



The genus *Cladonia* (Lichenized Ascomycota) from Restinga vegetation of Espírito Santo state, Brazil: Supergroups *Cladonia* and *Cocciferae*

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Abstract

This paper deals with 14 species of the genus *Cladonia*, occurring at Restinga vegetation of Espírito Santo state, with eight belonging to the Supergroup *Cladonia* and six to the Supergroup *Cocciferae*. *Cladonia corallifera*, *C. crustacea*, *C. subminiata*, *C. pityrophylla*, and *C. polyscypha* are new records for the state. An identification key, comments and illustrations are also provided.

Key words: Atlantic rainforest, Cladoniaceae, dimorphic lichens, lichenized fungi, taxonomy.

Resumo

Neste trabalho são tratadas 14 espécies do gênero *Cladonia* ocorrentes em vegetação de Restinga no estado do Espírito Santo, sendo oito pertencentes ao supergrupo *Cladonia* e seis ao Supergrupo *Cocciferae*. *Cladonia corallifera*, *C. crustacea*, *C. subminiata*, *C. pityrophylla* e *C. polyscypha* são novos registros para o estado. São fornecidas chave de identificação, ilustrações e comentários.

Palavras-chave: Mata atlântica, Cladoniaceae, líquens dimórficos, fungos liquenizados, taxonomia.

Introduction

The Restinga vegetation occupies the Quaternary sandy plains, being floristic and structurally associated with the Atlantic rainforest (Suguio & Tessler 1984; Araujo 1992; Martin *et al.* 1997) and is characterized by the phytophysiognomic gradient from the beach towards the continent, ranging from grasslands to shrubs and finally trees, intermingled or not by floodplains (Silva & Somner 1984). Brazilian Restinga woods exhibit an abundant and diverse lichen biota, with *Cladonia* P. Browne among its most representative components (Marcelli 1998).

Data about this genus in Brazilian coastal environments can be found in Ahti *et al.* (1993), Ahti & Marcelli (1995), Ahti (2000), Gumboski & Eliasaro (2011; 2012a,b) and Gumboski *et al.* (2013). Records of *Cladonia* species from Espírito Santo State are relatively few, with only 23 species so far reported by Ahti (2000), whereas to the neighbor Rio de Janeiro State, with a similar area, vegetation and geology, the same author registered over 100 species.

The Supergroup *Cladonia* has a quite diverse thallus morphology, with unbranched to very branched podetia, although always with closed axils and brown apothecial discs. The presence of depsides and depsidones such as atranorin and fumarprotocetraric acids are a diagnostic character for this group (Ahti 2000; Stenroos *et al.* 2002). In contrast, Supergroup *Cocciferae* is characterized by the red apothecial discs, and occasionally by a yellowish medulla, as well as the production of dibenzofurans and β -orcinol depsides such as didymic, barbatic, squamatic and thamnolic acids (Huovinen *et al.* 1989; Stenroos *et al.* 2002). For the Restinga vegetation of Espírito Santo, only six species of Supergroup *Cladonia* and three of *Cocciferae* were previously known (Ahti *et al.* 1993; Ahti 2000).

In order to increase our knowledge of the genus *Cladonia* in the southeastern coastal areas of Brazil, we investigated the diversity of this genus species present along the coast of Espírito Santo State, characterizing their morphology, chemistry, and ecology.

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Materials and Methods

This survey was conducted in Restinga vegetation areas along the coast of Espírito Santo State, with boundaries established by the coordinates 18°28'S and 21°15'S (Fig. 1). The collections were made in eight localities (Tab. 1). According to Köppen's classification, the climate is tropical hot and humid (Aw), with hot and rainy summers and dry winters (Pereira & Araujo 1995).

The specimens were collected and preserved following the standard methods in lichenology (Brodo *et al.* 2001), and deposited at the Herbarium of the Federal University of Paraná (UPCB). Morphological and anatomical analyses were performed under dissecting and compound microscopes using standard microscopic techniques. For the identification of lichen substances, spot tests (K, C, and KC), thin layer chromatography (TLC) with the solvent system C, as well as observation under UV light were conducted (Orange *et al.* 2001; Elix 2014).

Results and Discussion

A total of 14 *Cladonia* species belonging to the Supergroups *Cladonia* and *Cocciferae* were identified, five being new records for the state. The six species belonging to *Cocciferae* Supergroup identified are: *Cladonia corallifera*, *C. crustacea*, *C. subminiata* (new records for the state), as well as *C. didyma*, *C. macilenta*, and *C. secundana* [previously recorded by Ahti (2000)]. From Supergroup *Cladonia* the eight species recognized are: *C. pityrophylla* and *C.*

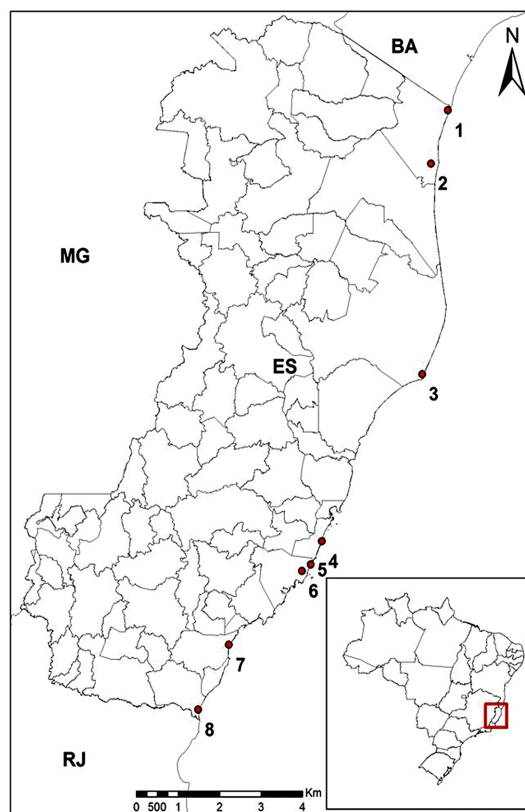


Figure 1- Espírito Santo state map with collection sites highlighted. 1. ISP; 2. EPACB; 3. RB; 4. MNPJ; 5. PCVSP; 6. EPAS; 7. ARB; 8. NB.

polyscypha, two new records for the state. The remaining taxa, *C. cartilaginea*, *C. clathrata*, *C. furfuracea*, *C. subradiata*, *C. subsquamosa* and *C. verticillaris* had already been cited by Ahti (2000) from the state.

