



CONTRIBUTION TO THE INVENTORY OF THE TERRICOLOUS AND SAXICOLOUS BRYOLOGICAL FLORA OF IFRANE NATIONAL PARK, MOROCCO.

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Abstract

Bryological flora is an important component of natural ecosystems. It can serve as an effective biomonitoring tool for the environmental quality. In MOROCCO, research studies on bryophytes is fragmentary. IFRANE National Park, which occupies the central part of the Middle Atlas Mountains, is under-explored from this point of view. For this purpose, the present study aims to inventory the terricolous and saxicolous bryological flora of the park. Thus, we established a list of 66 species of which 27 are terricolous, 19 are saxicolous and 20 are found on both types of substrates. We described each identified species with, in particular, the types of environment in which it has been observed, geolocation and altitudes. The floristic analysis of the established list of bryophytes shows that the class of Bryopsida is predominant with 55 species, that of Marchantiopsida by 9 taxa and that of Anthocerotopsida by only 2 species. In addition, these bryophytes belong to 38 genera and 23 families. The family of Brachytheciaceae is the richest species with 15 taxa, followed by Pottiaceae with 13 taxa and Grimmiaceae with 6 species. The comparison of this list with previous studies on bryophytes in Morocco shows the presence of 18 new species for the region and confirms the presence in Morocco of 4 taxa that was doubtful. Studying the park's bryological flora is a high added value contribution for the national park and even for the entire region.

Key words: Ifrane Natural Park, Middle Atlas, bryophytes, biodiversity, inventory.

Introduction

Bryological fauna is an important component of terrestrial and aquatic ecosystems. In addition to their role in carbon sequestration, these small plants can provide information on the health status of the environment as they are very good bio-accumulators of heavy metals (Zaouadzki *et al.*, 2014; Kempter *et al.*, 2017) and organic pollutants (Foan *et al.*, 2014). Furthermore, studies have focused on the phytochemistry of these plants; Krzaczkowski (2008), illustrated the variety and originality of the active compounds extracted from bryophytes and which would be active substances in antitumor pharmacology. All of these studies have encountered difficulties with the small size of bryophytes

that are difficult to identify in the field. It would therefore be quite justified to conduct extensive investigations on this group of plants that is under-explored in Morocco in general and in Ifrane National Park (INP) in particular. Indeed, several flora studies have been undertaken in INP and have evaluated the species richness of vascular plants at more than 1015 taxa (Benabid, 2006; HCEFLCD, 2007) but none has accurately estimated the diversity of bryophytes. With the aim of completing these floristic studies, the present study is devoted to the evaluation of bryological diversity in INP.

Materials and Methods

Study site

The present study was carried out in INP (Fig. 1)

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that occupies the central part of the Middle-Atlas Mountains and which is almost completely embedded in the watershed of Sebou. A geochronological study (Harmand and Cantagrel, 1984), showed that three distinct periods of volcanic activity were highlighted in the Moroccan Middle Atlas. The oldest is 35 million years old, located along the North Atlas accident. The second phase, between 15 and 6 million years ago, is more diffuse, dispersed throughout the region. The third phase is of quaternary age between 1.8 and 0.5 million years old. It is then a very uneven area and very heterogeneous from the ecological point of view. It is therefore a very rugged area and very heterogeneous from the ecological point of view. It is prone to strong erosions especially in areas where vegetation is degraded. The substrate is basaltic or limestone. According to Benabid, (2006), four soil groups can be distinguished in INP: (i) soils on andic fersialitic brown volcanic rocks, (ii) soils on andic brown volcanic

rocks, (iii) soils on limestone rocks red fersialitic and (iv) soils on pararendzine dolomitic rocks.

INP occupies an area of about 125 000 ha of which 83% is occupied by forests (HCEFLCD, 2007). It includes the largest Cedar forest that reach an area of 80 000 ha (67% of the Moroccan Cedar).

INP is located in the altitudinal range between 1300 m (Jaâba Forest) and 2440 m (Ij Peak). The climate is of the Mediterranean type with humid and subhumid bioclimates with cool variants on the average altitudes, cold on the rest of INP except for summits and the oriental exposures where winter is very cold. INP is located in one of the most watered regions of Morocco with a shorter dry period in summer than in the rest of the country; this period is spread over the months of June, July and August. According to the Ifrane meteorological station, the annual rainfall is about 1100 mm spread over 102 days, the average annual temperature is 11.1°C with

