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## **A contribution to the knowledge of the bryophytes of the Cape Verde Islands, with an emphasis on Santo Antão and São Vicente**

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### **Abstract**

**Introduction.** The Cape Verdean bryophyte flora comprises representatives of various floristic elements including Afrotropical, Neotropical, Mediterranean and Asiatic elements, together with some endemic taxa. However, the knowledge of Cape Verdean bryophytes lags far behind that of vascular plants. This study contributes to increase the knowledge of bryophytes in the Cape Verde archipelagos.

**Methods.** A total of seven sites were sampled during 2016 in the Cape Verde archipelago, one on São Vicente and six on Santo Antão.

**Results and conclusions.** Five species are reported new to Cape Verde, *Cheilolejeunea rigidula* (Nees ex Mont.) R.M.Schust., *Riccia trabutiana* Steph., *Lewinskya acuminata* (H.Philib.) F.Lara, Garilleti & Goffinet, *Lindbergia patentifolia* Dixon and *Timmiella cameruniae* Broth. The presence of *Porella canariensis* (F.Weber) Underw in the archipelago is also confirmed. Additionally, *Frullania spongiosa* Steph., *Bryum dichotomum* Hedw., *Cryptolepton longisetus* (Mont.) Enroth and *Didymodon hastatus*

(Mitt.) R.H.Zander are reported for the first time from Santo Antão island. *Cheilolejeunea rigidula*, *Lindbergia patentifolia* and *Timmiella cameruniae* are new to Macaronesia and a description of the last taxon is presented.

### **Keywords**

Africa; Atlantic islands; biodiversity; bryophyte flora; Macaronesia; *Timmiella cameruniae*

### **Introduction**

The Republic of Cape Verde is an oceanic archipelago lying 600 km west of Dakar, Senegal, the westernmost point of continental Africa. It occupies roughly 63,000 km<sup>2</sup> of ocean area and just over 4,000 km<sup>2</sup> of land area, and consists of ten islands divided into the Barlavento group (Santo Antão, São Vicente, Santa Luzia, São Nicolau, Sal and Boa Vista Islands) and the Sotavento group (Maio, Santiago, Fogo and Brava Islands) (Aistleitner et al. 2008). Cape Verde is composed of ancient rocks, the subaerial volcanism probably initiated during the Miocene (about  $25.6 \pm 1.1$  million years ago, mya) or pre-Miocene (Duarte and Romeiras 2009). The islands of Santo Antão and Brava represent the youngest subaerial Tertiary volcanism, which can be dated to  $7.57 \pm 0.56$  mya and  $5.9 \pm 0.1$  mya, respectively (Duarte and Romeiras 2009).

The biodiversity of Cape Verde is of global importance as it includes many endemic species of plants, birds, insects, as well as marine species (Arechavaleta et al. 2005), and its botanical richness is considered to be exceptionally high in the context of an oceanic archipelago (Caujapé-Castells et al. 2010). On Cape Verde, under current climatic conditions, laurisilva vegetation is absent (Brochmann et al. 1997) yet the

present vegetation provides an important refuge for endemic vascular plants and bryophytes, particularly epiphytic communities at higher elevations.

The knowledge of Cape Verdean bryophytes lags far behind that of vascular plants (Bizot 1969; Muhle 1982, 1986). The earliest bryophyte studies were by Bolle (1852, 1855), Geheeb (1910), Cardoso (1915), Potier de la Varde (1943, 1946) Bizot (1969), and Bizot & Dury (1978). Other significant works were made by Chevalier (1935), and Muhle (1982, 1986), which published a list of known species for the archipelago, followed more recently by Frahm et al. (1996a). The current Cape Verde check-list, up to 2005, enumerates 156 bryophyte taxa comprising, 37 liverworts and hornworts, and 119 mosses (Patiño Llorente and González Mancebo 2005). However, more recently, a total of 43 liverworts and hornworts, and 136 mosses have been listed based on recent works by González-Mancebo et al. (2009), Ellis et al. (2015a; 2015b), Cano (2016), Jiménez and Cano (2017), Sérgio and Stow (2017), Dirkse et al. (2018), Sérgio and Melo (2019) Sim-Sim et al. (2019) and Ellis et al. (2020).

