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The lichen family Cladoniaceae in Paraiba, Pernambuco and Sergipe, Northeast Brazil

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Abstract. Field and herbarium studies of the lichen family Cladoniaceae in the states of Paraíba, Pernambuco and Sergipe, Northeast Brazil, yielded 22 species, many of them being new reports for the region. The phenolic compounds identified in each species are reported. *Cladonia clathrata* Ahti & Xavier Filho, *Cladonia polita* Ahti, *Cladonia polyscypha* Ahti & Xavier Filho, and *Cladonia rugicaulis* Ahti are described as new. *C. clathrata, C. rhodoleuca* Vainio, *C. rugicaulis, C. salzmannii* Nyl., and *C. subminiata* Stenroos appear to represent an element confined to northeastern Brazil.

Northeast Brazil, i.e. the states Alagôas, Bahia, Ceará, Maranhao, Paraíba, Pernambuco, Piauí, Rio Grande do Norte, and Sergipe is a large tropical area, which is lichenologically still very poorly known. From Bahia there are some early and more recent (e.g., Britto et al. 1982) records but from Paraíba, for instance, the first lichen records probably date from von Luetzelburg (1923: 231-232), and for most of the states there are apparently no published lichen records at all. However, since about 1960 studies on lichens have been performed in the Federal Universities of Pernambuco, Recife, and of Paraíba, Joâo Pessoa. A. Chaves Batista and his coworkers studied many foliicolous microlichens, but their collections at Recife (URM) also include some macrolichens. From the seventies Lauro Xavier Filho and his coworkers have published many smaller papers on lichens of Paraíba and Pernambuco; their collections are primarily in Joâo

Pessoa (JPB), some in Recife (UFP). A small collection of lichens in another herbarium in Recife (IPA) was also checked.

As to the Cladoniaceae, the authors Ahti and Xavier Filho particularly collected specimens of this family in Paraíba in 1987, and Stenroos (together with Sibylle Grundtlehner) joined them on a trip to Sergipe in 1990. Ahti and Stenroos also collected in Pernambuco together with Eugênia Pereira in 1990. These collections are deposited in Joâo Pessoa (JPB) and Helsinki (H). In addition, we have examined the material in Tokyo (TNS) collected by S. Kurokawa and L. Xavier Filho in 1971 and that in Baton Rouge, Louisiana (LSU) collected by Shirley Tucker in 1976.

Our collecting was not exhaustive but because we visited some of the very few areas where species of this family are common and abundant we believe our report includes almost all the species found in the area.

The state of Bahia is excluded from the present study because we have not collected there, although we have examined many specimens from there. It has many more species which are not known elsewhere in the Northeast. One specimen of *Cladonia* was examined from Rio Grande do Norte, but not a single specimen has been seen from the rest of the northeastern states.

As to the earlier records of Cladoniaceae from the area they were mainly published in studies on physiology, antibiotic activity or chemistry of lichens. The identifications are often in need of revision. In many cases we have made an attempt to reidentify the species according to the modern taxonomy, based on recent, largely unpublished studies on neotropical Cladoniaceae by the author Ahti.

Study area

The western, mostly interior parts of the Northeast of Brazil belong to the *cerrado* vegetation province, the central, major part to the *caatinga*, and the coastal strip to the *Atlantic forest* (e.g., Lima 1957, F. Carvalho 1978, Eiten & Goodland 1979, F. Carvalho & M. Carvalho 1985).

The cerrado is poor in Cladoniaceae in general, though some 1-3 species can be found in the Distrito Federal, for instance. The northeastern cerrados are apparently so dry (3-5 months of effective dry season and annual precipitation about 800-1000 mm) that the Cladoniaceae cannot exist there.

The caatinga experiences a true semiarid climate, with 6-8 (occasionally even 12) months of dry season, so that the Cladoniaceae are definitely absent in most of this vegetation type. Some other lichens may be abundant, including saxicolous species, especially because rock outcrops and stones are common in this area. However, in Pernambuco, in the moister eastern edge of caatinga called the *Agreste* formation, some species of Cladoniaceae were recorded.

The 30-50 km wide coastal strip of the study area is included in the Atlantic rainforest. The annual rainfall is 1800-2200 mm, but about two months are fairly dry. The normal mesophytic forest is too shady a habitat for Cladoniaceae, but on road banks and on rotten wood in second-growth forests they can be found. Their major habitat is, however, the so- called *tabuleiro* vegetation, i.e. sandy coastal hills about 100 m (-300 m in Sergipe) in elevation, covered by open woodlands formed by *Byrsonima cydoniifolia, Hancornia speciosa, Anacardium occidentale, Ouratea spp., Curatella americana,* etc. Such local cerrado-like woodlands are still well-developed near Santa Rita (ca. 15 km NW of the town) and Alhandra (ca. 30 km S of Joâo Pessoa) in Paraíba, and on Serra do Itabaiana in Mun. Arenas Brancas, Sergipe, which were visited. Fires are common in such woodlands, but the Cladoniaceae flourish at certain postfire stages. In most other places on the tabuleiros the native vegetation has been replaced by vast fields of sugar cane plantations, now grown for production of alcohol (Proálcool) for automobile fuel. The Cladoniaceae are really endangered organisms in the whole region. In the sandy restinga communities near the seashore no Cladoniaceae were observed.

In Paraíba the antimicrobial and antitumorial activity of the Cladoniaceae has been studied extensively (e.g., Silva et al. 1986, Pereira 1989). The extracts of these lichens (especially *Cladonia substellata*; Pereira 1989) have been found to inhibit the Gram positive bacteria and some microfungi (including soil organisms), in particular. In extracts from lichens collected in the dry season the inhibition effects on microorganisms turned out to be highest (Pereira 1989). Being of potential practical interest the conservation of some of the lichen-rich tabuleiro communities is highly desirable.

Material and methods

In addition to the field and herbarium work almost all the lichen specimens were subjected to a chemical analysis in Helsinki with thin-layer chromatography (TLC) or in part also with high performance liquid chromatography (HPLC) for the identification of their phenolic products. The HPLC analyses, performed with Dr. Keijo Huovinen, are not considered in detail in this connection. A number of specimens from the area were also analyzed chemically in earlier studies with various methods (see, e.g., Xavier Filho 1973, Carrazzoni & Wanderley 1974, Cavalcanti et al. 1983b, Xavier Filho et al. 1984, Vicente et al. 1984, Legaz et al. 1987).

The taxa

The herbarium symbols follow the standard lists (Salomon 1985, Holmgren et al. 1990). The Brazilian distribution of each species is given with the standard abbreviations of the states (many are new state records!), the following ones being cited: AC (Acre), AM (Amazonas), BA (Bahia), DF (Distrito Federal), ES (Espírito Santo), GO (Goiás), MG (Minas Gerais), MT (Mato Grosso), PA (Pará), PB (Paraíba), PE (Pernambuco), PR (Paraná), RJ (Rio de Janeiro), RN (Rio Grande do Norte), RR (Roraima), RS (Rio Grande do Sul), SC (Santa Catarina), SE (Sergipe), SP (Sâo Paulo).

1. **Cladia aggregata** (Swartz) Nyl.

Synonyms: *Lichen aggregatus* Swartz, *Cladonia aggregata* (Swartz) Sprengel

Descriptions: Filson (1981), Stenroos et al. (1992).

Chemistry: Stictic, constictic, norstictic, and cryptostictic acids. Elsewhere in Brazil and through most of the range of *C. aggregata* a barbatic acid chemotype is dominant. However, the chemotype with the stictic acid group is also known from the Chapada Diamantina region, northern Bahia, which indicates that the Sergipe outlier is probably deriving from the same source.

Specimens examined: Sergipe. Mun. Arenas Brancas, 1989 *Ahti et al. 48930* (H).

Distribution in Brazil: BA, ES, GO, MG, PR, RJ, RS, SE, SP.

Notes: Although widespread in South America, this species is almost lacking in the tropical lowlands. The Sergipe locality is its northern outpost in eastern Brazil.