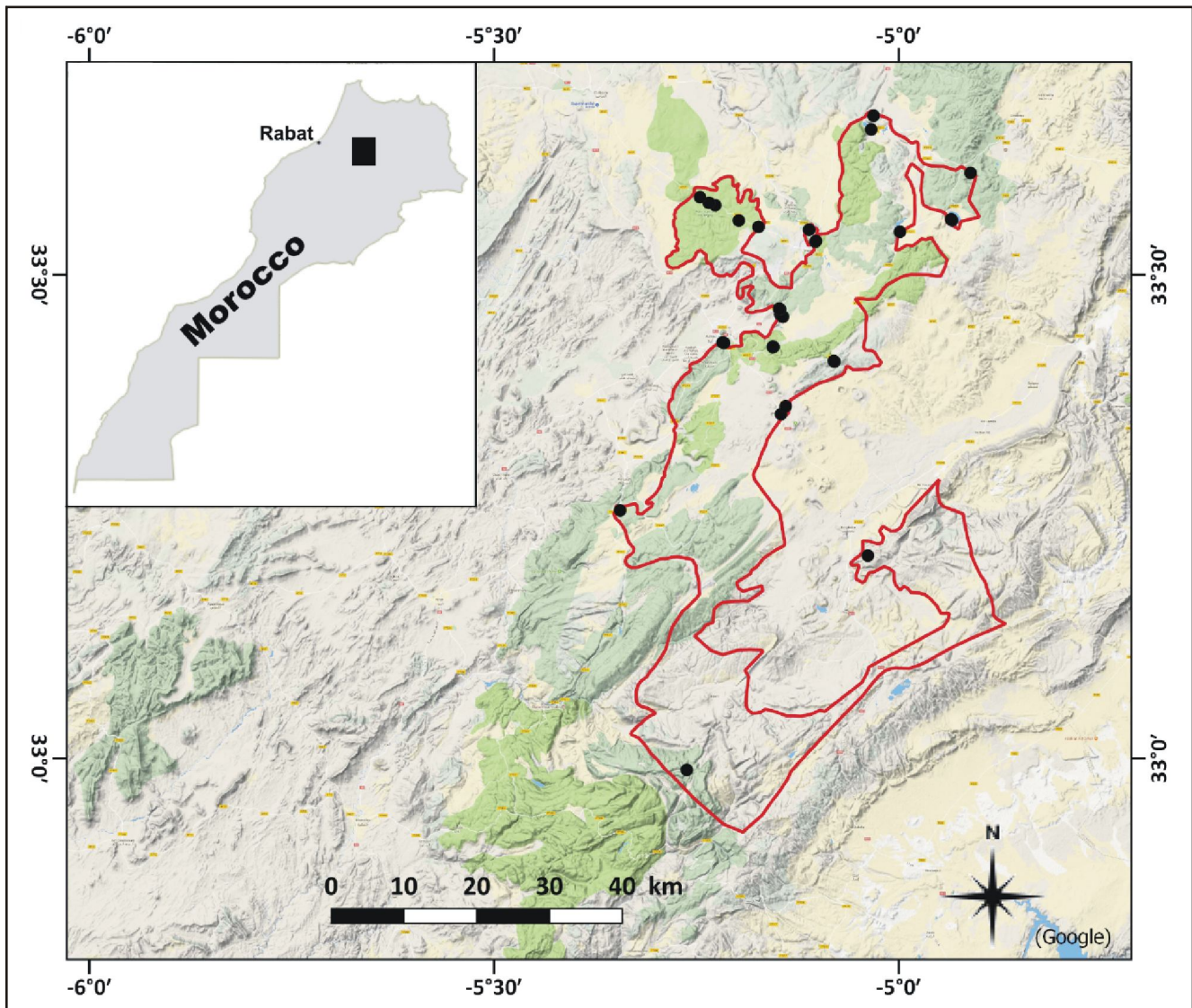


Fig. 1: Location of the study area INP (black dots represent the samples).

an absolute maximum of 34.4°C recorded in August and an absolute minimum of -9.8°C recorded in January. The average annual temperature range is 11.2°C and the extreme annual difference is 34.6°C (El Gharbaoui, 1987).

The vegetation strata of INP begin with the thermomediterranean series of Green Oak which occupies the thermomediterranean ceiling, then the mesomediterranean series of Green Oak, followed by the mixed supramediterranean series of mesophile Cedar-Green Oak and finally the meso-xerophilic mediterranean mountain series of Cedar-Green Oak (Benabid, 2000).

Sampling

We carried out a sampling according to altitudinal transects defined in almost all INP stations; a harvest is made in each encountered bryophyte stand. The harvest of bryophytes was carried out during four years from 2015 to 2018. The harvesting dates are then: November 2015, March 2016, June 2016, April 2017 and January 2018.

Sixteen stations were investigated: Jaâba forest, Ain Vittel, Ifrane, Ras El Ma forest, Azrou, Gouraud forest, Joint forest at the National Hydrobiology and Fish Farming Center of Ras El Ma, Dayet Aoua, Dayet Hachlaf, Jbel Habri, Michlifén crater, Immouzar, Dayet Ifrah, Dayet Iffer, Ain Leuh and Dayet Aguelmame Tifounassine located around the town of Timahdit. The exploration at all these stations totaled nearly 500 surveys.

The analysis of the surveys and the identification of taxa were carried out in the Laboratory of Botany, Biotechnology and Plant Protection thanks to the following documents: Augier, (1966); Pierrot, (1982) and essentially with the help of Smith, (1990, 2004), Casas *et al.*, (2006) and Casas *et al.*, (2009). We adopted the nomenclature of Ros *et al.*, (1999) and Ros *et al.*, (2013).

For each studied sample, binocular magnification (x2,

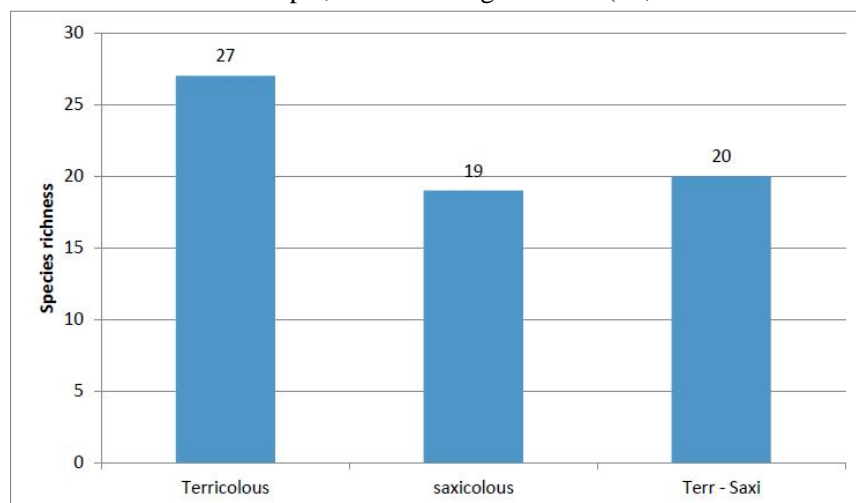


Fig. 2: Richness of terricolous and saxicolous species in INP.

x4, x10, x40) and optical microscope (x40, x100, x400) observations were made and illustrated by photos. These observations correspond to the clump of individuals harvested in the field, to the isolated individual, to the whole leaf and in cross-section, to the whole sporophyte and to the spores when the plant is harvested in the fertile state.

Identified species are presented by class, order and family. We start with the Anthocerotopsida class, followed by the Marchantiopsida class and finally the Bryopsida class. Each identified taxon is presented with its synonyms, its habitat type (terricolous or saxicolous), the localities, the geographical coordinates and the altitudes where it has been observed in INP.

The list of bryophytes thus established is compared with previous lists and catalogs of species observed in Morocco (Ros *et al.*, 1999); (Ros *et al.*, 2000); (Ros *et al.*, 2013); (Draper *et al.*, 2003); (Draper *et al.*, 2005); (Draper *et al.* 2006), (Draper *et al.* 2007), (Ahayoun *et al.*, 2007); (Ahayoun *et al.*, 2013), in order to deduce the potentially new species for the region and to confirm, when appropriate, the presence of species that were previously considered to be doubtful in Morocco. The new species for the region are preceded by the symbol ‘•’ and the species whose presence we have confirmed in Morocco are preceded by the symbol ‘▶’.

Results

The results of our sampling in INP amount to 66 terricolous and saxicolous species, of which 27 species are exclusively terricolous, 19 exclusively saxicolous and 20 taxa found both on an earthy substrate and on a bedrock (Fig. 2). The Bryopsida class predominates with 55 taxa, followed by the Marchantiopsida class with 9 species and the Anthocerotopsida class with only 2 species.

