INTRODUCTION

The genus *Pseudocyphellaria* was proposed by Vainio (1890) to separate species of *Sticta* (Schreb.) Ach. with pseudocyphellae on the lower surface, with *Pseudocyphellaria aurata* (Ach.) Vain. (based on *Sticta aurata* Ach.) as type species. Recent molecular studies have shown it is a polyphyletic genus (Magain et al., 2012; Moncada et al., 2013, 2014). Moncada et al. (2014) recognized five different clades within it, among them the *Crocodia* clade. The name *Crocodia*, previously proposed by Link (1833), was then reinstated by Moncada et al. (2013) for *P. aurata* and *P. clathrata* (De Not.) Trevis. The distribution range known for these species is extended: *C. arvidssonii* is recorded for the first time for the country; *C. aurata* for Corrientes, Misiones, and Salta provinces; and *C. clathrata* for Corrientes and Jujuy provinces. The morphology of each species is described and illustrated. A distribution map and a key to known species of the genus are also presented.

MATERIAL AND METHODS

Rainforests of northern Argentina are located in two disjunct areas within the South Brazilian and Parana dominions of the biogeographical regionalization of the Neotropical region (Morone, 2014). These forests are divided into three biogeographic provinces: Yungas, Parana Forest, and *Araucaria* Forest (Fig. 1). The Yungas is located in northwestern Argentina, on the eastern slopes of the Andes mountain range, between 300 and 3500 m, and is extended through Jujuy, Salta, Tucumán, and northern Catamarca.
Provinces (Cabrera, 1971; Morrone, 2014). Its predominant vegetation is the cloud forest. Within this province, three districts are distinguished: Transition Forests, Montane Jungles, and Montane Forests (Cabrera, 1971; Morrone, 2014; Oyarzabal et al., 2018). Parana Forest province, located in northeastern Argentina where it is extended through Misiones Provinces. The predominant vegetation is rainforests northward and savannas southward. In this province, two districts are distinguished: Campos and Mixed Forests (Cabrera, 1971; Cabrera & Willink, 1973; Morrone, 2014). The Araucaria Forest province, with dominance of *Araucaria angustifolia*, is restricted to the eastern region of Misiones Province, between 600 to 850 m (Morrone, 2014).

![Fig. 1. Biogeographic provinces of northern Argentinean rainforests, A – Yungas; B – Parana Forest; C – Araucaria Forest.](image)

Material from northern Argentina forests deposited at the herbarium of the Instituto de Botánica del Nordeste (CTES) was studied. Morphological and anatomical analyses were carried out using standard stereoscopic (Leica MZ6) and compound light microscopes (Leica CME). For anatomical study, thin sections of thallus, apothecia and pycnidia were cut by hand with a razor blade and then mounted in tap water for examination and thirty measurements of the different parts of the thallus (upper and lower cortex, photobiont layer, and medulla), apothecia (exciple, hypothecium, thecium, and epithecium), ascospores, and conidia were randomly made. These measurements were made with ImageJ software (Schneider et al., 2012). Lichen substances were identified with spots tests with 10% KOH (K), sodium hypochlorite (C), K followed by C (KC), and Steiner solution (P). In addition, specific and updated bibliography of the genus was consulted (Galloway & Elix, 2013; Moncada et al., 2013, 2014). Subsequently, descriptions of species found in the area were made, including comments, illustrations, and maps of their distribution. In addition, a key to known Crocodia species is presented. The descriptions of Galloway (1988, 1994) and Galloway & Elix (2013) for species that were not observed were used for the key (C. poculífera and C. rubella).

**RESULTS AND DISCUSSION**

Of 108 studied samples of Crocodia three species were identified: *C. arvidssonii*, *C. aurata*, and *C. clathrata* (11, 42, and 55 specimens, respectively).

