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RESEARCH ARTICLE

STUDY OF EPIPHYTIC BRYOPHYTES IN THE IFRANE NATIONAL PARK IN MOROCCO

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ABSTRACT

The Ifrane National Park (INP) is located in the heart of the Middle Atlas in central Morocco. It is characterized by a large biological and ecological diversity. Since bryophyte research is very fragmentary in the region, our study aims to establish an exhaustive list of bryophyte species of INP. The present work begins by establishing a list of epiphyte species. Surveys carried out from 2015 to 2017 showed the presence of 30 species of bryophytes that settled on trunks and branches of the main forest species of the Park: Atlas cedar (*Cedrus atlantica* M.), Green Oak (*Quercus rotundifolia Lam.*) and Zeen Oak (*Quercus faginea* Lam.). The listed species are divided into 10 families and 21 genera. Twenty-nine species were observed on Green oak, 28 on Zeen oak and 24 on Atlas cedar. INP includes the Atlas cedar that is best preserved but shows mostly signs of decline especially in areas with strong anthropozoogenic pressure. This regressive trend has repercussions on the bryological diversity whose expansion is limited in these area.

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INTRODUCTION

The Ifrane National Park (INP) covers the largest part of the central Middle Atlas including the plates and ridges located between Dait Aoua in the North, Jaaba forest in the North West, Ain Leuh forest in the South West, Bekrit and Senoual forest massifs in the south-east, and Aghbalou Laarbi forest in the north-east (HCEFLCD, 2007). It occupies the altitudinal fringe between 1100 m (Dir Azrou - Ain Leuh) and 2440 m (Jbel Ij peak - Aghbalou Laarbi massif) (HCEFLCD, 2006). It shelters the largest Atlas cedar forest in Morocco. It encompasses a group of sites with remarkable biodiversity, such as wetlands, bird sanctuaries (RAMSAR sites) and otters (Afenourir and Tifounassine lakes, Oued Bekrit, Dayet Aoua, Oued Tizguit, Oued El Khala) (HCEFLCD, 2007). Atlas cedar and Green oak, installed on limestone or basalt, form the main plant cover of the park and are the ligneous species found at high altitude in INP. El Gharbaoui (1987) states that the cedar of the Middle Atlas is a relic of the flora of cold episodes that Morocco has had during the quaternary. Downwards, another forest species, Zeen oak, structures the landscape to the west and north of the park. Finally, the maritime mountain pine constitutes an isolated stand in the northern part of INP. The current subtropical climate of Morocco (El Gharbaoui, 1987) undergoes fluctuations related to the movements of the Azores anticyclone, the Saharan depression and the various isobaric Mediterranean and North-Atlantic individuals. This climate has been subdivided into bioclimatic stages according to Emberger pluviothermal diagram (Sauvage, 1963). The dominant bioclimates are thus the subhumid and humid with nearly 1200 mm of annual precipitation on some heights and escarpments (HCEFLCD, 2007). INP has been the subject of several studies of geological, floristic and faunistic nature having allowed assessing the vascular flora of the park to more than 1015 species (HCEFLCD, 2006), birds with 142 species, mammals with 37 taxa and reptiles and amphibians with 33 species (Benabid, 2000). However, there is not yet an accurate estimate of the diversity of algae, fungi, lichens and mosses. Studies that have focused on these groups are rare and highly fragmented in the area. To fill this gap, we undertook to carry out prospections in the park to study the bryological flora. We began with the diversity of epiphyte species with the objective of establishing a list as complete as possible.

