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Bryophytes in urban and peri-urban areas: inventory and role in maintaining the biodiversity of ecosystems

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Dedication

I dedicate this work to:

The memory of my beloved grandfather **Abdelmadjid**, the kindest and most wonderful grandfather, I had always hoped to complete my doctorate with you by my side on my graduation day and make you proud with my accomplishments… but you passed away. Although you are not physically present, your spirit and influence will always be with me,

My dearest mother **Hasnaa**, the strongest and most patient woman in the world. You have never ceased to pray for me and have always been there to help me achieve my goals. Your love and dedication have shaped me into the person I am today. I am forever grateful for the positive qualities and values you have passed down to me.

My dear father **Mohamed**, you have always had faith in my abilities,

My siblings **Abir**, **Saber** and **Aisha**,

My lovely grandmother **Aisha** and my dear aunts and uncles,

All my friends and colleagues, especially, Dr. **MARROUCHE Hind**, you are more of a sister than a friend. You were always there for me, through thick and thin. I'll never forget this

My beloveds, Dr. **ADOUANI Imene** and Dr. **SAOULI Nacira**, I thoroughly enjoyed our time in the laboratory together.

Amira Shefaa

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Our deepest gratitude is due to Professor **GARILLETI Ricardo** and Professor **LARA Francisco** for their precious contribution in confirming the new records belonging to the Orthotrichaceae.

Abstract

Due to the lack of knowledge about bryophytes in Algeria, this study was carried out to update the bryophyte flora of the region, highlight the influence of environmental factors on their distribution, and explore their role in maintaining the biodiversity of ecosystems. In this context, two areas of the High Plains of Setif with distinct environmental characteristics were selected for the study: the peri-urban area, Megriss Mountain and the urban area, Setif 1 University - Ferhat ABBAS. Bryophytes sampling was conducted across various habitats, including rocks, trees, soils, and streams. Ground and rock bryophytes were sampled from minimum survey areas of 100 cm² (10×10 cm), while epiphytic bryophytes were sampled from the trunk base up to nearly 2 meters above the ground, in all cardinal directions. The samples of bryophytes were examined macroscopically and microscopically in the laboratory of the Urban Project, City and Territory (LPUViT). A total of 89 moss taxa were identified from the two study areas, with 63 taxa recorded in Megriss Mountain and 26 species recorded at Setif 1 University - Ferhat ABBAS. Some species were found in both areas, while neither area included liverworts or hornworts. The 63 moss taxa recorded in Megriss Mountain include 52 acrocarpous and 11 pleurocarpous mosses, distributed among 14 families and 30 genera. In contrast, all the 26 moss species identified at the University were acrocarpous, belonging to 7 families and 18 genera. For Megriss, the most species-rich families are the Pottiaceae, Orthotrichaceae, Brachytheciaceae, and Bryaceae, while the most diverse genera are *Didymodon*, *Syntrichia*, *Lewinskya*, and *Orthotrichum*. On the other hand, the prominent families at the University are the Pottiaceae and Bryaceae, and the most diverse genera are *Bryum* and *Tortula*. In terms of habitats, terrestrial mosses are the most dominant, followed by epilithic mosses in both study areas. The study also highlights the presence of four new species for Algeria: *Didymodon sinuosus*, *Orthotrichum macrocephalum*, *Orthotrichum scanicum*, and *Syntrichia calcicola*. A comprehensive description and microphotographs of these species are provided, and their ecology is also discussed.

Keywords: Algeria, Bryophytes, Distribution, High Plains of Setif, Peri-urban environments, Urban environments.

Résumé

En raison du manque de connaissances sur les bryophytes en Algérie, cette étude a été réalisée pour mettre à jour la flore des bryophytes de la région, mettre en évidence l'influence des facteurs environnementaux sur leur distribution et explorer leur rôle dans le maintien de la biodiversité des écosystèmes. Dans ce contexte, deux zones des Hauts Plaines de Sétif avec des caractéristiques environnementales distinctes ont été sélectionnées pour l'étude : la zone péri-urbaine, Montagne de Megriss, et la zone urbaine, Université Sétif 1 - Ferhat ABBAS. L'échantillonnage des bryophytes a été effectué dans divers habitats, y compris les rochers, les arbres, les sols et les ruisseaux. Les bryophytes terrestres et saxicoles ont été prélevés sur des aires minimales d'échantillonnage de 100 cm² (10×10 cm), tandis que les bryophytes épiphytes ont été échantillonnés à partir de la base du tronc jusqu'à près de 2 mètres au-dessus du sol, dans toutes les directions cardinales. Les échantillons de bryophytes ont été examinés macroscopiquement et microscopiquement dans le laboratoire du Projet Urbain, Ville et Territoire (LPUViT). Un total de 89 taxons de mousses a été identifiés dans les deux zones d'étude, dont 63 taxons enregistrés dans la Montagne de Megriss et 26 espèces enregistrées à l'Université Sétif 1 - Ferhat ABBAS. Certaines espèces ont été trouvées dans les deux zones, tandis qu'aucune des deux zones ne comprenait de Marchantiophytes ou d'Anthocérotes. Les 63 taxons de mousses enregistrés dans la Montagne de Megriss comprennent 52 mousses acrocarpes et 11 mousses pleurocarpes, réparties en 14 familles et 30 genres. En revanche, toutes les 26 espèces de mousses identifiées à l'Université étaient acrocarpes, appartenant à 7 familles et 18 genres. Pour Megriss, les familles les plus riches en espèces sont les Pottiaceae, Orthotrichaceae, Brachytheciaceae et Bryaceae, tandis que les genres les plus divers sont *Didymodon*, *Syntrichia*, *Lewinskya* et *Orthotrichum*. D'autre part, les familles prédominantes à l'Université sont les Pottiaceae et Bryaceae, et les genres les plus divers sont *Bryum* et *Tortula*. En termes d'habitats, les mousses terrestres sont les plus dominantes, suivies par les mousses épilithiques dans les deux zones d'étude. L'étude met également en évidence la présence de quatre espèces nouvelle pour Algérie: *Didymodon sinuosus*, *Orthotrichum macrocephalum*, *Orthotrichum scanicum* et *Syntrichia calcicola*. Une description complète et des microphotographies de ces espèces sont fournies, et leur écologie est également discutée.

Mots-clés: Algérie, Bryoflore, Bryophytes, Distribution, Hautes Plaines de Sétif, Milieux Périurbains, Milieux urbains.

ملخص

نظراً لعدم وجود معلومات كافية عن النباتات الطحلبية في الجزائر، أُجريت هذه الدراسة لتحديث النباتات الطحلبية في المنطقة، ولتسليط الضوء على تأثير العوامل البيئية على توزيعها، ولاستكشاف دورها في الحفاظ على تنوع الأنظمة البيئية. وفي هذا السياق، تم اختيار منطقتين من هضاب سطيف العليا ذات خصائص بيئية مختلفة للدراسة: المنطقة شبه الحضرية، جبل مقرس والمنطقة الحضرية، جامعة سطيف 1 - فرحات عباس. تمت جمع عينات من النباتات الطحلبية عبر موائل مختلفة، بما في ذلك الصخور، والأشجار، والتربة، والجداول المائية. تم أخذ عينات من النباتات الطحلبية الأرضية والصخرية من مساحات لا تقل عن 100 سم² (10×10 سم)، بينما تم جمع النباتات الطحلبية الهوائية من قاعدة الجذع حتى ارتفاع يقارب مترين فوق سطح الأرض، في جميع الاتجاهات الرئيسية. تم فحص عينات الحزازيات مجهريا في مختبر المشروع الحضري، المدينة والإقليم. تم التعرف على إجمالي 89 نوع من الحزازيات في منطقتي الدراسة، حيث تم تسجيل 63 نوعًا في جبل مغرس و26 نوعًا في جامعة سطيف 1 - فرحات عباس. وُجدت بعض الأنواع في كلا المنطقتين، بينما لم تتضمن أي من المنطقتين النباتات الكبدية و النباتات الزهقرنية. تشمل الـ 63 نوعًا المسجلة في جبل مغريس 52 نوعًا من الحزازيات عمودية التفرع، و11 نوعًا من الحزازيات أفقية التفرع، موزعة على 14 عائلة و30 جنسا. بينما كانت جميع الأنواع الـ 26 التي تم تحديدها في الجامعة من الحزازيات عمودية التفرع، وتنتمي إلى 7 عائلات و18 جنسًا. في جبل مغرس، العائلات الغنية من حيث عدد النواع هي Pottiaceae، Orthotrichaceae، Brachytheciaceae، وBryaceae، بينما الأجناس الأكثر تنوعًا هي *Didymodon*، *Syntrichia*، *Lewinskya*، و*Orthotrichum*. بالمقابل، العائلات الغنية بالأنواع في الجامعة هي عائلتا Pottiaceae وBryaceae، والأجناس الأكثر تنوعًا هي *Bryum* و *Tortula*. من حيث الموائل، كانت الحزازيات الأرضية الأكثر سيادة، وتليها الحزازيات الصخرية في كلتا منطقتي الدراسة. كما أبرزت الدراسة وجود أربعة أنواع جديدة للجزائر، وهي *Didymodon sinuousus*، *Orthotrichum macrocephalum*، *Orthotrichum scanicum* و *Syntrichia calcicola*. تم توفير وصف شامل وصور مجهرية لهذه الأنواع وتمت مناقشة بيئتها أيضًا.

الكلمات المفتاحية: البيئات الحضرية، البيئات شبه الحضرية، التوزيع، الجزائر، النباتات الطحلبية، هضاب سطيف العليا.

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List of abbreviations

°C: degrees Celsius

°K: degrees Kelvin

cm: centimeter

km: Kilometer

m: meter

Max: maximum

Min: minimum

mm: millimeter

P: the annual sum of rainfall in mm

S. l: sensu lato (it is a Latin abbreviation that translates to “in the broad sense”)

S. s: sensu stricto (it is a Latin abbreviation that translates to “in a narrow or strict sense”)

T: temperature

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Introduction

Bryophytes, includes mosses, liverworts, and hornworts, have been evolving in terrestrial and aquatic environments longer than any other group of land plants, surviving and thriving through an incredible range of climatic and environmental variation (Graham *et al.*, 2014). Mosses are the most diverse group among the three groups of bryophytes in terms of species richness (Crandall-Stotler & Bartholomew-Began, 2007).

Bryophytes occupy a broad range of ecosystems, habitats, and specific microhabitats, including substrates where vascular plants cannot thrive (Rice, 2009; Slack, 2011), they can also tolerate a wide range of temperatures (Turetsky, 2003; Sérgio *et al.*, 2011) and, despite their small size and inconspicuous nature compared to vascular plants, they play a vital role in their ecosystems (Spangler, 2021). They are common components of many natural landscapes such as peatlands, tundra environments and damp forests (Vanderpoorten & Goffinet, 2009). Particularly, epiphytic bryophytes play a significant role in the majority of forest canopies, from boreal forests in the Northern Hemisphere to temperate forests in the Southern Hemisphere, including tropical forests (Mellado-Mansilla *et al.*, 2017). Bryophytes also play a crucial role in urban vegetation due to their ability to thrive in limited urban microhabitats that may not support the growth of huge plants, benefiting from reduced competition with other plants (Grdović & Sabovljević, 2009; Sabovljević & Grdović, 2009). They maintain photosynthetic activity throughout the year, serving as a green filter that remains functional even in winter when other components of urban greenery are dormant or inactive (Żołnierz *et al.*, 2022).

The ability of bryophytes to thrive in a wide range of terrestrial and freshwater habitats suggests intriguing questions on how they manage to colonize, adapt and develop in such environments, and their presence in almost all ecosystems on Earth also raises inquiries about their ecological importance in those ecosystems (Vanderpoorten & Goffinet, 2009).

The importance of bryophytes in ecosystem regulation and biodiversity conservation is gaining recognition (Vanderpoorten & Goffinet, 2009). They are the primary producers in various ecosystems worldwide (Ogwu, 2019). Urban bryophytes can serve as bioindicators for assessing air quality or as accumulators of heavy metals through atmospheric deposition (Sabovljević & Sabovljević, 2009). However, the role of bryophytes in an ecosystem is determined by four key characteristics: their capacity to establish soils, retain moisture, exchange cations, and tolerate desiccation (Bahuguna *et al.*, 2013).

Over the last few decades, the expanding urban landscapes have prompted scientists from various countries to regard urban areas as a new field for advancing ecological studies (Lo Giudice & Bonanno, 2010; Lehosmaa *et al.*, 2017). Urbanization has been observed to alter the composition of biological communities, potentially resulting in biotic homogenization. This process involves the substitution of non-urban specialist species, which typically inhabit natural areas with specific habitat requirements, with urban-adapted generalist species that can thrive in diverse urban environments (Concepción *et al.*, 2015). This transformation of natural habitats due to urbanization poses a threat to biodiversity by reducing species distribution areas and endangering vulnerable biota groups (Mamchur *et al.*, 2021).

Bryophytes have been extensively studied as a group, but there is still limited knowledge about their ecology and distribution, especially in regions like Algeria. While research on vascular plants has been significant, the study of the bryophyte flora of Algeria has been historically restricted. Studies on the bryophyte flora of Algeria have been conducted extensively since the 19th century, with a decline in research activity noted from the latter half of the 20th century onwards. Bescherelle (1882) released the initial Catalogue of the mosses found in Algeria. Moreover, notable bryologists such as Camus, Trabut, Pinoy, Klincksieck, and Maire made occasional collections of mosses in various Algerian provinces during sessions of the Botanical Society of France. Camus (1906) and Trabut (1914, 1927, 1934) identified a limited number of bryophytes from these collections. Furthermore, Feódor Jelenc, a French bryologist, conducted significant fieldwork in Algeria and produced the initial compilation of reports on bryophytes from northern Africa (Jelenc, 1955, 1967). Furthermore, Ros *et al.* (1999) synthesized available references to compile an annotated list of bryophytes in northern Africa, in which Algeria had the most significant number of taxa (648 taxa). This checklist was later updated in the Mediterranean checklists of liverworts and mosses (Ros *et al.*, 2007, 2013). Also, Bischler (2004) contributed substantial data on Algerian hepatics without specific localities. Recently, Boukhatem *et al.* (2017) conducted an inventory of mosses in the Tonga watershed in northeastern Algeria.

The main objective of this study is to perform an inventory of bryophytes in two sites: one peri-urban, Megriss Mountain, and the other urban, Setif 1 University - Ferhat ABBAS (El bez), both of which have distinct ecological characteristics. The purpose of this inventory is to reveal the major relationships between bryophytes species and their environment, as well as to highlight how environmental factors influence the distribution of these species, and to update the checklist of bryophyte species in Algeria. Furthermore, this study aims to figure out the role of bryophytes in maintaining the biodiversity of both sites.

In order to achieve these objectives, our dissertation has been structured into four chapters:

- The first chapter, focuses on a literature review of bryophytes;
- The second chapter is devoted to with the presentation of the study areas: topographical

description, climate parameters, vegetation, etc.;

- The third chapter presents the methodological approach, describing the sampling method, the inventory method and the equipment used to identify the samples collected;
- The fourth chapter, focuses on the results obtained and their discussion.

Chapter I

Review of literature

1. History and evolution of bryophytes

The process of terrestrialization on Earth is believed to have started with the colonization of land by photosynthetic prokaryotes, such as Cyanobacteria, followed by eukaryotic algae, and then the first embryophyte plants, which were probably closely related to modern bryophytes (Graham *et al.*, 2014). Bryophytes have been continuously present on Earth for at least 75 million years before the age of the dinosaurs (Ogwu, 2019). Liverworts, in particular, are the earliest plants, evolving 472 million years ago, making them the ancestors of all land plants that exist today (Vanderpoorten & Goffinet, 2009; Asakawa & Ludwiczuk, 2017).

Bryophytes are a group of plants that are often referred to as non-vascular (Ruklani & Rubasinghe, 2013; Budke *et al.*, 2018; Patiño & Vanderpoorten, 2018), meaning they lack specialized vascular tissues like xylem and phloem. However, Glime (2017b) argues that the term "non-tracheophytes" might be more appropriate, as many bryophytes do have vascular tissue, such as hydroids that serve a similar function to xylem. Additionally, some mosses have leptoids, the equivalent of phloem.

2. Classification of bryophytes

The bryophytes are the second most diverse group of plants in terms of species richness, after flowering plants (angiosperms) (Mishler, 2001; Renzaglia *et al.*, 2007; Chandra *et al.*, 2016; Hodgetts *et al.*, 2019). Taxonomically, they are placed between algae and pteridophytes (Asakawa *et al.*, 2012). Recent studies have separated bryophytes into three different phyla: Bryophyta (mosses), Marchantiophyta (liverworts), and Anthocerophyta (hornworts) (Rice, 2009; Govindapyari *et al.*, 2012). However, more recently, a study using molecular sequencing to analyze the evolutionary relationships of these bryophytes has revealed that liverworts and mosses are more closely related to each other than to hornworts, leading to the creation of the Setaphyta clade, which is a sister group to hornworts, confirming that bryophytes are a monophyletic group (Puttick *et al.*, 2018) (Figure 1).

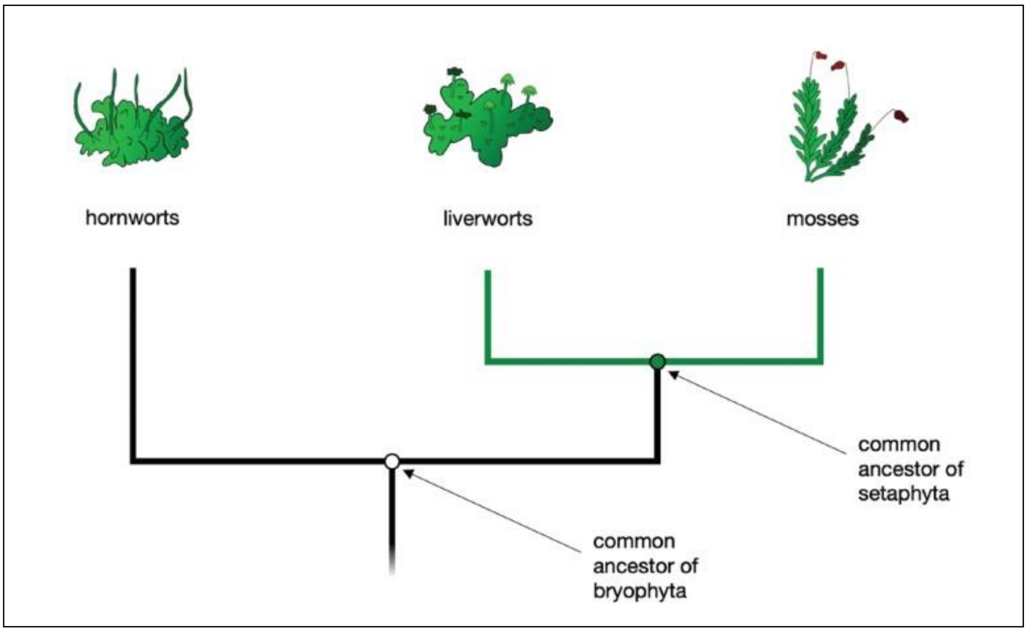

Figure 1. Illustration of the monophyletic bryophytes and the Setaphyta clade of liverworts and mosses (Pfeifer *et al.*, 2022).

Approximately 18,000 to 25,000 species of bryophytes have been identified worldwide (Sabovljević *et al.*, 2022), and this number may increase due to the growing interest in this group in recent years. Also, there are still many unexplored areas where new species may be found.

2.1. Bryophyta (mosses)

This group includes around 14,000 species (Asakawa & Ludwiczuk, 2017; Das *et al.*, 2022; Dziwak *et al.*, 2022) to 15,000 (Bahuguna *et al.*, 2013; Ogwu, 2019) species.

Most mosses can be identified by a strong stem supporting the capsule, although this feature is absent in peat mosses and certain plants found in dry environments. Some mosses may exhibit teeth around the opening of the capsule. The main body of the plant, known as the gametophyte, typically consists of a cylindrical axis with leaves attached directly to it (Vanderpoorten & Goffinet, 2009) (Figure 2).

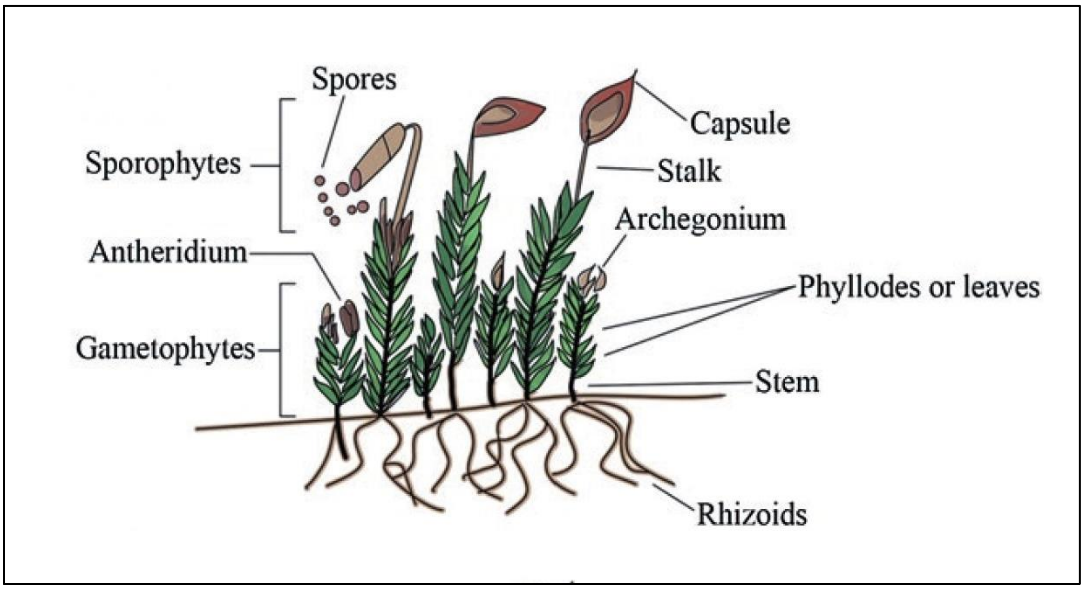

Figure 2. Main structure of a moss (Millán-Chiu *et al.*, 2020).