*Crocodia arvidssonii* (D.J. Galloway) D.J. Galloway & Elix. *Australasian Lichenology* 72: 34 (2013). (Fig. 3, A–C)

Description. Primary photobiont green algae. Thallus irregular to orbicular, up to 15 cm diam., branching pattern anisotomous to polytomous. Lobes horizontal to slightly ascendent, adjacent to imbricate, flat to undulate, with rounded to truncated, flat to revolute apices, (0.7–) 1–2 (–3.5) mm wide, margins sinuous to sometimes crenate, coriaceous. Upper surface scrobiculate to faveolate, yellowish brown to dark reddish in herbarium, pubescent towards the margins and apothecia base, without papillae, pruina and maculae. Cilia absent. Apothecia abundant, mainly marginal, aggregate, sessile, 1.5–7.5 mm diam.; disc dark red to brown, dull, concave, margin entire to crenate; amphithecium verrucose to pubescent, sometimes with pseudocyphellae, with yellow internal margin. Phyllidia abundant, mainly marginal, aggregate towards the oldest part of the thallus, coralloid to palmate, up to 1.3 mm long, 1.4 mm wide, dorsiventrally flattened, squamiform to lobuliform, basal stalk flattened. Medulla yellow. Lower surface creamy yellowish to dark brown towards the center. Tomentum dense to the margin, short, sometimes long towards the center, spongy to pubescent at the margin, brown to white greyish at the margin. Rhizines absent. Pseudocyphellae yellow, numerous, up to 100 for cm² towards the center of the thallus and up to 200 cm² towards the
margin, punctiform to irregular at center, margin with tomentum, (0.1–) 0.25–0.6 (–0.7) mm diam. towards the center of thallus. Cephalodia internal to erumpent at upper surface. Pycnidia numerous, laminal to sub-marginal, internal.

Fig. 2. Distribution of *Crocodia* species, A – *C. arvidssonii*; B – *C. aurata*; C – *C. clathrata*. Squares show studied specimens and dots those cited in literature.

Anatomy. Thallus (125–) 135–210 (–220) μm thick. Upper cortex paraplectenchymatous, (15–) 20–35 (–40) μm thick, cells 5.5–10.5 μm diam, wall 0.6–2 μm thick, rounded to isodiametric, lumen 3.5–9 μm diam. Photobiont layer (15–) 20–30 (–35) μm thick. Medulla (55–) 65–100 (–115) μm thick, yellowish orange, hyphae 2–4 μm thick, with orange crystals. Lower cortex paraplectenchymatous, (5–) 10–15 (–20) μm thick, 2–3 rows of cells; cells 6–11.5 μm diam, wall 0.7–2.5 μm thick, rounded to isodiametric, lumen 4–9 μm diam. Upper tomentum absent. Lower tomentum up to 170 μm long, septate, in fascicles of 12 hyphae together. Pseudocyphellae 118–175 μm diam. Apothecia: Exciple comprising cortex, photobiont layer and medulla, (187–) 219–312.5 (–406) μm thick. Hypothecium 45–50 μm high, red-brown, K–. Thecium colourless to pale straw, 46–62 μm high. Epithecium brown-orange, 4–7 μm high. Ascospores fusiform-ellipsoid, brown, 3-septate at maturity, central two locules larger, end locules small and often irregular, (18–) 23–27 (–28) × 5–8 μm. Conidia bacilliform, 2–3.5 μm long.

Chemistry. Cortex: K–; C–; KC– turning + red. Medulla: K–; C–; KC–; P–.


Ecology and distribution. On bark and branches of trees and shrubs, rarely on rocks, in edge and interior forest. Known from Colombia, Ecuador, Peru, Bolivia (Galloway, 1989; Galloway...
& Arvidsson, 1990; Sipman, 2002; Moncada & Forero, 2006), and Islas Canarias (Tønsberg, 1999). This is the first record for Argentina, from Misiones and Salta Provinces (Fig. 2, A).

Comments. Galloway & Arvidsson (1990) described *Crocodia arvidssonii* (under the name of *Pseudocyphellaria arvidssonii*) as a species with phyllidia that are delicately white-pubescent on the upper surface, differing from analyzed specimens in which no pubescence was observed. This material also differs in the absence of phyllidia on apothecial margins and pedicels. In addition, the thickness of the thallus, medulla, and lower cortex is thinner [(125–) 135–210 (–220) μm, (55–) 65–100 (–115) μm, (5–) 10–15 (–20) μm, respectively] than reported by Galloway & Arvidsson (1990) [150–350 (–440) μm, (90–) 110–280 (–360) μm, 18–22 (–27) μm, respectively].

