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# New bryophytes for Tunisia (North Africa). Part 2: other families

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**ABSTRACT**
As a result of our recent fieldwork, 16 bryophytes including three liverworts (*Clevea hyalina* (Sommerf.) Lindb., *Lophocolea fragrans* (Moris & De Not.) Gottsche, Lindenb. & Nees, *Riella mediterranea* Segarra, Puche, Sabovlj., M.Infante & Heras) and 13 mosses (*Bryum gemmilucens* R.Wilczek & Demaret, *B. gemmiparum* De Not., *Fissidens crassipes* Wilson ex Bruch & Schimp. subsp. *warnstorfii* (M.Fleisch.) Brugg.-Nann., *F. fontanus* (Bach. Pyl.) Steud., *F. ovatifolius* R.Ruthe, *Grimmia dissimulata* E.Maier, *Homalothecium meridionale* (M.Fleisch. & Warnst.) Hedenäs, *Hygroamblystegium varium* (Hedw.) Mönk. var. *varium*, *Isothecium myosuroides* Brid., *Orthotrichum comosum* F.Lara, R.Medina & Garilleti, *Philonotis marchica* (Hedw.) Brid., *Seligeria acutifolia* Lindb., *Schistidium helveticum* (Schkuhr) Deguchi) have been newly recorded in Tunisia. The localities of these taxa are briefly described, and their distinguishing criteria are specified with comments on taxonomy and variability. This work raises the number of known taxa in Tunisia from 334 to 350.

**KEY WORDS**
Maghreb,
floristics,
liverworts,
mosses,
new records.

**RÉSUMÉ**
*Nouvelles bryophytes pour la Tunisie (Afrique du Nord). Partie 2 : autres familles.*
Sur la base de nos récents travaux de terrain, 16 bryophytes dont trois hépatiques (*Clevea hyalina* (Sommerf.) Lindb., *Lophocolea fragrans* (Moris & De Not.) Gottsche, Lindenb. & Nees, *Riella mediterranea* Segarra, Puche, Sabovlj., M.Infante & Heras) et 13 mousses (*Bryum gemmilucens* R.Wilczek & Demaret, *B. gemmiparum* De Not., *Fissidens crassipes* Wilson ex Bruch & Schimp. subsp. *warnstorfii* (M.Fleisch.) Brugg.-Nann., *F. fontanus* (Bach. Pyl.) Steud., *F. ovatifolius* R.Ruthe, *Grimmia dissimulata* E.Maier, *Homalothecium meridionale* (M.Fleisch. & Warnst.) Hedenäs, *Hygroamblystegium varium* (Hedw.) Mönk. var. *varium*, *Isothecium myosuroides* Brid., *Orthotrichum comosum* F.Lara, R.Medina & Garilleti, *Philonotis marchica* (Hedw.) Brid., *Seligeria acutifolia* Lindb., *Schistidium helveticum* (Schkuhr) Deguchi) ont été nouvellement enregistrées en Tunisie. Les localités de ces taxons sont brièvement décrites, et leurs critères de distinction précisés, avec des commentaires sur la taxonomie et la variabilité. Ce travail porte le nombre de taxons connus en Tunisie de 334 à 350.

**MOTS CLÉS**
Maghreb,
floristique,
hépatiques,
mousses,
signalements nouveaux.

## INTRODUCTION

The main studies of the Tunisian bryoflora are disparate and largely quite outdated (Thériot 1900; Corbière & Pitard 1909; Jelenc 1955a, b, 1967; Jovet-Ast & Bischler 1971). Since 2000, there are very few publications that have identified new mosses in Tunisia (Pócs 2007; Draper *et al*. 2008; Ellis *et al*. 2017, 2018, 2019, 2021; Hugonnot *et al*. 2020; Ben Osman *et al*. 2021b, c). Ros *et al*. (2007) is the most recent national checklist for liverworts and Ros *et al*. (2013) for mosses.

Many regions in Tunisia remain underexplored: the general richness of bryophytes and the exact distribution of taxa are thus quite poorly documented. To fill this gap and to enhance and update our knowledge of the bryoflora, we have been undertaking intensive field surveys since 2018 in little known parts of the country.

In the present paper, we report 16 taxa that are new for Tunisia, collected in 2019 and 2020 in Kroumiria and Mogods (northern Tunisian Tell), the Teboursouk Mountains (Tunisian High Tell) and the Tunisian Dorsal. We include details about the habitat, taxonomy, and conservation of the newly recorded taxa.

## MATERIAL AND METHODS

### Fieldwork

We carried out the field surveys and collected bryophytes at 104 different locations in Kroumiria and Mogods from April 1-13, 2019, and at 52 different locations in the Tunisian High Tell and Tunisian Dorsal from March 10-15, 2020 (Fig. 1). We identified our specimens using classic methods with the help of binoculars and microscopes; they are housed in the herbarium of the Tunis Science Faculty (TUN) and the personal herbarium of Vincent Hugonnot.

We use the nomenclature provided by Sérgio *et al*. (2016), Hodgetts *et al*. (2020) for *Homalothecium meridionale* (M.Fleisch. & Warnst.) Hedenäs and Vanderpoorten (2004) for *Hygroamblystegium varium* (Hedw.) Mönk. var. *varium*. All species that are not cited in Ros *et al*. (2007, 2013) and Ellis *et al*. (2017, 2018, 2019, 2021) are considered new for Tunisia. These newly recorded species are listed in alphabetical order by family.

For each newly reported taxon, we describe both the general habitat and the microhabitat of the respective specimens. During our bryophyte study, we identified the main types of plant formations present, using the nomenclature of Le Floc'h *et al*. (2010) for vascular plants. We summarize the most relevant morphological characteristics of each taxon, provide taxonomic comments, indicate the respective floristic element and give an overview of its global distribution. The precise location(s) of collecting localities, collection dates, collectors and herbarium number(s) are specified.

The distributions were extracted from relevant syntheses and the individual publications that are cited under each species. Macaronesian records are included.

### Herbarium work

We examined the Jelenc collection stored in the herbarium of Musée Henri Lecoq in Clermont Ferrand (MHLCLF).