List of INP bryophyte species

Class: Anthocerotopsida

Order: Notothyladales

Family: Nothothyladaceae

Phaeoceros laevis (L.) Prosk. ;
Syn. *Anthoceros laevis* (L.); terricolous, moist siliceous substrate, Jaâba forest, coordinates: 33°33'21,4616"N and 5°11'50,6800"W, altitude : 1527 m.

Phaeoceros bulbiculosus (Brot.)
Prosk ; Syn. *Anthoceros dichotomus*
Raddi ; terricolous, hydromorphic soil near streams in Ain Vittel, coordinates: 33°32'47,2992"N and 5°6'38,0016"W, altitude 1604 m.

Class: Marchantiopsida

Order: Marchantiales

Family: Targioniaceae

Targionia hypophylla L., terricolous, on siliceous soil,, coordinates: 33°32'58,0992"N and 5°10'22,5984"W, altitude 1602 m; saxicolous in Jaâba forest, on basalt rock, coordinates: 33°35'23,3016"N and 5°15'45,7992"W, altitude 1335 m; at Ras El Ma on basalt rock, coordinates: 33°27'24,5485"N and 5°8'34,4345"W, altitude 1667 m.

Family: Aytoniaceae

Reboulia hemispherica (L.) Raddi., terricolous on calcareous substrate, Jaâba forest, coordinates: 33°35'23,3016"N and 5°15'45,7992"W, altitude 1335 m; saxicolous on limestone rock in Dayet Ifrah, coordinates: 33°33'25,8984"N and 4°56'6,1008"W, altitude 1621 m and Dayet Iffer, coordinates: 33°36'24,0984" N and 4°54'28,8000"W, altitude 1514 m.

Family: Lunulariaceae

Lunularia cruciata (L.) Lindb., saxicolous on basaltic and terricolous rock on siliceous soil in Ras El Ma, coordinates: 33°27'24,5485" N and 5°8'34,4345"W, altitude 1667 m. Saxicolous in Immouzer on wet and shaded limestone rock, coordinates: 33°43'51,9024"N and 5°0'56,2680"W, altitude 1346m. Terricolous and saxicolous in Jaâba forest, coordinates: 33°35'23,3016"N and 5°15'45,7992"W, altitude 1335m. Terricolous and saxicolous in Ain Vittel, coordinates: 33°32'47,2992"N and 5°6'38,0016"W, altitude 1604 m. Terricolous and saxicolous in Gouraud forest, coordinates: 33°25'31,0040"N and 5°9'19,2381"W, altitude 1722 m. Terricolous and saxicolous in Michlifen crater, coordinates: 33°24'40,3002"N and 5°4'48,0797"W, altitude 1906 m.

Family: Ricciaceae

Riccia lamellosa Raddi., terricolous on siliceous soil; Ain Vittel, coordinates: 33°32'47,2992"N and 5°6'38,0016"O, altitude 1604 m; Ain Leuh, coordinates: 33°17'38,5440"N and 5°20'10,5953"W, altitude 1472 m.

Riccia sorocarpa (Bisch) Syn., *Riccia raddiana* Jack., terricolous soil formed on basalt substratum in Jbel Habri, coordinates: 33°21'22,7016"N and 5°8'42,7992"W, altitude 1972 m.

Order: Metzgeriales

Family: Pelliaceae

• *Pellia neesiana* (Gottsche.) Limpr., terricolous on hydromorphic soil in Ain Vittel near streams, coordinates: 33°32'47,2992"N and 5°6'38,0016"W, altitude 1604 m.

Family: Fossombroniaceae

• *Fossombronia pusilla* (L.) Dum., terricolous on hydromorphic soil in Dayet Hachlaf, coordinates: 33°32'39,6996"N and 4°59'53,9988"W, altitude 1675 m.

Order: Jungermanniales

Family: Frullaniaceae

Frullania dilatata Dum., saxicolous, Michlifen crater, coordinates: 33°24'43.7"N and 5°04'31.2"W, altitude 1922 m; Ain Vittel coordinates: 33°32'47,2992"N and 5°6'38,0016"W, altitude 1604 m; Jaâba forest, coordinates: 33°34'17,9004"N and 5°13'35,5008"W, altitude 1434 m; Ras El Ma Forest, coordinates: 33°27'31,7016"N and 5°8'58,3008"W, altitude 1543 m; Gouraud Forest, coordinates: 33°25'32,3004"N and 5°9'16,2000"W, altitude 1711 m.

Family: Porellaceae

Porella platyphylla (L.) Lindb., Syn *Madotheca platyphylla* (L.) Dum., saxicolous, shaded bedrock in Ain Vittel, coordinates: 33°32'47,2992"N and 5°6'38,0016"W, altitude 1604 m.

Class: Bryopsida

Order: Encalyptales

Family: Encalyptaceae

Encalypta vulgaris Hedw., terricolous and saxicolous, Ifrane, coordinates: 33°32'5,6004"N and 5°6'7,2000"W, altitude 1643 m; Azrou, coordinates: 33°26'10,5000"N and 5°14'0,8988"W, altitude 1216 m.

Order: Funariales

Family: Funariaceae

Funaria hygrometrica Hedw., terricolous and saxicolous, basaltic substratum in Ifrane, coordinates: 33°32'2,1984"N and 5°6'10,1016"W, altitude 1640 m.

Enthostodon fascicularis (Hedw.) Mull. Hal., Syn. *Funaria fascicularis* (Hedw.) Lindb., terricolous and saxicolous soil formed on basalt substratum and basalt block in Ifrane, coordinates: 33°32'3,9012"N and 5°6'8,4996"W, altitude 1642 m.

Order: Grimmiales

Family: Grimmiaceae

Shistidium apocarpum (Hedw.) Bruch & Schimp., Syn. *Grimmia apocarpa* Hedw., terricolous soil around some apparent Cedar roots; saxicolous, Michlifen crater, coordinates: 33°24'40,3002"N and 5°4'48,0797"W, altitude 1906 m.

Grimmia pulvinata Hedw., saxicolous, on basaltic block, Jaâba forest, coordinates: 33°33'21,4616"N and 5°11'50,6800"W, altitude: 1527 m; saxicolous, on basalt block, Dayet Hachlaf, coordinates: 33°32'39,6996"N and

4°59'53,9988"W, altitude 1675 m; terricolous, Jaâba forest, fersialitic red soil, coordinates: 33°34'26,9004"N and 5°14'3,0984"W, altitude 1411 m.

