



## CONTRIBUTION TO THE STUDY OF THE BRYOLOGICAL DIVERSITY OF THE BENSLIMANE REGION, MOROCCO

Imane Fadel<sup>1</sup>, Najib Magri<sup>2</sup>, Lahcen Zidane<sup>3</sup>, Oumaima Benharbit<sup>4</sup>, Allal Douira<sup>1</sup>, Nadia Belahbib<sup>1</sup> and Jamila Dahmani<sup>1\*</sup>

<sup>1</sup>Laboratory of Botany, Biotechnology and Plant Protection, Faculty of Sciences, Ibn Tofail University, BP 133, Kénitra 14000, Morocco.

<sup>2</sup>Forest Research Center, Water and Forests Department, Avenue Omar Ibn El Khattab, BP 763, Rabat-Agdal, 10050, Morocco.

<sup>3</sup>Laboratory of Biodiversity and Plant Resources, Faculty of Sciences, Ibn Tofail University, BP 133, Kénitra 14000, Morocco.

<sup>4</sup>Laboratory of Biochemistry, Biotechnology, Health and Environment, Faculty of Sciences, Ibn Tofail University, BP 133, Kénitra 14000, Morocco.

### Abstract

The study of the diversity and distribution of bryophytes in the Benslimane region is part of a main study aiming to promote this group of organisms in Morocco. Nine stations of nearly 400 m<sup>2</sup> each were invested in the study area located south of Rabat and east of Casablanca: Rouidat Dam, Ain Dakhla, Ain Sferjla, Skhour Benslimane, Benslimane Cork Oak forest on hydromorph soil, Sakhrat Nmira, Wadi Cherrat, Beniabid forest and Wadi Sferjla. The sampling adopted is systematic according to a sinusoidal path starting from the middle of the station and covering its area; it has been spread over the four seasons of 2014, 2015 and 2018. A harvest is carried out each time a bryophyte population is encountered in the explored area. The study revealed the existence of 80 species belonging to 28 families: 4 Hornworts, 17 Liverworts, and 59 Mosses. The most represented families are Pottiaceae (11 genera and 16 species) and Brachytheciaceae (9 genera and 16 species). The species that shows the most important overlap is *Targionia hypophylla* and the most frequently encountered species are *Targionia hypophylla* and *Lunularia cruciata*.

**Key words** : Bryophytes, Mosses, Hornworts, Liverworts, Biodiversity, Benslimane, Morocco.

### Introduction

The Benslimane region is a set of schistose, quartzite and limestone lowlands sloping towards the Atlantic coast to the west and gradually rising eastwards and southwards to an altitude of 500 m (Ghanem, 1970). The tectonic accident at Bled Zidania brings together the Lower Paleozoic and the Strunian-Carboniferous and is interpreted by Pique (1979) as a dexterous decrease (El Hassani, 1994). The Strunian and Upper Visean quartzites form anticlines and synclines in the NW-SE direction, turning to N-S as they approach shear zones (El Hassani, 1994).

The region hosts the Cork Oak forest (*Quercus suber*

\***Author for correspondence** : E-mail: jamdahmani@gmail.com

forest) whose conservation status varies from one place to another, a tetraclinaie very degraded in places and an oleolenticetum that replaces the Cork Oak forest in areas of high erosion. The diversity of the vegetation cover gives the region a clear ecotourism value, the vascular flora of the area identified by Tahri et al (2011) reaches 450 taxa spread over 257 genera and 66 families. Several studies have focused on the region's geological, faunistic and floristic aspects. Vegetation studies have focused mainly on angiosperms and gymnosperms; bryophytes and pteridophytes in the area are still poorly explored. To this end, we have set the objective of continuing exploration already started in the area that had invested four stations in the Benslimane region and which had led to the identification of 30 species of bryophytes (Fadel *et*

*al.*, 2016). Our objective is then to complete the list of species inventoried during previous explorations of the area by targeting the periods after the rainfall.

## Materials and Methods

### The study area

Benslimane province is part of the Moroccan coastal meseta and barely touches the western end of the central meseta (Rachdi *et al.*, 2017). It is criss-crossed by the wadis Korifla, Yekem, Mellah, Cherrat and Nfifikh which all flow into the Atlantic Ocean. The geological substrate is schistose, quartzitic or limestone. However, the shale substrates predominate, giving rise to rather neutral soils.

Meteorological data from the Benslimane station (Rachdi *et al.*, 2017) show that the temperature of the coldest month ( $m=6.8^{\circ}\text{C}$ ) is recorded during the month of January, the temperature of the warmest month ( $M=32.2^{\circ}\text{C}$ ) is recorded during the month of August and the annual average temperature is around  $19.5^{\circ}\text{C}$ . These data also show that the average precipitation volume recorded at the Benslimane station between 1935 and 2004 is 452 mm, the wettest year being 1968 with 802 mm and the least rainy year being 1994 with 155 mm. The dry period is generally 6 months and can be as long as 7 months in less rainy years. The Benslimane region

is characterized by a Mediterranean climate of a superior semi-arid type with a tendency to sub-humid, especially towards the coast (Rachdi *et al.*, 2011).