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MATERIALS AND METHODS

Sampling

The plant formations in INP are organized mainly by three forest species: *Cedrus atlantica*, *Quercus rotundifolia* and

Quercus faginea. The sampling that we adopted is of systematic type starting from the middle of each considered station and extending over its entire surface. Whenever we observed a population of bryophytes in the trunk of one of the three forest species, we collected a sample of a few individuals. The collected samples are as complete as possible, including the fertile elements of the plant (sporophyte). We worked carefully by not collecting an entire population to avoid harvesting a rare or endangered species as recommended by IUCN. The first harvest was conducted in early December 2015 before snowfall, the second in March and April 2016 after snowmelt, the third in August 2016 and the fourth in November 2016. Two other collections were realized in 2017, the first in March and the second in July. The samples dried in the open air and were placed in paper envelopes with all the information relating to the harvest such as date, station name, gps coordinates, substrate, tree species. We preserve the collected samples in herbarium. The identification was carried out using the flora of Augier (1966), Pierrot (1982) and Smith (2004), and also with the help of references like (Malcoms, 2000) and (Lüth, 1988). Hereafter (Fig. 1), the study sites are geolocated in a map developed with the GIS software (QGIS 2.18) with as base map a layer coming from the Web service of Google.

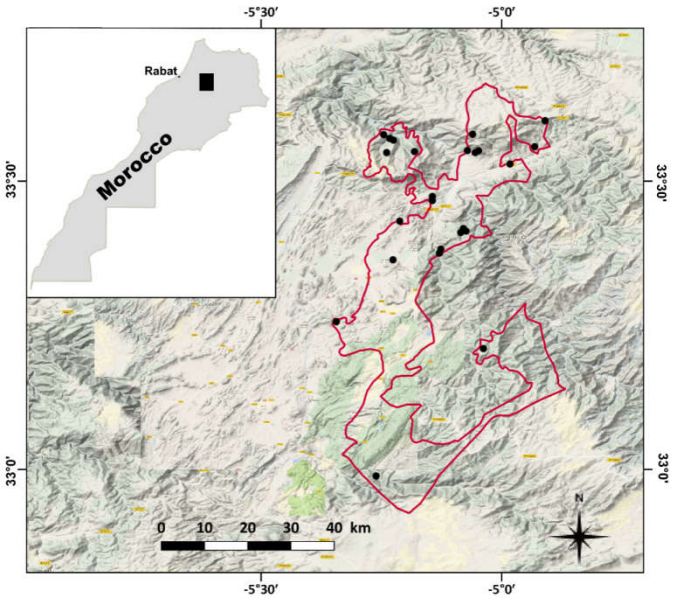


Figure 1. Location and boundaries of Ifrane National Park with black dots representing sampled stations

Description of study area

Morocco is committed to a national strategy for the conservation of natural heritage. National parks and protected areas have been set up throughout the country including our study area: Ifrane National Park.INP was created by decree promulgated on 08/10/2004. The territory of INP extended from 53,000 ha in 2004 (Benabid, 2000) to 123,000 ha in 2006(HCEFLCD, 2007). INP occupies the western part of central Middle Atlas. It is located in one of the most watered areas of Morocco with shorter dry periods in summer. The cultivated area is extremely reduced but pastoralism is practiced in an extensive way, especially sheep farming. Forest cover reaches 56% of the park area with 30,000 ha (HCEFLCD, 2007). Benabid (2000) sees this territory as a forest area by excellence that is individualized by its ecological and biological values. The bioclimate is subhumid temperate at low altitude and cool, cold to very cold on highlands; precipitations are between 650 mm in low altitude and more than 1200 mm on high mountain exposed to oceanic disturbances (Benabid, 2000).Precipitations are spread over a large period of the year. The highest number of days of precipitation of the area is recorded in Ifrane reaching 102 days (El Gharbaoui, 1987). The annual average of maximum temperatures is 16.7°C in Ifrane and the annual average of the minima is there of 5.5°C (El Gharbaoui, 1987). Relating to edaphic aspect, INP contains four major soil groups: soils on andic or brown andic volcanic rocks; soils on fersialitic red limestone rocks; soils on dolomitic pararendzine rocks (HCEFLCD, 2006). M'Hirit (2008) links soil types to the potential of forest formation. He argues that Cedar has good potential on basaltic substrate, average potential on calcareous or dolomitic limestone substrate and poor potential on compact sandy and calcareous dolomites. The stages of vegetation that exist in INP are: Thermo-Mediterranean ceiling, Meso-Mediterranean, Supra-Mediterranean and Mediterranean Highlander (Benabid, 2000).