### Study area

The Kroumiria and Mogods regions extend over the northwestern extremity of Tunisia. On the highest reliefs, located in Kroumiria on the Algerian-Tunisian border (Jbel El Ghorra, 1203 m a.s.l.), elevations fall from west to east, to the hill region of Mogods. Both regions border the Mediterranean Sea, along the valley of Mejerda, the country's main permanent river flowing SW-NE. Geologically, they correspond to the Numidian clay and sandstone flysch domains of Oligocene age. Located in a humid bioclimate (INRF 1975), these are the wettest regions in Tunisia (1000-1500 mm/year in Kroumiria). The vegetation is dominated by zeen oak (*Quercus canariensis* Willd.) forests in the meso-Mediterranean vegetation belt mainly represented in Kroumiria, and by cork oak (*Quercus suber* L.) forests in the thermo-Mediterranean vegetation belt. South of the Mogods lies the Hedhils, a limestone eroded range rising no higher than 700 m and covered by

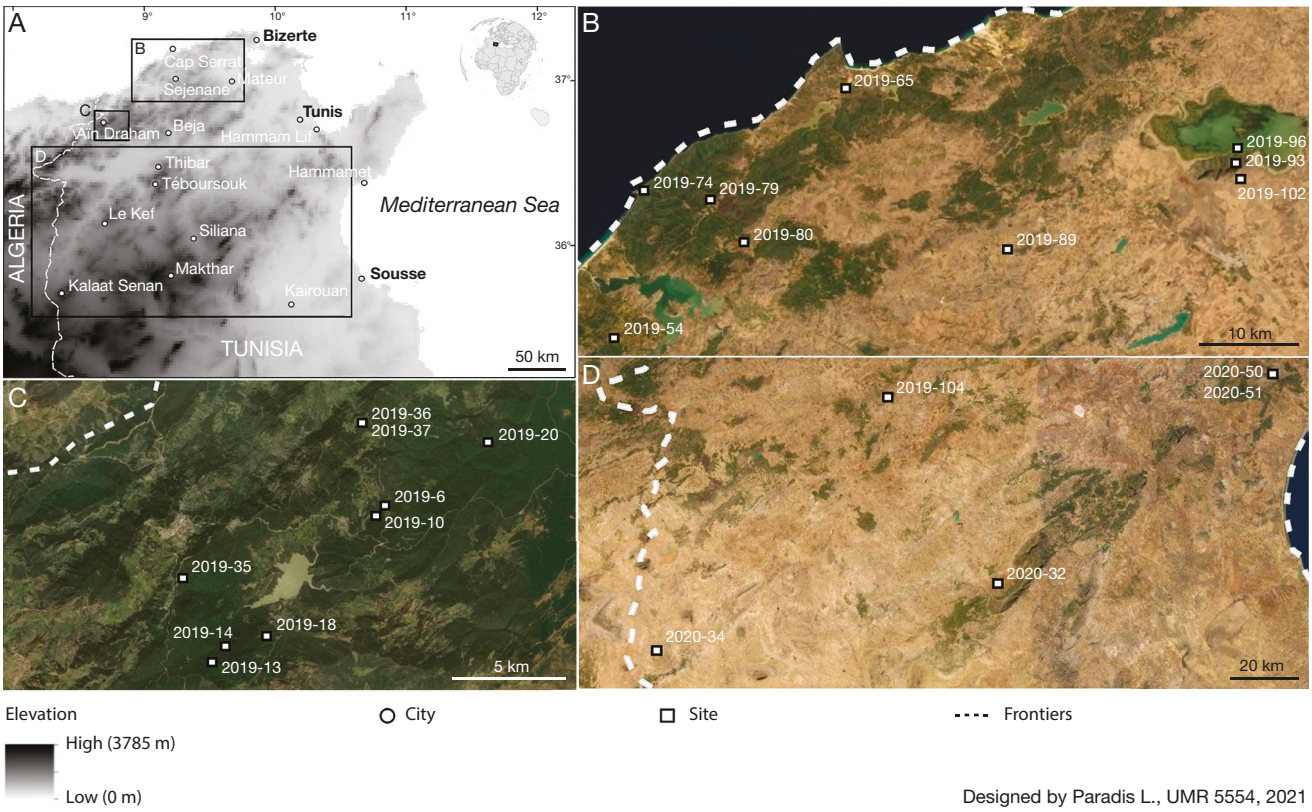


Fig. 1. — Location of the study sites in northern Tunisia.

degraded formations of olive (*Olea europaea* L. var. *sylvestris* (Mill.) Lehr) and mastic pistachio trees (*Pistacia lentiscus* L.).

Further south, the Teboursouk Mountains lie in the northeast of the Tunisian High Tell, where they are bounded to the north and east by the plains of the Mejerda Valley, to the south by the Tunisian Dorsal, and to the west by the wadi Tessa. This hilly limestone region culminates at Jbel Gorrâa (963 m a.s.l.). It is mainly subject to a semi-arid bioclimate that becomes sub-humid in the highest areas where it has greater exposure to wet maritime winds (INRF 1975). The vegetation is dominated by preforests of Aleppo pine (*Pinus halepensis* Mill.) associated in some places with holm oak (*Quercus ilex* subsp. *ballota* (Desf.) Samp.)

The Tunisian Dorsal constitutes the eastern extension of the Saharan Atlas and runs on a southwest-northeast axis. This mountain range extends over the north-central part of the country and is characterized by altitudes that fall from Jbel Chambi (1544 m a.s.l.) near the Algero-Tunisian border to Jbel Bou Kornine (576 m a.s.l.) near the Cap Bon peninsula. The limestone mountain massifs are more or less aligned, and alternate with large glacis typically with gentle slopes traversed by many wadis embedded with sediments. While the Tunisian Dorsal is located primarily in the semi-arid bioclimate, the summits of certain reliefs locally benefit from a sub-humid bioclimate (INRF 1975). Dominated by Aleppo pine preforests, the vegetation is also mixed with continental red juniper (*Juniperus turbinata* Guss.) and often associated with holm oak on the reliefs.

## RESULTS

Sixteen taxa are considered newly discovered for Tunisia, raising the number of known taxa from 334 (Ros *et al.* 2007, 2013; Ellis *et al.* 2017, 2018, 2019, 2021; Hugonnot *et al.* 2020; Ben Osman *et al.* 2021b, 2021c, pers. comm.) to 350, an increase of 11%. The number of liverworts thus rises from 92 to 95 and the number of mosses from 238 to 251. Four hornworts are already known in Tunisia. The presence of *Riccardia chamedryfolia* (With.) Grolle and *Sphaerocarpos europaeus* Lorb., considered dubious by Ros *et al.* (2007), is confirmed.

### Family Amblystegiaceae G.Roth
### Genus *Hygroamblystegium* Loeske

#### ***Hygroamblystegium varium*** (Hedw.) Mönk. var. ***varium***

Specimens examined. — **Tunisia.** Kroumiria, Jendouba Governorate, Delegation of Aïn Draham: Dar Fatma, with sporophytes, 36°49'06.92"N, 08°46'29.70"E, 783 m a.s.l. (site 2019-36), 05.IV.2019, Ben Osman & Hugonnot (TUN[TUN2019-278]); 36°49'08.15"N, 08°46'28.80"E, 782 m a.s.l. (site 2019-37), 05.IV.2019, Ben Osman & Hugonnot (TUN[TUN2019-279]); Mogods, Bizerte Governorate, Delegation of Sejenane: Cap Serrat, with sporophytes, 37°12'17.00"N, 09°13'50.60"E, 3 m a.s.l. (site 2019-65), 08.IV.2019, Ben Osman & Hugonnot (TUN[TUN2019-294]).

