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CONTRIBUTION TO THE INVENTORY OF THE BRYOLOGICAL FLORA OF THE TAFOUGHALT MASSIF, NORTH-EAST MOROCCO

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ABSTRACT

Knowledge of the diversity of the bryophytic flora of the Tafoughalt massif in north- eastern Morocco is insufficient and poorly known. The present study is the first bryological work on this massif. The bryophytic exploitation, which lasted three years (2015-2017) during periods favourable for sampling, revealed the existence of 30 bryophyte taxa, 27 of which belong to the Mosses and 3 to the Hepatica, divided respectively into 21 genders and 10 families (90%) then 3 genders and 3 families (10%). The most represented families are the Pottiaceae, Brachytheciaceae and Bryaceae. The most species rich genera are *Bryum* and *Tortula*. Four species are the most abundant in this massif, including three mosses and one liverwort:*Grimmia decipiens*, *Orthotrichum rupestre*, *Pleurochaete squarrosa* and *Targionia hypophylla*. We report the presence of two species new to the bryophytic flora of Morocco. These are *Amblystegium serpens* and *Oxyrrhynchium speciosum*. These two species are very rare in our study site according to the ecological significance index (ESI). There are five species newly observed in the region. The majority of taxa (more than 90% taxa) are saxicolous and/or terracolous.

Keywords: Bryoflore, Tafoughalt Massif, Beni Snassen; Morocco.

INTRODUCTION

Numerous floristic studies have explored the vascular flora of eastern Morocco (Khalil, 1999; Ben El Mostafa *et al.,* 2001; Achhal *et al.,* 2004; Chambouleyron *et al.,* 2015). The number of vascular taxa recorded in this region is 1114 species, belonging to 490 genera and 86 families (Khalil, 1999). On the other hand, bryoflora has not presented any studies in this region apart from the census of a few species cited during passing botanical expeditions carried out between 1931 and 1934 (Ahayoun *et al*., 2013), where nine species (2 mosses and 7 liverworts) were identified. This present work is the first in the region concerning the ecological study and biodiversity of the bryophytic flora in northeast Morocco.

Our study station is located in the rural commune of Tafoughalt (or Taforalt); it belongs to the Beni-Snassen chain, a site of biological and ecological interest in eastern Morocco (Denis, 2014). The choice of this study area is based on their bioclimatic characteristics and floristic diversity, which seem to be favourable conditions for the installation and proliferation of bryophytes. Thus, the aim of this study is to know and determine the specific diversity of the bryophytic flora of the Tafoughalt massif, then to establish a list of the taxa collected and also to verify if there are any new bryological taxa for Morocco.

MATERIEL AND METHODS

Presentation of the study site

The study site is located in the rural commune of Tafoughalt, 18 km south-west of the town of Berkane (Denis, 2014), in the Eastern Rif region of Morocco, at an altitude of about 850 m (Dakki *et al.*, 2003). Tafoughalt is part of the Beni Snassen massif, known as a site of biological and ecological interest (SIBE) and archaeological (Denis, 2014). It is a small chain of dolomitic limestone with a core of primary schists (Chaker, 1991). The SIBE is located on the Moroccan-Algerian border and is bounded to the north by the Triffa plain which descends to the Mediterranean coast, to the south by the Angad plain, to the east by the Garbous pass and to the west by the Oued Moulouya (Fig. 1). The massif extends as far as western Orania (Algeria) by the Felloussène and Traras mountains (Tayebi *et al*., 2011). This region presents climatic and edaphic conditions and also numerous wetlands (waterfalls, springs, wadis), which allow vegetation to proliferate and consequently a diversification of the fauna. The site of Tafoughalt, according to Emberger's climagram, belongs to a Mediterranean climate with a sub-humid bioclimatic level (Achhal *et al.*, 2004), but characterised by infrequent rainfall and very variable over time (monthly and annual) (Acherkouk *et al.*, 2011). It receives an average rainfall of 344 mm per year and records an average annual temperature of 15.4°C (Climate-data, 2020). Temperatures range from 1.9°C in January, the coldest month, to 28.5°C in the warmest month (July) (Dakki *et al.*, 2003). This implies a certain climatic coolness of the massif compared to other regions of the SIBE.