Table 1 – Collection sites localities and coordinates.

Municipality	Site name	Acronym	Coordinates
Conceição da Barra	Itaúnas State Park	ISP	18°20'40"S, 39°42'52"W
Conceição da Barra	Environmental Protection Area of Conceição da Barra	EPACB	18°39'28"S, 39°47'4"W
Linhares	Regência Beach	RB	19°39'38"S, 39°52'24"W
Vila Velha	Municipal Natural Park of Jacarenema	MNPJ	20°26'25"S, 40°18'45"W
Guarapari	Paulo Cesar Vinha State Park	PCVSP	20°33'50"S, 40°23'29"W
Guarapari	Environmental Protection Area of Setiba	EPAS	20°34'42"S, 40°25'27"W
Itaóca	Areial Rui Barbosa	ARB	20°56'6"S, 40°49'3"W
Presidente Kennedy	Neves Beach	NB	21°14'35"S, 40°56'48"W

**Key to *Cladonia* species of Supergroups *Cladonia* and *Cocciferae*
in the Restinga vegetation of Espírito Santo**

1. Apothecial disc and pycnidia red, hypothallus yellowish (Supergroup *Cocciferae*) 2
- 1'. Apothecial discs and pycnidia brown, hypothallus brown (Supergroup *Cladonia*) 7
 2. Primary thallus persistent, predominant, podetia short (up to 1 cm) and often scarce 3
 - 2'. Primary thallus somewhat evanescent, podetia fairly long (usually longer than 1 cm) and abundant 5
 3. Primary squamules sorediate at margins 4. *Cladonia crustacea*
 - 3'. Primary squamules esorediate 4
 4. Podetia yellowish green, phyllopodial (a flat squamule that gradually rolling up at the margins so that forms a podetium) 11. *Cladonia subminiata*
 - 4'. Podetia browned, laminal to marginal on primary squamules 10. *Cladonia secundana*
 5. Podetia scyphose 3. *Cladonia corallifera*
 - 5'. Podetia subulate 6
 6. Podetia cylindrical, with farinose soredia, sparsely squamulose 7. *Cladonia macilenta*
 - 6'. Podetia thickened at the base, with granulose soredia, granules, and usually with many microsquamules 5. *Cladonia didyma*
 7. Primary thallus persistent, longer than podetia 8. *Cladonia pityrophylla*
 - 7'. Primary thallus somewhat evanescent, smaller than podetia 8
 8. Podetia with verticillate scyphi (proliferating from the center) 9
 - 8'. Podetia not proliferating from the center 10
 9. Podetia short (up to 3 cm), scyphi clathrate (*e.g.*, perforate), margins dentate 2. *Cladonia clathrata*
 - 9'. Podetia tall (> 3 cm), scyphi not clathrate, margins lacerate (elongated lobes with sharp or irregular edges) 14. *Cladonia verticillaris*
 10. Podetia regularly scyphose 11
 - 10'. Podetia ascyphose to narrowly scyphose 12
 11. Podetia short (up to 1.5 cm), with fairly wide scyphi (up to 8 mm wide) 13. *Cladonia subsquamosa*
 - 11'. Podetia elongate (1–2.5 cm), with narrow scyphi (up to 2.5 mm wide) 9. *Cladonia polyscypha*
 12. Podetia esorediate, with reflexed to isidioid squamules throughout, usually with scyphoid to scyphose apex 6. *Cladonia furfuracea*
 - 12'. Podetia sorediate, ascyphose to narrowly scyphose when developed 13
 13. Podetia with farinose soredia, usually with microsquamules around the base, with an arachnoid white medulla, with a subulate or scyphoid apex when developed 12. *Cladonia subradiata*
 - 13'. Podetia with granulose soredia, phyllidiate, without medulla, never scyphose 1. *Cladonia cartilaginea*

1. *Cladonia cartilaginea* Müll. Arg., Flora 63 :260 (1880). Fig. 2a

Descriptions: Vainio (1894), Ahti (2000).

Spot tests: K+ yellow; C-; KC-; UV-.TLC: fumarprotocetraric and homosekikaic acids.

Selected specimens examined: Presidente Kennedy, NB, 15.I.2015, *C.A.V. Fraga Jr 271* (UPCB). Vila Velha, MNPJ, 24.II.2015, *C.A.V. Fraga Jr 412, 433a* (UPCB).

Cladonia cartilaginea is defined by the subulate, ecorticate podetia, with a hard stereome, covered mainly by granulose soredia and phyllidia (Vainio 1894; Ahti 2000). In this study we found specimens with fumarprotocetraric (*C.A.V. Fraga Jr 433a*) or with homosekikaic acid (*C.A.V. Fraga Jr 412*). Fumarprotocetraric acid is quite common in this species. However, the occurrence of this compound associated with homosekikaic acid has been detected only in Brazilian samples (Ahti 2000).