The Cape Verdean bryophyte flora comprises representatives of various floristic elements including Afrotropical, Neotropical, Mediterranean and Asiatic elements, together with endemic taxa, namely: *Bryum anomodon* Mont., *Entodon pseudoseductrix* (Müll.Hal.) A.Jaeger, *Fissidens allorgei* P.de la Varde, *Funaria chevalieri* P.de la Varde, *Perssonia sanguinea* Bizot, and *Pseudoleskeopsis bollei* (Broth. & Geh.) P.Rao (Patiño Llorente and González Mancebo 2005; O'Shea 2006). The highest biodiversity is on Santo Antão, where about 100 species are listed (Frahm et al. 1996a; Patiño Llorente and González Mancebo 2005). According to the criteria of Frahm et al. (1996b), the highest number of threatened bryophytes is also found on this island.

## **Material and Methods**

Field work was carried out on 11–15 October 2016, with a total of seven sites sampled, one on São Vicente and six on Santo Antão (Figure 1). More sites were studied on Santo Antão due to the greater diversity of habitats favorable to the growth of bryophytes. In the two islands, a range of habitats was investigated including soil, rocks, epiphytes and aquatic communities. Topographic GIS layers using ArcMap 10.5.1 (ESRI 2016) were used to ensure that representative areas of different land cover in the islands were surveyed. For each voucher, geographic coordinates, substrate and habitat was recorded in the field.

The specimens collected are stored in the University of Lisbon, National Museum of Natural History and Science Herbarium (LISU). The nomenclature of bryophytes follows Söderström et al. (2016) for liverworts and hornworts, O’Shea (2006), for mosses and Lara et al. (2016) for *Lewinskya*.

