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Research article

A SURVEY OF MARCHANTIALES FROM MADAGASCAR

Catherine Reeb[1]*, Lovanomenjanahary Marline[2], Lucile Rabeau[1], Ainazo Andriamanantena[3], Roger Lala Andriamiarisoa[4], Hery-Lisy Ranarijaona[3] & Tamás Pócs[5]

*[1]Institut de Systématique et Biodiversité, UMR7205, Sorbonne Université, Muséum National d'Histoire Naturelle, CNRS, EPHE. 57 rue Cuvier Case postale 39 France-75005 Paris; [2]Department of Biological Sciences, University of Cape Town, Private Bag X3, 7701 Rondebosch, South Africa; [3]Université de Mahajanga, Ecole Doctorale Ecosystèmes Naturels; [4]Missouri Botanical Garden P.O Box 3391 101 Antananarivo, Madagascar; [5]Department of Botany, Institute of Biology, Eszterházy Károly University , Eger, P.O. Box 43, H-3301;*E-mail: catherine.reeb@mnhn.fr*

Abstract: Based on the authors' recent collections and on older herbarium specimens (PC, TAN, EGR), the species of Marchantiidae (Marchantiopsida, Marchantiophyta) of Madagascar are reported with their description based on Malagasy specimens. A distribution map for each taxon is provided. Among the fifteen taxa identified, six are newly recorded for the island, including a new synonymy: *Asterella coronata* (Steph.) H.A.Mill = *Asterella bachmannii* (Steph.) S.W. Arnell. Most of Marchantiidae live in xeric areas (*Riccia* species, *Exormotheca pustulosa* Mitt.) or in exposed, only temporarily wet stations (*Plagiochasma*, *Asterella*). This preliminary study shows the evidence of under-prospection of such areas in Madagascar for bryophytes and the need of taxonomic work to clarify some genera (*Riccia*, *Asterella*, *Plagiochasma*) and to confirm the species hitherto reported.

Keywords: Madagascar, liverworts, Marchantiidae, distribution maps

INTRODUCTION

Madagascar is considered a hotspot of biodiversity and many studies were already conducted upon ferns and angiosperms (Myers *et al.* 2000, Gautier and Goodman 2009). Bryologists have taken interest in bryophytes *sensu lato* (mosses, liverworts and hornworts) in Madagascar since the nineteenth century (Bescherelle 1880, 1891; Renauld and Cardot 1895; Dorr 1997, Marline *et al.* 2012).

Liverworts were early cited for the island but without references for the complex thalloids (Gottsche *et al.* 1844, Pearson 1891a, 1891b). Pearson (1893) cited the first thalloid species, *Marchantia viridula* Lehm., known today as *Marchantia globosa* Brid. ex Web. and present in Comores Islands (Bischler-Causse 1993) and La Réunion, but without description, specimens or locality information. In Stephani's work (Stephani 1891, 1892, 1893), the only Malagasy thalloid liverwort described is *Fimbriaria coronata* Steph., a synonym of *Asterella coronata* (Steph.) H.A.Mill.

The first detailed bryological studies on the Western Indian Ocean Islands focused on mosses (Renauld and Cardot 1895, Renauld 1897, 1909). So did Thériot (1920) who published six volumes on Malagasy mosses including *Sphagnum*, where only seven liverworts were just reported (*M. viridula* being always cited as the unique complex thalloid species). Despite historical collections from botanists who gathered plants in Madagascar in the first half of the twentieth century, no general studies on Malagasy liverworts were conducted at that time (Jovet-Ast 1948). Examining new collections and informations from collectors, Jovet-Ast (1948) cited *Targionia hypophylla, Riccia fluitans, Fimbriaria wilmsii* as present in Madagascar. During the second half of the twentieth century, several studies were conducted on leafy liverworts, new species were described and records were added for Madagascar in a continuous effort, but once again no thalloid liverworts (Tixier 1977, 1984, 1992; Pócs 1995, 2001, 2006; Pócs and Geissler 2002; Pócs and Schäfer-Verwimp 2006; Pócs *et al.* 2015, Pócs & Váňa 2015; Vanden Berghen 1981). The most recent check-list of bryophytes of Madagascar published in 2012 reported 1143 species and infraspecific taxa (Marline *et al.* 2012) including 14 Marchantiidae. Marchantiidae are thalloid liverworts represented all over the world by 372 species (Söderström *et al*. 2016). They are divided in four orders (Crandall-Stotler *et al.* 2009): Lunulariales (1-2 species), Marchantiales (340 species and 19 infraspecific taxa), Neohodgsoniales (1 species, restricted to New Zealand) and Sphaerocarpales (32) (Söderström *et al*. 2016, Wigginton 2009, Marline *et al.* 2012). According to our study, only Marchantiales occur in Madagascar.

The thallus of Marchantiales is dichotomously branched, sometimes occurring in rosettes or in isolated lobes forming more or less crowded mats on substratum. They are called “complex thalloid” liverworts, because their thallus is morphologically and functionally stratified. The photosynthetic zone is often restricted to the upper part of the thallus, with an epidermis usually interrupted by air pores, simple or bordered by a complex ring. Scales are often present on the ventral face and their characters are useful for identification. Gametangia of Marchantiales are often born on erect gametangiophores. The sporophytes hang down from female gametangiophores, except in the Ricciaceae family, where gametangia and sporophytes are embedded in the thallus. Marchantiales are often photophilous and they may tolerate high illumination and temperature variations (Bischler-Causse *et al.* 2005) being often the first colonizers of disturbed and open environments. They colonize rocks and soils, near watercourse, water-falls or seepages or in temporary flooding areas, alternating with long period of drought (*Riccia, Targionia*).

Thalloid liverworts, like *Marchantia* are locally called *Vahohombato, Vahohontany* ("stone tong") or *Vohontany* (“earth blanket”). They are known to live in shady banks and crushed into mortar with other plants, are used to attract bees in new beehive (Boiteau *et al.* 1997). They may also be used in the process of huts construction (Boiteau *et al.* 1997).

This paper presents the description, distribution and ecological data of the species from the sub-class Marchantiales (Marchantiidae, Marchantiopsida, Marchantiophyta) encountered in Madagascar, based on the analysis of herbarium specimens and the authors’ recent collections. Six new records are proposed for Madagascar: *Asterella bachmannii* (Steph) S.W. Arnell*., Asterella marginata* (Nees) S.W. Arnell, *Exormotheca pustulosa* Mitt, *Riccia congoana* Steph, *Riccia atropurpurea* Sim, *Riccia stricta* (Lindenb.) Perold, including *Asterella coronata* (Steph.) Grolle proposed as a new synonym of the African *Asterella bachmannii* (Steph.) S.W. Arnell. One citation (*Riccia perssonii* S.A. Kahn) is not retained because no herbarium voucher is associated (Perold 1995b).

MATERIAL AND METHODS

Examined material came from specimen collections from field trips in Madagascar and historical collections from herbaria including TAN, PC, MO and EGR, in Madagascar, such as those collected by Decary or Bosser (Dorr 1997). The geographical distribution of the species were assessed from available literature (*e.g.* Pócs and Geissler 2002) and recent collections.

Recent investigated areas

Between 2006 and 2014, several sites have been investigated in Madagascar for bryophytes. These areas are mostly located in the low and mid elevation evergreen humid forest (300-1500 m) (Moat and Smith 2007, Goodman 2009), except for the southern Makay Massif belonging to the dry West domain, in the dry decidous forest area (Moat and Smith 2007, Goodman 2009). The sites are presented from North to South, each followed by the province and region in brackets (*Figure 1*).

The Makirovana Ambanjavala complex (Antsiranana, Sava) was visited in April-May 2010 during a field trip organized by the Missouri Botanical Garden in the context of a conservation project driven by the local populations (M.B.G 2008). The total area covers 5200 ha and is covered by an evergreen low elevation humid forest on a gneiss-granite substratum. The steep elevational gradient is probably the reason of a high diversity (M.B.G 2008).

Namoroka National Park (Mahajanga, Soalala district) is located 50 km south of Soalala and was visited in October 2016. It is a typical Tsingy massif, characterized by ragged calcareous needles up to 100 meters high and dissected by a karstic network. The vegetation is a seasonal dry forest with a seven-months dry season.

Vohimana New Protected Area (Toamasina, Alaotra-Mangoro region) is located 150 km east from Antananarivo. The total area of 1635 is covered by a tropical submontane evergreen forest (790-1030 m). Bryophyte collections were conducted in July 2006, April 2010 and June-July 2012 together with a fern inventory (Reeb *et al.* 2012).

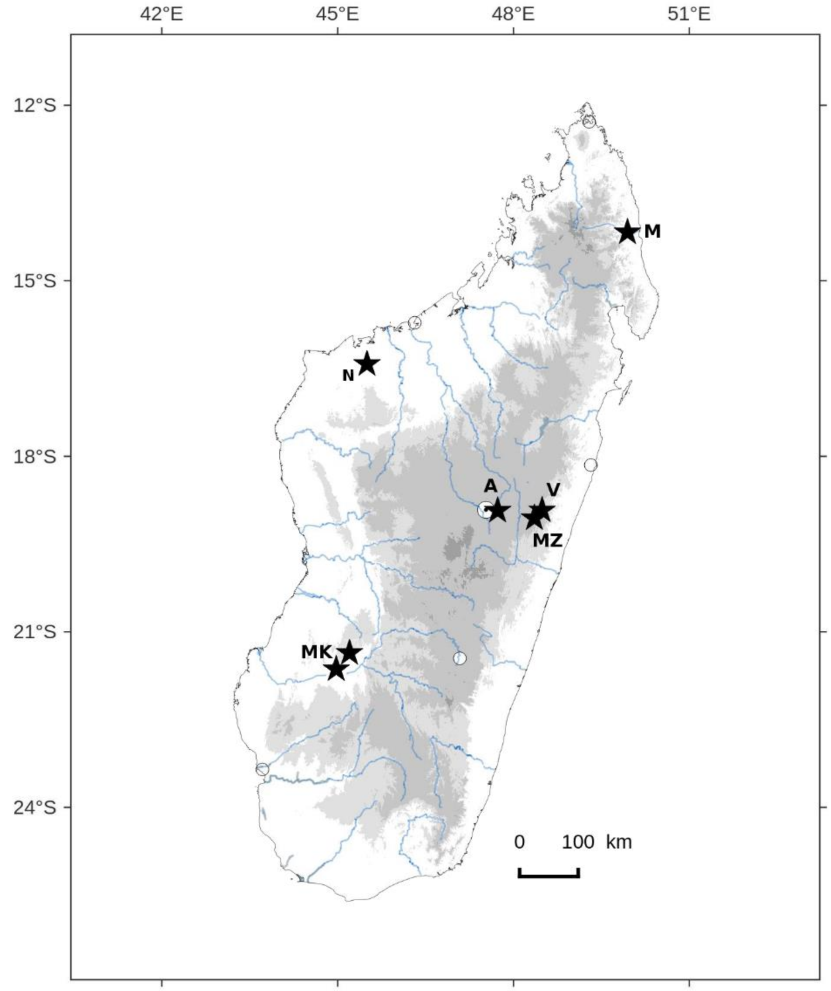


Figure 1. Map of recent missions in Madagascar, from North to South: M = Makirovana, N = Namoroka, V = Vohimana, MZ = Maromizaha, A = Angavokely, MK = Makay.

Maromizaha reserve (Toamasina, Alaotra-Mangoro region) is located 30 km west from Vohimana. It belongs to the same forest complex as Vohimana, 1880 ha covered by a mid-elevation evergreen forest (896-1213 m). The site was visited in July 2012.

Angavokely forest station (Antananarivo, Analamanga region) is located 36 km east from Antananarivo, and was visited in February 2011. It is in the central region (Perrier de la Bâthie 1921, Humbert and Cours Darne 1965) with dense evergreen seasonal forest (Faramalala 1995). Angavokely (1300-1787 m) although belongs to the Central High Plateau, is under influences of the eastern humid air. Its high elevation allows the presence of mountain vegetation types on the soil of intrusive gneiss-granitic rocks.

Makay massif (Tuléar, Astimo-Andrefana) was explored for bryophytes during the expedition "Makay Nature" in January 2011 (Wendenbaum 2011), June 2016, July 2017. Makay massif is located in the western part of Madagascar in subarid and dry series (Cornet 1974), west closed dry forest (Faramalala 1995, Moat and Smith 2007). It ranges from forests to impenetrable thickets, to bushland and low scrubs. Trees are largely deciduous apart from riparian elements along the rivers (Moat and Smith 2007). Vegetation is formed by many spiny and small-leaved species and the underlying vegetation is composed of succulents. Extending upon 14000 km^2, the Makay is constituted by crumbly sandstone hills notched by deep canyons which give a ruiniform relief, especially eroded by the heavy rains from October to March (near 1000 mm/month). At the bottom of canyons, narrow gallery forests resist (or not!) to human pressures, especially by the grazing of the zebus and by bush fire. Exposed and sunny riverbanks, bordered by sandstone blocks are convenient for the settling of thalloid liverworts well adapted to dry areas with temporary inundations, such as *Riccia* or *Targionia*.

All of the collected specimens were deposited in "Herbier National du Parc Zoologique et Botanique de Tsimbazaza" (TAN, Antananarivo) with duplicates in "Muséum National d'Histoire Naturelle Paris herbarium" (PC, Paris) and at the Missouri Botanical Garden (MO). Species integrated in the distribution maps correspond to all specimens found in PC, TAN and the authors collection, and some specimen identified on the field but not collected: (1) Ambohitantely reserve, visited during the AETFAT field trip in April 2010 and the (2) Montagne d'Ambre, visited in August 2010.

Studied herbarium specimens

Marchantiidae specimens from TAN, PC, MO and EGR were studied, including unreferenced and unidentified collections, even if sometimes annotated. Historical specimens were gathered by botanists who wandered across Madagascar collecting mainly angiosperms and ferns: Hildebrandt, the oldest (1879 and 1881), d'Alleizette (1906), Perrier de la Bathie (1921), Waterlot (1913-1914), Decary (1920-1940), Roger Heim (1934-1935), Bosser (1935-1962), Humbert (1960), Leandri (1952), Boiteau (1966-1968), Onraedt (1970-1974), Cremers (1973), Tixier (1975-1979). We could also study several untapped documents on Madagascar (specimens, micrographs etc.) gathered by S. Jovet-Ast (1914-2006), a specialist of the Ricciaceae family. Types (isotypes and syntypes) studied from PC herbarium are followed by “!”.

Identification, descriptions and distribution maps

Available literature on the African bryoflora (Arnell 1963, Perold 1999, Chuah-Petiot 2003, Jones 2004) and specific studies on Marchantiidae (Jovet-Ast 1955, Bischler-Causse 1978, Jovet-Ast 1989, Bischler-Causse 1993, Perold 1995a, b, c; Bischler-Causse *et al.* 2005, Long 2006, Fischer 2016) and herbarium specimens (from PC) were used as references for species identification.

For each species a short description of specimens is associated to a distribution map. For the complete description, we refer to the literature on African liverworts mentioned above. The measurements are given for the Malagasy specimens; if larger or smaller dimensions are found in the literature, they are reported in brackets. The barcode of PC specimens follows the abbreviation, when available. Spelling corrections of geographical names from original labels or additional geographic information may be added between squared brackets [ ]. When complete, dates were homogenized in "dd/mm/yyyy" format, in other cases the date from the original label was kept.

Distribution maps represent the known localities from all the studied specimens, and the comments about distribution are based on these maps.

RESULTS

Key of Malagasy Marchantiidae

1a Thalli large (mostly > 1cm width), dark to yellowish green, translucent when humid, margins hirsute, ventral face with parallel and often curved lines of white rhizoids; air pores and air chambers absent; male receptacle on very short stalk (seems sessile)..***Dumortiera hirsuta***

1b Thalli small to large, margins not hirsute, ventral face without parallel and curved lines of white rhizoids; air pores (see cross section) present; gametangia stalked or embedded……………….…..**2**

2a Dorsal epidermis in form of conical protuberances materializing the roof of air chambers, with a pore at apex of each protuberance..***Exormotheca pustulosa***

2b No dorsal conical protuberances, even if air chambers could be slightly elevated (see in cross section)……………………………….…....**3**

3a Thalli small to medium, in partial or complete rosette or fan-like, air chambers in vertical channels or polygonal to rounded, sporophytes embedded……….…………………………………………..…**4**

3b Thalli medium to large, not in rosette but in elongated lobe with dichotomous ramification; air pores compound or simple………..…**10**

4a Thalli iridescent, air chambers rounded to polygonal, in one layer; male gametangium marginal and disk shaped, sporophyte in apical cavities of the thallus, elaters and oil-bodies present...***Cyathodium cavernarum***

4b Thalli not iridescent; air chambers in vertical channels or large, polygonal in several layers (2-5), gametangia and sporophyte embedded in thallus but not apical; elaters and oil-bodies absent…..(***Riccia)*** **5**

5a Thalli less than 1 mm wide, cilia marginal and mixed with papilla on dorsal face.......................................***R. atromarginata*** **var.** ***jovet-astii***

5b No cilia on the thalli………………………………………………….....**6**

6a Thalli strap like, with rounded or polygonal air chambers, often aquatic or semi-aquatic, sporophyte bulging ventrally…………………..**7**

6b Thalli not strap like, air chambers in vertically parallel channels, sporophyte not bulging or bulging dorsally……………………...............**8**

7a Apex rounded without groove often thickened into a bulge;

spores with 5-6 complete alveoli on distal face..........................***R. stricta***

7b Narrow groove visible in apical part, apex narrow and emarginate, not thickened into a bulge; spores with 8-10 complete alveoli on distal face……………………….…….…….***R.* cf. *purpurascens***

8a Thalli spongiose, becoming lacunose with age. No ventral scales or evanescent ones......................………………………….……..…***R. cavernosa***

8b Thalli not spongiose, at least half of each ventral scale black coloured ……………………………….......……......…………….……..……..**9**

9a Large species, lobes up to 5 mm wide, green to blue-green, margin scallopped by conspicuous black ventral scales..................***R. congoana***

9b Medium size species, glaucous green, ventral scales purple-black in basal part with a conspicuous white upper margin, clasping together when dry, forming two typical white lips…..***R. atropurpurea***

10a Thalli rolled around itself when dry showing the completely purple-black and shiny ventral face; pores visible by naked eyes when wet; sporophyte apically and ventrally embedded in a mussel like black, clapping involucre ....…..................***Targionia hypophylla***

10b Thalli not showing a complete purple-black shiny ventral face; pores visible by naked eyes or not when wet; archegoniophore stalked and sporophyte hanging below archegoniophore lobes………………………………………………………………………………**11**

11a Pores barrel shape, air chambers in one layer, filled with chlorophyllose filaments; gemma cups present; antheridiophores and archegoniophores raised on a long stalk …........(***Marchantia)*** **12**

11b Pores simple, air chambers empty in one to several layers; no gemma cups…………………………………………………………….…….…..**13**

12a Thalli 5-10 mm wide without dark median line; pores of 70-125(-200) µm diameter bordered by 7-8 rings of cells; antheridiophores of 10-14 mm diameter…....***Marchantia pappeana***

12b Thalli 3-6(-7.5) mm wide generally with a conspicuous dark median line; pores 40–70(–100) µm diameter bordered by 5–6(–7) rings of cells; antheridiophores of 3-5(-8) mm diameter ....***Marchanta debilis***

13a Archegoniophore arising apically, on stalk, female receptacle with rhizoid furrows, pseudoperianth present and splitting longitudinally into 8-16 slender segments........................(***Asterella***) **14**

13b Archegoniophore not apically arising, on stalk, female receptacle without rhizoid furrows, pseudoperianth absent...............***Plagiochasma microcephalum* var. *microcephalum***
14a Carpocephalum covered with papillae more than 200 µm high, generally two yellow pseudoperianths, ventral scales generally with one appendage…………………………………………….***Asterella bachmanii***
14b Carpocephalum with low papillae and generally 4 pseudoperianths, 1-2 appendages.........................***Asterella marginata***

The species are presented in the alphabetical order within family. Synonyms and types are given by date of citation. Specimens are presented by geographic range, using the six official Malagasy provinces. Taxa recorded as new for Madagascar are followed by a "*". Types examined are followed by "**!**".

AYTONIACEAE

In older publications, the family name is often written as "Aitoniaceae"; the genus *Aytonia*, is also found spelled by the variant: (1) *Aytonia* J.R. & G. Forst, *Char. Gen. Pl.:* 147 (1776); Lindb.: 291 (1898); Schiffn.: 30 (1983). **Type**: *A. rupestris,* (2) *Aitonia* J.R. & G. Forst, *Comm. Soc. Reg. Göttingen* 9: 46, 73 (1787), orth. var.

But as "Aitoniaceae" is an Angiosperm family (Aitoniaceae Harv. & Sond.), endemic of South-Africa, the correct name for this liverwort family is "Aytoniaceae" and *Aytonia* for the genus, basionym of *Plagiochasma*.

Asterella bachmannii* (Steph.) S.W. Arnell. *Hepat. S. Africa* 62. 1963. **Basionym**: *Fimbraria bachmannii* Steph. *Hedwigia* 33(1): 7 (1894). **Type**: SOUTH-AFRICA, Transvaal, s.d., *MacLea* s.n., exsiccata *Rehman 3* (PC-PC 0736583**!** JE) (spelling var. *Fimbriaria*). **Synonym**: *Asterella coronata* (Steph.) H.A.Mill., *Phytologia* 47: 319 (1981) syn. nov. **Basionym**: *Fimbraria coronata* Steph. *Spec. Hep.* 6: 12 (1917). **Type**: MADAGASCAR, Vallée de la Mandraka, 15 août 1906, d'Alleizette 60 (PC-PC10155!), d'Alleizette 125 (PC-PC10156**!**). **Thallus** thick, clear and shiny green, with purple margin, only slightly undulated, 13–20 mm long and 2,5–4 mm wide. **Air**

chambers in several layers. Pores surrounded by 2 rings of 6–8 cells. **Ventral scales** in two ventral rows, triangular, pink, 1500–1650 µm long, 500–600 µm wide; appendage pink, lanceolate constricted at the basis, apex acute, 800–850 µm long, 120–160 µm large. Dioïcous. **Antheridia** in sessile cushions near apex of main branches, sometimes on lateral innovations. **Carpocephalum** papillose, with two yellow pseudoperianths. **Spores** yellow, translucent with crenulate margin, 90–120 µm diameter and with 8 alveoli in the proximal face.

Distribution: Humid to sub-humid central zone, above 400 m (*Figure 73*). Occurs also in Africa (South-Africa, Zimbabwe, Malawi).

Ecology: on rocks or humid banks along rivers and open areas.

Specimens examined: ANTANANARIVO, Tsanisana [*Nanisana*], 01/1906, d'Alleizette (PC-PC0049107); bord de la Manankaza, [*Manankazo*] 130 km de la route de Majunga*, Bosser,* (PC); 04/1904, *Waterlot 138* (PC-PC0738492); Ambohimanga, 06/1914, *Waterlot 169* (PC-PC0738503), *Waterlot* 167 (PC-PC0738501); Andramasina, 30 km SSE d'Antananarivo, *Leandri 3089* (PC); Andramasina, 1350 m, 25/05/1976, *Tixier* H10020 (PC-PC0738874); Befotaka, Pic de Karafanga [*Farafangana*], 06/08/1926, *Decary s.n.* (PC-PC0738499); Vallée de la Mandraka, 1200 m, 24/02/1974, *Onraedt 74M2003* (PC-PC0738867); Vallée de la Mandraka, 23/10/2015, *Reeb & Solofo CR15M91*; Ambatoloama [*Ambatoloana*], PK64 route de Tamatave [*Toamasina*], 1250 m 18/05/1976, *Tixier* H10019 (PC-PC0738873); MAHAJANGA, Bealanana, Mangindrano, forêt de moyenne d'altitude d'Antsihavo à 7 km de la commune rurale de Mangindrano, 14°14'37"S 49°00'34"E 1325 m, 02/12/2005. *R.L. Andriamiarisoa 660* (MO); FIANARANTSOA, Ranomafana National Park, Namorona river, alt 1080-1150 m, 26/07/2004, *S. & T. Pócs 04126/AR* (EGR, MO, PC-PC0738869, TAN); Ranomafana National Park, 3km from Vohiparara village, 24/07/2004, *T. Pócs & R. Ranaivojaona* 04121/E (EGR, MO, PC-PC0738870, TAN); Isalo National Park Malaso circuit on a sandstone block, 28/05/2016, *C. Reeb, L. Rabeau* CR16M159 (PC, MO).

Observation of isotypes of *A. coronata* and comparison with specimens and description of *A. bachmannii* led to the conclusion that these species are identical (vegetative characters, spore characters and dimensions). We propose the synonymy of *A. coronata* (Steph.) Grolle with *A. bachmannii* (Steph.) S.W. Arnell which is the accepted name of the species according art. 11 (priority rule ICN).

Asterella marginata* (Nees.) S.W.Arnell *Hepaticae of South Africa* 62. 1963. **Basionym**: *Fimbraria marginata* Nees. Hortae Physicae Berolinenses 44. 1820 **Type**: Capite b. spei, crescit iuxta viam in monte Leuwenstaart ad terram, leg. Bergius (BM) (spelling var. *Fimbriaria*).**Thallus** thick, undulate with purple margins (*Figure 2*), 20–23 mm long and 2,5–5 mm wide, sometimes with ventral innovations, some lobes cordate with overlapping apex after notches. Air chambers in several layers in cross section. **Pores** slightly elevated, surrounded by 2 rings of 5–6(–9) cells. **Ventral scales** in two lateral rows, triangular, red to purple, 1000–1500 µm long and 400–450 µm wide; appendages 1–2, lanceolate, pink, 450–700(–1200) µm long, 120–150 µm wide, not or slightly constricted at basis, few small papilla along the margin, apex acute with a single apical cell. Dioicous? **Antheridia** in sessile cushions on ventro-lateral innovations or at base of main branches. **Carpocephalum** rounded when young and slightly papillose due to air chambers, umbonate when mature with 3–4 (mostly 4) slanted pseudoperianths, palea up to 2 mm. **Spores** yellow-orange with a crenate margin, of 114–133(–140) µm diameter with 6 clear alveoli on the distal face and a net triradiate mark on the proximal face.

Distribution: Humid to sub-humid central zone, elevation more than 400 m (*Figure 73*). Occurs in South-Africa.

Ecology: on rocks or humid banks along rivers or trails.

Specimens examined: ANTANANARIVO, Entre Antananarivo et Befato [*Betafo*], juin 1894, *Caussèque 345* (PC-PC0738875); Ambohimanga, 27/03/1921, *Decary s.n.* (PC-PC0738500, PC0738502, PC0738495, PC0738496, PC0738497); Imerina, montagne de Behenjy, 11/05/1921, *Decary s.n.* (PC-PC0738498); Pk 28 route du Sud, 03/1956, *Bosser 9207* (PC-PC0738506), 09/1960, *Bosser14586* (PC-PC0738506); Iharanandriana, Pk 39 route du Sud, 05/1962, *Bosser 15898* (PC-PC0738505); Nanisana, *Alleizette*, (PC); Andramasina, 30 km SSE d'Antananarivo, 1400-1500 m 17 février

1960, *Leandri 3101bis* (PC); Analabe, près d'Ambositra, *Onraedt 70M359* (PC); MAHAJANGA, Bealanana, Mangindrano, forêt de Bemafo, Ambohimirahavavay. Forêt dense humide, sempervirente. 29/11/2005 *R.L. Andriamiarisoa 621* (MO). TOAMASINA, Zahamena, 1H30 de Ranofotsy along river Ankotokotroka [*Ankotrokotroka*] 1169 m, 17°36'39"S 48°40'21"E, *Reeb & Andriamanantena CR13Z65* (PC-PC0738872, TAN).

Figure 2. *Asterella marginata*, near Fianaransoa. Scale bar 1 cm.

Excluded species: *Asterella wilmsii* (Steph.) S.W.Arnell

Asterella bachmannii and *Asterella marginata* differ mostly by (1) larger dimensions for *A. marginata*, (2) number of pseudoperianths, regularly 2 for *A. bachmannii*, 4 for *A. marginata* and (3) the appendages, generally one constricted at basis in *A. bachmannii* and often 2 appendages not constricted at basis in *A. marginata* (this character is sometimes difficult to evaluate because of its variability within a single thallus).

A. wilmsii and the endemic species *Asterella coronata* (Steph.) Grolle are cited in Madagascar checklist (Wigginton 2009, Marline *et al*. 2012).

A. bachmannii and *A. marginata* can be easily confused (Vanden Berghen 1972, Perold 1999), but we found also that *A. wilmsii* is very close to *A. marginata.* This last species was retained for Malagasy specimens based on the ventral scales and appendages (2 not constricted, only one in *A. wilmsii*), carpocephalum characters and spore diameter (smaller than in *A. wilmsii* according Perold's description).

Plagiochasma microcephalum (Steph.) Steph. var. ***microcephalum***. *Bull. Herb. Boissier* 6: 781, 1898. **Basionym**: *Aytonia microcephala* Steph. *Botanisch Jaarboek* 20: 301, 1895. **Type**: TANZANIA, Usambara, Holst C.H.E 392 (G-G00121196).

Thallus dark green when dry and yellow–green and dull with purple margin when re-hydrated, 10–25 mm long and 4–5 mm large. **Pores** simple, slightly elevated, surrounded by 2 rings of 5–7 cells. In cross section, epidermal pore simple and slightly elevated. **Ventral scales** in two rows, purple, with external hyaline cells and central purple cells, 720–1550 µm long, up to 1000 µm large; appendages 1(-2), rounded to triangular, mostly apiculate, of different sizes, generally slightly constricted or folded at basis, 5-7(-8) rows of cells in the width of the appendage, some external cells oblique and internal cells elongated trapezoidal to rectangular; few cells with persistent oil–bodies in the body of scale and appendage. Monoicous. Antheridial receptacles on the median part of the thallus. **Archegoniophores** rounded and pedunculate. Spores not seen. No asexual reproduction structures.

Distribution: to date, only found in Madagascar at elevation > 1000 m (*Figure 74*). *P. microcephalum* occurs from East-Africa to South-Africa and from Yemen to South-West India (Perold 1995a, Bischler 1978).

Ecology: it grows in patches on shaded and temporary hydrated rocks, naked or covered by compact layer of humus, even if may support a long dry season.

Bischler (1978) identified specimens of Onraedt *70m158* and Decary *s.n.* This species is recognized by the characters of appendages especially by the presence of 1-2 rows of external cells in which oblique rectangular cells are always found. This is the main difference we found when compared with *Plagiochasma beccarianum* Steph., which seems to be close, when sterile. The shape of the antheridial receptacle differentiates also *Plagiochasma* species, but this character was not very clear on old collections. The examined Malagasy specimens have always apiculate appendages, a rare character according to Bischler (1978), but with a high variability in shape.

Specimens examined: ANTANANARIVO, Ambohimanga, 20 km d'Antananarivo, alt 1000 m, 06/01/1970, *Onraedt 70M158* (PC-PC0738865); Ambohimanga, 27/03/1921, *Decary* s.n. (PC-PC0738866); Andramasina, fév. 1958, Decoings *BD3069* (TAN); Andramasina 30 km SSE d'Antananarivo, 1400-1500 m 17/02/1960 *Leandri 3101bis* (PC). MAHAJANGA, bord de la Manankaza [*Manankazo*], 130 km de la route de Majunga [*Mahajanga*], 22/11/1951, Bosser s.n.

New fertile collections of Aytoniaceae are much needed in order to confirm the identity of these three species. *Asterella* has been studied both morphologically and molecularly with several sequences available on GenBank (Long 2001, 2005, 2006). Inclusion of Malagasy specimens in a molecular approach will be useful to delineate these species. In an upcoming study, DNA barcoding identification will be performed for Malagasy species.

CYATHODIACEAE

Cyathodium cavernarum Kunze, *Nov. Stirp. Pug.* 6: 18, 1834 (Lehmann 1834). **Type**: CUBA s. loc. 1824 Poeppig s.n. (holotype W, isotype, S. **Synonym**: *Cyathodium africanum* Mitt., *J. Proc. Linn. Soc.* London 22: 327 (1887). **Type**: TANZANIA, Usagara Mountains, J. Hanningtion s.n. (holotype, K).

