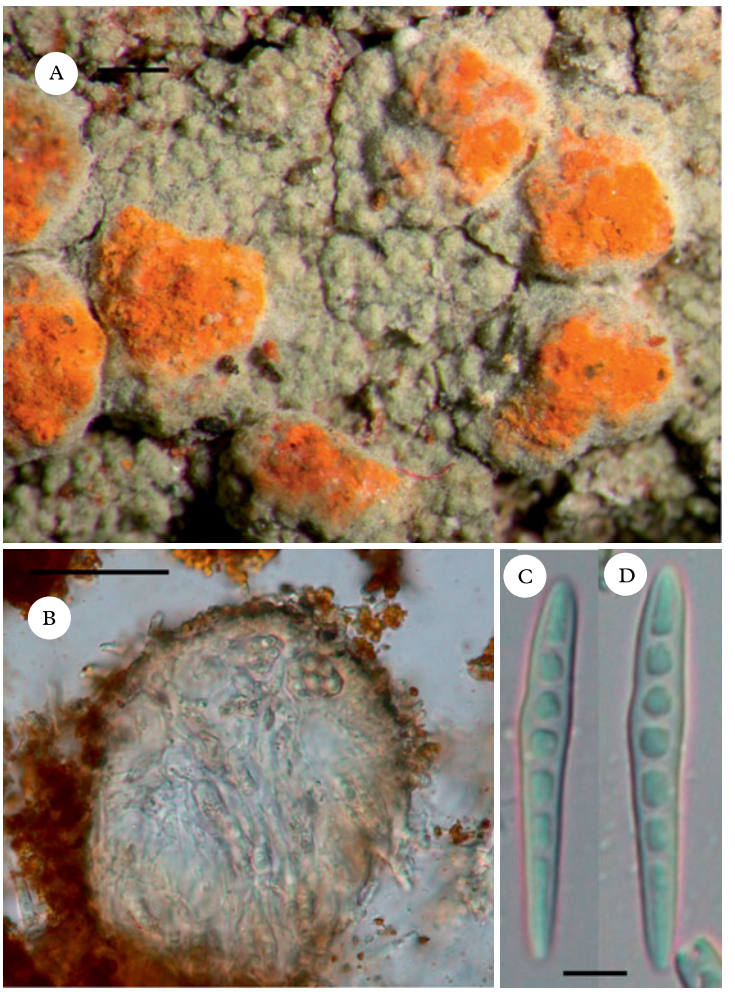

FIG. 1. *Sergipea aurata*, holotype. A, habitus; B, section through ascoma; C & D, ascospores. Scales: A = 0·5 mm; B = 50 μm; C & D = 5 μm. In colour online

aurata is a truly remarkable and unexpected species.

Additional specimen seen. **Brazil:** same as the type, *M. E. S. Cáceres & K. A. Jesus* 12540 (ISE).

Enterographa rotundata E. L. Lima, M. Cáceres & Aptroot sp. nov.

MycoBank No.: MB 802592

Corticolous *Enterographa* species with round apothecia, ascospores (3–)7-septate, 50–60 × 3·5–5·0 μm, without substances.

Type: Brazil, Pernambuco, Buíque, Vale do Catimbau National Park, on bark of tree, *c.* 900 m alt., 3 February 2012, *E. L. Lima* 668 (ISE—holotype).

(Fig. 2)

Thallus crustose, continuous but often seemingly absent, not corticate, dull, pale pinkish to pale brownish, very thin and closely following the bark surface, without prothallus. *Algae* trentepohlioid.

Ascomata round or slightly ellipsoidal, dark brown to black, 0·1–0·2 mm wide, margin raised above the disc, ochraceous