The plant cover of the SIBE of Beni Snassen presents a matorral dominated essentially by: thethuya, Aleppo pine, holm oak, kermes oak, cypress, rosemary, juniper

and esparto (Boumeaza, 1985; Achhal *et al.*, 2004; Tayebi, 2006; Denis, 2014). This massif was reforested with Aleppo pine and Eucalyptus from the 1950s and then again in the 1970s; these reforestations were very successful in Tafoughalt (Tayebi *et al.*, 2011). The holm oak constitutes a dense stand in some places, whereas the Aleppo pine stands, which grow on marly-limestone soils, are generally degraded. This vegetation cover is very sensitive to degradation caused by anthropo-zoogenic pressure (Cagniant and Galkowski, 2013) and/ or temporary periods of drought (Tayebi *et al.*, 2011).The vegetation cover in Tafoughalt occupies about 2876 ha (Et-Tobi *et al.*, 2000), with a very high cover rate near water sources. On the other hand, it is less important in dry and sunny places and in areas of artificial reforestation: alep pine and eucalyptus.The vegetation cover observed during the sampling in the Tafoughalt massif is mainly made up of varied herbaceous vegetation such as *Lavandula dentata*, *Drimia maritima*, *Rosmarinus officinalis*, *Urtica pilufifera* and *Cistus villosus*. The tree matorral is dense especially in humid areas with the remarkable presence of *Rosmarinus officinalis* and some fig trees, cork oak and holm oaknear the village of Tafoughalt.

Collecting plant material

The sampling of bryophytes in the study site is organised according to the climatic conditions favourable to the growth and fruiting of these plants. As far as possible, species are sampled with sporophytes to facilitate their identification. Harvesting was carried out in two periods, each lasting three days: in winter (January 2015) and spring (April 2017). Each sample is kept in a paper or plastic bag and then left to dry to avoid any risk of fungal contamination. All information relating to each harvest is noted: geographical coordinates (longitude, latitude, altitude) using GPS, date and place of harvest, ecological conditions and the nature of the substrates. Species identification was carried out in the laboratory using appropriate optical equipment based on macroscopic and microscopic characteristics. The floras used were those of: Augier (1966), Smith (2004), Pierrot (1982), Casas *et al.,* (2006), Casas *et al.,* (2009) and also specialised bryological glossaries (Chavoutier, 2016). The taxonomic nomenclature adopted for the species identified is that of the bryophytes of North Africa (Ros *et al.*, 1999).
The species inventoried in the Tafoughalt massif are grouped in Table 1 by phylum and then by family in alphabetical order of taxa. For each species, the nature of the substratum from which it was collected is noted [saxicolous "S" (on rocky substratum), terricolous "T" (on soil), epiphyte "E" (on tree bark), corticolous "C" (on tree trunks)] and the GPS coordinates of the survey. Some species are marked with a symbol : (*) for taxon new for Morocco, (**) new for the Eastern Rif region, compared to the checklists published by Ros *et al.,* in 2007, Ros *et al.,* in 2013 and Ahayoun *et al.,* in 2013.

Data analysis

Data processing was carried out using the Microsoft Office 2010 Excel spreadsheet to assess the centesimal specific frequency and the ecological significance index of bryoflora at the study site.

The specific centesimal frequency (FSCi) expressing the presence or absence of a species is calculated by the following formula:

$FSCi = (n_i / N) \times 100$.