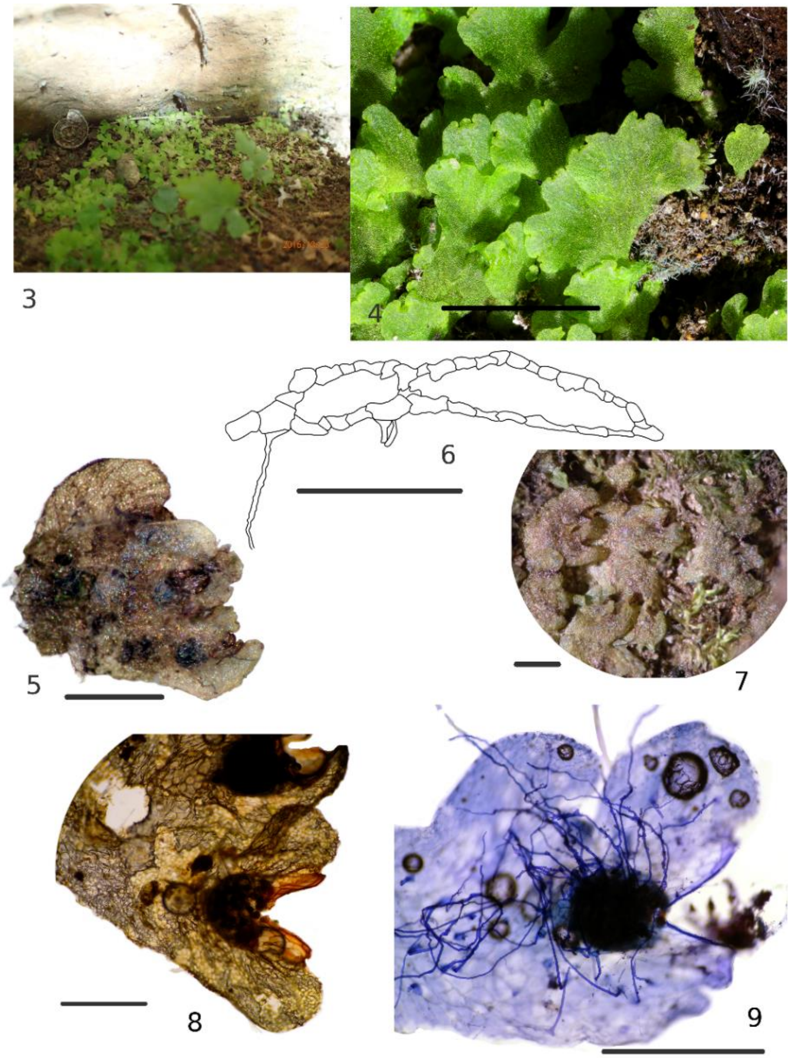
Cyathodium mexicanum Steph. Rev. Bryol. 36: 139 (1909). *Cyathodium barodae* Chavan, Bryologist 11: 57 (1937). **Type**: INDIA Baroda state, Baroda, 1934-1935 Chavan s.n.

Thallus dichotomous, very thin, no mid-rib, rounded apex and lobes overlapping, iridescent in fresh (*Figures 3, 4*) and in dry herbarium specimens (*Figures 5, 7*), 1–3 mm wide. **Air chambers** slightly forming a network, in one row in cross section (*Figure 6*). **Pores** bordered by 2–3 circles of hyaline cells. **Ventral scales** inconspicuous or absent. Monoïcous. (Antheridia not seen): antheridal receptacle lateral terminal, cushion shaped or disk-shaped. **Archegonia** and capsules protected by an involucre globose to elliptic, without hairs but bearing few to numerous and irregular rhizoids (*Figures 8, 9*); mouth emarginate and flaring after a small narrowing border formed by a few rows of thickened cells appearing orange-brown (*Figure 8*). **Spores** brown 45–50(–83) µm with spinae 2–3(–4) µm long.

Distribution: found in Réserve speciale of Manongarivo and in the Namoroka tsingys (*Figure 75*). Occurs in India, Java, Africa and America.

Ecology: in Madagascar at the entrance of caves on naked and compact soils in a shady ambiance.

The specimens show all the characters of the species (Mitten 1887, Srivastava and Dixit 1996, Jones 1952, 2004). The involucre of the capsule is especially crowded with rhizoids, but without white erect whitish bristles typical for *Cyathodium aureonitens* Griff.



Figures 3-9. *Cyathodium cavernarum* Kunze. (3) General view on the field at the entrance of a cave, in Namoroka tsingy. (4) Close view of iridescent thalli. Photo: Gernordt Kunz. (5) Iridescent thallus in collection. (6) Cross section: only one layer of air chambers, and one cell thick epidermis. (7) Ventral face. (8) Details of the involucre with thickened cells at the opening of the mouth. (9) Bleach and blue treatment highlights rhizoids on the involucre (not spiny hairs like in *C. aureonitens* (Griff.) Mitt.), 9855/C. Scale bar 1 mm.

This tiny species cannot be missed because of its iridescence that is due to the position of the chloroplasts in the lens-shaped cells of the upper epidermis. This allows light to reflect and to refract through cells and air-chambers (Duckett and Ligrone 2006). Traditionally placed in the Targoniaceae family (Grolle 1995), the placement of the genus *Cyathodium* in the Cyathodiaceae family was confirmed by molecular and phylogenetic analysis (Boisselier-Dubayle *et al.* 2002; Duckett and Ligrone 2006).

Mitten (1887) gave a very short and incomplete description of *C. africanum* and claimed that it was very similar to the Indian *Cyathodium aureonitens* Griff., but he did not put the two names in synonymy. Nevertheless, Griffith (1849) draw a typical capsule with whitish bristles (p. 354) not present in *C. africanum*. Its seems that a great confusion remained over time between *C. cavernarum* (= *C. africanum*) and *C. aureonitens* (Jones 1952, see Srivastava and Dixit 1996 p. 155), but Jones (1952) undoubtedly reported the two species in Africa.

In the more recent literature (Jones 1952, Jovet-Ast 1970, Vital 1974, Srivastava and Dixit 1996, Jones 2004, Bischler-Causse *et al.* 2005) *C. africanum* descriptions or illustrations are similar to those of *C. cavernarum* (Lehman 1834, Chavan 1937 under *C. barodae*) and Srivastava and Dixit (1996) proposed their synonymy in their revision of the genus. Vital (1974) and Jones (2004) observed the capsule of *C. cavernarum* crowded with rhizoids, like in Malagasy specimens (could they have been confused with the spiny whitish bristles observed in *C. aureonitens*?). We also examined all the African specimens from PC, reviewed by N. Salazar as *C. cavernarum* (Bischler-Causse *et al*. 2005) but primary identified as *C. africanum*. Jones (2004) followed the synonymy given by Srivastava and Dixit (1996) and considered *C. africanum* as a synonym of *Cyathodium cavernarum* Kunze. But Wigginton (2009) reinstated *C. africanum* waiting for clarification of the status of the *species. C. africanum* is also cited in the checklist of Madagascar (Marline *et al.* 2012). As in Söderström *et al.* (2016)*,* only *C. cavernarum* is retained, we considered that it is the species found in Madagascar.

Specimens examined: ANTSIRANANA, réserve de Manongarivo, elev. 90-150 m, 13°54.9'S 48°27.8'E 23/07/1998, *T. Pócs & A. Szabó*

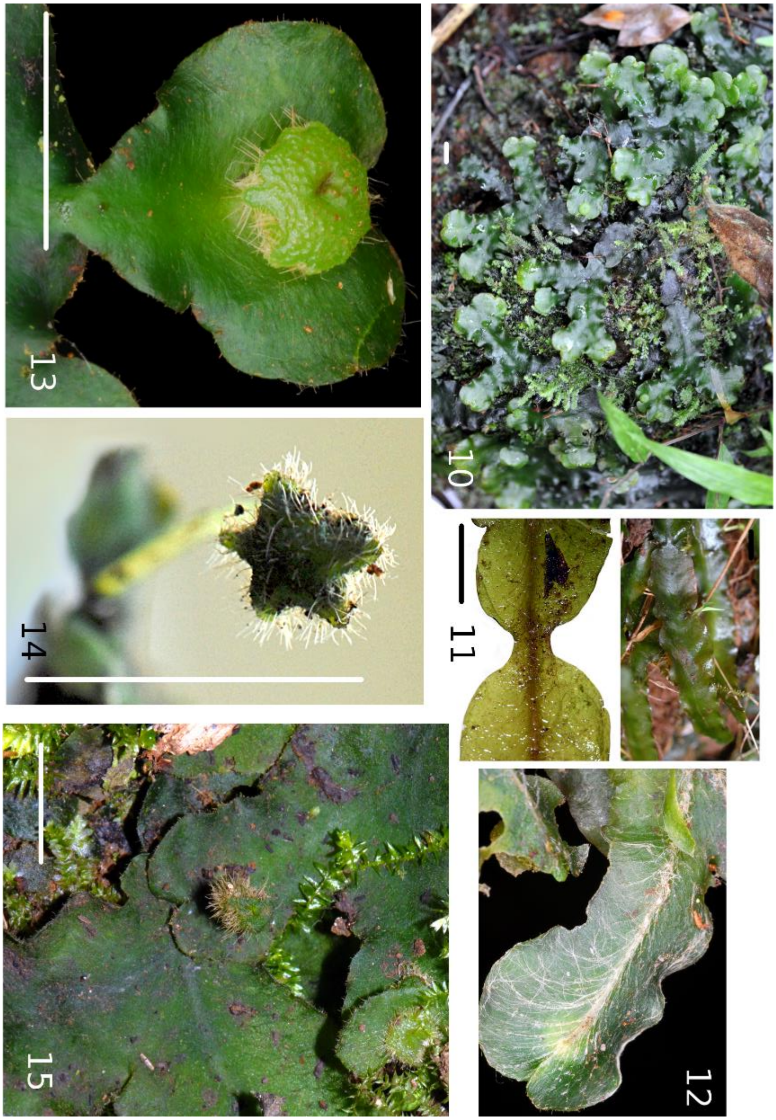
& R. Ranaivojaona 9855/B (EGR). MAHAJANGA, Tsingy de Namoroka on naked soil, very shady base of vertical walls in a cave opening 16°32’30S 45°18’39.9E *Reeb CR16M345*.

DUMORTIERACEAE

Dumortiera hirsuta (Sw.) Nees, Nova Acta Academiae Caesareae Leopoldino-Carolinae Germanicae Naturae Curiosorum XII: 410, 1824. **Basionym**: *Marchantia hirsuta* Sw.: Nova Genera et Species Plantarum seu Prodromus 145, 1788. **Type**: JAMAICA, leg. *Swartz* s.n. (holotype S-B36649; isotype MW-Hb. Hoffm. 8497, UPS-BOT: B-039582). **Thallus** striped, rigid and fleshy, to 100 mm long and 20 mm wide, yellow-green to dark green, translucent to obscure (*Figures 10, 11, 15*) with dichotomous branching and apical reiterations, often preceded by a constriction of the thallus (*Figure 11*), dorsal face smooth, ventral face with an obvious central nerve, sometimes pink with long shiny rhizoids. **Pores** invisible on dorsal epiderm, absent also in cross section. **Ventral scales** discrete, whitish, their insertion forming a succession of incurved and parallel lines on each side of the central nerve (*Figure 12*). Dioicous or monoicous? **Antheridiophores** in disc shape receptacle, sessile or with a very short stalk. **Archegoniophores** often seen sessile with typical bristles on margin (*Figures 13, 14, 15*) before the stalk grows. **Spores** not seen. No gemmae or propagules.

Distribution: humid and sub-humid forests from Center to North (Montagne d'Ambre) (*Figure 74*). *D. hirsuta* has an oceanic subcosmopolitan distribution (Perold 1993, Bischler 1998).

Ecology: in shady humid environment.



Figures 10-15. *Dumortiera hirsuta* (Sw.) Nees. (10) Specimen along a streambed with typical undulate margins. Zahamena, January 2014. (11) Branch showing constriction at the base. Réserve de Vohimana, 2010. (12) White ventral scales in parallel curved lines and central nerve. Vohimana, April 2010. Photo: Ehoarn Bidault. (13) (14) Archegoniophores. Vohimana, April 2010. (15) Mature archegoniophore on a mat thallus, Montagne d'Ambre, August 2010. Scale bar 1cm.

Most specimens are fertile. The species shows some variability with: (1) rigid, olive green thallus with long branches, especially in the Vohimana reserve where it is found creeping among Poaceae at the bottom of a waterfall or (2) deep green, more flexible thallus is observed in shady stations, on rocks, always around waterfalls or permanent water seepages. We suspect that this species could be more widespread in Madagascar, in the humid to sub-humid areas, especially near riverine forest, streams and waterfalls.

D. hirsuta was cited for the first time for Madagascar by Marline *et al.* (2012), after the Bryolat field trip in the Marojejy National Park in 2009. It seems to be present in each humid forest we visited. We found also numerous specimens of *D. hirsuta* in the historical collections. *D. hirsuta* was known for Mauritius since the nineteenth century (Gottsche *et al.* 1844), and this is an example of a thalloid liverwort being under-studied in Madagascar, unidentified plants being kept in herbarium since a long time.

Specimen examined: ANTANANARIVO, Anjozorobe 01/02/1959, *Bosser* 12648, (TAN) ; Cascade d'Ankitsoko, 24/09/1934, *Heim 1367a* (PC-PC0738507); s.l., 1934-1935, *Heim 1101a* (PC-PC0738518); Vallée de la Mandraka, 23/10/2015, *Reeb & Solofo CR15M94*; ANTSIRANANA, Marojejy National Park, elev. 690 m, 14°26'07.8S 49°45'49.9E, 27/11/2009, *Ah-Peng 349*; Anjangoveratra, forêt du Makirovana, elev. 508 m, 14°10'17.4S 49°57'07.5E, 07/05/2010, *Reeb* CR302, (TAN, PC-PC0738892); Massif du Makirovana, 22/08/2010*, Reeb* CR322, (TAN, PC-PC). FIANARANTSOA, Sud Betsileo, Ankafina [=Tsarafady], März 1881, Hildebrandt *s.n.* (PC-PC0738893); Ihosy, près de Ranotsara, 01/12/1963, *Bosser* 17768 (TAN, PC); Parc National de Ranomafana, near Ambodiamontana, valley Namorona, 25/07/2004, *S. & T. Pócs 04118/J* (EGR); TOAMASINA, Ambavaniasy, réserve de Vohimana, elev. 849 m, 18°55'43.6S 48°29'56.6E, 15/04/2010, *Reeb, Andriamanantena & Bidault* CRAE93*,* (PC-PC0738888, TAN); Ambavaniasy, réserve de Vohimana elev. 789 m, 18°55'12.7S 48°30'57.9E, 13/04/2010, *Reeb, Andriamanantena & Bidault* CRAE7*, (*TAN, PC-PC0738889); Zahamena, 1h30 de Ranofotsy, le long de l'Ankotrokotroka, 1169m, 17°36'39.0S 48°40'21E, 04/01/2014, *Reeb & Andriamanantena CR13Z93* (PC-PC0768890), *CR13Z85* (PC-

PC0768891). It was also observed in Ambohitantely forest and in Montagne d'Ambre National Park, above 400 m.

EXORMOTHECACEAE

Exormotheca pustulosa* Mitt. *Nat. Hist. Azores or Western Islands* 326, 1870 **Type**: MADEIRA, Pico de Barcellos, leg. *Johnson* (holotype, NY). **Synonym:** *Exormotheca africana* Steph. *Spec. Hep.* 6: 18, 1917. **Thallus** compact and bifurcate in two ligulate lobes, small, < 1cm long, (*Figure 16*), dorsal surface irregular due to air chamber elevation with pores, margin recurved when dry, scales covering the dorsal margin. **Air chambers** conspicuous, elevated up to 320 µm in cross section (*Figure 17*). **Ventral scales** conspicuous, purple-black, covering flanks (*Figure 18*), exceeding the margin, especially near apical zone; scales not present on the central zone of the ventral face. Monoiocous or dioicous? **Antheridia** sunken in the thallus, prolongated by a protruding neck, emerging between air chambers and around the same hight. **Archegoniophores** in a central cushion. **Spores** not seen.

Distribution: one collection in South Central area. Occurs in the Atlantic islands (St. Helena, Madeira, Azores), Mediterranean areas (Portugal, South of France, Italy, Spain), Arab Peninsula, widespread in tropical and South Africa, Comores and La Réunion (Bischler, 1976, Perold 1999) and was found finally in Mexico (Bischler *et al*. 2005).

This is the first record of the species for Madagascar. It is not surprising to find it in the semi-arid region of the island (*Figure 75*). New collections are needed in order to enlarge its known distribution and ecology in the country.

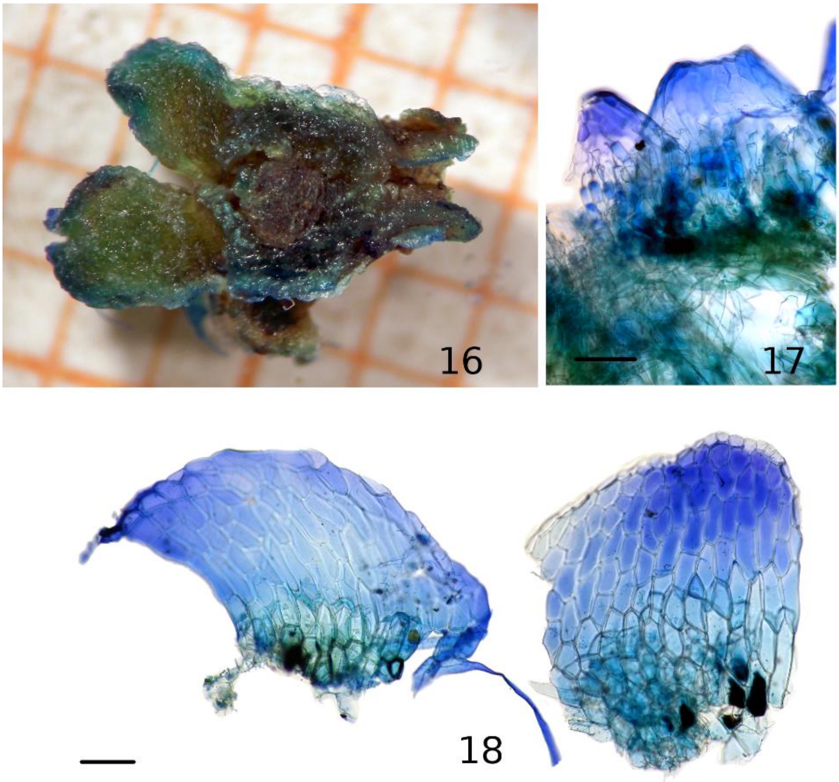
The unique specimen of *E. pustulosa* is more than fifty years old, and it was not easy to get clear and clean cross sections. However, this noteworthy liverwort is easy to recognize to the naked eyes by (1) the conically juxtaposed air chambers, (2) the lateral scales, and (3) the organization of reproductive structures.

Specimen examined: FIANARANTSOA**,** Ihosy, sur terre humide, Janv. 1962, *Bosser 15376* (PC-PC0715993, TAN).

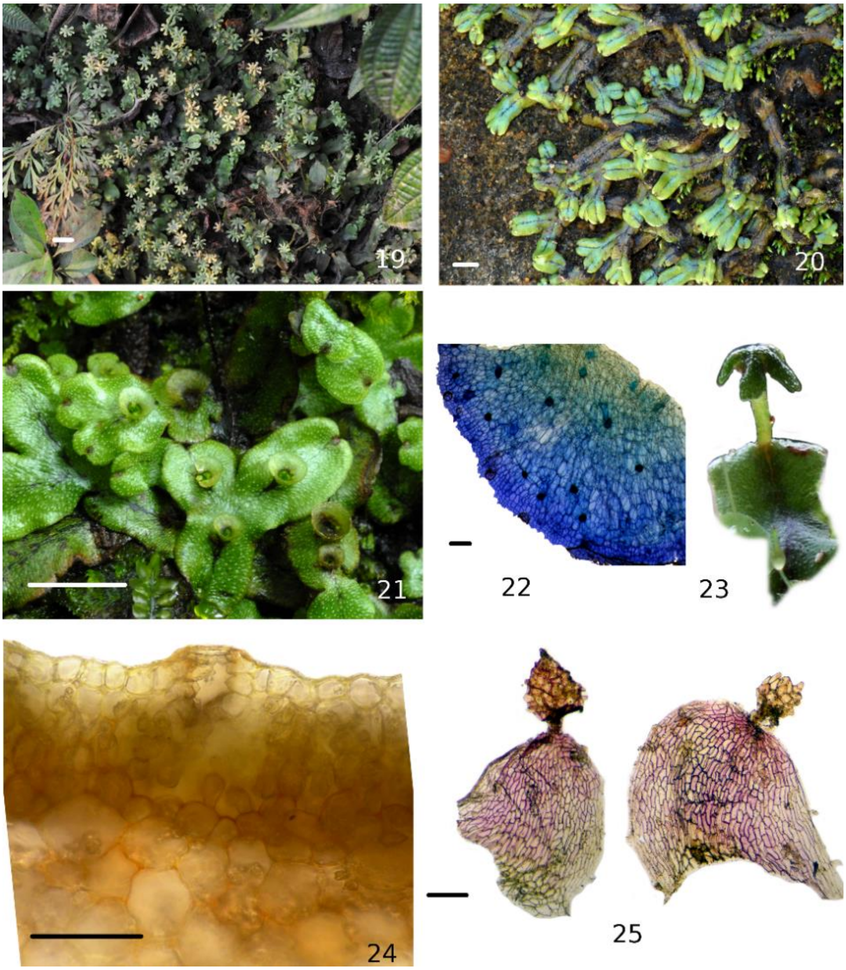
MARCHANTIACEAE

Marchantia debilis K.I.Goebel, Organographie der Pflanzen. Ed. 2 2(1): 901. 1915
Type: CAMEROON, Urwaldgebiet von Bipindi, Zenker, *Flora von Kamerun exs. 1339* (BM!, BR, E, F, G!, GOET, M, S, isotypes).
Synonym: *M. chevalieri* Steph. ex Bonner, Candollea14: 103 (1953).
Type: IVORY COAST, Haute Côte d'Ivoire, pays Dijola, environs de Ona, 4-1909, *Chevalier s.n.* (G, PC). **Thallus** dichotomous, elongated, bright green with a narrow median black line, often interrupted, margin recurved on fresh specimen, hyaline sometimes coloured with purple, entire, undulate to crisped; thallus small to medium sized 20–30 mm long, each axis 3–6(–7.5) mm wide (*Figures 19, 20*). **Air pores** visible, 40–70(–100) µm diameter bordered by 5–6(–7) rings of cells, 2–3 above epidermis, and 2–3 projecting into the cavity (*Figure 24*). **Ventral scales** in 4 rows, not extending more than 30-50 % of thallus width, purple at least in median portion, 1210–1950 µm long, 830–910 µm wide, oil cells scattered; appendage ovate to orbicular, purple, (300–) 450–550 µm long, bordered by unicellular teeth, oil-bodies absent (*Figure 25*). **Cupules** shorly ciliate, cilia 1–2 cells long (*Figures 21, 22*). Dioicous. **Antheridiophore** at apex of axis, stalk 13–15 mm long, with a single band of air cavities, receptacle 3-5(-8) mm diameter with (4–) 7–10 rays generally asymmetric. **Archegoniophore** at apex of axis, stalk 6-9 mm long, with a single band of air cavities, receptacle (3–)4–5 mm diameter, deeply divided to the 0.5–0.8 of the receptacle diameter into (5–)7–10 lobes, generally symmetric (*Figures 19, 23*). Lobes broadened and/or truncate at apex. Sporophyte not seen on Malagasy specimens.

Distribution: widely distributed from South to North, not in dryer areas (*Figure 76*). Occurs in continental Africa.



Figures 16-18. *Exormotheca pustulosa* Mitten. (16) Close view of a re-hydrated thallus. (17) Elevated air chamber: chlorophyllose filaments rise to more than half the high of the pore. (18) Ventral scales, *Bosser* 15376. Coloration with bleached (20 %), rinsed and diluted methylen blue. Scale bar 100 µm.



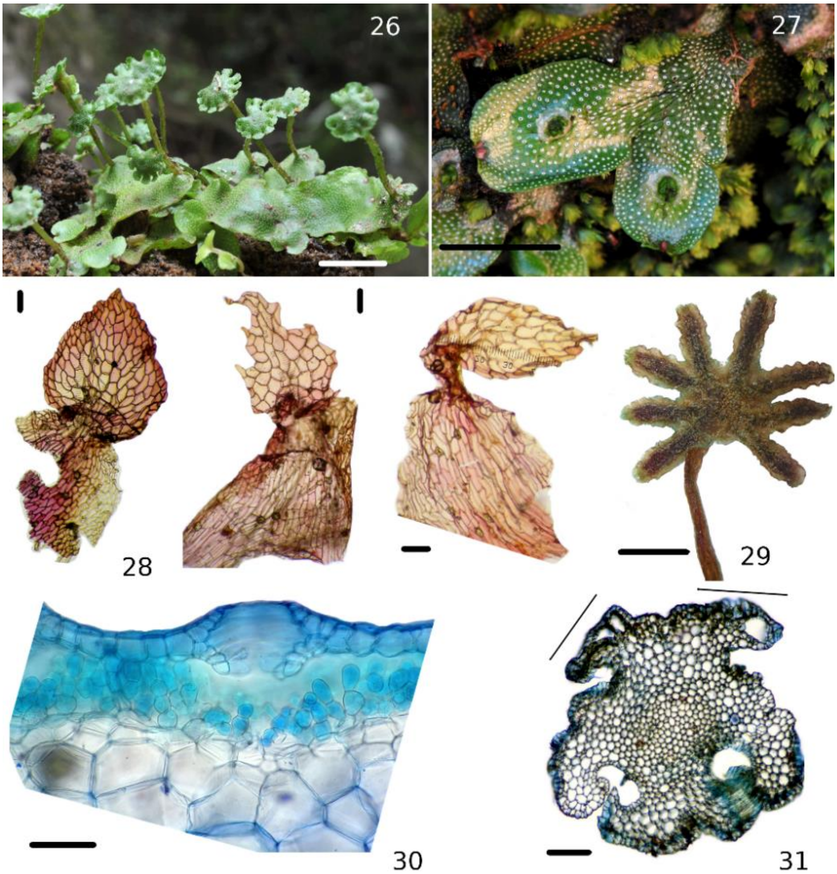
Figures 19-25. *Marchantia debilis* K.I.Goebel*.* (19) Population of *M. debilis*, with archegoniophores. Andasibe, Vakona Lodge, October 2015. Scale bar 1cm. (20) Closer view showing the typical black central line. Massif du Makay. Scale bar 5 mm. (21) Vegetative progapules in cupules. Vohimana, 2010. Scale bar 5 mm. (22) Lamina of the cupule: margin shortly ciliate, cilia less than 2 cells, *Cremers* 2685. Coloration with bleached (20 %), rinses and diluted methylen blue. (23) Archegoniophore, receptacle deeply divided. Vohimana reserve, July 2006. (24) Cross section of the thallus. Scale bar 100 µm. (25) Ventral scales, with relatively small appendages compared to the scale body. Scale bar 100 µm.

Selected specimens examined: ANTANANARIVO, 54 km route de Moramanga, Anosibe, 15/09/1653, *Bosser 6411* (PC-PC0738843); Ambohipotsy, 18/06/1880, *Wildebrandti 4234* (PC-PC0738836); 10/1913, *Waterlot 13* (PC-PC0738835), 14 (PC-PC0738833); Fort Voyron, 15/01/1921, Decary *s.n.* (PC-PC0738816); Mandraka Pk 69, forêt de la Mandraka, au sol, alt 1000 m, 18/07/1972, *Cremers 2259*; Anjozobé [*Anjozorobe*], 22/08/1977, *Tixier s.n.* (PC-PC0738840); Ambatomirahavavy, Lemurs Parc, 18°57'04.8S 47°21'2572E, 1280m , 20/10/2015, *Reeb CR15M61;* Ampefy, chutes de la Lily, 19°01'54.2S 46+41'03.4E, 1156 m, 19/10/2015, *Reeb, Riza & Albert CR15M51*. ANTSIRANANA, Sud d'Ambanja, sur rocher, 13°42'18.01S 48°27'6.93E, 13/08/1973, *Cremers 2455* (TAN); Sud Est d'Ambilobe, forêt d'Anjahana, 28/08/1973, *Cremers 2685*, (PC-PC0167105, TAN); Ambilobe, 26/07/1939, Decary *s.n.* (PC-PC0738844); Analavelona, Andriamiarisoa *ACR1131* (MBG); Diego-Suarez, Ambilobe, bords de la Mahavavy, s.d., *Waterlot 121* (PC-PC0738849); Diego-Suarez, Les Roussettes [Mt. Ambre], 06/11/1975, *Tixier 7474* (PC-PC0738838), *7667* (PC-PC0738846); Nossi-Bé, mai 1879, *Hildebrandt 4233* (PC-PC0738851); Parc national du Marojejy, Mandena, Andampibe valley, 22/03/1990, *Pócs 90110/J* (PC-PC0738839); Réserve spéciale de Manongarivo. Evergreen riverine forest along Ambakatra river, alt 90-150 m, 13°54.9'S 48°27.8'E, 23/07/1998, *T. Pócs, A Szabó & R. Ranaivojaona 9855/C* (EGR); Tsaratanana RNI. River Andilambe. Low elevation humid forest savoka on granite, 17/11/2001, *Chris Birkinshaw 1110* (MO); Sava, Andapa, Doany, Andranomilolo forêt dense humide de moyenne altitude située à environ 13 km à l'Ouest du village d'Andranopositra. 14°20'32"S 49°19'05"E 1438 m, 13/11/2006, *D. Ravelonarivo et al. 2048* (MO). FIANARANTSOA, [Atsimo-Atsanana], Vondrozo, Parc de Farafanga [*Farafangana*], 04/09/1926, *Decary* s.n (PC-PC0738850); Fort-Carnot, vallée de la Sandrananta, *Decary s.n.* (PC-PC0738847); Affluent du Haut Sascelava [*Sahasinka*], 14/09/1934, *Heim 1424a* (PC-PC0738536); vallée du Sakalena, 14/06/1939, *Decary s.n.* (PC-PC0738810) and 15/06/1939, *Decary s.n.* (PC-PC0738853); Près de Fort Carnot, *Heim s.n.* (PC-PC0738513); MAHAJANGA, Pk 274 RN4, rivière Antetezana, *Boiteau 1004* (PC-PC0738845) ; Vohitany (canton de Gogogogo), fev. 1962, *Bosser 15416* (PC-PC0738852); Tsingy de Namoroka, on rocks along Namoroka river, under shady mangoo trees 16°24’00S 45°17’22E. 21/10/2016 *Reeb CR16M308* TOAMASINA, Alaotra-Mangoro, Ambavaniasy, réserve de Vohimana, falaise entre pont de pierre et tunnel désaffecté, elev. 789 m, 18°55’13.1S 48°30’57.1E, 13/04/2010, *Reeb, Andriamanantena & Bidault CRAE10* (PC, TAN); réserve de Vohimana, sur sentier botanique, elev. 789 m, 18°55’12.7S 48°30’57.9E, 13/04/2010, *Reeb, Andriamanantena & Bidault CRAE9*, (PC, TAN); réserve de Vohimana, talus sur la rive gauche de la rivière Vohimana, elev. 798 m, 18°55’25.6S 48°30’41.5E, 15/04/2010, *Reeb, Andriamanantena & Bidault CRAE146, CRAE 150bis, CRAE151bis* (PC, TAN); Réserve de Vohimana, 771 m, 8°55'15.2S 48°30'56.1E, 10/07/2006 *Reeb MH4* (PC-PC0738877), *Reeb MH6* (PC-PC0738876); Zahamena, Andriamiarisoa *ACR108* (MBG); vallée de l’Anony, 05/08/1921, *Decary s.n.* (PC-PC0738837, PC0738841); Andasibe, Vakona Lodge, 18°53'20.5S 48°25'54.6E 979 m, 24/10/2015, *Reeb CR15M99*. TOLIARA, Atsimo-Andrefana, Massif du Makay, camp 1, falaise sur la rivière Androsy, elev. 259 m, 21°36’02.1S 45°06’40.8E, *Reeb CR119* (PC-PC0738855, TAN); Massif du Makay, camp 1, au pied de la cascade de la rivière Androsy, elev. 274 m, 21°35’36.5S 45°06’39.8E, 12/01/2011, *Reeb CR1121* (PC-PC0738854, TAN); Massif du Makay, camp 1, petit vallon affluent de l’Androsy, elev. 259 m, 21°36’13S 45°06’39.1E, 10/01/2011, *Reeb CR1111* (PC-PC0738856), *CR1116* (PC-PC0738857, TAN); Massif du Makay, camp 2, le long de la rivière d’Ambotorabatorano, elev. 303 m, 21°34’04.9S 45°04’33.7E, *Reeb CR11132* (PC-PC0738858, TAN); Massif du Makay, camp 2, remontée rivière Ambotorabatorano, 21°36’00S 45°06’41E, 15/01 /2011, *Reeb CR1166* (PC-PC0738859, TAN); Massif du Makay, camp 4, rivière Ankolitsiky, elev.1901 m, 21°37’46.5’S 45°00’18.5E, 22/01/2011, *Reeb CR11107* (PC-PC0738861, TAN), *Reeb CR11109* (PC-PC0738883, TAN), *CR11111* (PC-PC0738862, TAN); Massif du Makay, camp 4, cascade en surplomb, elev. 221 m, 21°37’30.6S 45°00’26.7E, 23/01/2011, *Reeb CR11116* (PC-PC0738860, TAN); Massif du Makay, camp 4, petit canon rive gauche de l’Ankolitsiky, elev. 224 m, 21°37’31.1S 45°00’25.5E, 23/01/2011, *Reeb CR11112bis* (PC, TAN); Fort-Dauphin, vallée de Mandrara, 01/08/1926, *Decary* s.n. (PC-PC0738842); Ihosy, 20/10/1940, *Decary s.n.* (PC-PC0738834).