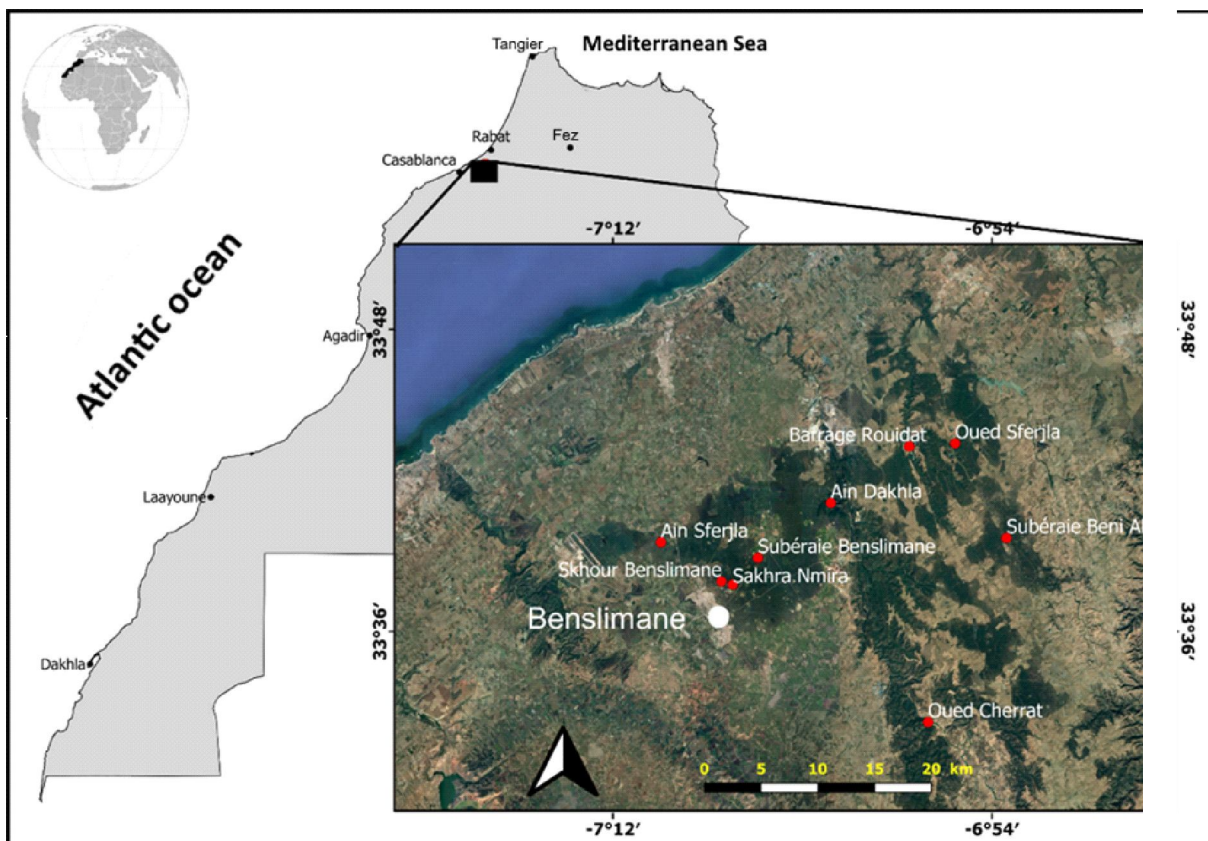
*Quercus suber* is located in the province of Benslimane in its southernmost limit on hydromorphic and fersialitic soil. The undergrowth is dominated by *Cistus monspeliensis* and *Cistus salviifolius* in clear Cork Oak forest and by *Rhus pentaphyllum*, *Arbutus unedo* and *Myrtus communis* in dense Cork Oak forest. The very degraded Cork Oak forest are completely therophytized with a clear dominance of *Asphodelus microcarpus*. The Cork Oak forest is replaced by the Oleo-lenticetum when the soil is less evolved and more eroded. The tetracliniae occupies the sides of mounds with relatively steep slopes and undeveloped soils.

Private estates have developed at the expense of the increasingly shrinking forest area. The quarries located in the area also contribute to the decline of forest species in the region.

The area is rich in temporary pools commonly known as Dayas, whose total flora is estimated at 300 taxa by Rhazi (2001).

### Sampling

Nine stations have been invested in the region (Fig.



**Fig. 1:** Location map of explored stations in the Benslimane area.

**Table 1:** Description of the studied stations in the Benslimane region.

Stations	Latitude	Longitude	Altitude (m)	Substrate	Vegetation
S1: Rouidat Dam	33°43'24"	-6°57'57"	169	Limestone	<i>Olea europea</i> , <i>Lavandula multifida</i>
S2: Ain Dakhla	33°41'09"	-7°01'41"	169	Limestone	<i>Vitex agnus castus</i> , <i>Nerium oleander</i>
S3: Ain Sferjla	33°39'35"	-7°09'45"	203	Quartzite	<i>Quercus suber</i> (25%), <i>Cistus monspeliensis</i>
S4: Wadi Cherrat	33°32'26"	-6°57'04"	213	Shales	<i>Vitex agnus castus</i> , <i>Fraxinus excelsior</i>
S5: Wadi Sferjla	33°43'31"	-6°55'46"	239	Shales	<i>Arbutus unedo</i> , <i>Pistacia lentiscus</i>
S6: Beniabid Cork Oak forest	33°39'46"	-6°53'20"	344	Shales	<i>Quercus suber</i> (25%), <i>Cistus salviifolius</i>
S7: Skhour Benslimane	33°38'02"	-7°06'53"	271	Quartzite	<i>Quercus suber</i> (50%), <i>Rhus tripartitum</i>
S8: Sakhra Nmira	33°37'54"	-7°06'20"	261	Quartzite	<i>Quercus suber</i> (50%), <i>Rhus pentaphyllum</i>
S9: Benslimane Cork Oak forest	33°38'58"	-7°05'09"	258	Shales	<i>Quercus suber</i> (75%), <i>Myrtus communis</i>

1): Skhour Benslimane, Rouidat Dam, Ain Dakhla, Ain Sferjla, Sakhra Nmira, Wadi Cherrat, Beniabid Forest, Benslimane Cork Oak forest on hydromorph soil and Wadi Sferjla. These stations were chosen to cover the different plant formations in the area, all of which are spontaneous and natural. The total number of surveys taken at the nine stations is around 600 stops. The explorations complementary to those carried out in 2014, 2015 and 2016 took place in spring 2018. These explorations were scheduled just after the rainfall.

Table 1, above, gives the geographical position of the explored stations, their substrate, their soil type and the species of the plant formation. The diversity of vascular plants at each station is detailed as follows, limited to the most remarkable species:

- Skhour Benslimane Station: *Quercus suber*, *Arbutus unedo*, *Cistus monspeliensis*, *Lavandula stoechas*, *Cistus salviifolius*, *Rhus tripartitum*, *Rhus pentaphyllum*, *Olea europea*, *Asplenium ceterach*.
- Station Rouidat Dam : *Olea europea*, *Pistacia lentiscus*, *Myrtus communis*, *Astragalus lusitanicus*, *Chamaerops humilis*, *Rhus pentaphyllum*, *Tamarix gallica*, *Lavandula multifida*, *Thymus broussonitii*, *Teucrium frutescens*.
- Ain Dakhla Station: *Vitex agnus-castus*, *Nerium oleander*, *Fraxinus excelsior*, *Phillyrea angustifolia*, *Crataegus oxyacantha*, *Clematis cirrhosa*, *Selaginella reptans*, *Asplenium ceterach*, *Anogramma leptophylla*, *Brionia dioica*.
- Ain Sferjla Station: *Quercus suber*, *Pistacia lentiscus*, *Cistus monspeliensis*, *Cistus salviifolius*, *Olea europea*, *Myrtus communis*, *Rhus pentaphyllum*, *Crataegus oxyacantha*, *Chamaerops humilis*, *Ruscus acutus*, *Asplenium ceterach*, *Anogramma leptophylla*.
- Benslimane Subterranean Station: *Quercus suber*, *Myrtus communis*, *Cistus monspeliensis*, *Cistus*

*salviifolius*, *Rhus pentaphyllum*.