RESULTS AND DISCUSSION

Sampling was carried out on the base and trunks of the three main forest species of INP: *Cedrus atlantica*, *Quercus rotundifolia* and *Quercus faginea*.Samples were determined in the laboratory. The harvests spread out during almost two years and covered all seasons. A list of epiphyte species has therefore been established; this list includes 29 species belonging to the phylum of mosses and 1 species belonging to the phylum of hepatica. No anthocerotes were found on the park's forest species. The 30 listed species belong to 10 families and 21 genera. Brachytheciaceae are rich of 7 species, Pottiaceae and Orthotrichaceae, 4 species each, Leucodentaceae and Grimmiaceae, 3 species each, Hypnaceae and Bryaceae contain 2 species each and finally families of Fissidentaceae, Fabroniaceae and Pterigynandraceae which are represented by only one species each (Figure 2).

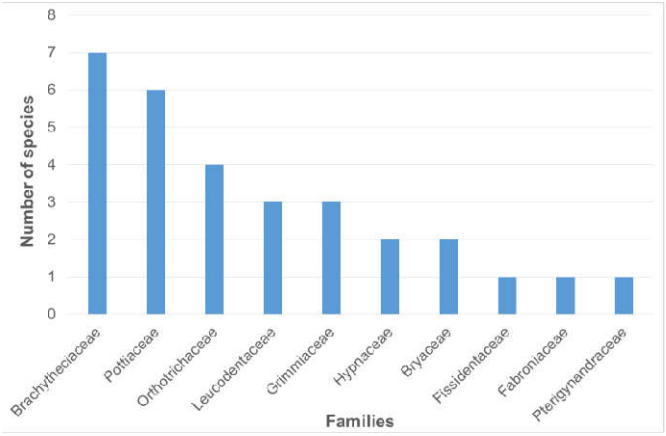


Figure 2. Species richness per family of the epiphytic bryophytes in Ifrane National Park

The number of epiphytic bryophytes genera recorded in INP is 21. The genus of *Orthothrichum* contains the most species with 4 taxa, the other genera are of one or two species each (Figure 3).

The three main forest species organize ecosystems rich in biodiversity but where undergo a very strong

anthropozoogenic pressure, especially in ecotourism zones and forest edges.

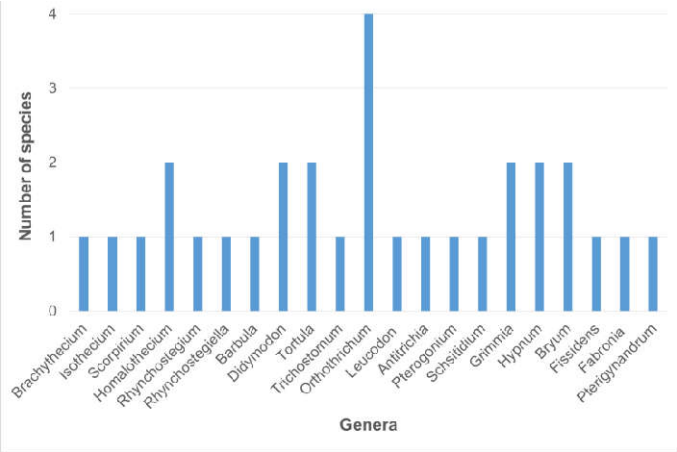
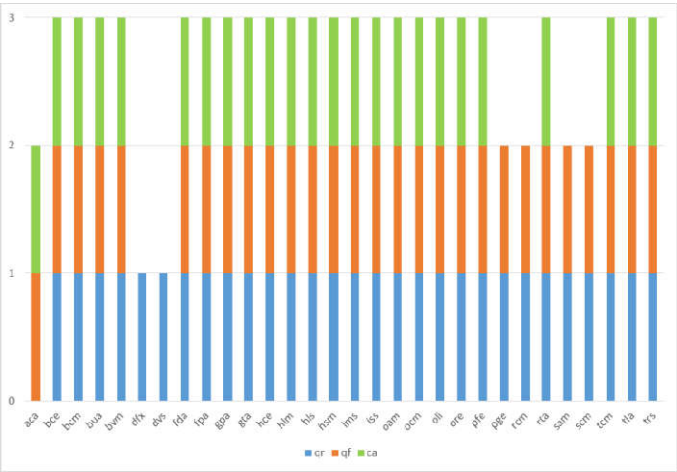