Based on the branching patterns and location of sexual organs, the phylum Bryophyta (mosses) has traditionally been divided into two major groups (Gradstein *et al.*, 2001; Glime, 2017b) (Figure 3).

2.1.1. The acrocarpous mosses

They have an upright growth habit and produce their sporophytes at the tips of their stems (Gradstein *et al.*, 2001; Shaw *et al.*, 2011; Slack, 2011; Glime, 2017b). They are usuallyunbranched or sparsely branched (Shaw *et al.*, 2011; Glime, 2017b).

2.1.2. The pleurocarpous mosses

They typically grow prostrate and form freely branched mats, producing their sporangia on short, specialized lateral branches or buds (Gradstein *et al.*, 2001; Shaw *et al.*, 2011; Slack, 2011; Glime, 2017b).

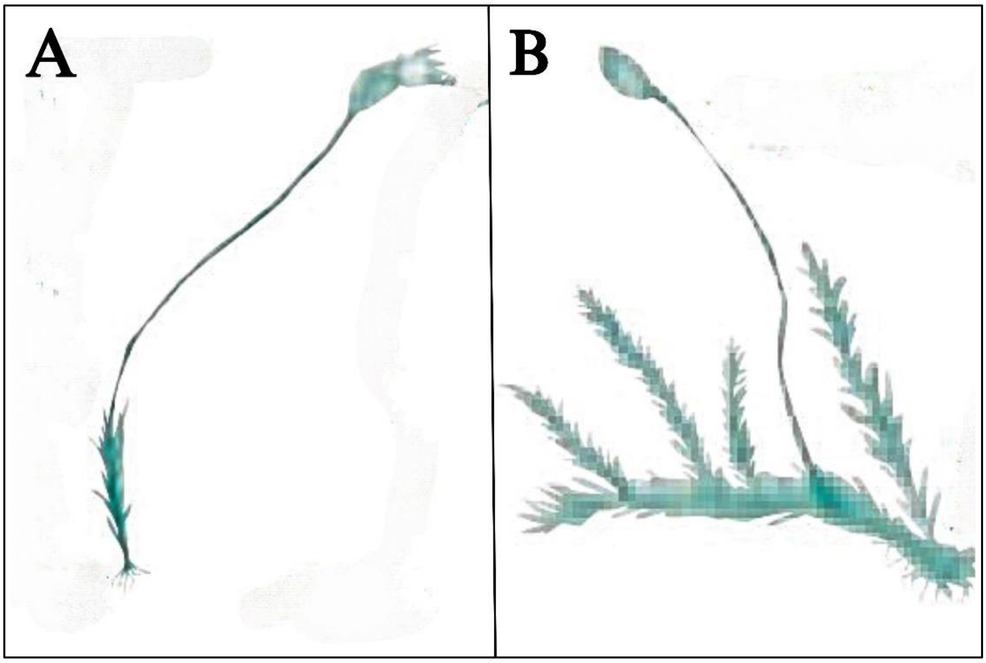

Figure 3. The biotypes of mosses: (A) acrocarpous, (B) pleurocarpous (Coudreuse *et al.*, 2005).

Currently, mosses are classified into eight morphologically distinct classes: Takakiopsida, Sphagnopsida, Andreaeopsida, Andreaeobryopsida, Oedipodiopsida, Polytrichopsida, Tetraphidopsida, and Bryopsida (Goffinet & Buck, 2004).

2.2. Marchantiophyta (liverworts)

The gametophyte of liverworts is either flattened into a thallus with little or no elaborate internal differentiation (Figure 4) or terete and lined with foliar appendages (Vanderpoorten & Goffinet, 2009). Both leafy and thallose liverworts belong to the phylum Marchantiophyta, which is also referred to by various names, such as Hepatophyta, Jungermanniophyta, Hepaticae, and Hepaticopsida. This group comprises approximately 6,000 species (Asakawa *et al.*, 2012; Chandra *et al.*, 2016; Asakawa & Ludwiczuk, 2017; Dziwak *et al.*, 2022) to 9,000 species (Hodgetts *et al.*, 2019).

Liverworts are classified into three classes: Marchantiopsida, Jungermanniopsida, and Haplomitriopsida (Linde *et al.*, 2023).

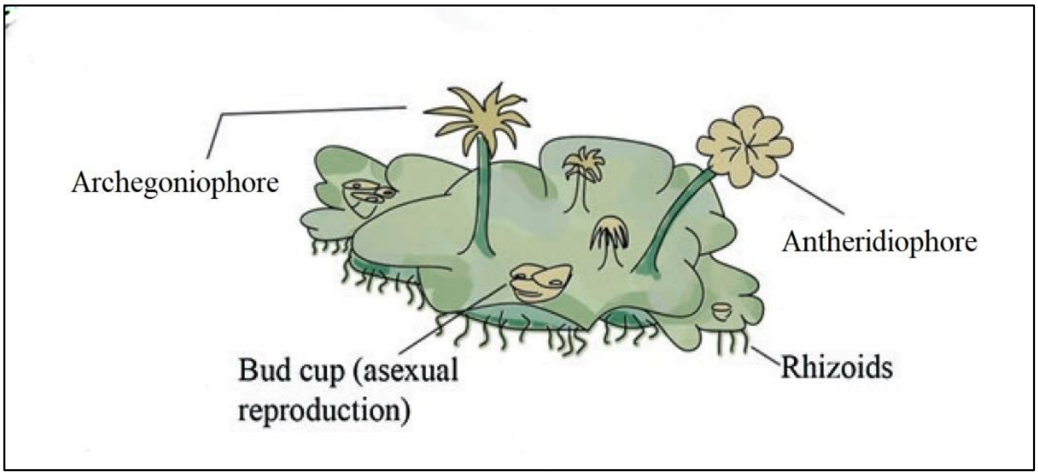

Figure 4. Main structure of a thallose liverwort (Millán-Chiu *et al.*, 2020).

2.3. Anthocerophyta (hornworts)

The hornworts have a thallose gametophyte in which the sex organs are completely embedded in the thallus. The sporophyte, always horn-shaped, mainly, comprises a sporangium that develops from the apex downward to its foot in the thallus (Hallingbäck & Hodgetts, 2000) (Figure 5). They consist of approximately 300 species (Asakawa & Ludwiczuk, 2017; Das *et al.*, 2022; Dziwak *et al.*, 2022) to 1,000 species (Ogwu, 2019).

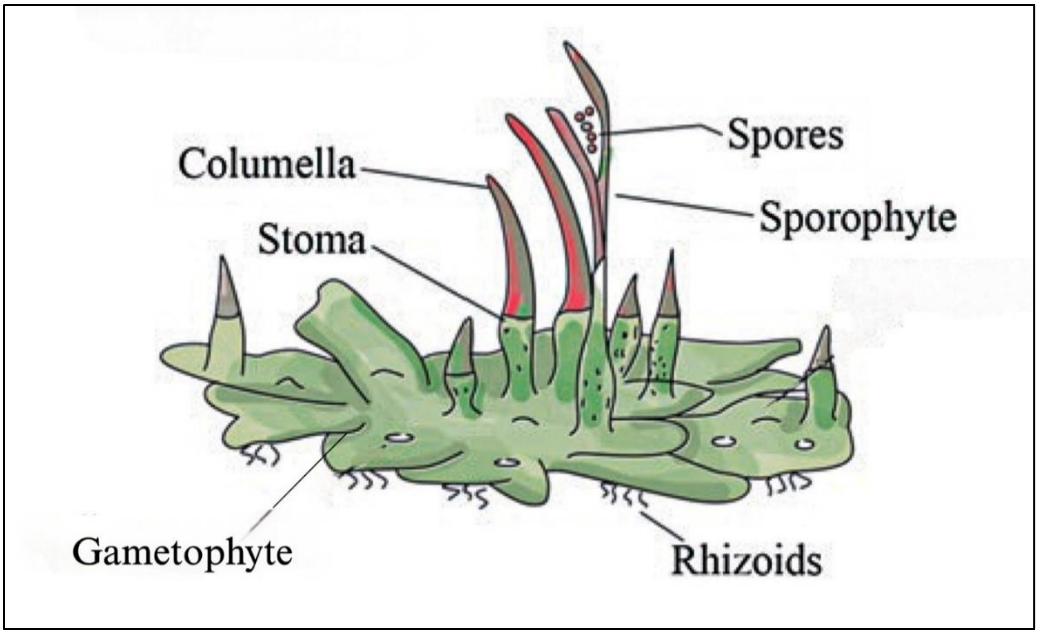

Figure 5. Main structure of a hornwort (Millán-Chiu *et al.*, 2020).

The hornworts are divided into two classes: Anthocerotopsida and Leiosporocerotopsida (Glime, 2017b).

The differences among these three phyla of bryophytes are illustrated in Table 1.

Table 1. Differences between the three phyla of bryophytes (Glime, 2017b; Ogwu, 2019).

Feature	Bryophyta	Marchantiophyta	Anthocerophyta
Protonema	Filamentous, forming many buds	Globose, forming one bud	Globose, forming one bud
Gametophyte	Leafy shoot	Leafy shoot or thallus; either simple or with air chambers	Simple thallus
Growth of sporophyte	Apical	Apical	Grows continuously from a basal meristem
Arrangement and form of leaf-like structures	Spiral, undivided and typically have a midvein (costa)	In three rows; divided into two lobes with no midveins	Not applicable
Branches	Developing from stem epidermis	Developing from leaf initial cells or inner stem cells, rarely stem epiderma	Not applicable
Gemmae	Common on leaves, stems, rhizoid or protonema	Common on leaves	Not applicable
Paraphyses	Usually associated with antheridia and archegonia	Usually lacking but they often have mucilaginous filaments	Not applicable
Special organelles	None or simple, small oil bodies	Oil bodies	Not applicable
Water-conducting cells	Present in both generations	Present in a few thalloid forms	Absent
Rhizoids	Brown and multicellular	Hyaline and one-celled	Hyaline and one-celled
Gametangial position	Apical clusters	Apical clusters (sometimes leaf like) or on the upper surface of the thallus	Sunken in thallus and scattered
Stomates	Present in sporophyte capsule	Absent in both generations	Present in both generations
Seta	Photosynthetic and emergent from the gametophyte early in the development	Hyaline, elongating just prior to spore release	Absent
Capsule	Complex with an operculum, theca, and neck	Undifferentiated, spherical or elongated	Undifferentiated, horn-shaped, growing continuously from a basal meristem

Sterile cells in the capsule	Columella	Spirally thickened elaters	Columella and pseudo-elaters
Calyptra	Ruptures and persist at the apex of seta and capsule. It influences the capsule shape	Ruptures and persist at the apex of seta and capsule. It influences the capsule shape	Not applicable

3. Generalities about bryophytes

Bryophytes are generally small plants, with most species measuring less than 5 cm in length. However, there are some exceptions, such as the mosses *Polytrichum* and *Dawsonia*, which can grow up to a length of 70 cm (Zechmeister *et al.*, 2003). Additionally, certain *Fontinalis* species can even attain lengths of up to 2 m (Glime, 2017b). The small size of bryophytes is due to their lack of developed conductive tissues and lignin (Hébant, 1977); however, according to Glime (2017b), the presence or absence of lignin in bryophytes is still controversial.

Bryophytes do not produce seeds and flowers (Hallingbäck & Hodgetts, 2000); thus, they are classified as cryptogams (Zechmeister *et al.*, 2003; Chandra *et al.*, 2016; Ogwu, 2019). They lack roots; instead, they have filamentous root-like structures called rhizoids, which primarily serve the purpose of anchoring the plant to its substrate rather than functioning as the main means of nutrient and water absorption (Rice, 2009). Therefore, bryophytes absorb water and nutrients through the gametophyte surface (Hallingbäck & Hodgetts, 2000; Slack, 2011; Budke *et al.*, 2018). Consequently, bryophytes have developed a poikilohydric strategy, depending on their surroundings for moisture and nutrients (Proctor & Tuba, 2002). This characteristic categorizes them as poikilohydric plants, meaning they don't have the ability to regulate water content independently of their environment (Mishler, 2001; Ah-peng, 2007; Pescott *et al.*, 2015; Ogwu, 2019; Spangler, 2021). They can dry out in the event of a moisture shortage, entering a state of dormancy or suspension of metabolic activity. They resume their physiological activity when rewetted (Gignac, 2001; Proctor & Tuba, 2002; Turetsky, 2003; Vanderpoorten & Goffinet, 2009; Jägerbrand *et al.*, 2011; He *et al.*, 2016; Hodgetts *et al.*, 2019; Ogwu, 2019); this is why bryophytes are considered "resurrection plants" (Gaff & Oliver, 2013).

Bryophytes possess chlorophyll as their primary photosynthetic pigment and depend on starch as their primary food reserve (Gradstein *et al.*, 2001; Streiff, 2005).

4. Distribution and habitat of bryophytes

Bryophytes tend to have broader distribution ranges than flowering plants, often spanning more than one continent, with some species being widespread across all continents, referred to as "cosmopolitan" (Vanderpoorten & Goffinet, 2009; Medina *et al.*, 2011). As indicated by Frahm (2012), approximately 60% of all bryophyte families and some genera have a worldwide distribution, suggesting a high phylogenetic age for this plant group. Moreover, bryophytes inhabit a very wide range of habitats (Crandall-Stotler & Bartholomew-Began, 2007; Vanderpoorten & Goffinet, 2009; Slack, 2011; Budke *et al.*, 2018), from coastal Antarctica to the tundra of the Northern Hemisphere and from the Australian deserts to the Amazon rainforests (Hallingbäck & Hodgetts, 2000), excluding the sea (Vanderpoorten & Goffinet, 2009; Hodgetts *et al.*, 2019).

Bryophytes are able to thrive in habitats that are difficult for vascular plants to colonize, including hard substrates like rocks and tree bark, as well as deep organic soils (Rice, 2009; Slack, 2011). They grow in stressful conditions such as cold, drought, shade and in nutrient-poor environment (Bahuguna *et al.*, 2013). Bryophytes are successful in various climates due to their exceptional and efficient water relation system, which enables them to survive. Their poikilohydric system allows them to grow during periods when water is available and to suspend their metabolism when water is lacking (Gignac, 2001; Proctor, 2011).

5. Reproduction of bryophytes

Bryophytes primarily spread through spores, which are forcefully released from the capsule with the help of hygroscopic movements of elaters and pseudo-elaters in liverworts and hornworts (Vanderpoorten & Goffinet, 2009), as well as the peristome in mosses (Johansson *et al.*, 2016). However, spore dispersal is not a viable option for a number of species that do not produce sporophytes (Patiño & Vanderpoorten, 2018). Approximately 4% of sporophyte species worldwide are still unknown (Frey & Kürschner, 2011), and up to 50% are dioicous (Figure 6), which can greatly limit sexual reproduction. In some cases, an entire continent may contain only male or female plants, leading to a complete absence of sexual reproduction (Vanderpoorten & Goffinet, 2009). Asexual reproduction *s. l.* and the formation of asexual diaspores are therefore remarkable features that are widespread in bryophytes (Vanderpoorten & Goffinet, 2009; Frey & Kürschner, 2011).

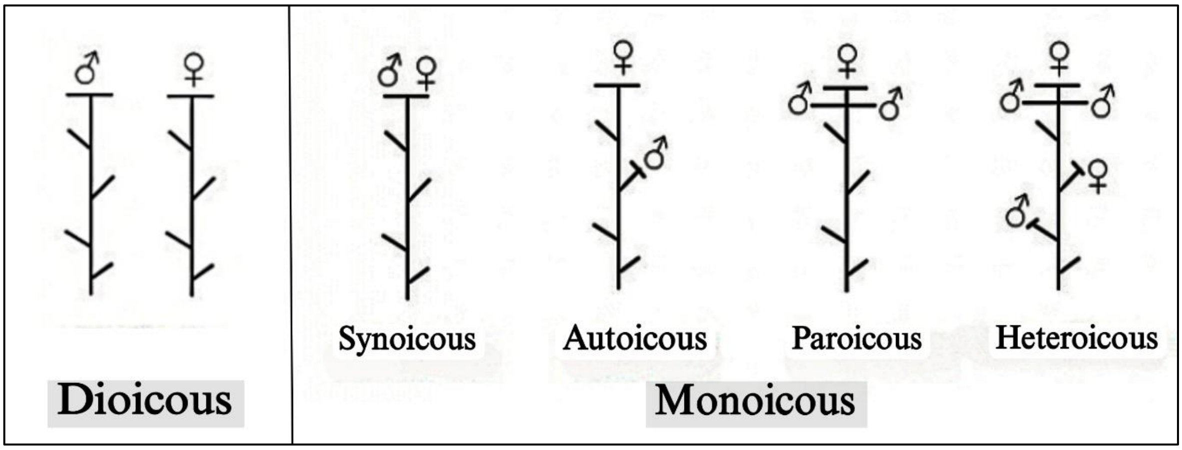

Figure 6. Distribution of gametangia (Chavoutier, 2017).

5.1. Sexual reproduction

In bryophytes, the process of sexual reproduction follows a consistent pattern: immobile female gametes (eggs) are produced in structures called archegonia, while mobile male gametes (sperm cells with flagella, or antherozoids) are produced in antheridia (Budke *et al.*, 2018). This type of reproduction is highly dependent on the availability of water, as the antherozoids must swim from the antheridia to the archegonia in order to fuse with the egg (Hallingbäck & Hodgetts, 2000; Shaw & Renzaglia, 2004; Slack, 2011; Rosenstiel *et al.*, 2012; Budke *et al.*, 2018; Ogwu, 2019) (Figures 7, 8, and 9).

Sexual reproduction increases the potential for long-distance dispersal and may enhance the chances of population survival during periods of environmental change by recombining genetic variation (Boquete *et al.*, 2022).

5.2. Asexual reproduction (vegetative reproduction)

In bryophytes, asexual reproduction often plays more important role than sexual reproduction (During, 1979), and it is not as significant in any other plant group as it is in bryophytes (Frey & Kürschner, 2011).

Bryophytes have evolved many types of asexual reproduction and dispersal (Slack, 2011). According to Frey & Kürschner (2011), there are three types of asexual reproduction:

1- Asexual reproduction s. s. by regeneration from ± specialized caducous organs (leaves, leaf apices, shoots, branches, bulbils) and by the production of specialized propagules (gemmae, protonemal brood cells, tubers);
2- Fragmentation of gametophytes or parts of gametophytes (leaves, shoots, thalli) into

unspecialized (indeterminate) fragments;

3- Clonal reproduction occurs through various processes such as protonema decay, disintegration of modules, and the formation of ramets (dividuals or "daughter plants").

Asexual reproduction promotes population expansion at relatively small spatial scales and may help maintain well-adapted phenotypes in environmentally stable habitats (Boquete *et al.*, 2022). Some monoicous species may utilize asexual reproduction as a strategy for rapid expansion after their initial establishment (Vanderpoorten & Goffinet, 2009).

6. Life cycle of bryophytes

The life cycle of bryophytes is characterized by an alternation of generations, where both haploid and diploid stages are present. However, unlike most land plants, the dominant stage in bryophytes is the haploid gametophyte (Slack, 2011).

The life cycle of bryophytes begins with the germination of haploid spores, which develop into green protonema—a thread-like structure from which the gametophyte develops. The gametophyte produces either a structure with a stem and leaves (as in mosses and leafy liverworts) or a structure with no differentiation, usually a flat plate of tissue called a thallus (as in thallose liverworts and hornworts). The gametophyte produces male and female sex organs, either on the same plant (bisexual) or on separate plants (unisexual). Each archegonium contains a single egg, which can be fertilized by a sperm cell, resulting in a diploid zygote. The zygote develops into a sporophyte, which remains attached to the gametophyte. At maturity, the sporophyte undergoes meiosis to produce haploid spores, which are then dispersed into the environment. These spores germinate to produce the gametophyte, and the cycle begins all over again (Gradstein *et al.*, 2001; Zechmeister *et al.*, 2003; Crandall-Stotler & Bartholomew-Began, 2007; Vanderpoorten & Goffinet, 2009; Medina *et al.*, 2011; Haig, 2016; Hodgetts *et al.*, 2019; Ogwu, 2019).

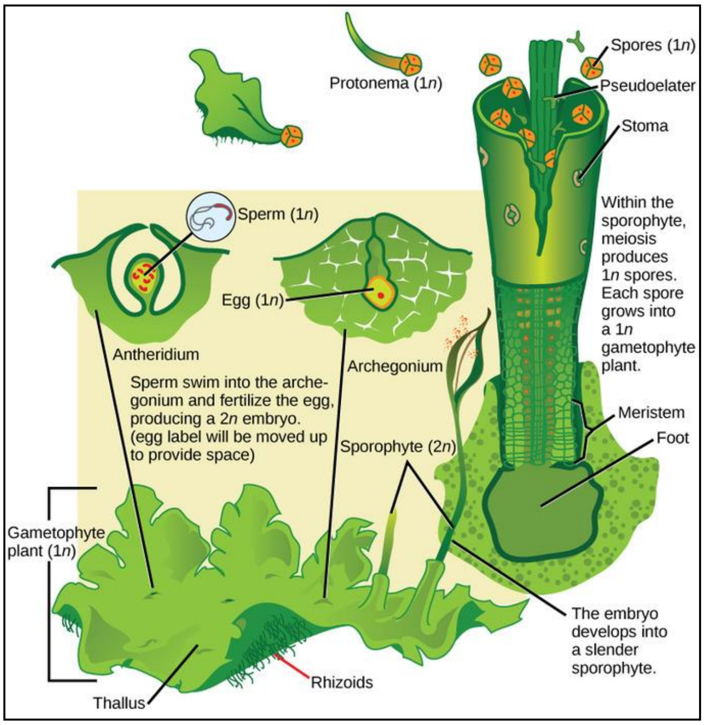

Figure 7. The life cycle of hornworts (Biology Dictionary, n.d.).