**Crocodia aurata** (Ach.) Link. *Handbuch zur Erkennung der nutzbarsten und am häufigsten vorkommenden Gewächse* 3: 177 (1833) (Fig. 3, D–F)

Description. Primary photobiont green algae. Thallus orbicular to irregular, up to 10 cm diam., polytomously branched. Lobes suborbicular to slightly ligulate, horizontal to slightly ascendent, adjacent to imbricate, flat to undulate, with their apices rounded, flat, becoming involute when sorediate, margins entire, (2–) 3–9 (–11) mm wide, coriaceous. Upper surface smooth to scrobiculate, green when wet, yellowish brown to dark reddish in herbarium, pubescent towards non-sorediate margins, without papillae, pruina and maculae. Cilia absent. Apothecia generally absent, when present marginal, aggregate, sub-pedicelate, (1–) 3–9 (–11) mm diam.; disc dark red to brown, dull, concave, margin crenate to denticulate; amphitheci um verrucose to scabrid, sometimes with soralia. Soralia abundant, marginal, labriform; soredia granular. Medulla yellow. Lower surface white yellowish to brown centrally. Tomentum dense to the margin, short to the margin, spongy to pubescent at the margin, brown to white greyish at the margin. Rhizines absent. Pseudocyphellae yellow, numerous, up to 41–60 for cm² towards the center of the thallus and up to 200 cm² towards the margin, punctiform to irregular at center, margin with tomentum, (0.4–) 0.5–0.9 (–1.2) mm diam. towards the center of the thallus. Cephalodia internal to erumpent dorsally. Pycnidia laminal, immersed.
Anatomy. Thallus 164–246 μm thick. Upper cortex paraplectenchymatous, 33–48 μm thick, cells 4–9 μm diam., cell wall 0.9–2.6 μm thick, with rounded to isodiametric lumina, cell lumina 3–7 μm diam. Photobiont layer 22–37 μm thick. Medulla 92–119 μm thick, yellowish-orange, hyphae 1.5–3.5 μm thick, with orange crystals. Lower cortex paraplectenchymatous, 18.5–35 μm thick, 3–4 rows of cells; cells 5–9.5 μm diam, cell lumina 3.3–8.8 μm diam, cell wall 1.1–3.7 μm thick. Upper tomentum present. Lower tomentum (175–) 200–250 (–268) μm long, solitary or in fascicles up to 10 hyphae together, hyphae branched. Pseudocyphellae 155–370 (–510) μm diam.

Chemistry. Cortex: K–; C–; KC–; P–. Medulla: K–; C–; KC–; P–. Hypothecium 45–50 μm high, red-brown, K–. Thecium colourless to pale straw, 58–74 μm high. Epithecium brown-orange, 7–15 μm high. Thecium colourless to pale straw, 58–74 μm high. Hypothecium 45–50 μm high, red-brown, K–.


Specimens examined: ARGENTINA. Corrientes.

Anatomy. Thallus 164–246 μm thick. Upper cortex paraplectenchymatous, 33–48 μm thick, cells 4–9 μm diam., cell wall 0.9–2.6 μm thick, with rounded to isodiametric lumina, cell lumina 3–7 μm diam. Photobiont layer 22–37 μm thick. Medulla 92–119 μm thick, yellowish-orange, hyphae 1.5–3.5 μm thick, with orange crystals. Lower cortex paraplectenchymatous, 18.5–35 μm thick, 3–4 rows of cells; cells 5–9.5 μm diam, cell lumina 3.3–8.8 μm diam, cell wall 1.1–3.7 μm thick. Upper tomentum present. Lower tomentum (175–) 200–250 (–268) μm long, solitary or in fascicles up to 10 hyphae together, hyphae branched. Pseudocyphellae 155–370 (–510) μm diam.

