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CONTRIBUTION TO THE STUDY OF BRYOPHYTIC BIODIVERSITY OF THE MAMORA FOREST (MOROCCO)

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Abstract

The cork oark forest of Mamora located in northwest Morocco is an important biodiversity reserve. Since the bryological component of the forest has only been the subject of sporadic investigations, the objective of this study is to establish an exhaustive list of this flora. For this purpose, stratified random sampling was adopted, the strata correspond to the cantons of the forest. Of the 245 plots of the Mamora, 50 were randomly selected. In these plots, bryophyte samples were collected each time a stand were encountered. The explorations took place in the fall and spring of 2015, 2016 and 2017. The determinations allowed us to inventory 70 species of bryophytes with 44 mosses, 22 hepatics and 4 Anthocerotes. Of these, 12 are rare in the study area and 22 are new to the Mamora. Among the Mosses, *Ptychostomum cappillare* is the most widespread species and among the Hepatics, *Riccia cilifera* has the highest recoveries. Among the Anthocerotes, *Phaeroceros laevis* is the most frequent. Terricolous bryophytes are the most common. Corticoles are mainly observed on the basis of the cork oak trunk. Canton A is the richest in bryophyte species with 60 taxa. Areas where the soil is covered with bryophytes show a high rate of acorn germination. This flora improves the soil's ability to absorb water, moisture will help the acorn to germinate easily instead of rotting.

Key words: Mamora, Cork oak, biodiversity, bryophytes, germination, Morocco.

Introduction

The Mamora Forest in northwest Morocco is the largest one-piece cork oak forest in the world (Natividade, 1956, Metro and Sauvage, 1955, HCEFLCD, 2015). It is a socio-economic area of great importance. For surrounding urban areas, the Mamora represents a great depolluting system for the air by collecting carbon dioxide and releasing oxygen. It is also an important biodiversity reserve. The vascular vegetation largely dominated by the Cork oak (*Quercus suber*) is estimated at 408 species, subspecies and varieties, which represents 48% of the vascular flora of Moroccan cork forests (Sauvage, 1961, Aafi *et al.*, 2005) and 9.3% of the whole forest of Morocco (Benabid, 2000). More than 250 species of Arthropods have been recorded in the Mamora forest, as well as 12 species of nesting birds (ONEM, 2001). The plant component that has been least explored in the area is that of non-vascular cryptogams. Indeed, it is only during the last two decades that studies on the census of bryophytes has begun in the Mamora forest (Ahayoun *et al.*, 2013), work that has remained sporadic. Bryophytes that have not yet been studied in Morocco are of increasing interest elsewhere for their bio-accumulative properties of heavy metals and organic pollutants and their role as bio-indicators (Ares *et al.*, 2012, Giordano *et al.*, 2005 and Gonzalez *et al.*, 2016). They represent

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between 15 000 (Gradstein *et al*., 2001) and 25000 species (Crum 2001) worldwide and thus constitute the second plant phylum after flowering plants (Mishler, 2001). It is therefore entirely justified to undertake the updating of the catalogue of bryophyte species in Morocco. To this end, the objective of this study is to establish an exhaustive list of bryophyte species in the Mamora forest.

Material and Method

Study area, geographical location and description

The Mamora forest is located in northwestern Morocco, along the Atlantic Ocean, between the longitudes 6° and 6°45' west and the latitudes 34° and 34°20' north (Fig. 1). It is part of a rectangle 60 km long, from west to east and 30 km wide, from north to south (Aafi, 2006). Lepoutre in 1966 described it as a vast quaternary platform that extended from the Atlantic Ocean between Rabat and Kénitra, up to 70 km inland, it was then bounded to the south by the Bou-Regreg valley and the foothills of the Central Plateau and to the north by the Gharb plain.