- Sakhra Nmira Station: *Quercus suber*, *Rhus Pentaphyllum*, *Rhus tripartitum*, *Lavandula stoechas*, *Cistus salviifolius*, *Cistus monspeliensis*.
- Wadi cherrat Station: *Fraxinus excelsior*, *Vitis vinifera*, *Vitex agnus castus*, *Nerium oleander*, *Crataegus oxyacantha*.
- Beniabid Cork Oak forest Station: *Quercus suber*, *Cistus monspeliensis*, *Cistus salviifolius*, *Myrtus communis*, *Olea europea*, *Rhus pentaphyllum*.
- Wadi Sferjla Station: *Arbutus unedo*, *Pistacia lentiscus*, *Olea europea*.

The collection of bryophyte samples is carried out according to a systematic sampling; a sinusoidal path is then followed, starting from the middle of the station and covering an area of nearly 400 m<sup>2</sup>. This area was considered sufficient to collect all the species present in the station.

Sampling was conducted in the spring, summer, fall and winter of 2014 and 2015, and spring 2016; during spring 2018, additional sampling was conducted to fill gaps in the first list (Fadel *et al.*, 2016). Each time a bryophyte population is observed, a few individuals are sampled; thus nearly 600 stops have been made. The samples, collected with their substrate, were as complete as possible and eventually included the fertile elements of the plant (sporophyte, perianth). The collected samples were kept in a herbarium; for this purpose, they were dried in the open air and then placed in paper envelopes with all the information relating to the harvest (date, station, geographical coordinates and substrate). Identification was carried out with the help of documents such as (Augier, 1966), (Smith, 1990 and 2004), (Coudreuse, 2005), (Casas *et al.*, 2006) and (Casas *et al.*, 2009). The nomenclature adopted follows the catalogues of Ros *et al.*, 1999 and Ros *et al.*, 2013.





**Fig. 2:** A: *Targionia hypophylla* growing in the cracks of boulders in the Benslimane Cork Oak forest. B: Young individuals of *Phymatoceros bulbiculosus* on siliceous hydromorphic soil in the Benslimane Cork Oak forest. C: *Riccia bicarinata* harvested on boulders at Sakhrat Nmira. D: *Physcomitrium pyriforme* harvested at the entrance of Ain Sferjla on earthy soil. E: *Targionia hypophylla saxicola* harvested from the station of Wadi Cherrat in mixture with *Trichostomum crispulum*. F: *Riccia cilifera*, soil harvested in the Benslimane Cork Oak forest on Sakhrat Nmira. G: *Bryum palescens* harvested from the Wadi Cherrat station. H: *Oxymitra incrassata* harvested on hydromorph soil in the Benslimane Cork Oak forest with *Fossombronia angulosa*.

## Results and Discussion

The determination of the samples collected allowed us to draw up a list of 80 species of bryophytes: 59 species of mosses belonging to 14 families, 17 species of Liverworts belonging to 11 families and 4 species of Hornworts belonging to 3 families. Among the inventoried species, *Lunularia cruciata* and *Targionia hypophylla* are the most widespread; they spread over rocky walls and wet soil.

The list of bryophytes found by class and family is as follows:

### Antheropsida Class

#### Order of Anthocerotales

##### Fam. Anthocerotaceae

*Anthoceros agrestis* Paton. Terricolous, Benslimane Cork Oak forest on hydromorph soil.

*Anthoceros punctatus* L. Terricolous, Ain Sferjla and Wadi Sferjla.

#### Order of Notothyladales

##### Fam. Nothothyladaceae

*Phaeoceros laevis* L. Terricolous, Benslimane Cork Oak forest on hydromorph soil.

#### Order of Phymatocerotals

##### Fam. Phymatocerotaceae

*Phymatoceros bulbiculosus* (Brot.) Prosk. (Fig. 2B). Terricolous, Benslimane Cork Oak forest on hydromorph soil.

### Marchantiopsida Class

#### Order of Marchants

##### Fam. Marchantiaceae

*Marchantia polymorpha* L. Terricolous on wet soil in Sakhrat Nmira.

##### Fam. Targioniaceae

*Targionia hypophylla* L. (Fig. 2 A and E). Terricolous and saxicolous, Ain Sferjla; terricolous, Wadi Cherrat, Beniabid forest, Sakhrat Nmira, Benslimane Cork Oak forest on hydromorphic soil and Ain Dakhla; saxicolous, Roudat Dam and Skhour Benslimane.

##### Fam. Aytoniaceae

*Reboulia hemispherica* (L.) Raddi. Terricolous and saxicolous, Ain sferjla and Wadi Cherrat; terricolous, Sakhrat Nmira, Benslimane Cork Oak forest on hydromorph soil, Beniabid forest and Ain Dakhla.

##### Fam. Lunulariaceae

*Lunularia cruciata* (L.) Dum. Terricolous and

saxicolous in all the visited stations. On rocks and shady wet ground at the edge of waterfalls and small water surfaces. It is very frequently encountered with a high coverage in all stations.

##### Fam. Oxymitraceae

*Oxymitra incrassata* (Broth.) Sergio & Sim-Sim. (Fig. 2H). Terricolous, Benslimane Cork Oak forest on hydromorph soil.

##### Fam. Corsiniaceae

*Corsinia coriandrina* (Spreng.) Lindb. Terricolous, Wadi Sferjla and Sakhrat Nmira.

##### Fam. Ricciaceae

*Riccia bicarinata* Hoffm. (Fig. 2C). Terricolous, Sakhrat Nmira.

