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New records to Brazil and Southern Hemisphere of corticolous and saxicolous lichens from the semiarid region in Ceará State

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ABSTRACT - Lichens are an important element of the biodiversity of tropical regions, found in a variety of substrates. The Brazilian semiarid biodiversity is highly threatened due to land conversion for agricultural and cattle ranch. Until recently, only a few species had been reported from Ceará, the only State in Brazil covered almost entirely by Caatinga vegetation. The present work was carried out in Quixadá and Quixerá, in Ceará State, an area characterized by the presence of rock outcrops and inselbergs. As a result, 82 lichen species are here reported, from which 52 species are new records for Ceará, and 14 are reported for the first time to Brazil. The great majority of species was saxicolous. This is the first lichen inventory in this semiarid region of the state, and also the first study to report a large number of saxicolous crustose microlichens in northeastern Brazil.

Key words: Caatinga, diversity, lichenized fungi, northeast, Quixadá

RESUMO - Novos registros para o Brasil e Hemifério Sul de liquens corticícolas e saxícolas da região semiárida no estado do Ceará. Os liquens são um elemento importante da biodiversidade das regiões tropicais, encontrados em uma variedade de substratos. A biodiversidade do semi-árido brasileiro é altamente ameaçada devido à conversão de terras para a agropecuária. Até recentemente, apenas algumas espécies tinham sido registradas para o Ceará, o único Estado no Brasil quase que inteiramente coberto pela vegetação da Caatinga. O presente trabalho foi realizado em Quixadá e Quixeré, em uma área caracterizada pela presença de afloramentos rochosos e inselbergs. Como resultado, 82 espécies de liquens são aqui registradas, das quais 52 espécies são novos registros para o Ceará, e 14 são citados pela primeira vez para o Brasil. A grande maioria das espécies encontrada é saxícola. Este é o primeiro inventário liquênico nesta região semiárida do Estado, e também o primeiro estudo a relatar um grande número de microliquens saxícolas crostosos no Nordeste do Brasil.

Palavras-chave: Caatinga, diversidade, fungos liquenizados, nordeste, Quixadá

INTRODUCTION

Lichens are an important element of the biodiversity of tropical regions, often covering most of the bark and twigs of trees and shrubs, exposed rock surfaces, the surface of living leaves, and even the ground in places where the soil is poor and dead leaves do not accumulate. These organisms are also important components of tropical ecosystems as primary producers, atmospheric nitrogen fixers, and to balance the water cycle especially after heavy precipitation; cyanobacterial lichens are often the only or main source of nitrogen in tropical ecosystems (Nash 2008).

All Brazilian biomes support lichen communities, often with high species richness and morphological diversity. Almost 4,000 lichen species are known from Brazil, but the total number of species for the country may well be over 8,000, since large areas of rainforest, and also of Cerrado and Caatinga vegetation, are so far unexplored.

The Brazilian semiarid biodiversity is highly threatened due to land conversion for agricultural and cattle ranch (Leal *et al.* 2005, Mamede & Araújo 2008). Ceará is one of the nine states in Northeastern Brazil located in the semiarid region, almost entirely covered by the Caatinga, a scrub savanna with xerophytic vegetation present in most of the semiarid.

Only recently a first comprehensive inventory on the lichen diversity of Ceará State has been published, as a result of an ecological study carried out in Chapada do Araripe, a plateau mountain in the border between the states of Ceará, Piauí, and Pernanbuco (Menezes 2013, Menezes *et al.* 2015). During this first study, it became apparent that the epiphytic lichen diversity of the area was high, with 189 species reported, 170 of which identified to species level (Aptroot & Cáceres 2014). Ten of these were described as new to science by Aptroot *et al.* (2013) and Menezes *et al.* (2013a, b, c).

The study of lichens in Ceará was continued by Alves (2014), who also studied epiphytic lichens in Chapada do Araripe and found around 100 additional species, including a few that were described as new to science by Alves *et al.* (2014a, b) and Aptroot *et al.* (2014). Altogether, 289 lichen species are currently known from Ceará.