The Mamora forest is the largest cork oak forest in the world. It covered more than 130000 ha at the beginning of the twentieth century (Emberger, 1939, Benabid, 2000). Today, it covers less than 60,000 ha (Benabid, 2000). This decline in the extent of cork oak in Mamora is mainly due to the substitution of this species by pine, eucalyptus and Australian acacias. The area occupied by cork oak in the Mamora is reduced to less than one-third of its potential surface area (HCEFLCD, 2004). The situation

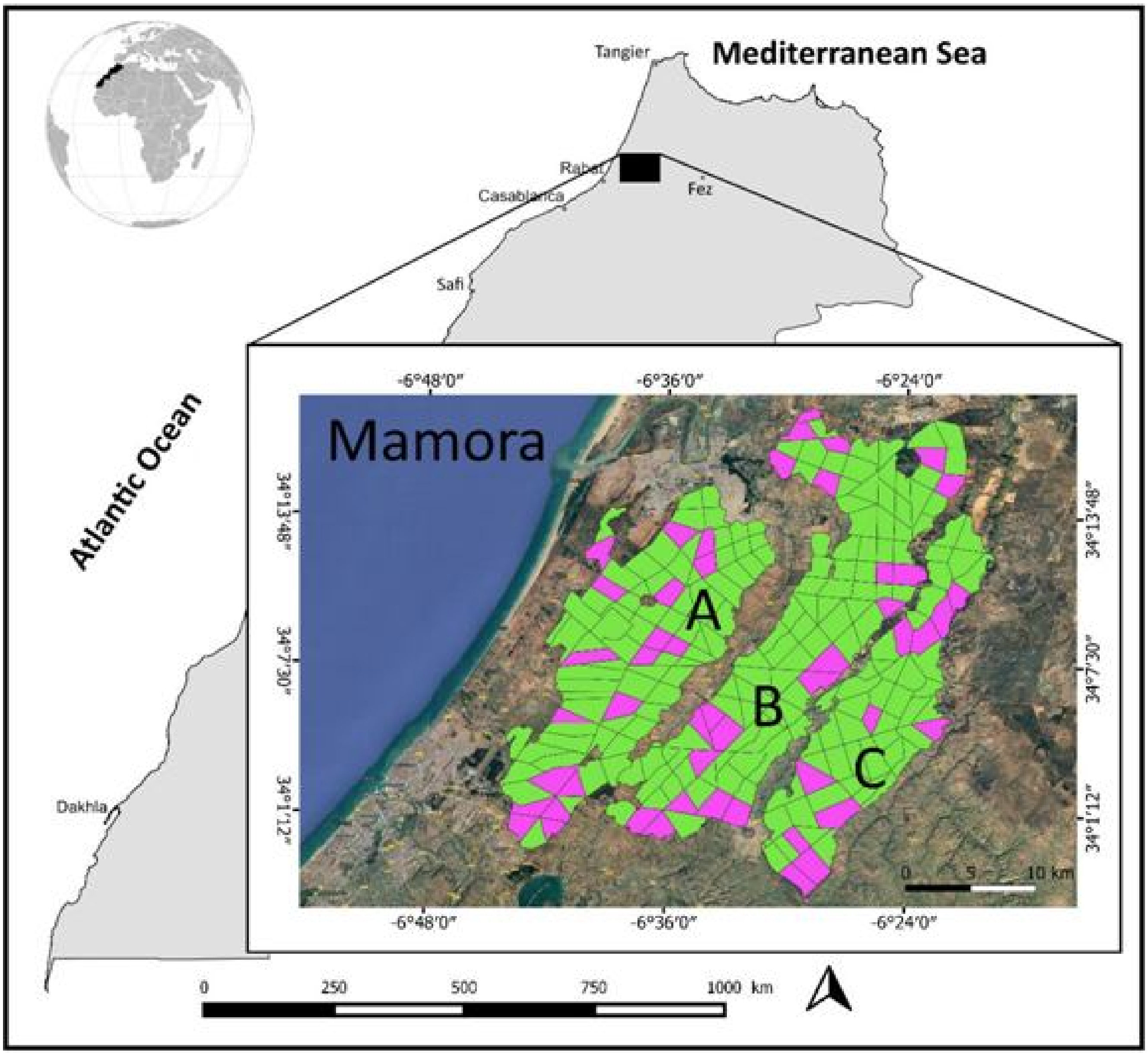

Fig. 1: Geographical location of Mamora (Cantons A, B and C). Sampled parcel in a red.

Table 1: Mosses of cork oak forest of Mamora.