Remarks

*Hygroamblystegium varium* var. *varium* was found in two contrasting habitats: on floating peat in the Dar Fatma peatland, covered by rich herbaceous carpets dominated by *Baldellia repens* (Lam.) van Ooststr. *ex* Lawalrée, *Lotus pedunculatus* Cav., *Lysimachia tenella* L., *L. tyrrhenia* (Thore) U.Manns & Anderb. and *Potamogeton polygonifolius* Pourr., and on soil in the riparian alder forest of Oued Ziatine on Cap Serrat.

The Dar Fatma peatland is unique in North Africa and designated as a Natural Reserve in 1993. Its raised circular mounds of waterlogged peat measuring 15-25 m² are separated by wet lawns and surrounded by hygrophilic scrublands of *Erica scoparia* L. and *Pteridium aquilinum* (L.) Kuhn (Muller *et al*. 2010). *Hygroamblystegium varium* var. *varium* was accompanied by a remarkable hygrophilous assemblage of species, including *Aulacomnium palustre* (Hedw.) Schwägr, *Philonotis fontana* (Hedw.) Brid., *Plagiomnium affine* (Bland. ex Funck) T.J.Kop., *Riccardia multifida* (L.) Gray and *Sphagnum auriculatum* Schimp., which are all rare bryophyte species in North Africa.

The taxonomic treatment of the *Hygroamblystegium varium* complex has changed substantially in recent years (Vanderpoorten 2004). The Tunisian material is particularly difficult to identify because it combines characteristics of var. *humile* (P.Beauv.) Vanderp. & Hedenäs and var. *varium*. However, it is attributed to var. *varium* because typical morphotypes occur in all the localities. The deviant morphs are considered juvenile or underdeveloped specimens.

*Hygroamblystegium varium* var. *varium* is characterized by its shortly acuminate or obtuse leaves, the nerve nearly reaching the apex, and the short rhomboidal cells.

*Hygroamblystegium varium* var. *varium* is a circumpolar temperate taxon present everywhere on the American continent as well as in Eurasia, South Africa, New Zealand and Antarctica (Vanderpoorten 2014).

## Family Aneuraceae H.Klinggr.
## Genus *Riccardia* Gray

### ***Riccardia chamedryfolia*** (With.) Grolle

Specimen examined. — **Tunisia**. Mogods, Beja Governorate, Delegation of Nefza: Khorguelia, with sporophytes, 37°04'35.24"N, 09°03'32.75"E, 93 m a.s.l. (site 2019-79), 09.IV.2019, Ben Osman & Hugonnot (TUN[TUN2019-127]).

Remarks

*Riccardia chamedryfolia* was collected on wet organic substrate on the banks of a wadi (see *Fissidens fontanus* for the site description). In other regions, this liverwort occurs on damp to wet substrates in shaded to exposed habitats where it grows on the ground or on tree roots. It can behave like a hydrophyte in wet mires, swamps or along rivers (Paton 1999; Damsholt 2002). *Riccardia multifida*, previously mentioned in Tunisia (Ros *et al*. 2007), seems to have ecological requirements similar to those of *R. chamedryfolia* (Jovet-Ast & Bischler 1971). Both are probably strongly linked to the most humid habitats of Tunisia, namely the main riverbeds of permanent waterways.

*Riccardia chamedryfolia* is characterized by the distribution of oil bodies within the epidermal cells. At the thallus apex, the oil bodies spread over the entire width of the lobe. The branches do not have clear wings, with the marginal cells of the thallus barely protruding.

The previous report of *Riccardia chamedryfolia* by Ros *et al*. (2007) was based on collections published before 1962 and considered dubious because of a possible confusion with *R. multifida*. The present report can thus be considered the first reliable mention for Tunisia.

*Riccardia chamedryfolia* is a European boreo-temperate species widespread in Europe, including Macaronesia (Hodgetts & Lockhart 2020), also present in North Africa (Ros *et al*. 2013), Asia (Russia, Konstantinova *et al*. 2009; China, Piippo 1990; and Japan, Yamada & Iwatsuki 2006) and North America (Faubert 2015).

## Family Bartramiaceae Schwägr.
## Genus *Philonotis* Brid.

### ***Philonotis marchica*** (Hedw.) Brid.

Specimens examined. — **Tunisia**. Kroumiria, Jendouba Governorate, Delegation of Fernana: eastern side of Beni Mtir: M'hrida, sterile, 36°43'54.53"N, 08°43'33.33"E, 554 m a.s.l. (site 2019-18), 03.IV.2019, Ben Osman & Hugonnot (TUN[TUN2019-292]); Delegation of Aïn Draham: Dar Fatma, sterile, 36°49'06.92"N, 08°46'29.70"E, 783 m a.s.l. (site 2019-36), 05.IV.2019, Ben Osman & Hugonnot (TUN[TUN2019-293]).

Remarks

*Philonotis marchica* was collected in two peaty habitats: in a peaty meadow of *Eleocharis multicaulis* (Sm.) Desv., *Isoetes duriei* Bory and *Ranunculus hederaceus* L. (M'hrida), and on floating peat of the Dar Fatma peatland (see *Hygroamblystegium varium* var. *varium* for the site description). Elsewhere, this pioneer species is said to occur in open environments, on seepy roadbanks, in mires, on peat, on wet rocks, and river banks (Dismier 1907; Dierßen 2001). In Tunisia, it seems to be strictly linked to peatlands.

The species is characterized by its keeled lanceolate leaves, with an acute to acuminate apex, dentate with simple, sharp teeth. The margins are plane at the base. The nerve is percurrent or slightly excurrent, and papillose. Axillary ovate bulbils are present. The laminal cells constantly bear regular distal mamillae. Herbarium specimens of *Philonotis marchica* have been confused on several occasions with *P. capillaris* Lindb. or *P. fontana* (Hedw.) Brid. (Dismier 1907), two species that are probably more frequent than *P. marchica* in Tunisia (Jelenc 1955a, 1967).

*Philonotis marchica* is a European southern-temperate species widespread in the Mediterranean area, including Macaronesia, but rare in Northern Europe (Ros *et al*. 2013; Hodgetts & Lockhart 2020). It also occurs in Southwestern Asia (Kürschner & Frey 2020), and in North (Zales 1973; Griffin 2014) and South America (Delgadillo *et al*. 1995).