Marchantia pappeana Lehm. Novarum et minus cognitarum stirpium, pugillus X: 21 (1857); Bischl.: 76 (1993); Perold: 197 (1995c).
Type: SOUTH AFRICA, 'In Prom. B.S. leg. *Pappe*', ex herb. Lehmann (RO, holo.?; G ex herb. Univ. di Roma). **Synonyms**: *M. planiloba* Steph. Bot. Jahrb. Syst. 8: 90 (1886); Steph.,: 181-182 '153-154' (1886b). **Type**: SÃO TOMÉ, Cachoeira do Rio Manuel Jorge, circa S. Nicolau, 800 m, 1885, *Moller 32* (G). *M. planiloba* Steph. var. w*alteri* Burgeff: Genet. Stud. Marchantia: 276 (1943). **Type**: TANZANIA, 'Nderema in Ost-Usambara, etwa 1000 m, leg. *H. Walter. M. wilmsii* Steph.: 126 (1892). **Type**: SOUTH-AFRICA, Transvaal, McLea in Rehmann Hep. austro-afr. Exs. 1 (PC, BM, G, NY, S). *M. parviloba* Steph.: Bot. Jahrb. Syst. 20: 305 (1895). **Type**: UGANDA, Runssoro, um 2800 m, 10 Juli 1891, *Stuhlmann 2368a* (G, BM). *M. winkleri* Steph. in Bonner Candollea 14: 112 (1953). **Type**: CAMEROON, *Winkler 270* (G). *M. stephanii* Vanden Berghen: Bull. Jard. Bot. Etat. 24: 50 (1954). **Type**: TANZANIA, Usambara, *Holst 692* (FH, G). *M. flavescens* Steph. in Bonner Candollea 14: 107 (1953). **Type**: GUINÉE ÉQUATORIALE, det. Fernando Póo, 1911 *Mildbraed 6275* (G).

Thallus dichotomous, green without median dark line (*Figures 26, 27*), ventral face green or purple, medium size, 25–65 mm long, each axis 5–10 mm large; margins entirely purple or not. **Pores** well visible (*Figure 27*), relatively large 70–125(–200) µm diameter bordered by 7-8 rings of cells, 3–4 above epidermis, 3-4(–5) projecting in air-cavities (*Figure 30*). **Ventral scales** in 4 rows not extending more than 50 % of the thallus width, often purple, 800–1400 µm long, oil bodies scattered; appendages rounded, orbicular or broadly triangular, 450–750 µm long, 330–550 µm wide, bordered by an irregularly toothed margin with one-celled teeth or regular margin (*Figure 28*). **Cupules** with cilia 2-3(– 6) cells long. Dioicous. **Antheridiophores** at apex of axis, stalk 22–25 mm long, in cross section with 2 bands of air cavities, receptacle (5–)10–13(–14) mm diameter, palmate and divided in into (6–)7–9 rays more or less asymmetric (*Figure 29*). **Archegoniophores** at apex of the axis, stalk

10–20 mm long, in cross section with two bands of air cavities (*Figure 31*), receptacle (5–)6–7(–11) mm diameter divided up to the quarter of the receptacle diameter into (8–)10–12 flat lobes (*Figure 26*). **Spores** 17-35 µm.



Figures 26-31. *Marchantia pappeana* Lehm. (26) Fertile population, with archegoniophores. Zahamena January 2014. Scale bar 1 cm. (27) Close view of a thallus showing the large pores easily visible by eyes, no central black line. Massif du Makay. Scale bar 1cm. (28) Ventral scales, *Cremers* 1987 and *Bosser* 13282. Scale bar 100 µm. (29) Antheridiophore. Scale bar 1cm. (30) Cross section of the thallus. Coloration with bleached (20 %), rinses and diluted methylen blue. Scale bar 100 µm. (31) Cross section of the stalk of an archegoniophore showing 2 opposite bands of air chambers (black lines). Scale bar 100 µm.

Distribution: widely distributed from South to North, not in dryer areas (*Figure 77*). Widely distributed in tropical Africa.

Ecology: on edges of water (waterfalls, rivers with slow current, ponds), terrestrial banks in shaded or open and exposed areas, on damp soils or rocks, sometimes flooded.

Bischler (1993), distinguished two subspecies of *M. pappeana*, *M. pappeana* subsp. *pappeana* and *M. pappeana* subsp. *robusta*, but only the former is found in Africa including Madagascar. In the African flora of Jones (2004) only the species *M. pappeana* is cited, we retained that choice.

Selected specimens specimen examined: ANTANANARIVO, 22/04/1906, *Alleizette 7bis* (PC-PC0738822); Tsimbazaza, tourbière de Tsimbazaza, sur terre, elev. 1250 m, 06/08/1972, *Cremers 2409* (PC-PC0738825, TAN), *Cremers 2417* (TAN); elev. 1100 m, 09/10/1927, *Decary s.n.* (PC-PC0738793); centre route du Sud Pk 210, rochers humides et ombragés, 01/12/1951, *Bosser 1254* (TAN); Pk 28 route du Sud, paroi rocheuse humide et ombragée, 01/09/1957, *Bosser 12232* (PC-PC0738832, TAN); Behenjy face Est 36 km Sud d'Antananarivo, elev. 1400 m, 07/09/1972, *Cremers 2325* (PC-PC0738827, TAN); Manjakatompo, 16/08/1934, *Heim s.n.* (PC-PC0738524); Manjakatompo, 25/05/1951 *Benoist 1076* (PC-PC0738796), *Benoist 1076* (PC-PC0738808); Imerina, Janv. 1881, leg. *Wildebranti 4235* (PC-PC0738792); Mandraka Pk 69, forêt de la Mandraka, au sol, alt 1000 m, 18/07/1972, *Cremers 2257* (PC-PC0738828, TAN), *Cremers 2258* (PC-PC0738831, TAN), *Cremers 2259* (PC-PC0738830, TAN); Mandraka, août 1906, *d'Alleizette 84* (PC-PC0738821); cascade de la Mandraka, 16/08/1953, *Bosser 6028* (PC-PC0738788); Mandraka, fev. 1953, *Bosser 5028* (PC-PC0738804); forêt de la Mandraka, elev. 800 m, 31/03/1972, *Cremers 1987* (PC-PC0738826, TAN); forêt de la Mandraka, talus ombragé humide, 01/09/1959, *Bosser 13282* (TAN); Mandraka, Gilles, (PC); Tananarive, Ambohimanga, bouquetau, juin 1914, *Waterlot 167* (PC-PC0738801), *169* (PC-PC0738798); MAHAJANGA, Bealana, Mangindrano, forêt de moyenne altitude d'Antsahivo sur rocher au bord de la rivière 02/12/2005 *R.L.Andriamiarisoa 662* (MO-66223240). ANTSIRANANA, entre Vohémar et Ambilobe, 29/07/1939, *Decary s.n.* (PC-PC0738809); entre Vohémar et

Ambilobe, 30/07/1939, *Decary s.n.* (PC-PC0738807); Marojejy, roche humide le long de la rivière Manantenina, elev. 600-700 m, 12/02/1989, *Miller* & *Lowry 4009* (TAN); massif du Betsomanga, Antongondriha, vallée inférieure de l'Androranga, 17-20/11/1950, leg. *Humbert* & *Capuron* (PC-PC0738818); Nord d'Anosibe, 17/02/1930, *Decary s.n*. (PC-PC078814); Tsaratiteraka (Tsianovoha), *Heim* 1350a, (PC-PC07738511); Diego-Suarez, Joffreville, domaine de Fontenay, 28/08/2010, *Reeb CR2010M (PC);* FIANARANTSOA, [Ranomafana], vallée du Namorona, 22/111938, *Decary s.n.* (PC-PC0738794); Ambatomboay, Octobre 1934, *Heim s.n*. (PC); Andrambovato, 27/04/1979 *Tixier 12391* (PC-PC0738824), *12393* (PC-PC0738823); Farafanga, Befotaka, 16/08/1926, *Decary s.n.* (PC-PC0738815); Fianarantsoa-Masongary Pk 28, chutes de Ranomafana, sur rochers en sous-bois, elev. 1165 m, 01/05/1972, *Cremers 2097* (TAN); parc national de Ranomafana, Along the N side of main road at the head the big waterfalls of Namorona river. Alt 1080-1150 m, 21°14.70-86'S 47°23.82'E, 29/07/2004, S. & T. Pócs 04126/AO, 04126/AN, 04126/AZ (EGR). Forêt de Saharevo, 01/09/1934, *Heim s.n.* (PC-PC0738529); Forêt de Saharevo, 02/09/1934, *Heim s.n.* (PC-PC0738531); Station forestière d'Andrambovato, elev. 1030 m, 01/11/1956, *Decoings 1848* (TAN); Vallée du Sakalena, 13/06/1939, *Decary s.n.* (PC-PC0738787); TOAMASINA, sud de Moramanga, entre Sandrangato et Anosibe, 3-7/11/1952, *Leandri 1572* (PC-PC0738806), *1600C*, *1603bis* (PC-PC0738799); 54 km route de Moramanga, Anosibe, 15/09/1953, *Bosser 6410* (PC-PC0738786); Ambatovavy, Bamafo river, Andriamiarisoa *ACR635*, *ACR662* (MBG); Ambohimangakely, *Decary s.n.* (PC); Analamazaotra, en forêt, 15/04/1939, *Decary s.n.* (PC-PC0738789); Imerimandroso, 0207/1921, *Decary s.n.* (PC-PC0738812); Nord d'Anosibe, 18/02/1930, *Decary s.n.* (PC-PC078803); Périnet, talus humide en borêt, *Boiteau 0228* (PC); près d'Ambositra, *Decary*, (PC); Forêt de Périnet, 9/11/1951, *Benoist 1822* (PC-PC0738800, PC0738805); Forêt de Périnet, elev. 900-1000 m, 02/10/1971, *Cremers 1928* (PC-PC0738829, TAN); station forestière de Périnet, 13/05/1966, *Boiteau 216* (PC-PC0738797), *228* (PC-PC0738790); Sud de Moramanga, entre Sandrangato et Anosibe, alt 800-1100 m; Alaotra-Manongarivo, Réserve de

Vohimana, 771 m, 18°55'15.2S 48°30'56.1E, *Reeb MH1* (PC-PC078878); Andasibe, Vakona Lodge, 18°53'20.5S 48°25'54.6E, 956 m, 24/10/2015, *Reeb CR15M100;* Zahamena, 1H30 de Ranofotsy, le long de la rivière Ankotrokotroka, 1169 m, 17°36'39S 48°40'21E *Reeb & Andriamanantena CR13Z82* (PC-PC0738879), *CR13Z74* (PC-PC0738880), *CR13Z82* (PC-PC0738881); Maroantsetra, 20/10/1920, *Decary s.n.* (PC-PC0738817); TOLIARA, col de Tapia, 29/12/1976, *Tixier 10071* (PC-PC0738813), *10079* (PC-PC0738811); Massif du Makay, cascade rivière Androsy, elev. 274 m, 21°35'36.5S 45°06'39.8E, 12/01/2011, *Reeb CR1120* (PC-PC0738882, TAN); Massif du Makay, au pied marécage tourbeux, elev. 295 m, 21°34'17.7S 45°04'32.6E, 15/01/2011, *Reeb CR1153* (PC-PC0738864, TAN); Midongy du Sud, 23/06/1926, *Decary s.n.* (PC-PC0738802).

It appears that in African historical collections, *M. debilis* and *M. pappeana* were often identified as several species listed now as synonyms (Bischler 1993, Grolle 1995). They were sometimes misidentified and often confused (Bischler 1993, Jones 2004). Several specimens were identified as *Marchantia globosa* Brid. ex Web. which is only encountered in Comores, Mauritius and Réunion islands (Bischler 1993).

The examined Malagasy specimens of *Marchantia* are all related to *M. debilis* or *M. pappeana.* The two species can be separated on by: (1) size, width of the thallus and diameter of the receptacle of the antheridiophore, (2) diameter of the pores (*Figure 32*), (3) size of the appendage of ventral scales (always smaller in *M. debilis*), (4) absence of median dark line in *M. pappeana*, ciliation of the cupules (shorter in *M. debilis*). The number of rings around the pores and cells projecting above epidermis and in air cavities appears variable but if associated with the pore diameter, the two species are distinct. If the plants are fertile, the number of bands of air-cavities in gametangiophores can also distinguish the species (one in *M. debilis*, two in *M. pappeana*). The diameter of spores overlaps and cannot be a diagnosis character. The two species are often in mixed populations (see *Cremers 2259*).

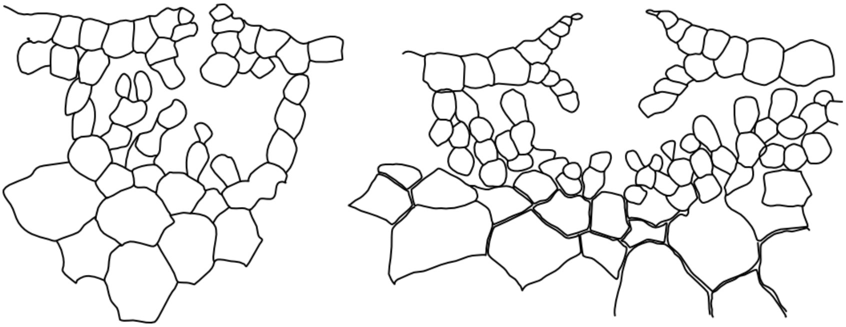


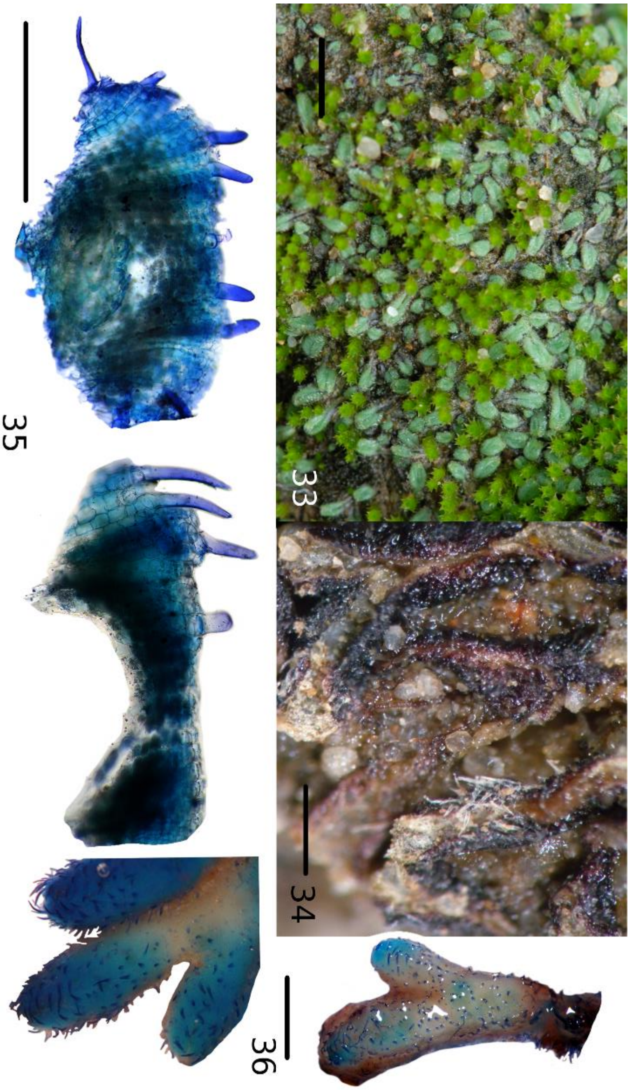
Figure 32. Comparison of the pores in cross section of (left) *Marchantia debilis,* Cremers 2455 and (right) *Marchantia pappeana,* Reeb CR1153.

RICCIACEAE

Riccia atromarginata **Levier var. *jovet-astii*** Rauh & Buchloh *Revue Bryologique et Lichénologique* 30: 77. 1961.

Type: MADAGASCAR Gneis-Hügel bei Fianarantsoa (Madag. Centr.) December 1959 N° *1900* leg. W. Rauh (isotype PC-PC0103703**!**).

Thalli in incomplete or partial rosettes, lobes linear to ovate, very narrow but deep central groove, apex emarginate; glaucous-green to bright green with dark purple flanks (*Figure 33*), small, less than 10 mm long, lobes 0.5–1 mm wide (*Figure 34*); in cross section as wide as thick, without bulging lobes, margin rounded, dorsal epithelium unistratose, cells globose, assimilation tissue in vertical columns of 6–8 isodiametric cells; marginal cilia curved and interlocking on dorsal face, in several rows, sometimes sparsely covering the dorsal face (*Figures 35, 36*), cilia smooth (80–) 150–250(–300) µm long. **Ventral scales** not reaching the margin of the thallus, purple or hyaline in part. Dioicous. **Antheridia** with prominent hyaline neck (not seen on Malagasy specimens). **Archegonia** with purple necks (not seen on Malagasy specimens). Several sporophytes per lobes (up to 3), slightly bulging on dorsal face. **Spores** massively black in mass, brown when alone, globular and irregularly triangular or polygonal with rounded angles, not winged, 68(–92) µm diameter; ornamentation similar on both faces, 10–12 rounded alveoli in diameter, separated by thick edges.



Figures 33-36. *Riccia atromarginata* Levier var. *jovet-astii* Rauh & Buchloh. (33) On the field in the Makay Massif, *Reeb* CR11104. Scale bar 1 cm. (34) Dry specimen showing the black-red flanks, *Bosser* 15420. Scale bar 1 mm. (35) Cross section of thallus, *Onraedt* 70M02. Scale bar 500 µm. (36) Lobes with paler margins after coloration, but allowing observation of ciliae and dorsal papillae in good conditions, *Onraedt* 70M02. Coloration with bleached (20 %), rinses and diluted methylen blue. Scale bar 1 mm.

Distribution: three localities, one in Tsimbazaza park, Southern, dry and lowland areas (*Figure 79*). Occurs in European Mediterranean countries, North Africa, Arabic peninsula and Socotra.

R. atromarginata var. *jovet-astii* is recognized by: (1) the small size of the thallus, (2) the marginal cilia and the dorsal cilia-papilla, (3) the low and inconspicuous purple scales, (4) the distal face of spore with thickened walls.

Ciliate *Riccia* are rather problematic taxa, with taxonomy not fully resolved. Grolle (1995) retained *R. atromarginata* var. *jovet-astii* and *Riccia trichocarpa* Howe for Madagascar. Kürschner (2000) reported it from several localities in Yemen. In the recent check-list (Marline *et al.* 2012), the only ciliate *Riccia* cited is *Riccia crinita* Taylor. As stated by Jovet-Ast (1986), *R. crinita* is an Australian species that she considered with doubt as synonym for *R. trichocarpa*. Grolle (1995) considered *R. trichocarpa* as a critical taxon, based on Jovet-Ast's remarks. Then, Perold (1999) recognized *R. trichocarpa* for South-Africa, but did not mention at all *R. crinita*! However, the ciliate Malagasy specimens cannot be *R. trichocarpa* or *R. crinita*, because of their very small size, the shorter cilia and smaller spores without wing.

This variety was described from one collection from Fianarantsoa (Rauh and Buchloh 1961) then Jovet-Ast (1955, 1989) discussed the "*atromarginata*" complex, including this variety. The distinction between cilia and papilla is not evident, dorsal papilla are described as finger-like and shorter (182–190 µm) than cilia (up to 430 µm), which are also slightly curved. We found that papilla could also be small cilia, and we could not find real distinction between the two in in literature.

The examination of the type specimens shows a morphological similarity between *R. atromarginata* and *R. atromarginata* var. *jovet-astii.* The latter is a little bit smaller and its spores bear thicker cell walls between alveoli (as noticed by Jovet-Ast 1989); we did not find that spores have pillar (thickness) at angles of the alveoli as described and illustrated in Rauh and Buchloh (1961).

Specimens examined: ANTANANARIVO, Tsimbazaza, 1200 m, 14/01/1970, *Onraedt 70MO2* (PC-PC738909); TOLIARA**,** Sud PK 434

Route Amboasary-Ft.Dauphin [Amboasary], fév 1962, *Bosser 15420*, (PC-PC0738908, PC0716004); Massif du Makay, camp 3, sur rochers, elev. 176 m, S 21°40'14.6 E 44°59'22, 20/01/2011, *Reeb CR1192* (PC-PC0738910, TAN), *Reeb CR1197* (PC-PC0738911, TAN).

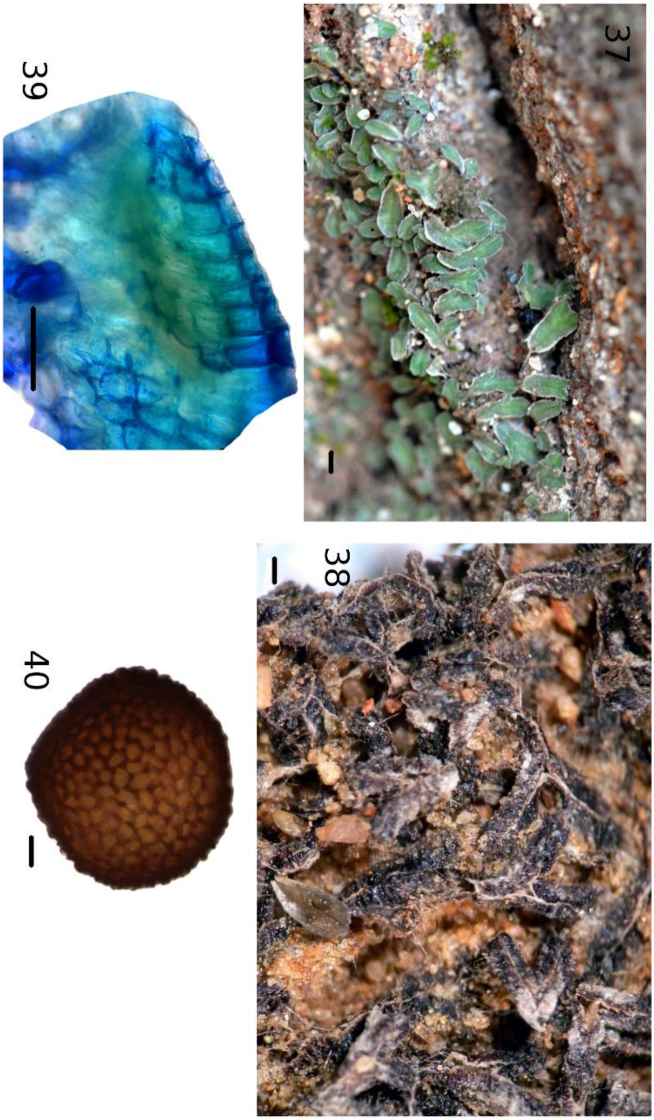
Supplementary material examined *Riccia atromarginata* Levier **Type**: SICILIA Villa Belmonte prope Panormum, 25 Dec 1888, *Dr. H.Ross s.n.* (PC-PC0103704**!**).

Riccia atropurpurea* Sim. *Trans. Roy. Soc. S. Afr.* 15: 11. 1926.
Type: SOUTH AFRICA, Natal, Edendale Falls, *Sim* 8112 (lectotype, PRE-CH1023). **Thalli** in incomplete rosettes up to 20 mm across, glaucous green with a white margin, lobes with a deep central furrow (*Figure 37*), 5–8(–10) mm long, often a smaller branch bifurcating below apex; when dry, margins clasp together dorsally, hiding the dorsal face, then covered by the ventral scales; in cross section, assimilation tissues in parallel lines with narrow air-chambers; epidermal cells soon collapsing, with thickened cell walls (*Figure 39*). **Ventral scales** obvious, black and bright, the white margin forming two lips rising upon the central part of the thallus (*Figure 38*). **Spores** 70–90 µm (*Figure 40*).

Distribution: from North to South, in a discontinuous distribution (*Figure 81*). Occurs in Sub-Saharan Africa.

Ecology: very common on exposed banks of the canyons in the Makay Massif, on temporary humid sandstone plates.

The species is easily recognizable by (1) the dorsally collapsing flanks, (2) the hyalin-white line bordering margins and (3) the thickened cell walls of the epidermis.



Figures 37-40. *Riccia atropurpurea* Sim. (37) On the field, humid thalli showing thin, white margins. Makay Massif, 2011. Scale bar 1 mm. (38) Dry thalli, dorsal faces clasping and white margins forming two lips. Scale bar 1 mm. (39) Cross section showing collapsed epidermal cells with thickened cell walls. Scale bar 100 µm. (40) Spore, distal face. Scale bar 10 µm.

Selected specimens examined: ANTANANARIVO, 24/12/1923, *Decary s.n* (PC-PC0738906); Tsimbazaza, chemin du jardin botanique, sol minéral, 14/03/1970, *Onraedt* (TAN); Tsimbazaza, Déc. 1960, *Bosser 14797* (PC-PC0715996, TAN); TOLIARA, 10 km avant Betroka, rocher temporairement humide, Fév. 1963, *Bosser 16908* (PC-PC0715985, PC0715997, TAN); Route de Betroka PK 65-66, Fév. 1963, *Bosser 16909* (PC-PC0715995); Forêt d'Anjahana, au sud-est d'Ambilobe, 28/08/1973, *Cremers 2687-a* (PC-PC0715986); Massif du Makay, camp 2, rive droite Ambotorabatorano, elev. 295 m, 21°34'13S 45°04'32.3E, 15/01/2011, *Reeb CR1159* (PC-PC0738895, TAN), *Reeb CR1160* (PC-PC0738896, TAN); Massif du Makay, camp 2, vallon à gauche en remontant la rivière Ambotorabotorano, 16/01/2011, *Reeb CR1173* (PC-PC0738897, TAN); Massif du Makay, camp 3 remontée de l'Ankolitsiky, gros bloc, 18/01/2011, *Reeb CR1176* (PC-PC0738898, TAN), *CR1183* (PC-PC0738896, TAN); Massif du Makay, camp 3 forêt d'Ambalamanga, sur terre, elev. 153 m, 21°40'29.3S 44°59'36.3E, 19/01/2011, *Reeb CR1186*, (PC-PC0738899, TAN), *CR1187* (PC-PC0738900, TAN), *CR1189* (PC-PC0738901, TAN); Massif du Makay, camp 3, sur rocher, elev. 176 m, 21°40'14.6S 44°59'22E, 20/01/2011, *Reeb CR1191bis* (PC-PC0738902, TAN), *CR1193* (PC-PC0738903, TAN); Massif du Makay, camp 3, rocher sur sable, elev. 176 m, 21°40'14.6S 44°59'22E, 20/01/2011, *Reeb CR11102, CR11105*; Massif du Makay, camp 4, falaise, elev. 214 m, 21°37'25.2S 45°00'05.0E, 23/01/2011, *Reeb CR11118*, *CR11119*, *CR11121*.

Riccia cavernosa Hoffm. *Deutschland Flora* 2: 95. 1796.
Synonym: *Ricciella rautanenii* Steph. Bulletin de l'Herbier Boissier 3: 374. 1895. **Type**: Africa occidentalis in agro Herera propre Usab in albeo fluminis Tsoacahub as terram. leg. M. Rautanen.

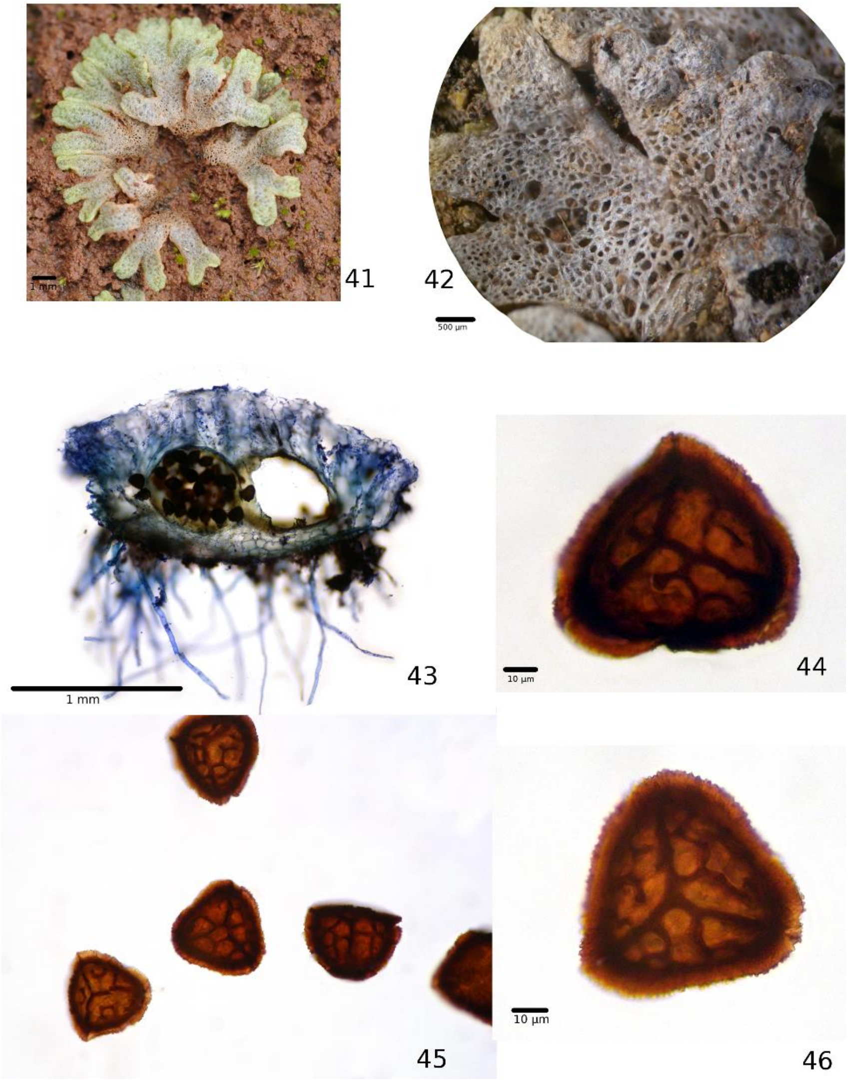
Thallus often in regular rosettes up to 30 mm wide (*Figure 41*), bright green to yellowish green, lobes up to 3.5(-4) mm wide, 10 mm long, becoming spongious and lacunose with age (disintegration of upper epidermis) (*Figures 41, 42, 43*). **Ventral scales** absent or evanescent. Monoicous. **Antheridia** and **archegones** sunk in the thallus. **Sporophyte** protruding somewhat ventrally, even if visible dorsally, numerous, crowded. **Spores** reddish brown to black, triangular-globular, winged, (60-)64-90(-120) µm with a network of few ridges forming sometimes complete alveoli, proximal face with a conspicuous triradiate mark (*Figures 44, 45, 46*).

Distribution: central and southern areas, 0-1200 m in a discontinuous distribution (*Figure 81*). Cosmopolitan species.

Ecology: *R. cavernosa* is a hygrophilous species occurring on fresh muddy soils close to rivers.

This species is easily recognizable by the spongious and lacunose thallus, mostly in rosettes. *R. crystallina* too has this spongious habit and may be confused. The two species were thoroughly compared by Jovet-Ast (1964, 1966, 1986) and Perold (1995b, 1999). They may be confused, but the latter one has not been identified for Madagascar. The main differences being on spore ornamentation (complete alveoli in *R. crystallina)* and size, smaller for *R. crystallina* even if they overlap (60-86.5 µm for *R. crystallina*; 60-120 µm for *R. cavernosa*).

Specimens examined: ANTANANARIVO, environs de Tananarive, PK22 route d'Arivonimamo bord de ruisseau, nov. 1960, *Bosser 14698* (PC -PC0716016); environs de Tananarive, PK23 route d'Arivonimamo terre mouillée bord de rivière, nov. 1957, *Bosser 12299* (PC-PC0716018); mbatomirahavavy, Lemurs Parc, 18°57'04.8S 47°21'25.2E, 1266 m, 20/10/2015, *Reeb CR15M66* FIANARANTSOA**,** chutes de l'Ikopa, sables humides bord de rivière, alt. 1200 m, août 1955, *Bosser 8316* (PC -PC0716015); TOAMASINA, Ambohijanahary, W. lac Aloatra terre humide en bord de ruisseau, juin 1955, *Bosser 8144* (PC -PC0716017); au bord du Fiarenana [*Fiherenana*], à Sakaraha, sur terre sabloneuse ombragée champ cultivé, alt. 380 m, 01/07/1971 *Onraedt 71M5500* (PC-PC0716018); au bord du Fiherenana, près de Miary, sur limon exondé du fleuve, alt. ca. 200 m, 30/06/1971, *Onraedt 71M5527* (PC-PC0716021); TOLIARA, bord de l'Onilahy, près de Ambohimahavelona, sur limon exondé au bord du fleuve, alt. ca. 30 m, 29/09/1971, *Onraedt 71M5501* (PC-PC0716020); Manombo, côte sud-est, sur argile à nu par le retrait des eaux, bush à l'ombre des arbres, alt. 20 m, 26/06/1971 [1972 on original label], *Onraedt 71M5502* (PC-PC0716022).



Figures 41-46. *Riccia cavernosa* Hoffm.. (41) Rosette with lacunose areas. Antananarivo, Lemurs Parc, 2015. Scale bar 1 mm. (42) Detail of a lacunose area, *Bosser* 14698. Scale bar 500 µm. (43) Cross section of a thallus with an embedded sporophyte and large, ill-defined air-chambers. Scale bar 1 mm. (45) Spores. (44) (46) proximal faces of spores, *Bosser* 14698. Scale bar 10 µm.