*Riccia perennis* Steph. Terricolous, Sakhrat Nmira, Benslimane Cork Oak forest on hydromorph soil.

*Riccia bifurcata* Hoffm. Terricolous, Wadi Sferjla.

*Riccia sorocarpa* Bisch. Terricolous, Benslimane Cork Oak forest on hydromorph soil and Beniabid forest.

*Riccia lamellosa* Raddi. Terricolous, Sakhrat Nmira.

*Riccia cilifera* Link ex Lindenb. (Fig. 2F). Terricolous, Sakhrat Nmira.

#### Order of the Jungermanniales

##### Fam. Frullaniaceae

*Frullania dilatata* (L.) Dum. Terricolous, Skhour Benslimane, Ain Dakhla; Benslimane Cork Oak forest on hydromorph soil.

#### Order of Metzgeriales

##### Fam. Fossombroniaceae

*Fossombronia pusilla* (L.) Nees. Saxicolous, Roudat Dam, Ain Dakhla and Skhour Benslimane. It is mainly confined to the wet crevices of the limestone blocks.

*Fossombronia angulosa* (Dicks.) Raddi. Terricolous, Benslimane Cork Oak forest on hydromorph soil.

##### Fam. Metzgeriaceae

*Metzgeria furcata* (L.) Dumort. Terricolous, Sakhrat Nmira.

#### Order of the Jungermanniales

##### Fam. Plagiochilaceae

*Plagiochila porelloides* (Nees) Lindenb. Terricolous, Benslimane Cork Oak forest on hydromorph soil.

### Class: Bryopsida



**Order. Hypnales****Fam. Amblystegiaceae**

*Amblystegium varium* (Hedw.) Lindb. Terricolous, Wadi Cherrat on wetland.

*Cratoneuron filicinum* (Hedw.) Roth. Terricolous, Wadi Sferjla.

**Fam. Brachytheciaceae**

*Rhynchostegiella curviseta* (Brid.) Limpr. (*Rhynchostegium curvisetum* Schimp., *Eurhynchium curvisetum* (Brid.) Husn.). Saxicolous on limestone shaded rocks and terricolous wet soil à Ain Dakhla ; mixed with *Lunularia cruciata*, Roudat Dam, Sakhrat Nmira.

*Scorpiurum circinatum* (Brid.) Fleisch. Loeske (*Eurhynchium circinatum* (Brid.) Schimp.). Saxicolous and epiphyte, Ain Dakhla, Roudat Dam, Ain Sferjla, and Wadi Sferjla.

*Rhynchostegiella tenella* (Dicks) Limp. Epiphyte and saxicolous, limestone blocks and base of *Quercus suber* trunks, Beniabid forest, Benslimane Cork Oak forest on hydromorph soil.

*Rhynchostegium megapolitanum* (Bland. ex F. Weber & D. Mohr) Schimp. (*Eurhynchium megapolitanum* (Bland ex F. Weber & D. Mohr) Milde). Saxicolous and epiphyte, Wadi Cherrat, Sakhrat Nmira.

*Rhynchostegium confertum* Dicks. Saxicolous and epiphyte, Ain dakhla and Skhour Benslimane.

*Brachythecium Rutabulum* Hedw. Terricolous, epiphyte, Benslimane Cork Oak forest on hydromorph soil, and Ain Dakhla.

*Riparian brachythecium* B.S.G. Terricolous, Ain Sferjla on the wet edge of the temporary daya.

*Brachythecium velutinum* Hedw. Epiphyte and saxicolous, Ain Dakhla, Wadi Sferjla and Beniabid forest.

*Brachythecium albicans* (Hedw.) Bruch, Schimper & W. Gumbel. Saxicolous, Roudat Dam and Sakhrat Nmira.

*Isothecium myosiroides* Brid. Epiphyte and saxicolous, Ain Sferjla and Roudat Dam.

*Homalothecium lutescens* (Hedw.) Schimp. Saxicolous on quartzite in Ain Sferjla.

*Homalothecium sericeum* (Hedw.) Bruch, Schimp. & W. Gumbel. Epiphyte and saxicolous in Wadi Cherrat.

*Eurhynchium hians* (Hedwig) Loeske. Terricolous, Benslimane Cork Oak forest on hydromorph soil.

*Cirryphyllum crassinervium* (Tayl.) Loeske and Flesch. Epiphyte and saxicolous, Skhour of Benslimane;

saxicolous, Ain Dakhla.

*Pseudoscleropodium purum* (Hedw.) M. Fleisch. Epiphyte on cork oak trees of the Benslimane Cork Oak forest on hydromorph soil, Beniabid forest and Ain Sferjla.

*Eurhynchium praelongum* (Hedw.) Schimp. Epiphyte on cork oak trees, Ain Sferjla, Wadi Sferjla. Terricolous, Roudat Dam.

**Fam. Leucodontaceae**

*Antitrichia californica* Sull... Epiphyte on cork oak tree and saxicolous on quartzite boulder, Ain Sferjla.

*Pterogonium Gracile* (Hedw.) Sm., Epiphyte and saxicolous, Skhour Benslimane and Ain Dakhla.

**Fam. Hypnaceae**

*Hypnum cupressiform* Hedw. Epiphyte on the basis of the trunk of *Fraxinus angustifolia*, Ain Dakhla.

**Order: Bryales****Fam. Bryaceae**

*Bryum capillare* Hedw. Terricolous, saxicolous and epiphyte on cut wood or on limestone shaded or on wet soil à Ain Sferjla, Ain Dakhla, Skhour Benslimane, Beniabid forest and Wadi Cherrat.

*Bryum radiculosum* Brid (*Bryum murale* Wils, *Bryum murorum* (Schimp.) Berk, *Bryum eurythrocarpum* v. *murorum* Schimp). Saxicolous, on moist limestone rocks in Wadi Cherrat.

*Bryum caespiticium* Hedw. (*Bryum badium* (Brid.) Schimp., *Bryum comense* Schimp.). Saxicolous on the limestone rocks and terricolous, Wadi Cherrat.

*Bryum mural* Wilson ex Hunt. Saxicolous, Roudat Dam.

*Bryum argenteum* Hedw. Saxon, Skhour Benslimane.

*Bryum palescens* Schleich. ex Schwaegr. (Fig. 2G). Terricolous. Wadi Cherrat.