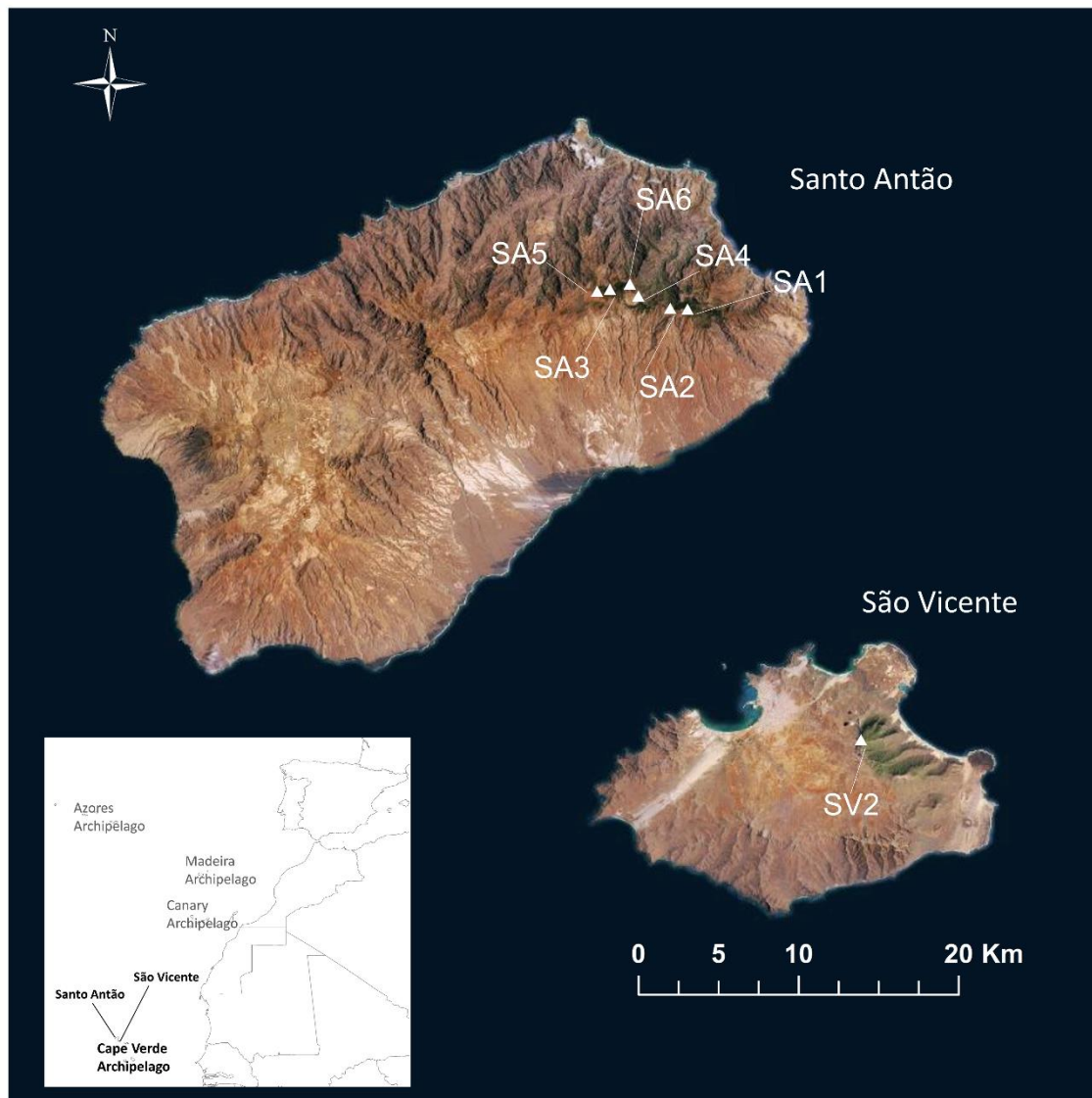


Figure 1. Location of sampling sites on Santo Antão and São Vicente. Image source: ESRI (2018).

## Results and discussion

A total of 170 bryophyte taxa (140 mosses and 30 liverworts) were identified for the two islands. Five species are reported new to Cape Verde (two liverworts and three mosses), the presence of one liverwort in the archipelago is confirmed, and four species

(one liverwort and three mosses) are reported for the first time from Santo Antão island. However, the great majority of the specimens were collected in Santo Antão island, especially in the Caldeira area (SA3, SA4, SA5 and SA6). Due to the dryness of the environmental conditions in the Island of São Vicente, the bryophytes were only found in a very restricted area of the Monte Verde Natural Park. Presently there are 185 bryophyte taxa in Cape Verde (139 mosses, 46 liverworts and hornworts), 131 of these occur in Santo Antão (109 mosses, 22 liverworts and hornworts) and 30 occur in São Vicente (20 mosses, 10 liverworts and hornworts) (Patiño Llorente and González Mancebo 2005; González-Mancebo et al. 2009; Ellis et al. 2015a, 2015b, 2020; Cano 2016; Jiménez and Cano 2017; Sérgio and Stow 2017; Dirkse et al. 2018; Sérgio and Melo 2019; Sim-Sim et al. 2019).

### **Liverworts new to Cape Verde**

*Cheilolejeunea rigidula* (Nees ex Mont.) R.M.Schust. **Cape Verde.** São Vicente: Monte Verde, near the military facilities, in a hollow at the base of a rock in crevices, 26QQD2066, 740 m a.s.l., 13 October 2016, sampling site SV1 (Figure 1), *leg.* C. A. Garcia & M. Sim-Sim (LISU266471).

This is a widespread species in the palaeotropical region from Africa to Asia continents and the Caroline Islands (Asthana et al. 1995; Manju et al. 2012; Zhu et al. 2002, 2018; Wigginton 2018). It is one of the most abundant Lejeuneaceae in many African countries in lowland rainforest, for example in São Tomé e Príncipe archipelago (Sérgio and Garcia 2011), where *Cheilolejeunea principensis* Steph. ex Schiffn. was described (synonym name). *Cheilolejeunea rigidula* is now reported for the first time to Macaronesia.

As indicated, on São Vicente *Cheilolejeunea rigidula* was found at a single locality, on the base of a rock, in a recess at the highest point of the island. It is most often found as an epiphyte throughout its range, but it is also known to occur on rocks. In the same area the following species were found: *Frullania ericoides* (Nees) Mont., *F. socotrana* Mitt., *F. spongiosa* Steph., *Microlejeunea ulicina* (Taylor) Steph., *Porella canariensis* (F.Weber) Underw., *Campylopus pilifer* Brid. and *Groutiella laxotorquata* (Besch.) Wijk & Margad.