Where (n_i) is the number of records in which the species (**i**) is present and (**N**) is the total number of records.
The relative abundance of species collected in the Tafoughalt massif was estimated using the Index of Ecological Significance (IES) (Lara & Mazimpaka, 1998; Albertos *et al.*, 2001). It is based on the combination of relative frequency and specific area coverage in the study site, and is calculated according to the following equation:

$IES = F (1 + C)$.

Where (**F**) the relative frequency of species = (100 x/n), and (**C**) the mean coverage of species in the surveys = $\Sigma(c_i)/x$, where (**x**) represents the number of surveys containing the species, (**n**) the total number of samples, and (c_i) corresponds to the coverage class of the species in each survey.

Coverage classes were estimated according to the following scale: 0.5 (<1%); 1 (1-5%); 2 (6-25%); 3 (26-50%); 4 (51-75%); 5 (> 75%). Then, the values of this index (IES) were combined in class frequency as follows: very scarce (<25), scarce (26-50), moderately abundant (51-100), abundant (101-200) and dominant (> 200).

RESULTS AND DISCUSSION

The study of the bryological flora of the Tafoughalt massif enabled us to identify 30 bryophytic taxa belonging to two classes, Mosses and Hepatics (Table 1), based on 51 samples. These taxa are divided into 13 families and 24 genera (Fig. 2). The family Pottiaceae is best represented in this study with 7 genera and 9 species (30% of the total taxa identified), followed by the family Brachytheciaceae with 5 genera and 6 species (20%) and then by the family Bryaceae with a single genus *Bryum* and 3 species (10%). Thus, these three families alone constitute 60% of the bryophytic taxa in the Tafoughalt massif (Fig. 2). Next, the families Bartramiaceae and Grimmiaceae each have two species (or 6,67%) and the other families each have only one species (3,33%) (Fig.2).

The bryological inventory revealed the existence of 27 species of mosses of which 56,67% were acrocarpous and 43.33% pleurocarpous. Concerning the class of Hepatics,

sampling of this study area revealed the presence of three families, each with only one species belonging to three different genera (*Fossombronia*, *Lunularia* and *Targionia*).

The exploration of this area has enabled us to identify two species new to Morocco: *Amblystegium serpens* and *Oxyrrhynchium speciosum*. In North Africa, they are cited in Algeria and Tunisia for the first species and only in Algeria for the second species (Ros *et al.*, 1999; Ros *et al.*, 2013; Ahayoun *et al.*, 2013). They are less frequent, respectively 5.56% and 11.11%, and classified as very rare in this site with IES values of 7 and 23 respectively. These two species are the subject of a separate publication that is in progress. The genus *Amblystegium* has a narrow ecological distribution in the Mediterranean region; it is represented only by *Amblystegium serpens* (Ros *et al.*, 2013). In Morocco, it is represented by two taxa: *Amblystegium filicinum* subsp. *formianum* (Fior.-Mazz.) J.J.Amann and *Amblystegium tenax* (Hedw.) C.E.O.Jensen observed near water sources on limestone rocks (Ahayoun *et al.*, 2013). Thus, the Mediterranean region currently has two species and a variety of the genus *Amblystegium*. The genus *Oxyrrhynchium* has three species and one variety in the Mediterranean region: *Oxyrrhynchium hians* (Hedw.) Loeske, *Oxyrrhynchium schleicheri* (R.Hedw.) Röll, *Oxyrrhynchium swartzii* (Turn.) Warnst var. rigidium (Boulay) Barkman (= *Eurhynchium hians*) and *Oxyrrhynchium speciosum* (Brid.) Warnst (Ros *et al.*, 1999; Ros *et al.*, 2013). In Morocco, it was represented only by *Oxyrrhynchium pumilum* (Wilson) Loeske (Ahayoun *et al.*, 2013) and with the determination of this new species (*Oxyrrhynchium speciosum*) this genus becomes represented by two species.