Figure 3. Specific richness per genera of epiphytic Bryophytes of Ifrane National Park

However, M'Hirit and Belghazi (2008) attribute the decline experienced by forests in INP mainly to climate changes with xeric tendencies. UNESCO declared the Middle Atlas cedar massif as a biosphere reserve in February 2016 in the concern of its protection. Cedar grows to the highest degree of maturity in the supra-Mediterranean series between 1600 and 2000 m a.s.l., on basaltic substrates (Benabid and Fennane, 1999). In this altitudinal slice, the Atlas cedar dominates green oak and zeen oak. Even though the number of species is 30, our observations have shown that only few species have an important cover: *Antitrichia californica*, *Brachythecium velutinum*, *Fabronia pusilla*, *Homalothecium lutescens*, *Homalothecium sericeum*, *Hypnum cupressiforme*, *Orthotrichum cupulatum*, *Orthotrichum rupestre*, *Pterigynandrum filiforme*, *Pterogonium gracile* and *Tortula laevipila*.



qr: *Quercus rotundifolia*, qf: *Quercus faginea*, ca: *Cedrus atlantica*

Figure 4. Distribution of epiphytic bryophytes according to the three studied forest species

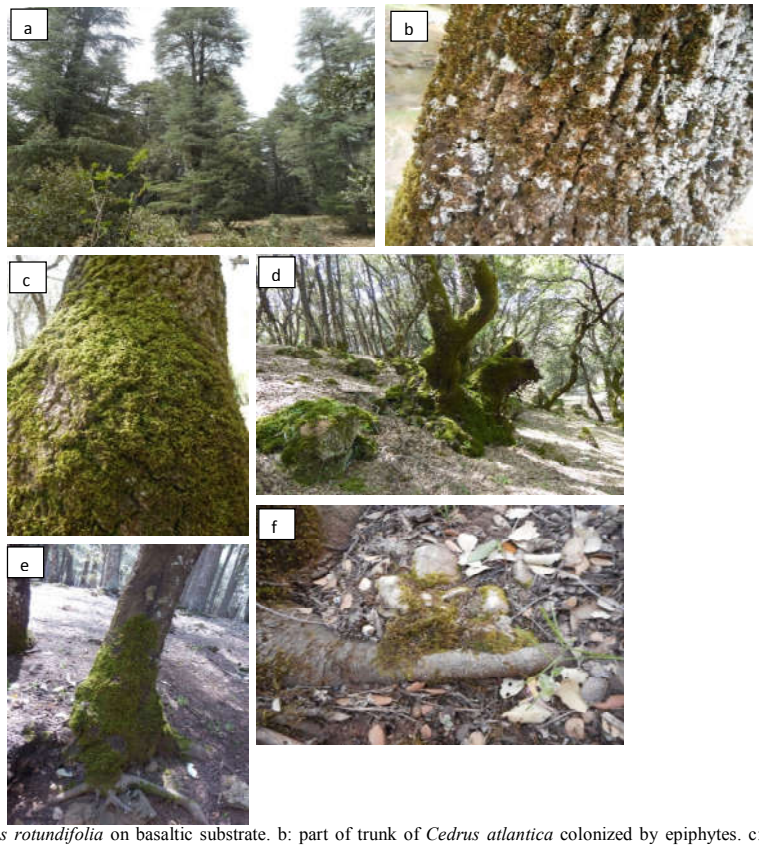
These species account for nearly 37% of the specific richness of epiphytic bryophytes of INP. They cover large areas on trunks and branches of trees. In the areas exposed to north and where Atlas cedar prevails, bryophytes most often have significant cover on trunks and branches. On the other hand, in the southern exposures where Green oak organizes the forest ecosystems, bryophytes are also diversified but generally less abundant, except in places where local moisture conditions allow their prosperity. *Homalothecium lutescens* and *Homalothecium sericeum* occupy very large areas on trunks and branches of *Quercus rotundifolia*, *Quercus faginea* and *Cedrus altantica* in north exposed forest's parts. These two species are very often observed together what would find its explanation in the work of Rosengren and Cronberg (2015) who showed that spores of *H. sericeum* could germinate and develop into dwarf males on shoots of *H. lutescens* at least as well as the spores of *H. lutescens*. *Orthotrichum cupulatum* and *Orthotrichum rupestre* are predominant in Jaaba forest on *Quercus rotundifolia* and *Quercus faginea*. They are also present at the level of *Cedrus atlantica* but with less recovery. Figure 4, based on a table in the appendix, illustrates the bryophyte specific richness on the three forest species. The explanation for abbreviations for bryophyte species is reported in appendix. The species found on *Quercus rotundifolia* and *Quercus faginea* and *Cedrus atlantica* are of 23 (Figure 4):