*Bryum pseudotriquetrum* (Hedw.) Schw. Terricolous, wet soil formed on quartzite block at Wadi Sferjla.

**Fam. Mielichhoferiaceae**

*Epipterigyum tozeri* (Grev.) Lindb. Saxicolous, Skhour Benslimane and Benslimane Cork Oak forest on hydromorph soil.

**Fam. Bartramiaceae**

*Bartramia pomiformis* Hedw. Saxicolous and soil, Beniabid forest, Roudat Dam, Wadi Sferjla.

**Fam. Mniaceae**

*Mnium hornum* Hedw. Soil on moist clayey soil, Ain dakhla Cave.

*Plagiomnium undulatum* (Hedw.) T.J. Kop....  
Terricolous on wet soil, Ain Dakhla Cave.

**Order: Dicranales**

**Fam. Fissidentaceae**

*Fissidens bryoides* Hedw (*Hypnum bryoides* (Hedw.) L. ex With.). Saxicolous et terricolous, Ain Dakhla cave, on wet limestone rocks and wet soils.

*Fissidens incurvus* Rohl. Terricolous and saxicolous, in Ain Dakhla Cave. The predominant species in the cave.

**Fam. Ditrichaceae**

*Ditrichum flexicaule* (Schwägr.) Hampe. Terricolous and saxicolous, Beniabid forest, on wet soil and limestone rocks.

**Fam. Dicranaceae**

*Dicranella varia* (Hedw.) Schimp. Soil on the banks of the Wadi Cherrat river on clayey soil. Met in association with *Aloina ambigua*.

**Order of Funariales**

**Fam. Funariaceae**

*Funaria hygrometrica* Hedw. Terricolous, saxicolous forest of Beniabid, saxicolous, Ain Dakhla, Skhour Benslimane, Wadi Cherrat and Wadi Sferjla.

*Enthostodon templetonii* (Sm.) Schwagr. Saxicolous, Wadi Cherrat; Terricolous, Ain Dakhla in the Cave.

*Entosthodon fascicularis* (Hedw.) Mull. Hal. Saxicolous, Ain Dakhla at the Cave; soil, Rouidat Dam.

*Physcomitrium pyriforme* (Hedwig) Hampe. (Fig. 2D). Terricolous, entrance to Wadi Sferjla.

**Order: Pottiales**

**Fam. Pottiaceae**

*Pottia truncata* (Hedw.) Mitt. Terricolous, Benslimane Cork Oak forest on hydromorph soil, Sakhlat Nmira.

*Barbula unguiculata* (Huds.) Hedw. Saxicolous and soil, Ain Dakhla, Skhour Benslimane, Wadi Sferjla, Ain Sferjla; epiphyte on *Quercus suber*, Ain Sferjla.

*Didymodon tophaceus* (Brid) (*Trichostomum tophaceum* Brid, *Barbula tophacea* (brid) Mitt). Saxicolous and terricolous, Ain Sferjla, Ain Dakhla, at the edge of water surface.

*Eucladium verticillatum* (Brid.) Bruch & Schimp. (*Weisia verticillata* Brid., *Mollia verticillata* Lindb). Saxicolous, Ain Sferjla, Skhour Benslimane.

*Didymodon vinealis* (Brid.) R.H.Zander. Epiphyte, Beniabid forest, Sakhlat Nmira and Wadi Sferjla.

*Didymodon rigidulus* Hedw. Taxon newly observed

in the region, terricolous, Sakhlat Nmira, Rouidat Dam.

*Didymodon luridus* Hornsch. Saxicolous, Wadi Cherrat.

*Tortula inermis* (Brid.) Mount. Terricolous, Beniabid forest.

*Pleurochaete squarrosa* (Brid.) Lindb. Terricolous, Wadi Cherrat, Wadi Sferjla, Rouidat Dam and Ain Dakhla; saxicolous, Ain Sferjla on quartzite.

*Timmiella barbuloidea* (Brid) Monk. Saxicolous and soil, on moist limestone rocks and moist soil, Ain Sferjla, Benslimane Cork Oak forest on hydromorph soil, Rouidat Dam.

*Tortella nitida* (Lindb.) Broth. Saxicolous, on shaded limestone rocks, Sakhlat Nmira, Wadi Cherrat.

*Tortella tortuosa* (Hedw.) Saxicolous limestone, Skhour Benslimane, Ain Sferjla on quartzite.

*Tortula muralis* Hedw. Saxicolous, Skhour Benslimane, Wadi Cherrat and Wadi Sferjla.

*Trichostomum crispulum* Bruch. Terricolous and saxicolous, Beniabid forest, limestone rocks are found in the cave of Ain Dakhla.

*Aloina ambigua* (Bruch & Schimp.) Limpr., Terricolous, Wadi Cherrat on clay soil; found in association with *Lunularia cruciata*.

*Weissia controversial* Hedw., Terricolous, Ain Dakhla, Rouidat Dam.

**Order: Grimmiales**

**Fam. Grimmiaceae**

*Grimmia trichophylla* Grev, Epiphyte, Ain Dakhla on the basis of the trunks of *Fraxinus angustifolia* and *Quercus Suber*. Terricolous, Rouidat Dam.