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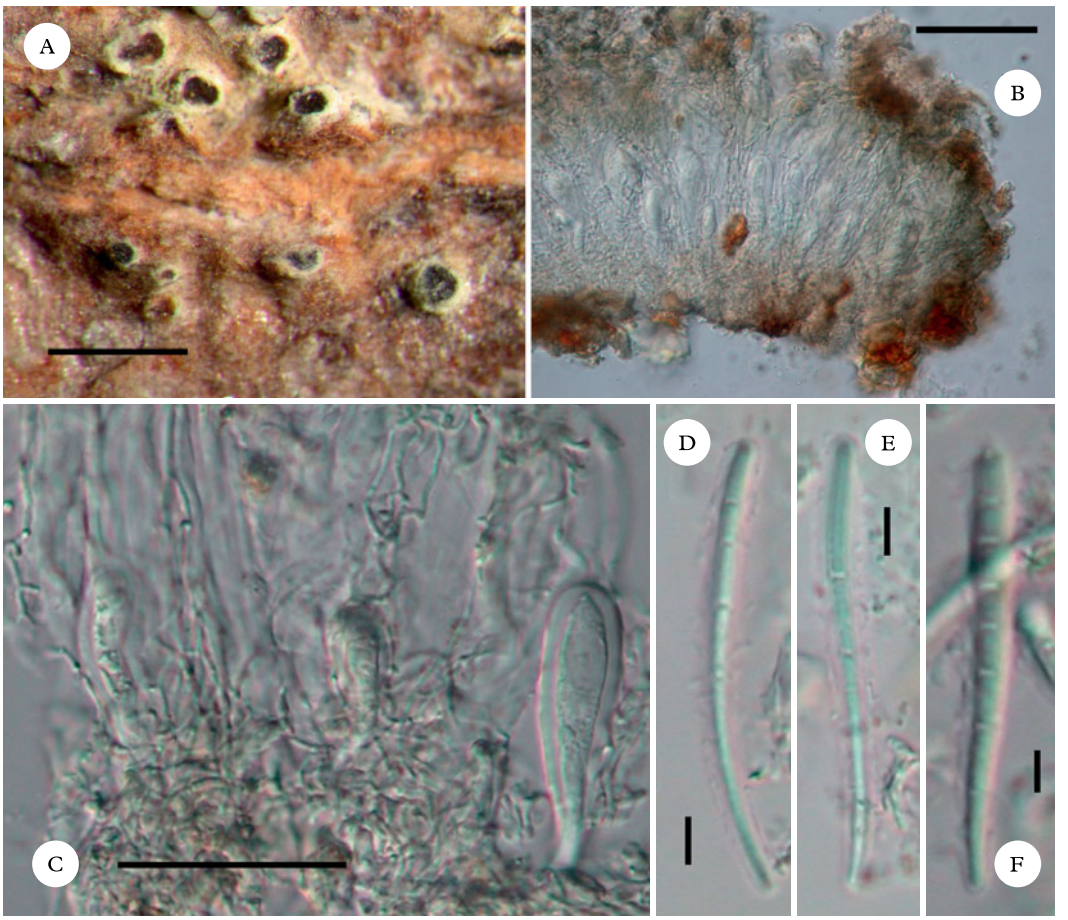

FIG. 2. *Enterographa rotundata*, holotype. A, habitus; B, section through ascoma; C, hamathecium and young ascus; D–F, ascospores. Scales: A = 0·5 mm, B & C = 50 µm; D–F = 5 µm. In colour online

white, *c.* 0·05 mm wide. *Excipulum* hyaline to pale brownish. *Epihymenium* internally with pale brown pigmentation. *Hamathecium* not inspersed, IKI+ pale blue (weakly amyloid), paraphysoids 1·0–1·5 µm wide, anastomosing and often somewhat curled. *Asci* cylindrico-clavate, 65–79 × 15–23 µm, tholus amyloid. *Ascospores* 8 per ascus, hyaline, (3–)7-septate, narrowly clavate, 50–60 × 3·5–5·0 µm, surrounded by a 1·5–2·5 µm wide gelatinous sheath, lumina somewhat rounded.

Pycnidia not observed.

Chemistry. Thallus and apothecia UV−, C−, P−, K−. TLC: no substances detected.

Ecology and distribution. On smooth bark of trees in Caatinga forest. Known only from Brazil. It grows together with, for example, *Dirinaria leopoldii* (Stein) D. D. Awasthi, *Lecanora leprosa* Fée, *L. leproplaca* Zahlbr., *Pertusaria ventosa* Malme, *Phaeographis ventosa* Redinger, and *Ramboldia haematites* (Fée) Kalb *et al*.