Barbula unguiculata, *Brachythecium velutinum*, *Bryum caespiticium*, *Bryum capillare*, *Fabronia pusilla*, *Frullania dilatata*, *Grimmia pulvinata*, *Grimmia trichophylla*, *Homalothecium lutescens*, *Homalothecium sericeum*, *Hypnum cupressiforme*, *Hypnum lacunosum*, *Isothecium myosuroides*, *Leucodon sciuroides*, *Orthotrichum anomalum*, *Orthotrichum cupulatum*, *Orthotrichum rupestre*, *Orthotrichum lyellii*, *Pterigynandrum filiforme*, *Rhynchostegium tenella*, *Syntrichia laevipila* (*Tortula laevipila*), *Syntrichia ruralis* (*Tortula ruralis*) and *Trichostomum crispulum*. The species exclusively common to *Quercus rotundifolia* and *Quercus faginea* are: *Pterogonium gracile*, *Rhynchostegiella confertum*, *Schistidium apocarpum* and *Scorpiurium circinatum*. We did not found these species on *Cedrus atlantica* despite numerous visits and explorations in the study area (Figure 4). Only one species is common and exclusive to *Quercus faginea* and *Cedrus atlantica*: *Antitrichia californica* (Figure 4). No species is exclusive to *Cedrus atlantica* alone or *Quercus faginea* alone. On the other hand, there are two species that are exclusive to *Quercus rotundifolia*, namely *Didymodon fallax* and *Didymodon vinealis*, which appear essentially on the basis of trunks on the entire altitudinal range that it occupies in INP (Figure 4). Green oak is a very plastic species that has a wide ecological amplitude. This could be why the majority of epiphytic bryophytes found on cedar and zeen oak are also found on green oak, which shows, according to Benabid (2000), a great disposition to withstand harsh ecological conditions.

The observations have also revealed the existence of a certain repetition of some species of bryophytes that have similar ecological requirements and that are found very often together. There is no phytosociological study yet to confirm this. These bryophyte species are:

- *Torutla laevipila* and *T. ruralis*
- *Homalothecium lutescens*, *Homalothecium sericeum* and *Brachythecium velutinum*
- *Orthotricum rupestre* and *Homalothecium sericeum*
- *Hypnum cupressiforme*, *Brachythecium velutinum* and *Homalothecium lutescens*
- *Leucodon sciuroides* and *Hypnum cupressiforme*
- *Antitrichia californica*, *Tortula ruralis* and *T. laevipila*
- *Hypnum lacunosum* and *Frullania dilatata*.

The forest dynamics in Morocco in general and in Middle Atlas in particular is marked according to Benabid and Fennane (1999) by a great dominance of the regressive trend. This trend is reflected in bryological biodiversity, which is undoubtedly weakened. Moreover, the park has pastoral cover, including forest one, at 90% (HCEFLCD, 2007); this may explain the weakness of the bryological biodiversity of the area. There is no previous work on bryophytes to make an objective comparison, but we believe that if the forest were prosperous, the bryological component would have been it too. The following figure 5 is an illustration of forest formations and epiphytic bryophytes in the area.



a: Stand of *Cedrus atlantica* and *Quercus rotundifolia* on basaltic substrate. b: part of trunk of *Cedrus atlantica* colonized by epiphytes. c: North exposed side of trunk of *Cedrus atlantica* covered by epiphytes. d: Base of *Quercus rotundifolia* resulting from a coppice trunk colonized by bryophytes. e: Zeen oak partially exposed by erosion with the base of trunk covered by bryophytes. f: The base of trunk and roots discovered by erosion and colonized by epiphytes.