2. **Cladina dendroides** (Abb.) Ahti

Synonyms: *Cladonia sandstedei* f. *dendroides* Abb., *Cladonia dendroides* (Abb.) Ahti

Description: Ahti (1961).

Chemistry: Atranorin, fumarprotocetraric and protocetraric acids, and the substance Cph-2. - The report on atranorin and fumarprotocetraric acid of Cladonia sprucei to occur in soil under the lichen in Santa Rita by García-Junceda & Xavier Filho (1986) actually belongs to *C. dendroides*. Besides these compounds Vicente et al. (1984) reported orsellinic acid, orcinol and methyl b-orcinol carboxylate and an unknown compound in this species (as *Cladonia sandstedei*) in Paraíba. However, the latter ones must be degradation products caused by the use of methanol in the mobile phase of the HPLC analysis or the storage

conditions (Huovinen & Ahti 1986: 99, Legaz et al. 1987: 86). In material collected at Santa Rita Legaz et al. (1987) and Legaz & Vicente (1989) reported only atranorin and usnic acid in *C. dendroides* in their thorough chemical analyses (incl. TLC, HPLC). Since no usnic acid has been found by us in our numerous analyses of this species, their material may have included some impurity (e.g., the species is commonly immixed with *Cladonia substellata*); the absence of fumarprotocetraric acid may be also doubtful, as discussed by the authors themselves.

Specimens examined: Paraíba. Mun. Alhandra, 1962 *Tavares 956* (JPB), 1987 *Ahti & Xavier Filho 45685*, 45696 (H, JPB); Mun. Santa Rita, 1985 *Pereira & Xavier Filho* (JPB), 1987 *Ahti & Xavier Filho 45619, 45637* (H, JPB), *45648* (B, H, ICN, JPB, NY, SP, US, UPS). Pernambuco. Tabuleiro de Gôiana, 1976, *Tucker 16779* (H, JPB, LSU).

Distribution in Brazil: BA, PB, PE, RJ, SP.

Notes: The recognition of this species by Ahti (1961) was based on very little material and its status was uncertain. On the tabuleiros in Paraíba it is one of the most abundant lichens, forming large colonies up to 15 cm tall. Our field studies confirm that it is a distinct species, characterized by a very dense, isotomic top of podetium, but with several distinct, angular main stems lower down, rapid disintegration of medullary layer on stereome (old stems bare), and red slime in conidiomata. - In earlier studies (Vicente et al. 1984, Xavier Filho et al. 1985) in Paraíba this species has been referred to as *C. sandstedei*, a West Indian species.

3. **Cladina rangiferina** (L.) Nyl. subsp. **abbayesii** (Ahti) Culb.

Synonyms: *Cladonia rangiferina* var. *abbayesii* Ahti

Descriptions: Ahti (1961), Sipman & Cleef (1979).

Chemistry: Atranorin, fumarprotocetraric acid, protocetraric acid (tr), Cph-2 (tr).

Specimens examined: Sergipe. Mun. Arenas Brancas, *Ahti et al. 48941* (H, JPB, SP), *Stenroos et al. 3875* (B, CTES, H, JPB, NY, R, US).

Distribution in Brazil: AM, BA, MG, RR, SE.

Notes: New to Brazil. This species has been confused with other taxa, e.g. *C. sprucei* (Ahti) Ahti and *C. dendroides*, in Brazil, but there are now scattered records from mountains of Minas Gerais, in particular. Only one scarce colony was found in the study area.

4. **Cladonia cartilaginea** Müll. Arg.

Description: Vainio (1894).

Chemistry: Fumarprotocetraric acid, protocetraric acid (tr), Cph-2 (tr).

Specimens examined: Pernambuco. S of Gôiana, 1971 *Kurokawa & Xavier Filho 8009* (TNS); Caruar£, 1976 *Tucker 16783* (H, LSU).

Distribution in Brazil: AM, MG, PE, RJ, RS, SP.

Notes: A widespread species of road banks in South America.

5. **Cladonia clathrata** Ahti & Xavier Filho, sp. nova (Figs. 1, 2)

A Cladonia rappii *A. W. Evans scyphis podetiorum clathratis et cortice tomentulato differt. Acidum fumarprotocetraricum continens.*

Primary thallus persistent, squamules 2-6 x 1-4 mm in size. Podetia 2-4.5 cm tall, pale grey to lilac; scyphose, scyphi proliferating from the centre, forming 5-8 tiers, which are 3-8 mm wide, soon perforate and finally strongly clathrate when viewed from above; scyphal margins deeply cleft, with few to 20 broad teeth. Surface of podetia matt, clearly felty down to the base, surface of central canal strongly papillate. Podetial wall 200-280 µm thick, with weak cortex 15-

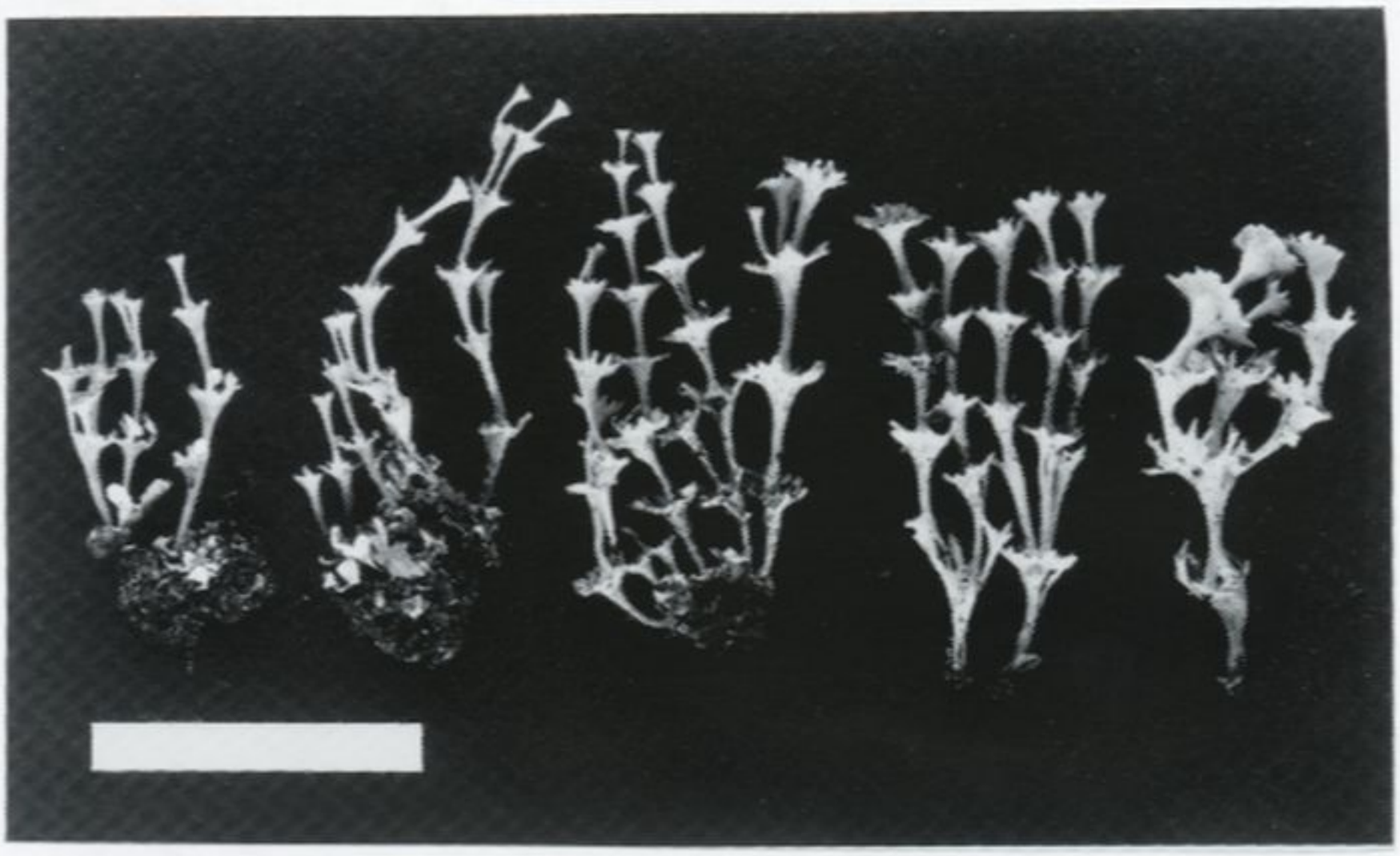

Fig. 1. Cladonia clathrata Ahti & Xavier Filho. Paraíba, Ahti & Xavier Filho 48940 (H). General habit. Bar = 2 cm.