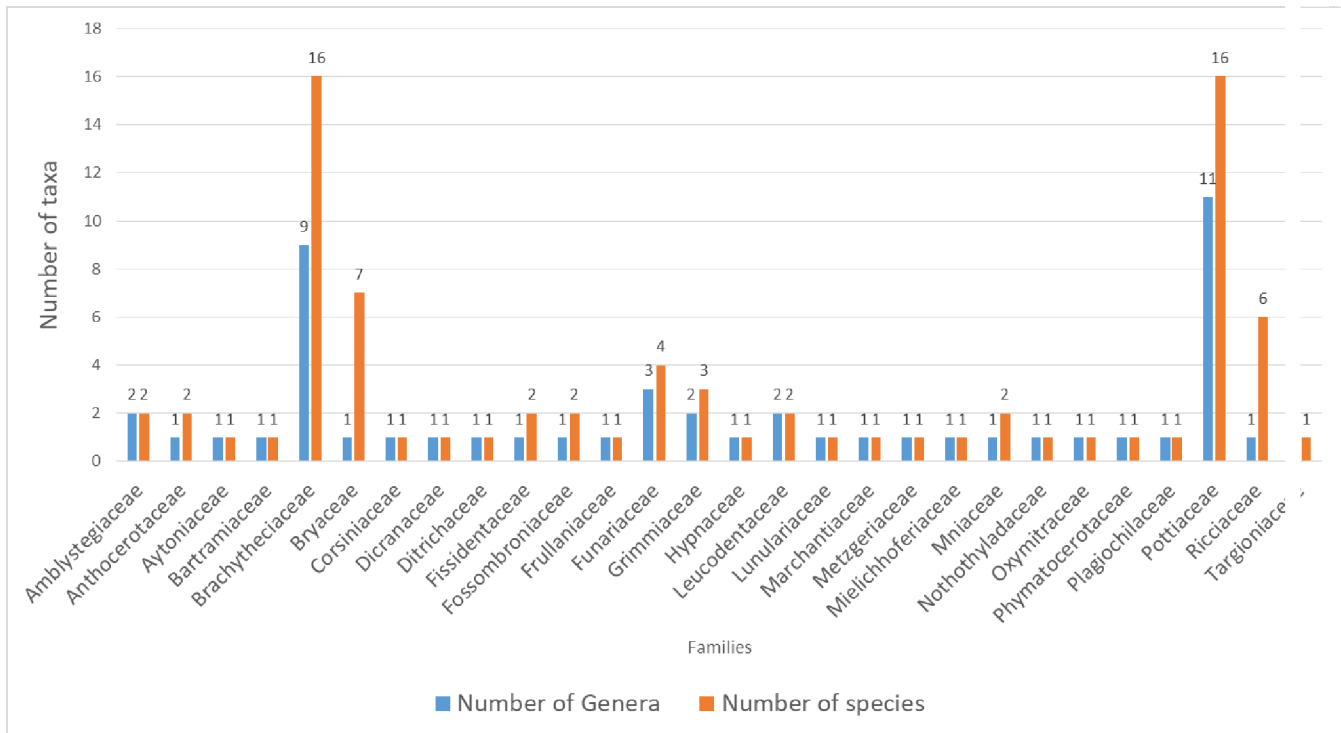
*Grimmia pulvinata* (Hedw.) sm. Epiphyte, Ain Sferjla on a trunk of *Quercus Suber*.

*Schistidium apocarpum* (Hedwig) Bruch & Schimper, Bryol. Saxicolous, Skhour Benslimane on quartzite.

**Floral analysis of the list of bryophytes observed in the study area**

The bryological flora of the Benslimane region is represented by 80 species divided into 3 phylums, that of the Liverworts with 21.25%, that of the Mosses with 73.75% and the phylum of the Hornworts with 5%.

Mosses are dominant with 59 species (73,75%) grouped in 14 families which the most important are Pottiaceae and Brachytheciaceae with 16 species chacune. On the other hand, liverworts are represented by 17 species grouped in 11 families; the most dominant



**Fig. 3:** Representation of families by number of genera and species in the Benslimane region.

of which is Ricciaceae, with 6 species followed by Fossombroniaceae with 2 species.

Hornworts are represented by 4 species, and 3 families; it is the Anthocerotaceae family which contains 2 species.

Fig. 3 shows that the family Pottiaceae (20%), represented by 11 genera and 16 species and the family Brachytheciaceae (20%) represented by 9 genera and 16 species are the most diversified in the region. The Bryaceae family, of which the genus *Bryum* is the only one observed, is represented by 7 species. Ricciaceae are materialized in the study area by the genus *Riccia* and 6 species. Funariaceae are represented by 3 genera and 4 species, Grimmiaceae by 2 genera and 3 species, Amblystegiaceae and Leucodontaceae are both represented by 2 genera and 2 species, Anthocerotaceae, Fissidentaceae, Fossombroniaceae, and Mniaceae are all four represented by one genus and two species. Finally, the families of Hypnaceae, Bartramiaceae, Ditrichaceae, Lunulariaceae, Targioniaceae, Aytoniaceae, Frullaniaceae, Plagiochylaceae, Oxymitracaceae, Corsiniaceae, Metzgeriaceae, Marchantiaceae, Nothothyladaceae, Dicranaceae, Mieliichhoferiaceae and Phymatocerotaceae are all represented by one genus and one species.

#### Specific richness by explored station

Each explored station is presented with its list of

bryophyte species. The exclusive ones at the station are bolded.

The station Roudat Dam (S1) contains 12 species of Bryophytes: *Brachythecium albicans*, *Bryum murale*, *Entosthodon fascicularis*, *Fossombronia pusilla*, *Isothecium myosiroides*, *Lunularia cruciata*, *Pleurochaete squarrosa*, *Rhynchostegiella curviseta*, *Scorpirium circinatum*, *Targionia hypophylla*, *Timmia barbuloidea*, *Weissia controversa*. The plant formation in the station is mainly organised by *Olea europea* and *Lavandula multifida* and takes place on a limestone substrate. The slope around the dam is quite steep, reaching 45° in places and the soil is dry for most of the year, which would explain the low specific richness in Bryophytes in the area.

The station of Ain Dakhla (S2) contains 25 species: *Barbula unguiculata*, *Brachythecium rutabulum*, *Brachythecium velutinum*, *Brachythecium velutinum*, *Bryum capillare*, *Cirriphyllum crassinervium*, *Didymodon tophaceus*, *Entosthodon templetonii*, *Entosthodon fascicularis*, *Fissidens bryoides*, *Fissidens incurvus*, *Fossombronia pusilla*, *Frullania dilatata*, *Funaria hygrometrica*, *Grimmia trichophylla*, *Hypnum cupressiforme*, *Lunularia cruciata*, *Plagiomnium undulatum*, *Pleurochaete squarrosa*, *Pterogonium gracile*, *Reboulia hemispherica*, *Rhynchostegiella curviseta*, *Rhynchostegium*



*confertum*, *Scorpirium circinatum*, *Targionia hypophylla*, *Weissia controversa*. It is a wetland whose vegetation is dominated by *Vitex agnus castus* and *Nerium oleander*. On either side of the Wadi Cherrat which crosses the area, the soil is humid for a large part of the year and rich in alluvium. This would explain the specific Bryophyte richness observed in the station.