This species is similar to *C. subradiata*, which also occurs on the State coast. However *C. subradiata* occasionally exhibits narrow scyphi (1–2 mm wide) when well-developed, and a white medulla and conspicuous microsquamules around the base of the podetia (Ahti & Kashiwadani 1984). *C. cartilaginea* is also similar to *C. corymbites* Nyl. and *C. corniculata* Ahti & Kashiw., but the former one has crenulated microsquamules (Ahti 2000), while the second one has larger (2–6 cm) and farinosely sorediate, branched podetia (Ahti & Hammer 2002).

The analyzed specimens often occur on sandy soil, together with mosses in the shades on the shrubs borders.

2. *Cladonia clathrata* Ahti & L. Xavier, Trop. Bryol. 7: 58 (1993). Fig. 2b

Descriptions: Ahti & Marcelli (1995), Ahti (2000).

Spot tests: K+ yellow; C-; KC-; UV-.TLC: Fumarprotocetraric acid.

Selected specimens examined: Conceição da Barra, ISP, 27.I.2015, *C.A.V. Fraga Jr 512* (UPCB); EPACB, 28.I.2015, *C.A.V. Fraga Jr 594* (UPCB). Guarapari, PCVSP, 10.II.2015, *C.A.V. Fraga Jr 347, 360* (UPCB). Itaóca, ARB, 16.I.2015, *C.A.V. Fraga Jr 728* (UPCB). Vila Velha, MNPJ, 24.II.2015, *C.A.V. Fraga Jr 456* (UPCB).

Cladonia clathrata belongs to the *C. verticillaris* complex, and is recognized by its small size (up to 3 cm), the distinctly clathrate (i.e., perforated) scyphi and by the felty surface of podetia (Ahti et al. 1993; Ahti 2000). It is similar to *C. rappii* A. Evans, which differs by not having

the perforations in the scyphi, and also has a strong melanotic base (Ahti & Marcelli 1995). The ascospores of *C. clathrata* measure 8–10 × 3 µm and the primary squamules have a distinct crenulate cortex, but these characters were still unreported. This species is present almost all along the State coast, mainly on sand in exposed areas, or borders of brushwood, also growing mixed with mosses of the family Dicranaceae.

3. *Cladonia corallifera* (Kunze) Nyl., Flora 57: 70 (1874). Fig. 2c

Descriptions: Stenroos (1989c), Ahti (2000).

Spot tests: K+ yellow; C-; KC-; UV-.TLC: rhodocladonic, thamnolic, decarboxythamnolic, didymic, 3α-hydroxybarbatic, squamatic and usnic acids plus unidentified compounds with Rf approximately 34, 38 and 56.

Selected specimens examined: Conceição da Barra, ISP, 27.I.2015, *C.A.V. Fraga Jr 509, 575* (UPCB); EPACB, 28.I.2015, *C.A.V. Fraga Jr 598* (UPCB). Guarapari, PCVSP, 10.II.2015, *C.A.V. Fraga Jr 297, 346* (UPCB); EPAS, 2.III.2015, *C.A.V. Fraga Jr 672, 661, 669* (UPCB). Itaóca, ARB, 16.I.2015, *C.A.V. Fraga Jr 725, 730* (UPCB). Presidente Kennedy, NB, 14.I.2015, *C.A.V. Fraga Jr 221* (UPCB). Vila Velha, MNPJ, 24.II.2015, *C.A.V. Fraga Jr 430* (UPCB).

Cladonia corallifera is characterized by a yellowish short podetia (up to 1.5 cm), that is regularly scyphose, granulose sorediate, often also squamulose, and by a diverse secondary chemistry. It occurs mainly in sandy environments of fluvial origin of northern Brazil (Stenroos 1989c; Ahti 2000).

Cladonia mollis Ahti & Sipman and *C. prancei* Ahti can be confused with *C. corallifera* as they occur in similar environments, and also have an ecorticate, scyphose podetia, with farinose to granulose soredia. However, both species have usually larger podetia (1–3 cm), with narrower scyphi (1–4 mm) (Ahti 2000; Ahti & Sipman 2013).

Cladonia corallifera is morphologically very similar to *C. coccifera*, differing primarily in the secondary metabolites. *C. coccifera* produces porphyritic acid and zeorin, which are absent in *C. corallifera* (Stenroos 1989a,c; Ahti 2000).

Ahti (2000) recorded *C. coccifera* from Restinga vegetation of Espírito Santo state, although in the same paper most specimens were mentioned from highlands, except the collections from the states of Espírito Santo and Bahia. We did not find *C. coccifera* in our study and, unfortunately the specimens mentioned by Ahti (2000) were not located in herbarium SP neither in H (M.P.



Figure 2 – a. *Cladonia cartilaginea*. b. *Cladonia clathrata*. c. *Cladonia corallifera*. d. *Cladonia crustacea*. e. *Cladonia didyma*. f. *Cladonia furfuracea*. (a. C.A.V. Fraga Jr 412; b. C.A.V. Fraga Jr 594; c. C.A.V. Fraga Jr 598; d. C.A.V. Fraga Jr 451b; e. C.A.V. Fraga Jr 698b; f. C.A.V. Fraga Jr 316). Scale bars = 1 cm.

Marcelli, personal communication) and in H (T. Ahti, personal communication). Thus, we could not confirm its occurrence in the Restinga vegetation of Espírito Santo state. We are inclined to believe that the specimen referred as *C. coccifera* in Ahti (2000) could possibly be related to *C. corallifera*, since in our investigation, this species is quite abundant along the collection sites and, *C. coccifera* is mostly reported for highlands in Brazil.