Grimmia trichophylla Grev., syn : *G. Britannica* A. J. E. Sm., *G. stirtonii* Schimp., *G. trichophylla* var. *robusta* (Fergusson) A. J. E. Sm. Saxicolous, Dayet Iffer, coordinates: 33°36'24,0984"N and 4°54'28,8000"W, altitude 1514 m; Gouraud Forest, limestone and basalt rock, coordinates: 33°25'33,7008"N and 5°9'19,2996"W, altitude 1708 m; Dayet Hachlaf, coordinates: 33°32'39,6996"N and 4°59'53,9988"W, altitude 1675 m; Jaâba forest, coordinates: 33°34'17,9004"N and 5°13'35,5008"W, altitude 1434 m; Ras El Ma forest, coordinates: 33°27'31,7016"N and 5°8'58,3008"W, altitude 1543 m; Dayet Aoua, coordinates: 33°38'58,7907"N and 5°2'1,6466"W, altitude 1466 m.

Grimmia lisae De Not., Syn. *G. retracta* Stirt., *G. subsquarrosa* Wilson, *G. trichophylla* var. *Subsquarrosa* (Wilson) A. J. E. Sm., Saxicolous, Jaâba forest, coordinates: 33°34'26,9004"N and 5°14'3,0984"W, altitude 1411 m, basaltic bedrock.

- *Grimmia dissimulata* E. Maier, terricolous on moderately deep brown soil in Jbel Habri, coordinates: 33°21'52,2000"N and 5°8'22,2000"W, altitude 1952 m; saxicolous, Jaâba forest, basaltic rock, coordinates: 33°35'23,3016"N and 5°15'45,7992"W, altitude 1335 m; terricolous, Jaâba forest, fersialitic red soil, coordinates: 33°34'26,9004"N and 5°14'3,0984"W, altitude 1411 m.

- *Grimmia meridionalis* (Müll.Hall.) E. Maier., terricolous, Jaâba forest, fersialitic red soil, coordinates: 33°34'26,9004"N and 5°14'3,0984"W, altitude 1411 m.

Order: Dicranales

Family: Fissidentaceae

Fissidens incurvus Starke ex Rohl., Deutschl., terricolous, fresh soil, Ain Vittel, coordinates: 33°32'47,2992"N and 5°6'38,0016"W, altitude 1604 m; Immouzer, coordinates: 33°43'51,9024"N and 5°0'56,2680"W, altitude 1346 m.

Order: Pottiales

Family: Pottiaceae

Syntrichia virescens (De Not.) Ochyra, *Tortula pulvinata* (Jur.) Limpr., *Tortula virescens* De Not., *Syntrichia laevipila* Brid., terricolous, Jbel Habri, moderately deep brown soil, coordinates: 33°21'52,2000"N and 5°8'22,2000"W, altitude 1952 m.

Syntrichia laevipila (Brid.) Schwägr., *T. laevipila* var. *laevipiliformis* (De Not.) Limpr., terricolous soil on siliceous and saxicolous soil on basalt or calcareous bedrock, Jaâba forest, coordinates: 33°35'23,3016"N and

5°15'45,7992"W, altitude 1335 m; Michliflen Crater, coordinates: 33°24'40,3002"N and 5°4'48,0797"W, altitude 1906 m; Gouraud forest, coordinates: 33°25'32,3004"N and 5°9'16,2000"W, altitude 1711 m.

Didymodon fallax Hedw. Syn. *Barbula fallax* Hedw., terricolous and saxicolous, Ain Vittel, coordinates: 33°32'47,2992"N and 5°6'38,0016"W, altitude 1604 m.

Didymodon tophaceus Brid., terricolous on siliceous soil, Jaâba forest, coordinates: 33°34'26,9004"N and 5°14'3,0984"W, altitude 1411 m.

Didymodon vinealis (Brid.) R. H. Zander, *Barbula vinealis* Brid., terricolous and saxicolous on calcareous and basalt substrates, Jaâba forest, coordinates: 33°35'23,3016"N and 5°15'45,7992"W, altitude 1335 m; Dayet Aoua, coordinates: 33°38'58,7907"N and 5°2'1,6466"W, altitude 1466 m; Dayet Ifrah, coordinates: 33°33'25,8984"N and 4°56'6,1008"W, altitude 1621 m.

Didymodon luridus Hornsch., *Barbula lurida* (Hornsch. ex Spreng.) Lindb., terricolous on limestone substrate, Ain Vittel, coordinates: 33°32'47,2992"N and 5°6'38,0016"W, altitude 1604 m.

Eucladium verticillatum (Brid.) Bruch & Schimp. *Weissia verticillata* Brid., terricolous and saxicolous, Immouzer, limestone soil and rock, coordinates: 33°43'51,9024"N and 5°0'56,2680"W, altitude 1346 m.

Barbula unguiculata Hedw., terricolous, soil on dolomitic limestone substrate; Jaâba Forest, coordinates: 33°32'58,0992"N and 5°10'22,5984"W, altitude: 1602 m; Ras El Ma forest, coordinates: 33°27'50,7996"N and 5°8'57,1992"W, altitude 1565 m; Gouraud forest, coordinates: 33°25'31,0040"N and 5°9'19,2381"W, altitude 1722m; Dayet Ifrah, coordinates: 33°33'22,2687"N and 4°56'1,3909"W, altitude 1622 m.

Barbula convoluta Hedw., terricolous on limestone, Azrou, coordinates: 33°26'7,4004"N and 5°13'44,4000"W, altitude 1233 m.

- *Tortella nitida* (Lindb.) Broth., Syn. *Trichostomum nitidum* Schimp., saxicolous, Jaâba forest on basalt rock, coordinates: 33°34'17,9004"N and 5°13'35,5008"W, altitude 1434 m.

Tortula muralis Hedw., saxicolous, Jaâba forest, on basalt rock, coordinates: 33°32'58,0992"N and 5°10'22,5984"W, altitude 1602m, terricolous on fersialitic red soil, coordinates: 33°34'26,9004"N and 5°14'3,0984"W, altitude 1411 m.

- *Aloina aloides* (D. J. Koch ex Schultz) Kindb., Syn. *Tortula aloides* (D. J. Koch ex Schultz) De Not., terricolous on dry siliceous soil, Ain Leuh, coordinates: 33°17'38,5440"N and 5°20'10,5953"W, altitude 1472 m.

Syntrichia montana Nees., saxicolous, Jaâba forest, basalt rock, coordinates: 33°35'23,3016"N and 5°15'45,7992"W, altitude 1335 m.

Order: Orthotrichales

Family: Orthotrichaceae

Orthotrichum cupulatum Brid., saxicolous, Jaâba forest, on basaltic rock, coordinates: 33°34'17,9004"N and 5°13'35,5008"W, altitude 1434 m and 33°35'23,3016"N and 5°15'45,7992"W, altitude 1335 m; Azrou, coordinates: 33°26'7,4004"N and 5°13'44,4000"W, altitude 1233 m; Ifrane, coordinates: 33°32'2,1984"N and 5°6'10,1016"W, altitude 1640 m; Michlifen crater, coordinates: 33°24'37,9599"N and 5°4'45,5871"W, altitude 1907 m.