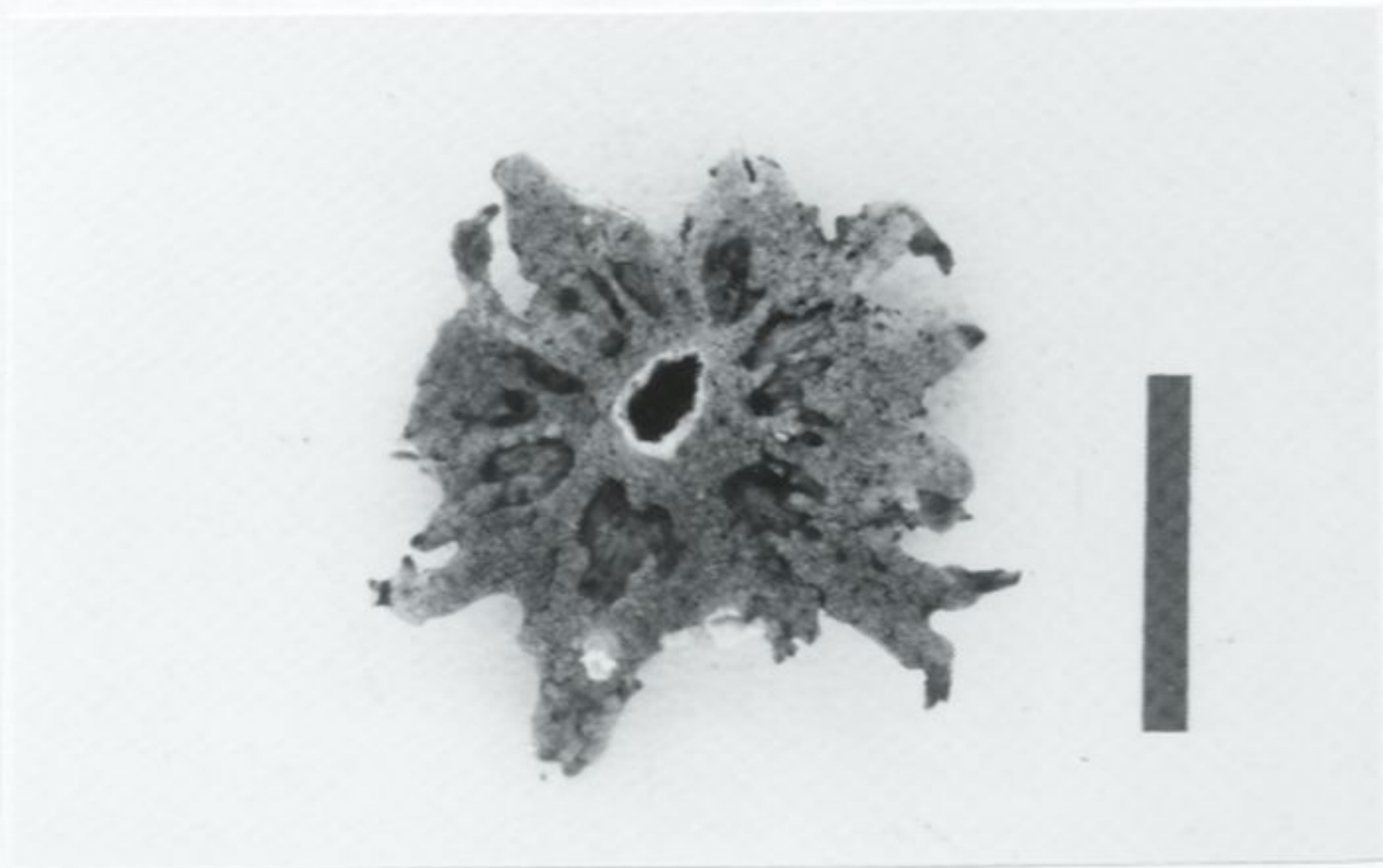

Fig. 2. Cladonia clathrata. Scyphal plate from above. Specimen as in Fig. 1. Bar = 5 mm.

25 µm, medulla 75-100 µm, and stereome 75-125 µm. Conidiomata pyriform, 120-150 x 80-120 µm, constricted at base, sessile or stalked. Hymenial discs brown, no mature spores seen.

Type. Brazil. Paraíba: Mun. Alhandra, near Highway BR-101 30 km S of Joâo Pessoa, 120 m, 1987 *T. Ahti & L. Xavier Filho 45697* (JPB, holotype; B, H, NY, SP, isotypes).

Chemistry: Fumarprotocetraric and protocetraric acids and the substance Cph-2, sometimes also Cph-1.

Specimens examined (paratypes): Paraíba. Mun. Alhandra, 1987 *Ahti & Xavier Filho 45681* (H, JPB, US), 45692 (H, JPB, UFP); Mun. Santa Rita, 1987 *Ahti & Xavier Filho 45621, 45643* (H, JPB, NY, RB), *45633* (H, JPB). Pernambuco. Gôiana, 1970 *Galileu 762* (US); S of Gôiana, 1971 *Kurokawa & Xavier Filho 8010, 8011* (TNS). Sergipe. Mun. Arenas Brancas, 1989 *Ahti et al. 48922, 48940* (H), *Stenroos et al. 3872* (H).

Distribution in Brazil: BA, ES, MG, PB, PE, SE.

Total distribution: Brazil, primarily in Northeast Brazil, particularly on sandy habitats near the coast.

Notes: This is a distinct species, characterized by numerous perforations on the scyphal plates, making the plates clathrate with age, and the felty surface.

6. **Cladonia didyma** (Fée) Vainio

Descriptions: Vainio (1887), Thomson (1968), Stenroos (1986).

Chemistry: Barbatic acid, 4-0-demethylbarbatic acid (tr), didymic acid, condidymic acid (tr), subdidymic acid (tr).

Specimens examined: Pernambuco. Recife, 1960 *Batista & Bezerra* (UFP); Serra do Bituri, 1968 *Carrazoni & Maríz* (JPB, UFP). Rio Grande do Norte. Mun. Nizia Floresta, 1986 *Roque da Fonseca* (JPB). Sergipe. Mun. Arenas Brancas, 1987 *Ahti et al. 48944* (B, H, JPB, SP), *48947* (H).
Distribution in Brazil: AM, BA, MG, MT, PA, PE, PR, RJ, RN, RR, RS, SC, SE, SP.

Notes: The thamnolic acid chemotype, which is also widespread in Brazil, has not been recorded in the study area.

7. **Cladonia furfuracea** Vainio

Description: Vainio (1894).

Chemistry: Fumarprotocetraric acid, protocetraric acid (tr), Cph-2 (tr).

Specimens examined: Paraíba. Mun. Alhandra, 1987 *Ahti & Xavier Filho 45679, 45683, 45703* (H, JPB), *45704* (H, ICN, JPB); Mun. Santa Rita, 1987 *Ahti & Xavier Filho 45627, 45628, 45629, 45654* (H, JPB). Sergipe. Mun. Arenas Brancas, 1989 *Ahti et al. 48920* (H, JPB), 48923 (H), *48928* (H).

Distribution in Brazil: AM, BA, MG, PB, PR, RR, SC, SE, SP.

8. **Cladonia miniata** G. Meyer var. **parvipes** (Vainio) Zahlbr.

Synonym: *Cladonia miniata* f. *parvipes* Vainio

Descriptions: Vainio (1887), Stenroos (1989).

Chemistry: Barbatic, 4-0-demethylbarbatic and rhodocladonic (also medullary) acids.