Family Brachytheciaceae Schimp.
Genus *Homalothecium* Schimp.

***Homalothecium meridionale***
(M.Fleisch. & Warnst.) Hedenäs

Specimens examined. — **Tunisia**. Mogods, Beja Governorate, Delegation of Nefza: Khorguelia, sterile, 37°04'35.24"N, 09°03'32.75"E, 93 m a.s.l. (site 2019-79), 09.IV.2019, Ben Osman & Hugonnot (TUN[TUN2019-288]); Tamra, sterile, 37°03'22.80"N, 09°05'45.42"E, 179 m a.s.l. (site 2019-80), 09.IV.2019, Ben Osman & Hugonnot (TUN[TUN2019-296]).

Remarks
*Homalothecium meridionale* was collected on soil, on the banks of a wadi (see *Fissidens fontanus* for the site description) (Khorguelia), and in an abandoned iron mine workings, and on earth-covered rocks (Tamra). It has been thoroughly studied in Portugal where it grows usually as an epiphyte and as a saxicolous species on limestone rocks (Sérgio *et al*. 2016). It seems to occupy a wide variety of unspecialized niches in distinct habitats.

The moss differs from *Homalothecium sericeum* (Hedw.) Schimp. mostly in the ornamentation of the seta, which is slightly rough in the upper ¼ (Hedenäs *et al*. 2014). The outer exostome ornamentation is diagnostic following Sérgio *et al*. (2016), but could not be verified owing to poor state of preservation of the peristome. Vegetative characters seem to be more difficult to interpret (branch leaves are usually widest at 15-30% above the leaf base; weak marginal denticulation at the alar region, with teeth that are rarely and only slightly bent outwards).

*Homalothecium meridionale* is a Mediterranean species, present also in Macaronesia (Hodgetts & Lockhart 2020). Recent phylogenetic analyses have shown that *H. sericeum s.l.* includes three molecular-based groups (*H. mandonii* (Mitt.) Geh., *H. meridionale* and *H. sericeum s.s.*; Hedenäs *et al*. 2014), and the detailed distribution of the two latter is incompletely known.

Family Bryaceae Schwägr.
Genus *Bryum* Hedw.

***Bryum gemmilucens*** R.Wilczek & Demaret

Specimens examined. — **Tunisia**. Kroumiria, Jendouba Governorate, Delegation of Aïn Draham: Majen Ma, sterile, 36°46'52"N, 08°47'24"E, 505 m a.s.l. (site 2019-6), 02.IV.2019, Ben Osman & Hugonnot (TUN[TUN2019-221, TUN2019-226]); Majen Sghaïer, sterile, 36°46'53.44"N, 08°47'12.32"E, 506 m a.s.l. (site 2019-10), 02.IV.2019, Ben Osman & Hugonnot (TUN[TUN2019-210]).

Remarks
*Bryum gemmilucens* was collected in a cork oak forest, on a wet lawn with *Isoetes histrix* Bory, *Ophioglossum lusitanicum* L. and *Radiola linoides* Roth (Majen el Ma), and on a peat meadow, bordering temporary ponds (Majen Sghaïer). This tiny species was previously neglected in Tunisia, probably because it is inconspicuous or has only recently received taxonomic recognition (Wilczek & Demaret 1976).

North African Mediterranean wetlands – semi-permanent lakes, peatlands and temporary pools – are habitats with high conservation value (Belouahem-Abed *et al*. 2011; Bouldjedri *et al*. 2011; Daoud-Bouattour *et al*. 2011; Rhazi *et al*. 2012). These fragile ecosystems are subject to strong pressures from overgrazing (Bouahim *et al*. 2010; Ferchichi-Ben Jamaa *et al*. 2014), which can cause severe trampling of the substrate. Paradoxically in Tunisia, wandering animals that scuff the superficial layer of soil can promote the spread of pioneer species such as *Bryum gemmilucens*, which are typically linked to open ground and bare soil (Demaret 1993). The occurrence of numerous long-lived gemmae buried in the substrate (Wilczek & Demaret 1976) may contribute to this species' success in such habitats.

*Bryum gemmilucens* is distinguished from similar species of the *B. dichotomum* complex by the occurrence of many very shiny yellowish-brown axillary gemmae with reduced apical appendages (Demaret 1993).

*Bryum gemmilucens* is primarily a European-western North American sub-oceanic temperate species, slightly penetrating to western Asia Minor and North Africa. It is scattered in Europe, including Macaronesia (Hodgetts & Lockhart 2020), present in Northwestern Africa (Ros *et al*. 2013), Southwestern Asia (Turkey; Kürschner & Frey 2020), and Northwestern America (California; Spence 1988).

***Bryum gemmiparum*** De Not.

Specimen examined. — **Tunisia**. Mogods, Bizerte Governorate, Delegation of Ghezala: Oued Zitoun, sterile, 37°00'16.00"N, 09°23'06.35"E, 389 m a.s.l. (site 2019-89), 10.IV.2019, Ben Osman & Hugonnot (TUN[TUN2019-222]).

Remarks
*Bryum gemmiparum* was found growing in a calcareous wadi bordered by riparian woods dominated by *Nerium oleander* L. and *Olea europaea* var. *sylvestris*, along tufa mini-dams obstructing water flows. In Europe, this moss grows in cushions on wet rocks running along watercourses (Demaret 1993), and on sunny, flat silty sandstone rocks in zones flooded by rivers (Holyoak 2014). Our specimen was collected in a comparable habitat. In Tunisia, violent periodic flooding may help maintain pioneer species such as *Bryum gemmiparum* by regularly denuding rock surfaces.

The species is immediately recognizable by the occurrence of several shiny gemmiform bulbils per axil. These are characteristically ovoid-obloid, foliated from the middle to the apex, attenuated and stipitate at the base.

*Bryum gemmiparum* is a Mediterranean-Atlantic species widespread in Europe, including Macaronesia (Hodgetts & Lockhart 2020; Holyoak 2021), and present in North Africa (Ros *et al*. 2013), Southwestern Asia (Kürschner & Frey 2020) and North America (Spence 2014).

Family Cleveaceae Cavers
Genus *Clevea* Lindb.

***Clevea hyalina*** (Sommerf.) Lindb.

Specimen examined. — **Tunisia**. Tunisian Dorsal, Siliana Governorate, Delegation of Siliana South: Jbel Serj, N side in the Park, sterile, 35°56'33.65"N, 09°32'57.28"E, 1018 m a.s.l. (site 2020-32), 12.III.2020, Ben Osman & Hugonnot (TUN[TUN2020-8]).