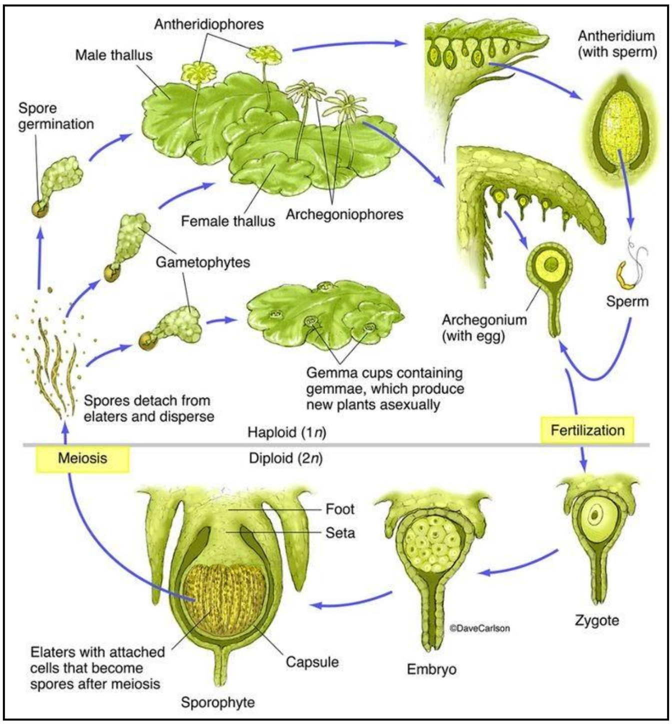

Figure 8. The life cycle of liverworts (Carlson, n.d.).

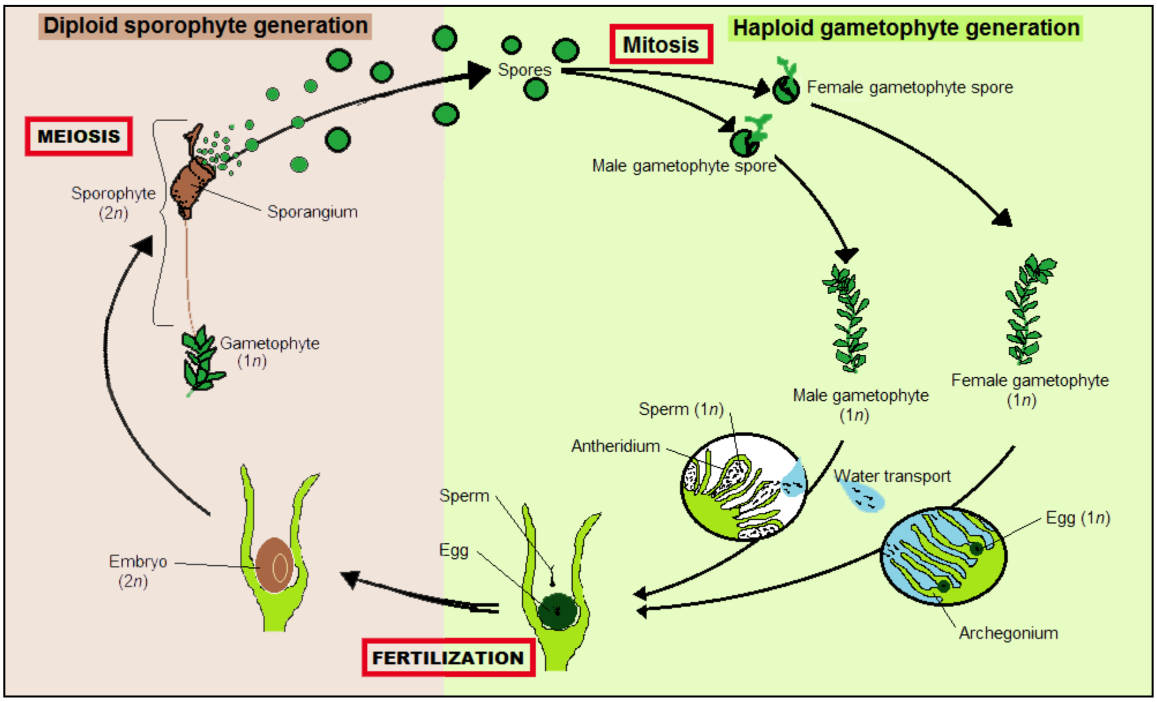

Figure 9. The life cycle of mosses (Hodgetts *et al.*, 2019).

7. The importance of bryophytes

Although bryophytes may be small and inconspicuous compared to many vascular species, they are equally significant in their ecosystems (Spangler, 2021).

7.1. Ecological importance

The ubiquitous presence of bryophytes in almost all terrestrial ecosystems prompts inquiries into their ecological importance within these environments (Vanderpoorten & Goffinet, 2009).

7.1.1. Colonization, soil stabilization, and erosion prevention

Bryophytes are often referred to as pioneers due to their ability to colonize and thrive in various challenging environments (Hallingbäck & Hodgetts, 2000; Gradstein *et al.*, 2001; Glime, 2007; Bahuguna *et al.*, 2013; Hodgetts *et al.*, 2019). They play a crucial role in stabilizing soil against wind and water erosion by binding erodible soil particles into less erodible soil aggregates. Additionally, they can also enhance soil infiltrability, improve the interception of raindrops, and influence the redistribution of runoff across the landscape (Eldridge, 1998). Some mosses help prevent soil erosion by forming a mat-like structure that binds soil particles with their rhizoids, which reduces water loss (Das *et al.*, 2022).

7.1.2. Water retention

Bryophytes have a high water-retention capacity due to their structure, which allows them to act like sponges, taking up water rapidly and releasing it slowly into the surrounding environment (Hallingbäck & Hodgetts, 2000; Hodgetts *et al.*, 2019). They tend to be most abundant in areas with high atmospheric humidity and low evaporation rates (Hallingbäck & Hodgetts, 2000).

7.1.3. Nutrient cycling and nitrogen fixation

Bryophytes are a significant contributor to the total biomass in various ecosystems, and as a result, they play a crucial role in the cycling of carbon and nutrients (Vanderpoorten & Goffinet, 2009; Kumari *et al.*, 2022). Their capacity to bind nutrients on their cell walls allows them to absorb these nutrients when they become hydrated (Glime, 2017d).

Bryophytes, particularly those belonging to the phylum Anthocerotophyta (Carella & Schornack, 2018), sometimes form symbiotic relationships with cyanobacteria that can fix atmospheric nitrogen. This means that bryophytes can work together with these bacteria to convert nitrogen from the air into a form that can be used by plants for growth (Glime, 2007; Vanderpoorten & Goffinet, 2009). Additionally, bryophytes form mutualistic associations with various fungi, particularly those from the Glomeromycotina, Ascomycota, and Basidiomycota phyla. These fungal partners play a crucial role in the nitrogen nutrition of bryophytes (Pressel *et al.*, 2021).

7.1.4. Habitat and food provision

Bryophyte communities play a crucial role in supporting a wide range of organisms, including insects, millipedes, and earthworms. Additionally, various arthropods such as Acarinae, Collembola, and Tardigrades depend on mosses and liverworts for habitat and as a source of food (Hallingbäck & Hodgetts, 2000). Bryophytes also provide food, shelter, and nesting material for birds and small mammals (Hallingbäck & Hodgetts, 2000; Glime, 2007; Hodgetts *et al.*, 2019), and act as protective habitats for amphibians (Hallingbäck & Hodgetts, 2000).

7.1.5. Bryophytes as indicators

Bryophytes are highly sensitive to environmental conditions due to their lack of a well-developed cuticle or epidermis, which results in their ability to absorb water and nutrients through their entire surface. This makes them an excellent model organism for studying the effects of environmental variability and pollution on community composition (Kumari *et al.*, 2022).

7.1.5.1. Indicators of natural environmental conditions

Liverworts and mosses have been found to be good indicators of environmental conditions. Some aquatic mosses can reveal the calcium and nutrient levels in water, while specific bryophytes thrive within a limited pH range, serving as indicators of soil pH (Saxena & Harinder, 2004). Certain bryophytes have a close association with particular mineral or metal deposits, such as copper ore. Additionally, bryophytes can serve as indicators of ecological continuity (Hallingbäck & Hodgetts, 2000).

7.1.5.2. Indicators of pollution

Bryophytes serve as bioindicators for both air and water pollution, and they also accumulate heavy metals. In disturbed environmental conditions, such as air pollution, communities of bryophytes can decrease in size over time (Bahuguna *et al.*, 2013). The use of certain types of mosses for standard transplantation has been found to be an effective method for monitoring the intensity and trends of air pollution in polluted areas (Saxena & Harinder, 2004).

7.1.6. Peat formation

Peat is a compacted and accumulated mixture of the remains of both vascular and non-vascular plants, primarily bryophytes. *Sphagnum*, a type of moss, is often the most significant plant in bogs and in the formation of peat (Hallingbäck & Hodgetts, 2000).

7.2. Economic importance

Bryophytes are economically significant primarily due to their use in fuel production and horticulture (Hallingbäck & Hodgetts, 2000; Vanderpoorten & Goffinet, 2009). Peat, which is derived from bryophytes, has been utilized for commercial purposes for over 150 years as both a fuel source and a soil additive (Hallingbäck & Hodgetts, 2000).

7.2.1. Bryophytes as fuel

Almost 50% of the global annual peat production is dedicated to fuel applications, highlighting the widespread utilization of peat resources internationally (Glime, 2007; Vanderpoorten & Goffinet, 2009). Peat proves to be a suitable resource for generating low and intermediate BTU gas, as well as facilitating the production of hydrogen, ethylene, natural gas, methanol, and Fischer-Tropsch gasoline. Peat moss is particularly well-suited for the production of methane, and peat is expected to become an important source of fuel for heat, methane, or electricity production in the future (Saxena & Harinder, 2004). According to Glime (2007), mosses have become significant sources of fuel in northern Europe, particularly in countries such as Finland, Germany, Ireland, Poland, Russia, and Sweden.

7.2.2. Horticultural Uses

Bryophytes have been used in horticulture for a long time as soil additives, ornamental materials, and in Japanese gardens due to their high water-holding capacity and air permeability (Saxena & Harinder, 2004).

7.3. Medicinal importance

Bryophytes have been used for various medicinal purposes. They are a rich source of bioactive compounds and secondary metabolites, making them valuable in traditional medicine (Das *et al.*, 2022; Dziwak *et al.*, 2022).

In the past, indigenous people from various regions, such as Africa, Europe, America, Australia, China, Taiwan, Pakistan, and different parts of India, used a variety of bryophytes for medicinal purposes. These bryophytes were utilized in the treatment of various conditions, including skin disorders, hepatic disorders, cardiovascular diseases, and wound healing (Das *et al.*, 2022). Furthermore, they have been found to have beneficial effects on various smooth muscles in the body, including those in the stomach, intestines, bladder, bronchioles, and uterus. Additionally, they have been associated with weight loss (Motti *et al.*, 2023).

Several liverworts have also been used as medicinal plants in China to treat a variety of ailments, such as cuts, burns, bruises, pulmonary tuberculosis, neurasthenia, fractures, convulsions, and uropathy (Asakawa, 2008). In addition to their traditional medicinal uses, certain bryophytes have demonstrated potential against various cancer cell lines, and this aspect of bryophytes should be a priority for future research (Chandra *et al.*, 2016; Ogwu, 2019).

Chapter II

Description of the study area

In order to address our subject properly, it is necessary to have a comprehensive understanding of the geographical, pedological, hydrographic, and climatic aspects of the study area, which includes the Setif 1 University - Ferhat ABBAS (El bez) and Megriss Mountain.

According to Chermat & Ouksel (2021), there are two main zones that distinguish the relief of the Setif region:

- The mountainous zone covers almost the entire north part of the Setif province, extending for about 100 km. It includes the Babors Mountains located in the eastern part of the Tell Atlas and is followed to the east by the Djurdjura range, which has a peak elevation of 2,004 m;
- The High Plains of Setif zone corresponds to the central and southern parts of the Setif region, characterized by isolated mountain ranges and the presence of Chotts and Sebkhas.

We have selected two distinct sites within the High Plains of Setif zone for our study (Figure 10): the Megriss Mountain area, representing a peri-urban ecosystem situated in the northern part of the High Plains of Setif, and Setif 1 University - Ferhat ABBAS, representing an urban ecosystem located in the central part of the same region. These sites were chosen based on various factors, including their accessibility and differences in abiotic and biotic parameters.

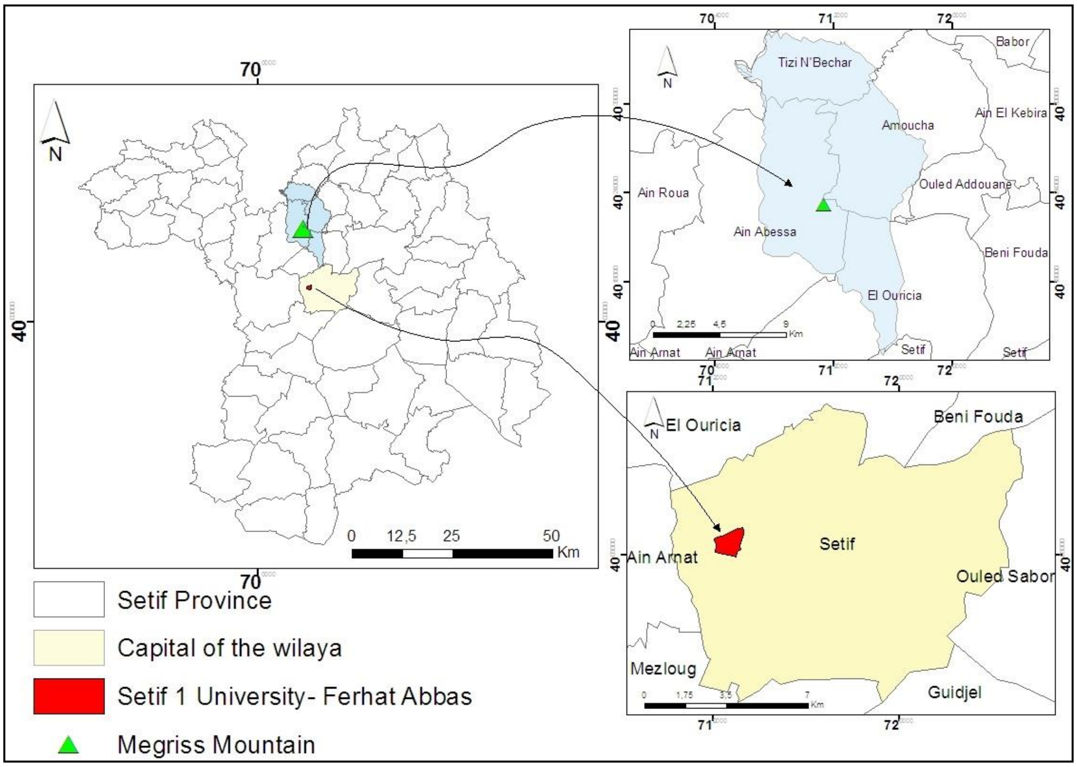

Figure 10. Geographic location of the two study areas: Megriss Mountain and Setif 1 University - Ferhat ABBAS (Mazari, 2024).

1. The first study area: Megriss Mountain

1.1. Geographical location

Megriss Mountain is situated in the northern region of the High Plains of Setif, with a latitude of 36°19'33.74" North and a longitude of 5°20'59.03" East (Figure 11), reaching an elevation of 1,737 m. It is part of a mountainous area that serves as the initial foothills before the Babors Mountain range, which is approximately 20 km to the north.

Megriss Mountain is bordered by the following municipalities:

- Tizi N'bechar to the north;
- Amoucha to the northeast;
- El Ouricia to the southeast;
- Aïn Abessa to the southwest.

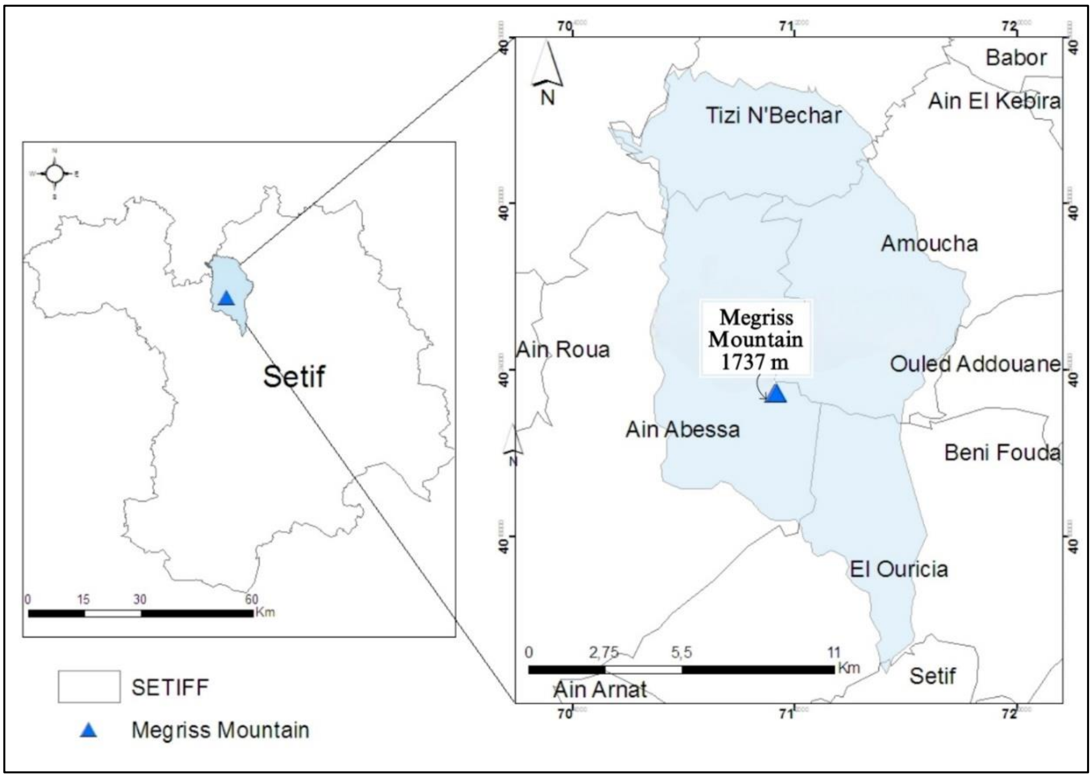

Figure 11. Geographical location of Megriss Mountain (Mazari, 2024).

1.2. Geology

The analysis of the excerpt from the 1:50,000 geological map of Algeria (Figure 12) and the reading of the explanatory notes of the 1:50,000 geological map of Setif by Vila (1976) and of Kherrata by Vila & Obert (1977) reveal that Megriss Mountain is composed of three geological formations.

1.2.1. The Numidian nappe

It displays its classic aspects from the tabular and slightly fractured mass of Megriss Mountain to the truncated formations at the foot of Chouf Karoun (to the southwest). The tabular mass of Megriss Mountain is composed of coarse sandstone with clay intercalations.

1.2.2. The Tellian formations

1- Ultra-Tellian nappe: this formation is found only in one section trapped under the base contact of the Numidian to the northeast of Megriss Mountain. It is composed of marls from three series: the Lower Oligocene (clayey gray drusy marls), the Upper Lutetian and Priabonian (homogeneous series of black lamellar marls), and the Upper Senonian (gray lamellar marls and light-patinated micrites, gray-flamed on fracture);

2- Upper nappe with Eocene material: this nappe is present on the southwestern slope of Megriss Mountain. It consists of black, brown, or gray marls with yellow layers and nodules.

1.2.3. The Quaternary and Miocene formations that are poorly or not tectonized

1- The Quaternary is characterized by three types of scree: scree with a marly matrix (more recent and active, located on the periphery of Megriss Mountain); mass scree (found on the periphery of Megriss Mountain, visible on the northern slope of this massif); and ancient scree (located on the northern slope, consisting of old solifluction flows or sheet solifluction);

2- The continental Mio-Pliocene consists of fluvio-lacustrine deposits that typically exhibit a strong reddish coloration.

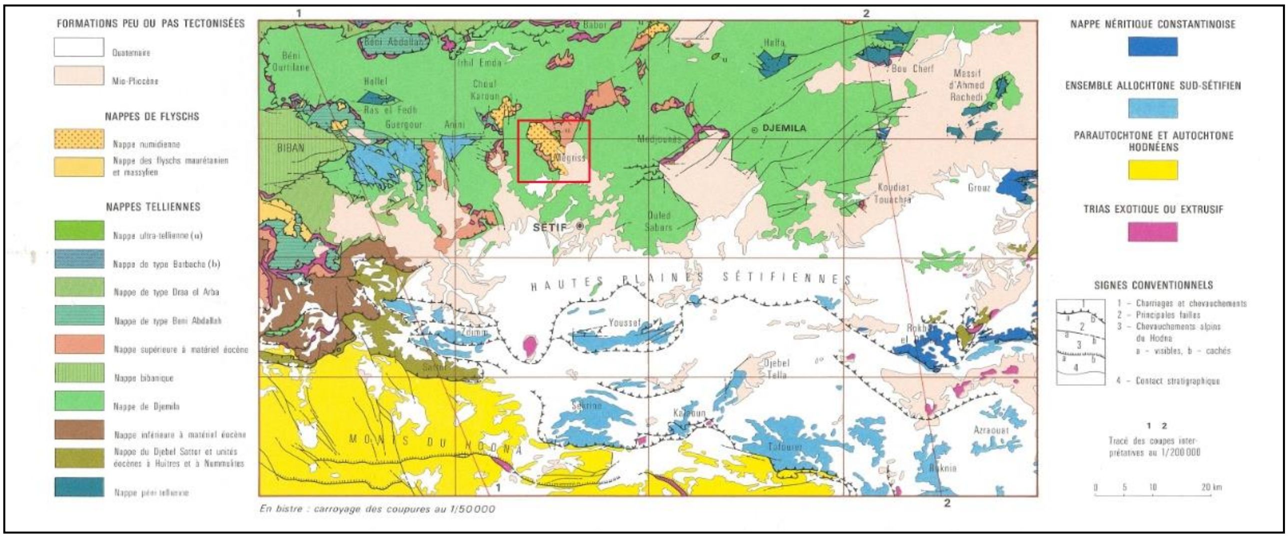

Figure 12. Geological map at a scale of 1:50,000, extracted from the geological map of Algeria at a scale of 1:200,000.

1.3. Pedology

According to Lahmar *et al.* (1993) in Boulaacheb (2009), Megriss Mountain features two primary soil types: vertisols and leached soils.

1.3.1. Vertisols

They are a type of soil known for their high clay content and characteristic ability to shrink and swell significantly with changes in moisture. Vertisols form on heavy geological materials such as marls and clays, or on the products of their erosion. They are found in flat or depressed areas as well as on slopes. The vertisols developed on the clayey materials of the foothills of Megriss Mountain are either not carbonated at all or only to a small extent.