Family	Species	Substratum	% Presence
Aneuraceae	*Isothecium alopecurioides*	terricolous	4
Brachytheciaceae	*Brachythecium rutabulum*	terricolous	46
	Brachythecium velutunum	terricolous	10
	Homalothecium sericeum	corticolous	10
	Rhynchostegium megapolitanum	terricolous	6
	Scorpiurium circinatum	corticolous	6
Bryaceae	*Bryum argentum*	saxicolous	10
	Bryum caespiticium	terricolous	40
	Bryum dichotomum	saxicolous	4
	Bryum radiculosum	saxicolous	4
	Ptychostomum capillare	terricolous	92
	Ptychostomum torquescens	terricolous	4
Ditrichaceae	*Cheilothela chloropus*	terricolous	4
	Pleuridium acuminatum	terricolous	50
	Pleuridium subulatum	terricolous	4
Fabroniaceae	*Fabronia pusilla*	corticolous	10
Fissidentaceae	*Fissidens bryoides*	terricolous	8
Funariaceae	*Entosthodon fascicularis*	saxicolous	2
	Entosthodon pulchellus	saxicolous	6
	Funaria hygrometrica	terricolous	30
	Funariella curviseta	saxicolous	2
	Physcomitrium pyriforme	terricolous	4
Leucobryaceae	*Campylopus introflexus*	corticolous	16
	Campylopus flexuosus	corticolous	6
Orthotrichaceae	*Orthotrichum anomalum*	Corticoole	4
	Orthotrichum diaphanum	corticolous	16
	Orthotrichum lyellii	corticolous	6
	Zygodon viridissimus	terricolous	2
Pottiaceae	*Aloina ambigua*	terricolous	12
	Barbula convoluta	saxicolous	28
	Barbula unguiculata	terricolous	22
	Didymodon fallax	saxicolous	4
	Didymodon tophaceus	saxicolous	4
	Didymodon vinealis	saxicolous	4
	Syntrichia laevipila	corticolous	4
	Syntrichia ruralis	corticolous	10
	Timmiella barbuloides	terricolous	10
	Tortella flavovirens	saxicolous	30
	Tortella nitida	saxicolous	4
	Tortella squarrosa	terricolous	16
	Tortula marginata	saxicolous	6
	Tortula muralis	saxicolous	20
	Trichostomum crispulum	terricolous	8
Sematophyllaceae	*Sematophyllum substrumulosum*	corticolous	16

is aggravated by overgrazing, herds are pushed back to the much more hospitable cork forests compared to forest formations organized by exotic species such as Eucalyptus, whose undergrowth is almost absent (Dahmani, 2005). The Mamora is divided from west to east into five cantons (A, B, C, D and E) delimited by four depressions where wadis flow northward. These cantons are subdivided into 33 groups, containing a total of 448 parcels and 23 enclaves (HCEFLCD, 2013).

The bioclimate of this cork forest is subhumid with warm winter in its western part and semi-arid with temperate winter in its central and eastern part (HCEFLCD, 2013, Benabid, 2000 and Aafi, 2007), determining a decreasing rainfall gradient from west to east. Rainfall thus varies from 300 to 680 mm (HCEFLCD, 2013). Intra-annual variability is of the order of 120 mm in December (most watered month) and 0.5 mm in July (driest month) (Fig. 2). Maximum temperatures range from 26.1°C to 35.5°C and minimum from 5°C to 8.2°C (HCEFLCD, 2013). The altitude is barely 7m at the level of the Atlantic coast. It increases towards the east to reach 290 m at the level of the city of Kémisset (Metro and Sauvage, 1955, HCEFLCD, 2013).

From a pedological point of view, the domanial massif presents various types of soils whose differentiation is essentially based on the thickness of the sand layers that cover the red clays of the Mamora, the nature of the covering sands and the more or less brutal transition from sands to deep clays (HCEFLCD, 2011). According to HCEFLCD (2013), a distinction is then made between (i) shallow beige sands on clay in the southern part of cantons C, D and E, (ii) deep beige sands on clay in the northern part of cantons C, D and E, (iii) beige sands resting on red sands on clay which constitute the dune relief of cantons A and B and (iv) hydromorphic soils located in the lowlands that are covered by temporary or permanent dayas.

Sampling method

This work is carried out in cantons A, B and C. Cantons E and D were excluded because they are largely private enclaves. The adopted sampling is randomly stratified. We then considered the three cantons A, B and C as strata whose elevation, bioclimate, precipitation and temperatures as well as the thickness

Table 2: Hepatics and Anthocerotes of cork oak forest of Mamora.