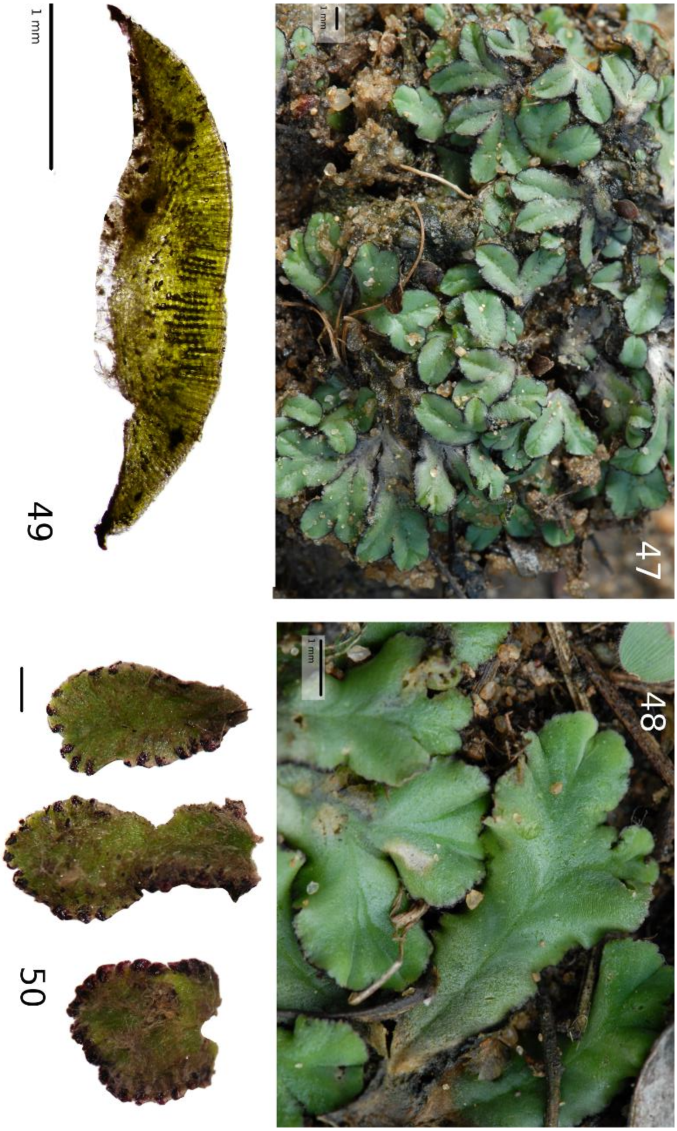
Riccia congoana* Steph. *Bull. Herb. Boissier* 6: 328, 1898.
Type: CONGO, Fr. Equatorial Africa, Forêts de Ceseles, *Voz M. de F., s.n.* (holotype, G-00067873).
Synonyms: *Riccia rhodesiae* S.W.Arnell. *Bot. Not*. 105: 313, 1952. **Type:** ZIMBABWE (S. Rhod.), Victoria Falls, on soil near Trolley Junction, 11/11/1951 *S.W.Arnell* 1291 p.p., (holotype, S-B45273; BOL; PRE). *Riccia berriei* E.W.Jones. *Trans. Brit. Bryol. Soc*. 3: 224, 1957. **Type:** NIGERIA, St Anne's Churchyard, Kudeti, Ibadan, *Berrie 1956*. *Riccia nigrosquamata* E.W.Jones. *Trans. Brit. Bryol. Soc.* 3: 222, 1957. **Type:** TANZANIA Tanganyika, Lighthouse Island, Dar-es-Salaam Harbour, *Jones 699* (BM, holotype). *Riccia aegyptiaca* S.W.Arnell. *Bot. Not*. 116: 9, 1963. **Type:** EGYPT, Gebl. Elba Dist., Wadi Aideib, 21/01/1962 *M. Kassas s.n.* (holotype, S-B43872; isotype, CAI). *Riccia limbatoides* O.H.Volk. *Vegetatio* 55: 58, 1984. **Type**: NAMIBIA, Grootfontein, Farm Gaikos, *Volk 00747* (M, PRE).

Thalli light to dark, green to bluish–green, in dense overlaying patches, generally in partial rosettes, large, 25–30 mm across; often bifurcated in two tongue–like branches, black scales forming a narrow scalloped border (*Figures 47, 48*), lobes (–2)–3–5 mm large, reticulate when young, degenerating in old age, with a narrow furrow all along the thallus, sometimes bifurcating near the apical zone, on larger or older thallus. In cross section, flanks very obliques, margin overhanging (*Figure 49*); dorsal epiderm unistratose, soon collapsing, assimilation tissue nearly half of the thallus thickness (*Figure 49*). **Ventral scales** black and conspicuous, shiny, adherent to the flanks and not easily removable (*Figures 47, 50*). Monoiocous. **Antheridia** along the furrow, projecting. No sporophytes seen.

Distribution: southern areas in open and dry lands at low elevation (*Figure 79*). Occurs in Africa.

Ecology: in semi–shaded position, at the bottom of bushes, on shaded sandstone or muddy banks.

R. congoana seems to be quite common in the Makay massif, and a few specimens have been found in the same type of environment in Toliara province (*Figure 79*); it is often close to *R. atropurpurea* stations, but always in a more shaded area.



Figures 47-50. *Riccia congoana* Steph.. (47) (48) On the field in the Makay massif, *Reeb* CR11103. Scale bar 1 mm. (49) Cross section of a thallus, *Reeb* CR1172. Scale bar 1 mm. (50) Ventral faces with scalloped margins, *Reeb* CR11103. Scale bar 1 mm.

This species is recognized by (1) its large size, *R. congoana* is the largest *Riccia* in Madagascar; morphologically close species are *R. angolensis* Steph. and *R. okahandjana* S.W. Arnell (not cited for Madagascar), which are smaller, (2) the scalloped margin drawn by the scales and (3) the overhanging margins. Flanks of close species rise more vertically with no overhanging margins. It is necessary to collect fertile specimen of *R. congoana* to confirm vegetative characters.

Specimens examined: TOLIARA, RN11 piste forestière d'Imonty, *Keranden 1544* (PC-PC0715991, TAN); Tombeaux des rois Mahafaly à 45 km Sud d'Ampany, Mars 1964, *Bosser 17811* (PC-PC0715994, TAN); Antanimora (S.O) déc 1959, *Bosser 13364* (PC-PC0738907); Massif du Makay, après piste aéroport Berohoroho, bord de lavaka, S 21°37'22 E 45°09'67.2, 09/01/2011, *Reeb CR111, CR111 bis*; Massif du Makay, camp 2, rive droite Ambotorabatorano, elev. 295 m, S 21°34'13 E 45°04'32.3, 15/01/2011, *Reeb CR1158*, *CR1162*; Massif du Makay, camp 2, premier vallon à gauche en remontant la rivière Ambotorabatorano, elev. 329 m, S 21°34'03.5 E 45°04'28.8, 16/01/2011, *Reeb CR1172*, *CR1174*, *CR1180*; Massif du Makay, camp 3, forêt d'Ambalamanga sur terre, elev. 153 m, S 21°40'29.3 E 44°59'36.3, 19/01/2011, *Reeb CR1188*; Massif du Makay, camp 3 forêt d'Ambalamanga, triangle de terre, elev. 153 m, S 21°40'29.3' E 44°59'36.6, 19/01/2011, *Reeb CR1189*; Massif du Makay, camp 3, sur rochers, elev. 176 m, S 21°40'14.6 E 44°59'22, 20/01/2011, *Reeb CR1195*; Massif du Makay, camp 3, sur rochers, elev. 176 m, S 21°40'14.6 E 44°59'22, 20/01/2011, *Reeb CR1198*, *CR11103* (PC-PC0738905, TAN).

Riccia* cf. *purpurascens Lehm. & Lindenb. *Linnaea* 4: 371. 1829. **Type**: Cape crescit humi in sylvula quercina ad latus boreale et ad radicem montis Tafelberg. Ecklon in Herb. L. **Thallus** in small ribbons, overlapping in dense populations (*Figure 51*), light green, margins undulated or straight; branches narrow, up to 5 mm long and 2 mm wide, apex narrowed and emarginate (*Figure 52*); dorsal epidermis areolate, groove narrow and distinct in the apical region, slightly enlarging after. In cross section, thallus concavo–convex to plano–convex with flanks oblique in older parts (*Figure 54*), assimilation tissue occupying most of the height of the thallus. **Air chambers** more or less visible, in cross section in 2–3 layers. **Ventral scales** hyaline, towards apex. Dioicous. **Sporophyte** bulging ventrally (*Figure 53*). **Spores** light brown to orange, semi–translucent, 70–80 μm diameter, with. 8–10 complete or reticulated alveoli on distal face (*Figure 55*). Triradiate mark on proximal face with incomplete alveoli.

Distribution: two localities, Tsimbazaza and Makirovana (*Figure 80*). South-Africa.

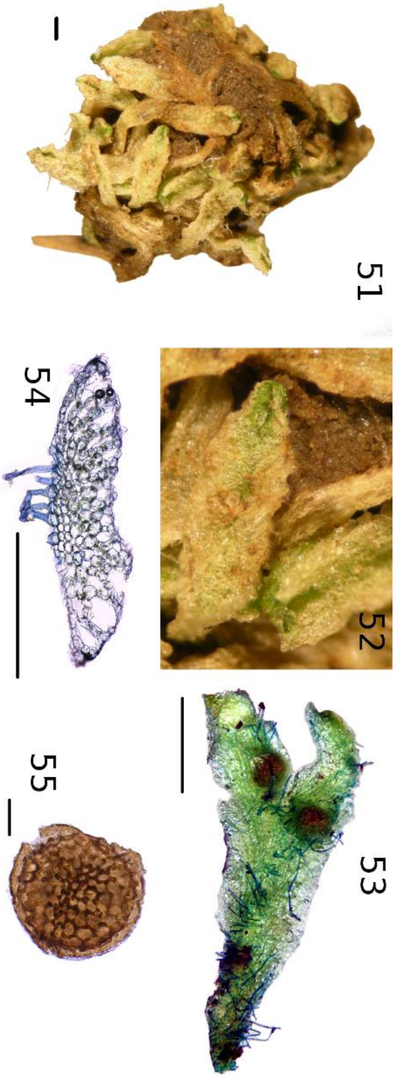
Ecology: Malagasy specimens are located in humid areas (Tsimbazaza park in Central plateau, and Makirovana in eastern humid forest), on naked and humid soil.

Specimens examined: ANTANANARIVO, Antananarivo, sur terre près des serres du parc de Tsimbazaza, elev. 1250 m, 06/08/1973, *Cremers 2418* (PC-PC0715987); ANTSIRANANA, Makirovana, Ambodimanga au pied de Makirovana, elev. 41 m, 14°11'13.6"S 49°59'09.2"E, 03/05/2010, *Reeb CR203* (PC).

In Malagasy specimens identified as *R. purpurascens*, although the number of alveoli on spore distal face is higher than in the type, and we could not observed the ventral tubercules. But all other characters match the description, especially the narrowed apex, the deep groove in apical region and the keeled ventral face.

The *Riccia fluitans* L. complex is very problematic (Schuster 1987, Jovet-Ast 1986, Manju *et al.* 2012) and its status for Africa has been lengthily discussed by Perold (1990, 1999). According to Perold (1990), a clarification of the *R. fluitans* complex is much needed. We follow Perold's treatment, and two species are considered to be present in Madagascar, *R. stricta* and *R. purpurascen*s. *R. purpurascens* was considered as endemic from the Cape province and we do not exclude that *R.* cf. *purpurascens* could be another variation in the *fluitans* complex.

The distinction between *R. stricta* and *R. purpurascens* are: (1) groove marked in *R. purpurascens*, and sporophyte ventral with a straight collar. (2) in *R. stricta*, sporophyte emerges to the dorsal face by an oblique collar, straight in *R. purpurascens*. (3) spore ornamentations.



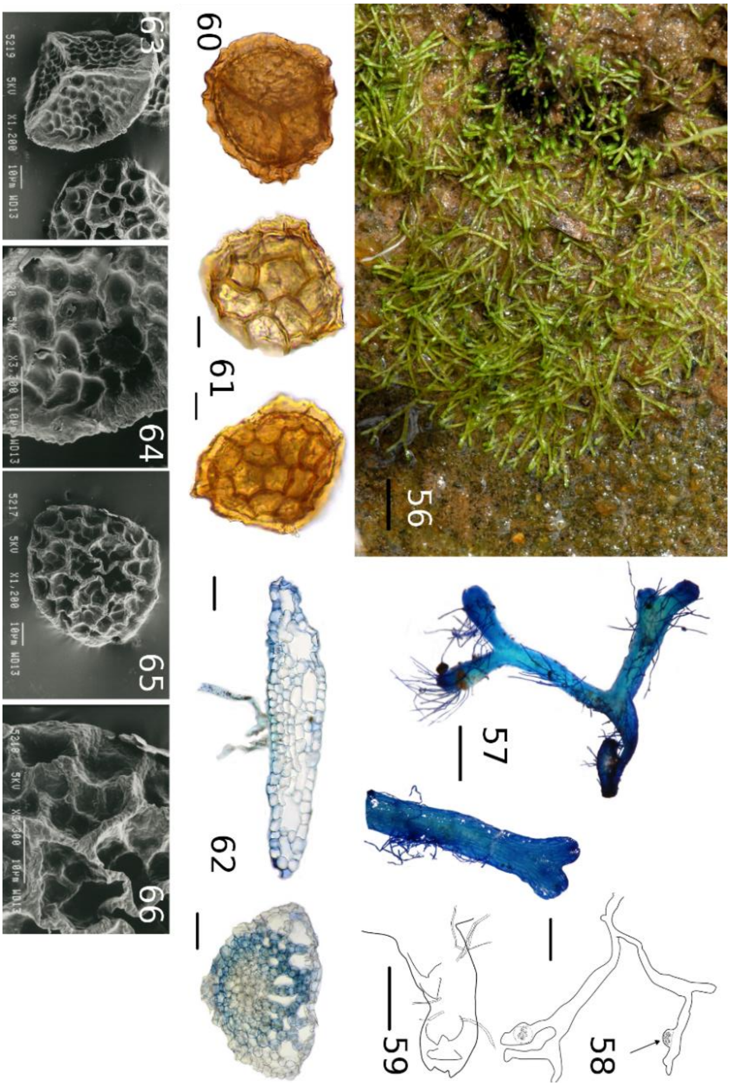
Figures 51-55. *Riccia purpurascens* Lehm. & Lindenb.. (51) Rehydrated thalli, Makirovana, *Reeb* CR203. Scale bar 1 mm (52) Details, *Reeb* CR203 (53) Ventral face. Scale bar 1 mm. (54) Cross section. Scale bar 500 µm. (55) Spore, distal face. Scale bar 10 µm.

Riccia stricta* (Lindenb.) Perold. *Bothalia* 20: 197. 1990.
Type: SOUTH-AFRICA, Cape, Philipstown, ad arborum truncos, Ecklon s.n. (BM) **Basionyme**: *Riccia fluitans* var. *stricta* Gottsche *et al. Synopsis Hepaticarium* 4: 610. 1846. **Thallus** strap like, green, branches furcate (*Figure 56*), up to 20 mm long, less than 1.2 mm wide, apex rounded and often thickened to bulbous, often slightly tapering and narrower than following segment (*Figures 56, 57*); distinct areolation materializing limits of air chambers visible or not on the dorsal face, often at the apical segment (*Figures 57, 62*). **Ventral scales** present at the apical zone, not protruding, single rounded to triangular, often divided but remaining joined at basis (*Figure 59*). Monoicous. Sexual reproduction very frequent, gametangia not seen. **Sporophyte** protruding on ventral face (*Figure 58*). **Spores** orange–brown to light brown, semi–translucent (not opaque), triangular globular, wing obvious 4–8 µm wide, (50–)60–80 µm diameter; 5–6 complete alveoli in distal face; triradiate mark obvious on proximal face, each facet with 6–10 alveoli complete or not; (*Figures 60, 61, 63-66*).

Distribution: from North to South, 0–1200 m (*Figure 80*). Occurs in Sub-Saharan Africa (Perold 1999), India (Manju *et al*. 2012) and probably also in North America (Schuster 1992).

Ecology: in freshwater, running or stagnant, or on banks, close to the river for terrestrial form.

Since 1836 this species has been considered as a variety of *R. fluitans, R. fluitans* var. *stricta* (Lindenberg 1836). Jones (1957) observed that the spores of African's specimens are different from the European ones. Perold (1990) proposed a new combination *R. stricta* (Lindenb.) Perold. This species appears also to be close to *R. stenophylla* Spr. (Schuster 1992). She argued that all the African collections of the difficult and very variable group of *R. fluitans* that she studied were indeed *R. stricta.* We have found in Jovet-Ast's archive documents of her study of Onraedt 14M2023 (*Figure 16 H-K*) that the spores by SEM show the same ornamentation as described by Perold (1990).



Figures 56-66. *Riccia stricta* (Lindenb.) Perold. (56) On the field along the banks of a small stream, Makay Massif, *Reeb* CR1144. Scale bar 1 cm. (57) Thallus ventral (left) and dorsal (right) face. Coloration with bleached (20 %), rinses and diluted methylen blue. (58) Bulging sporophyte in lateral view. (59) Ventral view with scales. Scale bars 1 mm. (60) Spore proximal face. (61) Spore distal face. Optical microscopy, scale bars 10 µm. (62) Cross section old branch (left), terminal branch (right). Coloration with bleached (20 %), rinses and diluted methylen blue. (63) (64) Spore proximal face. (65) (66) Spore distal face, *Onraedt* 14M2023, scanning electronic microscopy by Mme Jovet-Ast, 1994.

The main characters that differentiate the two species are: (1) apex narrowed in *R. stricta*; (2) frequent presence of sporophyte in *R. stricta* compared to *R. fluitans*. These species appear to be also close to *R. stenophylla* Spr. (Schuster 1992), but the *R. stricta* spore ornamentation shows large, very thick and deep walled alveoli and is different from both those of *R. fluitans* and *R. stenophylla*.

Specimen examined: ANTANANARIVO, Antananarivo, sur la terre près des serres du parc de Tsimbazaza, elev. 1250 m, 06/08/1973, *Cremers 2409* (PC-PC0738825, PC0715990, TAN); C*remers 2415* (PC); Antananarivo, Tourbière de Tsimbazaza, 1250 m, 06/08/1973, *Cremers 2417* (TAN); route d'Antsirabe, 11 km environ d'Antananarivo, rizières après la récolte, 14/07/1951, *Benoist* (PC); Antananarivo, Jard. Bot. de Tsimbazaza, elev. 1400 m, 28/02/1974, *Onraedt 14M2023,* (PC-PC0715988); In montibus Ankaratra 1877, *M. Borgen 110* (PC-PC0715999); Environs d'Antananarivo, PK 22 route d'Antananarivo, Sept. 1959, *Bosser 13262* (PC-PC0715992, TAN); ANTSIRANANA, forêt d'Anjahana, au sud-est d'Ambilobe, dans le lit du fleuve Antsiatsia, 28/08/1973, *Cremers 2686* (PC). FIANARANTSOA, Forêts de Ranomafana, 60km au Nord de Fianarantsoa, elev. 900 m, 16/08/1971, *Onraedt 71M5045* (PC-PC0715989); Andringitra, Mts near Ambalavao, elev. 1012 m, 21°56'S 45°65'E, 20/09/1994, *S. Orbán 9459/B* (EGR, PC-PC0716003); Fianarantsoa, Parc National de Ranomafana, S. slope of Mt. Vatolampy, elev. 1015 m, 21°15.37'S 47°24.76E 29/07/2004, *S. & T. Pócs 04127/C* (EGR, PC-PC00716001); Ranomafana National Park 1km W from Ambatolahy, elev. 1015 m, 21°15' 19"S 47°24'48"E, 27/09/1994, *S. Orbán 9466/C* (EGR, PC-PC0716002). TOAMASINA, Pays des Antsianaka [*Antsihanaka*], leg. Perrot 1890 (PC-PC0715898); Pays des Antsianaka [*Antsihanaka*], Mars1891 leg. *Perrot* (PC-PC0716000); route de Tamatave [Toamasina], 11 km est de Manjakandriana (Ambatoloana), elev. 1300 m, 09/1962, *Bosser 16201* (PC). TOLIARA, au bord du Fiherenana, près de Miary, elev. 200 m, 30/06/1971, *Onraedt 71M5526* (PC); Makay, le long de la rivière Ambotorabatorano, sur grès 21°34'04.9S 45°04'33.7E 303m 01/04/2011 *CR1144* (TAN-PC).

Species to be confirmed: *Riccia perssonii* S.A. Kahn is cited for Madagascar (Marline *et al* .2012), and was first identified by Perold

(1995b), but without any specimen reference. The spores of this heterothallic species are in tetrads, which is a rare character state in *Riccia.* But we could not see or collect specimens of this species.

TARGIONIACEAE

Targionia hypophylla L. *Species Plantarum* 2: 1136. 1753.
Type: 'Italia, Hispania, Constantinopoli' + citation (syn.); Dill.: 532. Lichen No. 9, tab. 78, fig. 9. (1741) (OXF, syn.); (H-SOL, isosyntype) [according to Isov. (1970) and quoted by Grolle (1976)]. **Synonymes**: *Targionia michelii* Corda. *Naturalientausch* 12: 649. 1829**. Type**: Italy, leg. *Sieber.Targionia mexicana* Lehm. & Lindenb. *Nov. Stirp. Pug*. 4: 27-28. 1832. **Type**: Mexico, leg. *Schiede. Targionia capensis* Huebener. *Hep. Germ*. 17. 1834. *Targionia bifurca* Nees & Mont. *Ann. Sci. Nat., Bot., ser*. 2, 9: 40 & 113. 1838**. Type**: Chile, 'prope Quillota', leg. *Brotero. Targionia convoluta* Lindenb. & Gott. *Syn. Hep*. 576. 1846. **Type**: Mexico, ad Chinantla, leg. *Liebman.*

Thalli in crowded patches of strap-like and simple branches (not in rosettes) (*Figures 67, 68*), cordate when young up to 3mm wide, fleshy to leathery, dark green, without groove, margin often purple; when dry, the margins are inrolled letting the ventral scales cover all the thallus. **Air pores** visible. **Ventral scales** in two rows reaching the margins, shiny purple-black (*Figures 67, 69*). Dioicous or autoicous. **Antheridia** terminal or lateral on branches which arise ventrally. **Archegonia** in ventral position just below the apex of the branches, protected by a black shiny involucre, opening by a longitudinal and central fissure. **Sporophyte** sub-sessile with globose capsules. "*When dry the apical portion of thalli bearing the sporophytes bends upward away from the substratum and the valves of the involucre gape apart like a mussel*" (Jones 2004). **Spores** light brown to reddish brown, 44-64(-77) µm; distal face with alveoli limited by thick walls, bottom of the alveolus covered by smaller and thinner reticulation (*Figure 70*).

Distribution: known from around Antananarivo and in central plateau (*Figure 78*). Sub-cosmolitan.

Ecology: on temporary humid banks, or compact banks.

All the specimens examined were assigned to *T. hypophylla*, although another species, *Targionia lorbeeriana* Müll.Frib. was cited for Africa (Arnell 1963). This last species is a triploid of *T. hyphophylla* (Zamora *et al.* 1990). After examining numerous South African specimens and the type specimen of *T. lorbeeriana*, Perold stated that all the studied African collections were *T. hypophylla*. The distinction of the two species can be done on thallus and cells dimensions and on spore ornamentation (Jovet-Ast and Zigliara 1966). Malagasy specimens match the *T. hypophylla* description.

Specimen examined: ANTANANARIVO, Tananarive, 03/1914, talus, *Waterlot 94* (PC- PC0716010), *Waterlot 97* (PC- PC0716009); Andramasina (Ambatolampy), vestige de forêt d'altitude, 1300 m, déc. 1958, *Bosser 12324* (PC-PC0716008); Fort-Voyron, 19/01/1921, *Decary s.n.* (PC- PC0716011); Antananarivo, 13/02/1921, *Decary s.n.* (PC-PC0716013, PC0716014); Forêt d'Angavokely, alt 1603 m, S 18°55'24.9 E 47°44'21.7, 02/02/2011, *Reeb & Andriamiarisoa CR11185* (PC, TAN). FIANARANTSOA, Ankafotra (Ambafiandrohana) 1700 m, 16/02/1938, *Decary s.n.* (PC-PC0716012).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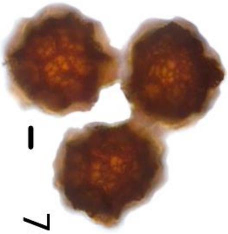
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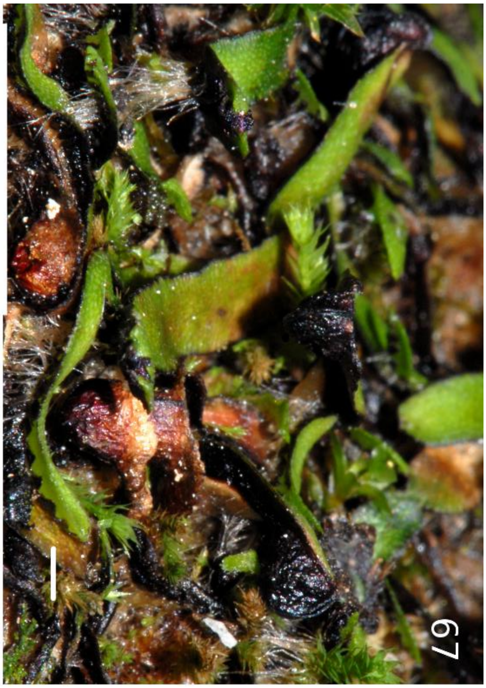
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Figures 67-70. *Targionia hypophylla* L. (67) Population, showing the mussel-like ventral valvae enclosing the sporophyte. Scale bar 1 mm. (68) Scale bar 5 mm (69) Scale bar 500 µm. (70) Scale bar 10 µm. Angavokely, *Reeb & Andriamiarisoa,* CR111855.

CONCLUSIONS

Six new records of Marchantiidae are proposed for Madagascar: *Asterella bachmanii* (Steph.) S.W.Arnell. (as synonym of *A. coronata* Steph.), *Asterella marginata* (Nees) S.W.Arnell, *Exormotheca pustulosa* Mitt., *Riccia congoana* Steph., *Riccia atropurpurea* Sim. and *Riccia stricta* (Lindenb.) Perold. Two cited species are not recognized here: (1) *Asterella wilmsii,* which is probably misidentified and assigned here to *A. marginata*, (2) *Riccia perssonii,* which was not seen in the collections and with no voucher references (Perold 1995).

No endemic Marchantiidae were discovered in Madagascar, and the synonymy of A. coronata could be seen as a confirmation of the relatively low level of endemism of bryophytes lineages and the need of further revisions including molecular studies (Vanderpoorten *et al.* 2010). We make the assumption than new records or new species could be discovered in the genus *Riccia*, where several specimens could not be identified using the available literature. One can notice that the *Lunularia* genus common in East Africa has not been cited before for Madagascar and was not recorded in the studied collections.

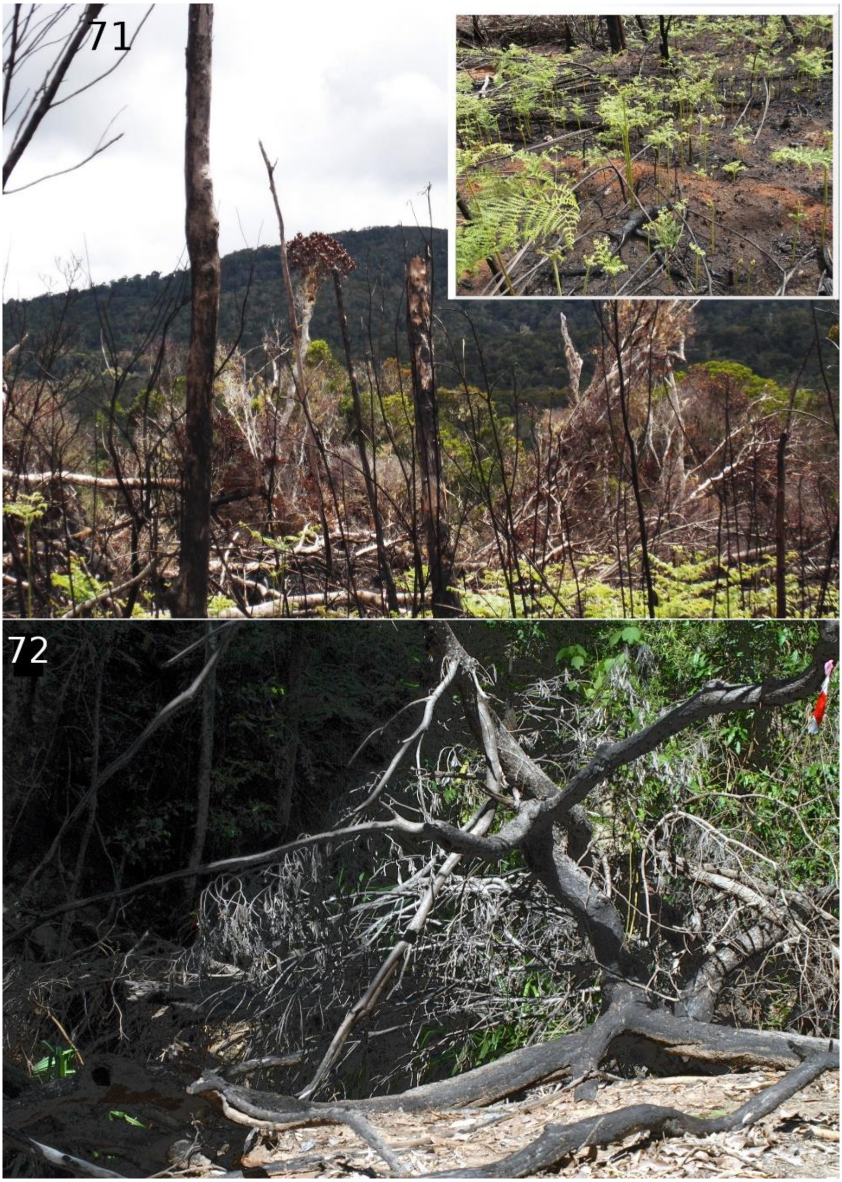
Morphological observations highlight the necessity of extensive studies to clarify or confirm the status of several taxa in order to assess their whole variability. An integrative approach combining molecular analysis and morphometry etc. should be one way to evaluate species delimitations in Malagasy and African related taxa. Although taxonomic work was achieved for Eurasian and American species, similar studies on African *Asterella* are awaiting (Long 2006). The same effort must be done for *Riccia*, especially for the *fluitans* group to clarify species. Some species are known only by a few specimens and collection effort in potentially favorable environments and seasons has to be conducted to enlarge the knowledge; this is the case of *Cyathodium africanum, Targionia hypohylla and Plagiochasma microcephalum.*

In our study, fifteen species of Marchantiidae are reported for Madagascar; fifteen species are also known for La Réunion, 230 times smaller than Madagascar (Ah-Peng and Bardat 2005). If we refer to the largest genus, *Riccia* (Ricciaceae), four species are cited for La Réunion, sixty-six for South Africa (Wigginton 2009) compared to only six (seven, if *Riccia perssonii* could be confirmed) species known in Madagascar. It is reasonable to hypothesize that Madagascar is understudied, especially for the complex thalloid species.

During our recent field trips in Madagascar, it seemed difficult to see Marchantiidae in *a priori* favourable environments (road banks, high plateau steppes etc.), except in the Makay Massif where abundant Ricciaceae were found. We suggest that these plants living in open areas are probably under a great fire pressure mainly due to the pratice of traditional *tavy* (slush and burn) culture (*Figures 71, 72*). Some species are known to be fire resistant and to appear as primitive colonizer after fire (Esposito *et al.* 1999). But repeated fire has not the same effect than occasional ones, and in numerous places the soil is bare, missing bryophytes on a degraded laterite substratum repeatedly burn. Further exploration of stations cited by former collectors or of favourable stations could test that hypothesis. Experimentation on thalloid liverworts resistance to fire could also help to understand their strategies and adaptations in such context.

Participation of the different authors

Catherine Reeb collected plants in Madagascar, identified and described specimens, wrote and illustrated the paper. Lovanomenjanahary Marline collected specimens in Madagascar and contributed to the writing of the whole publication. Lucile Rabeau collected plants in Madagascar and contributed to the writing on the Ricciaceae. Ainazo Andriamanantena collected plants in Madagascar, gathered historical references, identified and described specimens; this study was initiated in the context of her master thesis in 2010. Roger Lala Andriamiarisoa organized Angavokely fieldtrip, collected specimens all around Madagascar and provided drawings. Hery-Lisy Ranarijaona, supervised the project and reviewed the publication for Malagasy vegetation. Tamás Pócs collected specimens and gave his expertise and corrections for the publication.



