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Some species of *Parmotrema* (Parmeliaceae) from the Brazilian Amazon with salazinic acid[1]

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ABSTRACT – (Some species of *Parmotrema* (Parmeliaceae) from the Brazilian Amazon with salazinic acid). Six new species of *Parmotrema* (*P. aristidesii*, *P. hypoflavum*, *P. marjorieanum*, *P. marlitonii*, *P. nelihondae*, and *P. subcristiferum*) and *P. cristiferum*, all containing salazinic acid, were collected from the Amazon rainforest in Mato Grosso State, Brazil, (Central South America), and are described, illustrated, and commented by using the ultimate version of the GEL (Lichenological Studies Group) descriptive protocol, that has explained its most important recent improvements.
Keywords: axillary folds, Cristalino, lichen systematics, satin, Xingu

RESUMO – (Algumas espécies de *Parmotrema* (Parmeliaceae) da Amazônia brasileira com ácido salazínico). Seis novas espécies de *Parmotrema* (*P. aristidesii*, *P. hypoflavum*, *P. marjorieanum*, *P. marlitonii*, *P. nelihondae* e *P. subcristiferum*) e *P. cristiferum*, todas contendo ácido salazínico, foram coletadas da floresta amazônica em Mato Grosso, Brasil, (centro da América do Sul), e são descritas, ilustradas e comentadas usando a versão final do protocolo descritivo GEL (Grupo de Estudos Liquenológicos), cujas principais atualizações são descritas e explicadas.
Palavras-chave: acetinado, Cristalino, dobras axilares, sistemática de liquens, Xingu

Introduction

The 4,800,000 km^2 of the Amazon Forest, the largest humid tropical forest on the planet, occupies 5% of the entire dry surface of the world and 40% (nine countries) of South America (Lemos & Silva 2011). In Brazil, the Amazon spans nine states, representing about 61% of the territory (Assad 2016, Menin 2010).

According to Teixeira *et al*. (2017) the creation of Conservation Units in the Amazon is an effective mechanism to guarantee the "sustainable development and conservation of natural resources". However, the dynamism of activities linked to the exploitation of natural resources that use deforestation and fires as main resources, have promoted a decrease in soil quality, changes in the hydrological regime, emission of greenhouse gases and an irreparable loss of biodiversity (Fearnside 2005) often still hidden from science.

The center and north of the country, which includes the Amazon rainforest, has its lichen foliose mycota practically unknown.

Among the lichenized foliose fungi, the Parmeliaceae family stands out for its wide dispersion, with 2,765 species distributed in 80 genera (Thell *et al*. 2012, Lücking *et al*. 2017a, b).

The genus *Parmotrema* has about 350 species (Elix 1993, Brodo *et al*. 2001, Nash & Elix 2002) and more than 196 of them are cited for Brazil (A. Aptroot, unpublished data). There are at least 78 accepted species that produce salazinic acid (Spielmann & Marcelli 2020) and 53 (68%) of them are present in Brazil (Spielmann, pers. com.). The genus is recognized by the foliose thallus with rounded and

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broad lobes (generally more than 5 cm) and ciliated margins (commonly), by the upper cortex that may present macules, isidia, soredia or pustules, by the lower surface usually black in the center with margins ranging from brown to white, the ellipsoid ascospores with thick epispore and emerged pycnidia (Elix 1993, Brodo *et al*. 2001, Nash & Elix 2002).

Among the various secondary substances produced by lichens and of taxonomic character, salazinic acid can be easily recognized by means of spot tests with a typical reaction K+ yellow → blood red (sometimes orange), C- and P+ strong yellow (Hale 1979, Spielmann & Marcelli 2020).

Parmotrema species in this work were collected in two conservation units (Cristalino State Park I and II and Xingu State Park) and on the trails and plots of the Biodiversity Research Program (PPBio) installed at São Nicolau Farm. The three study areas are located in the extreme south of the Amazon.

Material and methods

From May/2020 to March/2021, samples of lichenized fungi were collected in three areas of the Amazon Forest located in the north of the Mato Grosso State.

Cristalino State Park I and II (9°28'17.45"S, 55°49'22.20"W) is characterized by a hot and humid climate, with average annual temperatures above 24 °C and average annual precipitation above 2400 mm (Sasaki *et al*. 2008). The Xingu State Park (9°53'47.15"S, 52°30'36.37"W) has well-defined wet and dry seasons with the annual rainfall ranging from 2,000 to 2,500 mm and temperatures between 21 and 32 °C (IBGE 2012). The São Nicolau Farm (09°49'09.0"S, 58°15'31.1"W) has a climate and average temperature similar to Cristalino State Park. The rainfall reaches an annual average of 2,034 mm (Noronha *et al*. 2015).

The methodology adopted for collection and herborizing was based on Brodo *et al*. (2016) and Peixoto & Maia (2013).

Specimens were morphologically studied using stereomicroscope and light microscopes. Anatomical sections, including those of apothecia and pycnidia, were hand made with razor blades. The chemical constituents were checked by spot tests with potassium hydroxide (K), sodium hypochlorite (C) para-phenylenediamine (P), and examined under UV light (360 nm). Microscopic measures were taken in water. Chemical constituents were identified by thin-layer chromatography (TLC) using solvents B, C and G (Huneck & Yoshimura 1996, Orange *et al*. 2010, White & James 1985). Furthermore, as additional control, the samples were run along authenticated salazinic acid containing samples of *Parmotrema reticulatum* (Linds.) Hale or *P. cetratum* Ach. (Hale), very common easily identifiable species, kept in the laboratory with this purpose.

Each new species diagnosis refers exclusively to holotype characters and the descriptions and comments to all the material studied. Deviating specimens are clearly pointed out.

The GEL protocol - The descriptions were made by using the ultimate version of the descriptive protocol for foliose Parmeliaceae developed by the Group of Lichenological Studies (GEL) of the Instituto de Botânica (São Paulo city, Brazil) during the last 20 years when attempting to pattern descriptions that efficient and adequately distinguish species and specimens of Parmeliaceae.

Obviously, older described material and types must be, in the future, submitted to the protocol to stablish the real differences and similarities, of manner that much of the comparative comments on the species presented here are yet based in bibliography and obligatorily traditional and elementary in relation to those that we hope will be produced in the future.

We consider that our descriptions, however improvable, arrived at a point that we consider satisfactory to describe the patterns of the Parmeliaceae general appearance of the thallus (habitus), which is the consequence of folds, turns, contortions, elevations, rolling, interlacement, fusions, and other characters of lobes that are commonly disregarded. The same applies for the surface's texture, cracks, stains, roughness, and other characteristics, as well the distribution, origin, development, organization, and details on the shape of structures such as cilia, rhizines, soredia, isidia, pustules, and others.

Since our descriptions include what we consider some important discoveries, interpretations, and considerations, added of the necessary new terminology, we present below the most relevant points where our protocol differs in relation to common descriptions.

With standardization purposes, we consider *soral* (pl. sorals) the definite as restricted place where *soredia* (plural of soredium) are produced and use *soralia* as a collective of soral (all the sorals of a thallus). Accordingly, an extensive laminal not delimited soredia production is not considered a soral.

We use *laciniae* exclusively for primary or secondary thalli branches that are ribbon-like, longer than wide and with parallel sides. Lacinules are secondary minor outgrowths, marginally developed from laciniae, lobes, apothecia, or else other structure. Thalli producing laciniae are *laciniate,* and a structure

that develops lacinules is referred to as lacinulate (many times the literature interchanges freely these terms). Analogically, lobes are roundish primary or secondary branches wider than long, and lobules are secondary outgrowths of the same shape; so, thalli with lobes are lobate and structures producing lobules are lobulate.

We use the strictest concepts of marginal and apical as those structures exclusively growing at the very edge of margins and apices, exactly in the contact point between upper and under cortices. Everything displaced up or down in direction to one cortex is considered submarginal.

Absolute attention is given to the description of the origin and development of the surface's micro-relief, always separately for distal and proximal parts of the thallus. Similarly, lobes and laciniae have margin, submargin and central part described. The absence of description (this is rare) means that there is nothing to mention, i.e., a such structure is in his most primary condition, *e.g.*, simple, smooth, continuous, not ornamented and so on.

To reach such objective, the mental design/sketch of the primary branches (lobes or laciniae) is obtained by describing (a) the central axis, an imaginary line that runs along the middle of a branch, from their visible origin in the proximal zone till the youngest part (the apex), and (b) the *transversal cut* at the mature parts (and other if necessary), perpendicular to the central axis, that has the features of its middle part and borders described.

In several genera of Parmeliaceae, the axils at the ramification points are naturally ascending, the *axillary folds*. We claim that their elevation, length, folding, aggregation, rolling, ornamentation, and other aspects are of fundamental importance in giving to many species its characteristic thallus general shape, including, for example, in making the central axis undulate depending upon the fold length.

The disposition of the lobes is also a remarkable species characteristic that gives the thallus of a species its characteristic habitus. The lobes are commonly described simply as contiguous, superposed, or heaped. However, we state that this feature must be much better described since each species has the relationship between adjacent lobes much more complex and fixed than commonly thought. Although a thallus can have more than one disposition of the lobes (or laciniae), there is a typical range that can be described. Much of the inter-lobar relationship depends, in reality, of how their lateral margins and/or submargins interact. For example, that disposition that is commonly loosely described as contiguous (we restrict the use of this term only for those juxtaposed by the margins), may be (and this is common) counterposed (the ascending lateral margins place the submarginal undersides one against the other), straddled (one counterposed side higher and turning down upon the other), or even (not so common) fused by the margins or other parts in a true tissue fusion, turning the thallus a rigid plate.

