

Contribution to the bryoflora of Morocco: Toubkal National Park (Ourika Valley)

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Abstract. The bryophyte flora of the upper Ourika valley, located to the east of the Toubkal National Park (Morocco), is catalogued. No such studies have been conducted in this valley before. As a result of this study, the catalogue consists of 47 species of mosses. No liverworts or hornworts are encountered. Of these taxa, two (2) are newly reported for Africa (*Amphidium mougeotii* (Schimp.) Schimp., *Pseudoleskeella nervosa* (Brid.) Nyholm), one (1) is new for North Africa (*Brachythecium mildeanum* (Schimp.) Schimp.), one (1) is new for Morocco (*Orthotrichum bistratosum* (Schiffn.) J. Guerra) and eleven (11) are new for the Toubkal National Park.

Keywords: Morocco, Toubkal National Park, Ourika Valley, catalog, bryophytes.

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Introduction

Studies of bryophytes in Morocco began in the early 20th century. They are fragmentary. There have been very few synthetic studies on this subject. A compilation of bryophyte lists from 1913 to 2011, carried out by Ahayoun *et al.* (2013), has resulted in a catalog of bryophytes from Morocco comprising 619 species, varieties and forms distributed into 507 mosses (82%), 107 liverworts (17%) and 5 anthocerotates (1%). Over the last two decades, bryological studies have mainly been carried out by Moroccan research teams (Ahayoun *et al.*, 2007, 2009, 2013, 2015a,b, 2016, 2019; Fadel *et al.*, 2016, 2017, 2015a,b, 2021a,b; Chtaibi *et al.*, 2018; Elharech *et al.*, 2017, 2018, 2020; Saadi *et al.*, 2018; Laouzazni *et al.*, 2018, 2020, 2021; Zaza *et al.*, 2018, 2020, 2021; Dabghi *et al.*, 2020; Achoual *et al.*, 2021a,b). They have especially affected a few regions in the extreme north and north-west of Morocco (Gharb region, the Rif Mountain range and the Middle Atlas chain).

Draper *et al.* (2003, 2005, 2006, 2007) have also carried out bryological studies in Morocco, focusing mainly on epiphytic bryophytes in the Rif and Middle Atlas. All these studies have enabled us to update the lists of bryophytes in the regions surveyed, and to discover many new local citations. They also enabled

us to extend the list of species cited in Morocco by 33 new taxa (species and varieties), including three liverworts and thirty mosses, and that of North Africa by 9 new species. In addition, Draper *et al.* (2003) described a new variety (*Orthotrichum speciosum* var. *brevisetum*).

In the High Atlas, bryological studies are rare, except for a few scattered in the most accessible regions (Fakihani *et al.*, 2024). This lack of studies is even more pronounced in the Toubkal National Park (hereafter TNP). The only studies that have been carried out are those by Ros *et al.* (2000) and Fakihani *et al.* (2024), both in the Rherhaya valley, the western part of the TNP. The bryophytes of the upper Ourika valley (Afella n'Oufra), to the east of the TNP, have never been studied. This lack of knowledge also affects many other areas of the TNP (Occidental High Atlas). Our study aims to fill this bryological gap in the Toubkal National Park (Ourika valley) and to enrich the list of Moroccan bryophytes. This choice is guided by the importance of this site as a protected area, classified as a National Park comprising five Biological and Ecological Interest Sites (BEIS), in addition to a mouflon sheep reserve and three Managed Natural Sanctuaries (Ouhammou, 2005).

Materials and Methods

Study site

The present study was carried out in the eastern part of the Toubkal National Park (Figure 1), a vast protected area of Morocco. It is located 75 km south of Marrakech, in the Occidental High Atlas. It was designated in January 1942 for an area of around 36,000 ha (Anon., 1942), and was extended in 1996 peripherally, covering an additional of 62,000 ha (Anon., 2017) (Figure 2). Established in the High Atlas region of Marrakech, it is one of the most biodiversity-rich regions (Anon., 2020). It is delimited by the following geographical coordinates (GPS points): 30° 08' N to 3° 22' N and 07° 40' W to 8° 22' W. The extreme altitudes of the TNP range from 1,200 m asl at the Takherkhorte Zoological Reserve to 4,167 m asl at the summit of Mount Toubkal (Ouhammou, 2005). It includes several Biological and Ecological Interest Sites (BEIS), including Assif n' Ait Mizane, Assif Rherhaya, Assif n'Ouarzane, Lake Ifni, Assif n'Tifnoute (Boulejiouch, 2003).

The Ourika basin, where this study was carried out, is one of Morocco's most famous tourist sites. It is located in the central part of the Occidental High Atlas, 40 km south of Marrakech city. Its surface area is estimated at 55,000 ha (Ouhammou & Aubin, 1991). It is a mountainous watershed located between latitudes 31° and 31° 21' North and longitudes 07° 30' and 07° 60' West (Saidi *et al.*, 2006). The main *Oued* (watercourse) has its source in the high foothills of the High Atlas range, in a watershed that spanning from 4,001 m asl to 900 m asl at the end of the Atlas range (Saidi *et al.*, 2010). The main course, which first flows in a NE direction and then in a NW direction after the locality of Sti Fadma, flows through a long, deep valley towards which a succession of valleys and tributary ravines converge on both banks. The Ourika valley is renowned for its high and abundant relief. 75% of the basin's surface area lies between 3,200 m asl and 1,600 m asl. The average altitude is 2,500 m asl (Saidi *et al.*, 2010). Slopes are generally steep. The steepest ravines are located upstream of the basin, with slopes reaching 30 to 40% in some places, as in the case of Assif n'Tifni (upper west valley) and Assif n'Oufra (upper east valley), the main focus of our study.

Geologically, the Ourika watershed has two main types of facies: a southern part, located to the east of the TNP, at altitudes above 2,000 m asl, consisting of magmatic (granodiorites and microdiorites) and metamorphic (quartzites, greenschists) rocks of Precambrian PII age, belonging to the basement of the Atlas chain (Michard, 1976). These crystalline formations are generally acidic in nature; a northern part, at altitudes of less than 2000 m asl, consisting of more tender Permo-Triassic and Quaternary deposits (Biron, 1982).

The climate of the Ourika valley is typically Mediterranean with semi-continental influences (Ouhammou *et al.*, 1991). Like all the valleys on the northern face of the High Atlas, the Ourika valley receives air masses from NW, W, N and NE origins, which are very dynamic and quite powerful (Ouhammou, 2005).

Analysis of monthly rainfall and flow rates in the Ourika at the Aghbalou climate meteorological station, over a 34-year period (1970–71 to 2003–2004), allowed to identify the variability of these two parameters (Saidi *et al.*, 2006). Annual rainfall can exceed 700 mm per year on the high peaks of the basin. Maximum rainfall is recorded in March and April. Another, less significant, rainfall occurs in November (Saidi *et al.*, 2010). Snowfall is normally frequent from November to April in regions above 2,200 m asl. During this period, snowfall is more persistent on the higher, often shaded slopes, but more fleeting on the warm slopes, exposed to the south (Ouhammou *et al.*, 1991).

The climate is also influenced by the existence of the dry, hot winds *Chergui*, which blow from the East, generally in August and September (Saidi *et al.*, 2006). In the Upper Ourika, formed by the Assif n'Oufra basin (the study site) and the Tinzart - Tifni basin, N-S oriented valleys, are penetration routes for N, NW and W flows (Ouhammou, 2005). Internal domains, located in internal valleys sheltered behind high massifs, are not very widespread in the Ourika basin. They exist only in the E-W section of the upper Ourika valley, where the valley is deeply encased (Ouhammou, 2005).