Figures 71-72. Fire and deforestation. (71) In Zahamena National Parc, 2015. Details of the soil show the potential impact on bryophytes. (72) In the Makay massif, 2011, on a river bank, a very favorable station for *Marchantia* and *Riccia*.

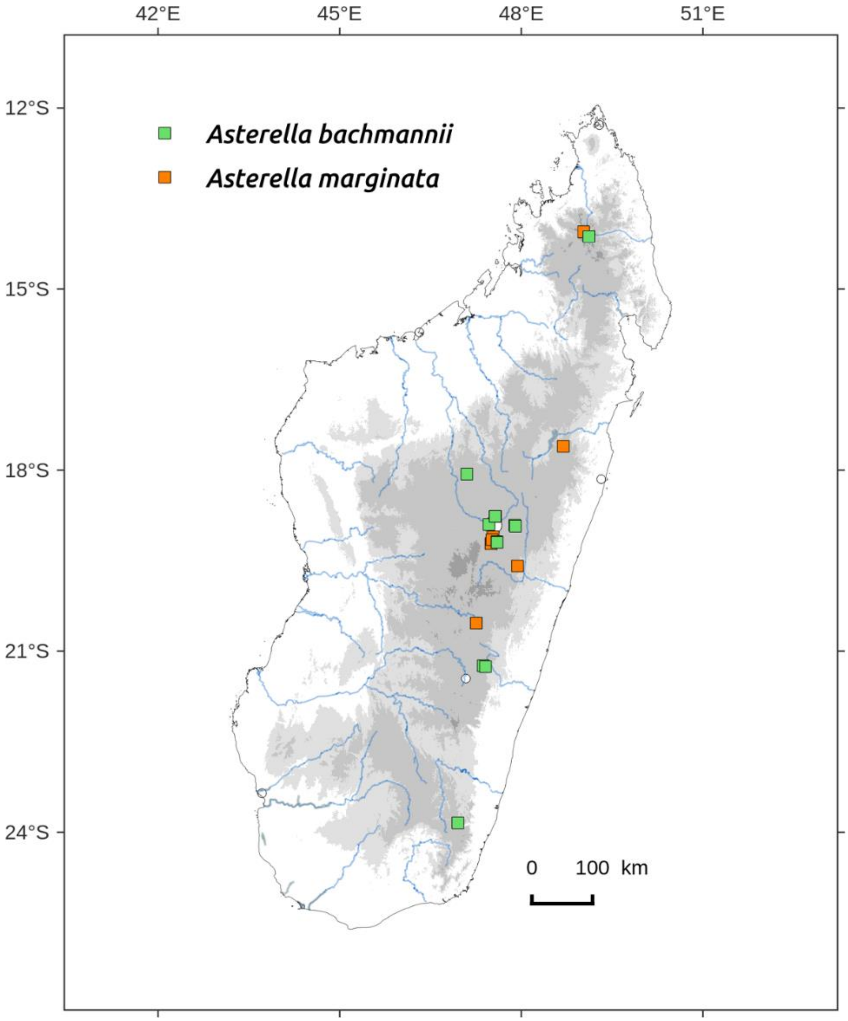


Figure 73. Distribution map of *Asterella bachmanii* and *Asterella marginata* in Madagascar, based on the specimens studied from EGR, PC and TAN herbarium and the authors' collections.

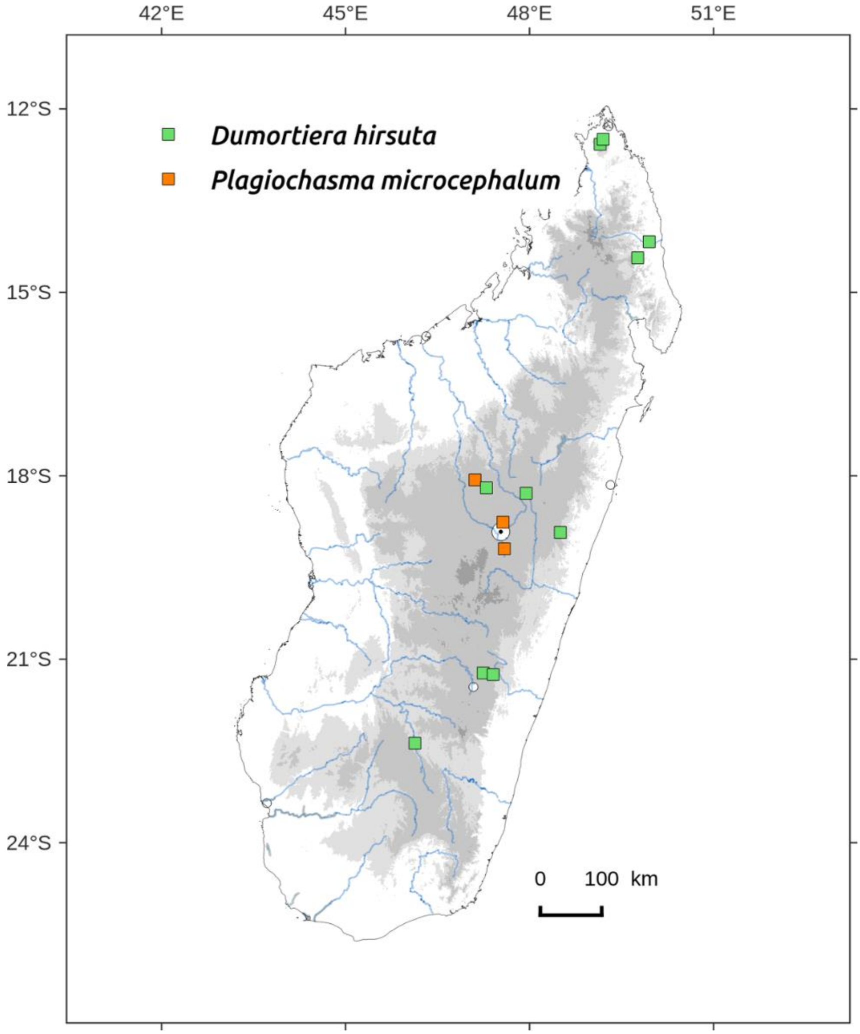


Figure 74. Distribution map of *Dumortiera hirsuta* and *Plagiochasma microcephalum* in Madagascar, based on the specimens studied from EGR, PC and TAN herbarium and the authors' collections.

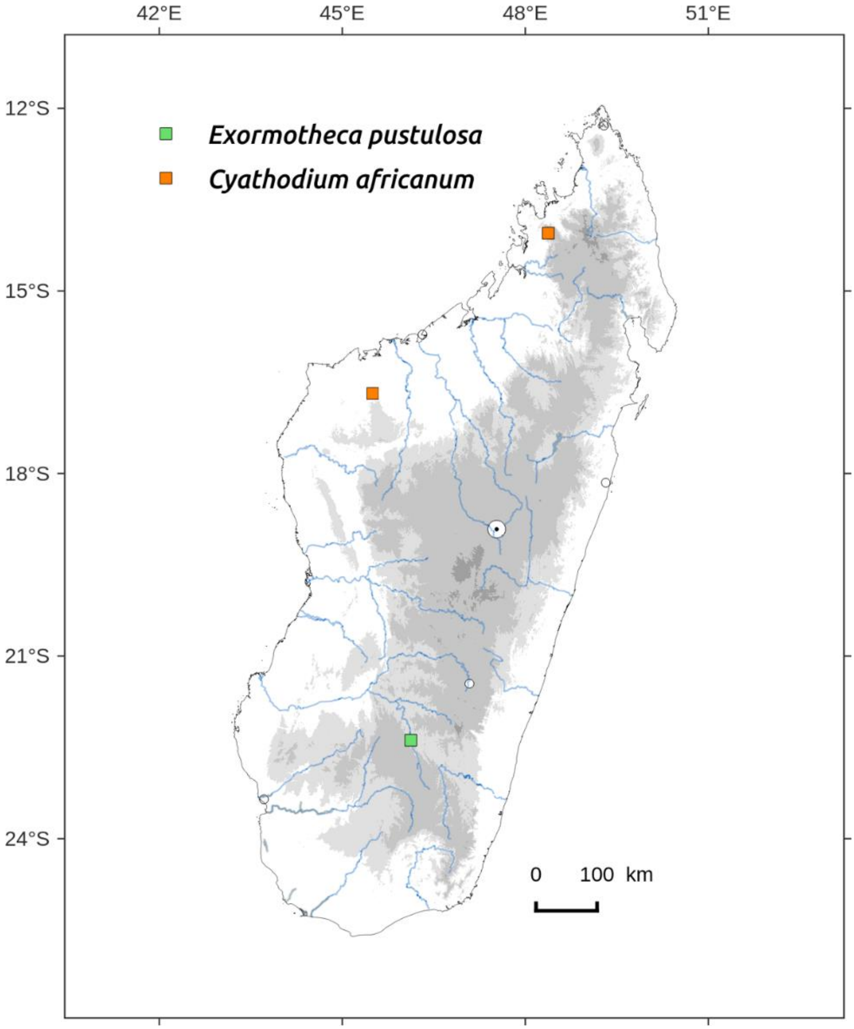


Figure 75. Distribution map of *Exormotheca pustulosa* and *Cyathodium africanum* in Madagascar, based on the specimens studied from EGR, PC and TAN herbarium and the authors' collections.

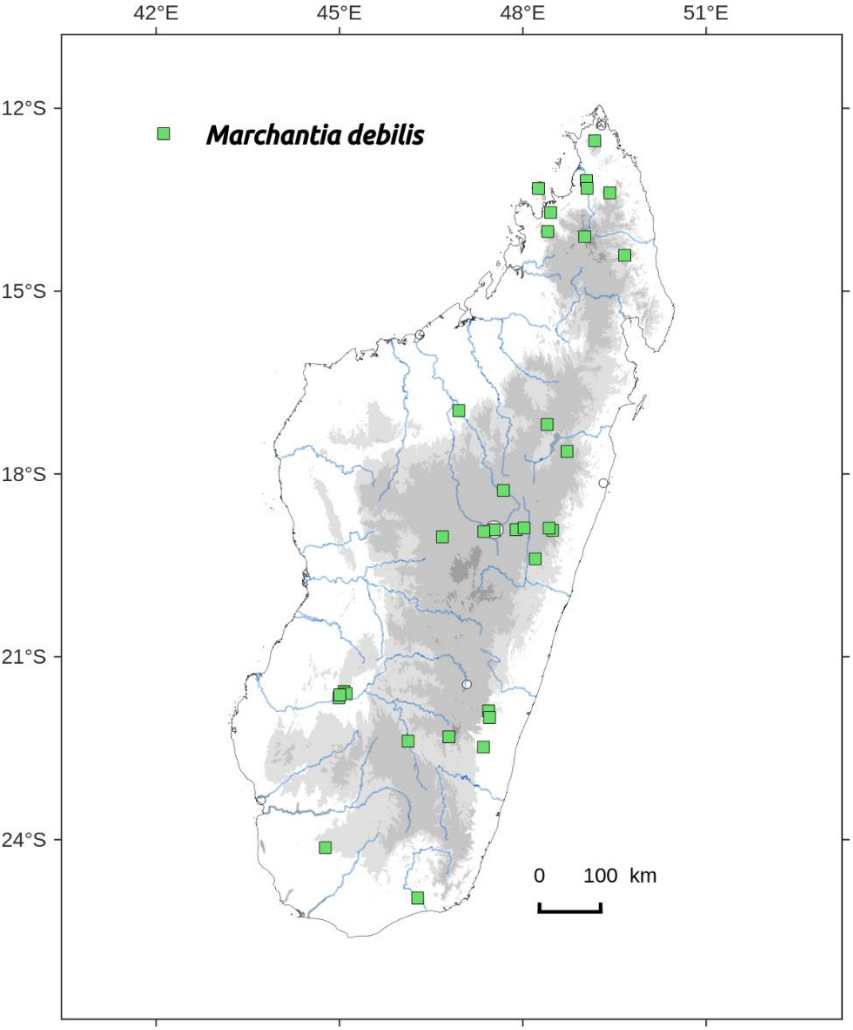


Figure 76. Distribution map of *Marchantia debilis* in Madagascar, based on the specimens studied from EGR, PC and TAN herbarium and the authors' collections.

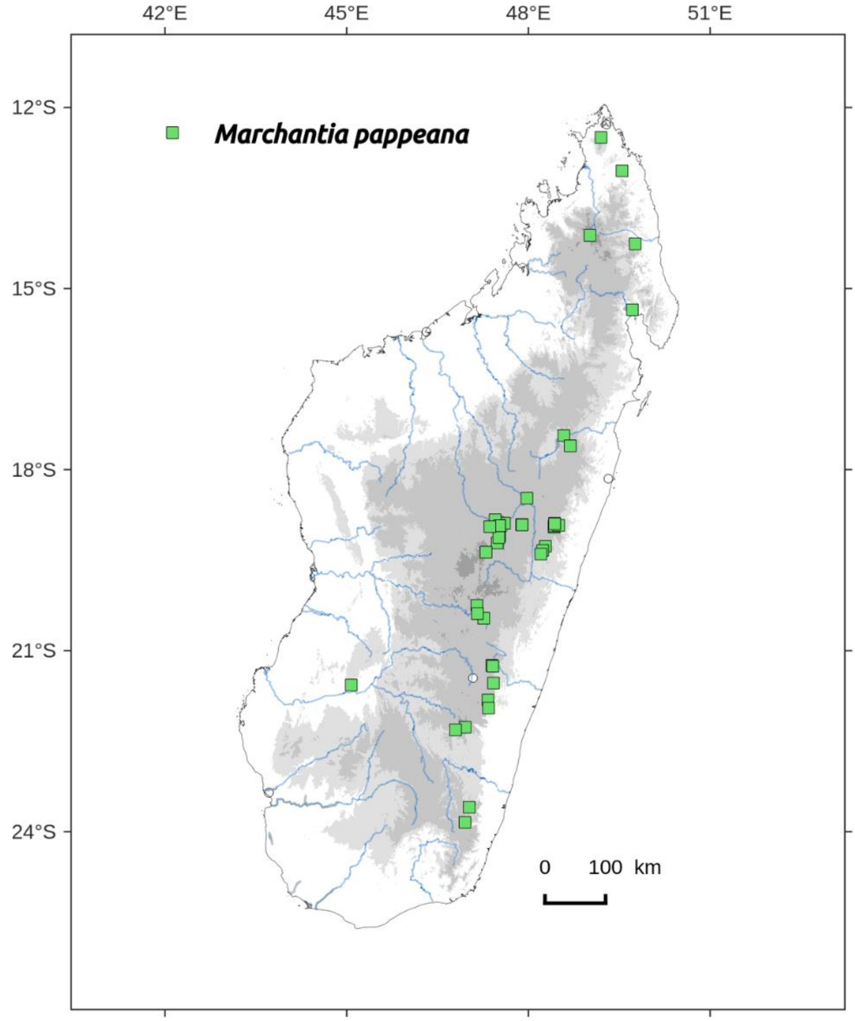


Figure 77. Distribution map of *Marchantia pappeana* in Madagascar, based on the specimens studied from EGR, PC and TAN herbarium and the authors' collections.

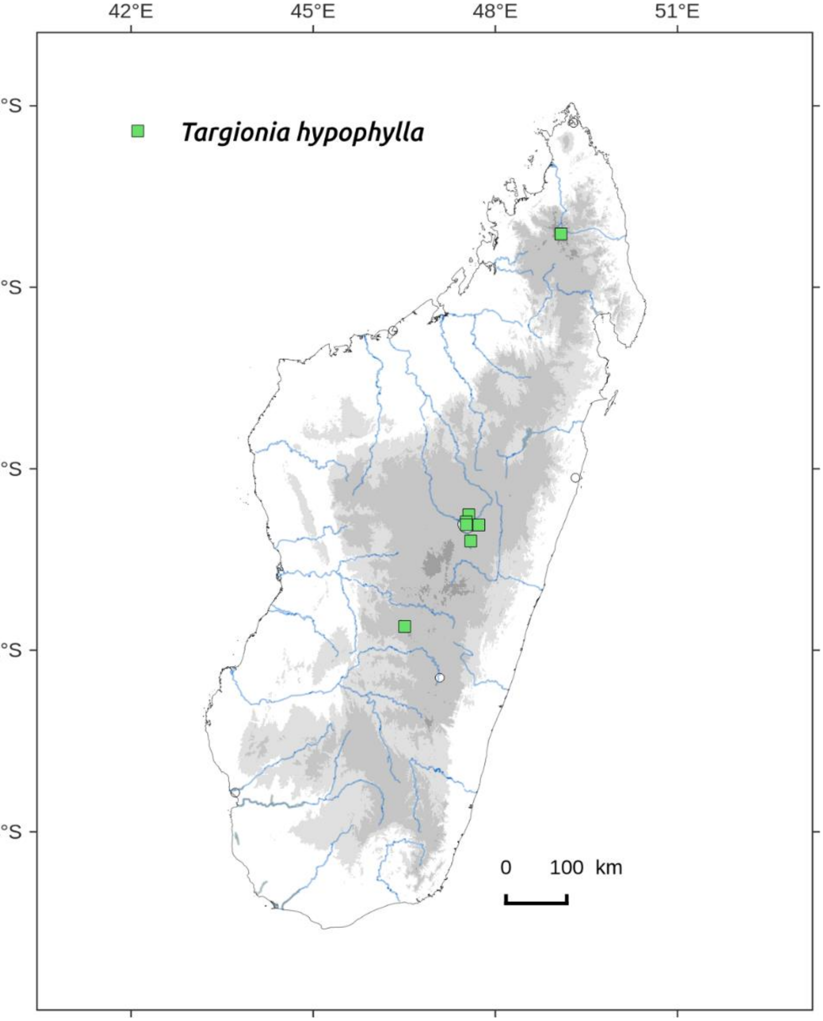


Figure 78. Distribution map of *Targionia hypophylla* in Madagascar, based on the specimens studied from EGR, PC and TAN herbarium and the authors' collections.

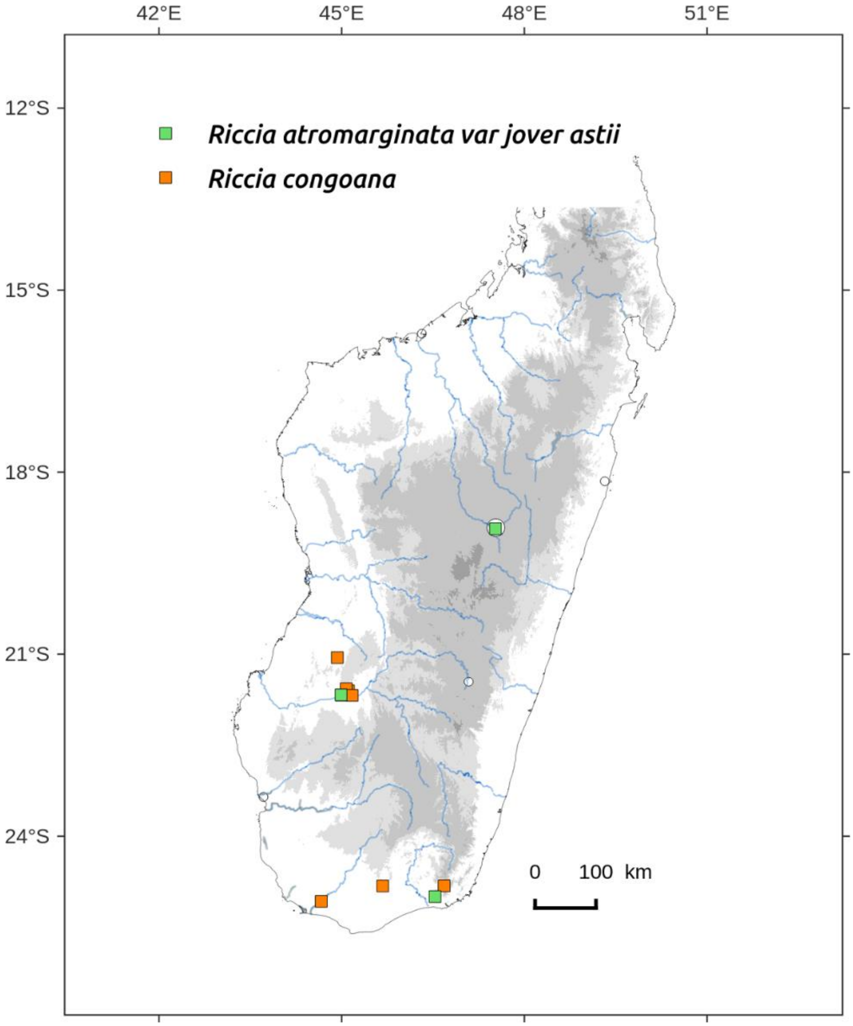


Figure 79. Distribution map of *Riccia atromarginata* var. *jovet-astii* and *Riccia congoana* in Madagascar, based on the specimens studied from EGR, PC and TAN herbarium and the authors' collections.

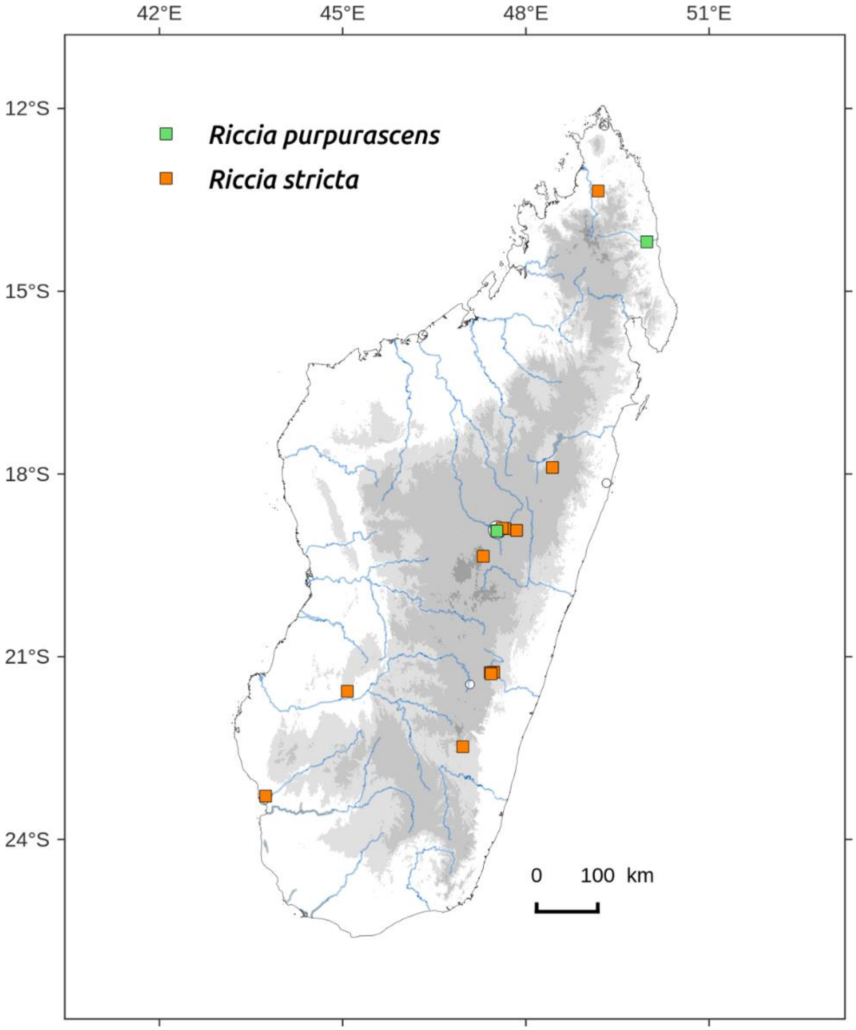


Figure 80. Distribution map of *Riccia purpurascens* and *Riccia stricta* in Madagascar, based on the specimens studied from EGR, PC and TAN herbarium and the authors' collections.

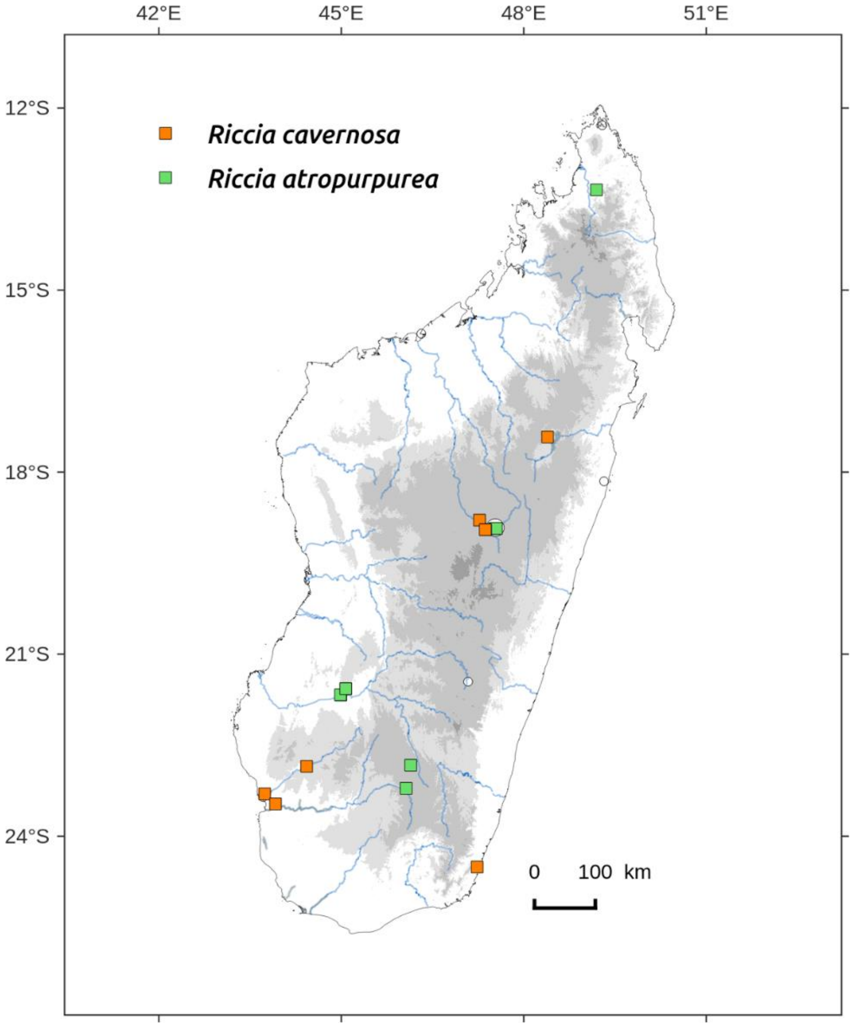


Figure 81. Distribution map of *Riccia cavernosa* and *Riccia atropurpurea* in Madagascar, based on the specimens studied from EGR, PC and TAN herbarium and the authors' collections.

Figure 82. Artistic representation of thalloid bryophytes taxa from Madagascar. Marchantiales (complex thalloid): A = *Marchantia pappeana*, B = *Symphyogyna podophylla*, (simple thalloid) C = *Riccia* sp. Pallaviciniaceae D = *Dumortiera hirsuta*, recently reported for Madagascar (Andriamiarisoa *et al.*, 2017). E = Anthocerotophyta. Drawings made by Roger Lala Andriamiarisoa.

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Research article

BRYOFLORISTICAL DATA FROM THE APUSENI MOUNTAINS (ROMANIAN WESTERN CARPATHIANS, TRANSILVANIA) 2.

Andrea Sass-Gyarmati* & Tamás Pócs

*Eszterházy Károly University, Institute of Biology, Department of Botany and Plant Physiology; Eger, Pf. 43, H-3301 Hungary; *E-mail: sassgyarmati@gmail.com*

Abstract: The main aim of this study was to explore the bryophyte diversity and distribution patterns in the Apuseni Mountains. From our collections hitherto 94 bryophyte species were identified. The 25 Marchantiophyta and 69 Bryophyta species belong to 73 genera of 42 families. *Syntrichia norvegica* are new for the whole Apuseni Mountains. Among them the endangered *Campylium protensum*, the near threatened *Barbula crocea, Platydictya jungermannioides* and the very rare *Abietinella abietina* var. *hystricosa* are worth to be mentioned.

Keywords: bryoflora, rare species, Apuseni Mts., Romania

Rezumat: Lucrarea prezintă distribuţia speciilor de briofite din cadrul Munţilor Apuseni. Din colecţia recentă fost identificate 94 de specii de briofite. Cele 25 specii de Marchantiophyta și 69 de specii de Bryophyta aparţin in 73 de genuri si 42 de familii. *Syntrichia norvegica* este semnalare nouă pentru Munţii Apuseni. *Campylium protensum* este specie periclitată, *Barbula crocea* şi *Platydictya jungermannioides* specii ameninţate iar *Abietinella abietina* var. *hystricosa* specie rară care merită să fie menţionată.

Cuvinte cheie: brioflora, specii rare, Apuseni, România

INTRODUCTION

The first bryological records of the climatologically and geologically very variable and biologically very rich Apuseni Mountains were published at the end of XIXth century (Csató 1885), but its intensive investigation started only in the XXth century, which till now is far from complete (Győrffy 1903; Péterfi 1908, 1910; Boros 1942a, 1942b, 1951; Páll 1960, 1962, 1963; Raţiu *et al.* 1966; Boros and Vajda 1967, 1974; Ştefureac 1975, 1977; Plămadă and Goia 1994). Investigations have continued intensively in the past twenty years

(Goia 2001, 2005; Goia and Mătase 2001; Jakab 1999, 2000; Goia and Schumacker 2000, 2002, 2003a, 2003b, 2004; Goia and Ştefănuţ 2004; Plămadă *et al*. 2000; Lüth 2002, and others). Csűrös (1981) gave a wide overview of the natural conditions and of Apuseni Mountains and its flora and fauna. A preliminary report on the Bihor mountains was published by Simon (1960) and a very detailed vegetation study is given by Pop *et al.* (2000) from its part in Cluj County. We started our bryological exploration in 2002 and published a series of papers from this area, some of them as result of the fruitful cooperation with Irina Goia, bryologist at the Babeş-Bolyai University (Pócs 2005, Sass-Gyarmati *et al.* 2005a, 2005b, Sass-Gyarmati *et al.* 2008a, 2008b, Sass-Gyarmati and Pócs 2017).

Study area

Muntele Mare and Gilăului Mountains form a distinct geomorphological unit, known as *Gilău – Muntele Mare*. The massif is covered with beech and spruce forests. The crystalline schists gave rise to a massive landscape, with wide interfluves separated by narrow and deep valleys. Reserve includes "Şesul Craiului" located on a limestone plateau above 1350 m altitude, the forest on the mountain scale and spectacular cliffs guard Belioara Valley (tributary of Poşaga Valley), with vertical walls, tanks, gully and sharp increases. It has an area of 47.7 hectares and houses many rare species of plants and animals. Initiative put under protection of the area had Alexandru Borza, since the early 20's of the twentieth century. Here have found their place those floral rarities and a relic forest of conifers (scotch pine and larch) for which in 1935 it was declared a botanical reservation. Csűrös (1958) presents in details vegetational studies made in Scărişoara-Belioara (Bélavár) Massif and published several more studies, partly together with Csűrös-Káptalan.

The Bihor Mountains occupy a central position within the Apuseni mountains range. The characteristic karstic topography is widely developed, parallel to places with other sedimentary and volcanic bedrocks. The Bihar Massif is the highest part of the Apuseni Mountains. Here the general aspects of vegetation of Cheile Ordâncușa – a narrow, 2.5 km long limestone gorge – were studied by I. Pop and I. Hodişan (1967). The streamlet has the side-branch of Gârdei Seacă on the left part. The Ordâncușa gorge has 400 m high limestone walls, between which there is a road leading to the

Scărişoara Ice Cave. In the cliffs more than 70 caves, gates and smaller halls are present. Among them the most popular is Poarta lui Ionele cave with different species of protected bats. In the right wall can be found the Zgurăști sinkhole, with interesting vegetation inversion and with an underground lake (Sass-Gyarmati *et al.* 2005a). The characteristics of the landscape are crevices, extended karst zones (with almost 430 caves described) and the third largest underground ice cave of Europe after the Eisriesenwelt cave in Austria and Dobsinska cave in Slovakia (Strug *et al.* 2006), the „Gheţarul de la Scărişoara" – which is the largest in Romania, declared a natural monument and a speleological reserve. It is situated at 1165 m a.s.l., the entrance being located on the western wall of a circular shaft 60 m in diameter and 47 m deep. Beyond the entrance, the ice block with a volume of 100 000 m^3 and area extent of 3000 m^2 (Perşoiu *et al.* 2011).

MATERIAL AND METHODS

The byophytes enumerated below were collected from Apuseni Mountains between 22-25 October 2006 by Tamás Pócs, Irina Goia, Zoltán Tóth and identified by Tamás Pócs and Andrea Sass-Gyarmati. The collection was made in various vegetation types: bogs, meadows, beech and spruce forests and subalpine belts. The Romanian distribution of mosses was established from Plămadă (1998) and Mohan (1998), while that of the liverworts from Ştefănuţ (2008). The nomenclature of liverworts follows Ştefănuţ (2008) modified by Söderström *et al.* (2016), nomenclature of mosses follows Hill *et al.* (2006), except *Racomitrium affine* which was recently included to *Bucklandiella* (F. Weber & D. Mohr) Bednarek-Ochyra & Ochyra (Ochyra *et al.* 2003). The classification of liverworts (Marchantiophyta) follows Söderström *et al.* (2016), while the classification of mosses (Bryophyta) follows Goffinet and Shaw (2009). The species in each family are arranged in alphabetical order. Species names are followed by the collecting site number, and by the substrate on which they were grown. The collected specimens are deposited in the Herbarium of Eger (EGR). The collecting sites are listed in the Appendix.