Damaged parts of thalli can produce adventitious structures as lacinules, lobules, cilia, and others, that can be similar or different of the originals, and this difference is also a specific feature. In *Parmotrema*, for example, it is very common that damaged parts are "recognized" by the thallus as edges (margins) and, because this, typical marginal structures can be found even in laminal damages (and these structures remain marginal by definition). However, some species can produce adventitious lobes/laciniae from integer lateral margins that can be smaller, narrower, or equal in size and shape to the primary ones. These *secondary* lobes and laciniae can, depending upon the species, have or not the same pattern of disposition and ramification than the primary. For example, from a prostrated thallus with contiguous primary lobes, secondary ones can grow up and enroll, or become canaliculated, or are flat and heaped, or are descending and grow just the sufficient to fill the not occupied inter-lobar substrate or yet acquire many other diverse forms. This "behavior" and shapes of the *secondary* lobes and laciniae must be reported meticulously.

As far we know, the regular fusion of lobes and parts of a thallus is a not reported phenomenon in descriptions; however, it is not so rare and occurs chiefly when naturally opened margins (also a not reported phenomenon) are present. Careful observations from the youngest to the older mature parts allow to understand the beginning as well the morphological development of the thalline structures and also deduce when the marginal opening is a natural process. Opened juxtaposed margins may fuse at anatomical level and make the thallus into a plate and, as the straddled margins also can do, tie the margins firmly at morphological level. Many times, opened margins have been interpreted as mechanical accidents or due to animal chewing, principally because this may be the case and "chewed" (corroded) is really the most common appearance of a mature naturally opened margin.

In many genera of Parmeliaceae the thallus is circumvented by a *black line* (meristematic zone), which is rarely mentioned in descriptions. Although its presence and thickness may vary in an only specimen, the range of this variation is a specific character. The black line can be *clear-cut* from the upper adjacent cortex or the black color can fade gradually, what we

qualified as an *attenuated* black line. Furthermore, the black line can appear as the final stage of a marginal cicatrization or regeneration process of mechanical lacerations, chewing, grasping, cracking, or naturally opened margins; in this case it has a continuous smooth external side and an irregular torn-shaped drawing in the contact with the lamina because the cicatrization process fills the edges irregularities, and then we named it *complementary* black line. In reality, we use *attenuate* for all gradual transition in shape, color, or limit in any part of a lichen thallus. It is declared *absent* when is not visible even at a magnification of 40×.

For descriptive practical purposes we have named a structure as *cilium* only if growing from the black line. All the other similar structures growing at the underside, even when very close to the margin, are considered *rhizines*, a very necessary distinction in several cases, *e.g.*, many species of *Hypotrachyna* (Hora 2015). Cilia that grow at the upper cortex, on isidia, soredia, and other structures, normally appear from very small black dots that act as "physiological" black lines.

It is very common that descriptions include the thallus brightness, since it was ever obvious to identifiers that this feature is very characteristic for each species. However, words as shiny, bright, lustrous, sublustrous, and opaque tends to be highly subjective and so, little reliable. Along the years we noted that the brightness of the thallus was not continuous as a mirror reflection, but in the reality a composition of countless very small densely aggregate bright points that could be easily seen with very little training under the stereomicroscope illumination. Initially we attempted to count these dots per square millimeter (unpublished laboratory data), but soon became very clear that the obtained densities measures are the same of the palisade cortical cells typical of the Parmeliaceae (Barbosa 2005, 2009, Zanetti 2018, Zanetti *et al.* 2015). We conclude that the bright dots (and thallus brightness) were consequence of the reflection of the microscope or natural light (no matter its position) on the convex tips of the cortical cells (Zanetti 2018), and, therefore, a direct consequence of the cortex structure and cells' size, that are constant for each species (Barbosa 2005, 2009, Zanetti 2018, Zanetti *et al.* 2015), and then of great importance, as suspected. We named this feature *satin* because of the visualization of the many reunited bright dots is very alike this fabric and it was already used successfully in descriptions by Hora (2015) and Buril (2015).

The satin becomes visible at different augments depending upon the size of the cortical cells' apices, and probably the thickness of the epicortex and deposit, secretion, or excretion of substances on the thallus. The fact is that we constated that when the satin is already visible at a magnification of 10×, the observed structure is clearly *lustrous*, at 20× it can be said *sublustrous*, at 30× *subopaque*, at 35× subopaque to opaque, only at 40× *opaque*, and when the satin cannot be visualized even at 40× or above the texture under the microscope (and at naked eyes) is very like velvet and so we named it velutinous (velvet-opaque).

The cracks on the surfaces are another feature related to the cortical structure and very commonly associated with spaces in the palisade cortex made of bundles of plume-ramified hyphae of the foliose Parmeliaceae, many times appearing on the surface as macules (Barbosa 2005), and are extremely frequent, for example, in *Parmotrema*. However, in most of the cases, the literature just mentions the presence, commonly disregarding distribution, intensity, and up to now nobody gave attention to the deepness of the cracks, directly related to cortex highness. They begin as superficial very small openings that reach only the upper cortical layer top and may remain definitively at this stage that we named crackled (crackling) or procced in deepness and/or in length. When growing only in deepness we call the cortex cracked, and if growing in length (or already born long and deep) we use fissured, that sometimes can be visible at naked eyes. Cracks and crackles are very frequent on the upper surface, while fissures (crevices) are almost restricted to the underside.

The fissures on the underside have been generally considered as resulting of casual mechanical accidents, that obviously occur, and very little or even no attention was given to them to now. However, after identifying a great amount of material along the years, it became clear that this feature is species-related, and even if the fissures are caused by the constant swelling/drying hydration cycle common to lichens, they will naturally appear at the places of lower resistance, i.e., again associated with the cortical structure. Therefore, distribution, size, ramification pattern, elevation of the borders, and the fact of them get cicatrized (at least with the crevice bottom corticate, sometimes filled and then corticated) or not, are aspects that must be reported.

It is very common to find specimens with dead parts of the thalli, mostly blackish but also brownish, with an aspect of decomposing, carbonized, eroded, torn, etc. These dead parts most commonly appear at the lateral margins of primary and secondary branches, but can also develop as rounded to irregular laminal complete (perforations) or incomplete (not trespassing, sometimes showing the upper side of the under cortex) damages, or yet be restrict to sorals or other limited

structure or area. Sometimes the thallus is found so damaged that is normally and promptly discarded as bad material. Students are commonly advised to not collect specimens with noticeable blackish parts.

One can very easily understand such situations as resulting of meteorological, climatic or pollution impacts, or see clearly them under the microscope as effects of interspecific allelopathy with other lichens (sometimes very small soredia may kill and perforate a thallus), bryophytes, tracheophytes, or because of the deposition of exudates or animals' excrements. However, apparently nobody gave attention to a very interesting and easy to observe phenomenon in which one part of the thallus can kill another part of the same thallus (frequently reciprocal), which we named auto (or self) incompatibility and that at first glance can be mistaken by the occurrences above mentioned. It looks like a competition for space between parts of a same thallus and is relatively common in touching or superposed branches, soredia, and other parts, and is certainly a species-specific feature that can be used to distinguish at least some species. The contacting or tentatively-superposed parts turn dead, blackened, and eventually fall or disintegrate, turning the thallus a one-layered structure plenty of rotten parts, sometimes a truly ugly appearance avoided even by experienced collectors, and it is possible that several species have been disregarded and not collected because this. Apparently, this condition is not triggered by microclimatic characteristics nor associated to the presence of certain lichen acids.

Pustules are so frequent in Brazilian species that its absence from basic textbooks was always strange to Brazilians. They are broadly recognized as highly species-specific according the size, shape, distribution, development, and because they can stay integer, or burst, dismantle into soredia, produce soredioid isidia, or become something else. The interior can be hollow or filled with a very lax medulla, that may be pigmented differently of the rest of the thallus. However, despite of their final mature size can range from practically submillimetric to several millimeters or even be extensive to almost a complete thallus surface, most of the times they have been reported in literature only when readily noticeable under the stereomicroscope. Nevertheless, in a great number of *Parmotrema* species (but also in *Hypotrachyna* and other genera), pustules are the starting point in the sorals formation. Sometimes, they dismantle into soredia so early that can be a little laborious to find them. These very rarely mentioned, normally hemispherical, small pustules have the same exclusive features of the bigger ones and shall be detailed in the descriptions. We do so and, because this, they became very present in our descriptions.

The normal appearance of the medulla of a medium to great (about 5 cm and above in diameter) Parmeliaceae, such as *Parmotrema*, *Hypotrachyna* or *Canoparmelia*, is cottony and soft. However, depending upon the species it can be lax (loose) and very soft, sometimes too fragile to hand-cut and commonly covered by a fragile cortex or, on the contrary, be firm and dense, easy for handmade cuts. No matter thickness or density, the medulla may be partial or totally colored by several types of yellowish (many shades from very light to goldish), orangish, ocher, brownish, rosed, or reddish pigments. In some cases, the colored part of the medulla appears as patches irregular in size, distribution, and deepness, demanding careful inspections for description and in taking samples for chemical analysis. However, in the great majority of the cases the colors are disposed into layers, most commonly one superior white and another colored bellow which, in rare cases, can appear only as a very thin layer just above the under cortex. Although the relative thickness of the layers varies in a same thallus with the thallus ageing, it is relatively constant for each age (from the apical to the proximal part) and is an important information.

For many years there was a tacit agreement in believing that the rhizines produced by a thallus were homogeneous in shape and size, obviously the size depending upon age. This was so only because some "different of the norm" rhizines are produced in much smaller quantity and considered irrelevant or abnormal and were disregarded. We are not certain that this is really the adequate approach since apparently each species has its own set of rhizines. Accordingly, we describe all types of found rhizines and attempt to quantify them. Specially in *Parmotrema*, we have found many cases of dimorphic or even trimorphic rhizines, but in a different way of that classical dimorphism concept in *Rimeliella* (now *Parmotrema*) of long simple rhizines growing mixed with short dichotomous, i.e., including two classes of sizes. We found that the shapes can be other than those and are no related to size. Because this, we included in the descriptions the terms monometric and dimetric (if necessary "tri" and so on) to indicate, respectively, "of the same size" and "of two different size classes". Furthermore, we also consider the apices of the rhizines a different characteristic, of manner that the rhizines described shapes do not include the apices, that are described separately. So, it is not surprising that monomorphic monometric rhizines have two or three different types of apices, for example.