The majority of the specimens analyzed correspond to the chemotype II (usnic and thamnolic acids), and only one to the chemotype I (usnic, thamnolic and didymic acids) mentioned by Ahti (2000). However, in our samples, 3 α -hydroxybarbatic and decarboxythamnolic acids are often present, though have not yet been reported. Despite showing a wide variation in the composition of its secondary metabolites, we did not notice any significant morphological correlation with the chemistry.

In the field, *C. corallifera* was found on white sand or on dry wood, in well-lit environments such as in open shrub formations, forming yellowish colonies, growing alone or together with *C. polystomata* Ahti & Sipman, *C. subradiata*, *C. didyma* and *C. polyscypha*. It is mainly reported for northern Brazil (Ahti 2000), being a new record for Espírito Santo State.

4. *Cladonia crustacea* Ahti, Fl. Neotrop. Monogr. 78: 191 (2000). Fig. 2d

Description: Ahti (2000).

Spot tests: K+ yellow; C-; KC-; UV-. TLC: thamnolic and decarboxythamnolic acids plus an unidentified compound with R_fc approximately 47. **Selected specimens examined:** Vila Velha, MNPJ, 24.II.2015, *C.A.V. Fraga Jr 440a, 439a, 451b* (UPCB).

Cladonia crustacea is defined by the abundantly sorediate margins of the squamules, forming a subcrustose coverage, sparsely bearing inconspicuous podetia (up to 5 mm tall), and by producing thamnolic and decarboxythamnolic acids (Ahti 2000).

It is similar to *C. ahtii* S. Stenroos and *C. miniata* G. Meyer by having squamules with a sorediate margin, but differs from *C. ahtii*, which has corticate podetia and from *C. miniata*, which has orange medulla. Also, both *C. ahtii* and *C. miniata* occur in higher altitudinal environments (Stenroos 1989b; Ahti 2000). It is also morphologically similar to *C. hypoxantha* Tuck. However, in this species, the squamules are narrower, and not abundantly sorediate (Ahti 2000).

It is an inconspicuous species, and is essentially corticolous/lignicolous, forming powdery, and easily overlooked crusts. It was found above 50 cm from the ground in an arboretum in open shrub formation. This is the first record of this species for the Espírito Santo State.

5. *Cladonia didyma* (Fée) Vain., Acta Soc. Fauna Fl. Fenn. 4: 137 (1887). Fig. 2e

Descriptions: Vainio (1887), Ahti (2000).

Spot tests: K+ yellow or -; C-; KC-; UV-; TLC: rhodocladonic didymic, condidymic, subdidymic, thamnolic and decarboxythamnolic acids, plus two unidentified compounds with R_fc approximately 30, 34 and 52.

Selected specimens examined: Conceição da Barra, ISP, 27.I.2015, *C.A.V. Fraga Jr 557* (UPCB). Guarapari, PCVSP, 13.II.2015, *C.A.V. Fraga Jr 315a* (UPCB); EPAS, 23.VII.2015, *C.A.V. Fraga Jr 904* (UPCB). Itaóca, ARB, 16.I.2015, *C.A.V. Fraga Jr 698b, 701* (UPCB). Presidente Kennedy, NB, 14.I.2015, *C.A.V. Fraga Jr 203, 220, 248* (UPCB). Vila Velha, MNPJ, 24.I.2015, *C.A.V. Fraga Jr 431* (UPCB).

Cladonia didyma is distinguished by its ecorticate and subulate ascyphose podetia, with a granulose to squamulose cover, without soredia (Vainio 1887; Fleig et al. 1995) and also, by the production of barbatic, thamnolic or didymic acids (Ahti 2000).

According to Gumboski & Eliasaro (2012b), *C. didyma* may comprise a complex of species accordingly to some morphological differences found in the populations studied by them. The specimens included here as *C. didyma* also exhibit some morphological variations, such a melanotic stereome in some specimens, and farinose soredia with granules and squamules. In addition, the specimen *C.A.V. Fraga Jr 557*, showed a clearly pellucid central canal with yellow hyphae in podetia section. Thus, a phylogenetic analysis using molecular data are required to elucidate if the different populations of *C. didyma* comprises or not a complex of species, and also to delimit the values of the taxonomic characters.

Cladonia didyma is very similar to *C. macilenta* since both species have subulate and ecorticate podetia, also by the production of the same secondary metabolites (Ahti 2000). However, *C. didyma* differs from *C. macilenta* by having a more granulose/squamulose podetia, leaving an exposed stereome. We also observed that the podetia of *C. didyma* are somewhat more robust than *C. macilenta*, and usually have a squamule ring below the apothecial discs.

When the apothecial discs and pycnidia are absent, *C. didyma* can be confused with *C. cartilaginea* or even with young specimens of *C. furfuracea*, by presenting an ecorticate surface and subulate podetia. However, both *C. cartilaginea* and *C. furfuracea* produce the fumarprotocetraric acid complex, and *C. furfuracea* is also usually scyphose (Ahti 2000; Gumboski & Eliasaro 2012a,b).

This is one of the most commonly found *Cladonia* species along the Espírito Santo Restinga woods, occurring throughout the coast, colonizing sand, termite hills, litter and dead branches. It occurs in open areas or borders of bushes, without accompanying species or together with *C. subradiata*, *C. subsquamosa*, and *C. furfuracea*.

6. *Cladonia furfuracea* Vain., Acta Soc. Fauna Fl. Fenn. 10: 375 (1894). Fig. 2f

Descriptions: Vainio (1894), Ahti (2000).

Spot tests: K+ yellow or -; C-; KC-; UV-; TLC: fumarprotocetraric acid.