Family	Species	Substratum	Presence rate
Anthocerothaceae	*Anthoceros agrestis*	Terricolous	4
	Anthoceros punctacus	Terricolous	4
	Phymatoceros bulbiculosus	Terricolous	2
Corsiniaceae	*Corsinia coriandrina*	Terricolous	8
Fossombroniaceae	*Fossombronia caespitiformis*	Terricolous	4
	Fossombronia caespitiformis subsp. multispira	Terricolous	2
	Fossombronia pusilla	Saxicolous	4
Jubulaceae	*Frullania dilatata*	Corticolous	2
Lunulariaceae	*Lunularia cruciata*	Saxicolous	6
Notothyladaceae	*Phaeoceros laevis*	Terricolous	12
Oxymitraceae	*Oxymitra incrassata*	Terricolous	6
Ricciaceae	*Riccia canaliculata*	Terricolous	10
	Riccia cavernosa	Terricolous	4
	Riccia ciliifera	Terricolous	24
	Riccia crozalsii	Terricolous	2
	Riccia crystallina	Terricolous	4
	Riccia fluitans	Hygrophilic	2
	Riccia gougetiana	Terricolous	24
	Riccia huebeneriana	Terricolous	2
	Riccia lamellosa	Terricolous	2
	Riccia macrocarpa	Terricolous	2
	Riccia sorocarpa	Terricolous	4
	Riccia warstorfii var. subinermis	Terricolous	2
Sphaerocarpaceae	*Sphaerocarpus michellii*	Terricolous	2
Targioniaceae	*Targionia hypophylla*	Saxicolous	4
	Targionia lorbeeriana	Saxicolous	2

of the sand layer vary from west to east. Out of a total of 245 plots in cantons A, B and C, 50 sampling stations were selected randomly, taking care to avoid plots containing private enclaves (Fig. 1). The proportional random stratified sampling was performed on Excel using the function *alea*.

Bryophytes were harvested in the fall and spring of 2014, 2015 and 2016 with further surveys in the spring. In these ecosystems, spring is the most favorable season to observe the majority of species under best conditions, especially with the sporophyte that is necessary for identification. The number of samples can be up to 25 in stations with high muscular coverage. All bryophyte stands encountered in the field were sampled for laboratory determination based on macroscopic and microscopic characteristics. The identified taxa are stored in the laboratory's herbarium. The determination keys used were those of Augier (1966), Smith (1990 and 2004), Coudreuse (2005), Casas et *al.,* (2006 and 2009). The nomenclature adopted is based on that of the list of Mediterranean species (Ros *et al*., 1999), (Ros *et al*., 2007) and (Ros *et al*., 2013). The list of bryophyte species is presented in a table by family, substrate type and presence rate. The presence rate is calculated according to the number of stations in which the taxon appears in relation to the total number of stations.

Results

Exploration of the 50 stations of the Mamora forest allowed us to inventory 70 species related to 38 genera and 21 families (Tables 1 and 2). Mosses are dominant with 44 species (62.85% of the whole population) (Table 1), Hepatics are represented by 22 species (31.42%) and Anthocerotes by only 4 species (5.71%) (Table 2). Tables 1 and 2 show the bryophyte species by family, substrate and presence rate. Table 3 shows bioclimate, soil type and specific richness of bryophytes in the three cantons.

Discussion

Explorations carried out through the cork forest of Mamora over three years have enabled the census of 70 species of bryophytes that floristic analysis allowed to link to 21 families, 4 of which are clearly dominant, these are Pottiaceae (15 species), Ricciaceae (12 species), Bryaceae (6 species) and Brachytheciaceae (5 species) (Table 1 and 2). These families alone account for 38 species or 54.28% of the whole population. The other families (17 taxa) contribute to 45.71% of the total population.

After comparison with previous work (Ahayoun, 2013), 22 species are observed for the first time in Mamora, including 21 mosses and a single hepatic. These taxa are: *Isothecium alopecurioides, Homalothecium sericeum, Scorpiurium circinatum, Bryum radiculosum*, *Cheilothela chloropus*, *Funariella curviseta, Entosthodon pulchellus, Campylopus introflexus, Campylopus flexuosus*, *Orthotrichum anomalum, Orthotrichum lyellii*, *Aloina ambigua, Barbula convoluta*, *Barbula unguiculata*, *Didymodon tophaceus*, *Didymodon fallax, Tortella flavovirens, Tortella nitida, Tortella squarrosa, Tortula marginata, Syntrichia ruralis* and *Fossombronia caespitiformis* subsp. *multispira.*

The most widespread species in the study site is essentially *Ptychostomum capillare*, which is found in

Table 3: Species richness, Bioclimate and soil of the three cantons in Mamora forest.