The present work was carried out in the municipalities of Quixadá and Quixeré, which is a region characterized by the presence of many rock outcrops, also referred to as an inselberg area (Moro *et al.* 2015). The inselbergs can be considered poorly studied environments in Ceará, in general. The study presented here is the first lichen inventory undertaken in this part of the state, including inselbergs and also a higher altitude forest in the middle of the Caatinga, although the lichens in these areas are considerably less speciose than in Chapada do Araripe. This time lichens were collected on all available substrates, also including rock and compacted soil. Thus, the main objective here is to report species found for the first time in Ceará and first records of lichen species for Brazil.

MATERIAL AND METHODS

Study Area

The municipality of Quixadá is located in the central hinterland of Ceará State, at 04°49'S and 38°58'W, about 200 km south of Fortaleza, the State Capital (Fig. 1). Quixadá stands out for the high concentration of monolithic rocky islands, the inselbergs (Fig. 2A). Quixeré is located on the road to Santa Lucia, at 05°05'S, 37°57'W, and altitude of 130 m.

The other collecting sites are: 1) Açude Cedro, trilha da Pedra da Galinha, alt. *ca.* 250 m, 04°58'S, 39°03'W, Caatinga vegetation; 2) Reserva Particular do Patrimônio Natural Fazenda Daniel de Queiroz, alt. *ca.* 200 m, 04°49'S, 38°58'W, Caatinga vegetation; 3) Serra do Estevão, near sanctuary, alt. *ca.* 250 m, 04°55'44''S, 39°08'50''W secondary rainforest enclave, near Caatinga vegetation; 4) Road from Quixeré to Santa Lucia, alt. *ca.* 130 m, 05°05'S, 37°57'W, Caatinga vegetation.

Lichen sampling, processing and identification

Lichen specimens were sampled in April 2014 in three areas of Caatinga and one rainforest enclave at a higher altitude, in the state of Ceará, Brazil. Three sampling sites were in the municipality of Quixadá, and one in Quixeré. The sampling procedure used was a one-time non-quantitative opportunistic technique, according to Cáceres *et al.* (2008), where the lichens are collected upon visual observation and following the trails present at the sites.

The sampled material was dried using a botanical press at room temperature. After that, the samples were transferred to the lichenological laboratory at Itabaiana Campus of Federal University of Sergipe, where each sample was glued on