Selected specimens examined: Conceição da Barra, ISP, 27.I.2015, *C.A.V. Fraga Jr 578* (UPCB); EPACB, 28.I.2015, *C.A.V. Fraga Jr 638* (UPCB). Guarapari, PCVSP, 10.II.2015, *C.A.V. Fraga Jr 316, 352, 369* (UPCB). EPAS, 2.III.2015, *C.A.V. Fraga Jr 660, 664* (UPCB). Itaóca, ARB, 16.I.2015, *C.A.V. Fraga Jr 685a* (UPCB). Presidente Kennedy, NB, 14.I.2015, *C.A.V. Fraga Jr 253b* (UPCB). Vila Velha, MNPJ, 24.II.2015, *C.A.V. Fraga Jr 421, 435* (UPCB).

This species can be distinguished by the ecorticate, esorediate and usually scyphose podetia, that are 3–6 (–8) cm tall, often with a bare stereome, and covered by some corticated verruculae (Vainio 1894; Fleig *et al.* 1995), and reflexed isidioid squamules, producing fumarprotocetraric acid (Fleig *et al.* 1995; Ahti 2000; Stenroos *et al.* 2002).

Cladonia furfuraceoides Ahti & Sipman is very similar, but it is smaller (1–3 cm tall) than *C. furfuracea*, and exhibits a strongly melanotic base of podetia and elongated podetial squamules (Stenroos *et al.* 2002; Ahti & Sipman 2013). In this study, some specimens also exhibited a melanotic base (ca. 15%), mainly in buried parts. The podetial squamules, range from isidioid to clearly flattened, elongated and reflexed, and the secondary thallus hardly reaches 3 cm tall. Such characteristics approach the description of *C. furfuraceoides*. However, we believe that these variations can be caused by environmental conditions, since the thallus size of *C. furfuracea* seems to increase with altitude (Charnei & Eliasaro 2014), whereas

is found smaller in coastal environments. These variations deserve further investigations with support of molecular data to evaluate the range of its phenotypic plasticity and of its taxonomical characters.

Cladonia polystomata Ahti & Sipman is another similar species, also have an ecorticate, esorediate podetia with squamules and both can occur together in field. However, *C. polystomata* usually has funnels and open axils, also differing by producing thamnolic acid and related compounds (Ahti 2000).

It is a common species along the Espírito Santo State coast, growing on sand at edge of shrubs, occasionally growing together with *C. clathrata* and *C. subradiata*.

7. *Cladonia macilenta* Hoffm., Deuschl. Fl. 2: 126 (1796). Fig. 3a

Descriptions: Vainio (1887), Ahti (2000).

Spot tests: K+ yellow; C-; KC-; UV-; TLC: rhodocladonic, barbatic, thamnolic, condidymic, didymic and subdidymic acids.

Selected specimens examined: Itaóca, ARB, 16.I.2015, *C.A.V. Fraga Jr 690, 704b, 713* (UPCB).

The diagnostic characters of *C. macilenta* are the cylindrical, ecorticate and always ascyphose podetia, covered by a farinose soredia (Vainio 1887), and the production of barbatic, didymic and thamnolic acids (Ahti 2000).

It is morphologically and chemically close to *C. didyma*, but it is often difficult to interpret their morphological characters (see discussion under *C. didyma*). The analyzed specimens displayed slender and usually proportionally cylindrical podetia. Also, the presence of a whorl of squamules below the hymenial discs is absent. We noticed that there is a tendency for the apothecial discs to be simple, flattened, and often with a central perforation (not funnel), rather than agglomerate, like in *C. didyma*. It was also observed that there are granular soredia and few granules, but to a lesser extent farinose soredia. *C. macilentoides* Ahti & Fleig is also very similar to *C. macilenta*, but it presents a more robust morphology, exhibiting taller podetia (3–5 cm), with an acuminate apex, tending to be more branched (Fleig *et al.* 1995). In addition, *C. macilentoides* does not produce both barbatic and didymic acids, which are present in *C. macilenta* (Ahti 2000). When sterile, it may be confused with *C. subradiata*, by its slender, ecorticate and subulate podetia, differing by their secondary metabolites, and by the presence of a scyphoid apex

in *C. subradiata*. *Cladonia macilenta* produces thamnolic and didymic acids, which are absent from *C. subradiata* (Fleig *et al.* 1995).

It is an inconspicuous species that occurs on litter and dead wood, rarely on sand, in fairly shaded areas. It was found mostly alone or intermixed with *C. didyma*.

8. *Cladonia pityrophylla* Nyl., Flora 57: 70 (1874). Fig. 3b

Descriptions: Vainio (1894), Ahti (2000).

Spot tests: K⁺ yellow → reddish; C⁻; KC⁻; UV⁻; TLC: fumarprotocetraric acid.

Selected specimens examined: Guarapari, PCVSP, 10.II.2015, C.A.V. Fraga Jr 314, 335b (UPCB). Vila