1.3.2. Leached soils

These soils are limited to the sandstone located on the heights. They are evolved soils, characterized by a thin to moderately thick sandy leached horizon that is neutral and massive, resting on a slightly acidic clay accumulation horizon, which locally showing signs of hydromorphism. Gaucher (1958) in Boulaacheb (2009) suggests that when the influence of the parent rock outweighs that of the climate and vegetation, the soils are categorized as azonal. Therefore, the soils at Megriss Mountain are considered azonal due to the prominent influence of the visible parent rock, which extends over the entire massif.

1.4. Hydrology

Megriss Mountain has a significant amount of water resources, as evidenced by its hydrographic network (Figure 13). The area is traversed by several Oueds, with the most important ones being the Oued El Bordj to the north and the Oued El Hader to the west. The water regime varies throughout the year, depending on rainfall. The numerous outcrops of marly-limestone rock allow little opportunity for water to infiltrate deeply. Water circulation occurs on the surface, increasing runoff. However, a small amount of water does infiltrate the sandy soil. The runoff is collected either by the many temporary ponds located below the cliffs or by small streams. The secondary network is quite dense, especially in spring, as water from snowmelt feeds numerous small springs, ponds, and temporary streams (Boulaacheb, 2009).

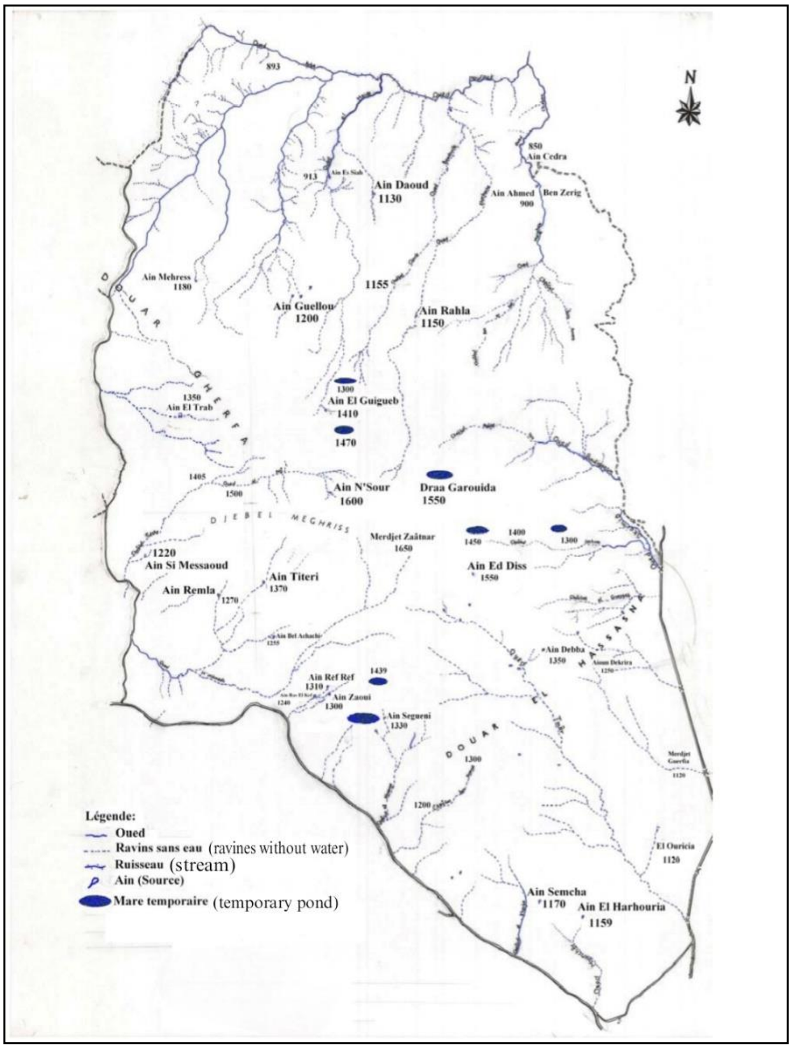

Figure 13. Hydrological network map of Megriss Mountain at a scale of 1:25,000 (Boulaacheb, 2009).

1.5. Vegetation

Megriss Mountain is characterized by the absence of a natural tree formation, with only a limited presence of tree specimens belonging to three families: *Fraxinus angustifolia* Vahl. (Oleaceae), *Populus alba* L., *Salix alba* L. (Salicaceae), as well as *Ulmus minor* Mill. (Ulmaceae). The predominant vegetation formations consist mainly of grasslands, meadows, and shrublands (matorral) (Boulaacheb *et al.*, 2005; Boulaacheb, 2009).

According to (Boulaacheb, 2009), the vegetation of Megriss Mountain consists of:

1.5.1. Natural formations

1.5.1.1. Rupicolous vegetation (Rocky outcrop vegetation)

These formations develop on cliffs, on the highest windy ridges. The most common species includes *Alyssum alpestre* L. and *Teucrium chamaedrys* L. These open herbaceous formations are dominated by hemicryptophytes. The woody species consist of shrubs (*Crataegus laevigata* (Poir.) DC., *Daphne gnidium* L., *Rosa canina* L.), vines (*Lonicera implexa* Aiton), and subshrubs (*Prunus prostrata* Labill., *Santolina rosmarinifolia* L., *Thymus munbyanus* subsp. *ciliatus* (Desf.) Greuter & Burdet) (Boulaacheb, 2009).

1.5.1.2. Thermophilic vegetation formations

They are associated with the warmest parts of the massif, such as cliffs. They predominate on the meridional slope, between 1,350 m and 1,500 m. These highly degraded plant formations, which are of limited extent, encompass a diverse and significant floristic assemblage. Within this type of formation, there are *Quercus ilex* L. matorrals and *Rhamnus alaternus* L. matorrals, enriched with Diss (*Ampelodesmos mauritanicus* (Poir.) T.Durand & Schinz) and calicotome (*Calicotome spinosa* (L.) Link), along with numerous everlasting plants, thyme, and yellow-flowered rock roses (*Helianthemum nummularium* (L.) Mill.) (Boulaacheb, 2009).

1.5.2. Shrublands

1.5.2.1. Shrublands with *Rhamnus alaternus*

This is the most abundant type of shrubland. It is dominated by Diss (*A. mauritanicus*) and

Calicotome (*C. spinosa*). This shrubland is characterized by a rich floristic assemblage. The shrub layer includes *C. spinosa*, *Pyrus communis* L., and *R. alaternus*. The herbaceous layer mainly consists of hemicryptophytes, along with geophytes, therophytes, and chamaephytes (Boulaacheb, 2009).

1.5.2.2. Shrublands with *Quercus ilex* L.

It concerns formations of evergreen oak shrubs which cover very small area and exhibit variations in density and height. Some stands are dense, with evergreen oak trees reaching heights of up to 5 m, while others are sparse and low (1 to 1.5 m tall) (Boulaacheb, 2009).

1.5.3. Grasslands

1.5.3.1. Grasslands with *Fumana thymifolia* (L.) Webb and *Santolina rosmarinifolia* L.

They are found at an elevation exceeding 1,640 m. Their physiognomy is characterized by the yellow flowers of *S. rosmarinifolia*. The shrub layer is sparse, consisting of a few species: *Clematis flammula* L., *C. laevigata*, *D. gnidium*, *L. implexa*, *R. canina*. The abundance of asphodel reflects the intensity of grazing, which is very active in these formations (Boulaacheb, 2009).

1.5.3.2. Grasslands with *Lagurus ovatus* L. and *Filago germanica* L.

These grasslands, with variable cover, consist mainly of therophytes and are typically found in more or less rugged areas. They are characterized by the dominance of specific plant species such as *Aegilops triuncialis* L., *A. ventricose* Tausch, *Anthemis pedunculata* Desf., *Asphodelus gracilis* Braun-Blanq. & Maire, *Dactylis glomerata* L., *Galium tunetanum* Lam., *Linum usitatissimum* L., *Rumex bucephalophorus* L., etc. The prevalence of asphodel in these grasslands indicates overgrazing, similar to previous formations (Boulaacheb, 2009).

1.5.3.3. Grasslands with *Trifolium campestre* Schreb. and *Linum strictum* L.

These mesoxerophilic grasslands are structured around species such as *Centaurium erythraea* Rafn, *Filago pyramidata* L., *L. strictum*, *Paronychia argentea* Lam., *Plantago serraria* L., *Taeniatherum caput-medusae* (L.) Nevski, *Trifolium campestre*, *T. ligusticum* Balb.

ex Loisel., *T. stellatum* L., etc. They exhibit different facies. On rocky soils, *L. strictum* tends to dominate, while on more or less hydromorphic soils, the facies with *T. campestre* dominates (Boulaacheb, 2009).

1.5.4. Meso-hygrophytic vegetation

1.5.4.1. Meadows

1.5.4.1.1. Meadows with *Lolium perenne* L. and *Cynosurus cristatus* L.

These mesophilic meadows, characterized by a diverse yet sparse flora (such as *Bellis perennis* L., *C. cristatus, D. glomerata, L. perenne, Lotus corniculatus* L., and *Trifolium repens* L.), are located on the southern slope between 1,350 m and 1,700 m in elevation. They are utilized for grazing. Some species typical of Mediterranean wet meadows are observed in these formations, including *Dittrichia viscosa* (L.) Greuter, *Hypericum tomentosum* L., *Potentilla reptans* L., and *Prunella vulgaris* L. On the other hand, other species are characteristic of more or less inundated meadows (*Juncus effusus* L. and *J. inflexus* L.) and wet pastures (*Hypericum tetrapterum* Fr., *Rumex crispus* L., and *Trifolium fragiferum* L.) (Boulaacheb, 2009).

1.5.4.1.2. Meadows with *Alisma plantago-aquatica* L. subsp. *plantago-aquatica* and *Helosciadium nodiflorum* (L.) W.D.J. Koch

These meadows thrive within an elevation range of 1,450 m to 1,665 m. They are characterized by the presence and abundance of the species *H. nodiflorum* (Boulaacheb, 2009).

1.5.4.2. Small sedge marshes

They are found in temporary ponds. Two types of small sedge marshes can be observed on Megriss Mountain:

1- Closed meso-eutrophic small-sedge marshes, characterized by high water levels and prolonged periods of inundation, contain specific plant species like *A. plantago-aquatica* subsp. *plantago-aquatica*, *Alopecurus bulbosus* Gouan, *Eleocharis palustris* (L.) Roem. & Schult., *Galium palustre* L., *Ranunculus aquatilis* L., *R. lateriflorus* DC., *R. ophioglossifolius* Vill., and *Sparganium erectum* L.;
2- Open meso-eutrophic small-sedge marshes, which resemble open flooded meadows grazed by herds due to their rich grass content, feature plants such as *Anacamptis*

palustris (Jacq.) R.M.Bateman, Pridgeon & M.W.Chase, *Cerastium atlanticum* Durieu, *Cyperus esculentus* L., *Juncus bufonius* L., *J. heterophyllus* Dufour, *Mentha suaveolens* Ehrh**.**, *Ranunculus macrophyllus* Desf., and *R. sardous* Crantz (Boulaacheb, 2009).

1.5.5. Other types of vegetation

The vegetation formation indicative of a colder climate during the Quaternary period, such as white or pubescent oak, is becoming increasingly rare and is now restricted to the coldest winter zones with thick soil. In these areas, we find accompanying species such as sorb trees and shadbush on Megriss Mountain (Boulaacheb, 2009).

1.5.6. Reforestation

This refers to reforestation carried out three decades ago in grasslands and meadows using *Cedrus atlantica* (Endl.) Carrière (Boulaacheb, 2009). This formation is characterized by a more humid atmosphere compared to other locations within Megriss Mountain. Additionally, the soils in these forests are notably rich in humus.

2. The second study area: Setif 1 University - Ferhat ABBAS

2.1. Geographical location

The Setif 1 University - Ferhat ABBAS is situated in the central region of the High Plains of Setif, specifically in the western part of Setif city, at a latitude of 36°11'48.0" North and a longitude of 5°21'41.9" East (Figure 14). It is bordered by:

- The Barchi Abid railway to the north;
- The Barchi Abid railway and the Western Bypass Road of Setif to the west;
- The Setif-Bordj Bou Arreridj expressway to the south;
- The Oucissa Laïd railway and Oued Boussellam to the east.

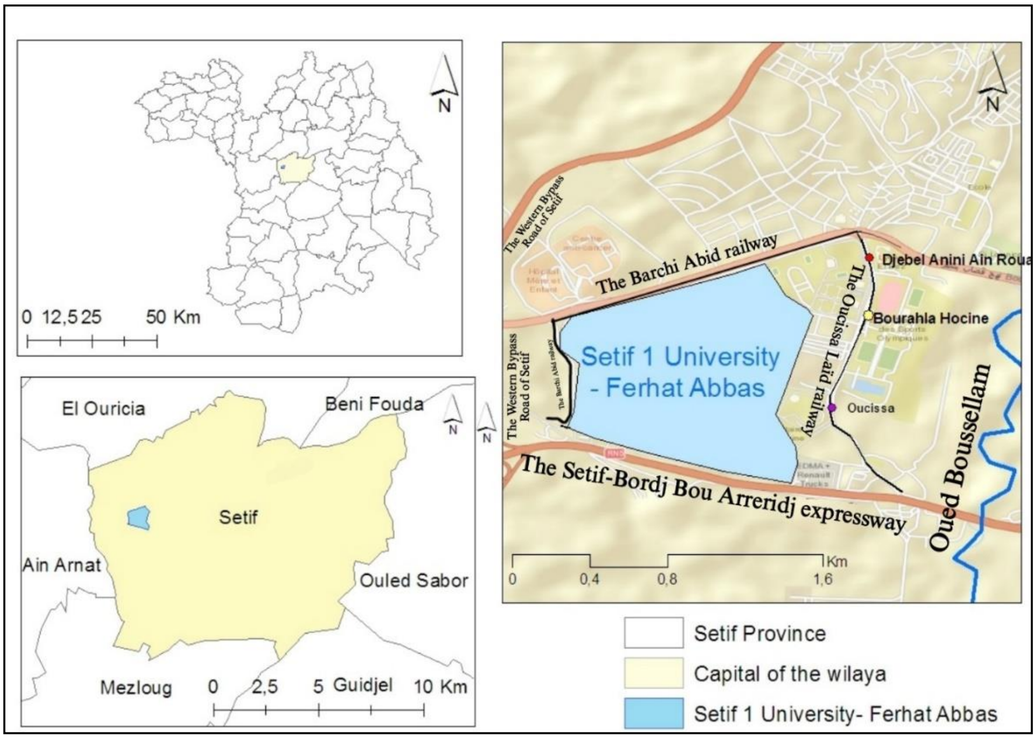

Figure 14. Geographical location of Setif 1 University - Ferhat ABBAS (Mazari, 2024).

2.2. Geology

The examination of the excerpt from the 1:50,000 geological map of Algeria mentioned above (Figure 12), along with the review of the explanatory notes of the 1:50,000 geological map of Setif by Vila (1976), indicates that the city of Setif is comprised of Quaternary alluvium along the Oued Bousselam, as well as reddish lacustrine sands, gravels, silts, clays, and limestones dating back to the continental Mio-Pliocene.

2.3. Pedology

The soils of Setif are calcium-rich (Figure 15), abundant in clay, and poor in humus in the northern region, while they become stony in the southern region (Lahmar *et al.*, 1993).

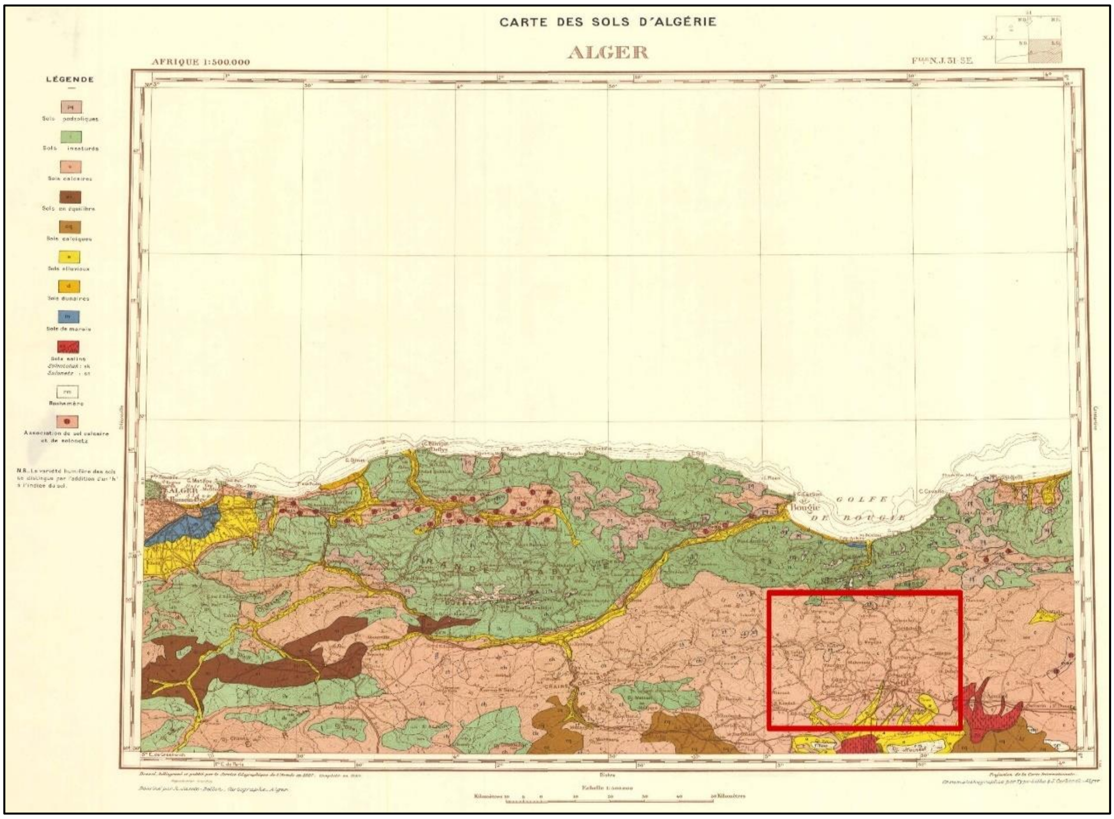

Figure 15. Soil map of Setif, extracted from the soil map of Africa at a scale of 1:500,000.

2.4. Hydrology

The main river in the city of Setif is the Oued Bousselam. It is located to the west of the city and to the east of Setif 1 University - Ferhat ABBAS. It is the only permanent and most important watercourse in the Setif region.

2.5. Vegetation

The tree layer consists of species such as, *Casuarina equisetifolia* L., *Celtis australis* L., *Cupressus sempervirens* L., *Cydonia oblonga* Mill., *Eucalyptus globulus* Labill., *Maclura pomifera* (Raf.) B.L.Rob., *Melia azedarach* L., *Morus alba* L., *Morus nigra* L., *Phoenix canariensis* H. Wildpret, *Populus nigra* L., *Prunus armeniaca* L., *Schinus molle* L., *Styphnolobium japonicum* (L.) Schott., etc.

The shrub layer is defined by the existence of *Acacia saligna* (Labill.) H.L.Wendl., *Ligustrum japonicum* Thunb., *Ligustrum vulgare* L., *Myoporum tenuifolium* G.Forst., *Nerium oleander* L., *Platycladus orientalis* (L.) Franco, *Rosmarinus officinalis* L.,etc.

The herb layer is characterized by the presence of *Aegilops geniculata* Roth, *Anacyclus clavatus* (Desf.) Pers., *Anchusa sp.*, *Astragalus sp.*, *Atractylis cancellata* L., *Calendula* *officinalis* L., *Carum carvi* L., *Daucus rouyi* Spalik & Reduron, *Diplotaxis erucoides* (L.) DC., *Echinops pappii* Chiov., *Erodium malacoides* auct., *Gazania sp.*, *Leucanthemum vulgare* Lam., *Malva sp.*, *Malus sp*, *Medicago truncatula* Gaertn., *Moricandia arvensis* (L.) DC., *Muscari neglectum* Guss. ex Ten., *Onopordum acanthium* L., *Oxalis pes-caprae* L., *Paliurus spina-christi* Mill., *Pallenis spinosa* (L.) Cass., *Paronychia sp.*, *Reichardia picroides* (L.) Roth, *Reseda alba* L., *Scolymus sp.*, *Scorpiurus sp.*, *Senecio sp.*, *Sisymbrium irio* L., *Sixalix atropurpurea* (L.) Greuter & Burdet, *Sonchus oleraceus* L., *Torilis sp.*, *Urospermum dalechampii* (L.) F.W. Schmidt, etc.

3. The climate

3.1. The source of the climate data

Obtaining climate data for Setif city and Megriss Mountain was challenging due to limited data availability. The weather station at Ain Arnat Airport (Setif) does not provide recent climate data free of charge, and the weather station located at the summit of Megriss Mountain has ceased its operations. Therefore, the climate data used for the city of Setif was sourced from the “WoFrance” database (https://www.wofrance.fr/Algerie/Setif.htm) for a period of 21 years (from 2002 to 2022). In the case of Megriss Mountain, we performed extrapolations using a reference station, Ain Abessa. The climate data of this reference station was obtained from the “Weather and Climate” data base (https://weatherandclimate.com/algeria/setif/ain-abessa) and cover an 11-year period (2010 to 2020). The choice of this station is based on its distance from Megriss Mountain (11 km) and the availability of data.

3.2. Rainfall (Precipitation)

3.2.1. Mean monthly and annual rainfall of Setif city and Megriss Mountain

From the analysis of the monthly rainfall data collected over a period of 21 years (2002–2022) (Table 2) at the Setif station and over a period of 11 years (2010–2020) (Table 3) at Megriss Mountain, we observe that the average annual rainfall is 401.9 mm and 662.87 mm for Setif and Megriss Mountain, respectively.

For the city of Setif, the maximum rainfall occurs in April and November, both averaging 50.4 mm, with a relatively significant amount in March (41.8 mm), while the minimum rainfall is observed in July (11 mm). On the other hand, Megriss Mountain experiences the highest rainfall in March (88.93 mm) and April (81.01 mm). November also sees a significant amount of rainfall, while July stands out as the driest month, with 11.68 mm of precipitation.

Table 2. Mean monthly rainfall of the city of Setif (2002–2021).