Methodology

The sampling was carried out along a decreasing altitudinal transect, oriented S-N, along the Afella n'Oufra valley (upper Ourika valley) (Figure 3). The choice of stations is estimated according to the variation in ecological factors determining bryophyte distribution (altitude, type of substrate, exposure, slope, humidity, etc.). The sampling has begun at the St 000 station, with a very wide, gently sloping valley geomorphology up to the St 002 station; hence the apparent long distance between it and St 001 bis. The slope then becomes steeper, with occasional waterfalls, until St 006. After St 002, the slope walls are generally almost vertical and covered by saxicolous bryophytes, which appear blackish, then turn greenish as soon as it starts raining. This phenomenon is linked to the reviviscence of bryophytes.

The plant cover from St 000 to St 002 is dominated by a lawn (*Ranunculus bulbosus*, *Festuca rubra*, *Cirsium chrysacanthum*, *Nardus stricta*, etc.) on waterlogged soil near the watercourse. The rest of the sites up to St 006 are rocky, with large boulders and sparse xerophyte steppes (*Arenaria pungens*, *Alyssum spinosum*, *Bupleurum spinosum*, *Cirsium dyris*...). Along the watercourse and at springs, there are occasional megaphorbia community with *Cirsium chrysacanthum*, *Festuca mairei*, *Heracleum sphondylium*, etc. All the transects are treeless, characteristic aspect in the height areas of Mediterranean mountains (Ouhammou, 2005). The dominant bedrock is siliceous, acidic in nature (granit, granodiorites, microdiorite, quartzite, greenschist). Sampling was also carried out at the St OAq1 station, outside TNP (Peripheral zone = TNP-PZ), in the Assif Ait Elqaq, another tributary of the Ourika valley, on the Oukaïmeden road. St OAq1 is characterized by predominantly siliceous parent rocks (clay, marl, red sandstone) and a floral procession comprising

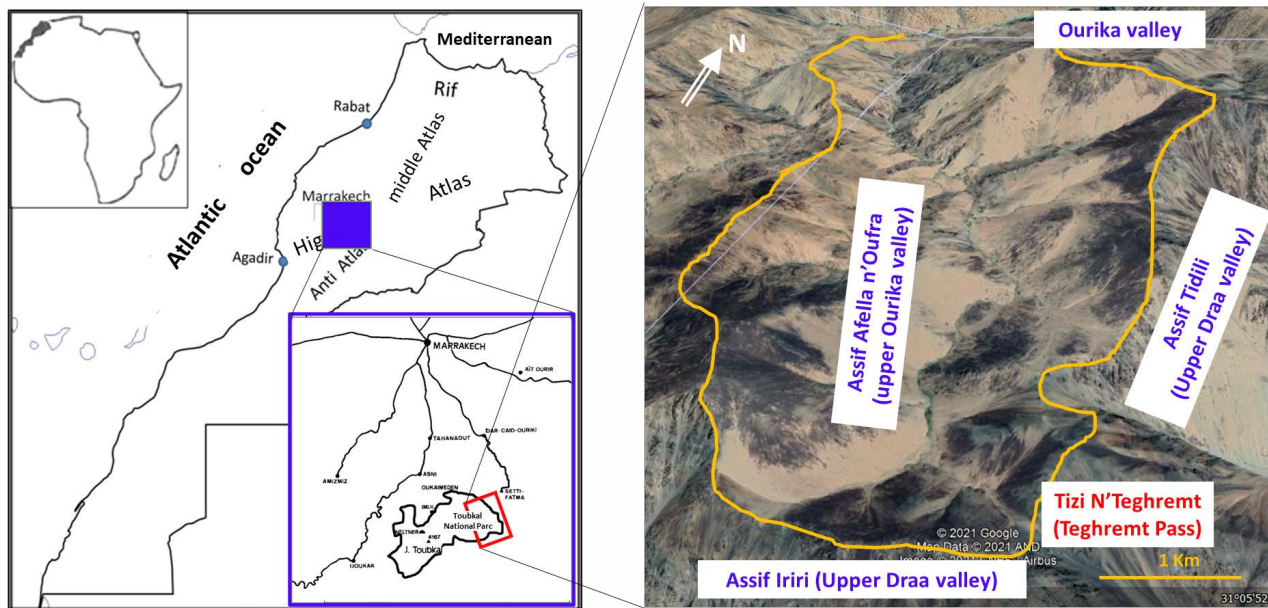


Figure 1. Geographical location of the study site. Assif Afella n'Oufra (Upper Ourika Valley, East Toubkal National Park).

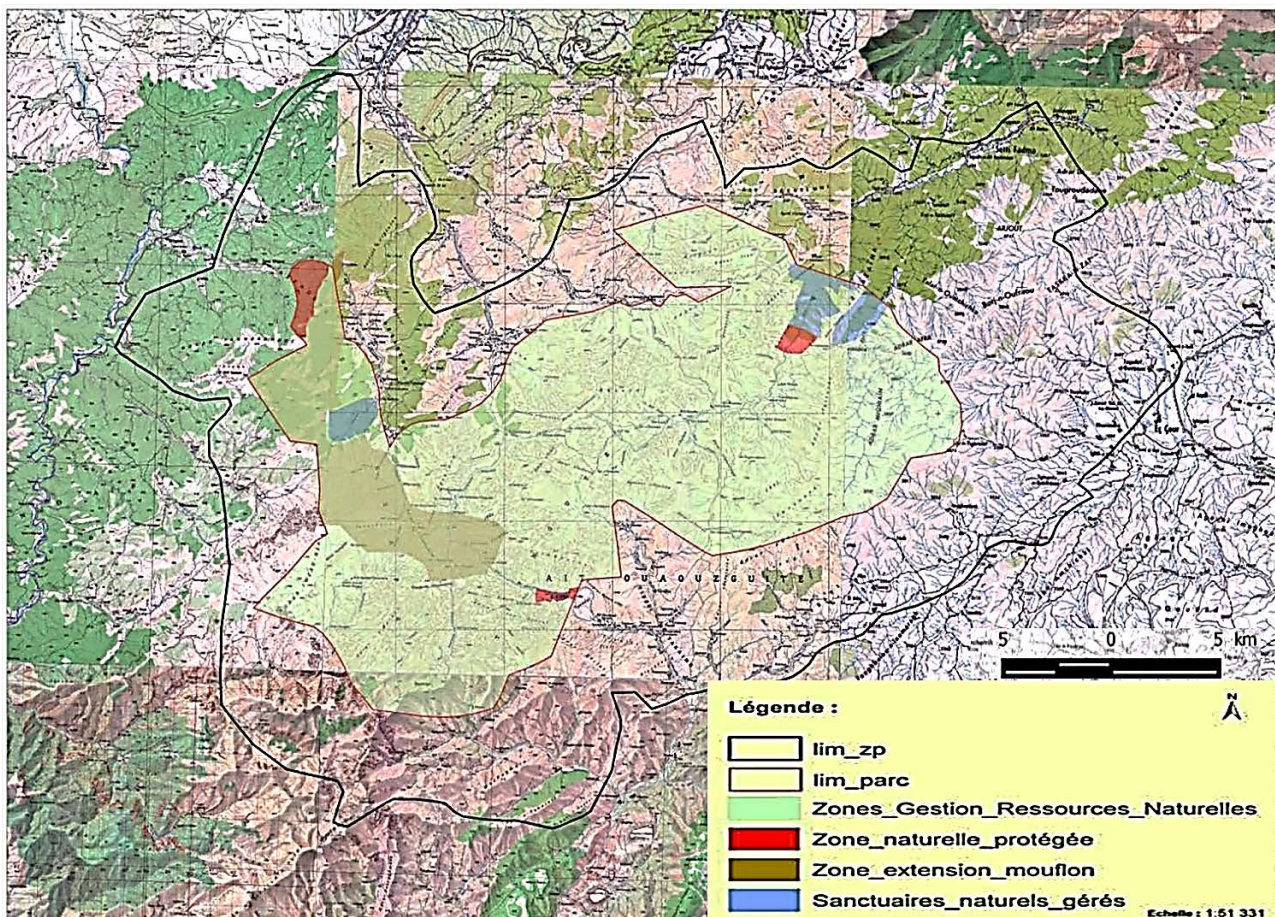


Figure 2. Toubkal National Park boundaries. Central zone (red line), Peripheral zone (black line), Explored zone (blue rectangle). Map from the DREFLCD-HA Annual Report (Anon., 2017).