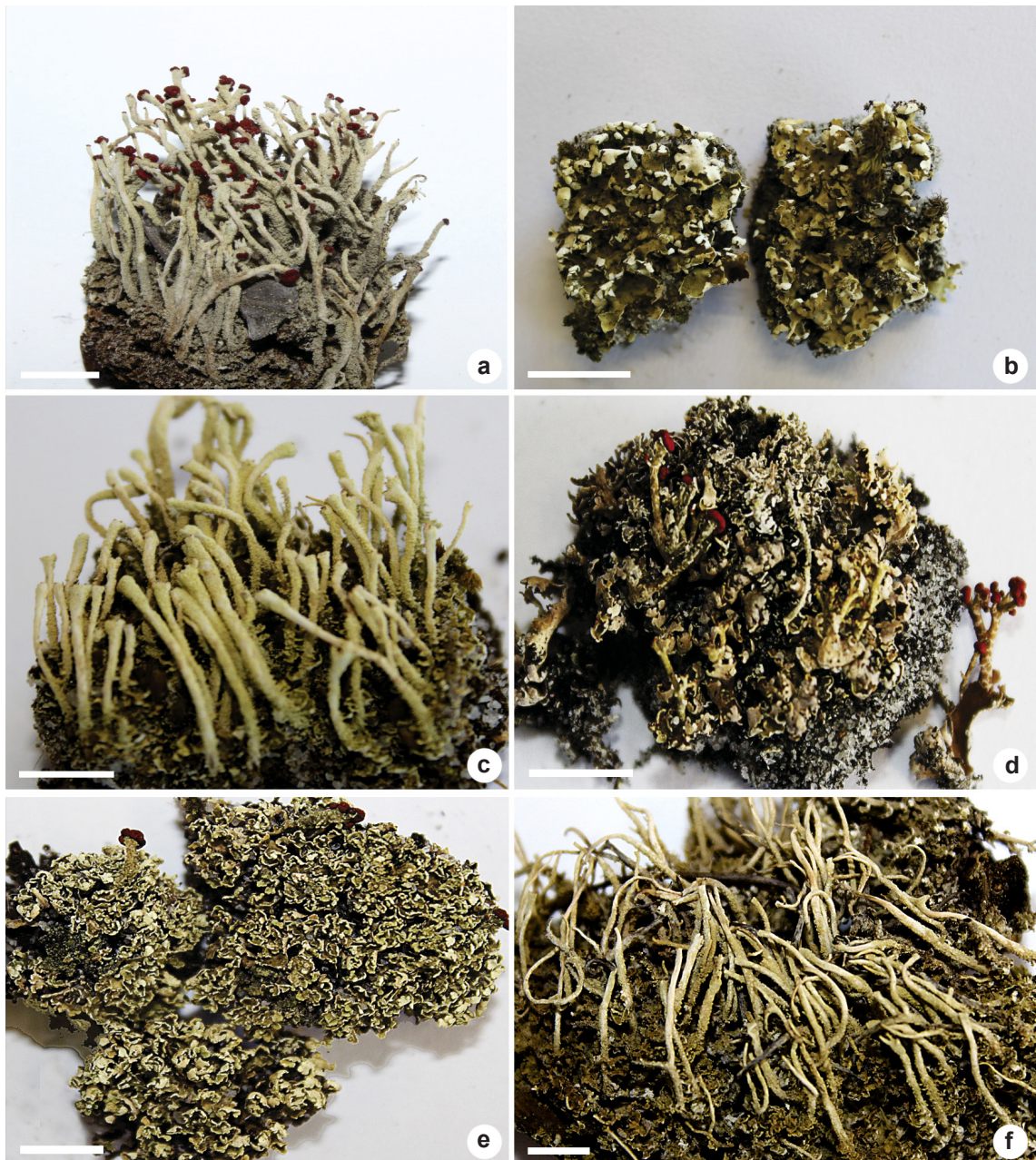


Figure 3 – a. *Cladonia macilenta*. b. *Cladonia pityrophylla*. c. *Cladonia polyscypha*. d. *Cladonia secundana*. e. *Cladonia subminiata*. f. *Cladonia subradiata*. (a. C.A.V. Fraga Jr 704b; b. C.A.V. Fraga Jr 335b; c. C.A.V. Fraga Jr 588; d. C.A.V. Fraga Jr 549; e. C.A.V. Fraga Jr 891; f. C.A.V. Fraga Jr 253a). Scale bars = 1 cm.

Velha, MNPJ, 24.II.2015, *C.A.V. Fraga Jr 386b, 433b, 444a, 452, 457a* (UPCB).

Cladonia pityrophylla is characterized by the well-developed primary thallus without rhizines in the margins, by the laminal growing, ecorticate, usually subulate podetia, covered by bullate to globose squamules, and by the production of fumarprotocetraric acid (Vainio 1894; Fleig *et al.* 1995; Ahti 2000).

Cladonia ceratophylla (Sw.) Spreng. is a similar species. However, the podetia do not exhibit globose or bullate squamules, and also can produce atranorin (Ahti 2000). In the specimens *C.A.V. Fraga Jr 444* and *457*, we found scarce black rhizines on the margins of squamules, which we consider as a morphological variation, since other morphological and chemical characters fits the description present in Ahti (2000). *C. latiloba* Ahti & Marcelli and *C. subcariosa* Nyl. are also similar because of the conspicuous squamules (Ahti 2000), but both are distinguishable by their podetia, which in *C. latiloba* are clavate and ecorticate, while in *C. subcariosa* they are corticate. Moreover, neither of them have bullate squamules, and generally produce atranorin, a compound not found in *C. pityrophylla*.

It is a rare species in the study area, essentially arenicolous, found mostly solitary in shady places, colonizing bare sand around shrubs or even buried. This is the first record of this species for Espírito Santo state.

9. *Cladonia polyscypha* Ahti & L. Xavier, Trop. Bryol. 7: 61 (1993). Fig. 3c

Descriptions: Ahti *et al.* (1993), Ahti (2000).

Spot tests: K+ yellow → brownish; C-; KC-; UV-; TLC: fumarprotocetraric acid.

Selected specimens examined: Conceição da Barra, ISP, 27.I.2015, *C.A.V. Fraga Jr 487* (UPCB); EPACB, 28.I.2015, *C.A.V. Fraga Jr 588, 616* (UPCB). Guarapari, PCVSP, 10.II.2015, *C.A.V. Fraga Jr 299* (UPCB); EPAS, 2.III.2015, *C.A.V. Fraga Jr 645* (UPCB). Linhares, RB, 26.II.2015, *C.A.V. Fraga Jr 468c* (UPCB). Itaóca, ARB, 16.I.2015, *C.A.V. Fraga Jr 704a* (UPCB). Presidente Kennedy, NB, 14.I.2015, *C.A.V. Fraga Jr 213c* (UPCB). Vila Velha, MNPJ, 24.II.2015, *C.A.V. Fraga Jr 424c* (UPCB).