Figure 5. Photographic illustrations of epiphytic bryophytes in Ifrane National Park: a: Stand of *Cedrus atlantica* and *Quercus rotundifolia* on basaltic substrate. b: part of trunk of *Cedrus atlantica* colonized by epiphytes. c: North exposed side of trunk of *Cedrus atlantica* covered by epiphytes. d: Base of *Quercus rotundifolia* resulting from a coppice trunk colonized by bryophytes. e: Zeen oak partially exposed by erosion with the base of trunk covered by bryophytes. f: The base of trunk and roots discovered by erosion and colonized by epiphytes

Figure 6. a, *Fabronia pusilla* real size ; b, *Fabronia pusilla* (x 10); c, *Brachythecium velutinum* real size; d, *Brachythecium velutinum* (x 4); e, *Schistidium apocarpum* (x 2); f, *Schistidium apocarpum* individual (x 4)

Figures 6, 7 and 8 illustrate the remarkable species for their abundance that are found on Atlas cedar as well as on Green oak and Zeen oak.

Conclusions and Recommendations

Our study carried out in INP to establish a list of epiphytic bryophyte species has identified 30 species including 29

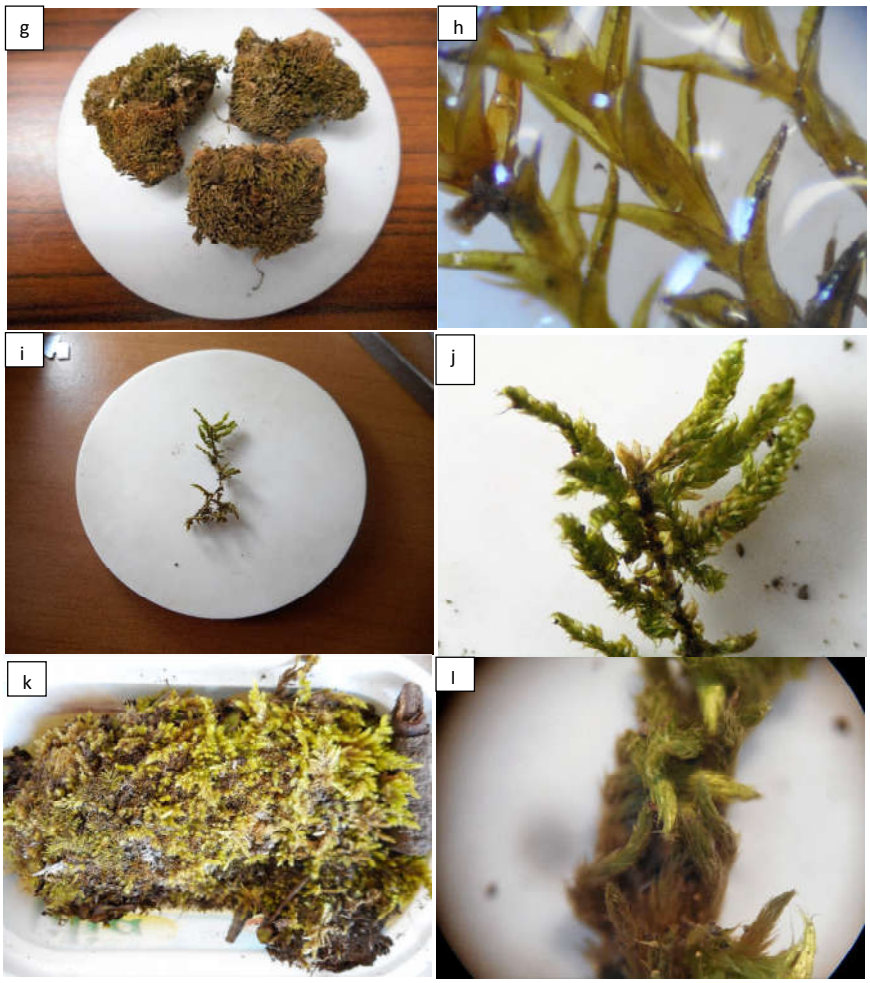


Figure 7. g, *Grimmia trichophylla* real size ; h, Grimmia trichophylla (x 100); I, *Hypnum lacunosum* real size; j, *Hypnum lacunosum* (x 4); k, *Homalothecium lutescens* real size ; l, *Homalothecium lutescens* (x10)

Figure 8. m, *Orthotricum rupestre* (x 3); n, *Orthotricum rupestre* (x 4); o, *Pterigynandrum filiforme* (x 2); p, *Pterigynandrum filiforme* (x 100)

mosses and only one hepatic; no hornwort were found on the main forest species of the study area. The recorded species are divided into 10 families and 21 genera with the predominance of the family of brachytheciaceae in terms of species richness with 7 taxa. The species with the most important cover are: *Antitrichia californica*, *Brachythecium velutinum*, *Fabronia pusilla*, *Homalothecium lutescens*, *Homalothecium sericeum*, *Hypnum cupressiforme*, *Orthotrichum cupulatum*, *Orthotrichum rupestre*, *Pterigynandrum filiforme*, *Pterogonium gracile* and *Tortula laevipila*. All these species, except *Antitrichia californica*, are