The normal condition of the underside color in several genera of Parmeliaceae is the presence of a lighter marginal zone that can be several millimeters wide, and a darker, commonly black, proximal part. However, this situation can be inversed and/or mottled white or ivory. This must not be confused with the "free of rhizines border" characteristic of *Parmotrema*. It is very common that rhizines or papillae growth at the marginal zone, and this is normally a species-specific feature.

Taxonomic treatment

Parmotrema aristidesii Ciecoski & Marcelli, *sp. nov.* - Type: BRAZIL. Mato Grosso State: municipality of Santa Cruz do Xingu; Xingu State Park, Ponto 30: 9°36'32.56"S, 52°27'43.52W, elevation 252 m, seasonal semidecidual submontane forest, on tree trunk in the forest, *R. Carpanedo A*, 11-IX-2020 (Holotype: CNMTf 512). MycoBank: MB842962.

Figure 1

Diagnosis: *Parmotrema aristidesii* is one species velvet-opaque (velutinous), greenish gray to bluish, subpergaminaceous till 27 cm broad, mostly eciliated, maculated, with axillary folds common and low, the medulla stramineous and firm, the underside commonly cracked with mostly not cicatrized crevices, apothecia concave and clefted, hymenia till 200 µm high., ascospores ellipsoid (20.0-) 25.0-27.5 × 12.5-15.0 µm, epispore 2.5 µm thick, conidia bifusiform straight 10.5-13.5 × 1.5-3.0 µm, and salazinic acid in the medulla.

Description: Thallus corticicolous; greenish-gray to slightly bluish; velvet opaque; lobed; subpergaminaceous; satin difficult to observe even at 45×; till 27.0 cm broad; maculae evident, irregularly distributed, efigurated. Lobes short, anisotomous to sympodial; axils acute to oval and auriculated; axillary folds common, low, sometimes descending; 6.0-10.0 mm wide at branching base, the major width 8.0-15.0 mm; contiguous to laterally superposed to straddled, some counterposed; loosely adnate to elevated; black line absent to subtle and clear-cut, till 0.2 mm thick, sometimes complementary; longitudinal axis undulated; transversal cut plane-concave at the center and strongly involute on the laterals. Proximal surface firm; continuous; smooth, rarely crumpled and rugose; oval to irregular perforations common, commonly cicatrized, and internally ciliated. Distal surface firm; continuous; smooth to rugose. Lateral margin smooth to irregularly cut, crenate and corroded; strongly involute; sinuous to undulated; closed and commonly studded with pycnidia; not auto incompatible; apical zone ascending while, sometimes, involute; apices rounded to irregular, mostly involute. Cilia black, few to rare; satin clear at 20×; not pigmented; straight to irregularly curved; cylindrical to pointed; 0.7-1.0 mm long × 0.1 mm thick; from erect to coplanar to the lobe; simple to forked since 0.2 mm from the base; common at the internal margins of the laminal perforations and at the lacerated lateral margins. Secondary lobes absent. Lobules rare; marginal at the internal margins of the perforations and lacerations, 0.4-0.6 mm wide at branching base, the major width 0.7-2.0 mm (*F. Ciecoski 1006*). Lacinules absent. Postules absent. Sorals absent. Isidia absent. Medulla stramineous, firm. Underside badius to brown or black in the marginal zone and black in the proximal part; a few whitish spots in the marginal zone. Marginal zone badius to brown or black, rarely white in involute part; lustrous; satin clear already at 10×; ca. 3.0-5.0 mm wide; attenuated in the badius and brown parts, in the black part there is not differentiation between the marginal zone and proximal part; smooth to crumpled and reticular-rugose; papillated (*F. Ciecoski 1006*); erhizinated; commonly cracked; crevices accidental, 2.00-5.00 mm long × 0.02-0.05 mm wide, a few cicatrized and with the borders slightly elevated. Proximal part black; sublustrous; satin already clear at 10×; crumpled to rugose; crackled to rugose and crumpled; papillate (*F. Ciecoski 1006*); reticular cracked (*F. Ciecoski 1006*), 0.50-1.00 mm long × 0.03-0.05 mm wide, commonly cicatrized and with the borders slightly elevated. Rhizines absent in the marginal zone; monomorphic, simple to arbusculiform (*F. Ciecoski 1006*), cylindrical; rare and irregularly distributed, in small sparse regions; black; not pigmented; sublustrous; not gomose; satin clear at 20×; sometimes interlaced (*F. Ciecoski 1006*); straight; erect; monometric; 0.20-0.50 mm long × ca. 0.05-0.10 mm thick; sparse groups irregularly distributed at the fixation points. Apothecia bullate (young) and concave (older); till 13.0 mm diam.; subpedicellate; laminal to submarginal; medulla of the basis K+ red; disc brown to light brown (*F. Ciecoski 1006*), epruinose, the young entire, 3-4 clefted till 1/3 of the radius at the older; open to 3-4 folded; imperforated; margin till 3.0 mm thick, smooth to crenate-cut; amphithecia smooth to crumpled, maculae punctiform to efigurated, not ornamented, amphithecial medulla K+ red; stipe short and central, 1.0-2.0 mm wide × 0.5-1.0 mm high, smooth to crumpled, maculae punctiform to efigurated, not ornamented, stipe K+ red; hymenia till 200 µm high. Ascopores ellipsoid, straight to slightly curved, (20.0-) 25.0-27.5 × 12.5-15.0 µm, epispore 2.5 µm thick, gutules absent. Pycnidia marginal to submarginal, immersed, ostiole black. Conidia bifusiform, straight, 10.5-13.5 × 1.5-3.0 µm.

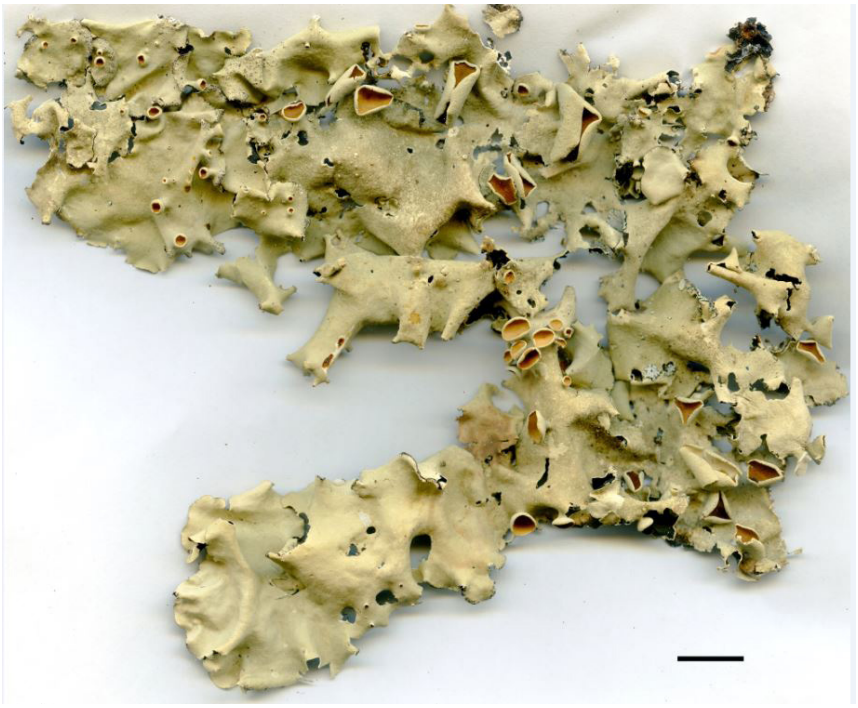

Figure 1. *Parmotrema aristidesii* (holotype, *R. Carpanedo* A, CNMTf 512). Scale bar = 10 mm.

Color tests: upper cortex K+ yellow, UV-; medulla K+ yellow → orange, C-, KC+ yellow, P+ orange, UV-. Substances of taxonomic importance: atranorin, salazinic acid.

Specimens examined (paratype): BRAZIL. Mato Grosso State; municipality of Alta Floresta; Cristalino I State Park, Ponto 29: 9°28'43.24" S, 55°48'52.81" W, elevation 440 m, dense ombrophilous submontane forest with canopy, on tree trunk in the forest, *F. Ciecoski 1006*, 3-III-2021 (CGMS).

Etymology: The epithet is given as homage to Mr. Aristides Adércio Filho, worker in the Santa Fé do Xingu Farm, a simple man full of charisma and with a great empiric knowledge at the field.

Comments: *Parmotrema aristidesii* is characterized by the greenish-gray to bluish, subpergaminaceous, velutinous, maculated, till 27 cm thallus, whose lobes are laterally superposed to straddled, with very few cilia, medulla stramineous and firm, underside lustrous and sparsely rhizinated, reticular-cracked, apothecia concave till 13.0 mm diam., with clefted discs, amphithecia smooth to crumpled and maculated, hymenia till 200 µm high and ascospores ellipsoid (20.0-) 25.0-27.5 × 12.5-15.0 µm, epispore 2.5 µm, conidia bifusiform 10.5-13.5 × 1.5-3.0 µm and salazinic acid in the medulla (K+ yellow → orange).

There are not very similar *Parmotrema* species with salazinic acid.

Parmotrema masonii L.I. Ferraro (Ferraro 1979) is similar in the presence of salazinic acid and differs by the presence of usnic acid and one unknown substance, and the ascospores 10-14 × 5-7 µm.

Parmotrema delicatulum (Vain.) Hale (Hale 1974) also has salazinic acid and differs by the saxicolous habit, the color evidently yellowish green (cortical usnic acid), the white medulla, and the smaller ascospores, 13-10 × 8-5 µm (Hale 1965, Vainio 1890).

Parmotrema cristiferum (Taylor) Hale, *Phytologia* 28(4): 335. 1974.≡ *Parmelia cristifera* Taylor. *London Journal of Botany* 6: 165. 1847. Type**:** INDIA, Calcutta, *Wallich s.n.* (lectotype: fh-tayl). MycoBank: MB343031

Figure 2

Distribution: Oceania, Africa, Indic Ocean Archipelagos, Asia, Pacific Ocean archipelagos. North Aerica, Central America, Caribe, South America, Brazil: Mato Grosso, Minas Gerais, Paraná, and São Paulo States (Spielmann & Marcelli 2020).