Three species are classified as rare in Morocco based on the same lists (Ahayoun *et al.*, 2013; Ros *et al.*, 2013): *Cirriphyllum crassinervium*, *Pseudoleskea incurvata* and *Eurhynchium hians*. Indeed, in our study site, the value of their IES is 30, 33 and 10 respectively, classifying them as rare for the first two species and very rare for the last one. This study also led to the discovery of five new species for the Eastern Rif: *Calliergonella cuspidata*, *Eurhynchium hians*, *Scorpiurium circinatum*, *Pseudoleskea incurvata* and *Homalia lusitanica*, in comparison with the species listed in the Ahayoun catalogue (Ahayoun *et al.*, 2007; Ahayoun *et al.*, 2013).

The taxa inventoried are found on four different types of substrate with unequal proportions: Saxicolous species are the most represented (43,34%), followed by Saxicolous and Terrestrial species which are less represented (36,67%) and Terrestrial species with a smaller proportion (10%), the other substrates are found with the same proportion (3,33%) (Fig. 3).

The most frequent species in the massif are *Orthotrichum rupestre* (72,22%) and *Grimmia decipiens* (61,11%) which are both saxicolous and classified by their index value as abundant (IES=167 and 133). They are followed by *Targionia hypophylla* (50%), *Pleurochaete squarrosa* (50%) and *Bryum capillare* (44,44%) which are respectively abundant and moderately abundant with their IES index values of 113, 113 and 93. These last five species are capable of adapting to a temperate and dry microclimate (Denayer, 2000; Mazimpaka *et al.*, 1993). They are classified as thermo-xerophilic taxa, with the exception of *Homalothecium sericeum*, which is found in wetlands (Mazimpaka *et al.*, 1993). These plants are well adapted to the climatic, topographical and edaphic conditions of the study area by their adaptive characteristics and/or by their mode of dispersal (vegetative multiplication and high spore production) (Bajon, 1987). Analysis of the IES ecological index revealed the abundance of three mosses and one liverwort in their sampling station: *Grimmia decipiens*, *Orthotrichum rupestre*, *Pleurochaete squarrosa* and *Targionia hypophylla*. In the Tafoughalt massif, ten species are noted as rare according to the value of the IES index, which varies from 27 to 47 (Table 1), for example: *Cirriphyllum crassinervium*, *Pseudoleskea incurvata*, *Homalia lusitanica*, *Bartramia stricta*, ect. While *Amblystegium serpens*, *Fossombronia angulosa*, *Didymodon tophaceus*, *Eurhynchium hians*, *Oxyrrhynchium speciosum*, *Tortula ruralis*, *Timmiella barbuloides* and *Trichostomum crispulum* are very rare species in the Tafoughalt massif (IES ranging from 7 to 27) and rare to relatively rare in the Mediterranean region (Ros *et al.*, 2013; Gabka *et al.*, 2014), with a very restricted distribution in the harvesting environment.

For Hepatics, *Fossombronia angulosa*, *Lunularia cruciata* and *Targionia hypophylla* are the only species encountered in the study area. *Fossombronia angulosa* is very rare (IES=7) and its frequency is very low (FSCi = 5,56%), whereas for the other two species the value of their FSCi is high. It is 38.89% in *Lunaria cruciata* and 50% in *Targonia hypophylla*, and they are moderately abundant (IES=77) and abundant (IES=113) respectively in the massif. These liverworts are found on damp rocks and soil forming more or less dense patches. Sometimes they live on substrates exposed to the sun; they are therefore able to withstand dry conditions (Denayer, 2000).

The bryophytes of this massif are essentially made up of saxicolous and terrestrial species with a percentage of 90% due to the dominant components of the study environment. The soil on which bryophytic species live remains moist for a long time, favouring the installation of pleurocarpous species which are mosses that prefer moist substrates (Mazimpaka *et al.*, 1993). On the other hand, acrocarpous species are often found on rocks exposed to sunlight. The epiphytes and corticolous (6,66%) appear to be less distributed compared to a study conducted in the eastern Middle Atlas where they represent 34% of the bryophytes in the environment (Saadi *et al.*, 2020). This is probably due to the fact that the plant cover is open,

Table 1: List of bryological species collected with the corresponding family, the nature of the substrates and the index ecological significance (IES).