Months	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Rainfall (mm)	40.4	33.4	41.8	50.4	38.7	19.9	11	20.3	30.3	28.9	50.4	36.4

The placement of the reference station (Ain Abessa) at a different altitude from that of Megriss Mountain has necessitated precipitation corrections to align more closely with the local climate. We have followed the pluviothermic gradient established by Boukarma and Garout (1997) in Gharzouli (2007), which proposes an increase of 41 mm per 100 m of elevation. This gradient is specifically applicable to the northern part of the High Plains of Setif. The corrections are based on the calculation of the precipitation adjustment factor (Cp), determined by the following formula (Miara *et al.*, 2013):

$$\boldsymbol{Cp = (A + P1)/P1}$$

Where:

- A is the increase in rainfall in mm, calculated as $\boldsymbol{A = \frac{d \times 41}{100}}$, where *d* is the difference in elevation between the two stations.
- P1 is the average annual rainfall of the reference station.

Table 3. The results of the adjustment factor of precipitation.

Elevation (m)		**Corrected average annual rainfall (mm)**		**Adjustment factor of rainfall**
Ain Abessa	**Megriss Mountain**	**P1**	**Megriss Mountain**	
1,170	1,737	430.4	662.87	1.5

Therefore, the estimated mean monthly rainfall results for Megriss Mountain are presented in Table 4.

Table 4. Corrected mean monthly rainfall (in mm) for Megriss Mountain (2002–2022).

Station	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Ain Abessa	40.65	38.47	59.29	54.01	43.44	20.07	7.79	22.01	37	32.31	45.94	29.42
Megriss Mountain	60.97	57.70	88.93	81.01	65.16	30.10	11.68	33.01	55.50	48.55	68.91	44.13

The mean monthly rainfall for the two study areas is clearly illustrated in Figure 16.

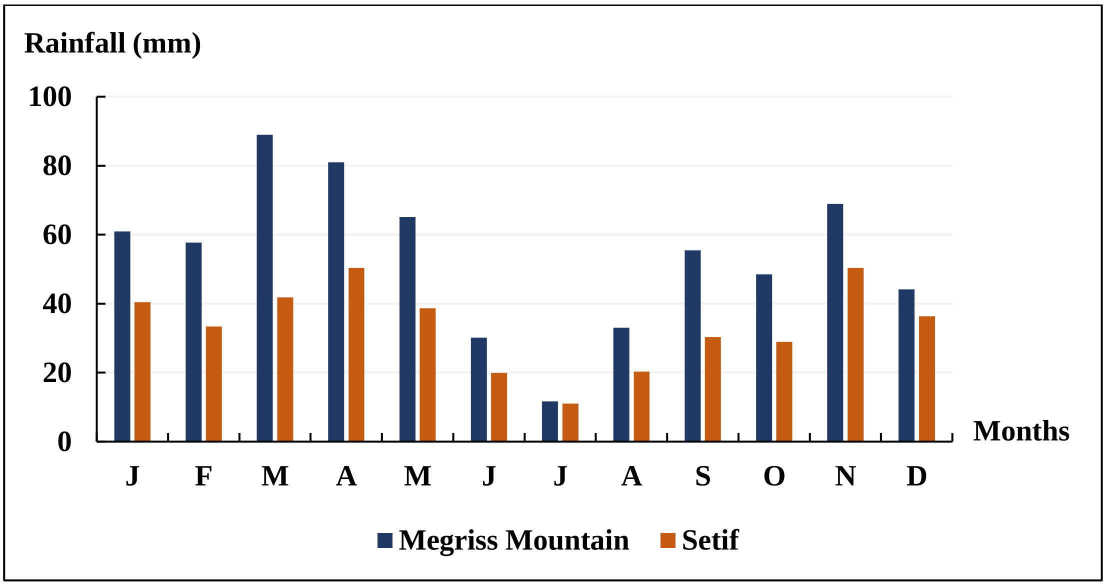

Figure 16. Variation of mean monthly rainfall in Megriss Mountain (2010–2020) and Setif city (2002–2022).

3.2.2. Seasonal rainfall pattern

The knowledge of the average annual rainfall is insufficient to characterize and accurately describe a regional rainfall pattern. It must be complemented by determining the seasonal distribution of rainfall throughout the year and its variation (Chaumont & Paquin, 1971 in Meddour, 2010). Musset (1953) in Meddour (2010) defined the concept of seasonal rainfall pattern as the calculation of the sum of precipitation by season, ranking them in descending order of rainfall and designating each season by its initial.

- Winter is defined as the period from December of the year *n* to January and February of the year *n* (W).
- Spring includes the months of March to May (S).
- Summer encompasses the months of June to August (S).
- Autumn is the period from September to November (A).

The results obtained from calculating the sum of rainfall amounts for each season indicate that the two stations exhibit different seasonal precipitation patterns. During the period 2002–2022, Setif is characterized by a seasonal rainfall pattern of type S.W.A.S, while Megriss Mountain presents a seasonal rainfall pattern of type S.A.W.S. for the period 2010–2020. However, both stations share the commonality that spring is the wettest season and summer is the driest season (Table 5).

Table 5. Seasonal rainfall patterns of Setif city (2002–2022) and Megriss Mountain (2010–2020).

Station	Winter	Spring	Summer	Autumn	Type of the seasonal rainfall pattern
Megriss Mountain	162.8	235.1	74.79	172.96	S.A.W.S (P.A.H.E)
Setif	110.2	130.9	51.2	109.6	S.W.A.S (P.H.A.E)

3.3. Average monthly maximum and minimum temperatures

From the analysis of temperature data collected over a period of 21 years (2002–2022) (Table 6) at the Setif station and over a period of 11 years (2010–2020) (Table 7) at Megriss Mountain, we observe that the average annual temperature is 15 °C and 13.12 °C for Setif and Megriss Mountain, respectively.

In Setif, the coldest month is January, with an average temperature of 5.5 °C and a minimum of 0.3 °C, while the warmest month is July, with an average temperature of 26.7 °C and a maximum of 35 °C. In contrast, Megriss Mountain experiences its coldest month in February, with an average temperature of 3.1 °C and a minimum of -1 °C, and its warmest month in July, with an average temperature of 25.4 °C and a maximum of 31.8 °C (Figures 17 and 18).

Table 6. Variation of monthly minimum, mean, and maximum temperatures in the city of Setif (2002–2022).

Months	J	F	M	A	M	J	J	A	S	O	N	D
Max. T. (°C)	10.7	11.9	14.9	18.9	24.2	30.8	**35**	33.9	28	22.8	15.2	11.5
Min. T. (°C)	**0.3**	0.9	3.3	6.2	9.8	14.7	18.4	18	14.3	10	4.8	1.7
Mean T. (°C)	5.5	6.4	9.1	12.5	17	22.7	26.7	25.9	21.2	16.4	10	6.6

With: $Mean\ T = \frac{Max\ T + Min\ T}{2}$

The temperatures are closely related to elevation, as they tend to decrease with increasing elevation. Boukerma & Garout (1997) in Gharzouli (2007) determined an altitudinal thermal gradient of 0.66 °C and 0.61 °C per 100 m of elevation for maximum temperature minimum temperature, respectively.

The temperature values for Megriss Mountain were estimated from the reference station (Ain Abessa) using correction factors calculated as follows:

- For maximum temperature:

$$\textbf{Correction factor}: \frac{\mathbf{567 \times 0.66}}{\mathbf{100}} = \mathbf{3.7}$$

- For minimum temperature:

$$\textbf{Correction factor}: \frac{567 \times 0.61}{100} = 3.4$$

Where 567 is the difference in elevation of between Megriss Mountain and Ain Abessa. Thus, the maximum and minimum temperature values for each month were adjusted by subtracting 3.7 °C and 3.4 °C, respectively. The corrected values are represented in Table 7.

Table 7. Corrected monthly minimum, mean, and maximum temperatures for Megriss Mountain (2010–2020).

Station	Months	J	F	M	A	M	J	J	A	S	O	N	D
Ain Abessa	Max. T. (°C)	10.9	11.8	15.6	20.6	24.5	30.7	35.5	34.6	28.7	23.1	15.9	12.1
	Min. T. (°C)	2.5	2.4	4.9	8.4	11.7	17.7	22.5	22.8	18.8	13.8	7.6	3.9
Megriss Mountain	Max. T. (°C)	7.2	8.1	11.9	16.9	20.8	27	**31.8**	30.9	25	19.4	12.2	8.4
	Min. T. (°C)	-0.9	**-1**	1.5	5	8.3	14.3	19.1	19.4	15.4	10.4	4.2	0.5
	Mean T. (°C)	3.1	3.5	6.7	10.9	14.5	20.6	25.4	25.1	20.2	14.9	8.2	4.4

4. Bioclimatic synthesis

4.1. Ombrothermic diagram of Bagnouls and Gaussen

+According to Bagnouls & Gaussen (1957), a period is considered dry when the total precipitation (P) is less than twice the average temperature (T) over the given period (P < 2T). Based on this principle, the position of the dry period in the year, as well as its duration and intensity, can be determined using the ombrothermic diagram proposed by these authors. The diagram is created using a graph that shows the months of the year on abscissa, the average monthly rainfall in mm on the left-hand ordinate, and the mean monthly temperature in degrees Celsius on the right-hand ordinate. It is important to note that the rainfall values should be plotted on a scale that is double that of the temperatures (1 °C = 2 mm). The dry period is identified when the rainfall (ombric) curve falls below the temperature (thermic) curve.

Figures 17 and 18 indicate that for the city of Setif, there is only one dry period lasting approximately five months, from the end of May to mid-October, with an intense drought occurring in July and August. Similarly, at Megriss station, there is also only one dry period lasting three months, from June to August, with a severe drought in July.

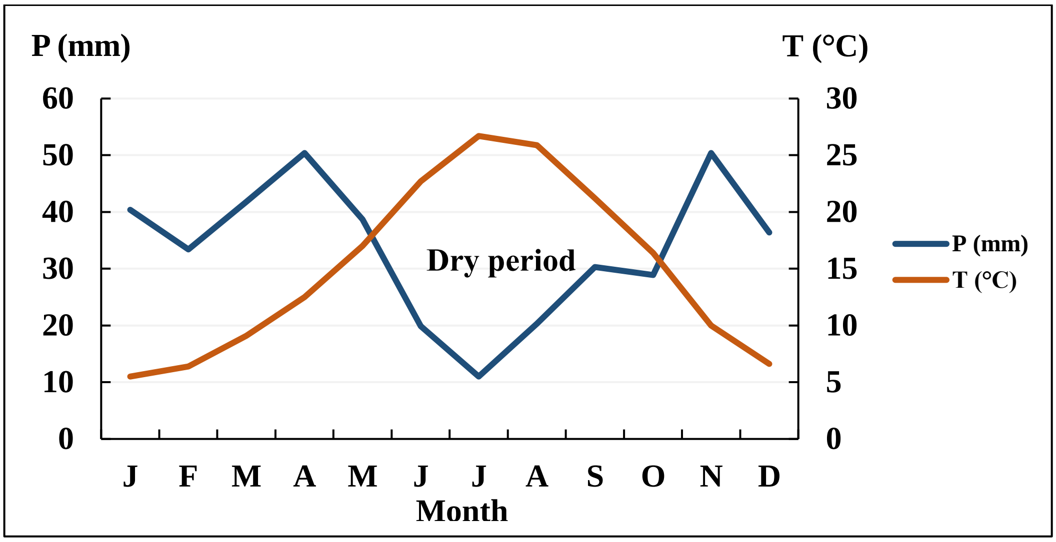

Figure 17. Ombrothermic diagram of the city of Setif (2002–2022).

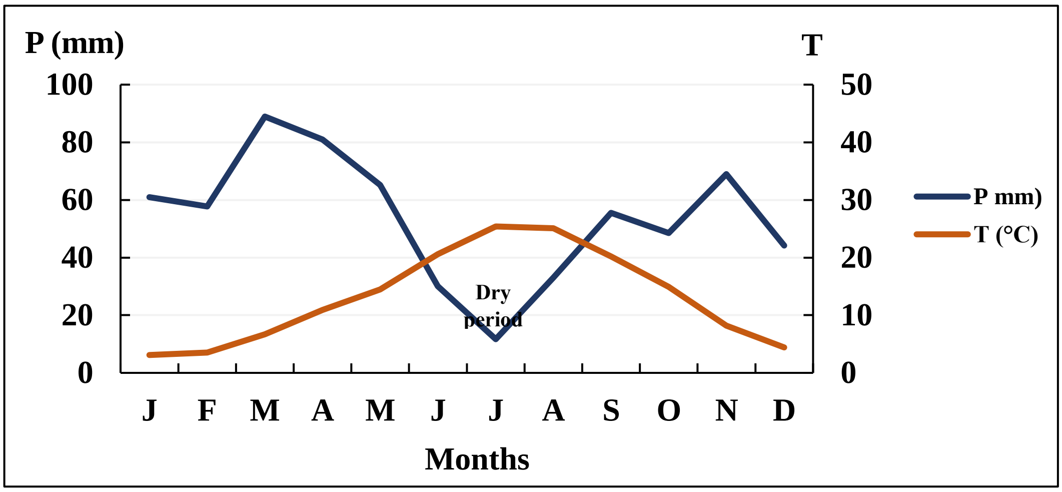

Figure 18. Ombrothermic diagram of Megriss Mountain (2010–2020).

4.2. Pluviothermic climagram and bioclimatic stages of Emberger

The bioclimatic classification of Emberger, used in the Mediterranean region, is based on “the climatic characteristics that have the strongest influence on plant life” (Emberger, 1955 in Le Houerou *et al.*, 1979). Bioclimates are defined by a pluviothermic climagram (Emberger, 1930, 1955 in Le Houerou *et al.*, 1979), where the pluviothermic quotient (Q_2) is plotted on the ordinate and the average of the minimum temperatures of the coldest months (m) is plotted on the abscissa.

To calculate the pluviothermic quotient, Emberger proposed the following formula:

$$Q_2 = \frac{2000P}{M^2 - m^2}$$

Where:

- P is the annual sum of rainfall in mm;
- M is the average of the maximum temperatures of the warmest month, in °K;
- m is the average of the minimum temperatures of the coldest month of the coldest month, in °K.

The result of Q2 for both study areas is shown in Table 8.

Table 8. Pluviothermic quotient values and the bioclimatic stages of the regions of Setif and Megriss Mountain.

Station	P (mm)	M (°C)	m (°C)	Q_2	Bioclimatic stage
Setif	401.9	35	0,3	39.72	Semi-arid with a cool winter
Megriss Mountain	662.87	31.8	-1	69.31	Subhumid with a cold winter

The bioclimatic stages of Megriss Mountain and Setif city are represented in the Emberger climagram (Figure 19).

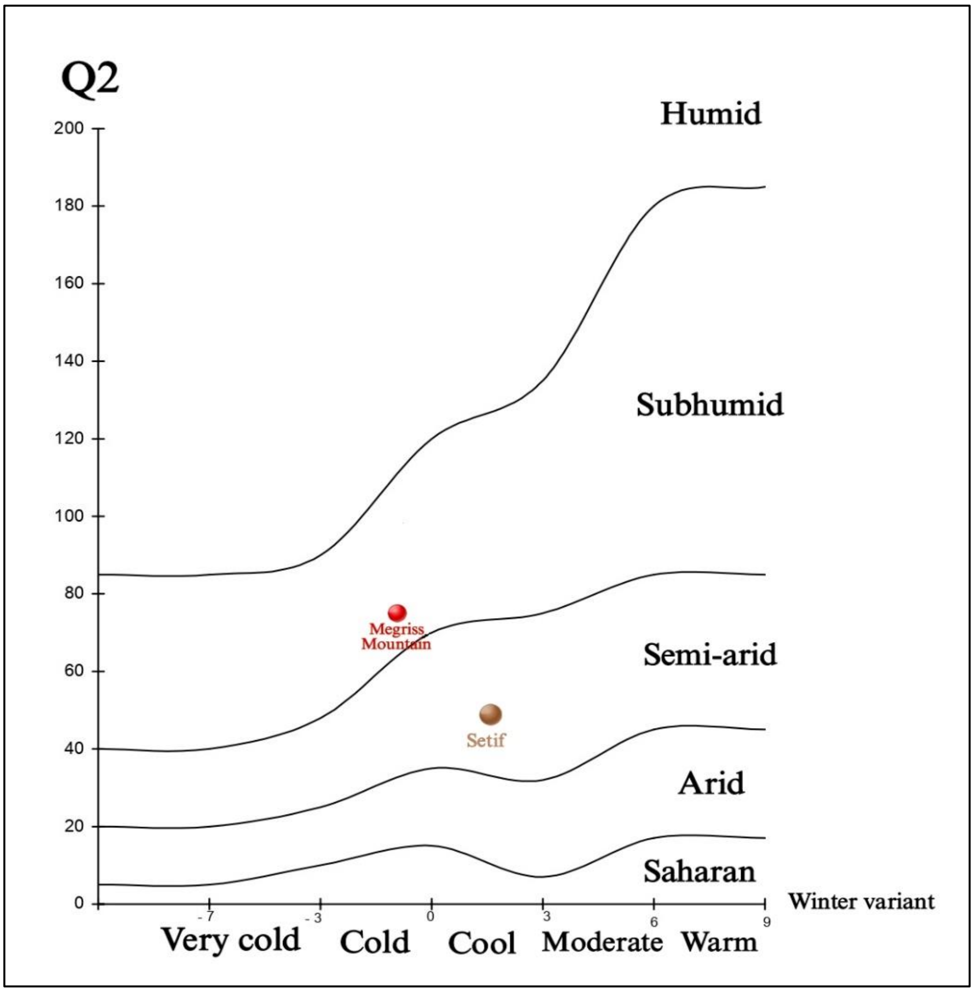

Figure 19. The climagram of Emberger of both study areas.

Chapter III

Materials and methods

The practical part of our study was divided into two main stages: in-situ work, conducted in the field, and ex-situ work, which took place in the laboratory.

1. Work in-situ

1.1. Date of fieldwork

The fieldwork conducted at Megriss Mountain and Setif 1 University - Ferhat ABBAS involved multiple visits. The study took place during the following periods:

- Megriss Mountain: April 2021, June 2021, October 2022, and February 2024.
- Setif 1 University - Ferhat ABBAS: February 2021 and April 2022.

1.2. Collecting equipment (field gear)

- Knife: Bryophytes are easy to collect (Buck & Thiers, 1996). Since they lack roots, they can often be gathered by hand. However, some species that are closely attached to their substrate may require scratching with a knife (Vanderpoorten *et al.*, 2010).
- Paper packets: Used a container for storing the gathered mosses and recording details about each specimen.
- Pencil and field book: Utilized for taking notes during the fieldwork.
- GPS: Employed to record the location of the collection site. Measuring tape: Used to determine the height of trees.
- Plastic bags: Used to collect all moss packets gathered from specific locations.

Figure 20. Field gear (Image by Mazari Amira).

1.3. Sampling stations

During our fieldwork, samples were collected at 15 stations in Megriss Mountain (Figure 21) and at eight stations in Setif 1 University - Ferhat ABBAS (Figure 22).

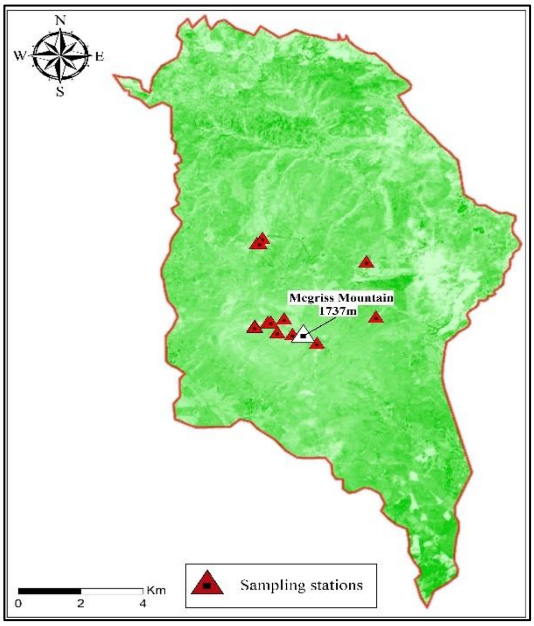

Figure 21. Map of the sampling stations in Megriss Mountain (Mazari, 2024).

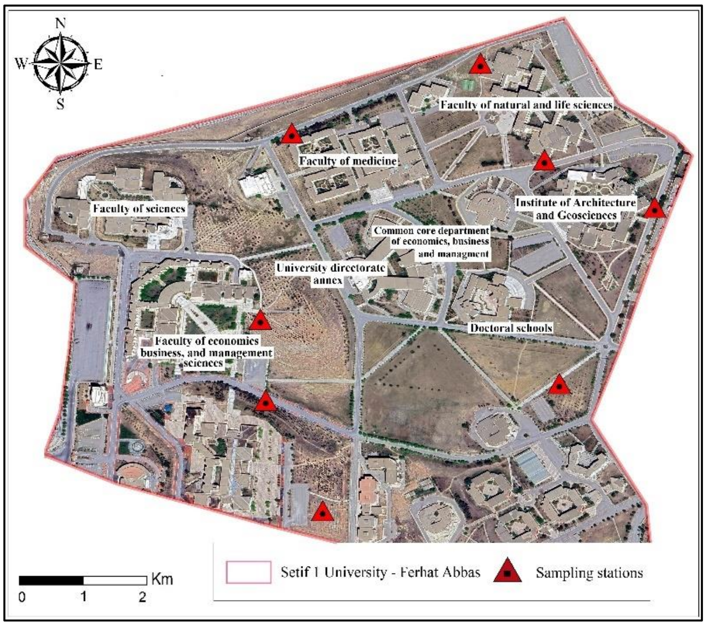

Figure 22. Map of the sampling stations in Setif 1 University - Ferhat ABBAS (Mazari, 2024).

The geographic coordinates of the sampled stations at both study areas are provided in Table 9.

Table 9. Geographic coordinates of the sampled stations at Megriss Mountain and Setif 1 University - Ferhat ABBAS.