Specimens examined: Sergipe. Mun. Arenas Brancas, 1981 *Xavier Filho* (H, JPB), 1987 *Stenroos et al. 3876, 3879* (H, JPB, NY, SP).

Distribution in Brazil: BA, MG, SC, SE.

Notes: The conspicuous species *Cladonia miniata* characterized (besides *C. salmonea* Stenr.) by its bright red medulla is widespread in tropical America, but in our area it is only represented by

var. *parvipes*. This variety was actually first reported from Sergipe by Stenroos (1989: fig. 8A), but the specimen was erroneously cited under Santa Catarina. More studies are still required to confirm whether var. *parvipes* is actually a distinct species. In habit its slender, branchy podetia are quite different from the normally very thick and short podetia of var. *miniata*.

9. **Cladonia pityrophylla** Nyl.

Description: Vainio (1894).

Chemistry: Fumarprotocetraric acid, protocetraric acid (tr), Cph-2 (tr).

Specimens examined: Paraíba. Mun. Alhandra, 1987 *Ahti & Xavier Filho 45687, 45741* (H, JPB); Mun. Santa Rita, 1987 *Ahti & Xavier Filho 45624, 45625, 45630* (H, JPB). Pernambuco. Mun. Bonito, 1989 *Ahti et al. 48847* (H); Caruar£, 1976 *Tucker 16783a* (H). Sergipe. Mun. Arenas Brancas, 1989 *Ahti et al. 48916, 48924, 48945* (H).

Distribution in Brazil: AM, BA, DF, MG, MT, PA, PB, PE, PR, RJ, RR, RS, SC, SE, SP.

10. **Cladonia polita** Ahti, spec. nova (Fig. 3)

A Cladonia sphacelata *Vainio differt podetiis brunneis, nitido-corticatis, minus squamulosis. Semper acidum squamaticum, interdum etiam acidum thamnolicum continens.*

Primary thallus persistent, consisting of up to 0.5 cm long, laciniate squamules, which have short, almost terete stalks, below often with ochraceous central streak. Podetia borne marginally on squamules, grey to usually more or less brown, up to 5 cm tall; sowhat branched, branching type irregular anisotomic dichotomy, rarely trichotomy or tetrachotomy; main axes 0.3-0.5 mm thick; axils closed, tips often divided into 2-10 short branchlets. Surface continuously corticate in upper parts, cortex smooth and shiny; soon partly transformed into microsquamules, being finally rather densely squamulose; mature squamules narrow, laciniate and imbricate, up to 4 mm long; esorediate. Podetial wall 200-290 µm, cortex (0)25-40 µm, consisting of large cells, medulla very thin, (0)10-25 µm (incl. the algae), stereome distinctly delimited, very horny, thick, 200-250 µm; inner surface papillate. Conidiomata terminal, 200-250 x 100-150 µm, dolioliform, constricted at base, shortly pedicellate, containing red slime, conidia 10 x 1 µm. Hymenial discs brown, aggregated into 0.5 cm wide corymbose heads at podetial tips; spores 12-15 x 3 µm.

Type. Brazil. Sâo Paulo: Ilha do Cardoso, near research center CEPARNIC, 1982 *M.P.Marcelli 3710* (SP, holotype; H, isotype).

Chemistry: Squamatic acid.

Specimens examined (paratypes): Paraíba. Mun. Santa Rita, 1987 *Ahti & Xavier Filho 45626, 45645, 45649* (H, JPB). Pernambuco. S of Gôiana, 1971 *Kurokawa & Xavier Filho 8006* (TNS).

Distribution in Brazil: PB, PE, PR, RJ, SC, SP.

Taxonomic notes: There are scattered records of this species from the Brazilian coast, from Santa Catarina up to Paraíba.

11. **Cladonia polyscypha** Ahti & Xavier Filho, spec. nova (Fig. 4)

A Cladonia ramulosa *(With.) Laundon podetiis tenuissimis (vulgo 0.3-0.8 mm crassis), ramosis, partim abundanter sorediosis, partim corticatis differt. Acidum fumarprotocetraricum continens.*

Primary thallus persistent but inconspicuous, consisting of 0.5-2 mm wide, esorediate but granular squamules. Podetia 1-3(3.5) cm tall, very slender and thin, (0.2)0.3-0.8(1.3) mm wide, whitish to greenish-grey, often becoming brownish when sun-exposed, necrotic bases slightly melanotic; unbranched or somewhat branched, either by dichotomy or scyphus formation; tips regularly becoming scyphose but the scyphi stay extremely narrow (0.1-0.2 mm) for a long time

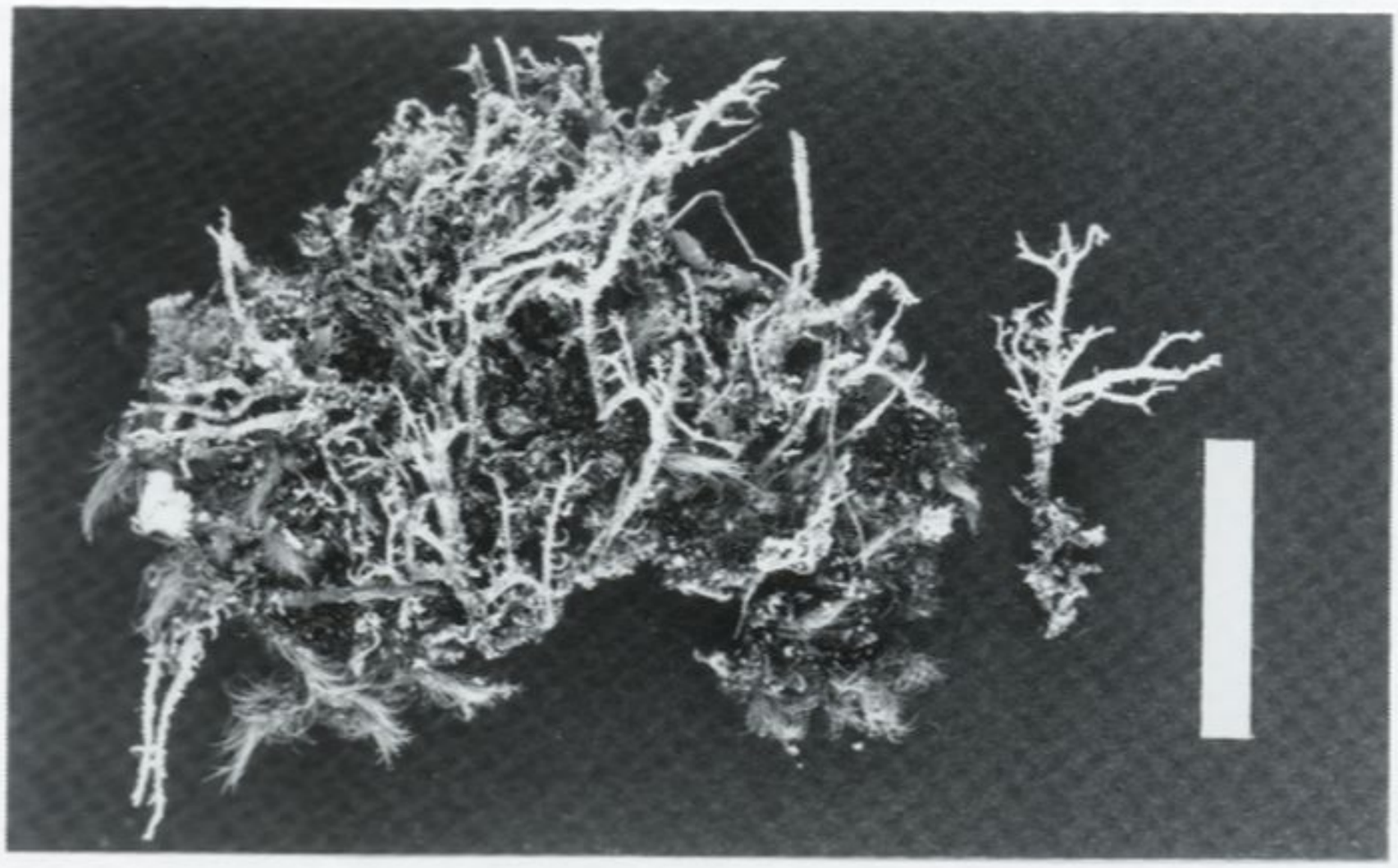

Fig. 3. Cladonia polita Ahti. Paran , Smith 910207004 (H). Bar = 2 cm.