RESULTS

List of species

During the field study, 94 bryophyte species were found in the investigated area. The 25 Marchantiophyta and 69 Bryophyta species belong to 73 genera of 42 families.

Marchantiophyta

Conocephalaceae

Conocephalum conicum (L.) Dumort. – 13: on irrigated rocks

Marchantiaceae

Preissia quadrata (Scop.) Nees – 2: on limestone rocks

Aneuraceae

Aneura pinguis (L.) Dumort. – 2, 12: on limestone rocks

Anastrophyllaceae

Barbilophozia barbata (Schmidel ex Schreb.) Loeske – 9: on volcanic rocks

Lepidoziaceae

Bazzania trilobata (L.) Gray. – 5: lignicolous

Lepidozia reptans (L.) Dumort – 5: on volcanic rocks; 10: lignicolous

Cephaloziaceae

Cephalozia pleniceps (Austin) Lindb. – 13: on vertical cliff

Lophoziaceae

Lophozia ventricosa (Dicks.) Dumort. – 5: on volcanic rocks.

Scapaniaceae

Scapania aequiloba (Schwagr.) Dumort. – 12: on vertical cliff

Scapania calcicola (S.W. Arnell & J. Perss.) Ingham – 13: on limestone rocks

Scapania nemorea (L.) Grolle – 5, 9: on volcanic rocks

Jubulaceae

Frullania dilatata (L.) Dumort. – 1, 3, 12, 13: on bark

Jungermanniaceae

Jungermannia atrovirens Dumort. – 12, 13: on limestone rocks

Tritomaria exsecta (Schmidel) Schiffn. ex Loeske – 5, 10: lignicolous

Blepharostomataceae

Blepharostoma trichophyllum (L.) Dumort – 5: on volcanic rocks; 10: lignicolous

Lophocoleaceae

Lophocolea heterophylla (Schrad.) Dumort. – 8, 12: on decaying log

Plagiochilaceae

Pedinophyllum interruptum (Nees) Kaal. – 12: on limestone rocks

Plagiochila porelloides (Torr. ex Nees) Lindenb. – 12: on limestone rocks

Trichocoleaceae

Trichocolea tomentella (Ehrh.) Dumort. – 5: twigs of a dead spruce

Radulaceae

Radula complanata (L.) Dumort. – 12, 13: on bark

Ptilidiaceae

Ptilidium pucherrimum (Weber) Hampe – 10: on spruce roots

Metzgeriaceae

Apometzgeria pubescens (Schrank) Kuwah. – 12: on limestone rocks

Metzgeria conjugata Lindb. – 12: on bark

Lejeuneaceae

Cololejeunea calcarea (Lib.) Schiffn. – 13: on limestone rocks

Lejeunea cavifolia (Ehrh.) Lindb. – 13: on limestone rocks

Bryophyta

Sphagnaceae

Sphagnum angustifolium (C.E.O. Jensen ex Russow) C.E.O. Jensen – 7: transition spring bog

Sphagnum capillifolium (Ehrh.) Hedw. – 5, 8: on raised bog

Sphagnum fuscum (Schimp.) Klinggr. – 8: on raised bog

Sphagnum girgensohnii Russ. – 5, 8: on turf

Sphagnum magellanicum Brid. – 6, 8: on turf
Sphagum subsecundum Nees – 7: transition spring bog

Tetraphidaceae

Tetraphis pellucida Hedw. – 10: lignicolous

Polytrichaceae

Polytrichum strictum Menzies – 8: on raised bog
Polytrichum longisetum Sw. ex Brid. – 5: on peaty soil

Encalyptaceae

Encalypta streptocarpa Hedw. – 1: on limestone rocks
Encalypta vulgaris Hedw. – 1: on limestone rocks

Grimmiaceae

Grimmia hartmanii Schimp. **–** 9: on volcanic rocks.
Bucklandiella affinis (F. Weber & D. Mohr) Bednarek-Ochyra & Ochyra, Syn.: *Racomitrium affine* (F. Web. et D. Mohr) Lindb. – 5: on soil
Schistidium apocarpum (Hedw.) Bruch & Schimp. – 10: on limestone rocks

Seligeriaceae

Seligeria acutifolia Lindb. – 13: on vertical cliff
Seligeria patula (Lindb.) I. Hagen – 13: on vertical cliff

Fissidentaceae

Fissidens adianthoides Hedw. – 12: on limestone rocks
Fissidens dubius P. Beauv. – 2: on limestone rocks

Dicranaceae

Dicranella heteromalla (Hedw.) Schimp. – 10: lignicolous
Dicranum scoparium Hedw. – 5: on bog; 10 on *Picea* roots; 11: on rotten spruce stumps
Dicranum fuscescens Sm. – 8: on raised bog
Dicranum montanum Hedw. – 10: on rotten spruce stumps
Paraleucobryum longifolium (Ehrh. ex Hedw.) Loeske – 5: on volcanic rocks

Pottiaceae

Barbula crocea (Brid.) F. Weber & D. Mohr – 2, 13: on limestone rocks

Bryoerythrophyllum recurvirostrum (Hedw.) P.C.Chen – 9: on volcanic rocks

Didymodon fallax (Hedw.) R. H. Zander – 2: on vertical cliff

Didymodon ferrugineus (Schimp. ex Besch.) M.O.Hill – 2: on limestone rocks

Gymnostomum aeruginosum Smith. – 13: on vertical cliff

Syntrichia norvegica F. Weber – 10: on limestone rocks

Tortella tortuosa (Hedw.) Limpr. – 1, 2: on soil; 10, 12: on limestone rocks

Orthotrichaceae

Orthotrichum anomalum Hedw. – 4: bark of *Fagus*

Orthotrichum speciosum Nees –12, 13: bark of *Salix*

Ulota crispa (Hedw.) Brid. – 4: bark of *Fagus*, 5: on *Picea* twigs, 12: bark of *Salix*

Hedwigiaceae

Hedwigia ciliata (Hedw.) P. Beauv. var. ***ciliata*** – 9: on volcanic rocks

Bryaceae

Bryum capillare Hedw. var. ***capillare*** – 13: on limestone rocks

Bryum pseudotriquetrum (Hedw.) P. Gaertn. – 2, 9: on rocks

Plagiobryum zieri (Hedw.) Lindb. – 13: on limestone rocks

Mniaceae

Mnium marginatum (Dicks.) P. Beauv. – 12: on limestone rocks

Plagiomnium undulatum (Hedw.) T. J. Kop. – 13: on earth covered rocks

Pohlia nutans (Hedw.) Lindb. – 13: on earth covered rocks

Pohlia wahlenbergii (F. Weber & D. Mohr.) A. L. Andrews – 13: on limestone rocks

Rhizomnium punctatum (Hedw.) T. J. Kop. – 10: lignicolous; 13: on irrigated rocks

Aulacomniaceae

Aulacomnium palustre (Hedw.) Schwaegr. – 7: transition bog

Amlystegiaceae

Amblystegium serpens (Hedw.) Schimp. – 11: on bark

Campylium chrysophyllum (Brid.) Lange – 2: on limestone rocks

Campylium protensum (Brid.) Kindb. – 7: transition bog

Campylium stellatum (Hedw.) Lange & C.E.O. Jensen – 7: transition bog

Sanionia uncinata (Hedw.) Loeske – 5: twigs of a dead spruce; 6: on irrigated soil

Hylocomiaceae

Hylocomium splendens (Hedw.) Schimp. – 5, 12, 13: on limestone rocks

Pleurozium schreberi (Willd. ex Brid.) Mitt. – 13: on soil

Rhytidiadelpus triquetrus (Hedw.) Warnst. – 13: on limestone rocks

Rhytidiaceae

Rhytidium rugosum (Hedw.) Kindb. – 1: on soil

Thuidiaceae

Abietinella abietina (Hedw.) M. Fleisch. – 3: on soil

Abietinella abietina (Hedw.) M. Fleisch. var. ***hystricosa*** (Mitt.) Sakurai – 3: on limestone rocks

Brachytheciaceae

Brachythecium rutabulum (Hedw.) Schimp. –12: on limestone rocks

Homalothecium sericeum (Hedw.) Schimp. – 12: on limestone rocks

Eurhynchium angustirete (Broth.) T.J. Kop. – 12: on limestone rocks

Plagiotheciaceae

Plagiothecium denticulatum (Hedw.) Schimp. – 8: raised bog, on litter

Platydictya jungermannioides (Brid.) Crum – 1: on earth covered soil

Hypnaceae

Calliergonella cuspidata (Hedw.) Loeke – 5: on soil

Ctenidium molluscum (Hedw.) Mitt. – 2, 12, 13: on limestone rocks

Hypnum cupressiforme Hedw. – 11: on bark, 13: on limestone rocks

Orthothecium rufescens (Dicks. ex Brid.) Schimp. – 12, 13: on limestone rocks

Ptilium crista-castrensis (Hedw.) De Not. – 13: on limestone rocks

Calliergonaceae

Straminergon stramineum (Dicks. ex Brid.) Hedenas – 6: on irrigated soil, 11: lignicolous

Warnstorfia exannulata (Schimp.) Loeske – 8: raised bog, on litter

Neckeraceae

Neckera crispa Hedw. – 12: on limestone rock
Neckera complanata (Hedw.) Hüb. – 12, 13: on limestone rocks

Leskeaceae

Leskeella nervosa (Brid.) Loeske – 12: on limestone rocks

DISCUSSION

Trichocolea tomentella (Ehrh.) Dumort. – it is reported only from two localities from the Bihor Mountains: Galbena Valley, 750 m alt., 08.1999 (Jakab 2000) and Cetăţile Ponorului, AB 46°33'55"N / 22°42'15"E, 1050 m alt., 3.09.2007, leg. & det. Ştefănuţ S. [BUCA B3827]. Based on Mohan (1998) it occurs sporadically in Retezat, Bucegi, Cibin, Arpaşului Mountains, tinovul Poiana Ştampei, Băile Chirui, Valea Ialomiţei, Cascada cu şapte scări, Piatra Mare Mountain, Iezer - Păpuşa Mountains.

Abietinella abietina (Hedw.) M. Fleisch. var***. hystricosa*** (Mitt.) Sakurai – it is known only from one locality in Romania from Pângăraţi valley near Piatra Neamţ (Mihai 1976), but missing from the checklist of Mohan (1998). It was collected by us on the limestone rocks of Scăriţa-Belioara. Another record was published by Pócs (2006) from Scărişoara. It is considered nowadays on molecular basis to be a separate species under the old name of *Abietinella hystricosa* (Mitt.) Broth.

Barbula crocea (Brid.) F. Weber & D. Mohr – European-mediterranean species and is treated as near threatened (NT) in Romania (Ştefănuţ & Goia, 2012). It is known from few localities in the Apuseni Mountains: Vl. Seacă, Băiţa and Şuncuiuş, here collected from Ordâncuşa gorge and Cheile Posăgii gorge (*Figure 1, 2*). Also known just from few localities in the country: Borsec, Piatra Craiului, Bucegi and Ciucaş Mountains, Cristianul Mare and Piatra Mare Mountain (Mohan 1998).

Figure 1. *Barbula crocea* (Brid.) F. Weber & D. Mohr, habit (photo: T. Pócs).

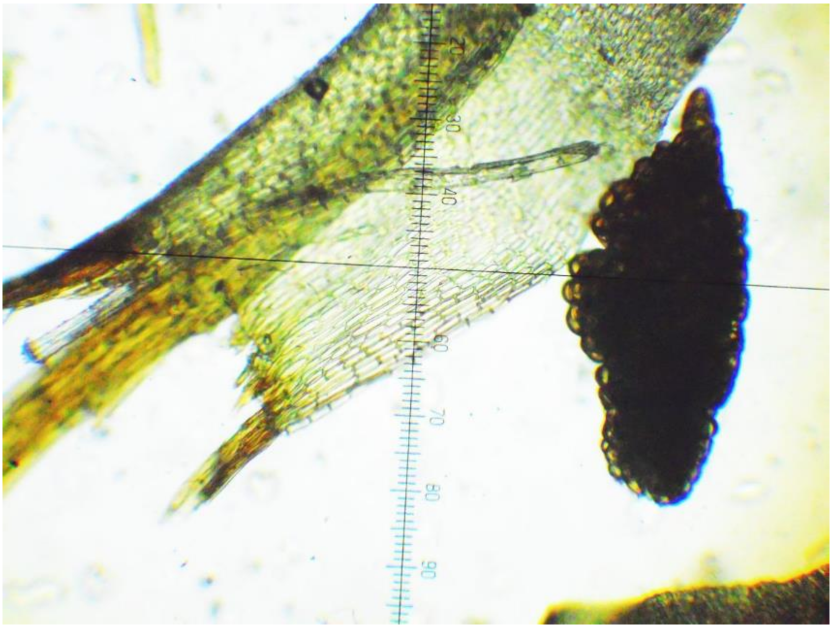

Figure 2. *Barbula crocea* (Brid.) F. Weber & D. Mohr, leaf and gemma (scale by 8 µm) (photo: T. Pócs).

Seligeria acutifolia (Lindb.) Broth. – is mainly sub-mediterranean and montane taxon (Düll 1984), widely scattered throughout Europe. Besides on Sicily it has also been found on the Italian mainland, in Belgium, (former) Czechoslovakia, France, Germany, Great Britain and Greece, on Ireland, in Norway, Poland, Romania, Sweden and former Yugoslavia (Düll 1985). It occurs in limestone rock crevices, data deficient (DD) in Romania (Ştefănuţ & Goia 2012). We have found it on a shaded limestone rocks at the narrowest part of Cheile Ordâncuşei gorge at 850 m alt.

Seligeria patula (Lindb.) Broth. – is an Alpine-Carpathian species, it was observed at several other places in the Bihor Mts., as in Ordâncuşa Valley, Galbena gorge, at Barsa ice cave and from Boghii Valley, near the Oşelu waterfall (Pócs 2006). *Seligeria patula*, similarly to *S. tristicha*, is always embedded in a thin or thick layer of cryptobiotic crust dominated by cyanobacteria.

Campylium protensum (Brid.) Kindb. – is an endangered species in Romania, many bryfloristical works did not separated it from its very close relative and more frequent *C. stellatum*. The high red list category of *C. protensum* should be reevaluated after taxonomical revision of herbarium specimens and future fieldworks, to provide the reliable distribution.

Platydictya jungermannioides (Brid.) Crum – the species is treated as near threatened (NT) in Romania (Ştefănuţ & Goia 2012). Distribution based on Mohan (1998): Piatra Craiului Mountains, Cristianul Mare Mountains, Cluj cimitery, Cărpiniş forest, Retezat Mountains, Laptelui Mountains, Puzdra Mountains, Neamţ county: Măgura-Petricica, Bucegi Mountains, Făgăraş Mountains, Ouşoru Mountains.

Syntrichia norvegica F. Weber – this species is treated as vulnerable in Romania (Ştefănuţ & Goia 2012). New to the Apuseni Mountains communicated in the country only from Retezat, Făgăraş Mountains and from Schitul Obârşia Ialomiţei (Mohan 1998). Circumpolar, Arctic-montane, strongly calcicolous element. Montane and northern Europe north to Svalbard, Iceland, Caucasus, Turkey, Cyprus, Asia, Madeira, N. Africa, N. America, Greenland and Mexico (Smith 2004).

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APPENDIX

List of collecting sites from the Apuseni Mts. (Nyugati Szigethegység):

1. Munţii Gilăului (Gyalui Havasok), Rezervaţia Şesu Craiului – Scăriţa Belioara (Bélavár). Şesu Craiului ridge, 2.5 km N of Poşaga de Sus (Felsőpodsága). 1350-1370 m alt. N 46°29'46.1", E 23°21'56.9" Hab.: Dry *Festuco-Caricetum humilis* sward on the steep (45°) S slope above the limestone cliffs. Date: 22. Oct. 2006 Coll.: T. Pócs, I. Goia & Z. Tóth. No. 06090
2. Munţii Gilăului (Gyalui Havasok), Cheile Poşegii, 500 m, N of Mănăstirea Poşaga in the gorge. N 46°27'30.5", E 23°23'53.1" Hab.: N facing, shady limestone rocks with scattered *Sesleria rigida* and abundant *Selaginella helvetica.* Date: 23. Oct. 2006 Coll.: T. Pócs & Z. Tóth. No. 06093
3. Munţii Gilăului (Gyalui Havasok), Rezervaţia Şesu Craiului – Scăriţa Belioara (Bélavár). Belioara Valley below the huge, SSE facing cliffs at 710-720 m alt. N 46°29.143', E 23°22.229' Hab.: Limestone scree covered by *Corylus* bush. Date: 23. Oct. 2006. Coll.: T. Pócs & Z. Tóth. No. 06095
4. Munţii Gilăului (Gyalui Havasok), Rezervat Şesu Craiului – Scăriţa Belioara (Bélavár). Belioara Valley below the huge, SSE facing cliffs at 920-1000 m alt. N 46°29.502', E 23°22.954'. Hab.: Beech (*Fagus silvatica*) forest. Date: 23. Oct. 2006. Coll.: T. Pócs & Z. Tóth. No. 06096
5. Munţii Gilăului (Gyalui Havasok), complex of Muntele Mare (Öreghavas). Valea Mare NE of Bistra below Cheleteni village, at 920 m alt. N 46°26'40", E 23°07'44.5". Hab.: Acidiphilous spruce forest on volcanic rocks and scree. Date: 24. Oct. 2006. Coll.: T. Pócs & Z. Tóth. No. 06097
6. Munţii Gilăului (Gyalui Havasok). W end of the plateau of Muntele Mare (Öreghavas) near the saddle to Vf. Prislop, at 1685 m alt. N 46°29'30.9", E 23°12'31.4". Hab.: Complex of transition, spring and raised peat bog. Date: 24. Oct. 2006. Coll.: T. Pócs & Z. Tóth. No. 06098
7. Munţii Gilăului (Gyalui Havasok). NW part of the plateau of Muntele Mare (Öreghavas), W from the mean summit, at 1715-1725 m alt. N 46°29'36.4", E 23°12'50.2". Hab.: Transition spring bog with *Carex hartmanii.* Date: 24. Oct. 2006. Coll.: T. Pócs & Z. Tóth. No. 06099

8. Munţii Gilăului (Gyalui Havasok). NW part of the plateau of Muntele Mare (Öreghavas), 1.5 km W from the mean summit, near the springs of Iara River, place called "Gemenele Ţiganului" at 1716-1725 m alt. N 46°29'51.7", E 23°13'09.0". Hab.: Big, raised bog (*Eriophoro vaginatae- Sphagnetum*). Date: 24. Oct. 2006. Coll.: T. Pócs & Z. Tóth. No. 06100
9. Munţii Gilăului (Gyalui Havasok), complex of Muntele Mare (Öreghavas). Valea Mare NE of Bistra at 716 m alt. N 46°24'37.5", E 23°06'34.1". Hab.: Spruce forest on volcanic ground with open lava rocks. Date: 24. Oct. 2006. Coll.: T. Pócs & Z. Tóth. No. 06101
10. Munţii Bihorului (Bihar Hegység), S ridge of Dealu Bocului 1 km NW of Scărişoara Ice Cave, at 1200-1290 m alt. N 46°29'39.9", E 22°48'19.3". Hab.: Mixed *Fagus-Abies-Picea* forest on limestone ground, alternating with openings. Date: 25. Oct. 2006. Coll.: T. Pócs & Z. Tóth. No. 06102
11. Munţii Bihorului (Bihar Hegység), 200-700 m N of Scărişoara Ice Cave near the Avenul din Şesuri sinkhole, at 1200 m alt. N 46°29'27.6", E 22°48'22.7". Hab.: Mixed *Fagus-Abies-Picea* forest on limestone ground. Date: 25. Oct. 2006. Coll.: T. Pócs & Z. Tóth. No. 06103
12. Munţii Bihorului (Bihar Hegység), Cheile Ordâncuşei gorge NE of Gârda de Sus village, near the Poarta lui Ionele cave, at 775 m alt. N 46°27'59.8", E 22°50'17.55". Hab.: Shady limestone cliffs with *Seslerietum rigidae.* Date: 25. Oct. 2006. Coll.: T. Pócs & Z. Tóth. No. 06104
13. Munţii Bihorului (Bihar Hegység), northern, very narrow part of Cheile Ordâncuşei gorge ("*Seligeria* Canyon") NE of Gârda de Sus village, at 850 m alt. N 46°28'30", E 22°50'30". Hab.: Shady, vertical limestone cliffs, almost no phanerogams. Date: 25. Oct. 2006. Coll.: T. Pócs & Z. Tóth. No. 06105

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ENVIRONMENTAL FACTORS AFFECTING THE HEAT STABILITY OF THE PHOTOSYNTHETIC APPARATUS

Dóra Szopkó & Sándor Dulai

Eszterházy Károly University, Institute of Biology, Department of Botany and Plant Physiology, H-3300 Eger, Leányka str. 6, Hungary;
**E-mail: szopko.dora@uni-eszterhazy.hu*

Abstract: Owing to greenhouse effect and severe dry periods in the agricultural fields, cultivated plants are increasingly exposed to the adverse impact of several abiotic stresses. Therefore, an increasing emphasis should be placed on how multiple stresses affect the physiological processes in plants and how plants respond to the coexistence of combined stress factors. Simultaneous environmental factors may elicit a response different from that given to a single factor, resulting in intensification, overlapping or antagonistic effects. Although the rate of photosynthesis is significantly reduced by salinity and decreased water availability, the thermotolerance of the photosynthetic apparatus may be altered by salt and drought preconditioning. In this short review, we focused on the individual effect of heat stress and the influence of dehydration and NaCl treatment on the heat tolerance of plants. According to our present knowledge, the thermostability of the photosynthetic apparatus may usually be improved by pretreatment of drought or NaCl. At the same time, several different mechanisms in the background of the higher thermostability are hypothesized. These possible drought- and salt-induced processes are also summarized by this review article.

Keywords: acclimation, heat stress, multiple stresses, photosynthesis, thermotolerance

INTRODUCTION

The effects of high temperature on photosynthetic processes

Increase in ambient temperature may cause a disruption in the cellular homeostasis exerting an inhibitory effect on growth, development and reproduction ability of plants. Heat stress alone but mainly combined with another abiotic stress factor (e.g. drought, high light intensity) negatively affects the success of agricultural production worldwide (Mittler *et al.* 2012) in connection with the prominent sensitivity of photosynthesis to stressful environment (Ashraf and Harris 2013). The optimum temperature for photosynthesis is in the range of 15-35 °C in plants of temperate regions. Above or below the optimum temperature, the structure and the operation of photosynthetic apparatus could be damaged (Wang *et al*. 2018). The degree of the damage is significantly affected by the temperature at which the plant has grown and the acclimatization and genetic properties of the plant species. The decreased capacity of photosynthesis may be manifested in the limitation of CO_2 assimilation and alterations of photosynthetic electron transport and photophosphorylation (Berry and Björkman 1980, Sharkey 2005). Although, there is a controversy in the literature (Law and Crafts-Brandner 1999), the temperature optimum and thermostability of the enzymes involved in CO_2 fixation in most cases exceed that temperature where photosynthesis is already significantly reduced, therefore the inhibited photosynthesis could primarily be associated with thermo-induced changes in the electron transport processes in the thylakoid lamellae of chloroplast (Berry and Björkmann 1980). In parallel with the slow heating, the strength of the hydrophilic and electrostatic interactions is weakened among the polar groups of proteins in the aqueous phase of the membranes, thereby modification in the structure of the membranes could be observed. Therefore, the strength of hydrophilic interactions are the most sensitive to heat resulting the physical dissociation of the light harvesting complexes (LHCII) from the PSII cores (CCII) (Schreiber and Berry 1977, Gounaris *et al*. 1984) and desintegration of the chloroplast grana and the conversion of PSII centers from α into β (Gounaris *et al*. 1984). This lateral reorganization of thylakoids is accompanied by other denaturation phenomena at more severe heat stress, such as the inactivation of oxygen-evolving complexes (OEC), caused by the dissociation of manganese ions and external proteins (Nash *et al*. 1985, Enami *et al*. 1994). The temperature at which the denaturation of PSII takes place is directly influenced by its lipid environment and by the fluidity of the thylakoids (Berry and Björkman 1980, Raison *et al*. 1982, Kunst *et al*. 1989). Parallel with these denaturation events, a similar decline of linear electron transport and photophosphorylation may be detected. The impaired photophosphorylation is partly attributable to the increase in the permeability of thylakoid lamellae, which forms a barrier to photophosphorylation by reducing the proton motive force (Havaux *et al*. 1996).

Under natural conditions, heat stress usually occurs in the presence of light. Positive correlation between thermostability of photosynthetic apparatus and light intensity have been found by Molnár *et al.* (1998). Their results indicated that the light-dependent energization of the thylakoid membranes could play a considerable role in the thermostability of the photosynthetic apparatus. It was also demonstrated that the xanthophyll cycle is induced by high leaf temperature even under low light intensity (Molnár *et al.* 1998) by increasing the transthylakoid proton gradient (Δ*p*H). The enhancement of cyclic electron flow around PSI (CEF) may also contribute to the increase in the Δ*p*H under heat stress (Bukhov *et al*. 1999) contributing to the protonation of the LHCII and the accumulation of zeaxanthin. As indicated by Havaux *et al.* (1996) and Lavaud and Kroth (2006) zeaxanthin maintains the stability of the thylakoid and promotes the induction of non-photochemical quenching (NPQ) (Kiss *et al.* 2008). The development of the light energy-dependent component of the NPQ requires a conformational change in the antenna system of PSII associated with zeaxanthin accumulation (Jahns and Holzwarth 2012), which ultimately results in aggregated LHCII (Horton *et al*. 1991). A linear correlation between the formation of heat-induced LHCII aggregation and NPQ was demonstrated by Tang *et al.* (2007). Thus, the changes in conformation of PSII can improve the thermostability of chloroplasts against high light intensity and heat stress by the thermal dissipation of excess excitation energy. Zeaxanthin is not only a determinant factor in the induction of NPQ but also contributes to avoiding photooxidative damage due to its non-enzymatic antioxidant activity by reducing lipid peroxidation (Johnson *et al.* 2007).

PSI is less susceptible to heat stress than PSII since the inhibition of PSI is not yet detectable at temperatures that trigger the complete inactivation of PSII (Havaux 1996). The heat sensitivity of PSII is closely related to the thermolability of OEC at the donor side of PSII (Yamane *et al.* 1998, Wang *et al.* 2010). The loss of OEC activity is mainly due to the detachment of the manganese-stabilizing extrinsic protein from PSII (Enami *et al*. 1994) and the release of manganese ions (Nash *et al*. 1985). In addition to changes affecting the donor side, the acceptor side of

PSII may also be limited due to a disruption of the electron transfer between the primary (Q_A) and the secondary (Q_B) acceptor plastoquinone of PSII resulting in the accumulation of reduced Q_A (Kouril *et al.* 2004). The electron flow from the stroma to the reaction center of PSII may be observed in heat-treated samples under dark conditions, which reduces the optimal quantum efficiency of PSII through the damage of D1 protein (Marutani *et al.* 2012). In the presence of light, excitation energy may be transmitted to PSI instead of PSII by the so-called state 1 – state 2 transition NPQ process in which phosphorylated LHCII acts as the light-collecting antenna of PSI (Haldrup *et al.* 2001). State transition contributes to preventing the over-reduction of the acceptor side of PSII and photodamage in PSII under excess light energy by increasing CEF and NPQ (Takahashi *et al.* 2009). Essemine *et al.* (2017) showed that thermal damages in PSII could be avoided by CEF in rice which might be facilitated by light-induced state transition (Lemeille and Rochaix 2010). At the same time, state transitions may be induced in the dark under moderately elevated temperature due to increased chlororespiration resulting in the migration of phosphorylated LHCII from the grana to the stroma region by the activated chloroplast thylakoid protein kinase (STN7) (Havaux 1996, Nellaepalli *et al.* 2011). In addition, increased CEF can also contribute to the maintenance of ATP homeostasis to indirectly prevent irreversible damages to the photosynthetic apparatus (Sharkey and Zhang 2010).

The thermal sensitivity of PSII can be characterized by the determination of critical temperature for photochemical damage (*T*c) based on minimum chlorophyll fluorescence (F_0) and steady-state fluorescence (F_S) *vs*. temperature (*T*) curves (Schreiber and Berry 1977, Molnár *et al*. 1998, Hill *et al.* 2009) (*Figure 1*).

The value of *Tc* is influenced by the fluidity of thylakoid membrane (Havaux and Gruszecki 1993), therefore *Tc* can be used as an indicator of the thermotolerance of the photosynthetic apparatus in connection with the integrity of thylakoid lamellaes (Hill *et al.* 2009).

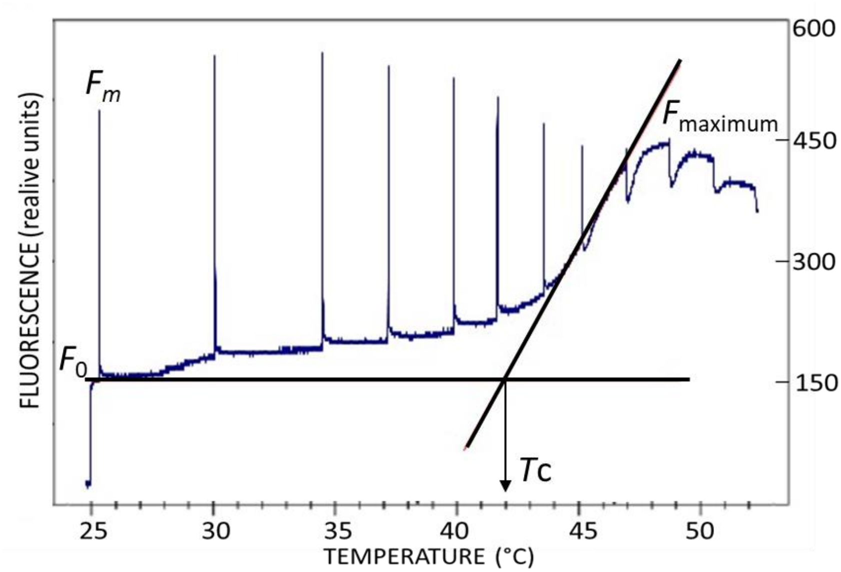

Figure 1. An example of F_0 *vs*. *T* curve where the temperature was increased at a rate of 1 °C min^{-1} (Hill *et al.* 2009). The critical temperature for photochemical damage (*T*c) was defined as the interception of regression lines fitted to fluorescence data.

In addition, *T*c may also indicate the critical temperature where the quantum efficiency of CO_2 fixation is impaired by heat treatment (Schreiber and Bilger 1987). Rising in F_o can be caused by the detachment of LHCII from the PSII core complex (Yamane *et al.* 1997) and/or by the accumulation of the reduced Q_A. The latter is connected to the reversed electron donation between Q_A and Q_B or the impaired electron transport capacity from Q_A to Q_B due to the damaged D1 protein (Gilmore *et al.* 1996, Kouril *et al.* 2004). At a temperature above *T*c, reversible or even irreversible degradation of thylakoid membranes occurs (Hill *et al.* 2009) leading to increased membrane permeability and decreased Δ*p*H which causes a reduction in NPQ.

In addition to the dysfunction in photosynthetic electron transport, heat stress also results in decreased chlorophyll content (Feng *et al.* 2014), deactivated Rubisco (ribulose-1,5-bisphosphate carboxylase/oxygenase) (Sharkey 2005) and denaturated Rubisco activase (Feller *et al.* 1998). The reduction in chlorophyll content may be attributed to the disturbance of chlorophyll synthesis or a considerable degradation or both of them (Ashraf and Harris 2013). It has been also observed that the inactivated OEC and the insufficient electron transport around PSII significantly inhibited the rate of ribulose-1,5-bisphosphate (RuBP) regeneration (Wise *et al.* 2004, Wang *et al.* 2018). In addition to high light intensity, increased temperature is also conducive to intense photorespiration even under moderate and constant light intensity (Peterhansel *et al.* 2010). The heat-induced photorespiration is due to the oxygenation of RuBP over carboxylation by Rubisco because the affinity of Rubisco for O_2 and the concentration ratio of O_2 to CO_2 are increased in the stroma by heating event (Hall and Keys 1983).