Chemistry. Cortex: K–; C–; KC–; P–. Medulla: K–; C–; KC–; P–.

Specimens examined: ARGENTINA. Corrientes.


Anatomy. Thallus 164–246 μm thick. Upper cortex paraplectenchymatous, 33–48 μm thick, cells 4–9 μm diam., cell wall 0.9–2.6 μm thick, with rounded to isodiametric lumina, cell lumina 3–7 μm diam. Photobiont layer 22–37 μm thick. Medulla 92–119 μm thick, yellowish-orange, hyphae 1.5–3.5 μm thick, with orange crystals. Lower cortex paraplectenchymatous, 18.5–35 μm thick, 3–4 rows of cells; cells 5–9.5 μm diam, cell lumina 3.3–8.8 μm diam, cell wall 1.1–3.7 μm thick. Upper tomentum present. Lower tomentum (175–) 200–250 (–268) μm long, solitary or in fascicles up to 10 hyphae together, hyphae branched. Pseudocyphellae 155–370 (–510) μm diam.

Chemistry. Cortex: K–; C–; KC–; P–. Medulla: K–; C–; KC–; P–.

Specimens examined: ARGENTINA. Corrientes.
Ecology and distribution: on the bark and branches of trees and shrubs, rarely on rocks, usually growing next to bryophytes, common in edge forests and on banks of rivers. Cosmopolitan species (Galloway & Elix, 2013). In Argentina, it is distributed in Jujuy (Osorio & Ferraro, 2001; Languasco et al., 2016; Lavornia et al., 2017), Tucumán (Grassi, 1950; Osorio, 1990), Rio Negro (Malme, 1899), and Tierra del Fuego (Calvelo & Liberatore, 2002). It is here recorded as new for Corrientes, Misiones, and Salta Provinces (Fig. 2, B).

Comments. The specimens analyzed lack of pruina on the upper surface differing from reported by Galloway (1988), although, this author consider this is a feature that could be influenced by particular microclimatic factors. In addition, apothecia are larger [(1–) 3–9 (–11) mm vs. 1–3 (–5) mm], and the thickness of the thallus, upper cortex, and photobiont layer is thinner (164–246 μm, 33–48 μm, 22–37 μm respectively) than described by Galloway (1988) [(200–) 250–350 (–450) μm, (40–) 45–70 (–80) μm, (45–) 55–75 (–90) μm, respectively].

**Crocodia clathrata** (De Not.) Trevis. Lichenotheca Veneta 75 (1869) (Fig. 4, A–B)

Description. Primary photobiont green algae. Thallus irregular, up to 15 cm diam., branching polytomous. Lobes ligulate to flabellate, horizontal to ascendent, adjacent to imbricate, flat to undulate, with truncate, flat to slightly revolute apices, margins entire to sinuose, 1–5 mm wide, coriaceous. Upper surface scrobiculate to faveolate, bright green when wet to yellowish brown to dark reddish in herbarium, without upper tomentum, papillae, pruina and maculae. Cilia absent. Apothecia numerous, marginal, aggregate, pedicellate, basal invagination pronounced, (0.8–) 1.4–5.5 mm diam; disc dark red, dull, concave, margin revolute, entire to crenate; amphithecium verrucose to ciliate, with yellow internal margin. Vegetative propagules absent. Medulla yellow. Lower surface white to reddish yellow at the margin to brown centrally. Tomentum dense to the margin, short, sometimes long in the center, spongy to pubescent at the margin, brown to white greyish at the margin. Rhizines absent. Pseudocyphellae yellow, numerous, up to 61–100 for cm² towards the center of the thallus and up to 200 cm² towards the margin, punctiform to irregular at center, margin with tomentum, (0.1–) 0.2–0.4 (–0.6) mm diam. towards the center of the thallus. Cephalodia internal to erumpent at upper surface. Pycnidia laminal, internal, immersed.