Cladonia polyscypha is characterized by the slender and ecorticate podetia, usually with a melanotic, compact corticate sheath around the base (Ahti 2000), with a very narrow scyphi, and by producing fumarprotocetraric acid (Ahti *et al.* 1993).

It is very similar to *C. subradiata*, which differs by the absence of a melanotic base of podetia and by the more subulate/ascyphose apex (Ahti *et al.* 1993). *C. ramulosa* (With.) J.R. Laundon and *C. ochracea* L. Scriba are also similar, but *C. ramulosa* has a more granular soredia and *C. ochracea* has granules, and in both cases the base of the podetia is neither melanotic nor well corticate (Ahti 2000; Gumboski & Eliasaro 2012a).

It was mainly found on sand, also occurring in termite hills, organic and clay soil in open areas or edges of brushwood. Found together with *C. didyma*, *C. furfuracea* and *C. subradiata*. This is the first record of this species for the Espírito Santo state.

10. *Cladonia secundana* Nyl., Flora 57: 71 (1874). Fig. 3d

Descriptions: Stenroos (1989b), Ahti (2000), Ahti & Sipman (2013).

Spot tests: K+ yellow; C-; KC-; UV-: TLC: rhodocladonic, didymic, condidymic, subdidymic, fumarprotocetraric and usnic acids, plus an unidentified substance with Rfc 58.

Selected specimens examined: Conceição da Barra, ISP, 27.I.2015, *C.A.V. Fraga Jr 549* (UPCB). Guarapari, PCVSP, 10.I.2015, *C.A.V. Fraga Jr 301a* (UPCB).

Cladonia secundana is characterized by the long and deeply laciniate squamules, that are olive brown in color, with podetia arising laminally or marginally (Stenroos 1989b), and by the highly variable chemistry, with about 30 compounds reported (Ahti 2000).

It is close related to *C. subminiata*, another species of the *C. miniata* complex. Both have a similar gross morphology and geographical distribution in eastern Brazil. However, in *C. subminiata* the thallus is more yellowish due the presence of usnic acid, and the podetia are clearly phyllopodial (Ahti *et al.* 1993; Stenroos 1989b). The specimen *C.A.V. Fraga Jr 549* presented usnic acid, in addition to didymic, condidymic and subdidymic acids, compounds reported for *C. subminiata*. Despite this, the specimen showed laminal to marginal podetia, with more brownish coloration, characteristics that morphologically distinguish it from *C. subminiata*. We accept the aforementioned specimen as *C. secundana* based in a similar case reported by Stenroos (1989b), which also considers a specimen with a similar morphology as *C. secundana*, arguing about its highly variable chemistry.

According to Ahti (2000), this species has long been confused with *C. miniata* G. Mey., but is differentiated by the color of the medulla, which is red in *C. miniata*.

It is an essentially an arenicolous species, found mainly buried in the white sand, leaving few parts exposed. It was recorded alone, forming inconspicuous patches on the soil in open and well-lit areas.

11. *Cladonia subminiata* S. Stenroos, Ann. Bot. Fenn. 26: 256 (1989). Fig. 3e

Descriptions: Stenroos (1989b), Ahti (2000).

Spot tests: K+ yellow; C-; KC-; UV-; TLC: Rhodocladonic, didymic, condidymic, subdidymic, barbatic and usnic acids.

Selected specimens examined: Conceição da Barra, ISP, 27.I.2015, *C.A.V. Fraga Jr 504, 518, 519, 535* (UPCB); EPACB, 28.I.2015, *C.A.V. Fraga Jr 541* (UPCB). Guarapari, PCVSP, 10.II.2015, *C.A.V. Fraga Jr 302, 334, 339, 365* (UPCB); EPAS, 2.III.2015, *C.A.V. Fraga Jr 891* (UPCB).

Cladonia subminiata is characterized by the conspicuous, ascending and yellowish primary squamules, with constantly phyllopodial podetia, and by the production of usnic and didymic acids (Stenroos 1989b).

Cladonia subminiata is also included in *Cladonia miniata* complex, and is very close to *C. secundana* (see comments under the later species).

This species forms extensive colonies on bare white sand, being highlighted by the red apothecial disc through the white sand. It was found mainly isolated, but was also registered together with *C. clathrata*. This is the first record of this species for Espírito Santo State.

12. *Cladonia subradiata* (Vain.) Sandst., Abh. Naturwiss. Vereine Bremen 25: 230 (1922). Fig. 3f

Description: Ahti (2000).

Spot tests: K+ yellow → brownish; C-; KC-; UV-; TLC: fumarprotocetraric acid.

Selected specimens examined: Conceição da Barra, ISP, 27.I.2015, *C.A.V. Fraga Jr 507, 552* (UPCB); EPACB, 28.I.2015, *C.A.V. Fraga Jr 611, 612a* (UPCB). Guarapari, PCVSP, 10.II.2015, *C.A.V. Fraga Jr 293* (UPCB); EPAS, 23.VII.2015, *C.A.V. Fraga Jr 882* (UPCB). Itaóca, ARB, 16.I.2015, *C.A.V. Fraga Jr 698* (UPCB). Linhares, RB, 27.I.2015, *C.A.V. Fraga Jr 458* (UPCB). Presidente Kennedy, NB, 15.I.2015, *C.A.V. Fraga Jr 239b, 253a* (UPCB). Vila Velha, MNPJ, 24.II.2015, *C.A.V. Fraga Jr 399* (UPCB).