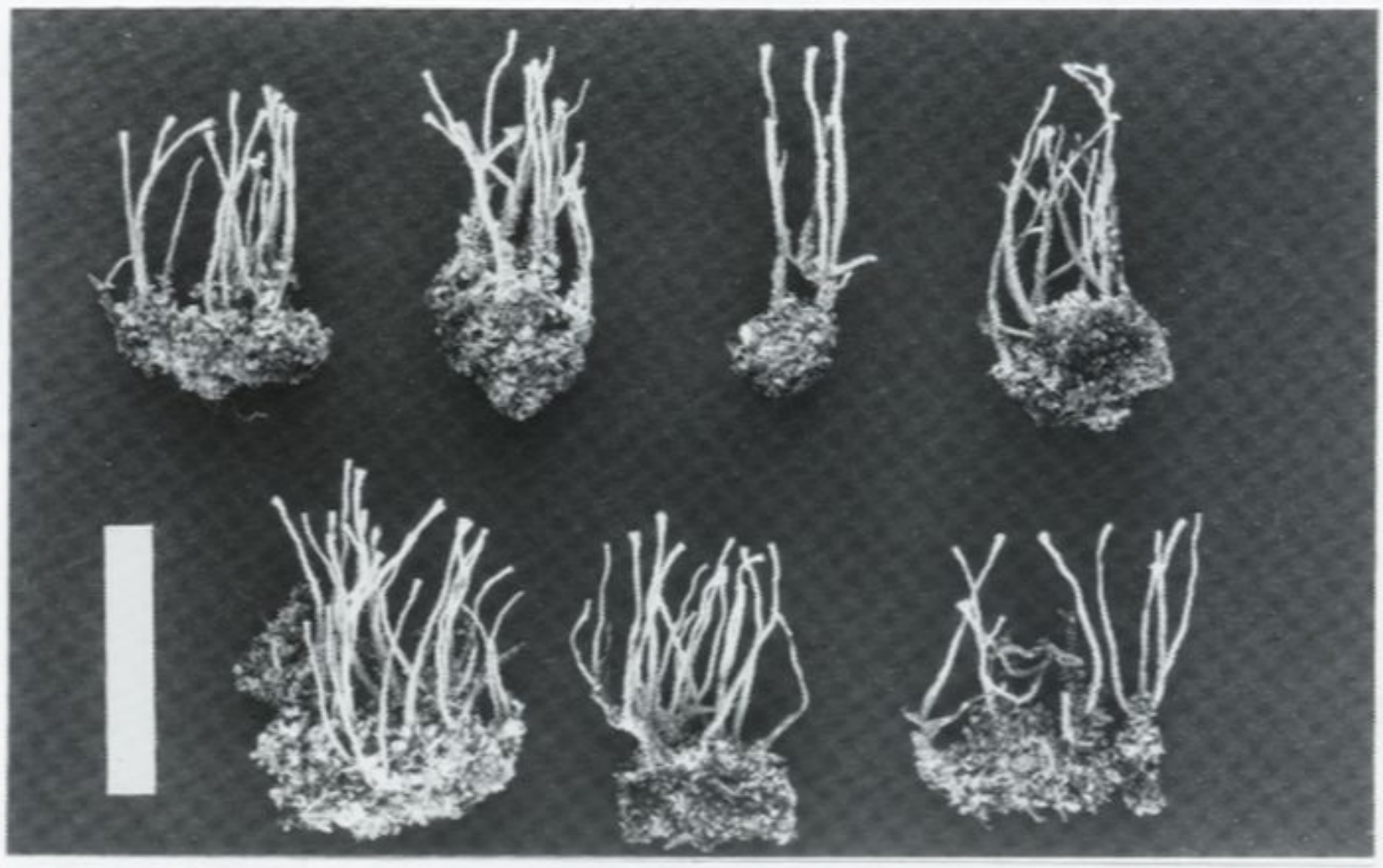

Fig. 4. Cladonia polyscypha Ahti & Xavier Filho. Paraíba, holotype (H). Bar = 2 cm.

until they open up to 1(2) mm wide at the maturity. Surface corticate at base or sometimes up to 1/2 of the podetial length, and regularly inside and outside the fertile scyphi, also often on basal parts of the branchlets; otherwise sorediate, soredia either farinose or immixed with granules or tiny squamules. Podetial wall 160-230 µm, cortex (0)10-25 µm, medulla (with algal layer) 50-75 µm, stereome 100-125 µm, inner surface densely papillulate. Conidiomata common, terminal, globose to pyriform, clearly constricted at base, 80-150 x 100 x 210 µm, conidia 12-10 x 1 µm, slightly arcuate. Hymenial discs brown, no mature spores seen.
Type: Brazil. Paraíba. Mun. Alhandra: by Highway BR-101 c. 30 km S of Joâo Pessoa, alt. c. 120 m, 7°27'S, 34°56'W, sandy tabuleiro, semiopen scrub (cerrado), 9 January 1987 *T.Ahti & L. Xavier Filho 45698* (H, holotype; JPB, isotype).

Chemistry: Fumarprotocetraric and protocetraric acids and the substance Cph-2.

Specimens examined (paratypes): Paraíba. Mun. Santa Rita, 1987 *Ahti & Xavier Filho 45652* (H, JPB). Sergipe. Mun. Arenas Brancas, 1989 *Ahti et al. 48946* (H), *Stenroos et al. 3874* (H, JPB, NY, SP).

Distribution in Brazil: MG, PB, SE; range poorly known.

Total distribution: Brazil, Guyana, Venezuela, range poorly known.

Notes: This species may resemble *C. subradiata* but is distinguished by frequent scyphi and much more corticate and often brown podetia. From *C. ramulosa* it is distinguished by its slender habit caused by thin, relatively tall podetia, which are finely sorediate in part; *C. ramulosa* is esorediate or has finely granulose (soredioid) structures. At the type locality it was growing side by side with *C. subradiata*, appearing distinctive.

12. **Cladonia ramulosa** (With.) Laundon

Synonyms: *Cladonia pityrea* (Fr.) Floerke, *C. anomaea* Ahti & P.James

Descriptions: Vainio (1894), Thomson (1968).
Chemistry: Fumarprotocetraric and protocetraric acids and the substance Cph-2.

Specimens examined: Pernambuco. Tabuleiro de Gôiana, 1971 *de Barros* (JPB 953), 1970 *Xavier Filho* (H, JPB 763).

Distribution in Brazil: MG, PA, PE, RJ, RS, SC, SP, range poorly known.

Notes: The present specimens are similar to those of *C. polyscypha* but the podetial surface is granular-corticate rather than sorediate, the scyphi are wider and the primary thallus well-developed. The specimen JPB 763 was reported as *C. "pityrea"* in Barros & Xavier Filho (1972).

13. **Cladonia rhodoleuca** Vainio

Description: Vainio (1887).

Chemistry: Thamnolic and decarboxythamnolic acids.

Specimens examined: Paraíba. Mun. Santa Rita, 1987 *Ahti & Xavier Filho 45641* (H, JPB). Pernambuco. S of Gôiana, 1971 *Kurokawa & Xavier Filho 8008* (TNS).

Distribution in Brazil: MG, PB, PE.

Notes: *Cladonia rhodoleuca* is very close to *C. sphacelata* Vainio, and it is still uncertain whether they are distinct species. *C. rhodoleuca* can be distinguished by its pink colouring in older parts and less squamulose podetia.