Discussion. One of very few *Enterographa* species with round apothecia and the third corticolous one with that character. *Enterographa lecanoracea* Sipman (Sipman 2011) differs by having larger ascomata (0·5–1·5 mm) that are sessile to nearly stalked, and a C+ red thallus. *Enterographa mesomela* Sparrius

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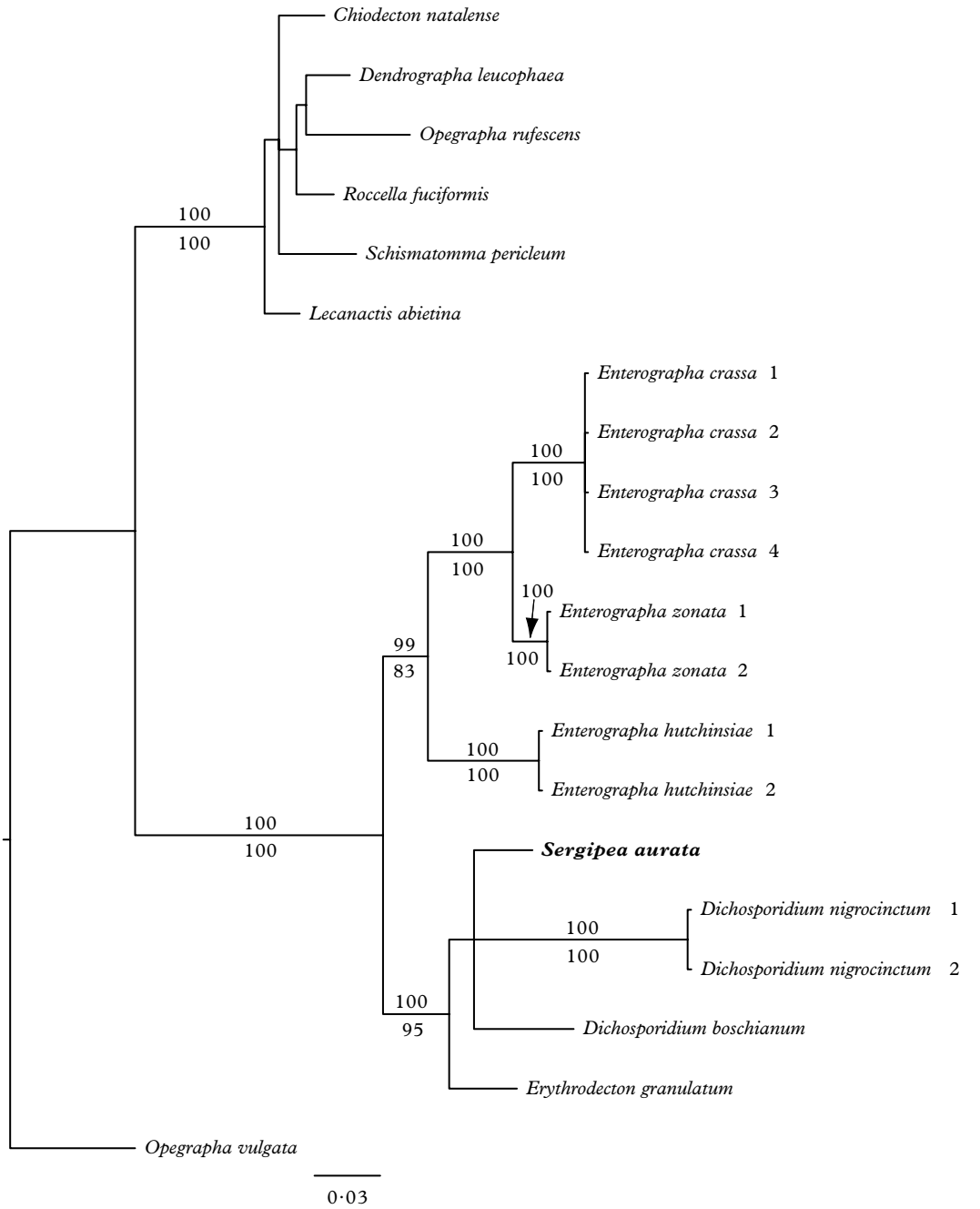