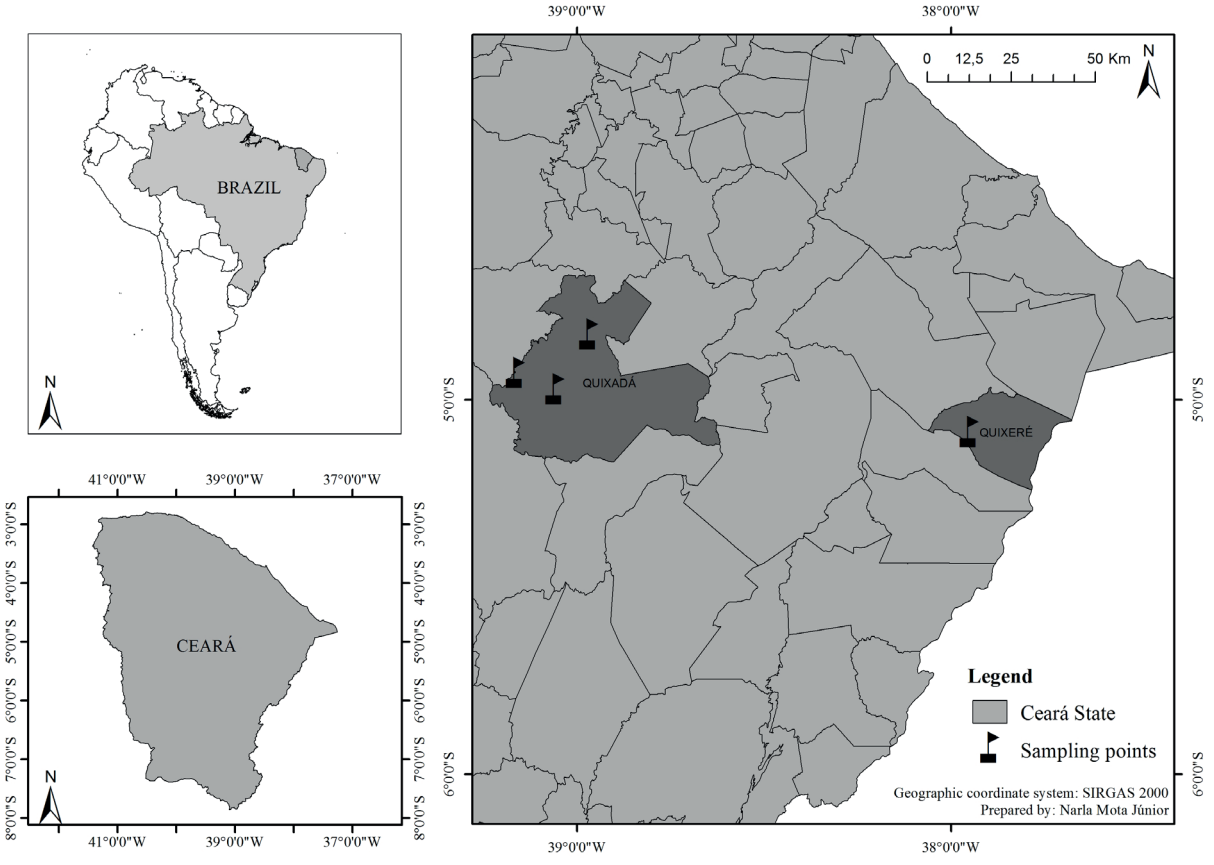


Fig. 1. Map of Ceará State, and the representation of the sampled sites.

cardboard (15 x 9 cm) and labeled with the main information, such as locality, date, and collector's number. The samples were then frozen at -22°C for seven days to prevent arthropod and fungal contaminations. All specimens from this study are preserved in the ISE Herbarium in Itabaiana, Sergipe, and ABL Herbarium in Soest, The Netherlands.

Identifications were made through transversal sections of thalli and ascomata using a Leica EZ4 stereomicroscope and a Leica DM500 compound microscope in Itabaiana-SE, and also in Soest in the Netherlands, 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, in which all measurements were taken. Spot tests were made using solutions potassium hydroxide 10% (KOH), lugol's iodine (2%), sodium hypochlorite (CaClO2), para-phenylenediamine (P) and fluorescence under UV-light to determinate the presence or absence of acids in the cortex and medula. The chemistry of some specimens was investigated by thin layer chromatography (TLC) using solvent C (Orange *et al.* 2001).

Table. 1. New records of corticolous and saxicolous lichens from Ceará, Brasil. B = tree bark, G = gneiss rock, L = limestone, S = soil, SR = schistose rock, NB = new record for Brazil, NC = new record for Ceará.

Family	Species	B	G	L	S	SR	NB	NC
Arthoniaceae	*Arthonia antillarum* (Fée) Nyl.	x						x
	Coniocarpon cinnabarinum DC.	x						x
	Stirtonia microspora Xavier-Leite, M. Cáceres & Aptroot	x						x
Caliciaceae	*Amandinea efflorescens* (Müll. Arg.) Marbach	x						x
Chrysotrichaceae	*Chrysothrix xanthina* (Vain.) Kalb	x						
Collemataceae	*Collema texanum* Tuck.		x				x	x
	Leptogium cyanescens (Pers.) Körb.		x					x
Graphidaceae	*Chapsa aggregata* (Hale) Sipman & Lücking	x					x	x
	Fissurina pseudostromatica Lücking & Rivas Plata	x						
	Glyphis cicatricosa Ach.	x						
	G. scyphulifera (Ach.) Staiger	x						
	G. substriatula (Nyl.) Staiger	x						x
	Graphis cincta (Pers.) Aptroot	x						x
	G. crebra Vain.	x						x
	Leucodecton occultum (Eschw.) Frisch	x						x
	Phaeographis punctiformis (Eschw.) Müll. Arg.	x						
Heppiaceae	*Heppia despreauxii* (Mont.) Tuck.				x		x	x
Lecanoraceae	*Lecanora galactiniza* Nyl.					x		x
	L. helva Stizenb.	x						
	L. leprosa Fée	x						
	L. subimmergens Vain.		x					x
	L. sulfurescens Fée		x					x
	L. tropica Zahlbr.	x						
Lichinaceae	*Pyrenopsis portoricensis* Zahlbr.					x	x	x
	Psorotichia americana Vain.			x			x	x
Monoblastiaceae	*Anisomeridium albisedum* (Nyl.) R.C. Harris	x						x
Parmeliaceae	*Parmotrema praesorediosum* (Nyl.) Hale		x					x
	Xanthoparmelia neopropaguloides Hale		x					x
Peltulaceae	*Peltula euploca* (Ach.) Poelt		x					x
	P. impressa (Vain.) Swinscow & Krog		x					x
	P. obscurans (Nyl.) Gyeln.		x					x
	Phyllopeltula corticola (Büdel & R. Sant.) Kalb	x						x
Pertusariaceae	*Pertusaria flavens* Nyl.	x						
Physciaceae	*Buellia dejungens* (Nyl.) Vain.		x				x	x
	B. halonia (Ach.) Tuck.		x					x
	B. mamillana (Tuck.) W.A. Weber		x					x
	B. stellulata (Taylor) Mudd					x		x
	Cratiria obscurior (Stirt.) Marbach & Kalb	x						
	Dirinaria applanata (Fée) D.D. Awasthi		x					x
	D. confluens (Fr.) D.D. Awasthi	x						
	Heterodermia tremulans (Müll. Arg.) W.L. Culb.		x					x
	Hyperphyscia adglutinata (Flörke) H. Mayrhofer & Poelt	x						x
	H. cochlearis Scutari	x						x
	Monerolechia badia (Fr.) Kalb					x	x	x