Families	Genus	Species	Substrates				IES Classe FSCi (%)	Latitude Longitude Altitude (m)
			S	T	E	C		
Phylum ofMosses								
Amblystegiaceae	Amblystegium	*Amblystegium serpens* (Hedw.) (*)	+	+	-	-	7 very rare 5,56	34°81'729''N -2°41'04023''W 755
Bartramiaceae	Bartramia	*Bartramia stricta* Brid.	+	+	-	-	43 rare 22,22	34°81'556''N -2°40'42635''W 672.5
	Philonotis	*Philonotis fontana* (Hedw.) Brid.	+	+	-	-	37 rare 16,67	34°81'8935''N -2°40'99717''W 744
Bryaceae	Bryum	*Bryum argenteum* Hedw.	+	+	+	-	63 moderately abundant 33,33	34°79'5998 ''N -2°402123''W 962
		Bryum caespiticium Hedw.	+	+	-	-	47 rare 27,78	34°80'4096''N -2°406298''W 824
		Bryum capillare (Hedw.)	+	+	-	-	93 moderately abundant 44,44	34°81'5266''N -2°40'1246''W 694
Brachytheciaceae	Cirriphyllum	*Cirriphyllum crassinervium* (Taylor) Loeske & M. Fleisch (**)	+	+	-	-	30 Rare 16,67	34°833607''N -2°41'14833''W 558
	Eurhynchium	*Eurhynchium hians* (Hedw.) Sande Lac(**)	+	-	-	-	10 very rare 11,11	34°82'009''N -2°38'89856''W 640.5
	Homalothecium	*Homalothecium sericeum* (Hedw.) B. e.	+	+	-	+	77 moderately abundant 27,78	34°81'4114''N -2°40'37268''W 743
	Scorpiurium	*Scorpiurium circinatum* (Brid.) Fleisch. & Loeske(**)	+	-	-	-	33 rare 16,67	34°81'3732''N -2°40'35165''W 717
		Scorpiurium deflexifolium (Solm.) Fleisch. & Loeske	+	-	-	-	33 rare 22,22	34°.81'01''N - 2°40'90629''W 806
	Oxyrrhynchium	*Oxyrrhynchium speciosum* (Brid.) Warnst (*)	-	+	-	-	23 very rare 11,11	34°81'5594''N -2°40'50922''W 705
Grimmiaceae	Grimmia	*Grimmia decipiens* (Schultz) lindb	+	-	-	-	133 abundant 61,11	34°80'062''N -2°40'05458''W 899
		Grimmia orbicularis Bruch.	+	-	-	-	90 moderately abundant 38,89	34°82'2662''N -2°40'97204''W 702
Hypnaceae	*Calliergonella*	*Calliergonella cuspidata* (Hedw.) Loeske (**)	+	+	-	-	23 very rare 11,11	34°81'3732''N -2°40'35165''W 717

continued...