Megriss Mountain			
Stations	**Latitude**	**Longitude**	**Elevation (m)**
1	36°21'15.4"N	05°22'39.6"E	1,074
2	36°21'40.0"N	05°20'19.8"E	1,108
3	36°21'46.7"N	05°20'27.7"E	1,130
4	36°21'40.9"N	05°20'23.8"E	1,149
5	36°20'9.0"N	05°22'50.2"E	1,321
6	36°20'1.9"N	05°20'14.4"E	1,550
7	36°20'5.8"N	05°20'31.5"E	1,554
8	36°20'0.7"N	05°20'14.1"E	1,556
9	36°20'5.47"N	05°20'34.80"E	1,559

10	36°20'9.4"N	05°20'52.5"E	1,589
11	36°19'52.89"N	05°20'42.87"E	1,626
12	36°19’39.10"N	05°21'33.31"E	1,675
13	36°19'50.08"N	05°21'2.5"E	1,682
14	36°19'46.94"N	05°21'20.20"E	1,719
15	36°19'49.61"N	05°21'14.06"E	1,735
Setif 1 University - Ferhat ABBAS			
Stations	**Latitude**	**Longitude**	**Elevation (m)**
1	36°11'47.5"N	05°22'4.4"E	1,011
2	36°11'58.5"N	05°22'10.9"E	1,015
3	36°12'1.2"N	05°22'3.9"E	1,017
4	36°12'07.5"N	05°21'59.3"E	1,024
5	36°12'2.7"N	05°21'47.5"E	1,034
6	36°11'51.6"N	05°21'45.6"E	1,035
7	36°11'46.0"N	05°21'45.4"E	1,045
8	36°11'39.9"N	05°21'49.2"E	1,048

1.4. Sampling method

Bryophytes sampling was conducted across various habitats, including rocks, trees, soils, and streams. According to Vanderpoorten *et al*. (2010), habitats with significant bryophyte cover tend to have higher species richness, Consequently, at each sampling station, we targeted areas where bryophytes were particularly abundant.

In most cases, bryophytes can be sampled by hand grabbing. However, those growing on bark or those that have been established for decades may require extraction with the help of a knife (Glime, 2017a).

When sampling bryophytes on rocks and soils, we used minimum survey areas of 100 cm² (10 × 10 cm), with the option to increase the surface area based on species diversity and availability. For epiphytic bryophytes, samples were collected from the base of the trunk up to nearly 2 meters high, in all cardinal directions, from all types of phorophytes.

The specimens collected were as complete as possible since fertile samples are easier to identify. Each sample was placed in a paper packet (Figure 23) that indicated the substrate type, habitat, locality, geographical coordinates, and collector(s). When collecting epiphytes, it was crucial to specify whether they were taken from the branch or the trunk and if so, from the upper, middle, or lower part of the tree trunk. Small specimens were first wrapped in appropriately sized pieces of paper before being placed in standard-sized packets. Bryophytes envelopes collected from a specific locality were grouped together in a single plastic bag, which was labelled with the number and geographic coordinates of the locality. Additionally, a field notebook was used to record descriptions of each location during material collection.

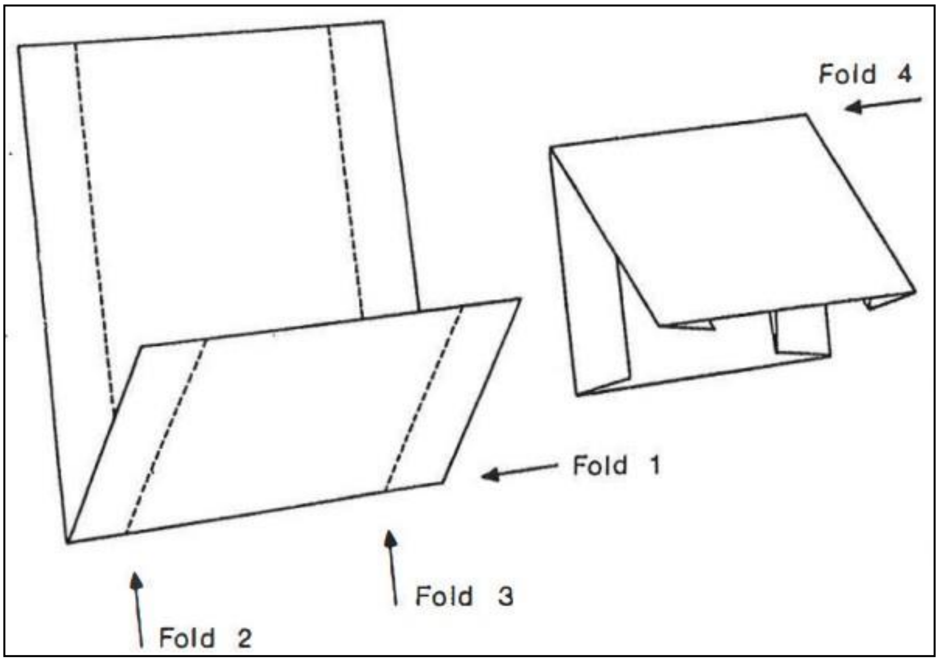

Figure 23. Folding procedure for packing-up bryophytes (O'Shea, 1989).

The samples were often not examined on the day of collection. Therefore, upon reaching the laboratory, it was necessary to take the plants out of the wet paper packets and allow them to air dry, as plants left in wet paper packets tend to develop elongated shoots and may be affected by mold (Smith, 2004; Vanderpoorten *et al.*, 2010).

2. Work ex-situ

Bryophyte samples were examined both macroscopically and microscopically in the laboratory of the Urban Project, City and Territory (LPUViT), using Zeïss Stemi 2000-C stereo microscope and Optika B-193PL compound microscope. Photomicrographs of the studied samples were captured using Optika ProView 4.8.15529 software. Some species were confirmed by ROS Rosa María in the laboratory of Sistemática Molecular, Filogenia y Conservación en Briófitos.

2.1. Identification equipment (laboratory gear)

- Petri dish: Used to hold the sample that needs to be identified.
- Small plastic spray bottle: Used to moisten the dried bryophyte sample.
- Small beaker: Used to contain water.
- Eye dropper: Used to transfer small amounts of water from the beaker to the slide, enabling the placement of the desired moss section for microscopic examination. It was also used to add a tiny bit of water to the edge of a slide in cases where the sample dried out during examination.
- Pair of dissecting forceps: Used for removing leaves from stems.
- Razor blades: Used for cutting sections.
- Slides and Coverslips: Used to prepare specimens for microscopic examination.
- Stereo microscope: Necessary for various purposes, such as locating small bryophytes among larger ones, obtaining a clear view of leaf arrangements, and guiding the hands when making sections or removing leaves.
- Compound microscope: Used for detailed examination and analysis.

Figure 24. Laboratory gear (Image by Mazari Amira).

2.2. Bryophytes identification

2.2.1. Macroscopic examination

To properly identify bryophytes, we should always observe the entire dry sample using a stereo microscope, as the features of bryophytes in this case are useful for identification. Next, we moisten the bryophyte sample and observe it again.

For foliose bryophytes, we take a stem and place it on a glass slide after adding a drop of water. We then strip the leaves by pulling them downward from the tip with dissecting forceps while holding the tip of the branch or stem with another forceps. The leaves are spread out so that some are in a dorsal position and others in a ventral position. We perform cross-sections along the entire length of the leaf to observe whether the leaf cells and margins are unistratose, bistratose, or pluristratose. These three basic steps are used for each species. Further steps are performed based on the morphological descriptions of each taxon provided in the identification keys.

For thallose bryophytes, cross-sectioning the thalli is necessary to observe their internal characteristics.

2.2.2. Microscopic examination

The use of the compound microscope was indispensable for observing additional characteristics and details that facilitate species identification. For instance, it allows us to examine cells shape, teeth on the leaves, special structures like gemmae, bulbils, paraphyllia, and reproductive organs, as well as to obtain a clear view of leaf and stem sections. Additionally, it enables the observation of details such as peristome decorations and stomata on the sporophyte in the case of mosses.

2.2.3. Identification keys and nomenclature

The identification of bryophytes was performed using specialized keys as well as online resources, which include:

- Flore des bryophytes (Augier, 1966);
- The moss flora of Britain and Ireland (Smith, 2004);
- The handbook of mosses of the Iberian Peninsula, the Balearic Islands (Casas *et al.*, 2006);

- All volumes of the series "Flora Briofítica Ibérica" (Guerra *et al.*, 2006; Brugués *et al.*, 2007; Guerra *et al.*, 2010; Guerra *et al.*, 2014; Brugués & Guerra, 2015; Guerra *et al.*, 2018);
- The paper titled "A new key to the genus *Orthotrichum* Hedw. in Europe and mediterranean region" by Lara *et al.* (2009) for the genus "*Orthotrichum*";
- Bryologia Gallica & Ultramarina (http://bryologia.gallica.free.fr/les-bryophytes-de-france.php);
- The British Bryological Society (https://www.britishbryologicalsociety.org.uk/).
- Bildatlas der Moose Deutschlands (https://www.bildatlas-moose.de/)

For mosses' nomenclature, the annotated checklist of bryophytes of Europe, Macaronesia and Cyprus Hodgetts *et al.* (2020) was followed.

2.2.4. Bryophytes storage

Bryophyte specimens have been placed in labeled packets and stored in boxes within BOULAACHEB's private herbarium. Each label contains various details, including the species name (if known), the scientific name author, elevation where it was found, habitat, substrate, collection date, and location (city, country) along with GPS coordinates. Additionally, the name of the collector, collection number, and the name of the identifier are also recorded.

3. Data treatment

The Excel software (version 2019) on Windows 10 was used to organize and visualize the data for our study.

Chapter IV

Results and discussion

I. Results

A total of 89 moss taxa were identified from the two study areas, with 63 taxa found in Megriss Mountain (Table 10) and 26 species in Setif 1 University - Ferhat ABBAS (Table 11). Some species were common to both areas; however, no liverworts or hornworts were detected in either area.

1. Diversity of mosses in Megriss Mountain and Setif 1 University - Ferhat ABBAS

1.1. Specific and generic richness within moss families

The study conducted on Megriss mountain has identified a total of 63 moss species to their specific/intraspecific level. These species are distributed across 30 genera belonging to 14 families. Among these families, four stand out for their remarkable richness: the Pottiaceae which is represented by 23 species (36,50% of the total species in Megriss Mountain) and eight genera (26,66% of the total genera found in Megriss Mountain), the Orthotrichaceae by 11 species (30,55%) and three genera (10%), the Bryaceae by seven species (11,11%) and three genera (10%), and the Brachytheciaceae by six species (9,52%) and five genera (16,66%). Other families are also well represented, the Grimmiaceae with four species (6,34%) and a single genus (3,33%), the Bartramiaceae and the Ditrichaceae, each are represented by two species (3,17%) and two genera (6,66%), and the Hypnaceae with two species (3,17%) and a single genus (3,33%). The remaining five families are each represented by only one species and one genus (Figure 25).

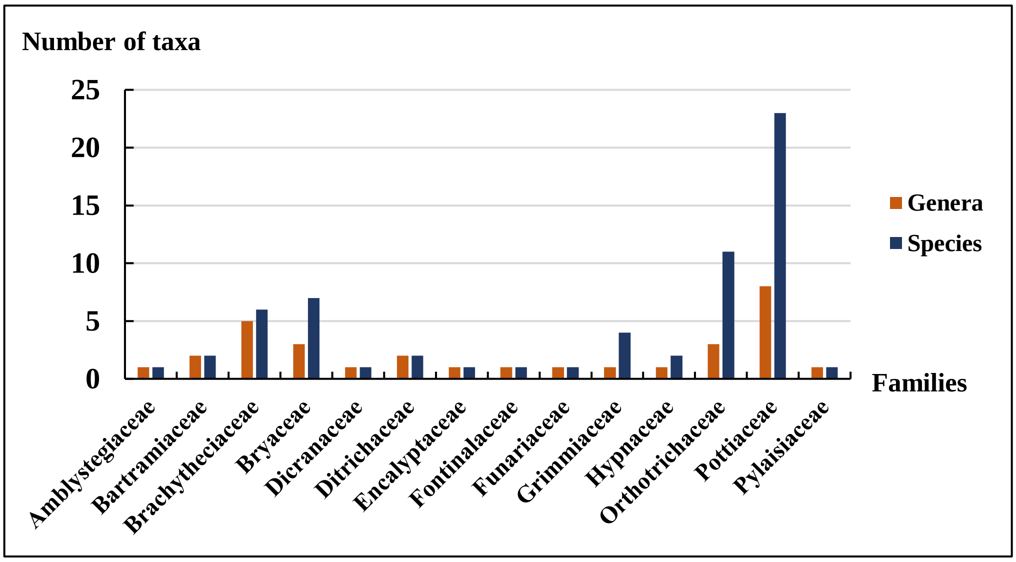

Figure 25. Distribution of genera and species within botanical families in Megriss Mountain.

On the other hand, the moss species survey carried out at Setif 1 University - Ferhat ABBAS has identified 26 species, including 18 genera and seven families. The prominent families are the Pottiaceae with 17 species (65,38% of the total species found in the university) and 11 genera (61,11% of the total genera found in the university) and the Bryaceae four species (15,38%) and two genera (11,11%), while the remaining families are each represented by a single genus and a single species (Figure 26).

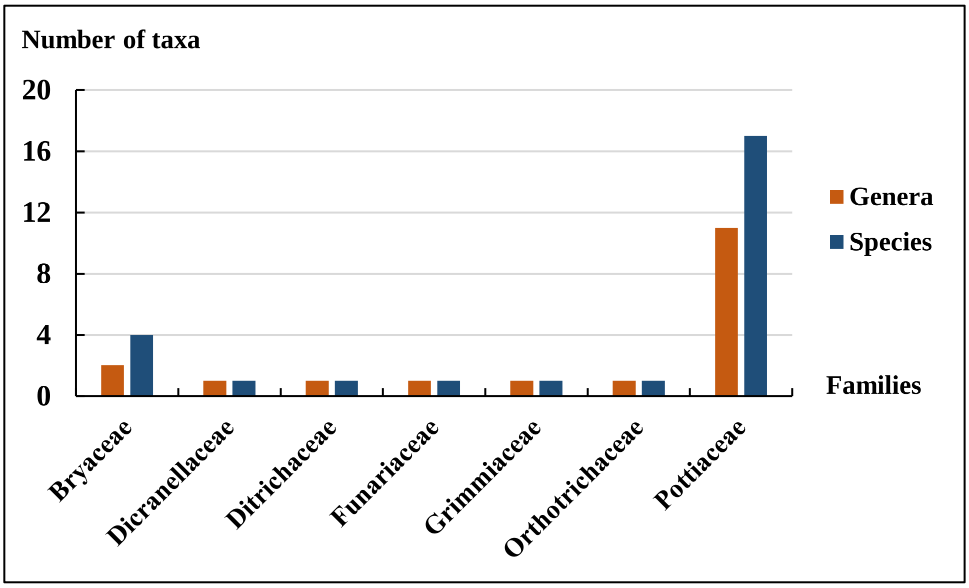

Figure 26. Distribution of genera and species within botanical families in the Setif 1 University - Ferhat ABBAS.

1.2. Diversity of moss species within genera

At the generic level, *Didymodon* Hedw. and *Syntrichia* Brid. exhibit the highest diversity at Megriss Mountain, each comprising six species (20% of the total genera found in Megriss Mountain). *Lewinskya* F.Lara, Garilleti & Goffinet and *Orthotrichum* Hedw. also demonstrate significant diversity, each consisting of five species (16,66%). Additionally, *Grimmia* Hedw. and *Bryum* Hedw. contribute to the diversity with four (13,33%) and three (10%) species, respectively. The remaining genera account for the rest of the diversity, ranging from two to one species (Figure 27).

At Setif 1 University - Ferhat ABBAS, *Bryum* and *Tortula* Hedw. are the most diverse genera, each having three species (16,66% of the total genera found in the university). *Aloina* Kindb, *Crossidium* Jur., *Didymodon*, and *Syntrichia* are represented by two species (11,11%) each, while the remaining genera are represented by a single species (Figure 28).

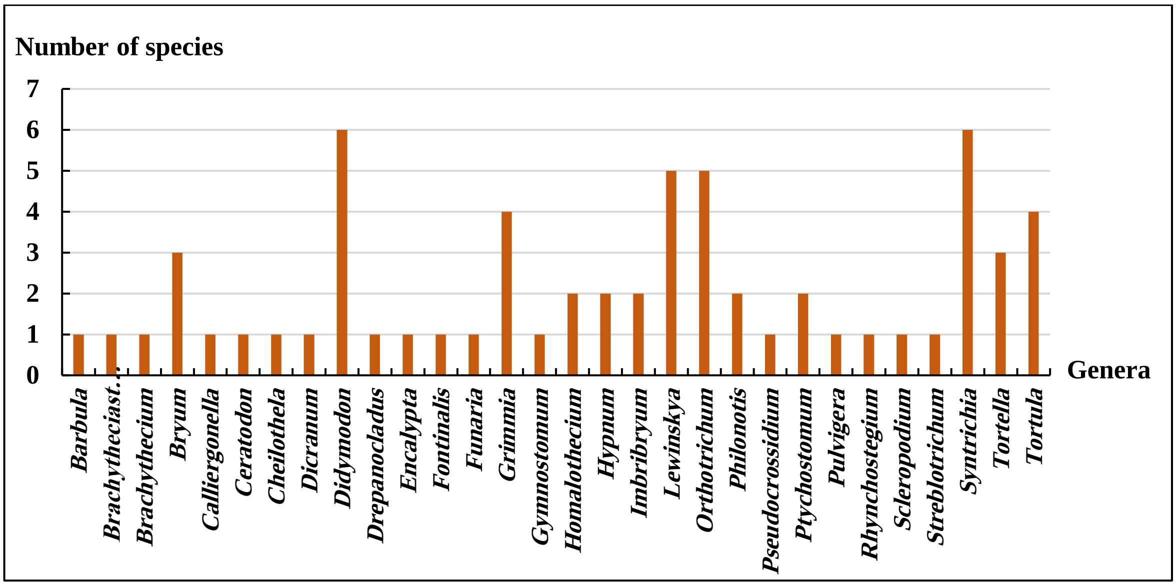

Figure 27. Number of species recorded for each genus at Megriss Mountain.

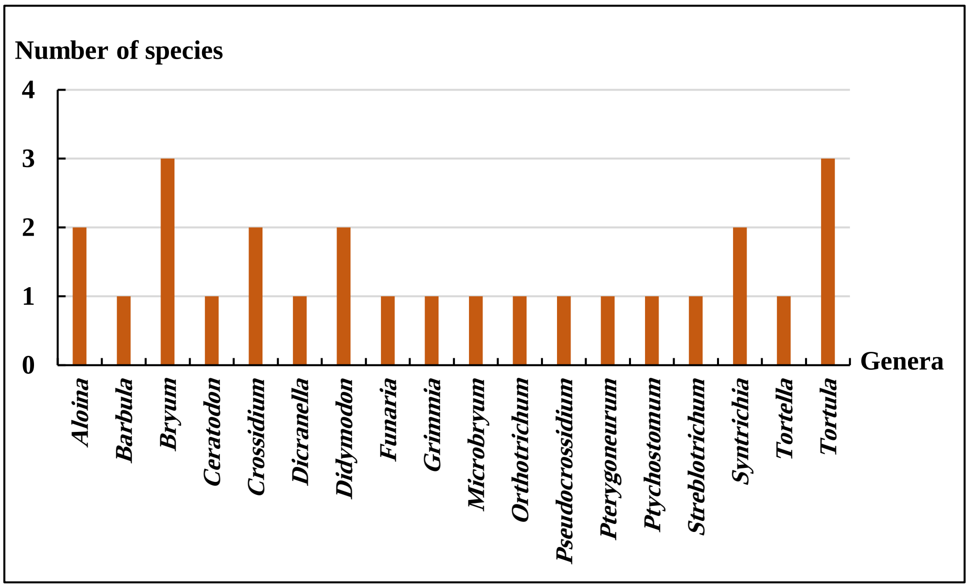

Figure 28. Number of species recorded for each genus at Setif 1 University - Ferhat ABBAS.

1.3. Abundance and frequency of moss species

Bryophyte plants are tiny and usually grow in short turfs or wefts, making it difficult to estimate species abundance in the field by directly counting the number of individuals (Jiang *et al.*, 2018). Consequently, determining the abundance of moss species collected from both study areas was challenging, and their frequency was also hard to estimate due to their previously limited recognition in the region. Unlike vascular flora, the distribution of bryophytes is generally difficult to establish.

However, based on our observations, some species were notably common across various locations, as indicated by their prevalence in most of the envelopes. For instance, in Megriss Mountain, the following species were observed to be prevalent: *Didymodon insulanus* (De Not.) M. O. Hill, *Grimmia pulvinata* (Hedw.) Sm., *Lewinskya acuminata* (H.Philib.) F.Lara, Garilleti & Goffinet., *Orthotrichum diaphanum* Brid., and *Tortella squarrosa* (Brid.) Limpr. Similarly, at Setif 1 University - Ferhat ABBAS, the following species were widely distributed: *Bryum argenteum* Hedw., *O. diaphanum*, and *Tortula muralis* Hedw.

2. Biotypes

The examination of mosses biotypes at Megriss Mountain and Setif 1 University - Ferhat ABBAS revealed that Megriss Mountain has 52 species (82,54%) of acrocarpous mosses and 11 species (17,46%) of pleurocarpous mosses (Figure 29). In contrast, Setif 1 University - Farhat ABBAS has only 26 species (100%) of acrocarpous mosses (Figure 30).

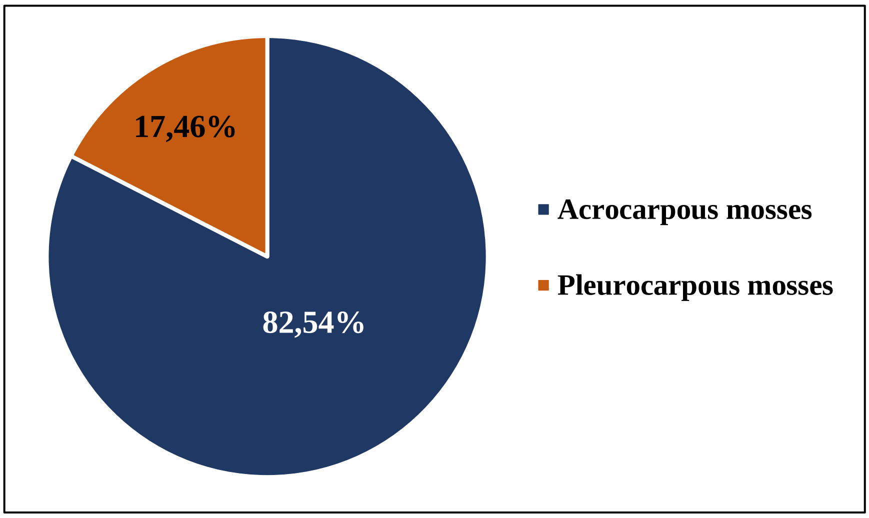

Figure 29. Biotypes of mosses collected from Megriss Mountain.