Remarks
*Clevea hyalina* grows in the Jbel Serj National Park on the north side of a calcareous cliff covered by rupicolous and grazing-resistant plants, on a sub-horizontal soil pocket. This strongly calcicolous species is known to occur in two distinct latitudinal belts, corresponding to two extremely dissimilar habitats. In the Arctic region, it occurs on polygons and solifluction slopes with such cold-adapted species as *Arnellia fennica* (Gottsche) Lindb. and *Sauteria alpina* (Nees) Nees (Schuster 1992). In warmer regions, at low elevations, it is usually restricted to steep, shaded, densely-forested slopes and cliff bases (Schuster 1992; Damsholt 2002), which remarkably, is the same ecological setting as the one observed in Tunisia. Associated species include xerothermophytes such as *Encalypta vulgaris* Hedw. and *Targionia hypophylla* L.

In this context, there are two major categories of strongly disjointed distributional ranges. Firstly, the so-called 'arctic-alpine taxa' occur both in boreo-arctic regions and at high elevations on the southernmost mountain ranges (Stevanović *et al*. 2009). Their disparate ranges are thought to be the product of the warming at the end of the last glaciation, which triggered both northward and upward migrations of the populations occupying previously the Europe's lowland steppes. Secondly, taxa at different levels of ploidy often present disjointed distributional ranges that could be associated with different ecological requirements. The proportion of polyploids in mosses also increases with latitude in North America as it does in Europe (Kuta & Przywara 1997), and this can be attributed to the heightened ability of polyploids to colonize northern deglaciated areas following the last glaciation (Brochmann *et al*. 2004). The disjointed distribution of *Clevea hyalina* may correspond to one (or both) of these patterns, but it is clearly the heritage of its ancient distribution in the Glacial Age.

The species is characterized by its long ventral hyaline scales projecting beyond the margins at the thallus apex, and the blackish ventral scales. The cells surrounding the pores are stellate with thickened radial walls. The Tunisian specimen was sterile.

Jovet-Ast & Bischler (1971) studied intensively the liverwort flora of Tunisia but failed to record *Clevea hyalina*. One hypothesis is that the species is quite difficult to spot in the field during the dry season (Rubasinghe 2011) or genuinely rare and localized, as indicated by the paucity of North African reports. The species reaches its southern distributional limit in the Maghreb. The species is also present in Algeria and Morocco (Ros *et al*. 2007).

*Clevea hyalina* is a circumpolar arctic-montane species occurring in Europe (Hodgetts & Lockhart 2020), North Africa (Bischler 2004; Ros *et al*. 2007), Central (Rubasinghe 2011) and North Asia (Borovichev & Bakalin 2013), and North America (Schuster 1992).

Family Fissidentaceae Schimp.
Genus *Fissidens* Hedw.

***Fissidens crassipes*** Wilson ex Bruch & Schimp.
subsp. ***warnstorfii*** (M.Fleisch.) Brugg.-Nann.

Specimens examined. — **Tunisia**. Kroumiria, Jendouba Governorate, Delegation of Fernana: Oued Zen, with sporophytes, 36°48'43.08"N, 08°50'41.33"E, 394 m a.s.l. (site 2019-20), 04.IV.2019, Ben Osman & Hugonnot (TUN[TUN2019-284]); Mogods, Beja Governorate, Delegation of Nefza: Oued Titria, with sporophytes, 36°57'51.33"N, 08°57'45.63"E, 71 m a.s.l. (site 2019-54), 07.IV.2019, Ben Osman & Hugonnot (TUN[TUN2019-285]); Bizerte Governorate, Delegation of Ghezala, Oued Zitoun, with sporophytes, 37°00'16.00"N, 09°23'06.35"E, 389 m a.s.l. (site 2019-89), 10.IV.2019, Ben Osman & Hugonnot (TUN[TUN2019-286]); High Tell, Beja Governorate, Delegation of Thibar: Djebba, with sporophytes, 36°28'15.20"N, 09°05'57.03"E, 620 m a.s.l. (site 2019-104), 13.IV.2019, Ben Osman & Hugonnot (TUN[TUN2019-397]).

Remarks
The populations of *Fissidens crassipes* subsp. *warnstorfii* were found growing on banks and on submerged rocks and roots in siliceous (Oued Zen, Oued Titria) and calcareous (Oued Zitoun) geological settings. The vascular vegetation consisted of riparian woods dominated by *Alnus glutinosa* (L.) Gaertn. and *Nerium oleander* on sandstone, and by *N. oleander* and *Olea europaea* var. *sylvestris* on limestone. In Tunisia, the subspecies is hydro-hygrophilic. At Oued Zitoun, it was encrusted with lime, which is also often the case in other parts of its range (Bruggeman-Nannenga 1982); it was also found along siliceous watercourses, as is the case in Europe.

*Fissidens crassipes* subsp. *warnstorfii* is characterized by leaves that narrow abruptly into an acute, obtuse or apiculate apex, with a border (at least in some portion of the lamina) that does not reach the apex. The apical part of the leaf is shorter than the sheathing part, and the limbidium is often lacking in dorsal and upper parts. It is a polymorphic subspecies (Potier de la Varde 1930; Bizot 1952) widespread elsewhere in North Africa (Algeria, Egypt, Libya, Morocco). It is considered a submediterranean subspecies present in South and Central Europe, including Macaronesia (Hodgetts & Lockhart 2020), in North Africa (Ros *et al*. 2013), and in Southwestern Asia (Kürschner & Frey 2020).

***Fissidens fontanus*** (Bach. Pyl.) Steud.

Specimen examined. — **Tunisia**. Mogods, Beja Governorate, Delegation of Nefza: Khorguelia, sterile, 37°04'35.24"N, 09°03'32.75"E, 93 m a.s.l. (site 2019-79), 09.IV.2019, Ben Osman & Hugonnot (TUN[TUN2019-287]).

Remarks
*Fissidens fontanus* was collected from a degraded riparian forest dominated by *Fraxinus angustifolia* Vahl, *Nerium*

*oleander*, *Quercus canariensis* and *Q. suber*, where it was growing below the mean low water level on rocks and on submerged roots. Its European habitat is comparable. *Fissidens fontanus* is an aquatic species that grows in a variety of situations (Godfrey 2005): in splash zones, on roots and stones, in water fountain tanks, and in river beds and irrigation canals.

*Fissidens fontanus* has been treated as a threatened species and included in the Red Lists of many European countries (Lilleleht 2001-2002; Kučera & Váňa 2003; Schnyder *et al*. 2004; Hodgetts 2015). However, according to Preston *et al*. (2014), the species has recently been found in many new sites, which suggests the absence of evidence of a significant general decline and, to the contrary, an apparent expansion of its range. Furthermore, the species is often found in man-made habitats (Piguet *et al*. 2007). In the Mediterranean region, including Tunisia, this species is found exclusively in natural habitats. Statements in the literature about its pollution tolerance are contradictory (Hill *et al*. 1992; Privitera & Puglisi 1994; Bednarek-Ochyra *et al*. 1996; Dierßen 2001; Godfrey 2005). In Tunisia, although there is no obvious sign of pollution, increasing anthropogenic pressures make pollution and eutrophication prominent risk factors.