Orthotrichum anomalum Hedw., saxicolous, Jaâba forest, on basalt rock, coordinates: 33°35'23,3016"N and 5°15'45,7992"W, altitude 1335 m, coordinates: 33°34'26,9004"N and 5°14'3,0984"W, altitude 1411 m.

Orthotrichum macrocephalum (Lara.), Garilleti and Mazimpaka, saxicolous on basalt rock, Dayet Hachlaf, coordinates: 33°32'39,6996"N and 4°59'53,9988"W, altitude 1675 m.

Orthotrichum rupestre Schleich. ex Schwägr., saxicolous, on basalt rock, Michlifen crater, coordinates: 33°24'40,3002"N and 5°4'48,0797"W, altitude 1906 m; Jbel Habri, coordinates: 33°21'52,2000"N and 5°8'22,2000"W, altitude 1952 m; Jaâba forest, coordinates: 33°35'23,3016"N and 5°15'45,7992"W, altitude 1335 m. Terricolous, Jaâba forest, on fersialitic red soil formed on basaltic substrate, coordinates: 33°34'26,9004"N and 5°14'3,0984"W, altitude 1411 m; Ifrane, coordinates: 33°32'3,9012"N and 5°6'8,4996"W, altitude 1642 m.

Order: Bryales

Family: Bartramiaceae

Bartramia pomiformis Hedw., terricolous and saxicolous, Ain Vittel, coordinates: 33°32'47,2992"N and 5°6'38,0016"W, altitude 1604 m.

Family: Bryaceae

Bryum argenteum Hedw., terricolous, Immouzer, coordinates: 33°43'51,9024"N and 5°0'56,2680"W, altitude 1346 m.

• *Bryum radiculosum* Brid. Syn. *B. murorum* (Schimp.) Berk., terricolous, siliceous soil, Ifrane, coordinates: 33°32'5,6004"N and 5°6'7,2000"W, altitude 1643 m; Ras El Ma forest, coordinates: 33°27'24,5485"N and 5°8'34,4345"W, altitude 1667 m.

Bryum capillare Hedw., terricolous and saxicolous in Dayet Iffer, coordinates: 33°36'24,0984"N and 4°54'28,8000"W, altitude 1514 m; Ras El Ma, coordinates:

33°27'50,7996"N and 5°8'57,1992"W, altitude 1565 m; Azrou, coordinates: 33°26'10,5000"N and 5°14'0,8988"W, altitude 1216 m; Dayet Hachlaf, coordinates: 33°32'39,6996"N and 4°59'53,9988"W, altitude 1675 m; Jaâba forest, saxicolous, basaltic rock, coordinates: 33°35'23,3016"N and 5°15'45,7992"W, altitude 1335 m and terricolous on siliceous soil in the same station, siliceous soil and basalt substrate, 33°34'26,9004"N and 5°14'3,0984"W altitude 1411 m.

Bryum caespiticium Hedw., terricolous and saxicolous on limestone and basaltic substratum, Ras El Ma, coordinates: 33°27'24,5485"N and 5°8'34,4345"W, altitude 1667 m; Azrou, coordinates: 33°26'7,4004"N and 5°13'44,4000"W, altitude 1233 m, Dayet Iffer, coordinates: 33°36'24,0984"N and 4°54'28,8000"W, altitude 1514 m.

Family: Mniaceae

Plagiomnium undulatum Hedw. Syn. *Mnium undulatum* Hedw., terricolous on limestone hydromorphic soil, near stream, in Ain Vittel, coordinates: 33°32'47,2992"N and 5°6'38,0016"W, altitude 1604 m.

Order: Hypnales

Family: Amblystegiaceae

• *Amblystegium serpens* (Hedw.) Schimp. Syn. *A. juratzkanum* Schimp., terricolous on hydromorphic calcareous soil, near stream in Ain Vittel, coordinates: 33°32'47,2992"N and 5°6'38,0016"W, altitude 1604 m.

Amblystegium tenax (Hedw.) Syn. *Hygroamblystegium tenax* (Hedw.) Jenn., terricolous, on limestone substrate, Ras El Ma forest, coordinates: 33°27'50,9004"N and 5°8'56,7996"W, altitude 1565 m.

Cratoneuron filicinum (Hedw.) Spruce. Syn. *Amblystegium filicinum* (Hedw.) De Not., terricolous, saxicolous, Ras El Ma forest, humid rocks and calcareous soil, coordinates: 33°27'50,9004"N and 5°8'56,7996"W, altitude 1565 m.

Palustriella commutata var. *commutata* (Hedw.) ochyra., terricolous, Ain Vittel, limestone soil near streams, coordinates: 33°32'47,2992"N and 5°6'38,0016"W, altitude 1604 m.

Family: Brachytheciaceae

•• *Brachythecium albicans* (Hedw.) Schimp. Syn. *Chamberlainia albicans* Hedw., terricolous soil formed on basalt rock, Ain Leuh, coordinates: 33°17'38,5440"N and 5°20'10,5953"W, altitude 1472 m.

Brachytheciastrum dieckii Roll., saxicolous, Ifrane, coordinates: 33°32'5,6004"N and 5°6'7,2000"W, altitude 1643m; Jbel Habri, basaltic bedrock, coordinates: 33°21'22,7016"N and 5°8'42,7992" W, altitude 1972m;

Jaâba forest on basalt rock, coordinates: 33°35'23,3016"N and 5°15'45,7992"W, altitude 1335 m. Terricolous, Jaâba forest, on soil formed on basalt substrate, coordinates: 33°34'26,9004"N and 5°14'3,0984"W, altitude 1411 m, coordinates: 33°32'58,0992" N and 5°10'22,5984"W, altitude 1602 m.

• *Brachytheciastrum olympicum* Jur., terricolous, Jaâba forest, fersialitic red soil, coordinates: 33°34'26,9004"N and 5°14'3,0984"W, altitude 1411 m

• *Isothecium myosuroides* Brid. Syn. *Eurynchium myosuroides* (Brid.) Schimp., saxicolous, Jaâba Forest, coordinates: 33°33'21,4616" N and 5°11'50,6800"W, altitude : 1527 m; and Ain Vittel, coordinates: 33°32'47,2992"N and 5°6'38,0016"W, altitude 1604 m, on rocky limestone.