Sedum dasyphyllum, *Helianthemum croceum*, *alyssum spinosum*, *Juniperus thurifera*, etc. A total of 70 samples were taken from the eight stations visited.

In each locality, all the substrate types (soil, rocks, trees, etc.) and environments (aquatic, supra-aquatic, terrestrial, etc.) encountered were explored. This diversity of substrates is accentuated by the variation in ecological factors governing the

distribution of bryophytes, which occurs along the transect. The area explored per locality is at least equal to 50 m by 50 m ($\geq 2500 \text{ m}^2$), so that all the habitats of the station are represented. On the same station, given the diversity of supports, all the samples collected on the same support constituted a survey, hence the presence, sometimes, of several surveys per station.

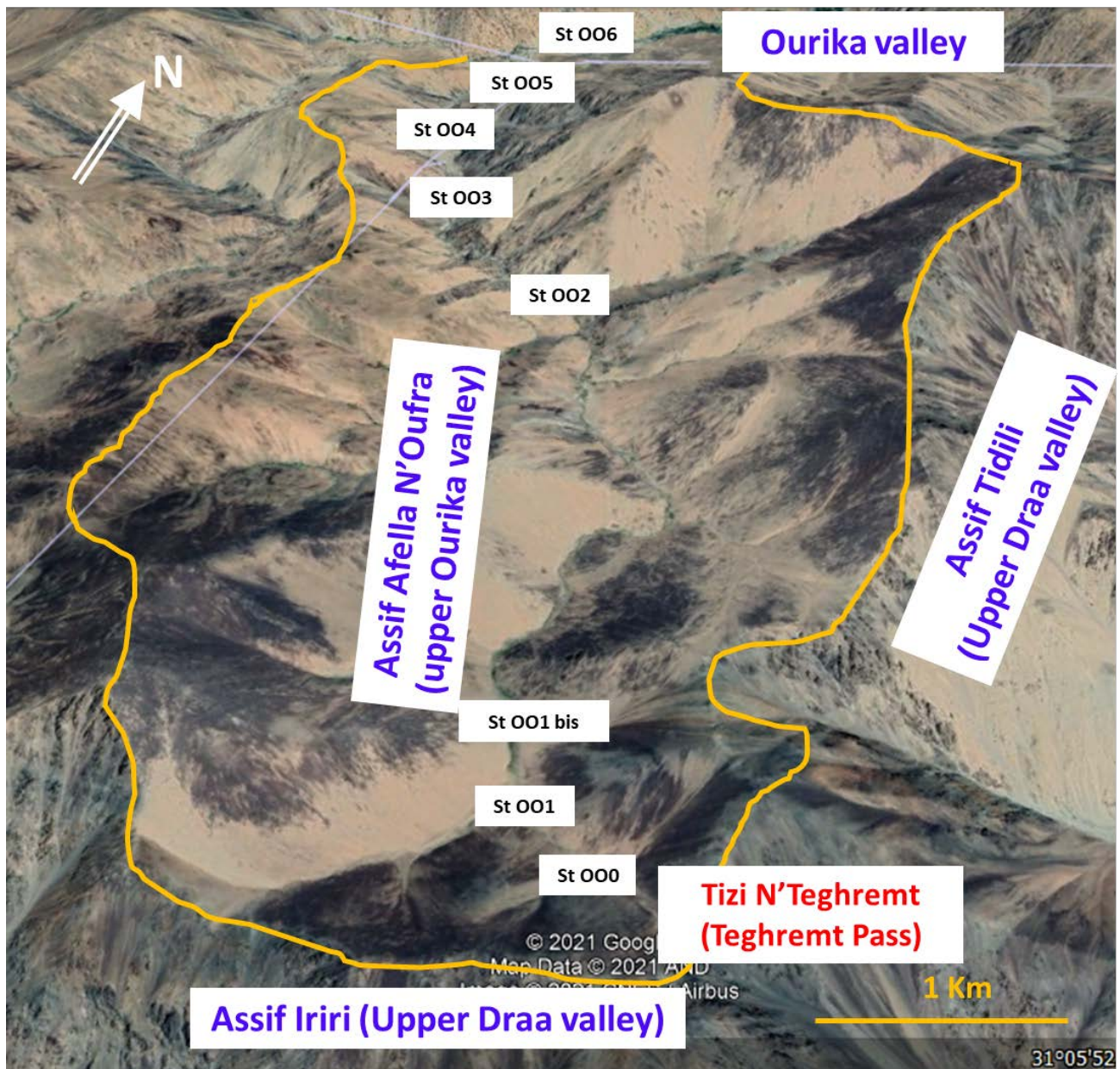


Figure 3. Distribution of stations sampled in the upper Ourika valley (Assif Afella n'Oufra). Boundary of the Afella n'Oufra sub-basin in yellow line (Google earth map). (Assif: Tributary stream; Tizi: mountain pass)

Table 1. Distribution of sampling stations according to valleys visited, GPS coordinates of each station and number of surveys (N.S.) and samples (N.s.) per station

River (Main Valley)	Assif (watershed)	Station code	Altitude (m asl)	Latitude	Longitude	N. S.	N.s.
Ourika	Assif Afella n'Oufra	St 000	3402	N31° 06,057'	W07° 41,995'	1	6
		St 001	3391	N31° 06,193'	W07° 42,127'	1	11
		St 001 bis	3350	N31° 06,294	W07° 42,451'	1	1
		St 002	3100	N31° 07,685'	W07° 43,455'	1	12
		St 003	2850	N31° 08,445'	W07° 44,375'	1	14
		St 004	2700	N31° 08,305'	W07° 44,289'	1	2
		St 005	2543	N31° 08,828'	W07° 44,662'	2	21
	Assif n'Oufra	St 006	2470	N31° 08,596'	W07° 44,383'	1	3
	Assif Ait Leqaq	St OAq1	1475	N31° 15,053'	W07° 48,862'	1	9
Total :						10	79

As soon as they were collected, the specimens were placed in small paper bags bearing the code of the sampling locality, its GPS coordinates (Table 1) and its ecological characteristics. They were then placed in a net bag, which allowed them to begin drying during transport in the days of the fieldwork (seven days on foot in very inaccessible area). To ensure good preservation, the drying process was continued in the laboratory, with spreading on bench in a well-ventilated room.

After rehydration and thin-sliding, the specimens were identified using the appropriate optical tools, and several specialized floras, Augier (1966), Smith (1978), Nyholm (1979–1981), Guerra *et al.* (2006, 2010), Lüth (2006–2010), Casas *et al.* (2006), Brugués *et al.* (2007). Partial floras were also used, such as those of Pierrot (1982), Douin (1985); Muller *et al.* (2002) and Coudreuse *et al.* (2005). On digital files, the Database of Nomenclatural Bryophytes of Europe (DNBE) (Lemonnier, 2008) was consulted. Checks on the Net were also carried out.