14. **Cladonia rugicaulis** Ahti, spec. nova (Fig. 5)

Cladoniae crispatulae *(Nyl.) Ahti (sect.* Perviae*) affinis sed axes principales podetiorum veteriores crassiores, verruculoso-rugulosi, ramuli apicales superficie fibrillosi, ecorticati, medulla crassa et gelatina pycnidiorum hyalina. Acidum thamnolicum continens.*

Primary thallus not seen. Podetia 4-8(11) cm tall, main axes 0.7-1.5(4) mm thick, greenish to glaucous-grey; richly branched, branching type anisotomic to subisotomic dichotomy (30-50%), trichotomy (20-30%) and tetrachotomy (20-40%); axils closed to open. Surface matt, smooth in the young parts, soon becoming verruculose-rugulose; ecorticate and fibrillose at the apex, lower down weakly but continuously corticate, rarely squamulose (a few small squamules seen in Ahti & Xavier Filho 45684). Podetial wall thick, 250-350 µm, cortex (0)10-20 µm, medulla (225)250-280 µm, stereome 35-50(80) µm, 1/4-1/3 of the wall thickness, very sharply delimited from the medulla. Conidiomata very shortly cylindrical, 150 x 100 µm, containing hyaline slime. Hymenial discs not seen.

Type: Brazil. Paraíba: Mun. Santa Rita, c. 15 km NW of Santa Rita, 120 m, 1987, *T. Ahti & L. Xavier Filho 45632* (JPB, holotype; B, BM, H, NY, SP, TNS, UFP, UPS, US, isotypes).

Chemistry: Thamnolic acid, decarboxythamnolic acid (tr).

Specimens examined: Paraíba. Mun. Alhandra, 1976 *Tucker 16778* (LSU), 1966 *Xavier Filho* (JPB 552, 564), 1985 *Xavier Filho & Pereira* (JPB), 1987 *Ahti & Xavier Filho 45702* (CTES, H, JPB, SP), *45678* (H, JPB, RJ), *45684* (DUKE, H, JPB, R); Mun. Condé 1971 *Kurokawa & Xavier Filho 8103-8106* (TNS). Mun. Pedra de Fogo, Lima (IPA 58-3226); Mun. Santa Rita, 1987 *Ahti & Xavier Filho 45620* (DUKE, FH, H, JPB, SP). Sergipe. Mun. Arenas Brancas, 1989 *Ahti et al. 48919* (H), *48942* (H, JPB, SP), *48948* (H).

Distribution in Brazil: PB, SE.

Notes: This species was included by us in *C. crispatula* (e.g., in Pereira 1989) until recently. *C. crispatula* (common in more southern states in Brazil) differs by having thin, smooth and more corticate main axes, very thin medulla (the stereome constituting 1/2 to 2/3 of the wall thickness) and red slime in the conidiomata.

15. **Cladonia salzmannii** Nyl. (Fig. 6)

Description: Vainio (1887).
Chemistry: Barbatic acid, 4-O-demethylbarbatic acid (tr). Additional thamnolic and decarboxythamnolic acids may be occasionally present, as well as several minor unknown compounds.

Specimens examined: Paraíba. Mun. Alhandra, 1987 *Ahti & Xavier Filho 45682, 45699, 45700* (H, JPB); Condé 1971 *Kurokawa & Xavier Filho 8103* (TNS); Mun. Santa Rita, 1987 *Ahti & Xavier Filho 45634, 45638, 45646, 45664* (H, JPB). Pernambuco. Mun. Gôiana, 1971 *Barros 951* (JPB, UFP), *Kurokawa & Xavier Filho 8004* (TNS). Sergipe. Mun. Arenas Brancas, 1989 *Ahti et al. 48917, 48918* (H), *Stenroos et al. 3877* (H, JPB, NY, SP).

Distribution in Brazil: BA, MG, PB, PE, SE.

Notes: This little known, distinct species has a relatively small range, being apparently confined to northeastern Brazil. It was especially abundant on sandy soil in Sergipe. Though it usually has scyphoid, dilated structures, it may occasionally be extremely similar to *C. crispatula* (like in Fig. 6), but can always be distinguished by abundant production of barbatic acid (the p-phenylenediamine reaction is usually negative).

16. **Cladonia secundana** Nyl.

Synonyms: *Cladonia erythromelaena* Müll. Arg.,
C. miniata var. *secundana* (Nyl.) Zahlbr.,
C. miniata var. *hypomelaena* (Nyl.) Zahlbr.

Description: Stenroos (1989).

Chemistry: Didymic acid, condidymic acid (tr). In its total area C. secundana is chemically very variable (Stenroos 1989). The common major substances, in addition to didymic acid, are barbatic, homosekikaic, and sekikaic acids.

Specimens examined: Paraíba. Mun. Santa Rita, 1987 *Ahti & Xavier Filho 45644, 45650* (H, JPB). Pernambuco. Mun. Gôiana, 1971 *Kuroka-*

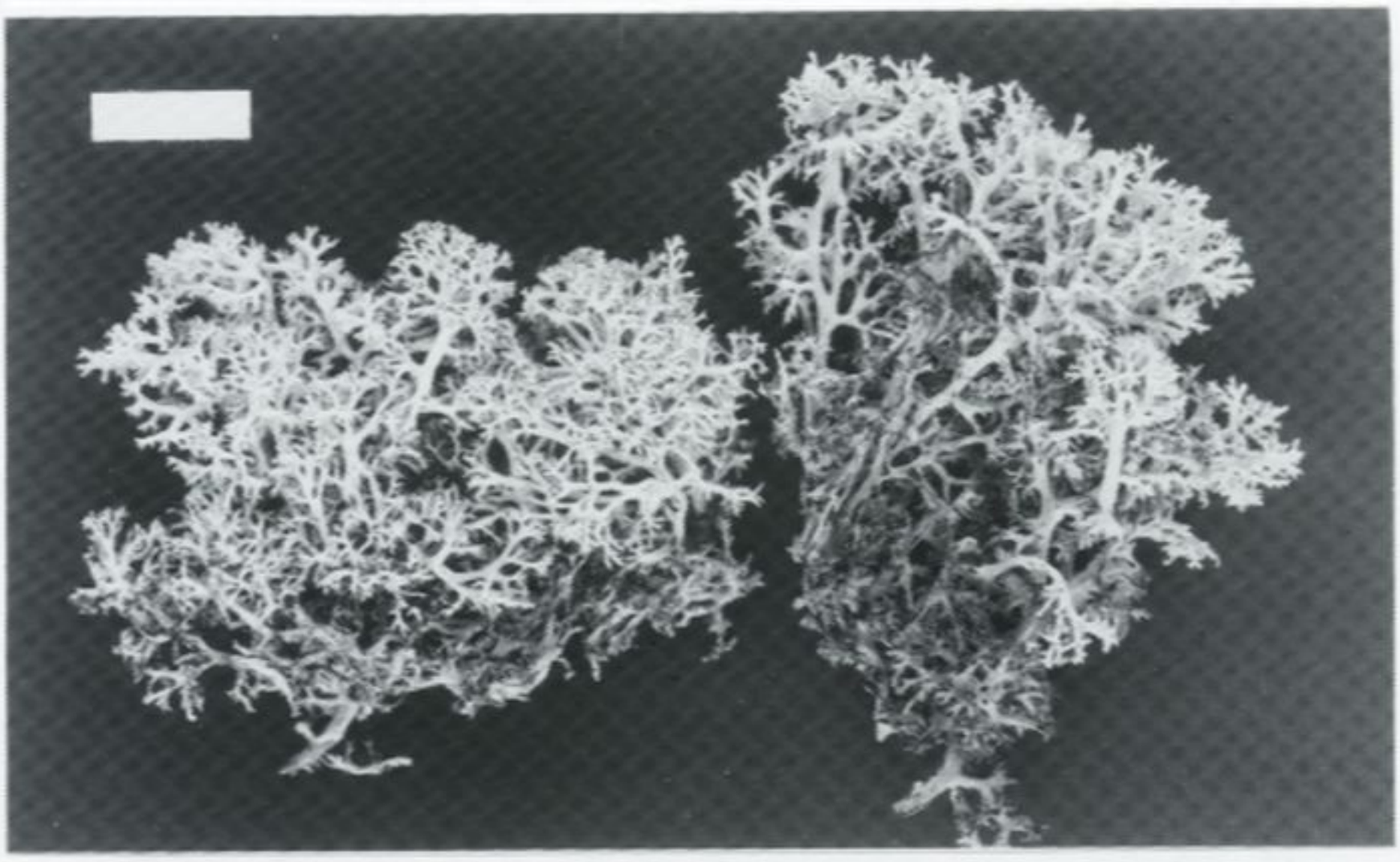

Fig. 5. Cladonia rugicaulis Ahti. Paraíba, Ahti & Xavier Filho 45632 (H). Bar = 2 cm.