Changes in the photosynthetic processes due to temperature acclimation

Plant can adapt to the adverse effects of supra-optimal temperature through long-term and short-term acclimation processes. These mechanisms are manifested in many metabolic processes, including photosynthesis, and affect both the lipid composition and the structure of proteins. The long-term acclimation to high temperature occurs in a range from some days to weeks thus it can only be suitable for defending from the effects of the seasonal temperature changes. This phenomenon is accompanied by reduced fluidity of thylakoid membranes (Dulai *et al.* 1998), with decreasing unsaturation of fatty acids of polar lipids (Berry and Björkmann 1980). A higher ratio of saturated fatty acid reduces the thermal sensitivity of PSII by rigidizing the membrane (Kunst *et al.* 1989), which forms an important part of the long-term acclimatization processes in plants suffering from heat stress. Other factors such as genetically-determined or environmental-induced differences in homologous proteins may also affect the thermostability of the photosynthetic apparatus. Adaptation of plants to elevated temperature entails reduced flexibility of the proteins through changes in intramolecular binding regardless of whether the proteins had high or low thermostability initially. In the long term, the efficient functioning of photosynthesis at high temperatures also depends on the presence of the heat stable protein synthesis system in the chloroplasts that enables heat-damaged proteins to be replaced or repaired (Berry and Björkmann 1980). Experimental evidences have suggested the prominent sensitivity of the reaction center D1 protein to strong light and heat stress (Komayama *et al.* 2007, Khatoon *et al*. 2009). Komayama *et al.* (2007) described two processes in connection with the turnover of heat-damaged D1 protein: dephosphorylation of the D1 protein in the stroma, and aggregation of the phosphorylated D1 protein with nearby polypeptides. These processes may be essential for the maintaining the activity of PSII under heat treatment. One of the most effective protection against high temperature stress can be provided by heat shock proteins (HSPs) contributing to the refolding of proteins, preventing of the aggregation of denaturated proteins and protecting PSII at supra-optimal temperatures (Al-Whaibi 2011). In chloroplasts, the 21-kDa HSP (Hsp21) may mostly contribute to the stabilization of the thylakoid membrane during thermal fluctuations by directly interacting with the membrane-bound PSII subunits such as D1 and D2 proteins (Chen *et al.* 2016). Several studies have shown that hydrophobic isoprene could also protect photosynthesis under heat and oxidative stress conditions (Sharkey and Singsaas 1995, Loreto and Schnitzler 2010) by improving integrity of the thylakoid membrane and quenching reactive oxygen species when temperature exceeded the optimum level (Sharkey and Yeh 2001, Velikova *et al.* 2011). It was suggested that the protective role of isoprene is based on its ability to make stable interactions between proteins and lipids in the membrane (Sharkey and Yeh 2001).

In addition to the long-term acclimatization, short-term mechanisms also play a prominent role in the emergence of heat resistance by facilitating rapid responses. Havaux and Tardy (1995) have demonstrated the flexibility of thermotolerance of PSII which was reflected in improved thermostability within a few minutes in plants grown at 25 °C. An explanation of this rapid acclimatization to elevated temperature is summarized by Havaux and Tardy (1995, 1996). Their hypothesis is based on the temperature-dependent conversion of the xanthophyll cycle pigments, namely, the violaxanthin convert to zeaxanthin through antheraxanthin by the operation of violaxanthin de-epoxidase (Yamamoto *et al.* 1967). The phenomenon can occur under light and also under dark conditions and may be triggered off by ascorbate treatment (Havaux and Tardy 1995). Zeaxanthin can provide a protection function against the negative effects of high temperature not only by enhancing the stability of the thylakoid membrane (Tardy and Havaux 1997) but also by promoting the induction of NPQ (Kiss *et al.* 2008).

Impact of water deficit and salt pretreatment on PSII thermostability

Water deficit and salt stress often occur in combination with heat stress under conditions of high light intensity. These stress factors may limit the processes of the carbon metabolism simultaneously (Dulai *et al*. 2005). During global climate change, it may become increasingly common for cultivated plants to tolerate the combined effects of the abiotic stress factors (Suzuki *et al.* 2014). Consequently, the survival and productivity of plants can be determined by their ability to coordinate mechanisms protecting against multiple stresses. The synchronization of regulating/protecting processes largely determines the flexibility of plants' tolerance under the effects of the combined factors at a given time and place. Accordingly, the improved phenotypic plasticity in the changing environment may be essential for the reserved photosynthesis and growth. Simultaneous environmental factors may elicit a response different from that given to a single factor, resulting in intensification, overlapping or antagonistic effects (Osmond *et al*. 1986), however these effects strongly depend on the severe of first stress, the species, genotypes and the age of plants. Although the rate of photosynthesis is significantly reduced by high temperatures (Berry and Björkman 1980), the thermostability of the photosynthetic apparatus can be induced by drought and salt preconditioning (Lu and Zhang 1999, Dulai *et al*. 2006, Yan *et al*. 2012).

Perhaps the most common combined stress is the drought together with high temperature, which frequently occurs in hot and dry summer periods. Under conditions of water limitation, the significantly decreased transpiration also contributes to the stimulation of heat stress due to the insufficient heat transfer from the leaves (Teskey *et al.* 2014). However, the drought stress can induce the defence mechanisms in plants against high temperatures as well, which results in an enhanced tolerance to high temperatures (Ahuja *et al.* 2010). As demonstrated by Dulai *et al.* (2006) and Ribeiro *et al.* (2008) drought as a previous stress before heating could increase the thermostability in PSII, which may be reflected in the lower thermal sensitivity of effective quantum yield of PSII (ϕ_{PSII}) (Dulai *et al.* 2006, Ribeiro *et al.* 2008). Osmotic stress-induced increase in thermotolerance can be associated with different mechanisms. The improved thermostability of the drought-preconditioned *Poa pratensis* was attributed to the expression of HSPs, a higher antioxidant activity and changes in lipid composition (Peng *et al*. 2012). In water-deficient plants, these changes may minimize the damages of proteins and membranes during the heating event. Osmolytes involved in osmotic adjustment in water-stressed plants, such as glycine betaine or proline, may also benefit above the thermal optimum due to their stabilization function in the thylakoid membranes (Rhodes and Hanson 1993). Based on the observation made by Seemann *et al.* (1986) on desert plants, a common signal can be attributed to the simultaneous development of higher thermostability and osmotic adaptation. Denaturation of PSII at high temperatures also relates to physical changes affecting the lipid matrix of thylakoid membrane, which also modifies the conformation of proteins in thylakoid by altering the interaction between membrane proteins and lipids (Gounaris *et al.* 1984, Havaux 1992). Accordingly, the modified lipid composition during dehydration can help to strengthen the interaction between PSII proteins and surrounding lipids (Havaux 1992). The quantitative reduction of polyunsaturated fatty acid chain lipids or the increased zeaxanthin content in the membranes of chloroplast may be induced by osmotic stress, thus resulting more rigid thylakoid membrane (Ferrari-Iliou *et al.* 1984, Demmig *et al.* 1988, Tardy and Havaux 1997). Zeaxanthin, in addition to supporting the rigidity of thylakoid membrane, also acts as an antioxidant by moderating lipid peroxidation (Johnson *et al*. 2007). The preservation of the integrity of thylakoid membrane is also necessary for conformational changes that accompany the development of NPQ (Dau 1994), which can improve the thermostability in plants against high light and heat stress by the dissipation of excess absorbed energy. LHCII trimers can be transformed into an aggregated form by the conformational changes, which also require zeaxanthin (Horton *et al*. 1991, Jahns and Holzwarth 2012).

CO_2 assimilation may show stronger sensitivity to salinity than the operation of the electron transport around PSII (Darkó *et al.* 2015), thus salt stress finally causes oxidative damage through over-reduction of photosynthesis (Asada 2006, Ashraf and Harris

2013). In salt adapted halophyte plants, enhanced NPQ was observed, which provided effective protection against photoinhibition not only under salt stress but also at high temperatures (Qiu *et al.* 2003). A linear relationship was found between the aggregated LHCII and NPQ in heat-stressed plants (Tang *et al.* 2007). Since aggregation was observed at a lower temperature than the decrease in F_v/F_m, aggregated LHCII could also play a protective role in thermal stress as well as in the case of salt treatment. Due to salt preconditioning, a less pronounced thermosensitivity of OEC and PSII reaction center in salt-adapted plants have been shown by several studies (Chen *et al.* 2004, Wen *et al.* 2005, Yan *et al.* 2012). Since reduced water-splitting activity is also associated with the detachment of chloride ions under heat conditions (Krishnan and Mohanty 1984, Nash *et al.* 1985), it is possible that the higher chloride ion content under salt stress may increase the stability of OEC and result in the formation of more thermoresistant PSII. The synthesis of NaCl-induced compatible osmotics can also result in higher thermal resistance. Salt-induced proline accumulation may also contribute to the protection of reaction center, donor and acceptor side of PSII in heat-treated plants due to its membrane stabilizing role (Yan *et al.* 2012). Similarly to proline, salt-induced betaine and glycine betaine may also play a prominent role in protecting thylakoid membrane components, the stabilization of OEC (Chen and Murata 2008, Tian *et al*. 2017), and in the prevention of the detachment of external proteins from PSII (Murata *et al*. 1992). Modification of the lipid composition in the thylakoid membrane could be observed as a result of ionic stress which may also be part of the adaptation processes to salinity (Müller and Santarius 1978). The saturation of fatty acid in the thylakoid membrane can be determinative for avoiding salt stress and preventing the stabilty of membrane during the heating. Shu *et al.* (2015) have described an increase in the saturated fatty acid contents of thylakoid membranes under severe ion toxicity caused by NaCl. The higher ratios of the saturated fatty acids to unsaturated fatty acids may be beneficial even at high temperatures due to the reduced membrane fluidity (Raison *et al.* 1982). Accumulation of raffinose family oligosaccharides, polyols and polyamines may also represent a successful plant response to salinity and decreased water availibility (Krasensky and Jonak 2012). Since these macromolecules have considerable implications for protection of membrane and alleviating oxidative stress (Nishizawa *et al.* 2008, Krasensky and Jonak 2012) therefore their increased amount in salt-adapted plants could also be advantageous when plants are simultaneously affected by elevated temperature. HSPs also play a prominent role in defense of membranes against the negative effect of abiotic stresses (Al-Whaibi 2011). The increased amount of HSPs may be induced not only by heating, but also by several stress treatments such as salinity and dehydration (Swindell *et al.* 2007) representing an overlap in the signal transduction pathways induced by different stresses (Krasensky and Jonak 2012).

CONCLUSION

It is now evident that photosynthetic apparatus is harmfully affected by stressful environment such as water deficit, salinity and high temperature having a considerable impact on plant growth and development. The impact of each of these stress factors has been extensively studied but we have a less knowledge about their combined effect on the physiology processes of plants. OEC and cellular membranes especially thylakoid membrane may be disrupted by heat stress resulting in decreased activity of membrane-associated electron carries thereby photosynthesis will be limited. Although salinity and drought are known as a significant inhibitor of photosynthesis, but these stress factors may induce responses in plant cells having a positive effect on the thermotolerance of photosynthetic apparatus. These stress-induced modifications are mainly manifested in more rigid membranes, improved thermal resistance of OEC by compatible solutes and less pronounced lipid peroxidation by quenching reactive oxygen species. Summarizing our present knowledge, we can conclude that responses of plants induced by individual stress could promote plants to acclimatize more successfully to another stress which often appears simultaneously under natural conditions.

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INTERRELATION AMONG PRECIPITATION AND ELEMENT-CONTENT OF GRAPE *VITIS VINIFERA* L. CV. KÉKFRANKOS, GROWN IN DIFFERENT TERROIRS

Richárd Nagy[1]*, Szilárd Szabó[2], Attila Kerényi[3]
& Borbála Bálo[4]

[1]Eszterházy Károly University, Innoregion Knowledge Centre, H-3300 Eger, Leányka str. 6; [2]Department of Physical Geography and Geoinformatics, University of Debrecen, H-4032 Debrecen, Egyetem Sq. 1.; [3]Department of Landscape Protection and Environmental Geography, University of Debrecen, 4032 Debrecen, Egyetem Sq. 1.; [4]Department of Viticulture, Szent István University;
**E-mail: nagy.richard@uni-eszterhazy.hu*

Abstract: Total nutrient content of soils and quantity of potentially available part in plants are determined in this study. Main affecting factors of nutrient uptake might be the geochemical conditions of soils and the applied agro-technological methods, while the real uptake of plants can be influenced by precipitation and evaporation conditions beside the rootstock and the used grafted scions. The element content of grape berries of *Vitis vinifera L.* Kékfrankos cultivar was studied in identical rootstocks and scions at different production areas in Northern Hungary, during two consecutive years with somehow contrasting natural precipitation. Significant effect of the precipitation was found on the elements-uptake by the plants in general. Furthermore, it was also found, that the role of production area becomes increasingly important in grape production and quality, as well. Higher precipitation resulting greater elemental content and variability in comparison with the drier years.

Keywords: climate, grapevine, precipitation, trace element

INTRODUCTION

The climatic conditions of a production area are determined as macro-, meso- and micro-climate. While macro-climate determines temperature and precipitation conditions at a regional scale, meso-climate varies according to local topographic conditions (Gladstones 1992). According to Hunter, Bonnardot (2011), climate has the main role in physiological processes of grapevine and thus

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determining the chemical composition of leaves and berries, the colour of the berries and the date of ripening, etc. Drappier *et al.* (2017) pointed out that the composition and character of wine from the vineyards around Bordeaux changes with climatic change. Bartholy, Pongrácz (2010) proved that the frequency of extreme precipitation increased in the Carpathian Basin in the second half of the 20th century while annual precipitation slightly decreased. On the basis of climatic models, they consider that the climate of the region becomes drier at summers and wetter at winters in the 21st century.

The quantity of micro- and macro-elements in the soil are influenced not only by the soil forming processes and geological conditions but by dry and wet deposition from the atmosphere as well. The latter is especially significant in urban environments (Soriano *et al.* 2012), therefore, the monitoring of micro- and macro-elements in soils and plants and studying their uptake are important.

Webb *et al.* (1995) studied the amount of cations regarding the relationship between soil and must and divided them into two groups. Cations belonging to the first group are accumulated in grapes, of exceeding even the concentration values, found in the soils. This group includes K, Na, Mn, Pb, Cu. Cations of the second group appear in the pressed must of the grapes in smaller quantity than in the soil. This group includes Ca, Sr, Zn. As a conclusion of detailed studies Bramley *et al.* (2011) stated that the quantity of the mineral components in the must is only in loose correlation with the pedological and geochemical conditions of the production area. Pepi *et al.* (2016) established a correlation between the rare earth elements (REE) concentration in the berries and REEs available fraction in the soil; which allowed the discrimination between the different origins of grapes.

Based on the relationship between soil pH and the uptake of nutrients, Candolfi-Vasconcelos *et al.* (1997) found significant differences among production areas with different soil conditions. Such concept of considering soil quality was supported by Bálo *et al.* (2010), and Biró (2015). Numerous vine studies and viticultural research (Swinchatt 2006; Coipel *et al.* 2006) studied the elemental transport in bed rock – soil type – grapevine – wine, however, with very varying results. No direct correlation was detected in the uptake of the different macro-, meso- and micro-elements and the various environmental factors. Results can be classified into two groups. Some scientists are highlighting the importance of the rootstocks in element-composition, while others are showing the necessity of proper water supply. Numerous studies focused on the joint effects of the two factors. Regarding the nutrient uptake Kocsis *et al.* (2001) associates the greatest effect with rootstock-scion relationship, showing also that dry conditions strongly influence element uptake compared to normal, wetter vintage years. In dry years, the potassium content of the grape must show lower values and the effect of the rootstocks are also considered (Brancadoro *et al.* 1995). According to Cus (2004), climatic and soil conditions can modify the properties of the rootstock and scion specifics, therefore, their effects could be different by vintage and production area.

Among factors determining water supply, vintage and the water budget conditions of the soil worth mentioning as these together influence the uptake of nutrients of plants in relation to the stress tolerance of the rootstock. Water supply is influenced by slope and soil conditions apart from precipitation. Andres de Prado *et al.* (2007) studied the chemical composition of wines in the case of soils having different water budget conditions. Beside those parameters, the extreme drought conditions had significant effect also on the characteristics of the wines.

Objective of the present study was to compare different wine grape production sites and the effect of annual variability of natural precipitation regarding some of the elements, taken up by grape fruits.

MATERIAL AND METHODS

The present research was carried out on 9 study plots in the area of the Eger wine region in the north-eastern part of Hungary (*Table 1*). Examinations were performed on *Vitis vinifera L.* Kékfrankos grapevine cultivar grafted on Berlandieri x Riparia, T.5.C. rootstock with vertical shoot positioning (VSP).

Table 1. Main characteristics of plantations in the study areas.

Vineyards	*GPS Coordinates*	*Row and vine distance*	*Training system*	*Year of planting*
Kőlyuktető – KT	N47.864; E20.383	3.00 x 1.20 m	Umbrella	1993
Nagy-Eged-dűlő lower – NEA	N47.920; E20.420	3.00 x 1.00 m	Umbrella	1988
Nagy-Eged-dűlő upper – NEK	N47.922; E20.418	3.00 x 1.00 m	Umbrella	1988
Síkhegy – SH	N47.916; E20.431	3.00 x 1.00 m	Umbrella	1989
Vidra – VD	N47.907; E20.419	3.00 x 1.00 m	Guyot	1988
Juhszalagos – JSZ	N47.867; E20.483	3.00 x 1.00 m	Guyot	1995
Szérűhely – SZH	N47.885; E20.496	3.00 x 1.00 m	Umbrella	1995
Tó-bérc – TB	N47.872; E20.289	3.00 x 1.00 m	Medium high cordon	1998
Nagy-galagonyás – NG	N47.867; E20.365	3.00 x 1.00 m	Umbrella	1985

The amount of precipitation was recorded by using a BES-06 tipping bucket rain gauge developed by Boreas Ltd. *(www.boreas.hu)* in automated meteorological stations operating during 7 study areas with the accuracy of 0.1 mm.

Fruit samples of grapes were all taken on the same day in the ripening season directly before harvesting in the different plots. Sampling was performed on the 3rd of October in 2010 and on the 24th September in 2011 due to differences in ripening. Sampling was performed on the basis of the random walk method. Samples were taken from bunches of various sizes at different heights from both sides of a given wine row. From various parts of bunches around 100 berries were taken from each plot. Samples were washed in distilled water after sampling and then dried in desiccators at 80°C. Finally, grapes were homogenized by using porcelain mortars. Destruction and exposition was made by using 5 ml cc. HNO_3 and 2 ml H_2O_2 (VWR, Hungary Ltd). The substrates were filtered via 228 nm filter-paper and diluted to 30 ml. A Perkin-Elmer 3000 FAAS device was used for destruction and elemental analyses were performed using an ICP-OES device.

RESULTS AND DISCUSSION

The relationship between precipitation and element uptake in different vintages

Automated meteorological stations were placed into 7 production areas out of the 9 plots (Kőlyuktető, Sík-hegy, Tó-bérc, Szérűhely, Juhszalagos, Nagy-Eged-dűlő lower and upper). The amount of precipitation in 2010 was 2-3 times higher than in 2011 (*Figure 1*).

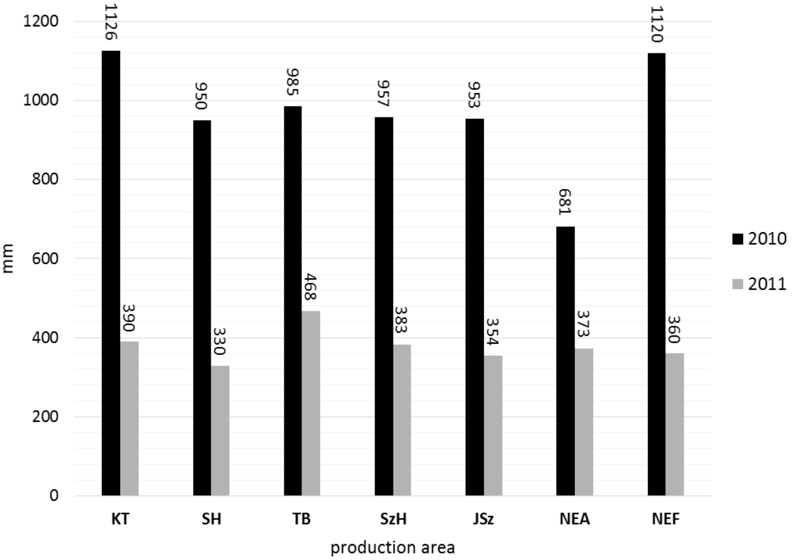

Figure 1. Amount of annual rainfall for 2010 and 2011 at production areas of grapes, assessed by meteorological stations (mm). Further details in text.

Since the amount of precipitation might significantly influences the element uptake of plants, the elemental content of grape samples from the two years were compared.

No significant differences were detected between the two vintages in the case of certain elements like Ba, Mn and Ni. In contrast, Al, Ca, Fe, K, Mg, Na, Zn were present in grapes in a significantly larger quantity in the vintage of 2010. This can be explained by an intensified sap flow in the plants driven by the greater amount of precipitation. As a result, higher amount of elements enter the plant and thus they appear in the berries in higher quantity as well. Cu, Cr, Pb, however, were present in the berries in significantly greater quantity in the vintage of the drier year, 2011 (*Figure 2, Table 2*). This can be explained with the fact, that all three elements were deposited from the atmosphere in the greatest quantity. This means mostly spraying in the case of copper which was deposited on the surface of grapes in large quantities (Weng *et al.* 2003). It can be washed from the berry surface moderately with rain, therefore in drier years it is present in significant amounts on the berry skin (Brun *et al.* 1998; Deluisa *et al.* 1996). The quantity of copper measured among the grape samples depends mostly on the type of chemicals used in the course of spraying, on the number of sprayings and on the time passed from the last spraying, till the date of sampling and this was not observed in the present study. Cr appear in the atmosphere as aerosols settling onto the surface of the Earth with either wet or dry deposition. Following dry deposition rain washes it into the soil from the leaves and different plant parts and this explains why it was found in smaller quantity in the sample from 2010 when the amount of precipitation was greater. Pb in the soil can be hardly taken up by plants thus atmospheric deposition has the most important role (Alloway 2012). Pb gets onto the surface of the Earth by dry deposition thus in drier years, it appears on the surface of plants and of grape bunches in greater quantities, that are not washed away by precipitation.

Table 2. Differences of certain elements between vintages from 2010 and 2011 (Mann-Whitney test; bold letters: $p<0.05$).

	Al	**Ba**	**Ca**	**Cr**	**Cu**	**Fe**	**K**
Mann-Whitney U	.000	54.500	8.000	24.500	10.000	30.000	30.000
Z	-4.157	-1.011	-3.695	-2.773	-3.580	-2.425	-2.425
Asymp. Sig. (2-tailed)	**.000**	.312	**.000**	**.006**	**.000**	**.015**	**.015**

	Mg	**Mn**	**Na**	**Ni**	**Pb**	**Zn**
Mann-Whitney U	8.000	55.500	.000	60.500	.000	18.000
Z	-3.695	-.953	-4.157	-.666	-4.158	-3.119
Asymp. Sig. (2-tailed)	**.000**	.341	**.000**	.506	**.000**	**.002**

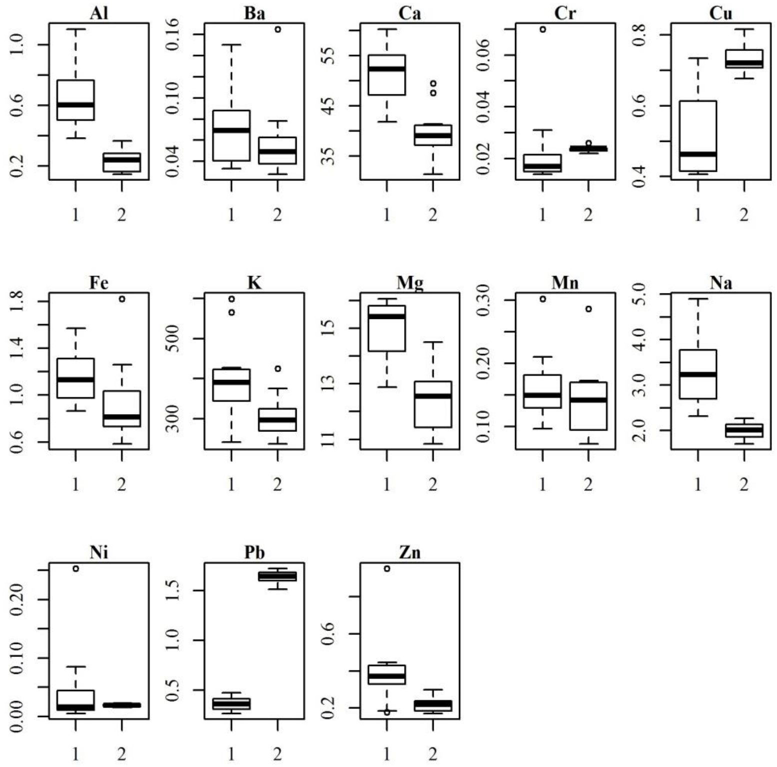

Figure 2. Statistical parameters of the elemental content of berries from vintages of 2010 (1) and 2011 (2) (minimum, maximum, median, lower quartile, upper quartile) as the average of the studied nine area.

Studying the elemental composition of the berry samples of the two years significant differences were found not only in the average quantity of individual elements and in the minimum and maximum values, but also in the standard deviation of the values (*Tables 3 and 4*). In the wet year of 2010 the standard deviation of values was higher in the case of Al, Ba, Ca, Cr, Cu, Fe, K, Na, Ni, Zn compared to that of 2011. Standard deviation of values of manganese and lead was the same in the two years while in the case of magnesium the values of 2011 showed greater standard deviation. This suggests that besides the effect of vintage, the effect of production area increases when the years show higher annual precipitation values regarding the nutrient quantity of grapes related to dry matter.

Table 3. Standard deviation values of the berry samples of 2010 (mg/kg).

	Al	**Ba**	**Ca**	**Cr**	**Cu**	**Fe**	**K**	**Mg**	**Mn**	**Na**	**Ni**	**Pb**	**Zn**
Min.	0.383	0.033	41.789	0.014	0.407	0.864	241.280	12.880	0.097	2.320	0.005	0.266	0.178
1st Qu.	0.507	0.041	47.477	0.015	0.417	0.978	348.965	14.275	0.134	2.773	0.011	0.318	0.345
Median	0.603	0.069	52.323	0.017	0.463	1.131	390.160	15.425	0.150	3.230	0.016	0.361	0.371
Mean	0.656	0.070	51.395	0.023	0.513	1.173	396.105	14.957	0.161	3.352	0.044	0.362	0.397
3th Qu.	0.742	0.084	55.061	0.021	0.597	1.276	420.735	15.758	0.174	3.725	0.033	0.407	0.426
Max.	1.105	0.150	60.300	0.070	0.734	1.572	599.460	16.060	0.302	4.900	0.253	0.475	0.953
Deviation	**0.214**	**0.035**	**5.392**	**0.016**	**0.120**	**0.235**	**106.168**	1.110	0.056	**0.817**	**0.070**	0.068	**0.196**

Table 4. Standard deviation values of the berry samples of 2011 (mg/kg).

	Al	**Ba**	**Ca**	**Cr**	**Cu**	**Fe**	**K**	**Mg**	**Mn**	**Na**	**Ni**	**Pb**	**Zn**
Min.	0.148	0.028	31.400	0.022	0.676	0.585	237.300	10.840	0.073	1.710	0.015	1.512	0.171
1st Qu.	0.164	0.038	37.477	0.023	0.708	0.733	272.018	11.535	0.096	1.870	0.017	1.600	0.192
Median	0.242	0.047	39.093	0.024	0.720	0.756	296.500	12.555	0.142	2.015	0.019	1.643	0.220
Mean	0.238	0.048	39.735	0.024	0.730	0.841	303.081	12.465	0.144	2.007	0.019	1.634	0.218
3th Qu.	0.277	0.055	40.956	0.024	0.757	0.927	318.565	13.073	0.169	2.123	0.021	1.682	0.238
Max.	0.367	0.078	49.499	0.026	0.816	1.260	424.870	14.500	0.286	2.270	0.023	1.722	0.299
Deviation	0.071	0.016	4.906	0.001	0.042	0.209	54.363	**1.153**	0.056	0.168	0.003	0.068	0.038

It is clear that according to literature references, the uptake of most elements – even if not all of them – varies from vintage to vintage depending primarily on the amount of annual precipitation.

Impact of rainfall distribution over the year on elements uptake

The second aspect of the present work was to study the variation of the quantity of different elements in the berries within two years with different amounts of precipitation.

Using the daily precipitation data of the plots equipped with a meteorological station, Spearman's rank correlation was performed in order to understand correlation with elemental concentration. In the course of the study, three periods were identified within the two studied years. Apart from annual precipitation data, the amount of precipitation in the growing season and also in the ripening periods was considered, as well (*Table 5*). As a result of different conditions of the two vintages, the length of the phenological phases and the date of harvest were different. The start of the growing season was taken as 1st April (bud break) while the starting date of ripening was determined to be 1st August. The end of the growing season and the ripening period are indicated by the date of harvest, 5th October in 2010 and 25th September in 2011.

Table 5. Amount of annual rainfall in 2010 and 2011, and also for the growing season and ripening (mm).

Production area	***Total for 2010***	***Growing season in 2010***	***Ripening period in 2010***	***Total for 2011***	***Growing season in 2011***	***Ripening period in 2011***
KT	1125.9	793.4	206	389.2	218.6	25.5
SH	949.9	693.5	204.7	329.6	185	16.9
TB	985.4	696.6	206	468.1	320.8	43.9
SzH	956.5	652.6	202.8	383.1	226.6	5.8
JSz	952.4	632.1	183.2	354	203.8	6
NEA	680.5	432.3	227.1	372.9	213.2	16.5
NEF	1120.4	805.4	252.9	359.8	186.4	7.9
FD	924.5	603.5	165.8	380.5	219.1	23.8
VP	1058.4	729.5	189.2	505.4	300.1	18.4

In 2010 with relatively high amount of precipitation, the annual amount of it shows weak positive correlation with calcium and nickel, and weak negative correlation with copper. Considering the growing season, weak negative correlation was found with aluminium and copper while weak positive correlation was detected with nickel. Calcium, however, showed medium positive correlation (r=0.567; p=0.112). During ripening the amount of precipitation showed medium positive correlation with calcium (r=0.770; p=0.015), sodium (r=0.603; p=0.086) and lead (r=-0.31; p=0.025) while with iron and zinc weak positive, with barium and chromium weak negative correlations were found (*Table 6*).

In the dry year of 2011, the total amount of precipitation showed significant correlation with chromium (r=-0.767; p=0.016) and copper (r=-0.720; p=0.029), and medium correlation with manganese (r=-0.633; p=0.067). Studying the growing season, significant correlation was found only with copper (r=-0.703; p=0.035), while medium correlation was detected with chromium (r=-0.575; p=0.105) and manganese (r=-0.567; p=0.112). In contrast, in the ripening period significant correlation was found only with aluminium (r=0.750; p=0.20), while weak correlation was detected with calcium, copper, manganese and zinc (*Table 7*).

The amounts of precipitation showed different correlations with different metals in the different studied periods in the two studied years. This enables to draw the conclusion that metal intake and accumulation are much more dependent on the amount of precipitation in the given year than on the distribution of precipitation in time.

Table 6. Spearman's rank correlation test of precipitation in 2010.

		Al	**Ba**	**Ca**	**Cr**	**Cu**	**Fe**	**K**	**Mg**	**Mn**	**Na**	**Ni**	**Pb**	**Zn**
total	**Correlation Coefficient**	-.233	.083	.417	.235	-.483	.133	-.150	.000	-.017	.133	.377	.025	-.126
	Sig. (2-tailed)	.546	.831	.265	.542	.187	.732	.700	1.000	.966	.732	.318	.949	.748
	N	9	9	9	9	9	9	9	9	9	9	9	9	9
growing season	**Correlation Coefficient**	-.417	-.133	.567	.176	-.333	.083	-.183	**.017**	.150	.183	.427	-.117	**.033**
	Sig. (2-tailed)	.265	.732	.112	.650	.381	.831	.637	.966	.700	.637	.252	.764	.932
	N	9	9	9	9	9	9	9	9	9	9	9	9	9
ripening period	**Correlation Coefficient**	.084	-.452	,770*	-.392	.109	.469	-.126	.117	.159	.603	-.105	-,731*	.361
	Sig. (2-tailed)	.831	.222	**.015**	.296	.781	.203	.748	.764	.683	.086	.788	**.025**	.339
	N	9	9	9	9	9	9	9	9	9	9	9	9	9

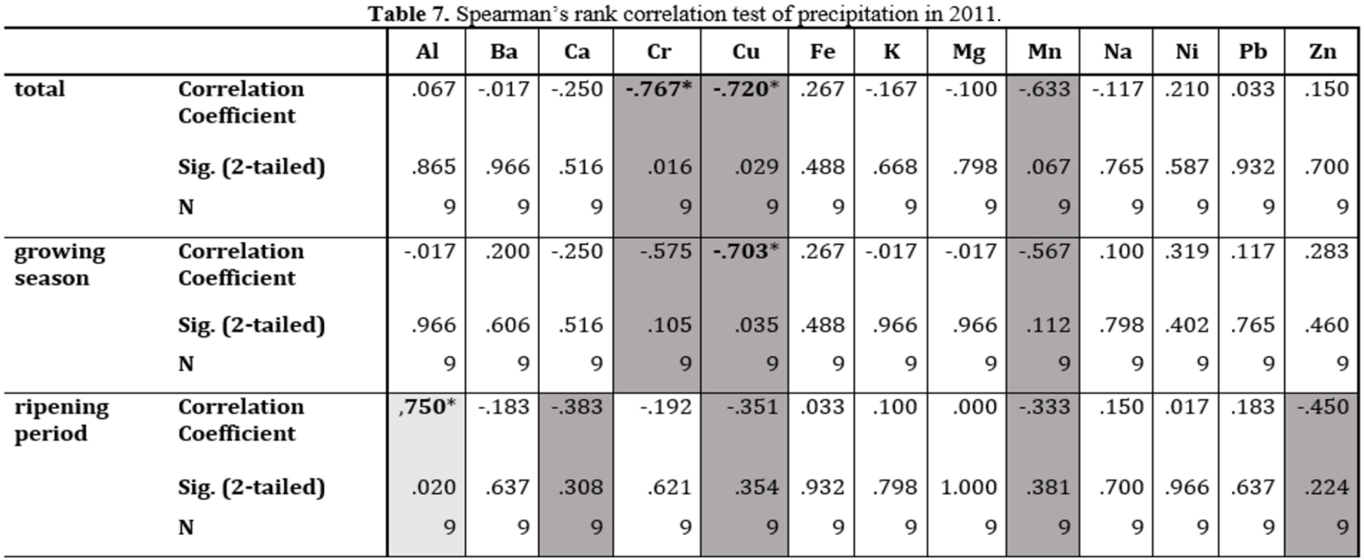

Table 7. Spearman's rank correlation test of precipitation in 2011.