When identifying species, we referred to the nomenclature of Ros *et al.* (2013). Where the name in the identification book differs, we retained the Ros *et al.* (2013) name and put the name of the book in brackets to facilitate comparison. For some species which are not cited by Ros *et al.* (2013), the names have been updated according to Lemonnier's synonymic index (2008).

Results and Discussion

Bryologically view, only six exploratory studies were carried out during the 20th century in the TNP: Maire & Werner (1934), Killian (1943), Rauh (1952), Jelenc (1955) Jovet-Ast (1955), and Ros *et al.* (2000). Other review articles were developed at the beginning of the 21st century, Mazimpaka *et al.* (2004), Draper *et al.* (2006), Medina *et al.* (2010). None of these previous studies have been carried out in the upper eastern Ourika valley, the site of our study, surely because of its difficult access.

Bryophytic exploration of the upper Ourika valley yielded a list of 47 mosses species. Even though we prospected all the supports present at each station, we didn't come across any liverworts or hornworts. This could be due to the dryness of the valley, especially during the long summer season in which we collected. On the other hand, the valleys of the High Atlas of Marrakech, especially those of the TNP, are deeply encased. They present a very pronounced characteristic thermal inversion due to local topography (Ouhammou, 2005).

Recent bryophytic studies carried out in the Rherhaya valley, inside of the TNP, Ros *et al.* (2000) and Fakihani *et al.* (2024), have reported together only eight species of liverworts and no hornworts. Nevertheless, the scarcity of studies carried out in the TNP must also be emphasized. Many areas are still virgin from a bryofloristic point of view.

In the catalog, the name of each species, is given, followed by the voucher of Cadi Ayyad University's herbarium. The code of the locality where they were collected, and a brief description are presented. It should be noted that, for some stations, there are different descriptions, depending on the sampling

supports of these species: (aquatic, supra-aquatic, soil, rocks, trees, etc.).

After the catalog, when we have a new citation, add a paragraph discussing the species was given, including a commentary describing its biogeography and chorology, usually with reference to Augier's (1966) flora, and describing its ecology, usually with reference to Lemonnier (2008)

In this work research, we mean North Africa, the region comprising Morocco, Algeria, Tunisia, Libya and Egypt.

All the species cited in this catalog were deposited in the Marrakech Regional herbarium MARK, at the Faculty of Sciences Semlalia- Cadi Ayyad University (UCA-FSSM-Maroc).

Bryophytes Catalog of the Ourika valley-TNP

The catalog resulting from this study of the Ourika valley includes 47 taxa, all mosses. No Hepatica or Anthocerotata were encountered during samples collection.

Amphidium mougeotii (Schimp.) Schimp. (B0409) St OO4. Very shaded area, on clayey soil, granitic bedrock. New for Africa (Ros *et al.*, 1999, 2013; O'Shea, 2006).

Brachytheciastrum bellicum (W.R. Buck, J.A. Jiménez, Ros & M.J. Cano) Vanderp. *et al.* (B0054) = *Brachythecium bellicum* W.R. Buck, J.A. Jiménez, Ros & M.J. Cano St OAq1. Area with Clay to sandy-clayey bedrock. Cited once in the Mediterranean, in Morocco (Buck *et al.*, 2001). New for the Ourika valley, outside TNP (TNP-PZ).

Brachytheciastrum velutinum (Hedw.) Ignatov & Huttunen (B0396) (= *Brachythecium velutinum* (Hedw.) Schimp.) St OO3. By the stream, on limono-sandy soil full of water. Shaded area, sheltered under granitic rock.

Brachythecium mildeanum (Schimp.) Schimp. (B0376) St OO0. Edge of the river, silty-sandy soil very high moisture, covered with lawn, ledge exposure N. New for North Africa (Ros *et al.*, 1999, 2013).

Brachythecium rivulare Schimp. (B0372) St OO0, St OO5. Edge of the river, silty-sandy soil very high humidity covered lawn, ledge exposure N. On the edge of the river, silty-sandy soil at high humidity, covered with lawn, exposition N.

Ptychostomum archangelicum (Bruch & Schimp.) J.R. Spence (B0371) = *Bryum archangelicum* Bruch & Schimp. St OO5. Shaded area under granite, on silty-sandy soil.

Bryum argenteum Hedw. (B0411) St OAq1, St OO5. Area with Clay to sandy-clayey bedrock. Exposure area, silty-sandy soil with very high humidity, covered with lawn, exposition N.

Bryum elegans Nees (B0403) = *Ptychostomum elegans* (Nees) D. Bell & Holyoak St OO3. Shaded area, sheltered under granitic rock.

Bryum intermedium (Brid.) Blandow. (B0364)
St OO0. Edge of the river, silty sandy soil very high moisture, covered with lawn, ledge exposure N. Cited only once in Morocco (Jelenc, 1955). New for the TNP.

Bryum mildeanum Jur. (B0367)
St OO1. In flowing water of river, on acidic rock.

Ptychostomum pallescens (Sw.) J.R.Spence (B0383)
=*Bryum pallescens* Sw.
St OO2. Shaded area under granite, silty-sandy soil.

Ptychostomum pseudotriquetrum (Schreb.) Lilj. (B0380)
=*Bryum pseudotriquetrum* (Hedw.) G.Gaertn., B.Mey. & Scherb.
St OO2, St OO5. At the edge of river. Exposed area, on the edge of the river, silty-sandy soil with very high humidity, covered with lawn, exposition N. In reference to Holyoak & Hedenäs (2006), we include here *B. neodamense*; which we consider synonymous with *B. pseudotriquetrum*.

Bryum radiculosum Brid. (B0412)
St OO5. Directly on unshaded granite, with N exposure.

Cratoneuron filicinum (Hedw.) Spruce. (B0384)
St OO2, St OO5. Shaded Area under granite, silty-sandy soil. On the edge of the river, silty-sandy soil with high humidity, covered with lawn, exposition N. On granitic acid rock, under small fall of source.

Distichium capillaceum (Hedw.) Bruch & Schimp. (B0417)
St OO5. Seepage zone of source, on silty-sandy-clay soil. New for the TNP.

Fontinalis antipyretica Hedw. (B0368)
St OO1bis. In flowing water of Afella N'Oufra river, on acidic rock. This is the only site where *Fontinalis antipyretica* has been observed in all the valleys of the TNP. New for the TNP.

Grimmia laevigata (Brid.) Brid. (B0382)
St OO2. At the edge of river.

Grimmia ovalis (Hedw.) Lindb. (B0399)
St OAq1, St OO3, St OO6. Area with Clay to sandy-clayey bedrock. Shaded area, sheltered under granite rock. Exposed area, directly on granite, exposition N.

Grimmia crinitoleucophaea Cardot (B0055)
=*Grimmia poecilostoma* Cardot & Sebille
St OAq1. Zone with clayey to sandstone-clayey bedrock. Acrocarpous pioneer, epilithic, basophilic, photophilic, xerophilic, mid-European [modal temperate] (Lemonnier, 2008). New to the Ourika valley, outside TNP (TNP-PZ).

Grimmia pulvinata (Hedw.) Sm. (B0056)
St OAq1. Area with Clay to sandy-clayey bedrock. New to the Ourika valley, outside TNP (TNP-PZ).

Homalothecium aureum (Spruce) H. Rob. (B0057)
St OAq1. Area with Clay to sandy-clayey bedrock. New to the Ourika valley, outside TNP (TNP-PZ).

Mnium marginatum (Dicks.) P. Beauv. (B0382)
St OO2. Shaded Area under granite, silty-sandy soil. Cited only once in Morocco, according to Ros *et al.* (1999).

Orthotrichum cupulatum Hoffm. ex Brid. var. ***bistratosum*** Schiffn. (B0398)
St OO3. Shaded area, sheltered under granitic rock. New for Morocco (Ros *et al.*, 1999, 2013; O'Shea, 2006; Osman *et al.*, 2021).