Cantons	Bioclimate	Soil type	specific richness of bryophytes
A	Sub-humid	deep beige sands on clay	60
B	Sub-humid	medium deep beige sands on clay	28
C	Semi-arid	shallow beige sands on clay	34

almost all samples (about 92%), followed by *Pleuridium acuminatum* (50%), *Brachythecium rutabulum* (46%) and *Bryum caespiticium* (40%). all these species are terricolous. Rare species, meaning those found in only two stations in the study area, are: *Zygodon viridissimus, Fossombronia caespitiformis* subsp. *multisp., Frullania dilatata, Riccia crozalsii, Riccia fluitans, Riccia huebeneriana, Riccia lamellosa, Riccia macrocarpa, Riccia warstorfii* var. *subinermis, Sphaerocarpus michellii, Targionia lorbeeriana, Phymatoceros bulbiculosus.* They are all species that like humidity and appear after the rains but they dry out very quickly.

Among the Hepatics, *Riccia ciliifera* appears during the first rains in autumn, but it flowers in spring, it is the most widespread species. All Anthocerotes are terricolous, *Phaeroceros laevis*, which is the most frequently encountered taxon, occupies the wet cracks of the clayey sand slopes.

The majority of the inventoried species (55.7%) are terricolous. They are found on the moist soil of the Mamora. The epiphytes are all corticolous (17.1%). They are found on the cork oak trunk: *Campylopus introflexus*, *Campylopus flexuosus*, *Fabronia pusilla*, *Homalothecium sericeum*, *Orthotrichum anomalum*, Orthotrichum *diaphanum*, *Orthotrichum lyellii*, *Scorpiurium circinatum*, *Sematophyllum substrumulosum*, *Syntrichia laevipila*, *Syntrichia ruralis* and *Frullania dilatata*. Saxicolous species (25.7%) occur on sandstone blocks that appear sporadically. Only one species is aquatic, *Riccia fluitans* that were sampled in plot A-IV-6 (Canton A) in a water flow that dries out in summer.

The specific diversity in bryophytes is highest in canton A (60 taxa), which can be explained by the frequency of small temporary pools that appear where the clay layer is exposed and by the proximity of the coast that provides the area with moisture to compensate for the dryness of sandy soils that are generally deep and sometimes dune-like. The proliferation of bryophytes occurs after rain and a brief period of sunshine. Canton B, with a specific population of only 28 taxa (Table 3), is characterized by a sparse forest formation, a very poor undergrowth and a compacted soil. All these factors hinder the diversification of bryophytes. Canton C, whose bioclimate is semi-arid, has a specific richness of 34 taxa with large recoveries, this is explained by the fact that this canton, where the clay layer is close to the surface, is characterized by an abundance of temporary pools.

The arborescent stratum of the Mamora is dominated by cork oak. The latter is rarer in the shrub stratum and practically non-existent in the herbaceous stratum, especially in the forest edges. We found that, where the muscular layer exists in the presence of an undergrowth, acorn germination is observed. This could be explained by the fact that bryophytes, by improving the soil's water retention capacity, promote the germination of acorns that rot in place where the muscular layer is absent. It should also be noted that bryophytes are more diversified and abundant when the woody and herbaceous undergrowth is significant.

Conclusion

The harvest of bryophytes according to a stratified random sampling in Mamora forest during the fall and spring of 2014, 2015 and 2016 allowed us to identify 70 species, including 44 mosses, 22 hepatics and 4 anthocerotes. This important diversity would be related to the environmental conditions that favor the establishment of bryophytes. Indeed, the Mamora area with the highest number of bryophyte species is canton A, where the bioclimate is sub-humid and the soil is moistened by temporary and permanent dayas that appear each time the sands are not deep and the clays are surfacing. In canton C, bryophytes show significant recoveries related to soil moisture that is maintained by the clay layer near the surface. The bryoflora of Mamora forest helps to improve the retention and infiltration of rainwater, which is no longer lost through dripping. Moisture thus preserved promotes the germination of acorns and subsequently the regeneration of cork oak.

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