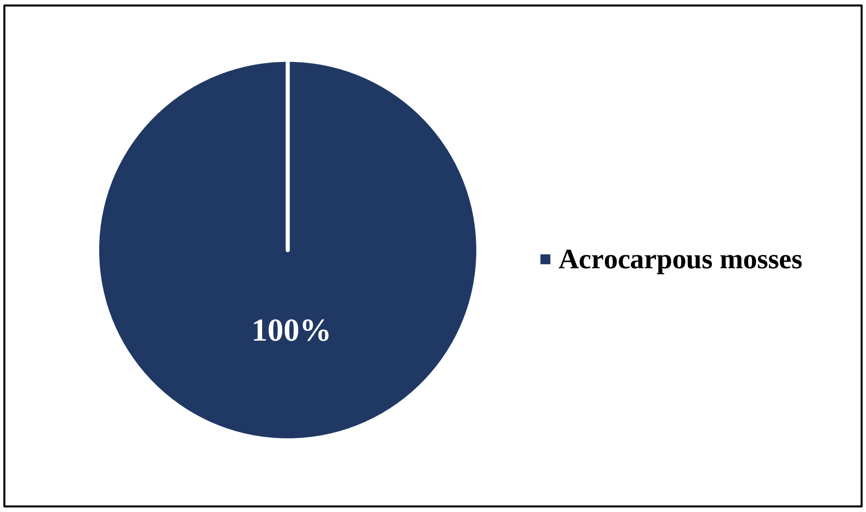

Figure 30. Biotypes of mosses collected from Setif 1 University - Ferhat ABBAS.

3. Habitats

In our study, the species have been classified based on their habitats into the following groups: terrestrial species, which grow on wet or dry soils; epilithic (saxicolous) species, which inhabit rocky substrates (natural or concrete); epiphytic species, which grow on the bark of living trees or on decorticated wood of dead trees; aquatic species, which inhabit waterlogged sites; and semi-aquatic species, which grow in soils or rocks that are more or less submerged. This classification was established by comparing prior scientific works (Dierssen, 2001; Jansová & Soldán, 2006; Wolski *et al.*, 2012; Heilmann-Clausen *et al.*, 2014; Táborská *et al.*, 2015; Kutnar *et al.*, 2023).

Mosses of Megriss Mountain were found inhabiting different types of habitats (Figure 31, Table 10); 18 species (i. e. 28,6% from the whole number of species found in Megriss Mountain) were terricolous, 17 species (26,9%) were epilithic, ten species (15,9%) were epiphytic, of which the majority belong to the Orthotrichaceae family, and two species (3,2%) were aquatic/semiaquatic, of which *Drepanocladus aduncus* Hedw. was semi aquatic while *Fontinalis antipyretica* Hedw. was aquatic. Furthermore, 13 species (20,6%) were found growing on both soils and rocks, namely, *D. insulanus*, *Encalypta vulgaris* Hedw., *Homalothecium aureum* (Spruce) H.Rob., *Hypnum cupressiforme* Hedw. var. *lacunosum* Brid., *Hypnum jutlandicum* Holmen & E. Warncke, *Imbribryum alpinum* (Huds. ex With.) N.Pedersen, *Rhynchostegium megapolitanum* (Blandow ex F.Weber & D.Mohr) Schimp., *Scleropodium touretii* (Brid.) L.F.Koch., *Streblotrichum convolutum* (Hedw.) P.Beauv., *Syntrichia ruralis* (Hedw.) F.Weber & D.Mohr, *T. squarrosa*, *Tortula inermis* (Brid.) Mont, *Tortula subulata* Hedw. Three species (4,8%) were found growing on rocks and trees, which are: *G. pulvinata*, *Orthotrichum cupulatum* Brid. var *cupulatum*, and *O. diaphanum*, although in Megriss Mountain, *O. diaphanum* was found growing more on trees.

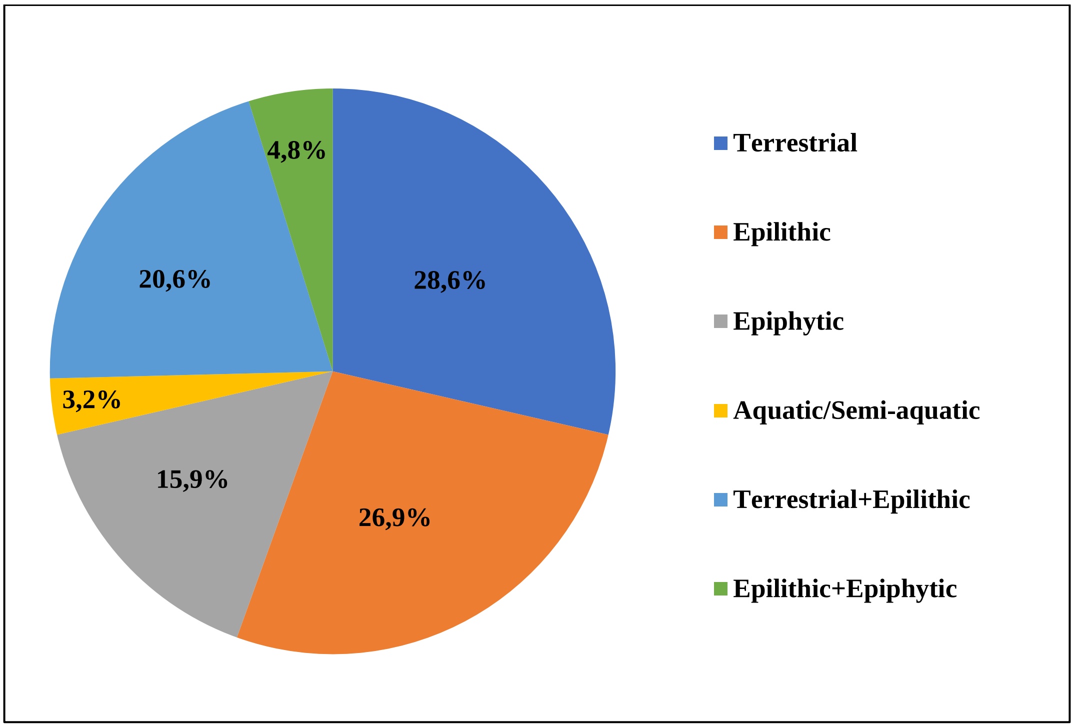

Figure 31. Habitat of the moss species collected from Megriss Mountain.

Mosses collected from Setif 1 University - Ferhat ABBAS were also found thriving in various habitats (Figure 32, Table 11); 15 species (57,7%) were terrestrial, seven species (26,9%) were epilithic, and only one species (3,9%) was epiphytic, which are *O. diaphanum*. The remaining three species (11,5%) were growing on soils and rocks, namely: *B. argenteum*, *Barbula unguiculata* Hedw., and *T. inermis*.

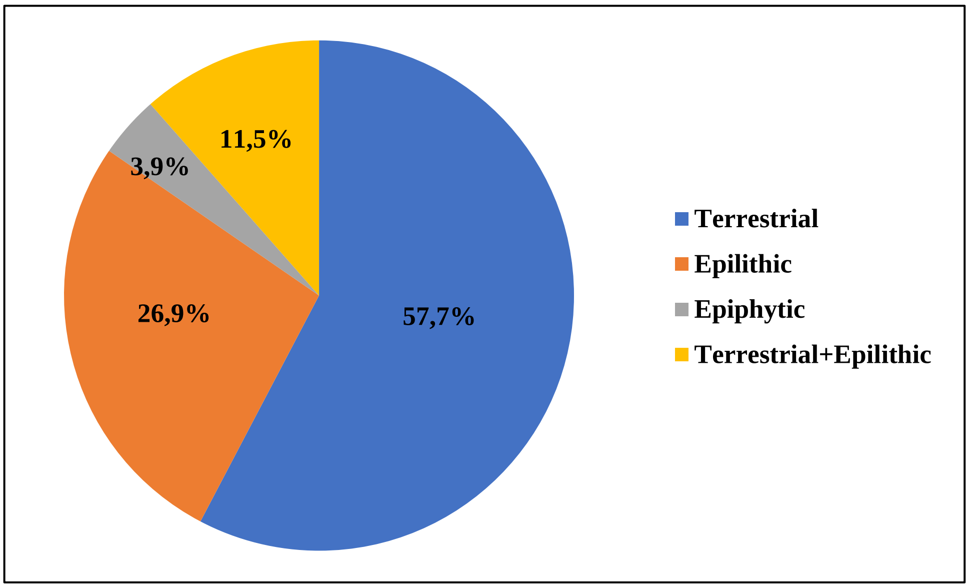

Figure 32. Habitats of the moss species collected from Setif 1 University - Ferhat ABBAS.

Table 10. Mosses collected from Megriss Mountain.

Mosses	**Habitat**				**Biotypes**
Species/Families	**Terrestrial**	**Epilithic**	**Epiphytic**	**Aquatic/Semi-aquatic**	**Acrocarpous/ Pleurocarpous**
Amblystegiaceae G.Roth					
Drepanocladus aduncus (Hedw.) Warnst.	-	-	-	+	Pleurocarpous
Bartramiaceae Schwägr.					
Philonotis calcarea (Bruch & Schimp.) Schimp.	+	-	-	-	Acrocarpous
Philonotis tomentella Molendo	+	-	-	-	Acrocarpous
Brachytheciaceae Schimp.					
Brachytheciastrum velutinum (Hedw.) Ignatov & Huttunen	+	-	-	-	Pleurocarpous
Brachythecium rutabulum (Hedw.) Schimp.	+	-	-	-	Pleurocarpous
Homalothecium aureum (Spruce) H.Rob.	+	+	-	-	Pleurocarpous
Homalothecium sericeum (Hedw.) Schimp.	+	-	-	-	Pleurocarpous
Rhynchostegium megapolitanum (Blandow ex F.Weber & D.Mohr) Schimp.	+	+	-	-	Pleurocarpous
Scleropodium touretii (Brid.) L.F.Koch.	+	+	-	-	Pleurocarpous
Bryaceae Schwägr.					
Bryum argenteum Hedw.	+	-	-	-	Acrocarpous

Table. 10 (Continued)

Bryum dichotomum Hedw.	-	+	-	-	Acrocarpous
Bryum radiculosum Brid.	-	+	-	-	Acrocarpous
Imbribryum alpinum (Huds. ex With.) N.Pedersen	+	+	-	-	Acrocarpous
Imbribryum mildeanum (Jur.) J.R.Spence	-	+	-	-	Acrocarpous
Ptychostomum capillare (Hedw.) Holyoak & N.Pedersen	-	+	-	-	Acrocarpous
Ptychostomum pseudotriquetrum (Hedw.) J.R.Spence & H.P.Ramsay ex Holyoak & N.Pedersen	+	-	-	-	Acrocarpous
Dicranaceae Schimp.					
Dicranum scoparium Hedw.	+	-	-	-	Acrocarpous
Ditrichaceae Limpr.					
Ceratodon purpureus (Hedw.) Brid.	-	+	-	-	Acrocarpous
Cheilothela chloropus (Brid.) Broth.	+	-	-	-	Acrocarpous
Encalyptaceae Schimp.					
Encalypta vulgaris Hedw.	+	+	-	-	Acrocarpous
Fontinalaceae Schimp.					
Fontinalis antipyretica Hedw.	-	-	-	+	Pleurocarpous
Funariaceae Schwägr.					
Funaria hygrometrica Hedw.	-	+	-	-	Acrocarpous

Table. 10 (Continued)

Grimmiaceae Arn.					
Grimmia funalis (Schwägr.) Bruch & Schimp.	-	+	-	-	Acrocarpous
Grimmia orbicularis Bruch ex Wilson	-	+	-	-	Acrocarpous
Grimmia ovalis (Hedw.) Lindb.	-	+	-	-	Acrocarpous
Grimmia pulvinata (Hedw.) Sm.	-	+	+	-	Acrocarpous
Hypnaceae Schimp.					
Hypnum cupressiforme Hedw. var. *lacunosum* Brid.	+	+	-	-	Pleurocarpous
Hypnum jutlandicum Holmen & E. Warncke	+	+	-	-	Pleurocarpous
Orthotrichaceae Arn.					
Lewinskya acuminata (H.Philib.) F.Lara, Garilleti & Goffinet	-	-	+	-	Acrocarpous
Lewinskya affinis (Schrad. ex Brid.) F.Lara, Garilleti & Goffinet	-	-	+	-	Acrocarpous
Lewinskya breviseta (F.Lara, Garilleti & Mazimpaka) F.Lara, Garilleti & Goffinet	-	-	+	-	Acrocarpous
Lewinskya rupestris (Schleich. ex Schwägr.) F.Lara, Garilleti & Goffinet	-	+	-	-	Acrocarpous
Lewinskya striata (Hedw.) F.Lara, Garilleti & Goffinet	-	-	+	-	Acrocarpous
Orthotrichum cupulatum Brid. var. *cupulatum*	-	+	+	-	Acrocarpous
Orthotrichum diaphanum Brid.	-	+	+	-	Acrocarpous

Orthotrichum macrocephalum F.Lara, Garilleti & Mazimpaka	-	-	+	-	Acrocarpous
Orthotrichum pumilum Sw. ex anon.	-	-	+	-	Acrocarpous
Orthotrichum scanicum Grönvall	-	-	+	-	Acrocarpous
Pulvigera lyellii (Hook. & Taylor) Plášek, Sawicki & Ochyra	-	-	+	-	Acrocarpous
Pottiaceae Schimp.					
Barbula unguiculata Hedw.	-	+	-	-	Acrocarpous
Didymodon acutus (Brid.) K.Saito	+	-	-	-	Acrocarpous
Didymodon fallax (Hedw.) R.H.Zander	+	-	-	-	Acrocarpous
Didymodon insulanus (De Not.) M.O.Hill	+	+	-	-	Acrocarpous
Didymodon sinuosus (Mitt.) Delogne	+	-	-	-	Acrocarpous
Didymodon tophaceus (Brid.) Lisa	+	-	-	-	Acrocarpous
Didymodon vinealis (Brid.) R.H.Zander	-	+	-	-	Acrocarpous
Gymnostomum calcareum Nees & Hornsch.	-	+	-	-	Acrocarpous
Pseudocrossidium hornschuchianum (Schultz) R.H.Zander	+	-	-	-	Acrocarpous
Streblotrichum convolutum (Hedw.) P.Beauv.	+	+	-	-	Acrocarpous
Syntrichia calcicola J.J.Amann	-	+	-	-	Acrocarpous
Syntrichia laevipila Brid.	-	-	+	-	Acrocarpous
Syntrichia montana Nees var. *calva* (Durieu & Sagot ex Bruch & Schimp.) J.J.Amann	-	+	-	-	Acrocarpous

Table. 10 (Continued)

Syntrichia ruraliformis (Besch.) Mans.	+	-	-	-	Acrocarpous
Syntrichia ruralis (Hedw.) F.Weber & D.Mohr	+	+	-	-	Acrocarpous
Syntrichia virescens (De Not.) Ochyra	-	-	+	-	Acrocarpous
Tortella flavovirens (Bruch) Broth.	+	-	-	-	Acrocarpous
Tortella nitida (Lindb.) Broth.	-	+	-	-	Acrocarpous
Tortella squarrosa (Brid.) Limpr.	+	+	-	-	Acrocarpous
Tortula inermis (Brid.) Mont	+	+	-	-	Acrocarpous
Tortula muralis Hedw.	-	+	-	-	Acrocarpous
Tortula revolvens (Schimp.) G.Roth	+	-	-	-	Acrocarpous
Tortula subulata Hedw.	+	+	-	-	Acrocarpous
Pylaisiaceae Schimp.					
Calliergonella cuspidata (Hedw.) Loeske	+	-	-	-	Pleurocarpous

Table 11. Mosses collected from Setif 1 University - Ferhat ABBAS.

Mosses	**Habitat**			**Biotypes**
Species / Family	**Terrestrial**	**Epilithic**	**Epiphytic**	**Acrocarpous/Pleurocarpous**
Bryaceae Schwägr.				
Bryum argenteum Hedw.	+	+	-	Acrocarpous
Bryum dichotomum Hedw.	-	+	-	Acrocarpous
Bryum radiculosum Brid.	-	+	-	Acrocarpous
Ptychostomum kunzei (Hornsch.) J.R. Spence	+	-	-	Acrocarpous
Dicranellaceae Schimp.				
Dicranella howei Renauld & Cardot	+	-	-	Acrocarpous
Ditrichaceae Limpr.				
Ceratodon purpureus (Hedw.) Brid.	+	-	-	Acrocarpous
Funariaceae Schwägr.				
Funaria hygrometrica Hedw.	+	-	-	Acrocarpous
Grimmiaceae Arn.				
Grimmia pulvinata (Hedw.) Sm.	-	+	-	Acrocarpous
Orthotrichaceae Arn.				
Orthotrichum diaphanum Brid.	-	-	+	Acrocarpous

Table. 11 (Continued)

Pottiaceae Schimp.				
Aloina aloides (Koch ex Schultz) Kindb.	+	-	-	Acrocarpous
Aloina rigida (Hedw.) Limpr.	+	-	-	Acrocarpous
Barbula unguiculata Hedw.	+	+	-	Acrocarpous
Crossidium aberrans Holz. & E.B.Bartram	+	-	-	Acrocarpous
Crossidium crassinervium (De Not.) Jur.	+	-	-	Acrocarpous
Didymodon acutus (Brid.) K.Saito	+	-	-	Acrocarpous
Didymodon vinealis (Brid.) R.H.Zander	+	-	-	Acrocarpous
Microbryum davallianum (Sm.) R.H.Zander	+	-	-	Acrocarpous
Pseudocrossidium hornschuchianum (Schultz) R.H.Zander	+	-	-	Acrocarpous
Pterygoneurum ovatum (Hedw.) Dixon	+	-	-	Acrocarpous
Streblotrichum convolutum (Hedw.) P.Beauv.	+	-	-	Acrocarpous
Syntrichia ruralis (Hedw.) F.Weber & D.Mohr	-	+	-	Acrocarpous
Syntrichia subpapillosissima (Bizot & R.B.Pierrot ex W.A.Kramer) M.T.Gallego & J.Guerra	-	+	-	Acrocarpous
Tortella inflexa (Bruch) Broth.	-	+	-	Acrocarpous
Tortula inermis (Brid.) Mont.	+	+	-	Acrocarpous

Table 11. (continued)

Tortula lindbergii Broth.	+	-	-	Acrocarpous
Tortula muralis Hedw.	-	+	-	Acrocarpous

4. New records

Based on the checklist of the Mediterranean mosses by Ros *et al.* (2013), this study revealed four new moss records for Algeria, including two species belonging to the Orthotrichaceae and two species belonging to the Pottiaceae. The locations of these new records are shown on the map below (Figure 33).

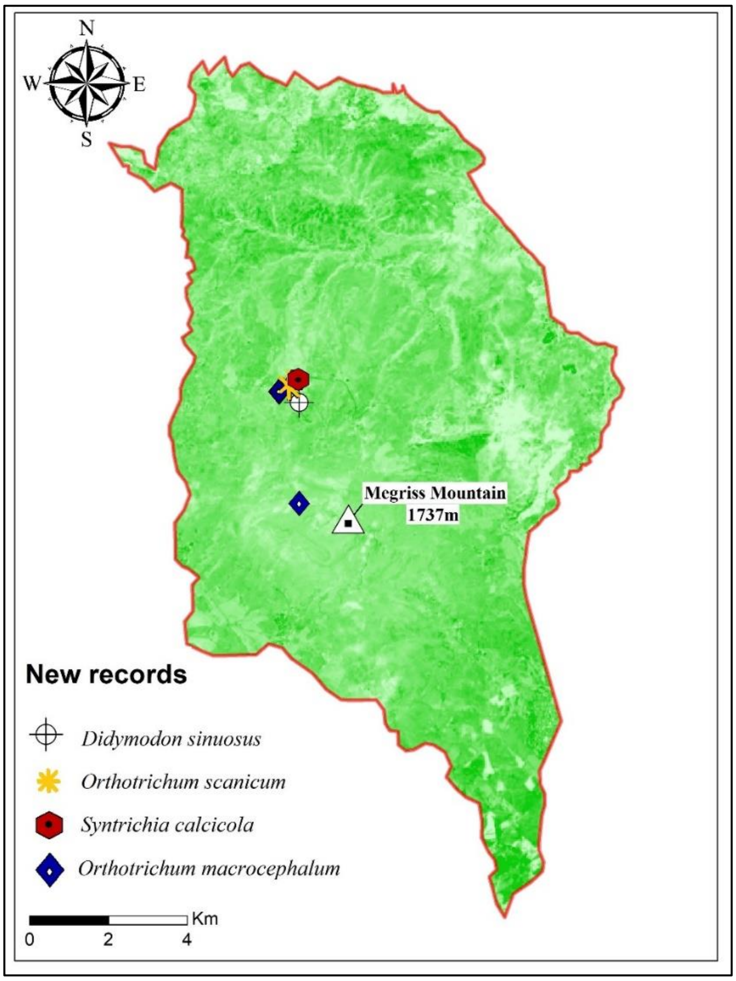

Figure 33. Map of the localities of the four new records collected from Megriss Mountain (Mazari, 2024).

4.1. *Didymodon sinuosus* (Mitt.) Delogne (Pottiaceae)

4.1.1. Specimen examined

Algeria. Setif: Megriss Mountain, Ain Guelou, 36°21'40.9"N 05°20'23.8"E, *ca* 1,149 m a.s.l., on a damp soil close proximity to a small stream, 04.10.2022, *leg*. A. Mazari, Boulaacheb private herbarium n° 29.

4.1.2. Morphological characteristics

Didymodon sinuosus is characterized by leaves that are crisped when dry (Jiménez *et al.*, 2004; Casas *et al.*, 2006), with undulate, sinuous margins that sometimes exhibit notches or irregular tooth-like features (Smith, 2004). The apices of these leaves are often missing, which is a distinguishing feature that separates *D. sinuosus* from other *didymodon* species (Shirzadian *et al.*, 2014). Our sample was recognized based on all the diagnostic characteristics mentioned above (Figure 34).