Anatomy. Thallus 150–250 μm thick. Upper cortex paraplectenchymatous, (19–) 25–43 (–50) μm thick, cells 5.5–11 μm diam., wall 0.7–2.5 μm thick, with rounded to isodiametric lumina of 4–13 μm diam. Photobiont layer (23–) 30–50 (–66) μm thick. Medulla (50–) 75–149 (–203) μm thick, yellowish orange, hyphae 1.5–3 μm thick, with orange crystals. Lower cortex paraplectenchymatous, (14–) 33–50 (–60) μm thick, 2–4 rows of cells; cells 7.5–14 μm diam., lumina of 5–12.5 μm diam., wall 1–4 μm thick. Upper tomentum absent. Lower tomentum (94–) 137–369 (–587) μm long, in fascicles of 12–20 hyphae together.

![Fig. 4. A – B. Crocodia clathrata, A – complete thallus, B – marginal apothecia. Scale bars: A = 1 cm & B = 1 mm.](image-url)
Pseudocyphellae 212–262 μm diam. Apothecia: Exciple comprising cortex, photobiont layer and medulla, (42–) 66–100 (–166) μm thick. Hypothecium 42–66 μm high, red-brown, K–. Thecium colourless to pale straw, (65–) 75–91 (–95) μm high. Epithecium brown-orange, 8–17 μm high. Ascospores fusiform-ellipsoid, brown, 3–4-septate at maturity (rarely 5-septate), central two locules larger, end locules small and often irregular, (22–) 25–32 (–35) × 5–8 μm. Conidia bacilliform, 2.5–5 μm.

Chemistry. Cortex: K–; C–; KC–. Medulla: K–; C–; KC–; P–.


Key to known *Crocodia* species

1. Vegetative propagules absent, apothecia commonly present .................. *C. clathrata*
   – Vegetative propagules present, apothecia rarely present .................................. 2

2. Thallus with marginal phyllidia ................................................................. *C. arvidssonii*
   – Thallus with soralia or isidia becoming sorediate ........................................... 3

3. Thallus with coralloid isidia, more or less corticate at first but soon erode becoming sorediate; apothecia with granular-isidiate margins ................................. *C. poculifera*
   – Thallus with soralia; apothecia sometimes with sorediate exciple ......................... 4

4. Soralia strictly marginal, labriform; upper surface glabrous to minutely tomentose towards non-sorediate margins; apothecia, when present, verrucose to scabrid exciple .......................................................... *C. aurata*
   – Soralia mainly laminal, punctiform to confluent, with coarse soredia covering large areas of the thallus, and marginal, linear to sublinear or labriform soralia; upper surface tomentose from margins to centre, occasionally glabrous centrally, apothecia, when present, with a corrugate-scabrid and tomentose exciple ... *C. rubella*

**CONCLUSION**

*Crocodia* species in northern Argentinean forests share characters such as growth form, photobiont, medulla and pseudocyphellae color, size and type of spores, and chemistry. However, they are easily distinguished as *C. arvidssonii* has marginal phyllidia and *C. aurata* labriform soralia, while *C. clathrata* lacks vegetative propagules. These species are commonly found together in tropical habitats and mountain forests (Galloway, 1989). As result of this study, we add one new record for Argentina (*C. arvidssonii*) and extend the distribution range of *C. aurata* (to Corrientes, Misiones, and Salta Provinces) and *C. clathrata* (to Corrientes and Jujuy Provinces). The remaining species of the genus, *C. poculifera* and *C. rubella*, share ecological preferences with studied species. However, their distribution range is different: *C. poculifera* is reported from East Africa, South-eastern Asia and Oceania (Galloway, 1994; Galloway & Elix, 2013; de Lange & Galloway, 2015) while *C. rubella* is known only from Australia and New Zealand.
(Galloway, 1988; Galloway & Elix, 2013). Therefore, it is not expectably to find them in northern Argentinean forests.

ACKNOWLEDGEMENTS

We are grateful to the authorities of the Administración de Parques Nacionales (APN) of Argentina for providing collection permits. Dr. Niveiro for his collaboration in the collection trip and for suggestions on the manuscript. This work was funded by the Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET) and the Secretaría General de Ciencia y Técnica (SGCyT-UNNE).

REFERENCES