***Riccia trabutiana* Steph. Cape Verde.** Santo Antão: Road from Fajã de Cima to Corda, on a rocky earth slope, 26QQD0493, 1450 m a.s.l., 14 October 2016, sampling site SA5 (Figure 1), leg. M. Sim-Sim & C. A. Garcia (LISU266461).

*Riccia trabutiana* is a liverwort widespread in the Mediterranean area-(Papp and Erzberger 2007; Ros et al. 2007) generally distributed in temperate regions but also in tropical Africa and Central Asia (Bischler 2004). The species is also present in the Arabian Peninsula (El-Oqlah et al. 1988; Kürschner 2000) and Socotra Island (Wigginton and Grolle 1996; Kürschner 2001; Wigginton 2018).

The population found is apparently small and restricted and is associated with *Exormotheca pustulosa* Mitt., *Mannia androgyna* (L.) A.Evans, *Plagiochasma rupestre* (J.R.Forst. & G.Forst.) Steph. and *Bryum dichotomum* Hedw.

### **Mosses new to Cape Verde**

***Lewinskya acuminata* (H.Philib.) F.Lara, Garilleti & Goffinet. Cape Verde.** Santo Antão: Pico da Cruz, epiphytic on *Cupressus lusitanica*, 26QQD0992, 1500 m a.s.l., 13 October 2016, sampling site SA1 (Figure 1), leg. C. A. Garcia & M. Sim-Sim (LISU266465). Santo Antão: near the Paúl, North of Caldeira, epiphytic on *Cupressus*

*lusitanica*, 26QQD0693, 1485 m a.s.l., 14 October 2016, sampling site SA6 (Figure 1), leg. C. A. Garcia & M. Sim-Sim (LISU266466).

This species is a typical epiphyte found throughout in the Mediterranean Basin (Ros et al. 2013). Elsewhere the species occurs in the volcanic region of the Simien Mountains in northern Ethiopia (Vigalondo et al. 2015) and on the American continent, it occurs in southern California (Garilleti et al. 2006). The populations found on the Santo Antão island were not abundant, but sporophytes were plentiful.

*Lewinskya acuminata* populations were mixed with other epiphytes such as *Frullania ericoides*, *F. spongiosa*, *Bryum argenteum*, *Cryphaea heteromalla*, *Cryptoleptodon longisetus*, *Leucodon sciuroides* (Hedw.) Schwägr., *Lindbergia patentifolia*, *Orthotrichum diaphanum*, *O. pumilum* Sw. and *Zygodon conoideus*.

***Lindbergia patentifolia* Dixon. Cape Verde.** Santo Antão: Pico da Cruz, epiphytic on *Cupressus lusitanica*, 26QQD0992, 1500 m a.s.l., 13 October 2016, sampling site SA1 (Figure 1), leg. C. A. Garcia & M. Sim-Sim (LISU266458); Santo Antão: near the Paúl. North of Caldeira, epiphytic on *Pinus canariensis*, 26QQD0693, 1485 m a.s.l., 14 October 2016, sampling site SA6 (Figure 1), leg. C. A. Garcia & M. Sim-Sim (LISU266464).

*Lindbergia patentifolia* is a species belonging to the neotropical-African moss disjunction group (Delgadillo 1993). It occurs from South America in Brazil (Schäfer-Verwimp 1992) to Africa (O'Shea 2006; Kürschner and Neef 2012). This species is now reported for the first time to Macaronesia.

The populations found on Santo Antão were abundant, with a high frequency of sporophytes. Associated species of both populations include *Frullania ericoides*, *F.*