Leskeaceae	Pseudoleskea	*Pseudoleskea incurvata* (Hedw.) Loeske(**)	+	-	-	-	33 rare 16,67	34°83’7646’’N -2°35’6299’’W 477
Neckeraceae	Homalia	*Homalia lusitanica* Schimp (**)	-	-	+	-	30 rare 16,67	34°81’675’’N -2°39’28301’’W 661
Orthotrichaceae	Orthotrichum	*Orthotrichum rupestre*Schleich.	+	-	-	-	167 abundant 72,22	34°81’7276’’N -2°40’7363’’W 708
Pottiaceae	Barbula	*Barbula unguiculata* (Huds.) Hedw.	+	+	-	-	80 moderately abundant 38,89	34°82’9254’’N -2°41’03715’’W 620
	Didymodon	*Didymodon tophaceus* (Brid.) Jur.	+	+	-	-	20 very rare 11,11	34°81’675’’N -2°39’28301’’W 661
	Eucladium	*Eucladium verticillatum* (Smith)B.E.	+	-	-	-	57 moderately abundant 27,78	34°79’5135’’N -2°39’71207’’W 877
	Pleurochaete	*Pleurochaete squarrosa* (Brid.) Lindb.	+	+	-	-	113 abundant 50,00	34°81’5594’’N -2°40’50922’’W 705
	Tortula	*Tortula norvegica* (Web.F.) Wg.	+	-	-	-	30 rare 16,67	34°80’4096’’N -2°40’6298’’W 824
		Tortula subulata Hedw.	+	+	-	-	23 very rare 11,11	34°81’3873’’N -2°40’34426’’W 700
		Tortula ruralis Ehrh.	+	-	-	-	83 moderately abundant 38,89	34°81’4034’’N -2°40’38453’’W 735
	Timmiella	*Timmiella barbuloides* Brid.	+	+	-	-	27 rare 11,11	34°81’393’’N -2°40’34188’’W 709
	Trichostomum	*Trichostomum crispulum* Bruch.	-	+	-	-	17 very rare 11,11	34°81’4335’’N -2°40’32075’’W 699
Phylum of Liverworts								
Fossombroniaceae	Fossombronia	*Fossombronia angulosa*(Dicks.) Raddi	-	+	-	-	7 very rare 5,56	34°813984’’N -2°4038453’’W 725
Lunulariaceae	Lunularia	*Lunularia cruciata* (L.) Dum.	+	+	-	-	77 moderately abundant 38,89	34°81’659’N -2°40’65557’’W 713
Targioniaceae	Targionia	*Targionia hypophylla* L.	+	+	-	-	113 abundant 50,00	34°81’418’N -2°40’33358’’W 702

Where (*) taxon new for Morocco, (**) new for the Eastern Rif region, “S”=saxicolous, “T”=terricolous, “E”=epiphytic, “C” =corticolous.

mainly in the form of matorral, which does not favour the installation and distribution of bryophytes.

CONCLUSION

Despite the great biological and floristic diversity of the Tafoughalt massif, the number of bryological taxa inventoried remains low in relation to the surface area exploited. The effect of the microclimatic conditions, more or less unfavourable, is characterised by the period of drought which has become longer, from summer to the end of Autonomy, by the open plant cover and also by the dominance of artificial reforestation of Aleppo pine in the massif (Tayebi *et al.*, 2011). Water deficit and temperature contrasts also play a major role in the functioning and distribution of bryophytes (Mazimpaka *et al.*, 2004). Thus, all of this has contributed to the low bryological diversity in this environment. On the other hand, this study has contributed to elucidating the diversity and ecology of the bryophytic flora in the Tafoughalt massif, eastern region of Morocco. This flora is characterised in this region by a large specific representation of Mosses (90%), species that are capable of withstanding the climatic conditions of exposed environments. In fact, 60% are mesophilic species, belonging to the families Pottiaceae, Brachytheciaceae and Bryaceae. Whereas the Hepatics that are most dependent on the freshness and/or humidity of the biotope represent only 10% of the species recorded in the massif. The study of the bryological flora of the Tafoughalt Massif has also made it possible to enrich the list of bryophytes in Morocco as well as in the Mediterranean basin by the identification of two species: *Amblystegium serpens* and *Oxyrrhynchium speciosum* where they are very rare. From an ecological point of view, the bryophytic flora of the Tafoughalt massif consists essentially of Saxicolous and Terrestrial taxa. The distribution and frequency of bryophytes depends on three factors: a cool microclimate, the degree of humidity and the density of the plant cover.

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