Table. 1. Cont.

Family	Species	B	G	L	S	SR	NB	NC
	Physcia alba (Fée) Müll. Arg.	x						x
	P. caesia (Hoffm.) Hampe ex Fürnr. aggr.		x					x
	P. crispa Nyl.	x						x
	P. rolfii Moberg	x						x
	P. sinuosa Moberg	x						x
	P. sorediosa (Vain.) Lynge		x					x
	P. undulata Moberg	x						x
	Pyxine cocoes (Sw.) Nyl.	x						x
	P. microspora Vain.		x					x
	P. petricola Nyl.	x						x
	Rinodina maculans (Kremp.) Müll. Arg.	x						
	R. sipmanii Aptroot	x						x
	Stigmatochroma gerontoides (Stirt.) Marbach	x						
Porinaceae	*Porina isidioambigua* M. Cáceres, M.W.O. Santos & Aptroot	x						x
	Porina subinterstes (Nyl.) Müll. Arg.	x						x
Pyrenulaceae	*Pyrenula confinis* (Nyl.) R.C. Harris	x						
	P. dissimulans (Müll. Arg.) R.C. Harris	x						x
	P. thelomorpha Tuck.	x					x	x
Ramalinaceae	*Bacidia medialis* (Tuck.) Zahlbr.	x						x
	B. schweinitzii (Fr. ex Tuck.) A. Schneid.	x					x	x
	Toninia massata (Tuck.) Herre		x				x	x
Roccellaceae	*Enterographa subserialis* (Nyl.) Redinger	x						x
Strigulaceae	*Strigula laureriformis* Aptroot & Lücking	x					x	x
Teloschistaceae	*Caloplaca araguana* Poelt & Hafellner		x				x	x
	C. diplacia (Ach.) Riddle		x					x
	C. leptozona (Nyl.) Zahlbr.		x				x	x
	C. ochraceofulva (Müll. Arg.) Jatta		x					x
	C. subsoluta (Nyl.) Zahlbr.		x					x
Thelenellaceae	*Thelenella brasiliensis* (Müll. Arg.) Vain.		x					x
Trapeliaceae	*Trapelia coarctata* (Turner) M. Choisy					x		x
Trypetheliaceae	*Mycomicrothelia exigua* (Müll. Arg.) D. Hawksw.	x					x	x
	M. hemisphaerica (Müll. Arg.) D. Hawksw.	x						x
	Polymeridium isohypocrellinum A.B. Xavier-Leite, M.Cáceres & A.Aptroot	x						x
	Trypethelium eluteriae Spreng.	x						
Verrucariaceae	*Agonimia opuntiella* (Buschardt & Poelt) Vězda		x					x
	Endocarpon pallidulum (Nyl.) Nyl.		x					x
	Flakea papillata O.E. Erikss.		x					x