This species is characterized by the simple to little branched, subulate and ecorticate podetia, often with squamules around the base, ascyphose

to and narrowly scyphose when mature, and by the production of fumarprotocetraric acid (Ahti 2000).

It is inconspicuous and easily confused with *C. cartilaginea* or *C. polyscypha* (see discussion on these taxa). *C. subradiata* is also very similar to *C. didyma* when both are sterile, due its ecorticate and subulate podetia, but *C. didyma* has a yellow hypothallus, and produces barbatic, didymic and thamnolic acids (Fleig *et al.* 1995; Ahti 2000). In some cases, the latter species can have a darker to melanotic podetia, which do not occur in *C. subradiata*. *Cladonia corniculata* Ahti & Kashiw. is also morphologically similar, but never produces scyphi and is reported mainly from highlands (Ahti 2000).

This is one of the most common species of *Cladonia* along the Espírito Santo state coast, occurring in a wide variety of substrates, like on sand, wood and termite hills, in open or shaded areas. Usually occurs together with *C. subsquamosa*, *C. didyma* and *C. polyscypha*.

13. *Cladonia subsquamosa* Kremp. in Warming, Vidensk. Meddel. Dansk Naturhist. Foren. Kjøbenhavn 5: 336 (1874, '1873'). Fig. 4a

Descriptions: Ahti (2000), Ahti & Sipman (2013).

Spot tests: K+ yellow → brownish or -; C-; KC-; UV-; TLC: fumarprotocetraric acid.

Selected specimens examined: Conceição da Barra, ISP, 27.I.2015, *C.A.V. Fraga Jr 483* (UPCB); EPACB, 28.I.2015, *C.A.V. Fraga Jr 633* (UPCB). Guarapari, PCVSP, 10.II.2015, *C.A.V. Fraga Jr 357, 374* (UPCB); EPAS, 2.II.2015, *C.A.V. Fraga Jr 635* (UPCB); 23.VI.2015, *C.A.V. Fraga Jr 885* (UPCB). Itaóca, ARB, 16.I.2015, *C.A.V. Fraga Jr 721* (UPCB). Linhares, RB, *C.A.V. Fraga Jr 467a, 468b* (UPCB). Presidente Kennedy, NB, 15.I.2015, *C.A.V. Fraga Jr 235* (UPCB). Vila Velha, MNPJ, 24.II.2015, *C.A.V. Fraga Jr 401, 454a* (UPCB).

This species is characterized by the ecorticate and scyphose podetia, with a throughout deciduous sorediate layer, that in most cases leaves a bare stereome, and by the production of fumarprotocetraric and quaesitic acids (Ahti & Kashiwadani 1984; Ahti 2000; Ahti & Sipman 2013).

Cladonia chlorophaea (Flörke ex Sommerf.) Spreng. is morphologically similar by having an ecorticate and scyphose podetia, however, it is covered mainly by granules rather than soredia, and is almost constantly corticated in the basal region (Bungartz & Ahti 2009). Ahti (2000) argues that *C. fimbriata* (L.) Fr. is also morphologically and chemically similar to *C. subsquamosa*, but differs by having a more persistent farinose soredia and medulla. Ahti (2000) reports the constant presence of

quaesitic acid (= convirensic acid) in *C. subsquamosa*, but all analyzed specimens here produced only fumarprotocetraric acid as a secondary metabolite. The same was noticed by Gumboski & Eliasaro (2012) and Charnei & Eliasaro (2014).

It is a widely distributed and common species, being one of the most common species in Espírito Santo Restinga woods. It occurs on sand, wood and termite hills, without accompanying species or with *C. subradiata*, *C. furfuracea* and *C. polyscypha*.

14. *Cladonia verticillaris* (Raddi) Fr., Lichenogr. Eur. Reform. 465 (1831). Fig. 4b

Descriptions: Ahti & Marcelli (1995), Ahti (2000).

Spot tests: K+ yellow → brownish; C-; KC-; UV-; TLC: fumarprotocetraric acid.



Figure 4 – a. *Cladonia subsquamosa*. b. *Cladonia verticillaris*. (a. *C.A.V. Fraga Jr 483*; b. *C.A.V. Fraga Jr 428*). Scale bars = 1 cm.

Selected specimens examined: Guarapari, PCVSP, 10.II.2015, *C.A.V. Fraga Jr 287, 322* (UPCB). Itaóca, ARB, 16.I.2015, *C.A.V. Fraga Jr 724, 731* (UPCB). Presidente Kennedy, NB, 15.I.2015, *C.A.V. Fraga Jr 230* (UPCB). Vila Velha, MNPJ, 24.II.2015, *C.A.V. Fraga Jr 428, 442* (UPCB).

Cladonia verticillaris is characterized by the brownish green podetia, with yellowish to brown or melanotic bases (Ahti & Marcelli 1995), bearing broad and verticillate scyphi, with lacerate margins that are often squamulose, producing fumarprotocetraric acid (Ahti 2000).

Besides *C. verticillaris*, *C. clathrata* is the only other species that has verticillate scyphi found in Espírito Santo Restinga vegetation. These species are quite distinct. However, as *C. verticillaris* exhibits taller podetia (3–15 cm), with lacerate scyphi, instead of being dentate. For additional information about species of the *C. verticillaris* complex in Brazil see Ahti & Marcelli (1995) and Charnei & Eliasaro (2013).

This is a common species along the Southeast and Northeast Brazilian coast, found growing on bare sand and litter, both in open areas and in borders of brushwood. Usually grows alone, but was found with *C. crispatula* (Nyl.) Ahti.

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