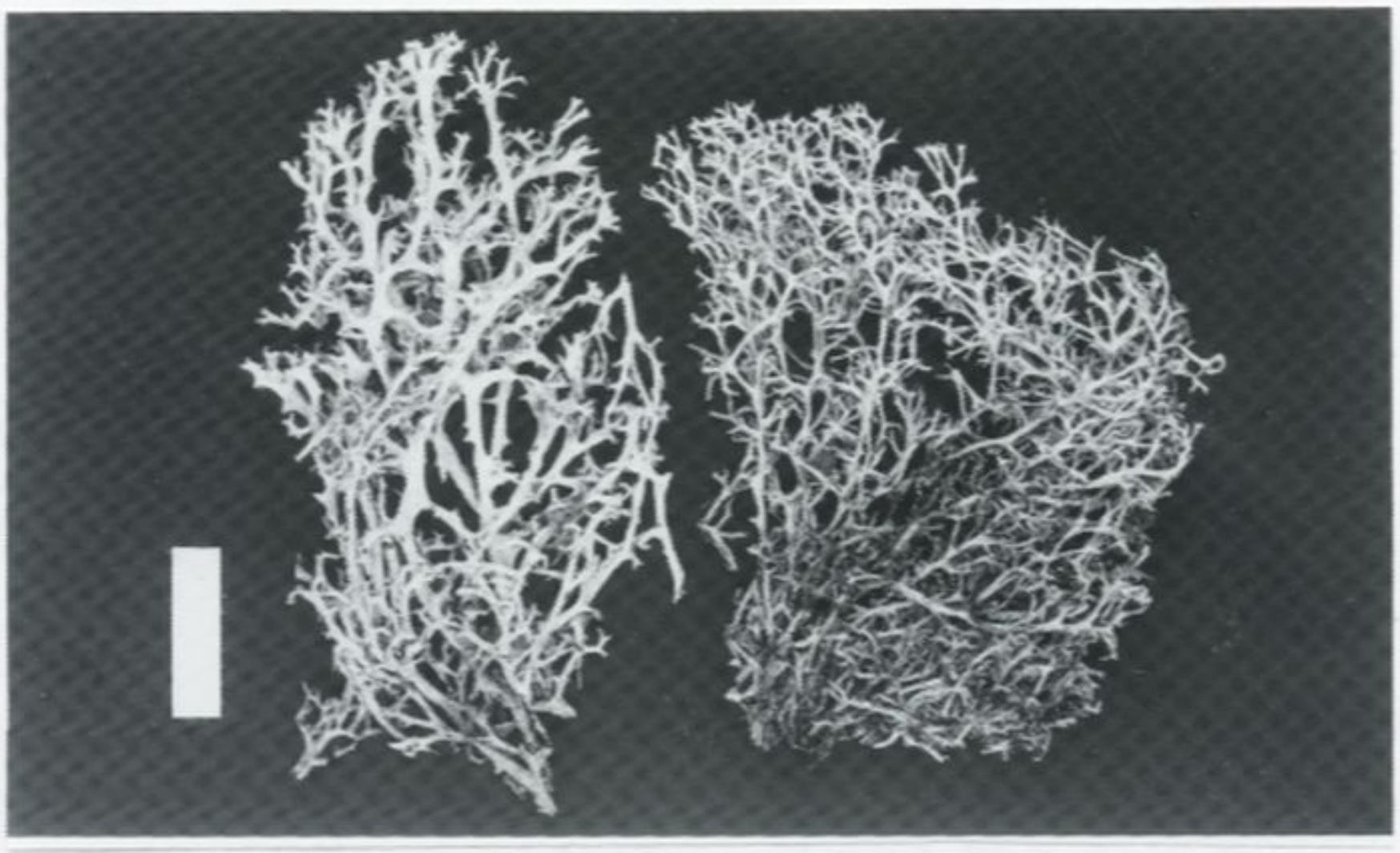

Fig. 6. Cladonia salzmannii Nyl. Fertile (left) and sterile (right) podetia. Pernambuco, Kurokawa & Xavier Filho 8004 (TNS). Bar = 2 cm.

wa & Xavier Filho 8003 (TNS).

Distribution in Brazil: AM, MG, PA, PB, PE, RJ, RR, SC.

Notes: *C. secundana* is the most widespread member of the so-called *C. miniata* group in Brazil. It ranges from the Guiana Highland in the north down to SE Brazil.

17. **Cladonia subminiata** Stenroos

Description: Stenroos (1989).

Chemistry: Usnic and didymic acids are major secondary substances. Accessory minor substances are condidymic, subdidymic, and fumarprotocetraric acids.

Specimens examined: Paraíba. Mun. Alhandra, 1987 *Ahti & Xavier Filho 45705* (H, JPB), 1976 *Xavier Filho* (JPB), *Krieger et al. 14255* (CESJ); Mun. Santa Rita, 1987 *Ahti & Xavier Filho 45642* (H, holotype; JPB, isotype), *45631, 45640, 45647* (H, JPB). Pernambuco. Mun. Gôiana, 1976 *Tucker 16782* (LSU). Sergipe. Mun. Arenas Brancas, 1989 *Stenroos et al. 3878* (H, JPB), *3880* (H, SP), *3881* (H).

Distribution in Brazil: PB, PE, SE.

Notes: This species is a rare endemic of NE Brazil, the type specimen being from Santa Rita. It can be distinguished from its closest relative *C. secundana* by its yellow colour caused by usnic acid and by strongly phyllopodial podetia. It may form extensive colonies on bare sand. The specimen *Stenroos et al. 3880* represents colonies observed on moist rocks by a creek; it is totally sterile, the squamules are unusually large (up to 1.5 cm long) and scarcely yellowish at all (usnic acid present in trace amounts), but in part turned bluish-grey below.

18. **Cladonia subradiata** (Vainio) Sandstede

Synonym: *Cladonia fimbriata* var. *chondroidea* subvar. *subradiata* Vainio.

Descriptions: Ferraro & Ahti (1987), Stenroos (1988), Swinscow & Krog (1988).
Chemistry: Fumarprotocetraric and protocetraric acids and the substance Cph-2.

Specimens examined: Paraíba. Mun. Alhandra, 1987 *Ahti & Xavier Filho 45680, 45701* (H, JPB), 1966 *Xavier Filho* (JPB 540, 554, 594), 1985 *Xavier Filho & Pereira* (JPB); Mun. Santa Rita, 1987 *Ahti & Xavier Filho 45639, 45658* (H, JPB). Pernambuco. Mun. Bonito, 1989, *Ahti et al. 48913* (H). Mun. Camaragibi, Aldeia, 1987 *Ahti 45613* (H), 45792 (JPB); Serra Negra, 900-1000 m, 1971 *Kurokawa & Xavier Filho 8050* (TNS). Sergipe. Mun. Arenas Brancas, 1989 *Ahti et al. 48921* (H).

Distribution in Brazil: AC, AM, BA, DF, MG, MS, PA, PB, PE, PR, RJ, RR, RS, SC, SE, SP.

Notes: One of the most common and widespread species of *Cladonia* in tropical America.

19. **Cladonia subsquamosa** Krempelh.

Synonym: *Cladonia fimbriata* var. *chondroides* subvar. *chlorophaeoides* Vainio

Descriptions: Ahti & Kashiwadani (1984), Ferraro & Ahti (1987), Stenroos (1988), Swinscow & Krog (1988).

Chemistry: Fumarprotocetraric and protocetraric acids and the substances Cph-1 and Cph-2.