RESULTS AND DISCUSSION

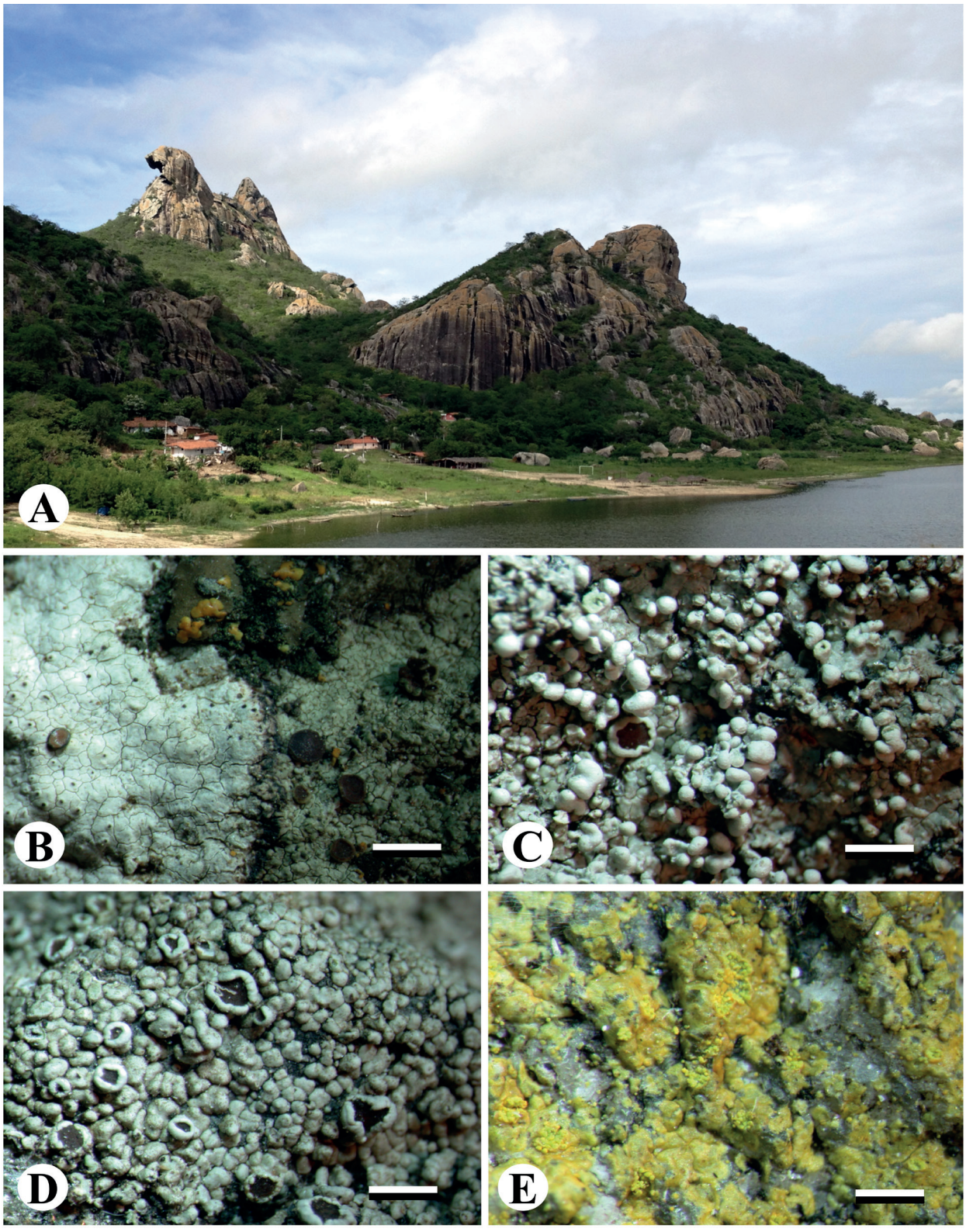
In total, around 300 specimens were collected in localities near Quixadá and Quixeré in Ceará State. In the material, 84 species could be identified (Tab. 1). Of these, 68 are new records for Ceará, and 14 are even new to Brazil.