The station of Ain Sferjla (S3) contains 23 species: *Aloina ambigua*, *Anthoceros punctatus*, *Antitrichia californica*, *Barbula unguiculata*, *Brachythecium rivulare*, *Bryum capillare*, *Bryum pseudotriquetrum*, *Didymodon tophaceus*, *Epipterygium tozeri*, *Eucladium verticillatum*, *Eurhynchium praelongum*, *Grimmia pulvinata*, *Homalothecium lutescens*, *Isothecium myosiroides*, *Lunularia cruciata*, *Pleurochaete squarrosa*, *Pseudoscleropodium purum*, *Reboulia hemispherica*, *Scorpirium circinatum*, *Targionia hypophylla*, *Timmiella barbuloidea*, *Tortella tortuosa*, *Trichostomum crispulum*. It is a wetland occupied by a temporary pond whose edges in winter and spring are occupied by a pteridophyte: *Isoetes velata*. The plant formation around the pond is a Cork Oak forest whose density does not exceed 25%, the undergrowth is dominated by *Cistus monspeliensis*. The shade provided by vascular plants favours the proliferation of soil bryophytes. Saxicolous flourish in the crevices of quartzite blocks where moisture accumulates.

The station of Wadi Cherrat (S4) contains 17 species: *Amblystegium varium*, *Bryum caespitium*, *Bryum capillare*, *Bryum paescens*, *Bryum radiculosum*, *Dicranella varia*, *Didymodon luridus*, *Enthostodon templetonii*, *Funaria hygrometrica*, *Homalothecium sericeum*, *Lunularia cruciata*, *Pleurochaete squarrosa*, *Reboulia hemispherica*, *Rhynchostegium megapolitanum*, *Targionia hypophylla*, *Tortella nitida*, *Tortula muralis*. The station is located in an incised area where the substrate is shale. The ripisylve is dominated by *Vitex agnus castus* and *Fraxinus excelsior*. The bryophyte species that develop in the area have significant cover, especially *Lunularia cruciata* and *Targionia hypophylla*.

The station of Wadi Sferjla (S5) contains 15 species: *Anthoceros punctatus*, *Barbula unguiculata*, *Brachythecium velutinum*, *Corsinia coriandrina*, *Cratoneuron filicinum*, *Didymodon vinealis*, *Eurhynchium praelongum*, *Funaria hygrometrica*, *Lunularia cruciata*, *Mnium hornum*, *Physcomitrium pyriforme*, *Pleurochaete squarrosa*, *Riccia bifurca*, *Scorpirium circinatum*, *Tortula muralis*. The plant formation is a matorral with *Pistacia lentiscus* and *Arbutus unedo* on schistose substrate. It is a clear

formation on ground with a slope of up to 30%.

The Beniabid Cork Oak forest (S6) contains 14 species: *Bartramia pomiformis*, *Brachythecium velutinum*, *Bryum capillare*, *Didymodon vinealis*, *Ditrichum flexicaule*, *Funaria hygrometrica*, *Lunularia cruciata*, *Pseudoscleropodium purum*, *Reboulia hemispherica*, *Rhynchostegiella tenella*, *Riccia sorocarpa*, *Targionia hypophylla*, *Tortula inermis*, *Trichostomum crispulum*. It is a sparsely populated Cork Oak forest (25%) whose undergrowth is dominated by *Myrtus communis*. Some bryophytes such as *Lunularia cruciata* and *Targionia hypophylla* have

**Table 2:** Number of species by substrate type.

Substrate	Number of species
Limestone	29
Quartzite	44
Shales	49

significant cover on clay soil formed on shale substrate.

Skhour Benslimane (S7) contains 15 species: *Barbula unguiculata*, *Bryum argenteum*, *Bryum capillare*, *Cirryphyllum crassinervium*, *Epipterygium tozeri*, *Eucladium verticillatum*, *Fossombronia pusilla*, *Frullania dilatata*, *Funaria hygrometrica*, *Lunularia cruciata*, *Pterogonium gracile*, *Schistidium apocarpum*, *Targionia hypophylla*, *Tortella tortuosa*, *Tortula muralis*. The Cork Oak forest has a recovery rate of nearly 50% and the undergrowth is dominated by *Rhus tripartitum*. The station is a set of quartzite blocks where bryophytes take refuge in wet crevices.

Sakhra Nmira (S8) contains 17 species : *Brachythecium albicans*, *Corsinia coriandrina*, *Didymodon rigidulus*, *Didymodon vinealis*, *Lunularia cruciata*, *Marchantia polymorpha*, *Metzgeria furcata*, *Pottia truncata*, *Reboulia hemispherica*, *Rhynchostegiella curviseta*, *Rhynchostegium megapolitanum*, *Riccia bicarinata*, *Riccia cilifera*, *Riccia lamellosa*, *Riccia perennis*, *Targionia hypophylla*, *Tortella nitida*. Cork oak with up to 50% coverage is accompanied by *Rhus pentaphyllum*. The identified bryophytes were found in the crevices of the quartzite blocks.

The station we called Benslimane Cork Oak forest (S9) contains 19 species: *Anthoceros agrestis*, *Brachythecium rutabulum*, *Epipterygium tozeri*, *Eurhynchium hians*, *Fossombronia angulosa*, *Frullania dilatata*, *Lunularia cruciata*, *Oxymitra incrassata*, *Phaeoros laevis*, *Phymatoceros bulbiculosus*, *Plagiochila porelloides*, *Pottia truncata*, *Pseudoscleropodium purum*, *Reboulia hemispherica*,

*Rhynchostegiella tenella*, *Riccia perennis*, *Riccia sorocarpa*, *Targionia hypophylla*, *Timmiella barbulooides*. It contains the densest Cork Oak forest with up to 75% coverage and an undergrowth dominated by *Myrtus communis*. The clay soil that develops on the shale substrate is soaked with water during the winter period, especially since the slope is almost nil. In summer, this soil is dry.