Description: Thallus corticicolous; greenish-gray; sublustrous; lobed; subcoriaceous; maculae weak, efigurated, irregularly distributed; satin clearly seen at 20×; till 13.0 cm broad; epruinose; common signs of auto incompatibility in the laterally superposed margins of the lobes. Lobes short, anisotomous; axils acute to oval; axillary folds common, erect to inclined, 1.0-1.5 mm high × 1/4 of the lobe width long; sometimes presents signs of auto incompatibility in laterally superposed lobes; 4.0-10.0 mm wide at branching base, the major width 5.0-14.0 mm; most

Figure 2. *Parmotrema cristiferum* (*F. Ciecoski* 274, CNMTf 513). Scale bar = 10 mm.

of the times laterally superposed to contiguous, and counterposed to straddled; loose adnate to elevated and revolute; black line absent to attenuated, till 0.1 mm thick, not complementary; longitudinal axis distended to undulated; transversal cut plane-concave, the margins ascending in the older lobes. Proximal surface firm; continuous to reticular crackled; smooth to crumpled and sometimes rugose in the lateral margin. Distal surface firm; principally continuous to slightly reticular and crackled; smooth to crumpled and subescrobiculated. Lateral margin smooth to irregularly cut and crenate; sinuous to undulated, commonly crispate in the older parts; closed and commonly ornate by sorals in lacinules; apical zone ascending to slightly descending in the younger parts, strongly ascending to erect in the old sorediated parts; apex rounded to irregularly cut, strongly crispate-sorediate in the proximal parts. Cilia very rare, in the apices of the lobes; black; satin clear at 30×; pigment absent; straight in the base to sinuous at the apex; pointed; 0.40-0.70 mm long × 0.05-0.10 mm thick; ascending; simple and forked since 0.4 mm of the length. Secondary lobes absent. Lobules few; concolored; common as cicatrization process of the lateral margin; 0.6-1.5 mm long × 0.4-0.6 mm wide; lamina canaliculated; sinuous; ascending; apex rounded; black line attenuated till 0.1 mm thick, complementary; eciliated; underside brown. Lacinules marginal in the proximal parts, sorediated; simple to irregularly ramified; contiguous to laterally superposed; elevated to revolute; 1.2-2.0 mm long × 0.5-1.2 mm wide. Pustules few; verruciform; rare capitate; apical and subapical on the lacinules; not confluent but somewhat aggregated and spread on the apex; till 0.5 mm wide; erumpent; dismantling into soredia; originated on the apices of the lacinules; rare caducous, leaving the apical extremities with the medulla completely exposed; pigment rosed K+ red; pustular medulla K+ red. Sorals common; marginal and on the apices and subapices of the lacinules, rare laminal from swellings of the upper cortex; orbicular to labriform when at the lacinules apices; those on the apices and margins of the very young are linear interrupted, when old become subcanaliculated, ascending and crispate, giving the sorals a strongly sinuous appearance; orbicular to labriform till 1.0 mm long × 0.5 mm wide and those linear interrupted till 2.5 mm long × 0.4 mm wide; sometimes coalescent; eciliated; cortex surrounding the sorals crackled to shedding plates; pigment reddish-brown K+ red. Soredia caducous to persistent; auto incompatibility affecting the coloration and changing it to brown or black, common at the apex of the lacinules and margins; mostly farinose and rare granular; the farinose ecorticated and those granular corticated (granules), rarely forming isidioid structures; heaped; commonly produced at the apical zones of the lacinules and on the crispate erect margins of the lobes; K+ red. Isidia absent. Medulla white, normal. Underside badius to brown and black in the marginal zone, black in the proximal part. Marginal zone sublustrous; satin clear at 20× in the badius and brown parts and clear at 30× in the black portion; ca. 4.0-8.0 mm wide; attenuated; smooth to crumpled; commonly papillated; sometimes rhizinated at the transition zone; few reticular-fissured, the crevices 0.50-3.00 mm long × ca. 0.05-0.10 mm wide, commonly cicatrized and with elevated borders. Proximal part sublustrous; satin clear at 20×; crumpled to rugose and papillated; reticular-fissured, the crevices irregularly ramified 3.00-10.00 mm long × ca. 0.05-0.10 mm wide, commonly cicatrized and with the borders slightly elevated. Rhizines absent in the marginal zone but present at the transition zone; monomorphic, simple, apices commonly penicillate to arbusculiform, cylindrical; common and irregularly distributed by small sparse regions at the fixation points; black; not pigmented; sublustrous; not gomose; satin clear at 20×; commonly interlaced

and difficult to measure; straight; erect; monometric; 0.40-0.70 mm long × ca. 0.05-0.10 mm thick; rare sparse groups irregularly distributed on the underside. Apothecia absent. Pycnidia absent. Color tests: upper cortex K+ yellow, UV-; medulla K+ yellow →orange, C-, KC-, P+ orange, UV-. Substances of taxonomic importance: atranorin, salazinic acid. Specimens examined: BRAZIL; Mato Grosso State; municipality of Alta Floresta; Cristalino I State Park, Ponto 5: 9°28'42.62"S, 55°49'50.82"W, elevation 300 m, open ombrophilous submontane forest with canopy, on tree trunk in the forest, *F. Ciecoski 274*, 07-VI-2020 (CNMTf 513). Comments: *Parmotrema cristiferum* (Taylor) Hale is a lobed, subcoriaceous, rarely ciliate, and weak maculated species that presents signals of auto incompatibility in the margins of the laterally superposed lobes, with common axillary folds, the proximal surface continuous to reticular crackled, the margin of the lobes crispate and ornated with sorals on the lacinules and lobes margins. The marginal sorals are linear interrupted and become subcanaliculated, ascending, and crispate. Lobules are common in the process of cicatrization of the lateral margin and produce pustules with a rosed pigment K+ red that dismantle into soredia; the medulla is white with rare stains resulting from the oxidation of the salazinic acid (K+ yellow → orange); the underside is rhizinated and has reticular cicatrized fissures with slightly elevated borders.

It is considered a cosmopolitan species broadly distributed in the tropical and subtropical regions (Hale 1965, Michlig *et al*. 2015) but complete descriptions are lacking.

Parmotrema cristiferum was described by Taylor (1847) and, among the studied specimens, there is one collection from Brazil. The species was characterized as having a whitish thallus ca. 15-20 cm broad, with the margins covered by a "fine and pulverulent powder". In 1965, Hale wrote about what could be that powder concluding that it was the soredia, which are originated in linear sorals on the lobes' margins; furthermore, Hale (1965) described the thallus as eciliate and with an opaque, continuous but broken upon ageing surface, the color reactions as upper cortex K+ yellow, medulla K+ yellow → red, C-, KC-, and P+ orangish-red due the presence of atranorin and salazinic acid.

Marcelli & Benatti (2010) studied Brazilian specimens identified as *P. cristiferum* collected in São Paulo State and described them as having a sublobed thallus till 30.0 cm broad with lobes irregularly ramified forming pleated and subcanaliculated folds, apices revolute when sorediated, cilia rare and sparse, medulla not pigmented but sometimes tinged by the oxidation do salazinic acid, and the underside partially papillated and rugose.

Donha (2005), with material from Paraná State, mentioned a coriaceous thallus and rhizines black, ivory, and bicolored. Bawingan *et al*. (2017) mentioned the presence of consalazinic acid in the medulla.

Parmotrema cristiferum (Taylor) Hale is like *P. subcristiferum* Marcelli & Ciecoski (described ahead) by the thallus opaque loose adnate, by the soredia subgranular and farinose, by the white medulla containing salazinic acid and by the color reactions K+ yellow → orange → red, C-, KC+ weak yellow, P+ orange. Differs by the sorals development as marginal (Hale 1965), the coriaceous thallus with a bright smooth surface (Donha 2005) and by the consalazinic acid in the medulla (Bawingan *et al*. 2017).

Benatti & Marcelli (2010) described *P. rubifaciens* (Hale) Hale (Hale 1974) with morphological similarities very near to *P. cristiferum* (Taylor) Hale, differing by producing norstictic acid (K+ yellow → orange), connorstictic acid, constictic acid in the medulla, and the sorals even more agglomerated.

Parmotrema margaritatum (Hue) Hale (Hale 1974) differs from *P. cristiferum* by the thallus membranous (Hue 1899) with an opaque to bright surface and submarginal sorals (Hale 1965), the habit sublaciniate, in being hypermaculated, and by producing chlroatranorine and consalazinic acid (Spielmann & Marcelli 2020).

Parmotrema stuppeum (Taylor) Hale (Hale 1974) also has a morphology somewhat like *P. cristiferum* in the linear and marginal sorals, and the salazinic acid in the medulla, the distinction between them made by the longer cilia (2.0–3.0 cm) and the smaller conidia (4.0-6.0 µm) in *P. stuppeum* (Marcelli & Benatti 2010) besides the size of the spores (Hale 1965). The specimen of *P. cristiferum* here studied has no apothecia and pycnidia to make comparisons; however, Donha (2005) mentioned conidia sublageniform 7–9 × 1 µm, confirming the difference pointed by Marcelli & Benatti (2010).