The following six species were so far not even known from the Southern Hemisphere: *Buellia dejungens* (Nyl.) Vain. (previously known from the Caribbean), *Caloplaca araguana* Poel & Hafellner (Fig. 2B, so far only known from the type locality in Venezuela), *Heppia despreauxii* (Mont.) Tuck. (Fig. 3A, widespread on the northern hemisphere), *Psorotichia americana* Vain. (so far known from the Caribbean), *Pyrenopsis portoricensis* Zahlbr. (so far known from Puerto Rico), *Strigula laureriformis* Aptroot & Lücking (Fig. 3C, so far only known from the type locality in Costa Rica), and *Toninia massata* (Tuck.) Herre (Fig. 3B, widespread on the northern hemisphere).

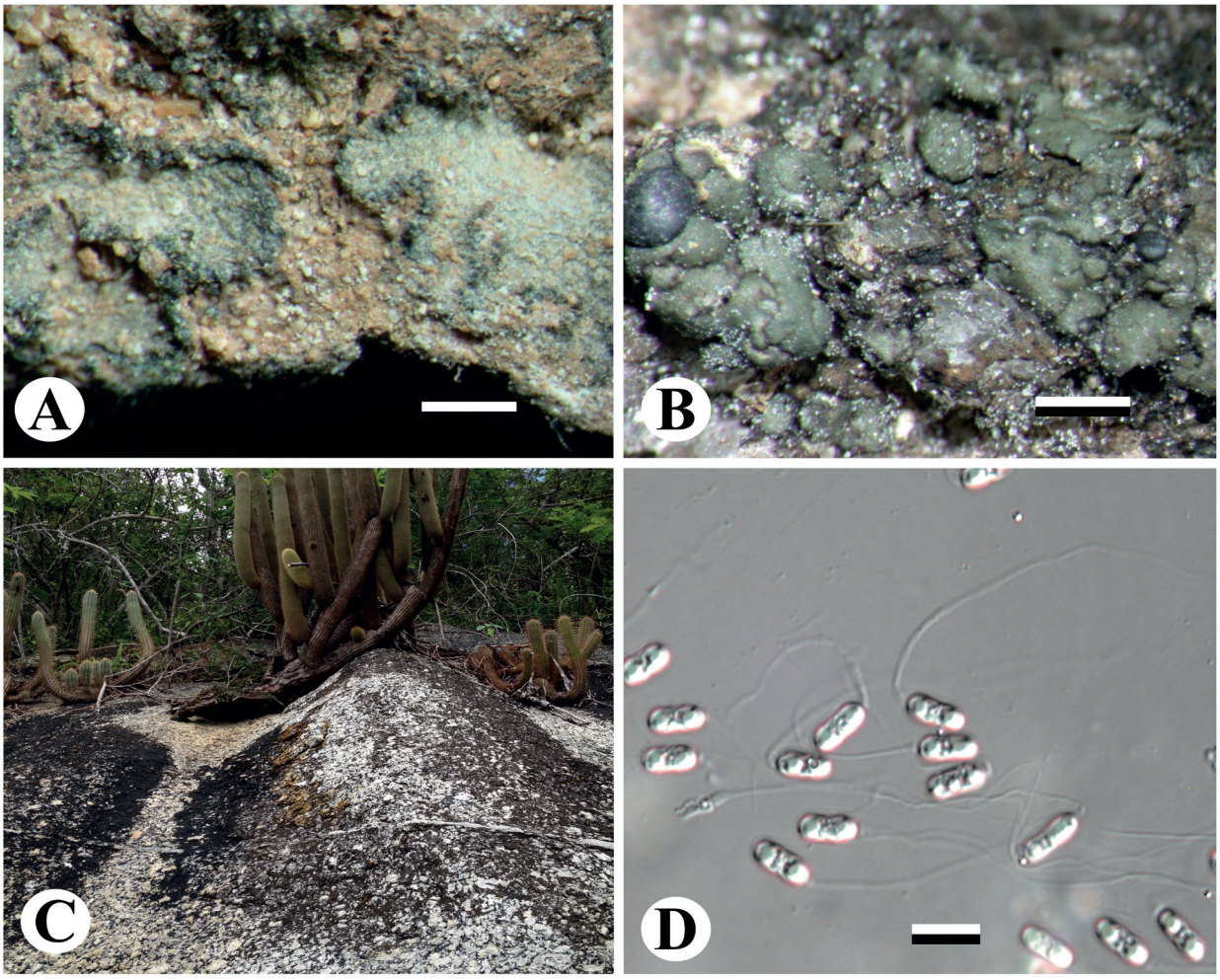
As can be seen already from the above list with the new records for the southern Hemisphere, the saxicolous lichen mycota of Ceará shows strong resemblances with that of some places in the Caribbean (used here in the sense of Caribbean Islands). The climate is similar; the lowland of Ceará can be seen as a Caribbean part of Brazil.