found on *Quercus rotundifolia*, whose epiphytic bryophyte number reaches 29 taxa. The number of bryophyte species recorded on *Quercus faginea* is 28, while that of the Atlas cedar does not exceed 24 taxa. The prospection carried out at INP for more than two years and having covered all the seasons made it possible to note the strong anthropozoogenic pressure that would lead to the deterioration of the forest species if it continues. The shrub layer is even overgrazed in some places. The edges of forests are entirely therophytised. This phenomenon inevitably affects the bryological flora. The number of species listed on tree trunks remains lower than the potentialities that these ecosystems can offer if they are well conserved. An awakening by the managers of the need for protecting this rich nature was crowned by the creation in 2004 of the Ifrane National Park and by UNESCO's declaration of Middle Atlas cedar massif as a biosphere reserve, in February 2016, in the concern of its protection.

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Appendix

Espèces	code	*Quercus rotundifolia (qr)*	*Quercus faginea (qf)*	*Cedrus atlantica (ca)*
Antitrichia californica	aca	0	1	1
Barbula unguiculata	bua	1	1	1
Brachythecium velutinum	bvm	1	1	1
Bryum caespiticium	bcm	1	1	1
Bryum capillare	bce	1	1	1
Didymodon fallax	dfx	1	0	0
Didymodon vinealis	dvs	1	0	0
Fabronia pusilla	fpa	1	1	1
Frullania dilatata	fda	1	1	1
Grimmia pulvinata	gpa	1	1	1
Grimmia trichophylla	gta	1	1	1
Homalothecium lutescens	hls	1	1	1
Homalothecium sericeum	hsm	1	1	1
Hypnum cupressiforme	hce	1	1	1
Hypnum lacunosum	hlm	1	1	1
Isothecium myosuroides	ims	1	1	1
Leucodon sciuroides	lss	1	1	1
Orthotricum anomalum	oam	1	1	1
Orthotricum cupulatum	ocm	1	1	1
Orthotricum rupestre	ore	1	1	1
Orthotricum lyellii	oli	1	1	1
Pterigynandrum filiforme	pfe	1	1	1
Pterogonium gracile	pge	1	1	0
Rhynchostegiella tenella	rta	1	1	1
Rhynchostegium confertum	rcm	1	1	0
Schistidium apocarpum	sam	1	1	0
Scorpiurium circinatum	scm	1	1	0
Tortula laevipila	tla	1	1	1
Tortula ruralis	trs	1	1	1
Trichostomum crispulum	tcm	1	1	1

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