Orthotrichum cupulatum Hoffm. ex Brid. var. ***cupulatum*** (B0405)
St OO3. Shaded area, sheltered under granite rock. New for the TNP.

Palustriella commutata (Hedw.) Ochyra (B0419)
St OO5. On granitic acid rock, under small fall of source.

Philonotis fontana (Hedw.) Brid. (B0366)
St OO0, St OO2, St OO5. Edge of the river, silty-sandy soil very high moisture, covered with lawn, ledge exposure N. Shaded Area under granite, silty-sandy soil. Seepage zone of water source, on silty-sandy-clay soil.

Philonotis seriata Mitt. (B0373)
St OO1. In flowing water of river, on acidic rock. Cited only once in Morocco (Jelenc, 1955). New for the TNP.

Philonotis tomentella Molendo (B0369)
St OO0. Edge of the river, silty-sandy soil very high moisture, covered with lawn, ledge exposure N.

Plasteurhynchium meridionale (Schimp.) M. Fleisch (B0051)
=*Eurhynchium meridionale* (Schimp.) De Not.
St OAq1. Area with Clay to sandy-clayey bedrock. News to the Ourika valley, outside TNP (TNP-PZ).

Pseudoleskeella nervosa (Brid.) Nyholm (B0392)
St OO3. Shaded area, sheltered under granitic rock. New for Africa (Ros *et al.*, 1999, 2013; O'Shea, 2006).

Pseudoleskeella rupestris (Berggr.) Hedenas & L. Soderstr. (B0408)
St OO3. Shaded area, sheltered under granitic rock. New for the TNP.

Pseudoleskeella tectorum (Funck ex Brid.) Kindb. Ex Broth. (B0391)
St OO3. Shaded area, sheltered under granitic rock. Cited only once in North Africa, in Morocco (Ros *et al.*, 2000).

Rhynchostegium riparioides (Hedw.) Cardot (B0390)
=*Platyhypnidium riparioides* (Hedw.) Dixon
St OO2. Under waterfall, on granite. New for the TNP.

Schistidium flaccidum (De Not.) Ochyra (B0377)
St OO2. On exposed granite.



Figure 4. *Amphidium mougeotii* (Schimp.) Schimp.: a, habit; b, rhizoids; c, leaves; d, Basal cells; e, median cells; f, leaf apex; g- cross-section at the median level of a leaf.

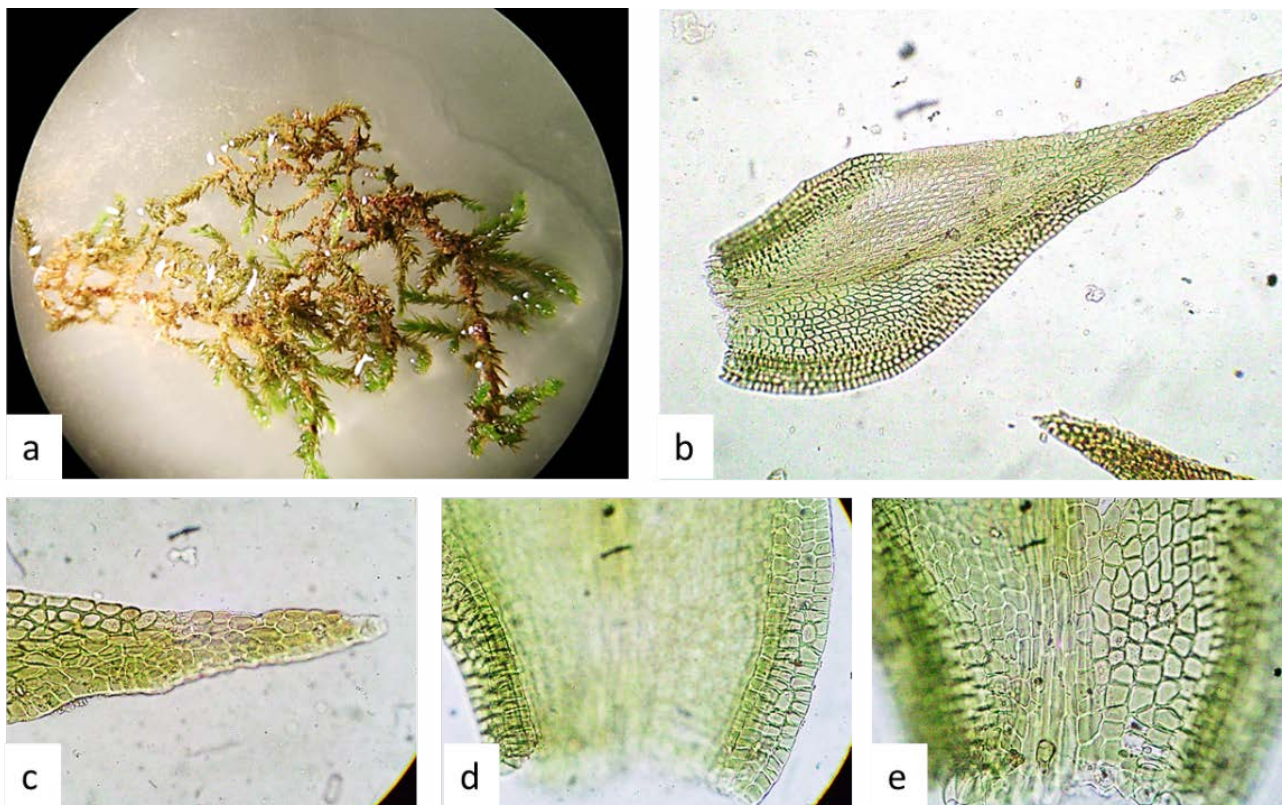


Figure 5. *Pseudoleskeella nervosa* (Brid.) Nyholm: a, habit; b, leaf; c, leaf apex; d, lateral basal cells; e, central basal cells with nerve cells.