Parmotrema hypoflavum Marcelli & Ciecoski, *sp. nov.*
Type: BRAZIL. Mato Grosso State: municipality of Novo Mundo, Cristalino I State Park, Ponto 7: 9°29'60.91"S, 55°51'28.06"W, elevation 311 m, seasonal semidecidual submontane forest with emergent canopy, on tree trunk in the forest, *F. Ciecoski 325*, 8-VI-2020 (holotype: CNMTf 514). MycoBank: MB842963
Figure 3

Diagnosis: *Parmotrema hypoflavum* is a greenish-gray, velvet opaque, pergaminaceous species that

Figure 3. *Parmotrema hypoflavum* (holotype, *F. Ciecoski* 325, CNMTf 514). Scale bar = 10 mm.

has pustules that dismantle into soredia K+ red, the major part of the medulla bicolored white above and yellow close to under cortex, which can be inverted or totally white in different parts of the thallus, contain salazinic acid and secalonic acid C, with the white medulla K+ yellow, C-, KC-, P+ yellow, UV-, and yellow medulla K+ yellow →orange → red, C-, KC-, P+ yellow, UV-. Description: Thallus corticicolous; greenish-gray; velvet opaque; lobed; pergaminaceous; rare reticular maculae (*F. Ciecoski 705*); satin visible only at 40×; till 10.0 cm broad; the counterposed parts are commonly ciliated and/or sorediated; epruinose; laminal perforations commonly oval, internally ciliated and of unknown origin, some of them not totally perforated and exposing the upper side of the lower cortex. Lobes short, anisotomous to sympodial; axils oval to irregular and acute; axillary folds frequent; 5.0-10.0 mm wide at branching base, the major width 6.0-18.0 mm; laterally superposed to contiguous and counterposed; loosely adnate to slightly revolute; black line absent to attenuated, till 0.1 mm thick, sometimes complementary; longitudinal axis distended to undulated; transversal cut initially concave, convex at the older parts, borders coplanar to slightly involute. Proximal surface firm; continuous to crackled; smooth to slightly crumpled. Distal surface firm; continuous to crackled; smooth to slightly crumpled. Lateral margin smooth to irregularly cut; sinuous to undulated; closed and sometimes sorediate; signals of auto incompatibility; apical zone slightly ascending, sometimes a little revolute at the sorediated parts; apex rounded to irregular, ascending to little revolute at the sorediated parts. Cilia black; satin clear at 20×; without pigments; sinuous; cylindrical and pointed; 0.4-1.5 (-2.0) mm long × 0.05-0.1 mm thick (*F. Ciecoski 361*); erect to ascending; simple to forked and irregularly 3-5 ramified since 0.5 mm of the length; few at the lobes' apical margins, rare on the sorediated lacinules and growing on the sorals, common on the distal margins. Secondary lobes and lobules absent. Lacinules marginal in parts of the proximal and distal surface, commonly sorediated; anisotomous to irregularly ramified; contiguous to laterally superposed, sometimes elevated and counterposed to form a tube with the apex open and sorediated; elevated to revolute; 1.5-2.0 mm long × 0.5-1.0 mm wide. Postules few; verruciform and irregular; not confluent; normally subapical on the shorter lacinules, a few marginal to submarginal and laminal on the lobes; till 1.0 mm diam.; erumpent; dismantling into soredia; originated on the apices and revolute ascending margins or from swellings on the laminal cortex; not caducous; without pigments; pustular medulla K+ red. Sorals abundant; subapical on the lacinules, even the shorter ones, rare marginal to submarginal; orbicular; till 1.0 mm long × 0.5 mm wide; not coalescent; a few ciliated; the cortex surrounding the sorals from entire to cracked and shedding plates. Soredia caducous to persistent, without signs of auto incompatibility; common the farinose and abundant the granular; ecorticated; heaped; commonly produced on the apical zones of the lobes; K+ red. Isidia absent. Medulla firm, white in some points, the major part bicolored, more commonly one upper layer white and one thin lower layer yellow with irregular relative thickness proportions, in some points inverted, with the yellow layer above the white. Underside badius to dark brown or black in the marginal zone and black in the proximal part. Marginal zone lustrous in the badius part to dark brown and sublustrous in the black; satin clear already at 10× in the badius to dark brown portion and clear only at 40× in the black one; ca. 4.0-6.0 mm wide; slightly attenuated in the badius and dark brown parts; smooth to slightly crumpled; epapillated; erhizinated; commonly cracked in the black part; crevices irregularly ramified, sometimes cicatrized, with elevated borders. Proximal part black; satin clear only at 40×; crumpled to rugose; reticular cracked, crevices sometimes ramified, commonly cicatrized

and with elevated margins. Rhizines absent in the marginal zone; monomorphic, simple, sometimes with penicillate to arbusculiform apex, cylindrical; rare and irregularly distributed in small sparse regions at the fixation points; black; not pigmented; sublustrous; not gomose; satin clear at 30×; commonly interlaced and difficult to measure; straight; erect; monometric; 0.20-0.70 mm long × ca. 0.08-0.10 mm thick. Apothecia absent. Pycnidia absent. Color tests: upper cortex K+ yellow, UV-; white medulla K+ yellow, C-, KC-, P+ yellow, UV-; yellow medulla K+ yellow → orange → red, C-, KC-, P+ yellow, UV-. Substances of taxonomic importance: atranorin, salazinic acid, secalonic acid C. Etymology: The epithet *hypoflavum* is a union of the Greek prefix "*hypo"* (=below) and the Latin word "*flavum"* (=yellow), as a reference to the yellow medullary layer near the under cortex by the most part of the thallus. Specimens examined (paratypes): BRAZIL, Mato Grosso State, Ponto 9: 9°30'25.04"S, 55°49'51.83"W, elevation 258 m, dense submontane ombrophilous forest with canopy, on tree trunk, *F. Ciecoski 361*, *381*, 10-VI-2020 (CNMT); idem, municipality of Santa Cruz do Xingu; Xingu State Park, Ponto 18: 9°48'20.54"S, 52°27'40.89"W, elevation 265 m, dense submontane ombrophilous forest with canopy, on tree trunk, *F. Ciecoski 705*, 13-II-2021 (CGMS). Comments: *Parmotrema hypoflavum* is characterized by the greenish-gray, loosely adnate to revolute, velvet opaque and pergaminaceous thallus, the lobes with simple, forked and irregularly ramified cilia, pustules dismantling into orbicular sorals with farinose and granular ecorticated soredia, with sorediated lacinules, medulla bicolored yellow and white; the underside is lustrous in the distal part, rhizinated and reticular cracked with cicatrized crevices of elevated borders, produces salazinic acid and secalonic acid C (medulla white K+ yellow, C-, KC-, P+ yellow, UV-; medulla yellow K+ yellow → orange → red, C-, KC-, P+ yellow, UV-).

Parmotrema paramoreliense W.L. Culb. & C.F. Culb. (Culberson & Culberson 1981) is similar in the color reactions (medulla K+ yellow → red, C-, P + orange-red) and, according to the analyses done by Spielmann & Marcelli (2020), differs from *P. hypoflavum* by the white medulla containing chlroatranorine and consalazinic acid. Nash *et al*. (2002) also cited gyrophoric acid and protocetraric acid in *P. paramoreliense*.

Parmotrema cristiferum (Taylor) Hale (Hale 1974) is presented in the original description by Taylor [1847] as a thallus with margins covered with a powder (soredia), and Hale (1974) states that its thallus is coriaceous till 24 cm broad and the medulla only white colored containing salazinic acid. Bawingan *et al*. (2017) cited the presence of consalazinic acid in the medulla, and Benatti & Marcelli (2010) mentioned not pustular sorals.

Parmotrema margaritatum (Hue) Hale (Hale 1974) differs from *P. hypoflavum* by the membranous thallus (Hue 1899), the capitate sorals on the lacinules apices (Benatti & Marcelli 2010) and in the chemistry, by the presence of chlroatranorine and consalazinic acid (Spielmann & Marcelli 2020).

Parmotrema stuppeum (Taylor) Hale is similar in the presence of ciliated sorals and salazinic acid in the medulla (Hale 1965), and differs by the thallus coriaceous 10-20 cm broad (Hale 1965), the sorals linear and marginal (Benatti & Marcelli 2010), the white medulla and production of chlroatranorine and consalazinic acid.

Parmotrema marjorieanum Ciecoski & Marcelli, *sp. nov.* Type: BRAZIL, Mato Grosso State, municipality of Novo Mundo, Cristalino I State Park, Ponto 8: 9°26'45.27"S, 55°50'40.08"W, elevation 242 m, open dense ombrophilous submontane forest with canopy, on fallen tree branch in the forest, *F. Ciecoski 355*, 10-VI-2020 (Holotype: CNMTf 515). MycoBank: MB842964
Figure 4

Diagnosis: *Parmotrema marjorieanum* is a subpergaminaceous, not maculate, lobed, lacinulated, little ciliated species with a cracked surface, orange-reddish pigmented pustules (K+ yellow) that dismantle into farinose soredia, has confluent sorals which form aggregates spreading on the submarginal region, and the white medulla contains salazinic acid.

Description: Thallus corticicolous; greenish-gray; opaque; lobed; subpergaminaceous; not maculated; epruinose; satin little perceptible even at 40× at the distal parts, where the surface is continuous; the opacity of the proximal surface is due to the cracking of the upper cortex; till 6.0 cm broad. Lobes short, anisotomous; axils oval to acute; axillary folds common; auto incompatibility of the lateral margins; 0.5-3.0 mm wide at branching base, the major width 1.0-6.0 mm; contiguous to laterally superposed; conformed to the substrate to slightly elevated; longitudinal axis distended to slightly undulate; transversal cut plane to concave in the center, the laterals ascending to revolute. Proximal surface firm; continuous to crackled; smooth, with sparce foveola. Distal surface firm; continuous to reticulated; sometimes crumpled. Lateral margin smooth to irregularly cut and crenate; straight to sinuous and revolute; closed and sorediated; epruinose; black line subtle, till 0.1 mm thick, attenuated, complementary at many parts. Apical zone ascending to involute,