*spongiosa*, *Bartramia stricta* Brid., *Brachymenium notarisii* (Mitt.) A.J.Shaw, *Braunia alopecura* (Brid.) Limpr., *Bryum argenteum* Hedw., *B. canariense* Brid., *B. capillare* Hedw., *Campylopus pilifer*, *Cryphaea heteromalla* (Hedw.) Brid., *Cryptoleptodon longisetus* (Mont.) Enroth, *Didymodon hastatus* (Mitt.) R.H.Zander, *Grimmia incurva* Schwägr., *G. laevigata* (Brid.) Brid., *G. lisae* De Not., *Leucodon sciuroides* (Hedw.) Schwägr., *Lewinskya acuminata* (H.Philib.) F.Lara, Garilleti & Goffinet, *Pterogonium gracile* (Hedw.) Sm., *Orthotrichum diaphanum* Brid., *Pleurochaete squarrosa* (Brid.) Lindb., *Ptychomitrium nigrescens* (Kunze) Wijk & Margad., *Syntrichia fragilis* (Taylor) Ochya, *Timmiella cameruniae* Broth., *Tortula cuneifolia* (Dicks.) Turner, *Trichostomum brachydontium* Bruch and *Zygodon conoideus* (Dicks.) Hook. & Taylor.

***Timmiella cameruniae* Broth. Cape Verde.** Santo Antão: Pico da Cruz, on earthy roadside banks, 26QQD0992, 1500 m a.s.l., 13 October 2016, sampling site SA1 (Figure 1), *leg.* C. A. Garcia & M. Sim-Sim (LISU266470). Santo Antão: between Caldeira and Pico da Cruz, roadside banks, 26QQD0892, 1350 m a.s.l., 13 October 2016, sampling site SA2 (Figure 1), *leg.* C. A. Garcia & M. Sim-Sim. Santo Antão: Nearby Pico da Cruz, west of Caldeira, roadside banks, 26QQD0493, 1450 m a.s.l., 13 October 2016, sampling site SA3 (Figure 1), *leg.* C. A. Garcia & M. Sim-Sim (LISU266472); Santo Antão: Between Caldeira and Pico da Cruz, roadside banks, 26QQD0892, 1350 m a.s.l., 13 October 2016, sampling site SA2 (Figure 1), *leg.* C. A. Garcia & M. Sim-Sim (LISU266473); Santo Antão: Caldeira, rocks and on rocky roadside banks, 26QQD0692, 1230 m a.s.l., 14 October 2016, sampling site SA4 (Figure 1), *leg.* C. A. Garcia & M. Sim-Sim (LISU266460).

*Timmiella cameruniae* is an African endemic species described from a single locality on Cameron Mountain at 2100 m (Brotherus 1897) and it was later discovered

on Mt Mbeya, at 2400 m, in Tanzania (Bizot 1973).

Only *Timmiella barbuloides* (Brid.) Moenk. was hitherto known from Cape Verde, on Santo Antão, São Nicolau, Santiago and Fogo (Frahm et al. 1996a), in several localities (Geheeb 1910; Cardoso 1915; Bizot 1969; Bizot and Dury 1978; Frahm et al. 1996b).

The plants now identified as *Timmiella cameruniae* from Cape Verde have small leaves (ca. 3 mm long), obtuse to broadly acute, usually cucullate apex, subpercurrent costa not ending in apiculus, incurved leaf margins above ½ of length, irregularly denticulate margins in the apical part or almost entire and median laminal cells 8–9 (10.5) µm wide; capsules with a weakly differentiated persistent annulus, peristome with erect teeth to 300–400 µm long and a much-reduced basal membrane (5–10 µm long); spores 14–18 (20) µm in diameter.

*Timmiella barbuloides* has distinct morphological characters distinguishing it from *T. cameruniae* namely: leaves ca. 6 mm long, acute apex, percurrent costa; capsules without annulus, peristome with erect teeth to 700–800 (950) µm long and a bigger basal membrane (20–30 µm long); spores 8–12.5 µm in diameter. Our collections demonstrate the distinct morphological characters, particularly the sporophytes and spores (observed for the first time), that confirm *Timmiella cameruniae*.

The populations found on the Santo Antão Island were abundant and fertile. Associated bryophytes included *Brachymerium notarisii*, *Bryum argenteum*, *B. canariense*, *Braunia alopecura*, *Campylopus pilifer*, *Didymodon hastatus*, *Grimmia laevigata*, *G. lisae*, *Pleurochaete squarrosa*, *Ptychomitrium nigrescens*, *Tortula cuneifolia* and *Trichostomum brachydontium*.