Scorpirium circinatum (Brid.) M. Fleisch. & Loeske. Syn. *Eurhynchium circinatum* (Brid.) Schimp., saxicolous on basalt rock, Jaâba forest, coordinates: 33°34'26,9004"N and 5°14'3,0984"W, altitude 1411 m, coordinates: 33°35'23,3016"N and 5°15'45,7992"W, altitude 1335 m; Ifrane, coordinates: 33°32'5,6004"N and 5°6'7,2000"W, altitude 1643m and Dayet Ifrah, coordinates: 33°33'22,2687"N and 4°56'1,3909"W, altitude 1622 m.

• *Rhynchostegium megapolitanum* Schimp., terricolous in Jaâba forest on fersialitic red soil, coordinates: 33°34'26,9004"N and 5°14'3,0984"W, altitude 1411 m.

Homalothecium sericeum (Hedw.) Schimp. *Camptothecium sericeum* (Hedw.) Kindb., saxicolous in Jaâba forest on basalt rock, coordinates: 33°35'23,3016"N and 5°15'45,7992"W, altitude 1335 m.

• *Homalothecium lutescens* (Hedw.) H. Rob. Syn. *Camptothecium lutescens* (Hedw.) Schimp., saxicolous, Jaâba forest, coordinates: 33°32'58,0992"N and 5°10'22,5984"W, altitude 1602 m. ; Michlifén crater, coordinates: 33°24'40,3002"N and 5°4'48,0797"W, altitude 1906 m; Azrou, coordinates: 33°26'10,5000"N and 5°14'0,8988"W, altitude 1216 m; Dayet Ifrah, coordinates: 33°33'22,2687" N and 4°56'1,3909"W, altitude 1622 m; Ain Vittel, coordinates: 33°32'47,2992"N and 5°6'38,0016"W, altitude 1604 m; Dayet Hachlaf, coordinates: 33°32'39,6996"N and 4°59'53,9988" W, altitude 1675 m; Ras El Ma Forest, coordinates: 33°27'24,5485"N and 5°8'34,4345"W, altitude 1667 m.

Homalothecium aureum (Spruce) H. Rob. *Camptothecium aureum* (Spruce) Schimp., terricolous, Jaâba forest, on red fersialitic soil, coordinates: 33°34'26,9004"N and 5°14'3,0984"W, altitude 1411 m.

• *Kindbergia praelonga* (Hedw.) Ochyra., *Eurhynchium stokesii* (Turner) Schimp., *Oxyrrhynchium praelongum* (Hedw.) Warnst., *Stokesiella praelonga* (Hedw.) H. Rob. *Eurhynchium praelongum* (Hedw.) Schimp., *Eurhynchium praelongum* var. *stokesii* (Turner), terricolous, in Ain Vittel, coordinates: 33°32'47,2992"N and 5°6'38,0016"W, altitude 1604 m near streams.

• *Brachythecium rivulare* Schimp., terricolous in Ain Vittel, coordinates: 33°32'47,2992"N and 5°6'38,0016"W, altitude 1604 m.

• *Brachythecium rutabulum* (Hedw.) Schimp., saxicolous terricolous in Jaâba forest, coordinates: 33°33'21,4616"N and 5°11'50,6800"W, altitude : 1527 m; Ain Vittel, coordinates: 33°32'47,2992"N and 5°6'38,0016"W, altitude 1604 m.

Brachythecium velutinum (Hedw.) Schimp. Syn. *Chamberlainia velutina* (Hedw.) H. Rob., saxicolous in Azrou, wet siliceous soil, coordinates: 33°26'10,5000"N and 5°14'0,8988"W, altitude 1216 m; Gouraud forest, limestone rock, coordinates: 33°25'32,3004"N and 5°9'16,2000"W, altitude 1711 m; Ras El Ma forest, coordinates: 33°27'50,9004"N and 5°8'56,7996"W, altitude 1565 m.

Rhynchostegium confertum (Dicks.) Schimp. Syn. *Eurhynchium confertum* Dicks., saxicolous, Ain Vittel, coordinates: 33°32'47,2992"N and 5°6'38,0016"W, altitude 1604 m.

Brachytheciastrum velutinum var. *velutinum*., saxicolous in Jaâba forest on a basaltic rock., coordinates: 33°35'23,3016"N and 5°15'45,7992"W, altitude 1335 m, terricolous in Jaâba forest on fersialitic red soil, coordinates: 33°34'26,9004"N and 5°14'3,0984"W, altitude 1411 m.

Family: Fabroniaceae

Fabronia pusilla Hedw., saxicolous, on shaded rock in Michlifén crater, coordinates: 33°24'37,9599"N and 5°4'45,5871"W, altitude 1907 m; Gouraud forest, coordinates: 33°25'32,3004"N and 5°9'16,2000"W, altitude 1711 m; Jaâba forest, coordinates: 33°34'17,9004"N and 5°13'35,5008"W, altitude 1434 m.

Family: Pterigynandraceae

Pterigynandrum filiforme Hedw., saxicolous, Michlifén crater, coordinates: 33°24'40,3002"N and 5°4'48,0797"W, altitude 1906 m; Gouraud forest, coordinates: 33°25'32,3004"N and 5°9'16,2000"W, altitude 1711 m.

Family: Leucodontaceae

Pterogonium gracile Hedw., terricolous in Jaâba

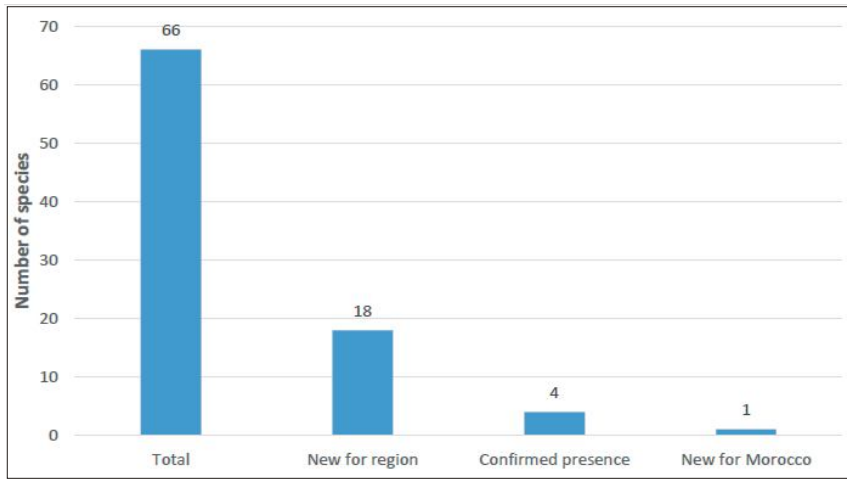


Fig. 3: Distribution of bryophyte species.

forest on fersialitic red soil, coordinates: 33°34'26,9004"N and 5°14'3,0984"W, altitude 1411 m.