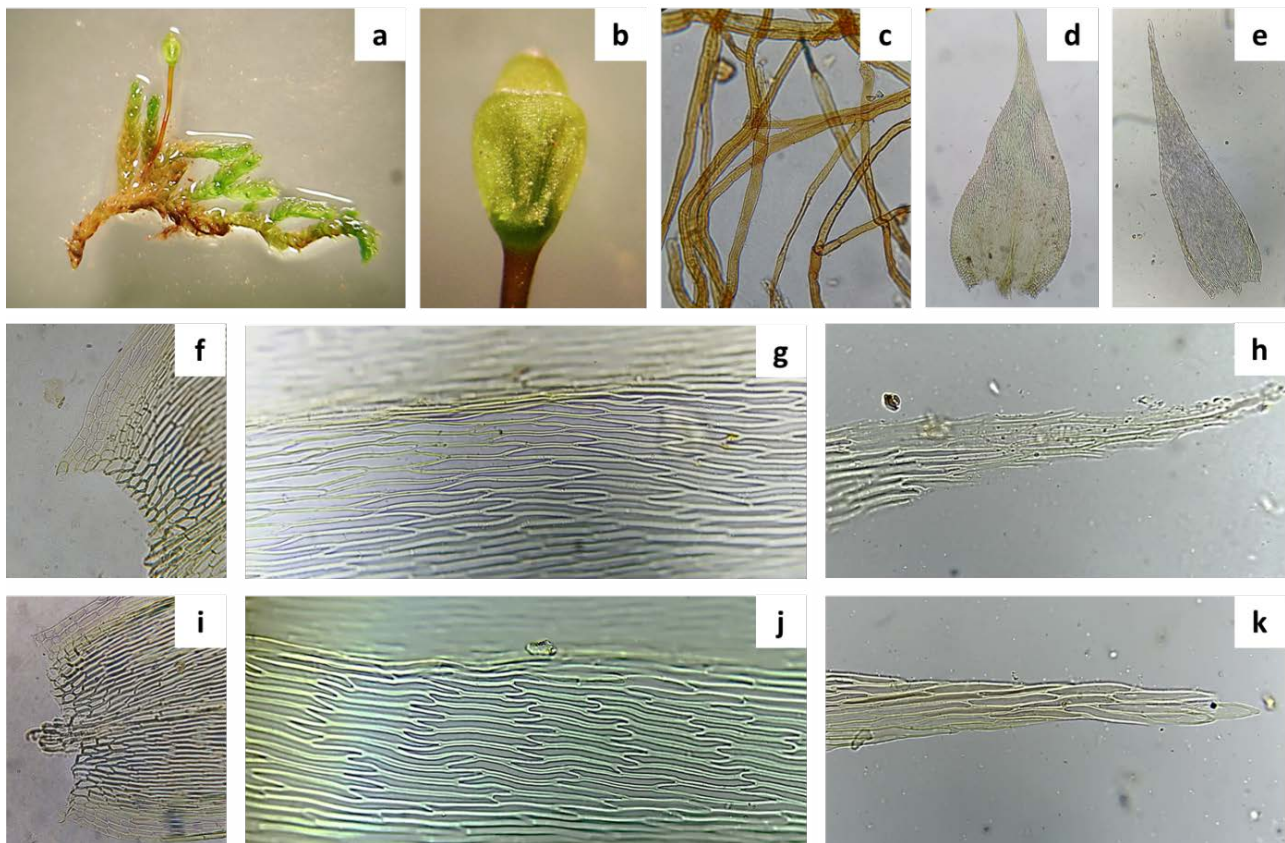


Figure 6. *Brachythecium mildeanum* (Schimp.) Schimp; a, general appearance; b, young capsule; c, rhizoids; d, stem leaf; e, branchial leaf; f, central and lateral basal cells of the stem leaf; g, median laminal cells of the stem leaf; h, leaf apex; i, central and lateral basal cells; j, median laminal cells; k, leaf apex.

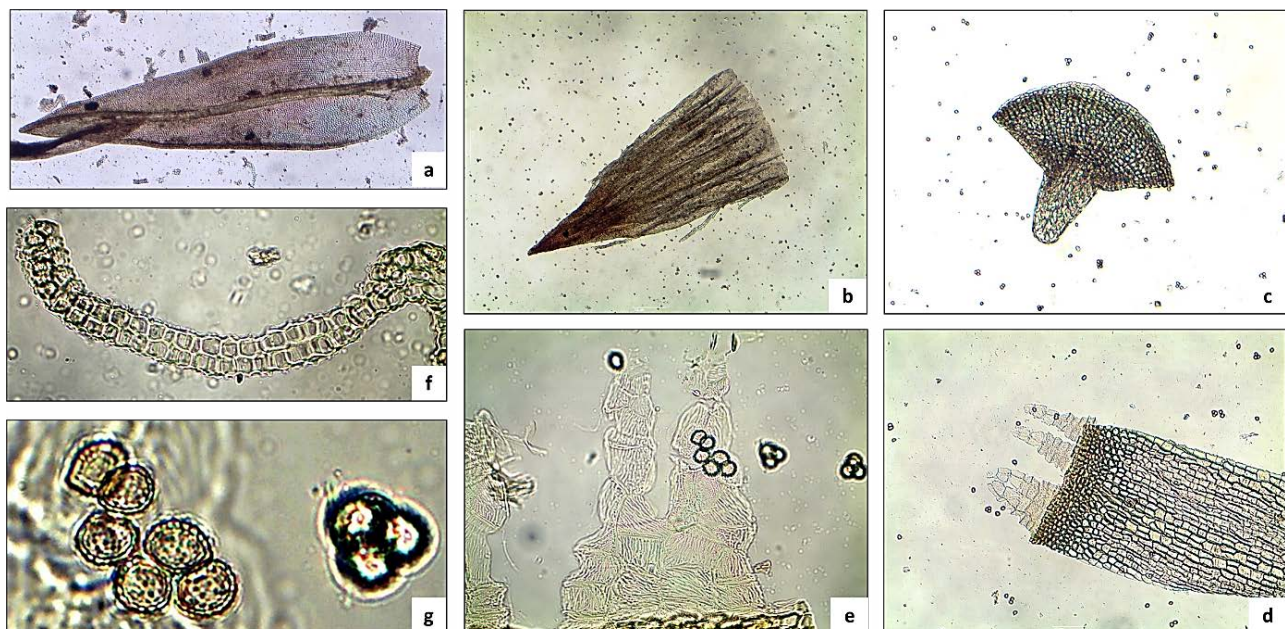


Figure 7. *Orthotrichum bistratosum* (Schiffn.) J. Guerra; a, leaf; b, Calyptra; c, Capsule lid; d, Capsule (upper part); e, peristome teeth (with spores); f, lamina (cross section); g, spores.

Schistidium helveticum (Schkuhr) Deguchi (B0397)
= *S. singarense* (Schiffn.) Laz.
St OO3. Shaded area, sheltered under granitic rock.

Schistidium rivulare (Brid.) Podp. (B0363).
St OO1. In flowing water of river, on acidic rock. Cited only once in Morocco (Ros *et al.*, 2000).

Syntrichia calcicola J. J. Amann (B0410)
St OO4. Very shady area, on clayey-silty soil, granitic bedrock.

Syntrichia norvegica F. Weber (B0386)
St OO2. On exposed granite. On silty-sandy soil.

Syntrichia ruralis (Hedw.) F. Weber & D. Mohr (B0385)
St OO2, St OO3. On exposed granite. Shaded area, sheltered under granitic rock.

Timmia bavarica Hessel. (B0394)
St OO3. Shaded area, sheltered under granitic rock. New for the TNP.

Tortella tortuosa (Hedw.) Limpr. (B0395)
St OO3. Shaded area, sheltered under granitic rock.

Tortula hoppeana (Schultz) Ochyra (B0365)
St OO0. Edge of the river, silty-sandy soil very high moisture, covered with lawn, ledge exposure N. On lawn in exposed high floor, high recovery soil, high humidity of the soil, exposure N. Cited in North Africa only in Morocco (Ros *et al.*, 2013). New for the TNP.

Tortula inermis (Brid.) Mont. (B0050)
St OAq1 - Area with Clay to sandy-clayey bedrock. News to the Ourika valley, outside TNP (TNP-PZ).

Tortula lindbergii Broth. (= ***Pottia lanceolata*** (Hedw.) Mull. Hal.). (B0379)
St OO2 - On exposed granite. New for the TNP.

Tortula obtusifolia (Schwagr.) Mathieu (B0049)
St OAq1 - Area with Clay to sandy-clayey bedrock. News to the Ourika valley, outside TNP (TNP-PZ).

Tortula vahliana (Schultz) Mont. (B0378)
St OO2 - On exposed granite. New for the TNP.

Two new species in Africa

The results concerning new citations were deduced, following consultation of the checklists of the Mediterranean region (Ros *et al.*, 2013), that of North Africa (Ros *et al.*, 1999) and that of mosses from sub-Saharan Africa (O'Shea, 2006), in addition to the inventory of Bryophytes from the "RAB" Herbarium of the Scientific Institute (Rabat, Morocco) (Ahayoun *et al.*, 2007) and from the Bibliographic Catalog of Bryophytes of Morocco (1913-2011) (Ahayoun *et al.*, 2013). This resulted in the identification of

Amphidium mougeotii (Schimp.) Schimp. (B0409)
Epilithic, basophilic, shade-tolerant, aeromesoxerophilic, mesothermic (Lemonnier, 2008). Orophyte, all altitudes. Europe, North America (Augier, 1966) (Figure 4).