The species is characterized by narrowly linear leaves. The conduplicate part of the leaf reaches between ¼-⅓ of its length.

This European temperate species is widespread in Europe, including Macaronesia (Hodgetts & Lockhart 2020), and present in North Africa (Ros *et al*. 2013), Southwestern Asia (Kürschner & Frey 2020), and in North (Pursell 2007a) and Central America (Pursell 2007b). It has been also reported from Australia and New Zealand, but these populations were recently assigned to *F. berterii* (Blockeel *et al*. 2014).

### ***Fissidens ovatifolius*** R.Ruthe

Specimens examined. — **Tunisia**. Kroumiria, Jendouba Governorate, Delegation of Fernana: Oued Zen, with sporophytes, 36°48'43.08"N, 08°50'41.33"E, 394 m a.s.l. (site 2019-20), 04.IV.2019, Ben Osman & Hugonnot (TUN[TUN2019-399]); Mogods, Beja Governorate, Delegation of Nefza: Cap Negro, with sporophytes, 37°06'05.06"N, 08°59'07.00"E, 10 m a.s.l. (site 2019-74), 09.IV.2019, Ben Osman & Hugonnot (TUN[TUN2019-297]); Khorguelia, with sporophytes, 37°04'35.24"N, 09°03'32.75"E, 93 m a.s.l. (site 2019-79), 09.IV.2019, Ben Osman & Hugonnot (TUN[TUN2019-295]); Mogods, Bizerte Governorate, Delegation Tinja: Jbel Ichkeul, with sporophytes, 37°08'04.52"N, 09°40'49.64"E, 65 m a.s.l. (site 2019-93), 11.IV.2019, Ben Osman & Hugonnot (TUN[TUN2019-428]).

Remarks

*Fissidens ovatifolius* was collected on well-drained detritic soil from a thermophilic coastal scrubland (Cap Negro), and from the banks of a wadi colonized by a *Quercus canariensis* and *Phillyrea media* L. woodland (Khorguelia). In the northern Mediterranean basin, this moss grows on calcareous and siliceous soils and in wet rock crevices, which is comparable to its ecology in Tunisia. It also grows on humid rocks at low altitudes (Guerra & Ederra 2015; IUCN 2019).

The species is characterized by leaves whose conduplicate part is half the length of the leaf, bordered by narrow, elongated cells at least in some part of the lamina. The dorsal lamina does not reach the leaf base.

*Fissidens ovatifolius* is a Mediterranean species found primarily albeit rarely in the Mediterranean basin, including Algeria and Morocco (Ros *et al*. 2013). This species is thought to be under-recorded and could be far more widespread than is currently known (IUCN 2019).

## Family Grimmiaceae Arn.
## Genus *Grimmia* Hedw.

### ***Grimmia dissimulata*** E.Maier

Specimens examined. — **Tunisia**. Mogods, Bizerte Governorate, Delegation of Tinja: Ichkeul National Park, with sporophytes, 37°08'21.00"N, 09°40'23.35"E, 20 m a.s.l. (site 2019-96), 11.IV.2019, Ben Osman & Hugonnot (TUN[TUN2019-251]); High Tell, Beja Governorate, Delegation of Thibar: Djebba, with sporophytes, 36°28'15.20"N, 09°05'57.03"E, 620 m a.s.l. (site 2019-104), 13.IV.2019, Ben Osman & Hugonnot (TUN[TUN2019-252]); Tunisian Dorsal, Kef Governorate, Delegation of Kalaat Senan, Table de Jughurta, N side, with sporophytes, 35°44'50.28"N, 08°22'44.33"E, 1090 m a.s.l. (site 2020-34), 13.III.2020, Ben Osman & Hugonnot (TUN[TUN2020-10]).

Remarks

*Grimmia dissimulata* was found growing on calcareous rocks and screes in deep semi-wooded valleys dominated by woods composed of olive and pistachio mastic trees (Jbel Ichkeul), on a cultivated slope (fig trees, pomegranate, etc.) and xerophytic scrubland (Djebba), and in a rupicolous calcicolous community (Table de Jughurta). In Tunisia, this strongly calcicolous species was observed mainly on scree in natural habitats, which corresponds to its known ecology in Europe (Maier 2002). However, it has also been reported from such artificial substrates as limestone walls and tombstones (Smith 2004; Lüth 2012).

The species bears a superficial resemblance to *Grimmia meridionalis* (Müll.Hal.) E.Maier, *G. lisae* De Not. and *G. trichophylla* Grev., but it can be easily distinguished by examining a transverse nerve section that shows 4 guide cells in a single layer at insertion and at the leaf base arranged (*G. lisae* has 6 guide cells at insertion, and *G. trichophylla* has additional guide cells that form an incomplete second band). From *G. meridionalis*, it is harder to set apart: *G. meridionalis* has two guide cells in the upper part of the leaf, as *G. dissimulata*, but these are elliptical and oblique, whereas they have a large more or less circular lumen that is not oblique in *G. dissumulata*.

*Grimmia dissimulata* is a European southern-temperate species widely distributed in the Mediterranean area (Ros *et al*. 2013). Scattered elsewhere in Europe (Hodgetts & Lockhart 2020), it also occurs in Western Asia (Kürschner & Frey 2020). Because it is a relatively newly described species (Maier 2002), its distribution is not yet completely known (Porley 2014).

Genus *Schistidium* Bruch & Schimp.

***Schistidium helveticum*** (Schkuhr) Deguchi

Specimens examined. — **Tunisia**. Tunisian Dorsal, Ben Arous Governorate, Delegation of Mornag: Jbel Ressas, northwestern side, 36°36'14.39"N, 10°19'56.07"E, 610 m a.s.l. (site 2020-50), 15.III.2020, Ben Osman & Hugonnot (TUN[TUN2020-11]); Jbel Ressas, north side, with sporophytes, 36°36'15.46"N, 10°19'57.79"E, 620 m a.s.l. (site 2020-51), 15.III.2020, Ben Osman & Hugonnot (TUN[TUN2020-12]).

Remarks

*Schistidium helveticum* was growing on calcareous rocks on the slopes and cliffs of the Jbel Ressas in a degraded woodland of arar trees (*Tetraclinis articulata* (Vahl) Masters).

In North Europe, this saxicolous moss grows on highly exposed calcareous rocks in warm sites (Blom 1996; Bosanquet 2014b). In southern regions, it also occurs in more shaded and humid localities, sometimes on north-facing slopes. The ecological situation of Tunisian populations is clearly representative of its general requirements in southern regions.