## **Confirmation of *Porella canariensis* (F. Weber) Underw. in the Cape Verde archipelago**

*Porella canariensis* (F.Weber) Underw. **Cape Verde**. São Vicente: Monte Verde, near the military facilities, on the base of rocks, 26QQD2066, 740 m a.s.l., 11 October 2016, sampling site SV1 (Figure 1), *leg.* C. A. Garcia & M. Sim-Sim (LISU266468).

This species is widespread in Madeira, Azores and Canary archipelagos (Fontinha 2004; Ros et al. 2007; Casas et al. 2009). In continental Europe *Porella canariensis* is only reported in Portugal, Spain and France (Schumacker and Váña 2005; van Dort and Smulders 2006). Bischler (2004) report the taxon for Morocco, however Ros et al. (2007) considers the identity of the North African plants questionable.

The taxonomy of *Porella* is regarded as difficult with incongruences between phylogenetic and morphological data (Hentschel et al. 2007). Morphologically *Porella canariensis* is characterized by imbricate leaves with obtuse-rounded or slightly truncate or acute apices and entire margins, lobules with weakly spinose to entire margins, median cells of dorsal lobe 18–22  $\mu\text{m}$  (Schumacker and Váña 2005), with uniformly thickened walls. In the past *P. canariensis* has often been considered conspecific with *P. arboris-vitae* (With.) Grolle, but a recent molecular study has shown that this is not phylogenetically supported, and a close relationship between *P. obtusata* (Taylor) Trevis and *P. canariensis* was observed (Hentschel et al. 2007; Heinrichs et al. 2011). Nevertheless, morphologically, *P. obtusata* can be distinguished by its median cells 28–32  $\mu\text{m}$  wide (Schumacker and Váña 2005) with large bulging trigones.

Various authors have reported *Porella* in the Cape Verde archipelago, on São Vicente and on São Nicolau. The current Cape Verde check-list (Patiño Llorente and

González Mancebo 2005), only refers to *P. arboris-vitae*. However, *P. canariensis* was referred to the archipelago by Freitas and Brehm (2001). In the present study all *Porella* populations detected in the two islands were analyzed morphologically and corresponded to the characters of *P. canariensis*, corroborating the findings of Freitas and Brehm (2001).

On São Vicente *P. canariensis* was found growing in the same area as *Cheilolejeunea rigidula*, *Frullania ericoides*, *F. socotrana*, *F. spongiosa*, *Microlejeunea ulicina*, *Campylopus pilifer* and *Groutiella laxotorquata*.

#### **Liverworts new to Santo Antão Island**

*Frullania spongiosa* Steph. **Cape Verde.** Santo Antão: near the Paúl, north of Caldeira, epiphyte on *Cupressus lusitanica*, 26QQD0693, 1485 m a.s.l., 14 October 2016, sampling site SA6 (Figure 1), *leg.* C. A. Garcia & M. Sim-Sim (LISU266467).

#### **Mosses new to Santo Antão Island**

*Bryum dichotomum* Hedw. **Cape Verde.** Santo Antão: Road from Fajã de Cima to Corda, roadside banks, 26QQD0493, 1450 m a.s.l., 14 October 2016, sampling site SA5 (Figure 1), *leg.* M. Sim-Sim & C. A. Garcia (LISU266462).

This species was recently reported for Cape Verde, on Fogo Island at an altitude of 570 m a.s.l. (Dirkse et al. 2018).

*Cryptoleptodon longisetus* (Mont.) Enroth. **Cape Verde.** Santo Antão: Pico da Cruz. epiphytic on *Cupressus lusitanica*, 26QQD0992, 1500 m a.s.l, 13 October 2016, sampling site SA1 (Figure 1), *leg.* C. A. Garcia & M. Sim-Sim (LISU266469).

This species was reported for Cape Verde, on São Nicolau and Santiago (Patiño Llorente and González Mancebo 2005).

*Didymodon hastatus* (Mitt.) R.H.Zander. **Cape Verde.** Santo Antão: Pico da Cruz, on rocky roadside banks, 26QQD0992, 1500 m a.s.l., 13 October 2016, sampling site SA1 (Figure 1), *leg.* C. A. Garcia & M. Sim-Sim (LISU266459).

This species was reported for Cape Verde, on São Nicolau and Fogo (Patiño Llorente and González Mancebo 2005).

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