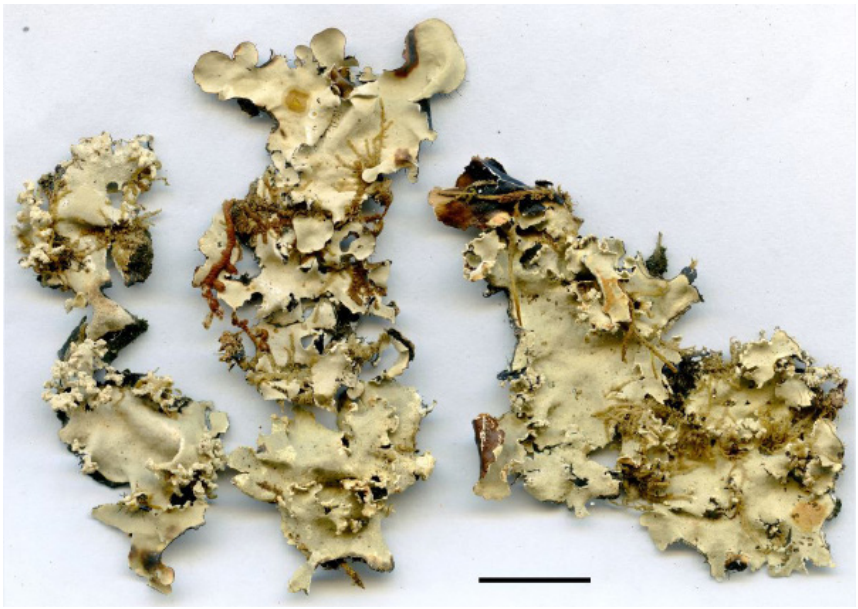

Figure 4. *Parmotrema marjorieanum* (holotype, *F. Ciecoski* 355, CNMTf 515). Scale bar = 10 mm.

revolute in the sorediated parts; apex rounded, plane to involute, revolute in the sorediated parts. Cilia black; satin clear at 30×; without pigments; straight to slightly sinuous; cylindrical and pointed; 1.00-2.00 × 0.10-0.15 mm; erect to coplanar to the lobe; simple to rarely forked since 0.4 mm from the base; few, in the apical margins of the lobes to absent principally at the sorediated apices. Secondary lobes absent. Lobules absent. Lacinules marginal in the young parts; sympodial to irregularly ramified; contiguous; elevated to revolute; 0.5-1.5 × 0.5-1.0 mm. Postules common; oval-verruciform to capitate; commonly confluent forming aggregates that spread on submarginal region; marginal to submarginal; till 0.7 mm wide; erumpent; dismantling into sorals; originated in the lacinules apices and in the revolute and ascending margins of the lobes; caducous, exposing the medulla at the apices of the lacinules; with an orange-reddish K+ yellow pigment; pustular medulla K+ yellow. Sorals frequent; marginal to submarginal; labriform to orbicular; till 0.7 mm long × 0.5 mm wide; not coalescent; eciliate; the cortex surrounding sorals from entire to crackled and shedding plates; with orange-reddish K+ yellow pigment. Soredia caducous to persistent, without signs of auto incompatibility; farinose; ecorticated; heaped; commonly produced at the apical zones of the lobes; K+ yellow. Isidia absent. Medulla white, loose. Underside brown or black in the marginal zone and black in the proximal part. Marginal zone lustrous; satin clear already at 10×; ca. 2 mm wide in the brown part; smooth in the brown part and crackled to crumpled in the black part; epapillate; erhizinate; rare not ramified, not cicatrized crevices without elevated borders. Proximal part sublustrous; satin clear at 30×; smooth to papillated and crumpled to rugose; a few times irregularly fissured; crevices not ramified, part of them cicatrized and with elevated margins; rare roundish decorticated regions with elevated borders sometimes cicatrized, looking like pseudocyphellae, till 0.5 mm diam. and exposing the medulla (consequence of rhizines fall). Rhizines absent in the marginal zone; monomorphic, cylindrical; rare and irregularly distributed in small sparse regions; black; not pigmented; lustrous; not gomose; satin clear already at 10×; simple; not interlaced; straight; erect; monometric; 0.30-0.40 mm long × ca. 0.10-0.15 mm thick; in rare groups irregularly distributed in the fixation regions, difficult to measure. Apothecia absent.
Pycnidia absent.

Color tests: upper cortex K+ yellow, UV-; white medulla K+ yellow → orange → red, C-, KC-, P+ yellow, UV-.

Substances of taxonomic importance: atranorin, salazinic acid.

Etymology: The epithet is given after F. Ciecoski's daughter Marjorie Sofientini Ciecoski. Comments: *Parmotrema marjorieanum* is characterized by the greenish-gray, lobed, and pergaminaceous thallus and lobes 1.0-6.0 mm wide with only a few cilia restricted to the apices, by the laciniae with pigmented orange-reddish (K+ yellow) pustules that dismantle into farinose soredia (K+ yellow), the white medulla, and the presence of salazinic acid in the medulla (K+ yellow → orange → red, C-, KC-, P+ yellow, UV-).

Parmotrema paramoreliense W.L. Culb. & CF Culb. (Culberson & Culberson 1981) is similar in the thallus size (7 cm), the medullary color reactions K + yellow → red, C-, P+ orange-red (Culberson & Culberson 1981) indicating the salazinic acid

(Spielmann & Marcelli 2020). Differs by the thallus lacinulated, maculate, the granular soredia (Culberson & Culberson 1981) and in the presence of chlroatranorine in the upper cortex and consalazinic acid in the medulla (Spielmann & Marcelli 2020).

Parmotrema cristiferum (Taylor) Hale (Hale 1974) differs in the greater coriaceous till 24 cm thalli (Donha 2005), not pustular sorals with granular soredia (Benatti & Marcelli 2010), and the presence of consalazinic acid in the medulla (Bawingan *et al*. 2017).

Parmotrema margaritatum (Hue) Hale (Hale 1974) differs in the thallus sublaciniate, membranous, and granular soredia (Hue 1899), by the size of the thallus (6-17 cm), the presence of chlroatranorine in the upper cortex and consalazinic acid in the medulla (Spielmann & Marcelli 2020).

Taylor (1847) described *P. stuppeum* (Taylor) Hale (Hale 1974) as having a coriaceous thallus 6 cm large and Hale (1965) mentioned thalli 10-20 cm broad with grayish color and ciliated sorals. Marcelli & Benatti (2010) cited the lobes width as 1.0-1.5 cm. Spielmann & Marcelli (2020), studying the holotype, described it as not lacinulate, with farinose soredia, the underside densely venate, and with chlroatranorine and consalazinic, in which it differs from *P. marjorieanum*, that has an underside smooth to crumpled, and produces lacinules.

Parmotrema marlitonii Ciecoski & Marcelli, sp. nov. Type: BRAZIL. Mato Grosso State: municipality of Novo Mundo, Cristalino I State Park, Ponto 8: 9°26'45.27"S, 55°50'40.08"W, elevation 242 m, open dense ombrophilous submontane forest with canopy, on a fallen branch in the forest, *F. Ciecoski 351*. 10-VI-2020 (Holotype: CNMTf 516). MycoBank: MB842965

Figure 5

Diagnosis: *Parmotrema marlitonii* is a submembranaceous, lobed, whitish-gray, ciliated, velvet-opaque (velutinous), small 3 cm broad species whose pustules dismantle into both farinose and granular soredia, has most of the medulla bicolored white above and lemon-yellow below, the proximal part of the underside papillate and with deep not cicatrized fissures, rhizines both planiform and cylindrical, and contains salazinic acid in the medulla (K+ orange → red). Description: Thallus corticicolous; whitish-gray; not maculated; velvet-opaque, satin not visible even at 40×; lobed; submembranaceous; small, till 3.0 cm broad. Lobes short, subdichotomous; axils oval to squared; 4.0-8.0 mm wide at branching base, the major width 4.0-12.0 mm; laterally superposed to counterposed; loose adnate to elevated; longitudinal axis slightly undulated; transversal cut plane to concave at the center, the border coplanar to revolute; axillary folds common, low; proximal surface firm to brittle, reticular cracked to crackled; distal surface smooth to foveolate and with folds becoming elevated near the center of the thallus; epruinose; lateral margin smooth to irregularly cracked and involute, closed; sorediated; black line very subtle, till 0.1 mm thick, attenuated, complementary at many parts; apical zone elevated or involute, revolute at the sorediated parts; apices rounded, plane to involute, revolute in the sorediated parts. Cilia black; satin evident at 30×; without pigments; straight to irregularly curved; cylindrical to pointed; 2.0-4.0 mm long × 0.1 mm thick; erect; simple to forked to irregularly 2-3 ramified since 0.5 mm of the length; common at the axillary folds, frequent in parts of the lateral margin, absent principally from the esorediate apices. Secondary lobes absent. Lacinules and lobules absent. Postules rare; oval-verruciform to capitate; not confluent; marginal to submarginal; till 1.0 mm wide; erumpent; dismantling into soredia; originated on the apices of the involute ascending margins; not caducous; without pigments; K+ yellow. Sorals frequent; marginal to submarginal, rarely laminal from eruptions near the lateral margins; labriform to orbicular, efigurated when laminal; till 2.0 mm long × 1.0 mm wide; not coalescent; eciliate; cortex surrounding the sorals entire or cracked and shedding plates; without pigments. Soredia persistent, without signs of auto incompatibility; farinose to granular; commonly corticated (granules); heaped; rarely produced directly in the lateral margin; K+ yellow. Isidia absent. Medulla loose, irregularly bicolored, the upper part white and the lower strong lemon-yellow in the proportion of 1:2 to 2:3, or completely white at some points, without K+ pigment. Underside brown in the marginal zone and black in the proximal part; continuously black since below the sorals in the marginal zone till the proximal region. Marginal zone sublustrous; subsatin at 20×; ca. 7 mm width in the brown part; smooth in the brown part to papillated and crumpled in the black part; black papillae common in the black part of the margin; erhizinated; fissures absent. Proximal part sublustrous; subsatin clear at 30×; smooth to papillated and crumpled at rugulose; commonly fissured in the region where the lower medulla is yellow, with rare sympodial to perpendicular ramifications, 1.0 × 0.2 mm, not cicatrized and with margins elevated, on those more accentuated may rarely occur deep fissures the can exposed even the white medulla above the yellow one; decorticated rounded regions with elevated borders are common, sometimes cicatrized and similar to pseudocyphellae, till 1.5 mm diam. which expose the yellow medulla (consequence of rhizines fall). Rhizines absent in the

Figure 5. *Parmotrema marlitonii* (holotype, *F. Ciecoski* 351, CNMTf 516). Scale bar = 10 mm.

marginal zone; dimorphic (planiform and cylindrical); few and irregularly distributed in small sparse fixation regions; black; not pigmented; sublustrous; not gomose; satin clear at 20×; simple to irregularly 2-4 branched; coplanar to the lobes; the first branch since 2.0 mm of the length; not interlaced; sinuous to curved; bent to erect and prostrated without orientation; dimetric; the planiform near the marginal zone 1.0-1.2 mm long. × ca. 0.1 mm thick, and the cylindrical present at the proximal region 0.2-0.4 mm long × ca. 0.1 mm thick; few; small groups distributed irregularly on the underside. Apothecia absent. Pycnidia absent.