The species is characterized by its deep brown-blackish color with a golden sheen. The leaves are muticous or have a very short hyaline point in the perichaetial leaves. The lamina is partially bistratose and the cells are mostly isodiametric and slightly sinuose. The perichaetial leaves are enlarged, lanceolate, and do not conceal the entire capsule. The exothecial cells are mostly oblong. The peristome is well developed with long semi-perforate teeth.

*Schistidium helveticum* is a European southern-temperate species. It occurs commonly in Mediterranean Europe but is restricted to the lowlands in central Europe and seems to be absent from Eastern Europe (Blom 1996; Hodgetts & Lockhart 2020). It also occurs in North Africa (Ros *et al.* 2013) and Southwestern Asia (Kürschner & Frey 2020).

Family Lembophyllaceae Broth.
Genus *Isothecium* Brid.

***Isothecium myosuroides*** Brid.

Specimens examined. — **Tunisia**. Kroumiria, Jendouba Governorate, Delegation of Fernana: Oued Zen, fertile with sporophytes, 36°48'43.08"N, 08°50'41.33"E, 394 m a.s.l. (site 2019-20), 04.IV.2019, Ben Osman & Hugonnot (TUN[TUN2019-289]); Delegation of Aïn Draham: El Mérij, with sporophytes, 36°44'55.03"N, 08°41'13.80"E, 599 m a.s.l. (site 2019-35), 05.IV.2019, Ben Osman & Hugonnot (TUN[TUN2019-290]); Aïn Draham surroundings, spring 1951, A. Labbe (MHLCLF, herbarium F. Jelenc, ex herbarium A. Labbe: Kj 10613, box 107).

Remarks

*Isothecium myosuroides* was found growing in a riparian alder forest on soil, on the banks of a permanent wadi and on large earth-covered blocks, in Oued Zen and El Mérij, and on trees in a wet, deep valley with *Ilex aquifolium* L. and *Blechnum spicant* (L.) Sm., for the Jelenc herbarium specimen. In Western Europe, this species often occurs in forests and on woodland soils and rocks, the same ecological setting as in Tunisia. In Europe, it also grows in open habitats (grasslands) and screes (Rothero & Blockeel 2014; IUCN 2019).

This moss is characterized by its dendroid habit and irregular branching: the primary stem is prostrate and the secondary is decumbent to erect. Its leaves are imbricate, ovate, ovate-oblong or cordate-triangular, with a long, narrow acumen. The margins are dentate from the base to the apex or only in the upper part, and its alar cells are shortly rectangular or rhomboidal.

*Isothecium myosuroides* is a sub-oceanic boreo-temperate species widespread in Europe including Macaronesia (Hodgetts & Lockhart 2020), extending to North Africa (Ros *et al.* 2013), Southwestern Asia (Kürschner & Frey 2020) and North America (Bednarek-Ochyra *et al.* 1994).

Family Lophocoleaceae Vanden Berghen
Genus *Lophocolea* (Dumort.) Dumort.

***Lophocolea fragrans***
(Moris & De Not.) Gottsche, Lindenb. & Nees

Specimen examined. — **Tunisia**. Kroumiria, Jendouba Governorate, Delegation of Fernana: Oued Zen, with sporophytes, 36°48'43.08"N, 08°50'41.33"E, 394 m a.s.l. (site 2019-20), 04.IV.2019, Ben Osman & Hugonnot (TUN[TUN2019-52]).

Remarks

*Lophocolea fragrans* was collected in a wet valley on rocks on the banks of a permanent wadi surrounded by a riparian alder forest. In Europe, this species occurs frequently in shaded conditions in wet areas, on rocks, on tree roots and on woodland floors (Casas *et al.* 2009; Bosanquet 2014a). This is similar to the habitat in Tunisia where it is accompanied by a variety of strongly oceanic vascular plants such as *Athyrium filix-femina* (L.) Roth, *Carex remota* L. and *Osmunda regalis* L. (Braun-Blanquet 1953).

The species is characterized by its strong aroma of camphor. The leaves are succubous, 3-lobed, usually with strongly dentate margins. The Tunisian specimen has a perianth with one-celled projections on the surface, which recalls *Lophocolea muricata* (Lehm.) Nees. in this regard (Schuster 1980). Obviously, the variability of *L. fragrans* is underestimated.

*Lophocolea fragrans* is an oceanic southern-temperate species present in Europe including Macaronesia (Hodgetts & Lockhart 2020), North (Ros *et al.* 2013), Central and South Africa (Dauphin *et al.* 2017).

Family Orthotrichaceae Arn.
Genus *Orthotrichum* Hedw.

***Orthotrichum comosum*** F.Lara, R.Medina & Garilleti

Specimen examined. — **Tunisia**. Mogods, Beja Governorate, Delegation of Nefza: Khorguelia, with sporophytes, 37°04'35.24"N, 09°03'32.75"E, 93 m a.s.l. (site 2019-79), 09.IV.2019, Ben Osman & Hugonnot (TUN[TUN2019-291]).

Remarks

*Orthotrichum comosum* was found growing on the bark of *Quercus canariensis* on the banks of a wadi (see *Fissidens fontanus* for the site description). In Europe, this species is mainly an epiphyte that prefers a relatively exposed habitat. It occurs usually in open woods or on isolated trees (Medina *et al*. 2013).

The taxonomic revision of *Orthotrichum tenellum s.l.* by Medina *et al*. (2013) led to the recognition of six morphologically distinct species. Among those, *O. comosum* was described as a new species characterized by its linear or ovate-acute leaves, acute to acuminate but not channeled apices, never rounded or cucullate. The capsule is immersed, with a naked vaginula or only sparse hairs. The exostome teeth are triangular, not truncate and the OPL is ornamented with vermicular lines (it is papillose in *O. tenellum*). The calyptra bears an apical tuft of robust erect hairs (these are more regularly distributed in *O. tenellum*).

*Orthotrichum comosum* is a Mediterranean-Macaronesian species restricted to Europe including Macaronesia (Hodgetts & Lockhart 2020), and present in North Africa (Medina *et al*. 2013).

Family Riellaceae Engl.
Genus *Riella* Mont.

***Riella mediterranea***
Segarra, Puche, Sabovlj., M.Infante & Heras

Specimen examined. — **Tunisia**. Mogods, Bizerte Governorate, Delegation of Tinja: Ichkeul National Park, with sporophytes, 37°06'36.73"N, 09°40'55.83"E, 0 m a.s.l. (site 2019-102), 12.IV.2019, Ben Osman & Hugonnot (TUN[TUN2019-134]).