Specimens examined: Paraíba. Mun. Alhandra, 1987 *Ahti & Xavier Filho 45695* (H, JPB); Mun. Santa Rita, 1985 *Xavier Filho & Pereira* (JPB). Pernambuco. S of Gôiana, 1971 *Kurokawa & Xavier Filho 8012* (TNS); Tabuleiro de Gôiana, 1976 *Tucker 16781* pp. (LSU). Sergipe. Mun. Arenas Brancas, 1989 *Ahti et al. 48949* (H).

Distribution in Brazil: AM, BA, MG, PB, PE, PR, RJ, RS, SE, SP.

Notes: Another very common species in tropical America, though not frequent in the study area.

Earlier confused with *C. fimbriata* (L.) Fr. (see Stenroos 1988).

20. **Cladonia substellata** Vainio

Descriptions: Vainio (1887), Ahti (1973).

Chemistry: Usnic, stictic, cryptostictic and constictic acids. Norstictic and connorstictic acids can be found in this species elsewhere in Brazil. - Usnic acid was reported by Carrazzoni et al. (1976) apparently in this species under the name *Cladonia polia*.

Specimens examined: Paraíba. Mun. Alhandra, 1966 *Xavier Filho* (JPB 560, 562); Mun. Condé 1971 *Kurokawa & Xavier Filho 8102* (TNS); Mun. Santa Rita, 1981 *Xavier Filho* (H, JPB), 1987 *Ahti & Xavier Filho 45651* (H, JPB), 1985 *Xavier Filho & Pereira* (JPB); sine loco, 1959 *Moraes 2177* (TNS, US). Pernambuco. Mun. Gôiana, 1968 *Alves* (JPB 550), 1971 *Barros 952* (JPB); S of Gôiana, 1971 *Kurokawa & Xavier Filho 8005* (TNS). Sergipe. Mun. Arenas Brancas, 1989 *Ahti et al. 48931* (H).

Distribution in Brazil: BA, MG, PB, PE, RS, SE.

Notes: Reported for the area by Ahti (1973). It grows particularly on bare, exposed sands.

21. **Cladonia verticillaris** (Raddi) Fr.

Description: Vainio (1894).

Chemistry: Fumarprotocetraric and protocetraric acids and the substance Cph-2. - Vicente & Xavier Filho (1979) were the first to report fumarprotocetraric acid in Paraíban material. Legaz et al. (1986) reported that in sunny locations in Paraíba this species produces 1-2.5 times more phenolic lichen substances than in shady places. However, in addition to rather low amounts of fumarprotocetraric acid they (and Xavier et al. 1984) reported orcinol, methyl α-orcinol carboxylate and atranorin, but these substances must be degradation products caused by the maceration of the material in methanol (Huovinen et al. 1990: 227).

Specimens examined: Paraíba. Condé 1971 *Kurokawa 8101, Lich. Rar. Crit. Exs. 270* (H, TNS); Mun. Alhandra, 1985 *Xavier Filho & Pereira* (UFP), 1987 *Ahti & Xavier Filho 45686* (H, JPB); Mun. Santa Rita, 1987 *Ahti & Xavier Filho 45637, 45659* (H, JPB). Pernambuco. Tabuleiro de Gôiana, 1976 *Tucker 16784* (LSU).

Distribution in Brazil: BA, ES, MG, PE, PB, RJ, SP.

Notes: *C. verticillaris* in the sense of Vainio (1894) is a still unclarified collective species, but the Paraíba populations seem to belong to *C. verticillaris* s.str. The lichen forms extensive, showy colonies on the tabuleiros.

22. *Cladonia* sp.

Primary thallus inconspicuous. Podetia 1-1.5 cm tall, simple, smoothly corticate in lower parts, verruculose to granular higher up, scyphose, scyphi rather narrow, tending to have short marginal proliferations, conidiomata and hymenial discs brown.

Chemistry: Fumarprotocetraric acid, protocetraric acid (tr), Cph-2 (tr).

Specimens examined: Paraíba. Mun. Santa Rita, 1987 *Ahti & Xavier Filho 45623* (H, JPB).

Distribution in Brazil: PB.

Notes: This is almost certainly an undescribed species but it is not described here because of meagre material. It was found scattered in a very young postfire pioneer community on bare sand.

Excluded species

A number of additional species have been reported from the study area, but because of major recent changes in taxonomic concepts and nomenclature of the neotropical Cladoniaceae the identifications have become outdated. For many of the reports the original material was not available for corrections.

1. **Cladonia crispatula** (Nyl.) Ahti - Reported by Pereira (1989) and others. The reports refer to *C. rugicaulis*.

2. **Cladonia furcata** (Hudson) Schrader - Reported by Xavier Filho & Maríz (1970) from Recife and Joâo Pessoa, but the reports must refer to some other species.

3. **Cladonia macilenta** Hoffm. - Reported from Pernambuco by Barros & Xavier Filho (1972) and Bezerra et al. (1973), the latter report indicating thamnolic, barbatic and didymic acid in the lichen. The reports may refer to *C. didyma*.

4. **Cladina polia** (R. Sant.) W. Weber - See *Cladonia substellata.*

5. **Cladina sandstedei** (Abb.) Ahti - See *C. dendroides*.

6. **Cladina sprucei** (Ahti) Ahti - See *C. dendroides*.

7. **Cladina subtenuis** (Abb.) Hale & Culb. - The report from Pernambuco by Bezerra et al. (1973) - with usnic acid - seems to refer to *Cladonia substellata*.

8. **Cladonia verticillata** (Hoffm.) Schaerer - Reported by Barros & Xavier Filho (1972) and Bezerra et al. (1973) from Pernambuco, probably referring to *C. clathrata*. Carrazzoni & Wanderley (1974) reported evernic acid in Paraíban material of this species. Since evernic acid is not otherwise known in *Cladonia*, their report is doubtful, and the identification of the lichen species must also be incorrect.

Conclusions

The Cladoniaceae are relatively infrequent lichens in the Northeast of Brazil. They can tentatively be grouped into the following distribution patterns:

1. Wide temperate-tropical species: 3
2. Wide tropical: 2
3. Wide neotropical: 3
4. NE Brazilian: 5
5. SE to NE Brazilian: 3
6. Eastern South American tropical: 6

The primarily NE Brazilian (with extensions to Espirito Santo and Minas Gerais) species are *Cladonia clathrata, C. rhodoleuca, C. rugicaulis, C. salzmannii, C. subminiata.* It is possible that when their ranges will be better known the group should be merged with the SE Brazilian inland element (cf. Frahm 1990: 5). However, three centres of distinctive endemism of flowering plants, viz. Pernambuco, Bahia and and Rio-Espírito Santo have been recognized in the present area of Atlantic coast rain forest (Prance 1978: 61), so that the presence of an endemic lichen element in this area is also possible.

Paraíba is the state in South America which is closest to West Africa. In light of the plate tectonic history of the continents one could expect that their Cladoniaceae floras would show some similarities. Though West Africa is very poorly known, it seems that these floras have very little in common, however, showing that the later climatic histories of these areas are more important than the continental movements when the distribution patterns of these lichens are explained. There are certainly similarities in the South American and African Cladoniaceae in general, but without a taxonomic revision of the African species, in particular, it is premature to make any far-reaching conclusions.

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(Legends):

Fig. 1. Cladonia clathrata Ahti & Xavier Filho. Paraíba, Ahti & Xavier Filho 48940 (H). General habit. Bar = 2 cm.

Fig. 2. Cladonia clathrata. Scyphal plate from above. Specimen as in Fig. 1. Bar = 5 mm.

Fig. 3. Cladonia polita Ahti. Paran , Smith 910207004 (H). Bar = 2 cm.

Fig. 4. Cladonia polyscypha Ahti & Xavier Filho. Paraíba, holotype (H). Bar = 2 cm.

Fig. 5. Cladonia rugicaulis Ahti. Paraíba, Ahti & Xavier Filho 45632 (H). Bar = 2 cm.

Fig. 6. Cladonia salzmannii Nyl. Fertile (left) and sterile (right) podetia. Pernambuco, Kurokawa & Xavier Filho 8004 (TNS). Bar = 2 cm.