Color tests: upper cortex K+ yellow, UV-; white medulla K+ orange → red, C-, KC+ yellow, P+ yellow, UV-; yellow medulla K+ orange → red, C-, P+ yellow, UV-.

Substances of taxonomic importance: atranorin, salazinic acid.

Etymology: The epithet is a homage to the entomologist Dr. Marliton Rocha Barreto from Federal University of Mato Grosso, for his contributions to Amazonian research and the incomparable friendship.

Comments: *Parmotrema marlitonii* is characterized by the thallus whitish-gray, velvet-opaque, submembranaceous and lobed, by the cilia simple to forked or ramified, the pustules dismantling into farinose and granular soredia, the bicolored medulla with the upper part white and the lower lemon-yellow or completely white in some points, by the underside with a papillated marginal zone and the proximal part with deep not cicatrized fissures, the rhizines dimorphic (planiform and cylindrical) and by the presence of salazinic acid in the medulla (K+ orange → red).

Parmotrema paramoreliense W.L. Culb. & CF Culb. (Culberson & Culberson 1981), despite producing salazinic acid in the medulla (Spielmann & Marcelli 2020), differs in the laciniated 7 cm broad thallus (Culberson & Culberson 1981), maculated, the presence of chlroatranorine and consalazinic acid (K+ yellow → blood red) (Spielmann & Marcelli 2020), and gyrophoric acid and protocetraric acid in the medulla (Nash *et al*. 2002).

Parmotrema cristiferum (Taylor) Hale (Hale 1974) is similar in the whitish thallus (Taylor 1847), loose-adnate with marginal sorals, soredia farinose to subgranular (Donha 2005), and the presence of salazinic acid in the medulla (Bawingan *et al*. 2017). Differs in the thallus size 15-20 cm (Taylor 1847), coriaceous, white medulla (Donha 2005), the sorals not pustulated (Marcelli & Benatti 2010), and by the presence of consalazinic acid in the medulla (Bawingan *et al*. 2017).

Parmotrema margaritatum (Hue) Hale (Hale 1974) also has salazinic acid in the medulla but differs by the presence of maculae (Hale 1965), the presence of sorediated marginal lacinules (Marcelli & Benatti 2010), the sublaciniated 6-17 cm broad thallus, the white medulla, and the presence of chlroatranorine and consalazinic acid (Spielmann & Marcelli 2020).

Parmotrema stuppeum (Taylor) Hale (Hale 1974) also has a lobed loose-adnate thallus containing salazinic acid in the medulla (Hale 1965) and differs

by the coriaceous thallus (Taylor 1847), the thallus size 10-20 cm broad, ciliated sorals (Hale 1965), the white medulla and the presence of chlroatranorine and consalazinic acid in the medulla (Spielmann & Marcelli 2020).

Parmotrema nelihondae Marcelli & Ciecoski, sp. nov. Type: BRAZIL. Mato Grosso State: municipality of Cotriguaçu, São Nicolau Farm, Ponto 11: 9°48'59.15"S, 58°16'70.42"W, elevation 244 m, dense open ombrophilous forest, on tree trunk in the forest, *F. Ciecoski 459*, 10-VI-2020 (holotype: CNMTf 517). MycoBank: MB842966.

Figure 6

Diagnosis: *Parmotrema nelihondae* is an opaque to sublustrous, ciliated, cracked, and coriaceous species with many strongly counterposed sorediate-isidiated lobes whose fused margins turn the thallus a rigid plate, has sorediated and isidiated lacinules, white medulla, the pustules dismantle into sorals, the underside is papillated and rhizinated, and contains salazinic acid (medulla K+ yellow → red).

Description: Thallus corticicolous; greenish-gray; mostly opaque (to sublustrous); lobed; coriaceous; not maculate; satin clear only at 40×; till 9.0 cm broad, rare reddish stains irregularly spread; epruinose. Lobes short, dichotomous to sympodial; axils oval to acute and squared; axillary folds common, elevated;

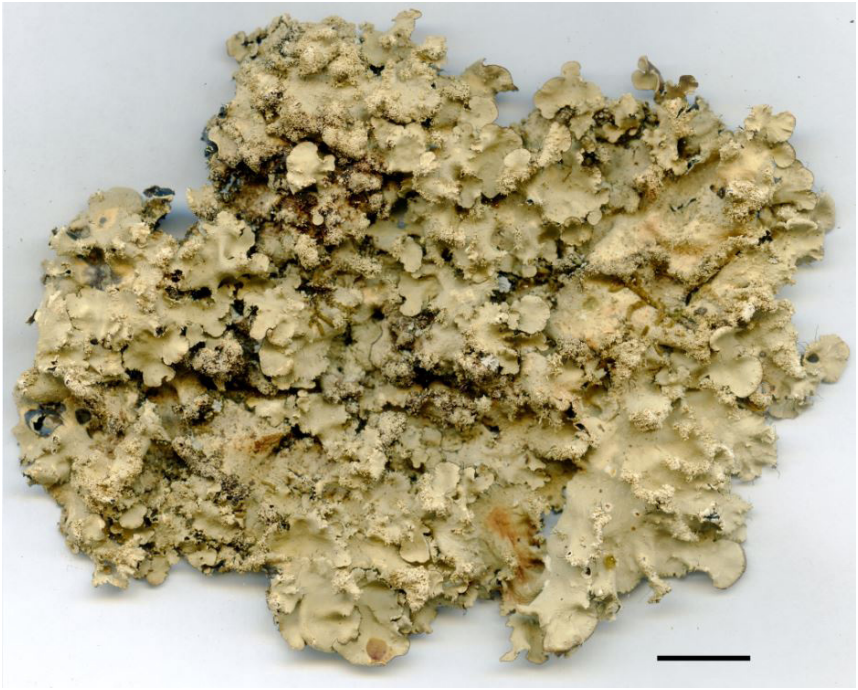

Figure 6. *Parmotrema nelihondae* (holotype, *F. Ciecoski 459*, CNMTf 517). Scale bar = 10 mm.

without signs of auto incompatibility; 1.0-6.0 mm wide at branching base, the major width 3.0-7.5 mm; laterally superposed to heaped, sometimes forming layers, commonly strongly counterposed and with the margins so fused that the "sewing" is practically invisible, only a few straddled; conformed to the substrate to loose adnate; black line clear-cut to rarely attenuated, till 0.1 mm thick, complementary in many parts; longitudinal axis distended to strongly undulate; transversal cut convex to concave, the borders undulated to descending. Proximal surface firm; continuous to crackled and reticular cracked; crumpled to escrobiculated and rugose. Distal surface firm to brittle and shedding plates of the upper cortex; continuous to reticular cracked; smooth to crumpled and escrobiculated to rugose. Lateral margin smooth to irregularly cut and crenate to bicrenate; straight to sinuous, revolute when sorediated and isidiated, ascending when without reproductive structures; closed; sorediated-isidiated; apical zone ascending, revolute in the sorediated-isidiated parts; apex roundish, plane, revolute in the sorediated parts. Cilia bright black; satin already clear at 10×; without pigments; straight to slightly sinuous; cylindrical and pointed; 0.90-2.00 mm long × 0.10-0.15 mm thick; erect to ascending; simple to rarely squarrose since the base or forked since 0.5 mm of the length; few at the apical margins of the lobes, common on the sorediated lacinules that grow on the sorals and on the isidia, a few laminal to submarginal growing on cortical swellings or on small and sparse isidia agglomerations, some growing on the folds of the longitudinal axis, rare

on the distal younger margins. Secondary lobes rare; marginal; anisotomous, rare dichotomous; isolated and sparse to heaped and contiguous; on the primary lobes; elevated; 0.5-1.5 mm long × 0.5-1.0 mm wide. Lobules absent. Lacinules marginal all over the thallus, intensely sorediated-isidiated; sympodial to irregularly ramified; heaped and counterposed; sometimes the counterposed margins are circumvented by grouping sorals and isidia growing on the apical zone; after the margins becomes counter positioned they turns involute, straddled and also fused by marginal and submarginal soredia and isidia; elevated to revolute; 0.5-1.7 × 0.2-0.3 mm; when revolute, the fusion promoted by the sorals result in a cauliflower-like structure. Postules few; verruciform and irregular; not confluent; marginal to submarginal; till 1.0 mm wide; erumpent; dismantling into sorals; originated on revolute and ascending apices and margins; not caducous; without pigment. Sorals abundant; marginal to submarginal, very frequently along the fused margins; labriform to capitate; till 1.0 mm long × 0.5 mm wide; coalescent, forming irregular agglomerations difficult to measure; eciliated; cortex surrounding the sorals integer to cracked and shedding plates. Soredia caducous to persistent, without signs of auto incompatibility; common the farinose, abundant the granular that commonly originated the isidia; ecorticated; heaped; commonly produced in the apical zones of the lobes; K+ yellow. Isidia concolored but with darkened apices, common the decapitated, sublustrous; dense; erect; principally marginal to submarginal and on the lacinules apices, a few laminal; grouped to cespitose; firm, fragile, a few caducous with the lost parts adhered to the submarginal cortex and becoming cespitose; conical to irregular and barreled; surface integer, smooth to slightly crackled and undulated; straight to principally irregular; commonly both the pointed and the roundish, sometimes truncate (decapitate); apex brown, integer to fallen; base not constricted; few irregularly 2-3 ramified since half height, rare the antleriform; 1.0-4.0 mm high × ca. 1.0-1.5 mm thick; a few with one apical commonly simple cilium 0.30-0.70 mm high × ca. 0.10-0.15 mm thick, rare the forked cilia 10.0-12.0(-17.0) mm high × ca. 0.2-1.0 mm thick, and rare the squarrose 0.30-0.80 mm high × ca. 0.05-0.10 mm thick; rarely developing lobules; without signs of auto incompatibility. Medulla white, firm. Underside dark brown or black on the marginal zone and black on the proximal part. Marginal Zone sublustrous; satin clear at 30×; ca. 1.0-2.0 mm wide on the dark brown part; smooth to crumpled on the dark brown part and rugose to crumpled on the black part; a few concolored papillae sparsely distributed on the convex apices of the folds; erhizinated; rare fissures not ramified, not cicatrized, with not elevated borders. Proximal part black; sublustrous; satin clear at 30×; smooth to papillated and crumpled to rugose; reticular fissured, the crevices with irregular ramifications, commonly cicatrized and with elevated margins. Rhizines absent from the marginal zone; simple and forked, cylindrical; commonly irregularly distributed in small sparse patches at the thallus fixation points; black; not pigmented; sublustrous; not gomose; satin clear at 20×; erect; monometric length; those simple with pointed apices 0.20-0.70 mm long × ca. 0.10-0.12 mm thick, the simple with penicillate apex straight 0.50-0.70 mm long × ca. 0.09-0.10 mm thick, the forked ramified 0.5 mm from the base, apices pointed, 0.20-0.70 mm long × ca. 0.10-0.15 mm thick. Apothecia absent. Pycnidia absent.