Terricolous and saxicolous bryophytes in INP

The species of exclusively terricolous are 27 (Fig. 2). In the high elevations of INP, the forest formation protects the soil against erosion and allows the development of a rather deep fersialitic brown soil that favors the installation of relatively demanding bryophytes in organic matter. In low-lying areas, the soil under the Green oak and other derived formations is superficial to slightly deep fertialitic red soil. When the forest is lacking due to anthropogenic or natural pressure such as a rugged topography, the bedrock outcrops and saxicolous bryophytes less demanding in organic nutrients appropriate these quasi-mineral areas.

Newly observed species in INP region

The inventory carried out in INP has allowed us to

found 18 species newly encountered in the region. It also allowed us to confirm the presence of four species (*Grimmia meridionalis*, *Brachythecium olympicum*, *Brachythecium albicans* et *Homalothecium lutescens*) that were considered doubtful in Morocco according to Ros *et al.*, (2013) (Fig. 3).

The floristic families according to their generic and specific richness

The 66 saxicolous and terricolous species observed in INP are affiliated to 23 families (Fig. 4). The family of Brachytheciaceae (15 taxa) followed by the family of Pottiaceae (13 taxa) show the highest species richness.

Discussion

The sampling carried out in INP covered all the seasons from 2015 to 2018 (November 2015, March 2016, June 2016, April 2017 and January 2018), in order to have chance to observe plants in all development phases.

Thus, surveys that have been spread over nearly four years have identified 66 bryophyte taxa, 27 of which are exclusively terricolous, 19 exclusively saxicolous and 20 observed as well on earthy substrate as on rocky substrate (Fig. 2). Of the 66 terricolous and saxicolous species inventoried, 8 are underwater sometimes totally submerged (*Plagiomnium undulatum*, *lunularia cruciata*, *Brachythecium rivulare*, *Kindbergia praelonga*, *Brachythecium velutinum*, *fissidens incurvus*, *Pellia neesiana* and *Phaeoceros bulbiculosus*). The epiphytic bryophytes of the zone have

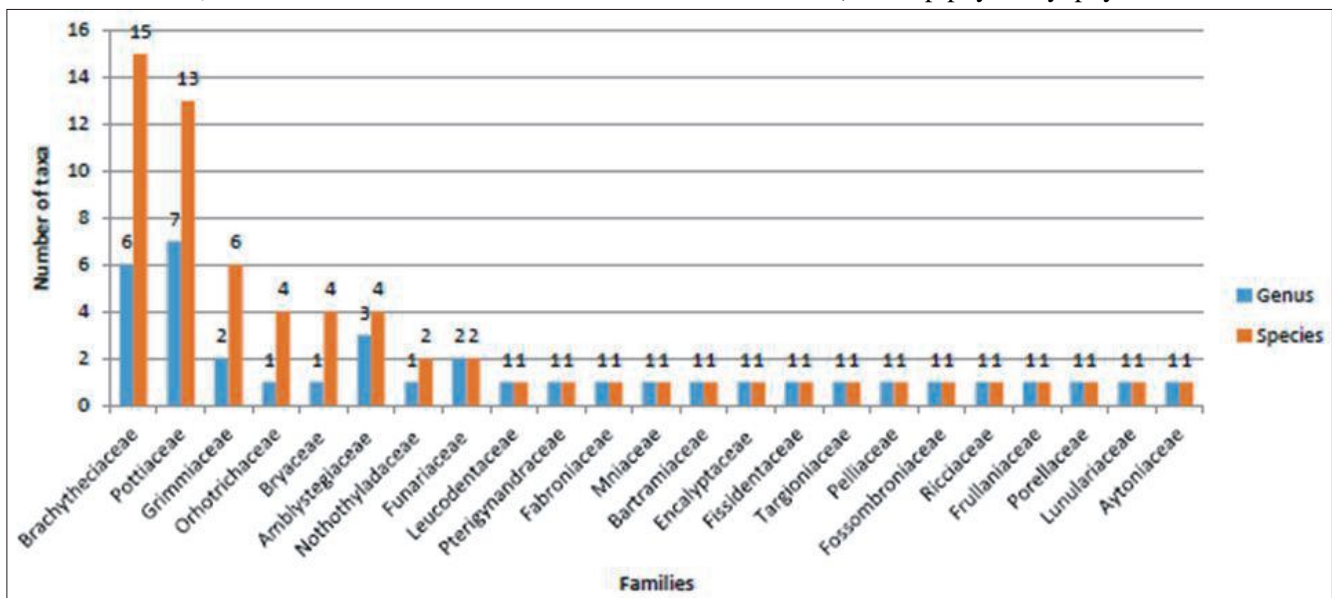


Fig. 4: Generic and specific richness of floristic families.

been estimated at 30 species (Fadel *et al.*, 2017). The only epiphytic species are of 8 (*Hypnum cupressiforme*, *Leucodon sciuroides*, *Hypnum lacunosum*, *Brachythecium albicans*, *Orthotrichum lyellii*, *Rhynchostegiella tenella*, *tortula ruralis* and *Trichostomum crispulum*) (Fadel *et al.*, 2017), which rise the specific bryological number in INP to 74 taxa.

Comparing our inventory with previous studies such as Ros *et al.*, (1999, 2013); Draper *et al.*, (2003, 2005, 2006, 2007) and Ahayoun *et al.*, (2007, 2013), allowed us to found 18 news species for the region. These species are: *Grimmia dissimulata*, *Grimmia meridionalis*, *Tortella nitida*, *Aloina aloides*, *Didymodon luridus*, *Bartramia pomiformis*, *Bryum radiculosum*, *Amblystegium serpens*, *Brachythecium albicans*, *B.rutabulum*, *B.rivulare*, *Brachytheciastrum velutinum var velutinum*, *Isothecium myosuroides*, *Homalothecium lutescens*, *Kindbergia praelonga*, *Rhynchostegium megapolitanum*, *Pellia neesiana*, *Fossombronina pusilla*.

In addition, the present study confirms the presence of 4 species in Morocco that were considered with doubtful: *Grimmia meridionalis*, *Brachytheciastrum olympicum*, *Brachythecium albicans* and *Homalothecium lutescens*.

Thus, *Homalothecium lutescens* which was cited by Ros *et al.*, (2013) as a species reported only by a single old reference dated before 1962 without specifying the locality, is now observed in several stations including Jaâba forest (33°32'58,0992"N and 5°10'22,5984"W) and Michlifén crater (33°24'40,3002"N and 5°4'48,0797"W). Similarly, for *Brachytheciastrum olympicum* reported by Maire and Werner in 1934 and by Jelenc in 1955 and that Ros *et al.*, (2013) cited as a species reported by old references without accurate locality data; we found it in Jaâba forest (33°34'26,9004"N and 5°14'3,0984"W).