The most speciose group by far in the material are the *Teloschistales*, to which almost half of the identified species belong; *Lichinales*, *Lecanorales* and *Ostropales* are also relatively well represented.

The majority of the newly reported species are saxicolous, only growing on bare rock. The visited area was especially surprisingly rich in species of the genus *Caloplaca* Th. Fr. (*lato sensu*). Species of *Caloplaca* are



Figs. 2A-E. **A.** Pedra da Galinha, showing the abundance of yellow *Caloplaca* species; **B.** Habitus of several *Caloplaca* species in close contact: *Caloplaca araguana* (right hand), *C. diplacia* (left hand) and *C. ochraceoflava* (upper center); **C.** Habitus of undescribed *Caloplaca* species with *Lecanora*-like apothecia and pustules; **D.** Habitus of undescribed *Caloplaca* species with *Lecanora*-like apothecia but without pustules; **E.** Habitus of probably undescribed *Caloplaca* in the *citrina* aggregate. Bars = 1 mm.



Figs. 3A-D. A. Habitus of *Heppia despreauxii*; **B.** Habitus of *Toninia massata*; **C.** Siliceous rock with influence of run-off, showing the black *Peltula impressa* close to the gully in the right and the dark brown *P. obscurans* higher up, mostly to the left and the extreme right; the right is *Caloplaca ochraceoflava*; no lichens in the gully in the center; **D.** Conidia of *Strigula laureriformis* showing the long flagellae. Bars: **Figs. 3A**, **B** = 1 mm; **Fig. C** = 10 μm.

not only numerous, they are also very abundant on some rock outcrops. The famous Pedra da Galinha mountain (Chicken rock) is coloured yellow (Fig. 2A) by several yellow *Caloplaca* species, mainly *C. ochraceofulva* (Müll. Arg.) Jatta (Figs. 2B, 3D) and an unidentified species (Fig. 2E) and could be called Curry chicken rock. Several different species of *Caloplaca*, including species without yellow colour, can grow in close contact (Fig. 2B). Finally, two undescribed but related *Caloplaca* species (Figs. 3, 4) were found to be locally rather common on the Galinha mountain. They will be described as new to science in a forthcoming publication. It is worth noting here that this abundance and diversity of *Teloschistaceae* is here on siliceous rock outcrops, such as the gneiss of the Galinha mountain, not on limestone as usually.

Lichinales grow in two different habitats in this region, *viz.* on siliceous rock outcrops that periodically wet, *e.g.* under influence of run-off from vegetation, and on limestone blocks. Several *Peltula* Nyl. species can form large colonies on places with run-off, avoiding both the wettest and the dry areas (Fig. 3C). Limestone blocks are present (but usually not abundant) all over the area, and two species of Lichinales, *viz. Leprocollema* sp. and *Psorotichia americana* Vain., were found on limestone on all visited locations, making it potentially the commonest lichen in the area. This is rather unexspected for this previously very rarely reported genus and species.

As mentioned before, six species had never been previously reported from the Southern Hemisphere, some of these are widespread, but others were only known from a few localities before, most commonly from then Caribbean. It stresses the similarity between the lichen mycota of Caatinga forest with the Caribbean. The lichen mycota of the Caatinga with inselbergs in Ceará shows some peculiar characteristics: *Teloschistaceae* are dominant on inselbergs (they are even visible form a kilometer distance), even though they are built of siliceous rock, not the substratum usually favoured by members of this family. *Lichinaceae*, usually a rare or inconspicuous element of the lichen mycota, are the most widespread lichens. The results show the importance of

investigating other substrates other than the tree bark, mostly in areas where the corticolous lichen diversity is very poor, compared to other species rich Caatinga areas.

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