Color tests: upper cortex K+ yellow, UV-; medulla K + yellow → red, C+ weak yellow, KC+ yellow, P+ yellow, UV-.

Substances of taxonomic importance: atranorin, salazinic acid.

Comments: *Parmotrema nelihondae* is characterized by the opaque to sublustrous, coriaceous, emaculate thallus with rare reddish stains, by the sorediate-isidiated lacinules, the presence of dichotomous to sympodial lobes, many of them strongly counterposed with fused margins what turns the thallus a rigid plate, by the proximal surface crackled and reticulate cracked, cilia in the margins of lobes, sorals, and isidia, by the pustules dismantling into sorals, the white medulla, underside with concolored papillae, by the rhizines both simple and forked, by the presence of salazinic acid (medulla K+ yellow → red), and the medullary color reactions C+ weak yellow, KC+ yellow of unknown cause.

Among the species with salazinic acid, *P. coralliforme* (Hale) Hale (Hale 1974) is somewhat like *P. nelihondae* in relation to the size of the thallus (10 cm) loose adnate and rigid and the white medulla (Hale 1965). Differs by the lustrous thallus, the coralliform ciliate and concolor isidia till 5 mm high, the KC- medullary color reaction (Hale 1965), the fissured underside (Spielmann & Marcelli 2020). Furthermore, *P. nelihondae* presents pustules that dismantle into sorals and the lobes, besides strongly counterposed, have the densely sorediated and isidiated margins fused.

Parmotrema ramusculum (Hale) Hale (Hale 1974) is somewhat similar in the opaque and ciliate thallus, the white medulla with salazinic acid (Hale 1965) and differs in the color reactions C-, KC-, by developing sorediated eciliate ivory arbuscules and on the chemistry by the presence of chlroatranorine and consalazinic acid (Spielmann & Marcelli 2020).

The epithet is to homage our dear Dr. Neli Kika Honda, for her very significant studies on the Brazilian lichen chemistry and several other contributions to Brazilian lichenology, besides her great sweetness, affability, and friendship.

Parmotrema subcristiferum Marcelli & Ciecoski, *sp. nov.* Type: BRAZIL. Mato Grosso State: municipality of Novo Mundo, Cristalino I State Park, Ponto 5: 9°28'42.62"S, 55°49'50.82"W, elevation 300 m, seasonal semidecidual submontane forest with emergent canopy, on tree trunk in the forest, *F. Ciecoski 273*, 7-VI-2020 (holotype: CNMTf 518). MycoBank: MB842967.

Figure 7

Diagnosis: *Parmotrema subcristiferum* is a lobed, subpergaminaceous, eciliate, and opaque species whose proximal surface is corrugated and escrobiculated, develops pustulated and sorediated lacinules, the pustules dismantle into granular and farinose soredia (K+ red), the medulla is white and contains salazinic acid (K+ yellow → orange → red).

Description: Thallus corticicolous; greenish-gray; opaque; lobed; subpergaminaceous; not maculated; satin visible only at 45×; till 10.0 cm broad; epruinose; without signs of auto incompatibility. Lobes short, anisotomous to sympodial; axils oval to irregular and squared; axillary folds common; 3.0-10.0 mm wide at branching base, the major width 5.0-20.0 mm; laterally superposed to contiguous and rare counterposed; loose adnate to adnate to slightly revolute when sorediated; black line absent to very thin and attenuated, till 0.1 mm wide, not complementary; longitudinal axis distended to undulated; transversal cut plane to strongly convex-canaliculated with the borders plane to descending or involute. Proximal surface firm; continuous to crackled; smooth to slightly crumpled to strongly corrugated and escrobiculated. Distal surface firm; continuous to crackled; smooth to slightly crumpled and rugose. Lateral margin smooth to irregularly cut; sinuous to undulated; closed and sometimes sorediate; apical zone slightly ascending, revolute in the sorediated parts; apex rounded to irregularly cut, plane to ascending to revolute in the sorediated parts. Cilia absent. Secondary lobes absent. Lobules rare; marginal in the young parts and absent in the proximal part. Lacinules marginal in places of the proximal part, commonly sorediated; dichotomous to irregularly ramified; contiguous to laterally superposed; elevated to revolute; 2.0-4.0 mm long × 0.5-1.0 mm wide. Postules frequent; verruciform; not confluent; apical and subapical on the lacinules, some marginal to submarginal and rarely laminal; till 1.5 mm wide; erumpent; dismantling into soredia; originated at the apices and those margins revolute and ascending or from swellings of the laminal cortex; caducous, few, leaving exposed a red pigmented K+ yellow medulla below. Sorals abundant; originated from the pustules; orbicular; 1.5 mm long × 0.7 mm wide; not coalescent; not ciliated; cortex surrounding the soral integer to crackled and shedding plates. Soredia caducous to persistent, common the farinose and abundant the granular; ecorticated; heaped; K+ red. Isidia absent. Medulla white, firm. Underside brown to dark brown or black in the marginal zone and black in the proximal part. Marginal zone lustrous to sublustrous; satin clear already at 10×; ca. 1.0-5.0 mm wide; slightly attenuated; smooth to slightly crumpled; epapillated; erhizinated; rarely fissured, fissures not ramified, sometimes cicatrized and with not elevated borders. Proximal part sublustrous to opaque; satin clear at 30×; crumpled to rugose and papillated; cracked; reticular fissured; the crevices very narrow and commonly parallel, sometimes perpendicular ramified, commonly cicatrized and with elevated borders, 1.00-4.00 mm long × 0.05-0.10 mm wide Rhizines absent

Figure 7. *Parmotrema subcristiferum* (holotype, *F. Ciecoski* 273, CNMTf 518). Scale bar = 10 mm.

in the marginal zone; monomorphic, simple, sometimes with the apices penicillate to arbusculiform, cylindrical; common and irregularly distributed into small sparse regions in the fixation points; black; not pigmented; sublustrous; not gomose; satin clear at 20×; commonly interlaced and difficult to measure; straight; erect; monometric; 0.2-1.0 mm long × ca. 0.1-0.2 mm wide. Apothecia absent. Pycnidia absent.

Color tests: upper cortex K+ yellow, UV-; white medulla K+ yellow → orange → red, C-, KC+ weak yellow, P+ orange, UV-; reddish medulla under the pustules K+ yellow.

Substances of taxonomic importance: atranorin, salazinic acid.

Etymology: The epithet is a reference to *Parmotrema cristiferum* because of the morphological and chemical similarity.

Comments: *Parmotrema subcristiferum* is characterized by the greenish-gray, opaque, lobed, subpergaminaceous thallus, the proximal surface typically corrugated and escrobiculated, the lobes loose adnate to slightly revolute when sorediate, the red pigmented (K+ yellow) pustules that dismantle into soredia (K+ red) both granular and farinose, by the medulla white with salazinic acid and the consequent color reactions K+ yellow → orange → red, C-, KC+ weak yellow, P+ orange, UV-.

Parmotrema cristiferum (Taylor) Hale (1974) is similar in the big loosely adnate thallus, the subgranular and farinose soredia, the white medulla containing salazinic acid and by the medullary color reactions of the white medulla. Differs by the marginal sorals (Hale 1965), the coriaceous thallus with a lustrous smooth surface, and by the consalazinic acid in the medulla (Bawingan *et al*. 2017). Furthermore, *P. subcristiferum* has characteristically different pustules.

Parmotrema margaritatum (Hue) Hale and *P. stuppeum* (Taylor) Hale (Hale 1974) are commonly compared to *P. cristiferum* because of the similarity of the soredia development. So, they are somewhat like *P. subcristiferum* in general habit. *Parmotrema margaritatum* differs *in* the membranous thallus, the presence of chlroatranorine and consalazinic acid in the medulla, and *P. stuppeum* differs by the coriaceous thallus and by the same chemistry observed in *P. margaritatum* (Spielmann & Marcelli 2020, Hale 1965). Furthermore, all these species do not have the typical corrugated-escrobiculated surface of *P. subcristiferum*.

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Author Contributions

Fabiana Aparecida Rego Ciecoski: Substantial contribution to data collection, study concept and design; contribution to data collection; contribution to the analysis and interpretation of data, contribution to the structuring and preparation of the manuscript.
Flávia Rodrigues Barbosa: Substantial contribution in critical review, structuring the manuscript and adding intellectual content.
Marcelo Pinto Marcelli: Substantial contribution to the concept and design of the study, contribution to data collection; contribution to the critical review, adding intellectual content.
Bianca Regina da Hora: Substantial contribution to the development of the descriptive protocol.

Conflicts of interest

The authors declare no conflict of interest.

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