Pseudoleskeella nervosa (Brid.) Nyholm. (B0392)
Epilithic, basophilic, vertical wall, shade-tolerant, aerohygrophilic, pedohygrophilic, mountainous (Lemonnier, 2008) (Figure 5).

These two species are not cited in northern Africa, nor in the Mediterranean checklist of Ros *et al.* (2013), nor in that of North Africa by Ros *et al.* (1999) and also not cited in the checklist of sub-Saharan African mosses by O'Shea (2006).

One new species for North Africa

Brachythecium mildeanum (Schimp.) Schimp. (B0376).
Pleurocarpous climax, prairial, hygrophilous (Lemonnier, 2008). Mountainous plains and ponds.

Boreal and middle Europe, Siberia (Augier, 1966). This species is found in the North African checklist (Ros *et al.*, 1999), without specifying the country. Its presence is doubtful according to this author, whereas in the more recent checklist of Mediterranean bryophytes by Ros *et al.* (2013), it is not cited in any North African country. It can therefore be considered new for North Africa (Figure 6).

One new species for Morocco

Orthotrichum cupulatum Hoffm. ex Brid. var. ***bistratosum*** Schiffn. (B0398).

Its distribution area is mainly southwest Asia and the West of the Mediterranean (Hugonnot, 2010). *Orthotrichum cupulatum* var. *bistratosum* is an epilithic moss, usually observed in dry environments on various types of rocks (limestone, volcanic, plutonic) Hugonnot (2010). In reference to Guerra (1985), *Orthotrichum cupulatum* Hoffm. ex Brid. var. *bistratosum* Schiffn. was elevated to the species status.

Orthotrichum bistratosum (Schiffn.) J. Guerra. It is characterized by leaves bistratified in the middle, broadly ovate-lanceolate, upper leaf cells with thickened walls, with few or no papillae, submerged capsule, ellipsoidal peristomatic teeth articulations and smooth or weakly striated teeth (Guerra, 1985).

Our specimen corresponds to the description given above, with the specification that the lamina is partially bistratose, the clearly striated peristome teeth have ellipsoidal articulations and the spores are papillose (Figure 7). For this reason, we adopt Guerra's (1985) new nomenclature for this species, which is *Orthotrichum bistratosum* (Schiffn.) J. Guerra.

Eleven species are newly cited for the TNP

All the species identified in the Assif Afella n'Oufra are cited for the first time in the upper Ourika valley, located in the area of the TNP.

Seven species are newly cited for the Ourika valley, TNP-PZ

All the species collected and identified in the St OAq1 station of Assif Ait Elqaq (tributary of the Ourika river), are cited for the first times in the Ourika valley, in its part outside the TNP. In reference to the bibliography consulted, the only previous citation in the Ourika valley is *Mnium* sp., collected alone, in 1929; on the edges of Assif Ait Iren, small stream in the Oukaimeden region, which opens into Assif Ait Elqaq, a tributary of the Ourika valley (Ahayoun *et al.*, 2007). All new citations are presented in Table 2.

This wealth of new citations, in the upper Ourika valley, at all geographical levels (continental, N-African, Moroccan, in the TNP and outside the TNP), is due to several factors: 1) The TNP is a protected area, and therefore less subject to the anthropic pressures that would degrade its biodiversity, except in the case of its valleys much frequented by tourists, such as the Upper Rherhaya Valley, leading to the summit of Toubkal (the highest peak in North Africa, 4167m asl). 2) The large valleys of the TNP are very deep and have particular mesoclimates, which would be favorable

Table 2. Main new citations discovered in the Ourika valley. Abbreviations are: TNP, Toubkal National Park, PZ, Peripheral Zone.

Herbarium code	Species	Comments
B0409	<i>Amphidium mougeotii</i> (Schimp.) Schimp.	New for Africa
B0392	<i>Pseudoleskeella nervosa</i> (Brid.) Nyholm	New for Africa
B0376	<i>Brachythecium mildeanum</i> (Schimp.) Schimp.	New for North Africa
B0398	<i>Orthotrichum bistratosum</i> Schiffn.	New for Morocco
B0364	<i>Bryum intermedium</i> (Brid.) Blandow	New for TNP
B0417	<i>Distichium capillaceum</i> (Hedw.) Bruch & Schimp.	New for TNP
B0368	<i>Fontinalis antipyretica</i> Hedw.	New for TNP
B0405	<i>Orthotrichum cupulatum</i> var. <i>cupulatum</i> Hoffm. Ex Brid.	New for TNP
B0373	<i>Philonotis seriata</i> Mitt.	New for TNP
B0390	<i>Rhynchostegium riparioides</i> (Hedw.) Cardot	New for TNP
B0408	<i>Pseudoleskeella rupestris</i> (Berggr.) Hedenas & L. Soderstr.	New for TNP
B0394	<i>Timmia bavarica</i> Hessel.	New for TNP
B0370	<i>Tortula hoppeana</i> (Schultz) Ochyra	New for TNP
B0379	<i>Tortula lindbergii</i> Broth.	New for TNP
B0378	<i>Tortula vahliana</i> (Schultz) Mont.	New for TNP
B0054	<i>Brachythecium bellicum</i> W.R. Buck, J. A. Jiménez, Ros & M.J. Cano	New for Ourika, outside TNP (TNP-PZ)
B0055	<i>Grimmia crinitoleucophaea</i> Cardot (= <i>Grimmia poecilostoma</i> Cardot & Sebillé)	New for Ourika, outside TNP (TNP-PZ)
B0056	<i>Grimmia pulvinata</i> (Hedw.) Sm.	New for Ourika, outside TNP (TNP-PZ)
B0057	<i>Homalothecium aureum</i> (Hedw.) Lindb.	New for Ourika, outside TNP (TNP-PZ)
B0051	<i>Plasteurhynchium meridionale</i> (Schimp.) M. Fleisch.	New for Ourika, outside TNP (TNP-PZ)
B0050	<i>Tortula inermis</i> (Brid.) Mont.	New for Ourika, outside TNP (TNP-PZ)
B0049	<i>Tortula obtusifolia</i> (Schwagr.) Mathieu	New for Ourika, outside TNP (TNP-PZ)

to the development of certain species that require particular climatic conditions. 3) The upper Ourika valley, our study site, is extremely difficult to access, very encased and very sheltered, providing its stations with specific microclimates. Add to this their wide diversity of supports (aquatic, supra-aquatic and saxicolous), you'll understand the bryophytic richness newly cited in this work. 4) Nor should we forget the scarcity of bryological studies previously carried out at TNP. Only two have been carried out here, in the Rherhaya valley. In the one by Ros *et al.* (2000), of 101 taxa, 9 were new to Africa, 3 to North Africa, 6 to Morocco and 89 to TNP. In that of Fakihani *et al.* (2024), of 67 taxa, 6 were new to Africa, 1 to North Africa, 2 to Morocco and 27 to TNP. Further studies at TNP would reveal more new citations and enrich the African, N-African, Moroccan and TNP checklists.

From a vulnerability point of view, there is no red list of bryophytes neither for the whole of Africa, nor for North Africa nor for Morocco. Only one study of epiphytic bryophytes, by Draper *et al.* (2007), has established a hierarchization of Moroccan mountain ranges, according to their number of rarity hotspots. They report that the importance of these hotspots decreases with latitude, from the Rif to the Anti Atlas, and that the High Atlas range contains no localities that could be considered as epiphytic bryophyte rarity hotspots.