#### Specific richness by substrate type

A total of 29 species are recorded on limestone substrate (12 for S1 and 25 for S2): *Barbula unguiculata*, *Brachythecium albicans*, *Brachythecium rutabulum*, *Brachythecium velutinum*, *Brachythecium velutinum*, *Bryum capillare*, *Bryum murale*, *Cirryphyllum crassinervium*, *Didymodon tophaceus*, *Enthostodon templetonii*, *Enthostodon fascicularis*, *Fissidens bryoides*, *Fissidens incurvus*, *Fossombronia pusilla*, *Frullania dilatata*, *Funaria hygrometrica*, *Grimmia trichophylla*, *Hypnum cupressiforme*, *Isothecium myosiroides*, *Lunularia cruciata*, *Plagiomnium undulatum*, *Pleurochaete squarrosa*, *Pterogonium gracile*, *Reboulia hemispherica*, *Rhynchostegiella curviseta*, *Rhynchostegium confertum*, *Scorpirium circinatum*, *Targionia hypophylla*, *Timmiella barbulooides*, *Weissia controversa*.

On quartzite substrate, 44 species have been inventoried (23 for S3, 15 for S7 and 16 for S8). These species are: *Aloina ambigua*, *Anthoceros punctatus*, *Antitrichia californica*, *Barbula unguiculata*, *Brachythecium albicans*, *Brachythecium rivulare*, *Bryum argenteum*, *Bryum capillare*, *Bryum pseudotriquetrum*, *Cirryphyllum crassinervium*, *Corsinia coriandrina*, *Didymodon rigidulus*, *Didymodon tophaceus*, *Didymodon vinealis*, *Epipterygium tozeri*, *Eucladium verticillatum*, *Eurhynchium praelongum*, *Fossombronia pusilla*, *Frullania dilatata*, *Funaria hygrometrica*, *Grimmia pulvinata*, *Homalothecium lutescens*, *Isothecium myosiroides*, *Lunularia cruciata*, *Marchantia polymorpha*, *Metzgeria furcata*, *Pleurochaete squarrosa*, *Pottia truncata*, *Pseudoscleropodium purum*, *Pterogonium gracile*, *Reboulia hemispherica*, *Rhynchostegiella curviseta*, *Rhynchostegium megapolitanum*, *Riccia bicarinata*, *Riccia cilifera*, *Riccia lamellosa*, *Riccia perennis*, *Schistidium apocarpum*, *Scorpirium circinatum*, *Targionia hypophylla*, *Timmiella barbulooides*, *Tortella nitida*, *Tortella tortuosa*, *Tortula muralis*, *Trichostomum crispulum*

On schistous substrate, 49 species were observed

(17 for S4, 15 for S5, 14 for S6 and 19 for S9): *Amblystegium varium*, *Anthoceros agrestis*, *Anthoceros punctatus*, *Barbula unguiculata*, *Bartramia pomiformis*, *Brachythecium rutabulum*, *Brachythecium velutinum*, *Bryum caespiticium*, *Bryum capillare*, *Bryum palescens*, *Bryum radiculosum*, *Corsinia coriandrina*, *Cratoneuron filicinum*, *Dicranella varia*, *Didymodon luridus*, *Didymodon vinealis*, *Ditrichum flexicaule*, *Enthostodon templetonii*, *Epipterygium tozeri*, *Eurhynchium hians*, *Eurhynchium praelongum*, *Fossombronia angulosa*, *Frullania dilatata*, *Funaria hygrometrica*, *Homalothecium sericeum*, *Lunularia cruciata*, *Mnium hornum*, *Oxymitra incrassata*, *Phaeoceros laevis*, *Phymatoceros bulbiculosus*, *Physcomitrium pyriforme*, *Plagiochila porelloides*, *Pleurochaete squarrosa*, *Pottia truncata*, *Pseudoscleropodium purum*, *Reboulia hemispherica*, *Rhynchostegiella tenella*, *Rhynchostegium megapolitanum*, *Riccia bifurca*, *Riccia perennis*, *Riccia sorocarpa*, *Scorpirium circinatum*, *Targionia hypophylla*, *Timmiella barbulooides*, *Tortella nitida*, *Tortula inermis*, *Tortula muralis*, *Trichostomum crispulum*

Wetlands such as Ain Dakhla and Ain Sferjla have the highest rates of specific bryophyte richness in the area. The first is on a limestone substrate and the second on a quartzite substrate. This shows that the environmental factors related to humidity are more decisive with regard to the installation of bryological flora than the type of substrate. The least rich stations are those where the cover of vascular plants is not very important and where the slopes are steep as at Roudat Dam. In the subairies, bryophytes show very high recovery rates. The most common species in the 9 stations studied are *Lunularia cruciata*, *Targionia hypophylla* (Fig. 2), *Pleurochaete squarrosa* and *Bryum capillare*. In addition, associations between bryological species are often observed. Among these associations, we noted:

*Weissia controversa* and *Pleurochaete squarrosa* at Roudat Dam.

*Bartramia pomiformis*, *Funaria hygrometrica*, *Trichostomum crispulum* and *Riccia sorocarpa* at the Sidi Bettache Plateau in the Beniabid Forest.

- *Targionia hypophylla* and *Trichostomum crispulum* in the station of Wadi Cherrat.
- *Tortula muralis* and *Pseudoscleropodium purum* in Ain Sferjla.
- *Bartramia pomiformis* and *Bryum capillare* in the station of Wadi Cherrat.
- *Riccia bicarinata* and *Riccia Perennis* in Sakhrat

Nmira.

- *Phaeoceros laevis* and *Didymodon vinealis* in the Cork Oak forest de Benslimane station.
- *Lunularia cruciata* and *Tortula inermis* in the Beniabid forest.
- *Tortula muralis* and *Pseudoscleropodium purum* in Ain Sferjla.

Morocco has experienced a change in rainfall amounts and their spatial and temporal distribution. Sebbar *et al.*, (2011), showed that the period of rainfall regime failure appeared in the 1970s. The number of bryophytes recorded in the area is high (80 taxa) but perhaps it was higher before the 1970s when rainfall was higher and temperatures lower (Sebbar *et al.*, 2011); we would then have lost species before we could even inventory or describe them.

### Conclusion

Surveys carried out in the Benslimane region have resulted in a list of 80 species, including 59 mosses, 17 Liverworts and 4 Hornworts. This is an important biodiversity that reflects the diversity of the ecosystems and vascular flora of the area. This diversity is dominated in the majority of stations explored by *Lunularia cruciata*, *Targionia hypophylla*, *Reboulia hemispherica*, and *Bryum capillare* which show high recovery rates. The stations where the greatest specific richness in bryophytes is noted are located around water points. Genetic resources in the Benslimane region are a heritage to be preserved and protected from the impact of human activities that seriously threaten their durability.

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