FIG. 3. One locus (mtSSU) 50% majority-rule consensus tree produced by the Bayesian analysis and representing the proposed phylogenetic relationships among 20 specimens of *Arthoniales*. PP ≥ 95% and MP-bs values ≥ 70% are considered strongly supported and shown respectively above and below internal branches. The new genus and species *Sergipea aurata* is noted in bold.

https://doi.org/10.1017/S0024282913000303 Published online by Cambridge University Press

et al. is superficially similar to the new species but differs by a grey-green, slightly cracked to areolate thallus, slightly shorter ascospores (32–40 µm) and a different chemistry (confluentic acid in the thallus, and norstictic acid in the hypothecium; Sparrius *et al.* 2006). The morphs of *E. anguinella* (Nyl.) Redinger [now *Opegrapha anguinella* (Nyl.) Ertz & Diederich] that were described as *E. lecanoroides* R. C. Harris also have nearly round apothecia (Sparrius 2004), but they differ by nearly flush apothecia without a prominent margin and by a different chemistry (presence of psoromic acid). Three foliicolous species of *Enterographa*, viz. *E. batistae* Lücking & Sérus. (Lücking *et al*. 1998), *E. byssoidea* Lücking (Lücking 1991) and *E. perez-higaredae* Herrera-Campos & Lücking (Herrera-Campos & Lücking 2002), also have usually rounded apothecia (Lücking 2008). All differ by various characters from the new species, besides their foliicolous habitat, in each case also by very tiny ascomata which are smallest in *E. batistae* (*c.* 0·1 mm diam.); *E. byssoidea* differs also by the byssoid apothecium margin and *E. perez-higaredae* by the presence of psoromic acid. A superficially similar species is *Lecanographa atropunctata* Sparrius *et al*.; it differs from the new species by a thick dark brown to black excipulum and hypothecium, more septate ascospores (7–13-septate) and a different chemistry (presence of schizopeltic acid; Sparrius *et al.* 2006).

Additional specimens examined. **Brazil:** same as the type, *E. L. Lima* 662, 665, 670 & 673 (ISE).

Discussion of the phylogenetic position of *Sergipea* and *Dichosporidium*

In our phylogenetic tree (Fig. 3), *Sergipea aurata* clusters close to the genera *Dichosporidium* and *Erythrodecton* in the basal branch of the *Roccellaceae* s.str. as defined by Ertz & Tehler (2011). It is included in a strongly supported clade sister to the genus *Enterographa* and thus cannot be described in this latter genus. The generic type of *Dichosporidium*, *D. nigrocinctum*, was here newly sequenced and our phylogenetic tree confirms the position of the genus close to *Erythrodecton granulatum* (Mont.) G. Thor, as first shown by Nelsen *et al.* (2009) for *D. boschianum* (Mont.) G. Thor. The relationships within the clade *Erythrodecton-Sergipea* are not supported. Therefore the generic position of the new taxon is uncertain within this clade.

Erythrodecton mainly differs from *Sergipea* by biclavate ascospores, a red pigment in the thallus medulla and internal carbonization of the ascomata. All species of *Dichosporidium* have internal carbonization of the ascomata, a different chemistry and a distinctly byssoid thallus, contrasting with *Sergipea*. Moreover, *D. nigrocinctum* differs, for example, by biclavate ascospores and *D. boschianum* by hooked ascospores. As a consequence, we prefer to describe a new genus to accommodate our new species.

It should be noted here that both species of *Dichosporidium* do not cluster together in our phylogenetic tree, suggesting that the genus might be paraphyletic. More data will have to be included in future phylogenetic studies to resolve the generic delimitation of these taxa.

The CNPq (Conselho Nacional de Desenvolvimento Científico e Tecnológico) is thanked for a research grant to MESC (Processo 501633/2009-0) and for financial support for the collecting trips (CNPq-Protax Process 562.330/2010-0 and INCT-Herbário Virtual Processo 573.883/2008-4). The Fundação de Amparo à Ciência e Tecnologia do Estado de Pernambuco – FACEPE is also thanked for a Master's scholarship to ELL. AA is grateful to the Hugo de Vries-fonds for travel support. Leo Spier is thanked for performing thin-layer chromatography.

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