The third species confirmed in INP is *Grimmia meridionalis* from Jaâba forest (33°34'26,9004"N and 5°14'3,0984"W).

Brachythecium albicans as Ros *et al.*, (2013) cited as a species published by Emberger and Maire, (1928) and Jelenc, (1955) and that Jelenc, (1955) presented under its synonymous name (*Campylopus introflexus*) in Ros *et al.*, (1999), is now recorded at 1450m altitude in Ain Leuh.

The floristic analysis of the inventory of bryophytes recorded in INP has shown that 2 species belong to the class of Anthocerotopsida, 9 belong to the class of Marchantiopsida and 55 are Bryopsida.

The total number of recorded families is 23. The

family with the highest species richness is Brachytheciaceae, with 15 species belonging to 6 genera. The family Pottiaceae is also rich in species; it has 13 taxa affiliated to 7 genera. Grimmiaceae are represented in INP by 6 species and 2 genera, Orthotrichaceae by 4 species and 1 genus, Bryaceae by 4 species and 1 genus, Amblystegiaceae by 4 species and 3 genera, Nothothyladaceae by 2 species and 1 genus and Funariaceae by 2 species and 2 genera. The remaining families (Leucodontaceae, Pterigynandraceae, Fabroniaceae, Mniaceae, Bartramiaceae, Encalyptaceae and Fissidentaceae) are represented by only one species each and thus by only one genus each (Fig. 4).

The Bryopsida class, therefore, has the highest species richness with 55 taxa, of which 60% (33 species) are acrocarpous and 40% (22 species) are pleurocarps.

Acrocarps are usually ascending stems and pleurocarps are essentially lying stems. The terricolous species of Bryopsida class are 21, the saxicolous are 17 and those that are observed on both the earthy and rocky substrates are 17.

The most common species in INP are *Homalothecium sericeum*, *Orthotrichum rupestre*, *Didymodon vinealis*, *Antitrichia californica*, *Grimmia trichophylla*, *Bryum capillare* and *Orthotrichum cupulatum*.

The number of taxa of the class Marchantiopsida in INP is 9, of which 6 are liverworts with thallus (*Lunularia cruciata*, *Targionia hypophylla*, *Riccia lamellosa*, *Riccia sorocarpa* and *Reboulia hemispherica*, *Pellia neesiana*) and 3 are leafy liverworts (*Fossombronina pusilla*, *frullania dilatata* and *Porella platyphylla*). Of these taxa, 4 were found only on earthy substrate, 2 were collected only on bedrock and 3 were observed on both types of substrates. This low numbers compared to that of Bryopsida class is in agreement with the findings of Jiménez *et al.*, (2002) who worked on terricolous and saxicolous bryophytes of Jbel Bouhalla and found 13 liverworts for 108 mosses surveyed and with the findings of Ros *et al.*, (2000) who worked on the bryological flora of Jbel Toubkal and found 6 liverworts for 95 inventoried bryophyte mosses.

The class of Anthocerotopsida is less diversified and is represented in INP only by 2 species affiliated to the family of Nothothyladaceae: *Phaeoceros laevis* and *Phaeoceros bulbiculosus*. Globally, this class is less diversified compared to mosses and liverworts. The number of Anthocerotes inventoried in the Mediterranean region is close to 7 taxa and that of Morocco is of 5 (Ros *et al.*, 2007).

Snow that covers ground for most of the winter and

varies between 60 and 120 cm near Ifrane and exceeds 200 cm beyond 2200 m of altitude (El Gharbaoui, 1987) and the relatively high temperatures in summer reduce significantly the growing season in general and that of bryophytes in particular. This is an additional constraint to the harvest of bryological plant material whose life cycle is thus reduced especially for liverworts and hornworts that can be considered as ephemerophytes. We should noted that the impact of climate change would be felt in the study area. The drying of some dayas is spectacular; Dayet Aguelmam Tifounassine for instance dries unusually during dry years.

Conclusion

The INP bryophyte study is a demanding task that requires a lot of effort and resources. Harvested specimens are small and fragile and the environmental conditions are heterogeneous. The snow that covers the area for much of the winter reduces the growing season of bryophytes in particular.

Surveys carried out in the INP enabled the identification of 66 species, of which 27 are terricolous, 19 saxicolous and 20 are both terricolous and saxicolous. Of these species, 55 belong to the Bryopsida class, 9 to the Marchantiopsida class and 2 to the Anthocerotopsida class. The established list of bryophytes shows 18 new species for the region and 4 taxa with dubious presence that have been confirmed in Morocco: *Grimmia meridionalis*, *Homalothecium lutescens*, *Brachythecium albicans* and *Brachytheciastrum olympicum*.

The unusual frequent dryness of INP dayas, with the most spectacular of Dayet Aguelmame Tifounassine, would show the effect of climate change on the area; this leads to profound changes in the biotopes, even to the loss of habitat for certain organisms. In addition, the strong anthropo-zoological pressure linked to the increased needs in rangelands and firewood and thus to an overexploitation of natural resources leads to the ecosystems degradation. Thus, bryophytes, an essential component of these ecosystems, are negatively impacted in their biodiversity.

The creation of INP is a best way of rationalizing the management of natural resources. However, sensitization campaigns of the local population to the importance respecting natural heritage must be conducted to ensure the success of development strategies applied in the region. Population should realize that their current needs could be met without compromising the future of coming generations.

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We warmly thank Professor Rosa Maria Ros from the University of Murcia (Spain) who has generously helped us to identify the following species: *Brachytheciastrum dieckii*, *Orthotrichum rupestre*, *Brachytheciastrum olympicum*, *Grimmia lisae*, *Bryum radiculosum*, *Grimmia dissimulata*, *Syntrichia virescens*, *Brachytheciastrum velutinum var. velutinun*, *Bryum gr. capillare*, *Homalothecium sericeum*, *Orthotrichum anomalum*, *Orthotrichum cupulatum*, *Scorpiurium circinatum*, *Syntrichia Montana*, *Targionia hypophylla*, *Tortella nitida*, *Tortula muralis*, *Bryum gr. Capillare*, *Homalothecium aureum*, *Brachytheciastrum olympicum*, *Brachytheciastrum velutinum var. velutinun*, *Grimmia dissimulata*, *Grimmia cf. meridionalis*, *Grimmia pulvinata*, *Pterogonium gracile*, *Rhynchostegium megapolitanum*, *Tortula muralis*, *Palustriella commutata*.

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