Remarks

*Riella mediterranea* was collected under *c*. 20-30 cm of water in a temporary marsh located in the northern part of the Ichkeul National Park. In the slightly brackish water, the liverwort was growing on dense clay mixed with *Chara galioides* DC., *C. oedophylla* Feldm., *Damasonium alisma* Mill. subsp. *bourgaei* (Coss.) Maire and *Ranunculus peltatus* Schrank subsp. *baudotii* (Godr.) Ball. In other areas, this species occurs in arid or semi-arid environments submerged in temporary ponds of fresh or slightly brackish waters (Segarra-Moragues *et al*. 2014), which fully corresponds to the ecology in Tunisia.

*Riella mediterranea* is characterized by its helicoid thallus wing. Female involucres are acuminate, and generally have more than 10 low discontinuous, wings that reach neither the tip nor the base of the involucres. The wing cell margins are formed by 1-3 rows of hyaline cells, which are densely spinose and have distal spines that are longer than 8 µm with proximal acute spines. In a recent taxonomic review of *Riella* subg. *trabutiella*, *R. mediterranea* was described as a new species (Segarra-Moragues *et al*. 2014). Accordingly, the Tunisian records of *R. cossoniana* Trab. (Ros *et al*. 2007) should be checked.

*Riella mediterranea* is a Mediterranean species. In Europe, this liverwort is reported only on the Iberian Peninsula and in Malta (Segarra-Moragues *et al*. 2014). It is also present in North Africa and Southwestern Asia (Segarra-Moragues *et al*. 2014). Because of its recent taxonomic recognition, its distribution remains to be clarified.

Family Seligeriaceae Schimp.
Genus *Seligeria* Bruch & Schimp.

***Seligeria acutifolia*** Lindb.

Specimen examined. — **Tunisia**. High Tell, Beja Governorate, Delegation of Thibar: Djebba, with sporophytes, 36°28'15.20"N, 09°05'57.03"E; 620 m a.s.l. (site 2019-104), 13.IV.2019, Ben Osman & Hugonnot (TUN[TUN2019-131]).

Remarks

*Seligeria acutifolia* was growing on cool, deeply shaded calcareous rocks in a recess at the base of a small cliff in a semi-wooded cultivated habitat (fig trees, pomegranate, etc.), along a small waterway. This is a famous site for tourists and shows obvious signs of habitat degradation (unauthorized dumping, water pollution, eutrophication, invasive plants species, etc.). In other areas, the species is present mainly on the bare surfaces of shaded, often north-facing, calcareous rocks. It occurs in wet habitats, at least in winter, but is not normally subject to dripping or running water (Corley & Blockeel 2014), which is identical to its setting in Tunisia.

This moss is characterized by its lanceolate-subulate leaves with entire margins arranged in more than three rows. The apices of the upper leaves are typically acute. The differentiated perichaetial leaves all reach the peristomate capsules and make the fertile plants look compact.

*Seligeria acutifolia* is a temperate European species. It is scattered through Europe (Hodgetts & Lockhart 2020) but also occurs in North Africa (Ros *et al*. 2013), Southwestern Asia (Turkey; Kürschner & Frey 2020) and North America (Vitt 2007). The first and only previous mention of the moss in Africa was in North Morocco by Jiménez *et al*. (2002). The predominantly holarctic genus *Seligeria* (Fedosov *et al*. 2017) is represented in Africa only by *S. acutifolia*, which is now known in the two localities in North Tunisia and North Morocco respectively. This suggests that this moss, while probably rare in North Africa, is likely to be present in Algeria.

Family Sphaerocarpaceae Heeg
Genus *Sphaerocarpos* Boehm.

***Sphaerocarpos europaeus*** Lorb.

Specimen examined. — **Tunisia**. Mogods, Bizerte Governorate, Delegation of Sejenane: Cap Serrat, with sporophyte, 37°12'17.00"N, 09°13'50.60"E, 3 m a.s.l. (site 2019-65), 08.IV.2019, Ben Osman & Hugonnot (TUN[TUN2019-68]).

Remarks

*Sphaerocarpos europaeus* was collected in a swampy willow (*Salix pedicellata* Desf.) grove on mud deposited on large aerial roots.

The species is characterized by its reddish-brown spore tetrads measuring 135-170 µm in diameter. The distal surface has 4-6 large alveoli. The papillose lamellae bordering the alveolae reach 10-13 µm high, and are spineless at the angles.

Ros *et al.* (2007) noted that Bischler (2004) reported *Sphaerocarpos texanus* (now considered as *S. europaeus*; Hodgetts *et al.* 2020) in Tunisia without any details of locality and that its presence therefore requires verification. The present mention can then be considered as the first reliable citation for Tunisia. *Sphaerocarpos europaeus* is a Mediterranean-Atlantic species presently known in Europe and North Africa (Ros *et al.* 2007).

## CONCLUSION

The discovery of 16 new taxa in Tunisia highlights the lack of knowledge of the current bryophyte flora, due in part to the marked ecological specialization of some species (*Clevea hyalina*, *Fissidens fontanus*, *Lophocolea fragrans*). However, it should be noted that some of the newly discovered species (*Grimmia dissimulata*, *Orthotrichum comosum*, *Riella mediterranea*) are recently described taxa that were unknown to botanists working in Tunisia until the mid-20th century.

Our investigations also make it possible to identify some taxa with high conservation or patrimonial interest. Some exist in habitats that are both rare and threatened in North Africa in general and in Tunisia in particular. This is particularly true for northern species characteristic of peatlands, such as *Aulacomnium palustre*, *Pallavicinia lyellii* (Hook.) Carruth., *Sphagnum auriculatum* and *S. subnitens* Russow & Warnst. (Muller *et al.* 2010, 2011; Ben Osman *et al.* 2021a). The peatlands of Dar Fatma and Camp du 18e in Kroumiria (North Tunisia) are good illustrations of this problem: these North African habitats are unique and are being severely damaged by illegal overgrazing and cutting.

Some other taxa with oceanic affinities are confined to the riverbeds of deep wet valleys of Kroumiria, in highly relictual situations: *Heterocladium flaccidum*, *Isothecium algarvicum*, *Lophocolea fragrans*, *Pseudotaxiphyllum elegans* and *Saccogyna viticulosa* (Hugonnot *et al.* 2020; Ben Osman *et al.* 2021c, pers. comm.). Such habitats clearly warrant protected status to ensure the sustainability of the restricted populations of these endangered bryophyte species.

Comparisons with Algeria and Morocco are difficult given unequal geographically heterogeneous pressures of prospection, but our discoveries suggest a floristic unity that existed originally throughout the Maghreb. There is an urgent need for further fieldwork and taxonomic research to improve our knowledge of the liverworts and mosses of North Africa, and particularly to specify their distribution and their conservation status.

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