To estimate the threats of bryophytes in the TNP, we referred to the red list of bryophytes of Auvergne (Hugonnot, 2014), which is the most complete red list of the regions of France. The latter also does not have a red list covering its entire territory. The criteria used in the red list

of bryophytes of Auvergne are based on the recommendations of the IUCN-France (2011). The biological specificities of bryophytes raise difficulties which led Hallingbäck *et al.* (1998) to propose adaptations of the criteria, subsequently validated by the IUCN as guidelines for bryophytes (Hugonnot, 2014). The three categories Critically Endangered (CR), Endangered (EN) and Vulnerable (VU) bring together species threatened with extinction. These species face a relatively high (VU), high (EN) or very high (CR) risk of extinction (Hugonnot, 2014). In the Ourika valley, 20% of species are threatened with extinction. 10% are critically endangered (CR), 4% are endangered (EN) and 6% are vulnerable (VU) (Fig. 8). These results are backed up by studies carried out on vascular plants in the TNP by Ouhammou (2005). He reports that the TNP is characterized by a specific richness of 12.8% and an endemism rate of 4%, compared with the flora of Morocco. Within the TNP, the upper Ourika valley, the site of our study, has an endemism rate of 45% to 50% and a rare species rate of 20% to 25%. The TNP, specifically the upper Ourika valley, is therefore a hot spot of rarity and vulnerability for plant biodiversity, and in particular for non-epiphytic bryophytes. Given the high tourist numbers in the lower Ourika valley and the government's policy of opening up remote areas of the High Atlas, there is a risk that the threats will spread to the upstream part of the valley and harm the particular biodiversity that characterizes it. Protection and preservation measures are therefore constantly required.

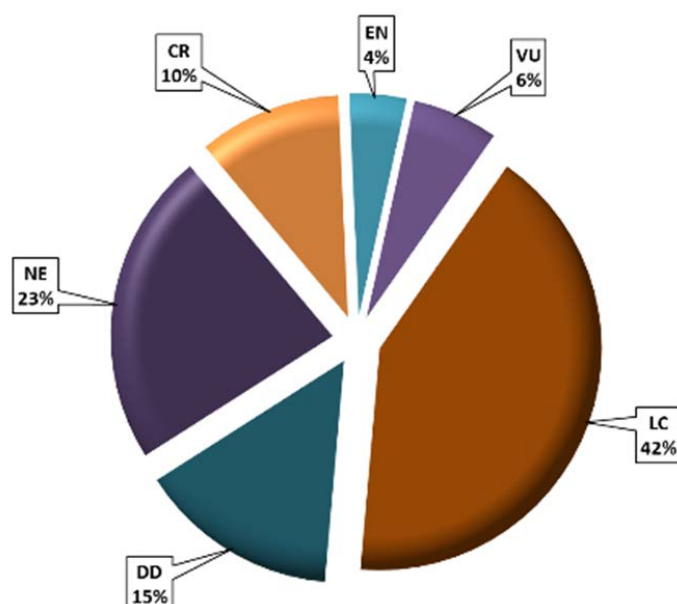


Figure 8. Threat categories of bryophyte species in Toubkal National Park, Ourika Valley, with reference to the red list of Auvergne bryophytes (Hugonnot *et al.*, 2014). CR, Critically endangered; EN, Endangered; VU, Vulnerable; LC, Least concern; DD, Data deficient; NE, Not evaluated (IUCN France, 2011).

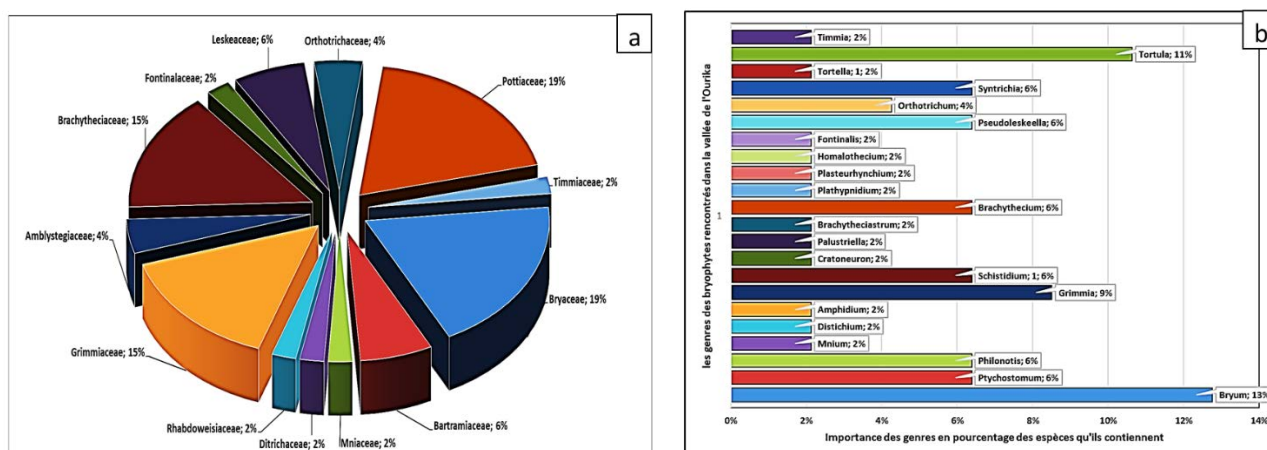


Figure 9. Bryophytic biodiversity of the Ourika valley; a, Relative importance of families; b, Relative importance of genera.

From a biodiversity point of view, all the species encountered belong to the moss phylum, divided into 7 orders, where Bryales and Hypnales dominate (28% each), followed by Pottiales (19%), then Grimmiaceae (15%). Among the thirteen families recorded, we note the preponderance of four, which bring together 68% of the species. Species of Bryaceae and Pottiaceae each represent 19% of the species, followed by those of Brachytheciaceae and Grimmiaceae, with 15% each. The remaining nine families total 32% of the species, varying between 2% and 6% each (Fig. 9a). On a generic level, we observe a clear predominance of the genus *Bryum*, with a proportion of 13% of the identified species, followed by *Tortula* (11%), and *Grimmia* (9%). The proportions of the remaining genera vary between 2 and 6% (Figure 9b).

Conclusion

As part of the global systematic study covering the bryophytes of the Toubkal National Park, this study made it possible to explore for the first time the bryoflora of the eastern part of the TNP, at the level of the upper Ourika valley. All the species that have been identified there are new for this valley, even those discovered in its

part outside the TNP, in the Assif Ait Elqag, tributary of the Ourika valley, on the Oukaimeden road.

In addition to its contribution to the knowledge of the bryophytes of the TNP and to the expansion of its catalog of eleven (11) new species, our study allowed us to enrich the list of African bryoflora with two (2) new species, the North-African one (1) new species and the Moroccan one (1) new species. These results confirm the relevance of our choice of the TNP as a study site and its bryophytic richness. Nevertheless, the TNP remains largely understudied in bryological terms. Further research would shed much light on its unexplored areas. The upper Ourika valley is a very sparsely frequented area, due to the difficulty of access. Biodiversity is well preserved. However, the rest of the valley is known to be a tourist site, where anthropogenic activity is intense all year round, due to the large influx of visitors. The degradation of sites with high biodiversity potential along the valley is very apparent. The lack of access regulations to vulnerable areas and the weak development of ecological tourism exposes general biodiversity and bryodiversity, to strong pressure in this valley. Hence the need to implement conservation and preservation programs of its specific richness.

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Author contributions

A.F., A.O. and A.D.: Conceptualization and methodology; A.F. and A.O.: validation; A.F., A.O. and A.D.: resources; A.O.: data curation; A.F., A.O. and M.L.: writing, original draft preparation; A.F., A.O., M.L. and A.D.: review and editing; All authors have read and agreed the published version of the manuscript.

Conflicts of interest

None.

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