		Al	Ba	Ca	Cr	Cu	Fe	K	Mg	Mn	Na	Ni	Pb	Zn
total	**Correlation Coefficient**	.067	-.017	-.250	**-.767***	**-.720***	.267	-.167	-.100	-.633	-.117	.210	.033	.150
	Sig. (2-tailed)	.865	.966	.516	.016	.029	.488	.668	.798	.067	.765	.587	.932	.700
	N	9	9	9	9	9	9	9	9	9	9	9	9	9
growing season	**Correlation Coefficient**	-.017	.200	-.250	-.575	**-.703***	.267	-.017	-.017	-.567	.100	.319	.117	.283
	Sig. (2-tailed)	.966	.606	.516	.105	.035	.488	.966	.966	.112	.798	.402	.765	.460
	N	9	9	9	9	9	9	9	9	9	9	9	9	9
ripening period	**Correlation Coefficient**	**,750***	-.183	-.383	-.192	-.351	.033	.100	.000	-.333	.150	.017	.183	-.450
	Sig. (2-tailed)	.020	.637	.308	.621	.354	.932	.798	1.000	.381	.700	.966	.637	.224
	N	9	9	9	9	9	9	9	9	9	9	9	9	9

CONCLUSIONS

The effects of vintage were studied in two years (2010 and 2011) with contrasting climatic conditions. The results supported of preliminary hypotheses, that precipitation can significantly influence on the quantity of elements taken up by grapevine. Statistical analyses revealed that the effect of the production area is more characteristic in years with more precipitation (2010 in this case) regarding the elemental content related to dry matter content of grape berries. At the same time, no significant correlation was found between the uptake of certain elements and the amount of precipitation measured in the growing season and also in the ripening periods. This suggests that the intake and accumulation of the studied elements are much more dependent on the precipitation in a certain year than on the distribution of precipitation in time.

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THE BRYOPHYTE FLORA OF THE PARK OF MÁTRAI GYÓGYINTÉZET SANATORIUM (NE HUNGARY)

Péter Szűcs[1]*, Gergely Baranyi[2] & Gabriella Fintha[2]

[1]Eszterházy Károly University, Institute of Biology, Department of Botany and Plant Physiology, H-3300 Eger, Leányka str. 6, Hungary; [2]Eszterházy Károly University, Faculty of Natural Sciences, H-3300 Eger, Leányka str. 6, Hungary;
**E-mail: szucs.peter@uni-eszterhazy.hu*

Abstract: The aim of this study was to explore the bryophyte diversity in the garden of Mátrai Gyógyintézet Sanatorium. In the investigated area 65 bryophytes were found, 3 liverworts and 62 mosses. Some near threatened taxa according to the Hungarian Red List were detected in the territory: *Brachythecium glareosum, Cirriphyllum piliferum, Orthotrichum pumilum, Rhynchostegiella tenella* and *Syntrichia latifolia.* The recent record of *Syntrichia latifolia* is the second in the North Hungarian Mountains, and the first in Mátra Mountains.

Keywords: bryophytes, high altitude, *Syntrichia latifolia,* semi-natural habitats

INTRODUCTION

Parks and large public gardens can be interesting hot spots of biodiversity, since they are places where the human endeavor to form a landscape meets the tendency of nature to conquer back any area where the anthropogenic impact is diminished (Nielsen *et al*. 2014).

During the last decades, the bryophyte floras of several Central and Eastern European parks and gardens have been studied, for example Warsaw, Łódź and other Polish cities (Fudali 2006, Wolski *et al.* 2012), Bucharest (Gomoiu and Ştefâţnuţ 2008), Veľký Krtíš (Mišíková *et al.* 2007), Olomouc (Vejmelková 2014), Bratislava (Godovičová and Mišíková 2017), Martonvásár (Nagy *et al.* 2016), and Almásfüzitő (Szűcs *et al.* 2017). The main objective of the present study was the examination of the bryophyte diversity of the garden of Mátrai Gyógyintézet Sanatorium. Such a study seemed particularly promising since the area is situated in a mountain area, at high elevation, thus exceptional compared with similar studies (e.g. manor park in Martonvásár (Nagy *et al.* 2016)) which refer to lowland areas.

MATERIAL AND METHODS

The nomenclature follows Király (2009) for vascular plants, Söderström *et al.* (2016) for liverworts, Hill *et al.* (2006) for mosses. In order to characterise the conservation and indicator status of taxa the Hungarian Red List was used (Papp *et al.* 2010).

Site details descriptions (in the Appendix) include data in the following order: habitat, GPS-coordinates, date of collection. The identifiers of the quadrates according to the Central European Flora Mapping System were indicated in sqaure brackets (Király *et al.* 2003). Each collection point belongs to the 8185.1 square. Specimens were collected on 22.09.2018 and 03.10.2018, respectively, as indicated in the Appendix.

Collected specimens are stored at the Cryptogamic Herbarium of the Department of Botany and Plant Physiology at the Eszterházy Károly University, Eger (EGR).

Study area

The study area (14 ha), between 650 and 700 meters above the sea level, is situated within Észak Magyarországi Középhegység, (North Hungarian Mountains), in Mátravidék, Magas Mátra, the highest of the Hungarian mountain ranges. It is located in Heves county, within the administrative unit of Mátraháza (Gyöngyös) (Dövényi 2010). We can mainly find volcanic rock, mostly andesite and andesite-liparite tuff. The area involves the highest parts of Mátra Mts with relatively high amount of precipitation, resulting in strong soil leaching. Soils, mostly lava clay, usually have medium water absorption, low water conductivity, and high water retention. Among the soil types, the most common is the brown-forest soil with clay leaching, with various depths and varying bedrock (Baráz *et al*. 2000). The climate of the area is cool and wet. The annual number of sunny hours is 2000 at the highest peaks, and 1900 lower. During summer the number of sunny hours is 740-750, and during winter 250 hours at the highest points. The annual average temperature is 6-8°C. (Dövényi 2010). The southeastern side of the hospital garden is affected by the Bene-stream in a short distance. The flora of the Mátra is rich in mountain elements. The distribution of the vegetation is dependent on the bedrock and the soil type on it. Montane species of vascular plants appear in the submontane beech forests (*Polystichum aculeatum, Lunaria rediviva, Daphne mezereum)* (Baráz *et al*. 2000).

The hospital (and probably its own garden) was established between 1927 and 1931 in a former meadow called Nagy Somorrét. In addition to the main building, there were 7 smaller buildings in the area including laundry, garage, residential building, kindergarden and gate. Because of the isolation of the site self-sufficiency was attempted, with own water supply and sewage treatment systems, laundry, bakeries, horticulture, pig farm, maintenance workshops. The staff lived in the premises (Padányi 1933). The current regular garden care works include mowing lawns and gathering leaves. The bryofloristic exploration was carried out by the authors in the fenced-in area of the hospital garden, exploring the following micro-habitats: road bridges, road edges, concrete and stone constructions (*Figure 2*), rooftops, mowed lawns (*Figure 3*), creeks, rock gardens, bark of trees and soil.

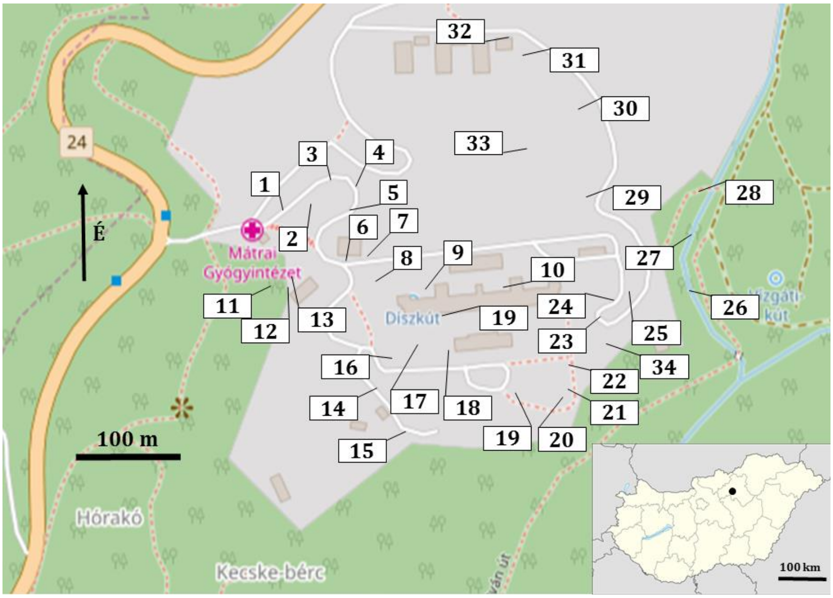

Figure 1. Map of the park of the Mátrai Gyógyintézet Sanatorium and the collecting points (© OpenStreetMap contributors)

RESULTS AND DISCUSSION

List of species

Numbers refer to sites (*Figure 1*) listed in the Appendix. The substrates given after a colon refer to all listed sites.

Marchantiophyta

Frullania dilatata (L.) Dumort. – 11: bark of *Quercus petraea*
Plagiochila porelloides (Torr. ex Nees) Lindenb. – 4, 7: soil
Metzgeria furcata (L.) Corda – 26: bark of *Fagus sylvatica*

Bryophyta

Amblystegium serpens (Hedw.) Schimp. – 17: root of *Carpinus betulus*
Atrichum undulatum (Hedw.) P.Beauv. – 3, 5, 7: soil
Barbula unguiculata Hedw. – 1, 7, 14, 18: soil
Brachytheciastrum velutinum (Hedw.) Ignatov & Huttunen – 4, 28: soil
Brachythecium glareosum (Bruch ex Spruce) Schimp. – 7, 9: soil; 10: artifical stone
Brachythecium rutabulum (Hedw.) Schimp. – 3, 5, 18, 28: soil
Brachythecium rivulare Schimp. – 27: concrete
Bryum argenteum Hedw. – 1, 14, 18: soil; 32: mortar debris
Bryum caespiticium Hedw. – 32: mortar debris
Bryum moravicum Podp. – 17: root of *Carpinus betulus*
Calliergonella cuspidata (Hedw.) Loeske – 9: soil
Calliergonella lindbergii (Mitt.) Hedenäs – 7, 24: soil
Campyliadelphus chrysophyllus (Brid.) R.S.Chopra – 7: soil
Ceratodon purpureus (Hedw.) Brid. – 8: asphalt roofing felt; 18: soil
Cirriphyllum piliferum (Hedw.) Grout – 7: soil
Cirriphyllum crassinervium (Taylor) Loeske & M.Fleisch. – 7: soil
Climacium dendroides (Hedw.) F.Weber & D.Mohr – 2, 3, 5: soil
Dicranella heteromalla (Hedw.) Schimp. – 4, 7: soil
Dicranella varia (Hedw.) Schimp. – 14: soil
Drepanocladus aduncus (Hedw.) Warnst. – 19: artifical stone
Dicranum montanum Hedw. – 34: decayed wood

Dicranum scoparium Hedw. – 34: decayed wood
Eurhynchium angustirete (Broth.) T.J.Kop. – 20, 21, 22, 29: soil
Fissidens taxifolius Hedw. – 28: soil
Grimmia muehlenbeckii Schimp. – 23: andesite stone
Grimmia pulvinata (Hedw.) Sm. – 13: artifical stone
Isothechium alopecuroides (Lam. ex Dubois) Isov. – 11: bark of *Quercus petraea*
Homalia trichomanoides (Hedw.) Brid. – 12: stone
Homalothecium lutescens (Hedw.) H.Rob. – 25: soil
Homomallium incurvatum (Schrad. ex Brid.) Loeske – 25: concrete
Hedwigia ciliata (Hedw.) P.Beauv. –8: asphalt roofing felt; 14, 16, 23: andesite rock
Hygroamblystegium tenax (Hedw.) Jenn. – 26: stone
Hypnum cupressiforme Hedw. – 25: concrete; 30: bark of *Betula pendula*
Orthotrichum affine Schrad. ex Brid. – 30: bark of *Betula pendula*
Orthotrichum anomalum Hedw. – 13, 19: artifical stone; 25: concrete
Orthotrichum cupulatum Hoffm. ex Brid. – 13: artifical stone
Orthotrichum diaphanum Schrad. ex Brid. – 6, 16, 32: artifical stone
Orthotrichum pumilum Sw. ex anon. – 25: bark of *Fraxinus*
Oxyrrhynchium hians (Hedw.) Loeske – 2, 7, 17, 29: soil
Mnium marginatum (Dicks.) P.Beauv. – 7: soil
Plagiomnium affine (Blandow ex Funck) T.J.Kop. – 7, 24: soil
Plagiomnium cuspidatum (Hedw.) T.J.Kop. – 28: soil
Plagiomnium undulatum (Hedw.) T.J.Kop. – 9, 10: soil
Plagiothecium nemorale (Mitt.) A.Jaeger – 26: soil
Platygyrium repens (Brid.) Schimp. – 15: bark of *Quercus petraea*
Pleurozium schreberi (Willd. ex Brid.) Mitt. – 24: soil
Pohlia nutans (Hedw.) Lindb. – 34: decayed wood
Polytrichastrum formosum (Hedw.) G.L.Sm. – 3: soil
Polytrichum juniperinum Hedw. – 3: soil
Pseudoleskeella nervosa (Brid.) Nyholm – 11: bark of *Quercus petraea*
Pseudoscleropodium purum (Hedw.) M.Fleisch. – 20, 21, 33: soil
Pteryginandrum filiforme Hedw. – 26: bark of *Fagus sylvatica*
Pylaisia polyantha (Hedw.) Schimp. – 30: bark of *Betula pendula*
Rhynchostegiella tenella (Dicks.) Limpr. – 22: shaded stone

Rhytidiadelphus triquetrus (Hedw.) Warnst. – 21, 31: soil
Rhytidiadelphus squarrosus (Hedw.) Warnst. – 19, 20, 21, 22: soil
Rhizomnium punctatum (Hedw.) T.J.Kop. – 26, 27: soil
Syntrichia latifolia (Bruch ex Hartm.) Huebener – 13: artifical stone
Syntrichia ruralis (Hedw.) F.Weber & D.Mohr – 8: asphalt roofing felt; 25: concrete
Syntrichia virescens (De Not.) Ochyra – 13: artifical stone
Thuidium assimile (Mitt.) A.Jaeger – 3, 7, 22, 29: soil
Tortula muralis Hedw. – 6, 13, 16, 19, 32: artifical stone, 25: concrete

Number of taxa, conservation status, indicator species

According to the present study, 65 bryophytes were collected in the park of the Mátrai Gyógyintézet Sanatorium, including 3 liverworts and 62 mosses.

The authors found some mosses which are still not threatened, but need attention (LC-att) according to the Hungarian Bryophyte Red List (Papp *et al.* 2010) (e.g. *Brachythecium rivulare, Climacium dendroides, Grimmia muehlenbeckii, Homalia trichomanoides, Hypnum lindbergii, Mnium marginatum*, *Orthotrichum cupulatum*, *Syntrichia virescens*).

Near threatened species were as follows from the study area: *Brachythecium glareosum*, *Cirriphyllum piliferum*, *Orthotrichum pumilum*, *Rhynchostegiella tenella* and *Syntrichia latifolia.*

Some indicator species, which show a greater level of conservation value of the habitat, also occur in the park, e.g. *Grimmia muehlenbeckii*, *Homalia trichomanoides, Mnium marginatum, Orthotrichum cupulatum, Orthotrichum pumilum* and *Rhynchostegiella tenella.*

Syntrichia latifolia

Syntrichia latifolia is a temperate floral element with circumpolar distribution, which mainly occurs on roots and boles of *Salix* and *Populus* trees in Cental Europe, but has also been collected from anthropogenic substrate, for example concrete, bitumen and asphalt (Dierßen 2001, Düll 2010).

In Hungary, this moss has been found until recently only on the bark of trees or less often thatched roofs along the riparian zone of the rivers of Danube and Tisza in Hungary (Orbán and Vajda 1983).

P. Erzberger detected the first record of this species growing on andesite rock in a colline area of Hungary (Cserhát Mts., Zsunyi-brook) (Erzberger 2002). New interesting data from bark of *Fagus sylvatica* were published from Zala county (W Hungary), 300 m above sea level (Papp and Szurdoki 2018).

Our find is the first data from a mountain region, and the first published record from a man-made substrate (artifical stone) in Hungary (*Figure 2*). However, earlier in 2018 the species was found on concrete in the region of Zselic by K. Baráth and P. Erzberger in the village of Bárdudvarnok-Bánya in Somogy County (unpublished, P. Erzberger pers. comm.) On the other hand, our record represents the second locality to the North Hungarian Mountains, and the first to the Mátra Mts.

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APPENDIX

Site details

1. roadside (22.09.2018, 03.10.2018,) N47°51’53” E19°58’26”
2. mown lawn (22.09.2018) N47°51’53” E19°58’29”
3. embankment of road (22.09.2018, 03.10.2018) N47°51’54” E19°58’30”
4. roadside (03.10.2018) N47°51’54” E19°58’30”
5. embankment of road (22.09.2018, 03.10.2018) N47°51’53” E19°58’29”
6. artifical stone wall (03.10.2018) N47°51’52” E19°58’30”
7. submontane beech forest (03.10.2018) N47°51’52” E19°58’31”
8. asphalt roofing felt (03.10.2018) N47°51’51” E19°58’32”
9. mown lawn (03.10.2018) N47°51’51” E19°58’32”
10. mown lawn and pavement (03.10.2018) N47°51’51” E19°58’37”
11. woody vegetation (03.10.2018) N47°51’50” E19°58’26”
12. stony embankment of road (03.10.2018) N47°51’51” E19°58’27”
13. stairs handrail (03.10.2018) N47°51’51” E19°58’28”
14. roadside, public flowerpot and andesite rock (22.09.2018) N47°51’47” E19°58’29”
15. roadside (22.09.2018) N47°51’47” E19°58’31”
16. rockery (22.09.2018, 03.10.2018) N47°51’48” E19°58’32”
17. mown lawn (22.09.2018,03.10.2018) N47°51’49” E19°58’34”
18. roadside (03.10.2018) N47°51’49” E19°58’35”
19. abandoned fountain pool (22.09.2018) N47°51’48” E19°58’38”
20. embankment and mown lawn (22.09.2018) N47°51’48” E19°58’39”
21. embankment and mown lawn (22.09.2018) N47°51’48” E19°58’39”
22. stony ditch (22.09.2018) N47°51’49” E19°58’39”
23. stony embankment of road (03.10.2018) N47°51’48” E19°58’44”
24. embankment of road (03.10.2018) N47°51’50” E19°58’45”
25. mown lawn and roadside (03.10.2018) N47°51’50” E19°58’44”
26. brook (03.10.2018) N47°51’50” E19°58’52”
27. brook (03.10.2018) N47°51’52” E19°58’52”
28. roadside, construction waste (03.10.2018) N47°51’52” E19°58’52”
29. dirt road, mown lawn (03.10.2018) N47°51’54” E19°58’42”
30. roadside, trees (03.10.2018) N47°51’57” E19°58’41”
31. mown lawn (03.10.2018) N47°51’57” E19°58’41”
32. building, artifical stone (03.10.2018) N47°51’59” E19°58’38”
33. mown lawn (03.10.2018) N47°51’56” E19°58’39”
34. *Picea* plantation, stump (03.10.2018) N47°51’56” E19°58’39”

Figure 2. The occurence of *Syntrichia latifolia* on the stairs handrail (photo: P. Szűcs)

Figure 3. The mown lawn habitat of park of Hospitals Mátra (photo: P. Szűcs)

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NEW DATA ON THE DISTRIBUTION OF *CAMPYLOPUS INTROFLEXUS* (HEDW.) BRID. IN HUNGARY

Péter Szűcs

Eszterházy Károly University, Institute of Biology, Department of Botany and Plant Physiology, H-3300 Eger, Leányka str. 6, Hungary;
E-mail: szucs.peter@uni-eszterhazy.hu

Abstract: As a result of the research conducted between 2016 and 2018, 12 new populations of *Campylopus introflexus* were discovered in Hungary, of which 5 occurences were from the Transdanubian region and 7 were from Nyírség. The majority of new locations are connected to pine plantations, where they mainly appear on mixed raw forest humus.

Keyworks: invasive moss, planted pine forests, distribution map, Eastern Hungary

INTRODUCTION

The work of Hassel & Söderström (2005) summarized the expansion and temporal dynamics of two neophytic mosses, one of them *Campylopus introflexus*. By now this species has reached Southeastern Europe, its presence in Croatia, the ecological background of its spread and its potential invasion was discussed by Algero *et al.* (2018).

In Hungary, the first record of this newcomer species was reported in 2007 (Szűcs & Erzberger 2007), where today it forms stable populations and based on its ecological needs we can expect further expansion not only in the secondary but also in native forest communities. As a result of a few targeted studies the bryophyte was found mainly in pine plantations, furthermore its largest population appeared in disturbed native forests with an acidic soil surface (Szűcs *et al.* 2014). More recently, its presence has been detected in Transdanubian region (Somogy and Tolna County) and in Praematricum (Bács Kiskun County) (Csiky *et al.* 2017, Matus *et al.* 2018).

This study publishes new data on its distribution, and based on the published data it presents a map of the current distribution of the species in Hungary.

MATERIAL AND METHODS

Site details (descriptions of localities) include data in the following order: settlement, habitat, substrate, population size, GPS-coordinates, quadrate according to the Central European Flora Mapping System, altitude, date of collection, associated bryophytes and bryophytes within 50 meters. The identifiers of the quadrates according to the Central European Flora Mapping System were indicated in sqaure brackets (Király *et al.* 2003). Each specimen was collected and determined by the author. The nomenclature follows Király (2009) for vascular plants, Söderström *et al.* (2016) for liverworts, Hill *et al.* (2006) for mosses.

Collected specimens are stored at the Cryptogamic Herbarium of the Department of Botany and Plant Physiology at the Eszterházy Károly University, Eger (EGR).

RESULTS AND DISCUSSION

New localities in Hungary

Győr-Moson-Sopron region

1. Sopron, *Quercus rubra* plantation, on mixed raw forest humus, 1 dm^2, N47°38'50.4" E16°33'24.0" [8365.3] 400 m, 01.11.2016. Associated bryophyes: *Dicranum montanum*, *Dicranum tauricum*, bryophytes within 50 meters: *Dicranum scoparium*, *Hypnum cupressiforme*, *Polytrichum formosum*, *Bryum capillare*.

2. Gönyű, old *Pinus nigra* plantation, on sandy soil, 2 dm^2, N47°43'41.1" E17°48'53.2" [8272.4], 120 m, 02.11.2016. Associated bryophyes: *Hypnum cupressiforme*, *Ceratodon purpureus*; bryophytes within 50 meters: *Bryum moravicum*, *Brachythecium rutabulum*.

Hajdú-Bihar region

3. Debrecen Martinka, old *Pinus sylvestris* plantation, on mixed raw forest humus, 4 dm^2, N47°34'19.4" E21°47'21.0" [8496.2] 132 m,

09.09.2017. Associated bryophyes: *Dicranum scoparium*, *Hypnum cupressiforme*, *Polytrichum formosum*; bryophytes within 50 meters: *Bryachythecium rutabulum*, *Dicranum scoparium*, *Hypnum cupressiforme*, *Leucobryum* sp., *Pohlia nutans*, *Polytrichum formosum*, *Pseudoscleropodium purum*.

4. Létavértes, in an *Pinus sylvestris* plantation, on decayed *Pinus nigra*, 1,5 cm^2, N47°23'47.6" E21°50'53.4", [8697.1] 124 m, 09.09.2017. Associated bryophyes: *Hypnum cupressiforme, Ceratodon purpureus, Dicranum montanum*; bryophytes within 50 meters: *Bryachythecium rutabulum, Ceratodon purpureus, Hypnum cupressiforme*.

5. Monostorpályi, at the edge of an old *Pinus sylvestris* plantation, on mixed raw forest humus, 0,5 m^2, N47°24'51.9" E21°47'10.2" [8596.4] 115 m, 09.09.2017. Associated bryophyes: *Hypnum cupressiforme, Ceratodon purpureus*; bryophytes within 50 meters: *Aulacomnium androgynum, Ceratodon purpureus, Dicranum scoparium, Hypnum cupressiforme, Pleurozium schreberi, Polytrichum piliferum*.

6. Vámospércs, in an old *Pinus sylvestris* plantation, on mixed raw forest humus, 1 cm^2, N47°29'55,5", E21°56'06.4" [8597.2] 137 m, 09.09.2017. Associated bryophyes: *Hypnum cupressiforme*, *Ceratodon purpureus*, Another bryophytes within 50 meters: *Dicranum scoparium*, *Leucobryum* sp., *Pseudoscleropodium purum*, *Ptilium crista-castrensis*.

7. Nyíracsád, Asszonyrész tanya, border of an old *Pinus nigra* plantation, on decayed *Pinus nigra* trunk, 1 cm^2, N47°38'36.2" E21°56'43.5" [8397.4] 160 m, 01.04.2018., bryophytes within 50 meters: *Brachythecium albicans, Brachythecium rutabulum, Bryum* sp.*, Ceratodon purpureus, Dicranella heteromalla, Hypnum cupressiforme, Pleurozium schreberi, Pseudoscleropodium purum*.

8. Nyírábrány, glade of an old *Pinus sylvestris* plantation, on sandy soil surface, 1 dm^2, N47°34'57.0" E21°59'54.6" [8497.2] 152 m, 01.04.2018. Associated bryophye: *Ceratodon purpureus*; bryophytes within 50 meters: *Brachythecium albicans, Brachythecium rutabulum, Bryum* sp., *Ceratodon purpureus, Dicranum polysetum, Dicranum scoparium, Dicranum tauricum, Eurhynchium angustirete, Hylocomium splendens, Hypnum cupressiforme, Plagiomnium affine, Pleurozium schreberi, Pohlia nutans, Polytrichum formosum, Pseudoscleropodium purum, Ptilium-crista castrensis.*

9. Nyírbéltek, an old *Pinus sylvestris* plantation, on sandy soil surface, 1 dm^2, N47°42’09.6” E22°08’50.9” [8298.4] 154 m, 01.04.2018., Associated bryophyes: *Hypnum cupressiforme*; Bryophytes within 50 meters: *Atrichum undulatum, Brachytheciastrum velutinum, Brachythecium albicans, Brachythecium rutabulum, Brachythecium salebrosum, Ceratodon purpureus, Funaria hygrometrica, Hypnum cupressiforme, Pleurozium schreberi, Polytrichum juniperinum, Pseudoscleropodium purum*.

Komárom-Esztergom region

10. Nagyszentjános, old *Pinus nigra* plantation, on decayed *Pinus nigra* trunk, 4 cm^2, N47°43’55.6” E17°53’39.0” [8273.3] 125 m, 02.11.2016. Associated bryophyes: *Hypnum cupressiforme, Herzogiella seligeri, Brachythecium rutabulum*. Bryophytes within 50 meters: *Abietinella abietina, Dicranum montanum, Eurhynchium angustirete, Hypnum cupressiforme, Lophocolea heterophylla, Plagiomnium affine, Plagiomnium undulatum, Pohlia nutans, Pseudoscleropodium purum,*

Somogy region

11. Szenta, in an old *Pinus sylvestris* plantation, on sandy soil surface, 1 dm^2, N46°15’26.7” E17°13’43.6” [9769.1] 163 m, 21.06.2018. Associated bryophyes: *Ceratodon purpureus*; bryophytes within 50 meters: *Bryum argenteum, Brachythecium rutabulum, Dicranum scoparium, Dicranum polysetum, Frullania dilatata, Hypnum cupressiforme, Platygyrium repens, Pleurozium schreberi, Polytrichum formosum, Polytrichum juniperinum*.
12. Nagybajom, in *Pinus sylvestris* plantation, on bare, sandy soil surface, 2 dm^2, N46°24’02.1”, E17°28’34.8” [9570.4] 150 m, 21.06.2018. Associated bryophyes: *Hypnum cupressiforme*; Bryophytes within 50 meters: *Brachytheciastrum velutinum, Brachythecium rutabulum, Dicranum polysetum, Dicranum scoparium, Hypnum cupressiforme, Plagiomnium cuspidatum, Pleurozium schreberi, Polytrichum formosum, Pseudoscleropodium purum*.

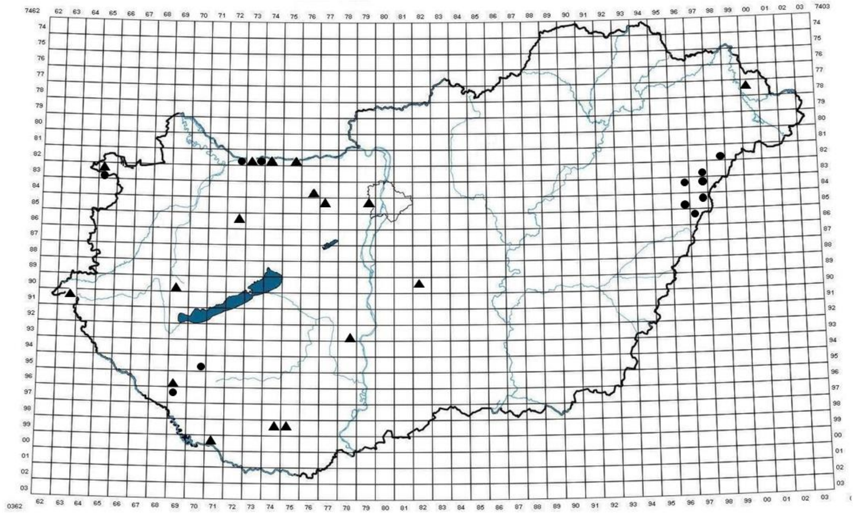

Figure 1. Distribution of *Campylopus introflexus* in Hungary; ● new occurrence, ▲ published occurrence (based on Szűcs *et al*. 2014, Csiky *et al*. 2017 and Matus *et al*. 2018).

During the investigations 12 new inland populations were successfully identified, of which 5 were from the Transdanubian region and 7 from Nyírség (*Figure 1*). Regarding their binding to substrate, we can claim that the majority of the moss cushions were bound to mixed raw forest humus of pine forests, less often to sandy soil, and in three case to decayed *Pinus*. The occurence in Sopron was on colline level (400 m above sea), the rest was on lowland level (125-170 m above sea). The size of the cushions was between 4cm^2 and 0,5 m^2, the biggest one was located at the border of Monostorpályi village. The most common moss species to form associations were *Hypnum cupressiforme* and *Ceratodon purpureus.* In the population of Vámospércs *Ptilium crista-castrensis,* a threatened species listed on the national red list was also present (Mesterházy *et al.* 2017).

The majority of identified localities were bound to pine plantations, so the significance of this habitat (Szűcs *et al.* 2014) was successfully proven for inland populations.

The 12 localities are divided among 7 microregions (Kelet Belső Somogy, Nyugat Belső Somogy, Soproni-hegység, Győr-Tatai teraszvidék, Dél-Nyírség, Délkelet-Nyírség, Érmelléki löszös hát). Of these new are data of the moss species coming from Kelet Belső

Somogy, Dél-Nyírség, Délkelet-Nyírség, Érmelléki löszös hát microregions, as well as from Berettyó-Kőrös-vidék and Nyírség mesoregions.

Previously published records of *C. introflexus* are mainly from the Transdanubian region (Szűcs *et al.* 2014, Csiky *et al.* 2017, Matus *et al.* 2018), the currently identified Eastern Hungarian populations are far away from the majority of these known localities. Gusztáv Jakab in 1997 (Jakab 1997) published his work bryophyte flora of the Nyírség which does not mention the neophytic moss species. We can assume that *Campylopus introflexus* reached the pine forests of Nyírség in the past 20-30 years and formed several bigger populations since then. These current investigations also included several *Corynephorus canescens* grass populations in the Nyírség, however the species was not found there.

Based on the stable populations of *Campylopus introflexus* in Eastern Hungary, there is a likelihood that the moss species is also present in the pine forests of Western Romania located by the border.

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