4.2. *Syntrichia calcicola* J.J.Amann (Pottiaceae)

4.2.1. Specimen examined

Algeria. Setif: Megriss Mountain, Ain Guelou, 36°21'46.7"N 05°20'27.7"E, *ca* 1,130 m a.s.l., on the base of an electric utility pole made of concrete substrate, 04.10.2022, *leg*. A. Mazari, Boulaacheb private herbarium n° 30.

4.2.2. Morphological characteristics

Syntrichia calcicola was identified as the sample exhibit all the diagnostic features stated by Guerra *et al.* (2006): leaves spreading when wet, ovate-lingulate, lingulate, lingulate-elliptic, and not constricted in the middle part. Its leaves are characterized by recurved margins up to the upper third, papillose-crenulate, and lack a differentiated border. The excurrent nerve ends in a hyaline hair, which may sometimes be brown at the base, and is weakly spiny. The cross section of the nerve with (1)2-3 layers of guide cells (eurycystes), (2)3-5 layers of dorsal stereids, without hydroids; with papillae on the dorsal surface, simple or bifurcated, 2.5 µm long (Figure 35).

4.3. *Orthotrichum macrocephalum* F.Lara, Garilleti & Mazimpaka (Orthotrichaceae)

4.3.1. Specimens examined

Algeria. Setif: Megriss Mountain, Ain Guelou, 36°21'40.0"N 05°20'19.8"E, *ca* 1,108 m a.s.l., on the lower part of the bark of *Fraxinus angustifolia*, 01.06.2021, *leg.* A. Mazari 11, Boulaacheb private herbarium n° 95; *Idem*, 04.10.2022, *leg.* A. Mazari 12, Boulaacheb private herbarium N° 67; Megriss Mountain, Oued El Bordj, 36°20'5.8''N 05°20'31.5''E, *ca* 1,554 m a.s.l., on the lower part of the bark of *Cedrus atlantica*, 01.06.2021, *leg.* N. Boulaacheb 10, Boulaacheb private herbarium nº 66; *Idem*, 25.10.2022, *Leg.* N. Boulaacheb 03, Boulaacheb private herbarium N° 94 (Mazari *et al.*, 2024).

4.3.2. Morphological characteristics

Orthotrichum macrocephalum was readily recognized as the samples showed all the diagnostic characteristics stated by Lara *et al.* (2009) and Guerra *et al.* (2014) in Mazari *et al.* (2024): small-sized plants with lingulate or lanceolate-lingulate leaves that have rounded or obtuse apices and costa that ends below the apex. The leaves feature recurved and unistratose margins, pluripapillose and unistratose laminal cells, and cylindrical gemmae containing 6 to 15 cells. Other morphological characters observed were the emergent capsule with eight longitudinal orange ribs and a star-shaped mouth when dry, which is scarcely constricted below the mouth, immersed stomata in the capsule wall, and very papillose endostome segments (Figure 36).

4.4. *Orthotrichum scanicum* Grönvall

4.4.1. Specimen examined

Algeria. Setif: Megriss Mountain, Ain Guelou, 36°21'40.0''N 05°20'19.8''E, *ca* 1,108 m a.s.l., on the medium part of the bark of *Fraxinus angustifolia*, 25.10.2022, *leg*. A. Mazari 13, Boulaacheb private herbarium n° 92 (Mazari & Boulaacheb, 2023).

4.4.2. Morphological characteristics

Orthotrichum scanicum was easily identifiable based on the presence of the diagnostic characteristics stated by Lara *et al.* (2009) and Guerra *et al.* (2014) in Mazari & Boulaacheb (2023): leaves linear-lanceloate to ovate-lanceolate with a costa ending below the apex, an acute and irregularly toothed apex, recurved and unistratose margins, unistratose laminal cells and, often with broad oval base. Leaves are also characterized by rounded upper cells, rectangular-elliptical median cells and rectangular basal cells. Furthermore, *O. scanicum* collected in our area was also characterized by capsules broadly emergent and which contain eight ribs, immersed stomata located in the lower ½ of the urn, exostome with eight pairs of teeth and endostome with 16 segments (eight long segments interspersed with eight short ones), often appendiculate. Spores 18–19 µm in diameter (Figure 37).

Figure 34. Microphotographs of the leaves of *Didymodon sinuosus* from Megriss Mountain (Boulaacheb private herbarium nº 29) (Microphotographs by Mazari Amira).

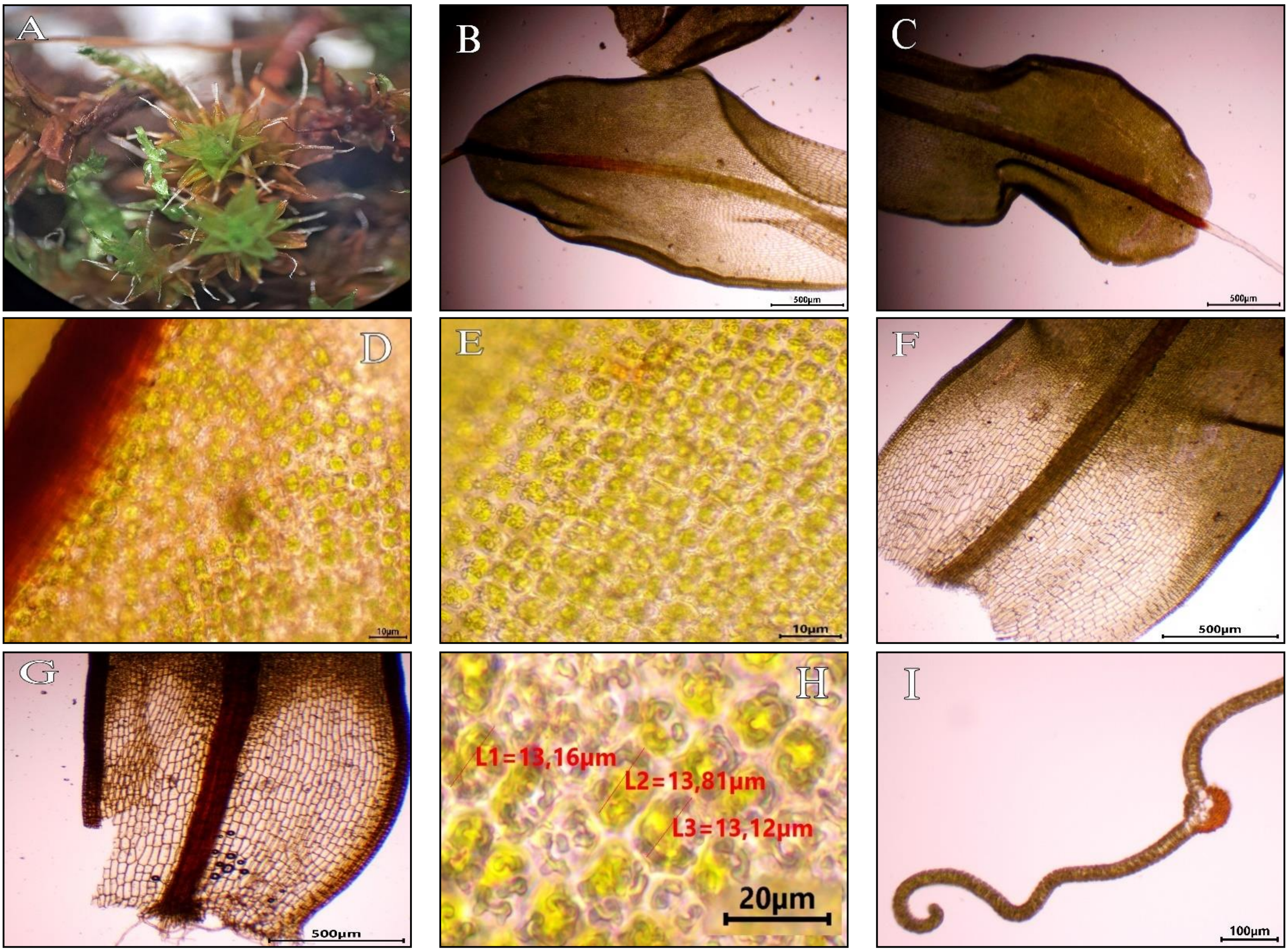

Figure 35. Microphotographs of *Syntrichia calcicola* from Megriss Mountain (Boulaacheb private herbarium nº 30): (A) Moist plant, (B-C) leaves, (D) apical cells, (E) median cells, (F G) basal cells, (H) median cells width measurements, (I) leaf cross-section at the median part (Microphotographs by Mazari Amira).

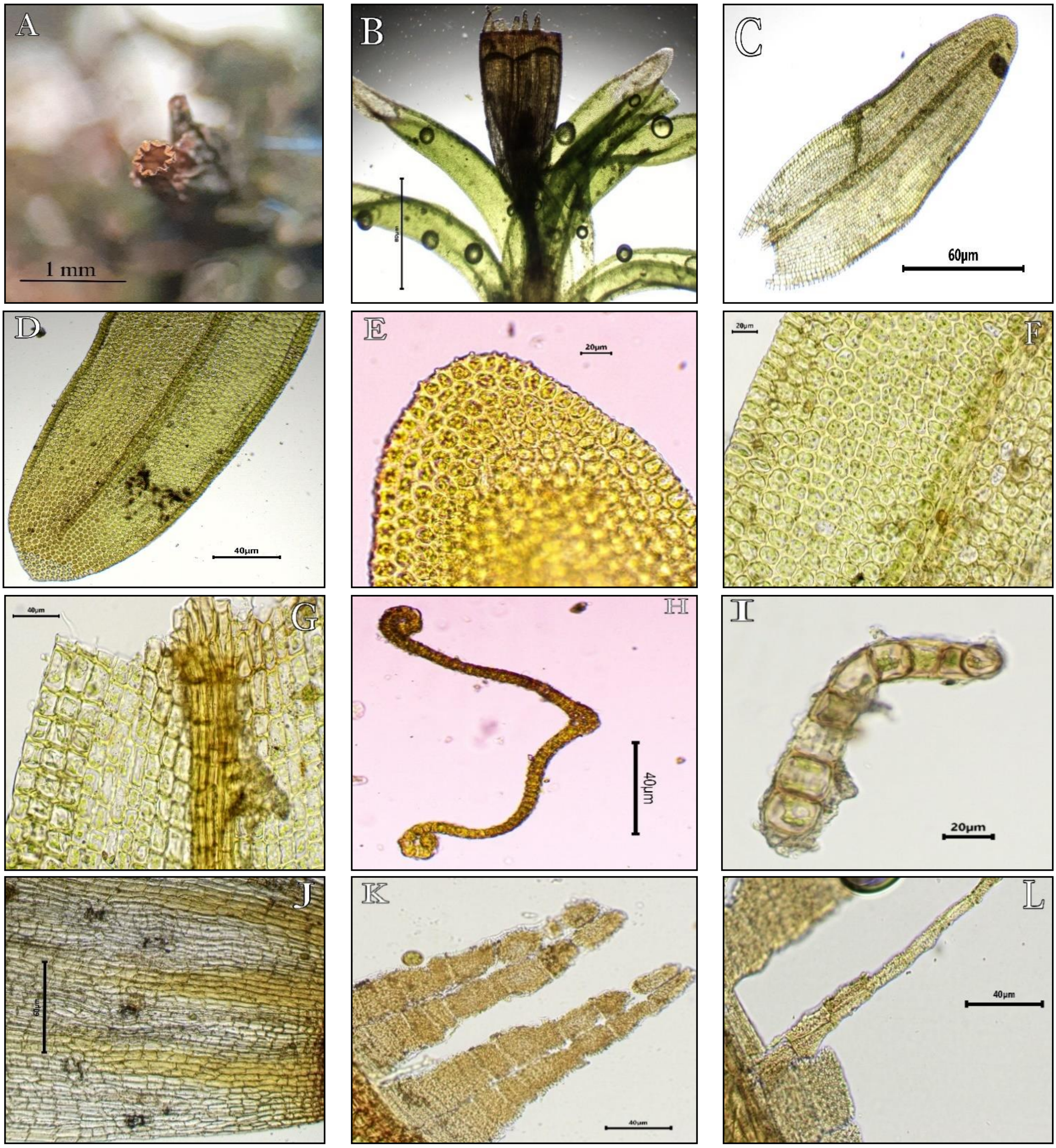

Figure 36. Microphotographs of *Orthotrichum macrocephalum* from Megriss Mountain (Boulaacheb private herbarium nº 95 and n° 66): (A) capsule showing the star-shaped mouth, (B) habitus of the plant, (C-D) leaves, (E) apical cells, (F) median cells, (G) basal cells (Mazari *et al.*, 2024).

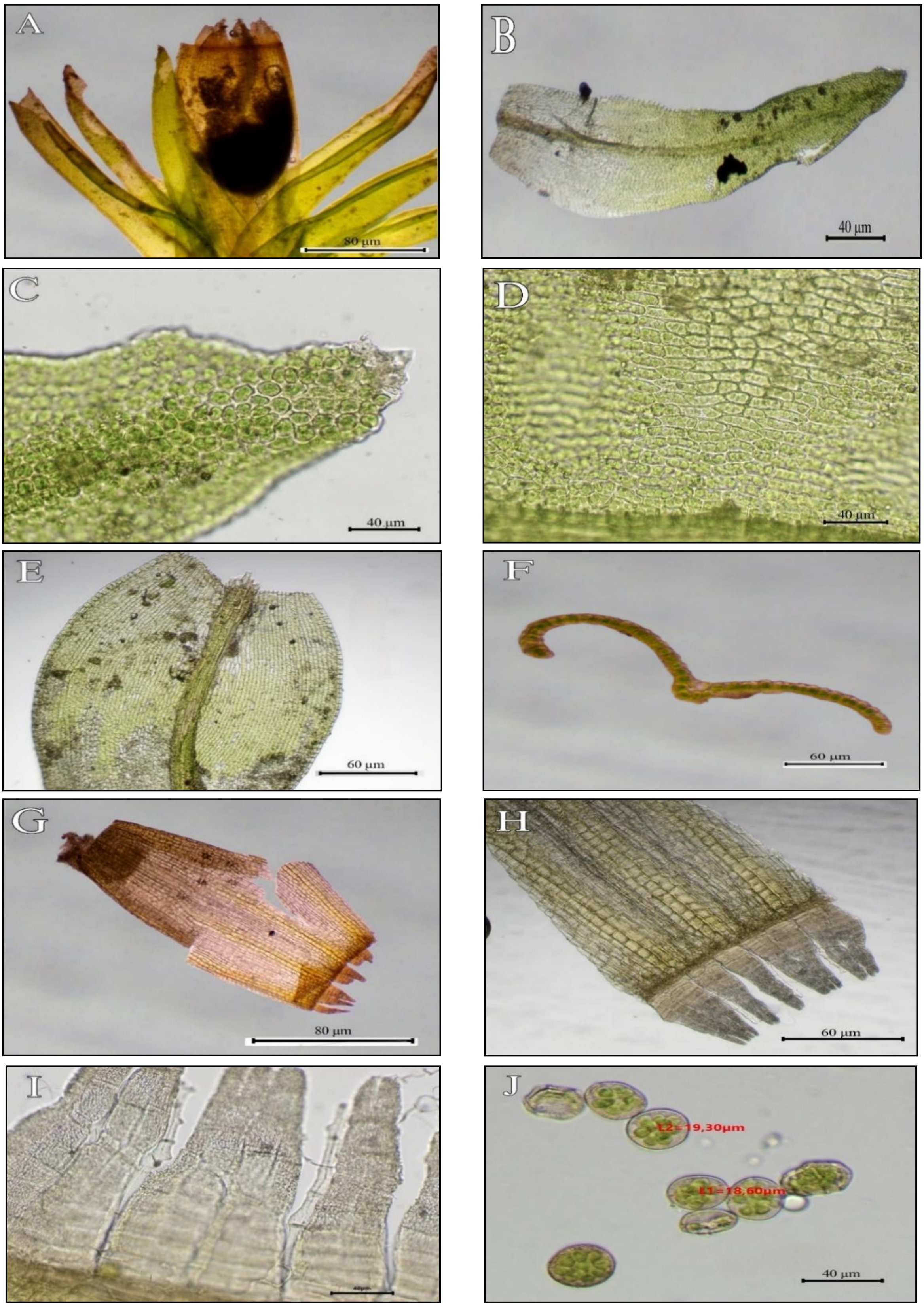

Figure 37. Microphotographs of *Orthotrichum scanicum* from Megriss Mountain (Boulaacheb private herbarium nº 92): (A) habitus of the plant, (B) leaf, (C) apex of leaf showing apical

cells, (D) median cells, (E) base of leaf, (F) leaf cross-section at base of leaf, (G-H) capsule wall showing ribs, immersed stomata and exostome teeth, (I) endostome segments and exostome teeth, (J) spores (Mazari & Boulaacheb, 2023).

5. Comparative approach between the two study areas

A comparative analysis was performed between Megriss Mountain and Setif 1 University - Ferhat ABBAS, which exhibit differences in climate and anthropogenic action. The analysis considered the specific and generic diversity of mosses, the biotype of mosses, and the diversity of moss habitats.

5.1. Specific and generic richness within moss families

Megriss Mountain has a greater number of botanical families compared to Setif 1 University - Ferhat ABBAS. Several families, including Amblystegiaceae, Bartramiaceae, Brachytheciaceae, Dicranaceae, Encalyptaceae, Fontinalaceae, and Hypnaceae, are entirely absent from Setif 1 University - Ferhat ABBAS. Additionally, the Dicranellaceae is completely absent from Megriss Mountain (Figure 38).

The Pottiaceae exhibits the highest number of species and genera in both areas, indicating its significant abundance and diversity. The number of species and genera in the Bryaceae is nearly the same in both study areas. However, there is a notable difference in the species and genera count of the Orthotrichaceae, with Megriss Mountain having a higher count.

The Grimmiaceae is represented by a single genus in both study areas, but there is a significant difference in the number of species between the two sites. Megriss Mountain has a much higher number of Grimmiaceae species compared to Setif 1 University - Ferhat ABBAS, which only has one species. Furthermore, the Funariaceae is the only family that exhibits the same number of species and genera in both sites.

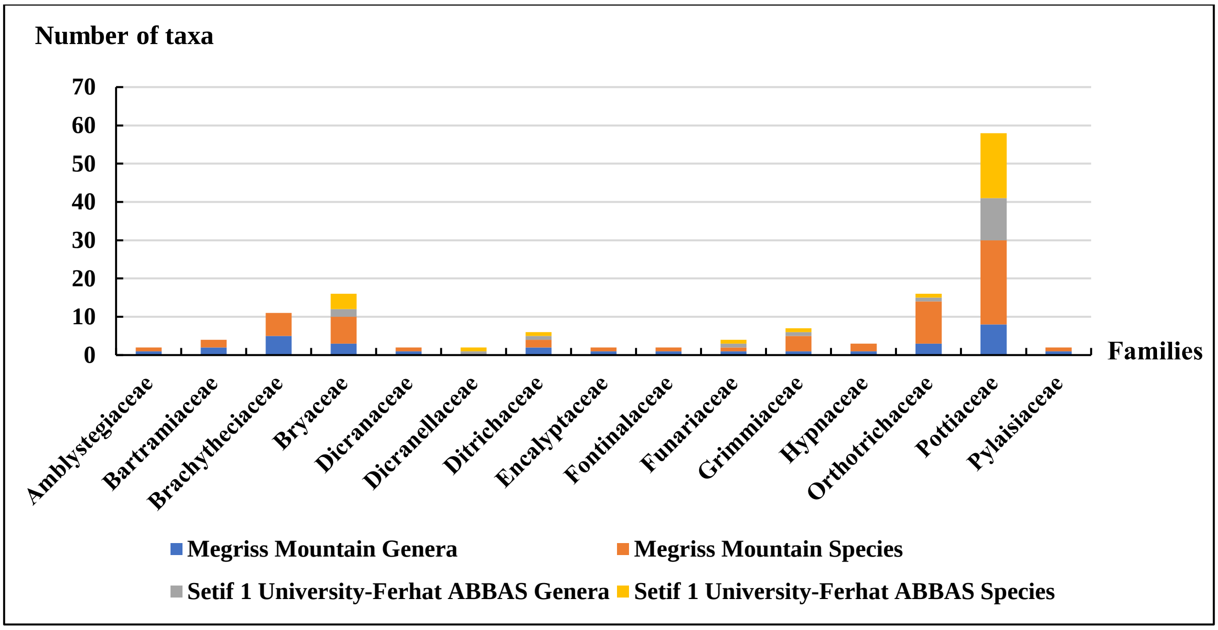

Figure 38. Distribution of genera and species within botanical families in Megriss Mountain and Setif 1 University - Ferhat ABBAS.

5.2. Diversity of moss species withing genera

The results indicate that the diversity of genera is significantly greater in Megriss Mountain than in Setif 1 University - Ferhat ABBAS, with several genera completely absent from each area. The most prevalent genera in both study areas belong to the Pottiaceae. Notably, several genera are entirely absent from Megriss Mountain, including *Aloina*, *Crossidium*, *Dicranella* (Müll.Hal.) Schimp., *Microbryum* Schimp., and *Pterygoneurum* Jur. Similarly, the following genera are completely absent from Setif 1 University - Ferhat ABBAS: *Brachytheciastrum* Ignatov & Huttunen, *Brachythecium* Schimp., *Calliergonella* Loeske, *Cheilothela* Broth., *Dicranum* Hedw., *Drepanocladus* (Müll.Hal.) G.Roth, Encalypta Hedw., *Fontinalis* Hedw., *Gymnostomum* Nees & Hornsch., *Homalothecium* Schimp., *Hypnum* Hedw., *Imbribryum* Pedersen, *Lewinskya*, *Philonotis* Brid., *Pulvigera* Plášek, Sawicki & Ochyra, *Rhynchostegium* Bruch & Schimp., and *Scleropodium* Bruch & Schimp. On the other hand, the genera *Barbula* Hedw., *Bryum*, *Ceratodon* Brid., *Funaria* Schwägr., *Pseudocrossidium* R.S.Williams, and *Streblotrichum* P.Beauv. are found in equal numbers at both sites (Figure 39).

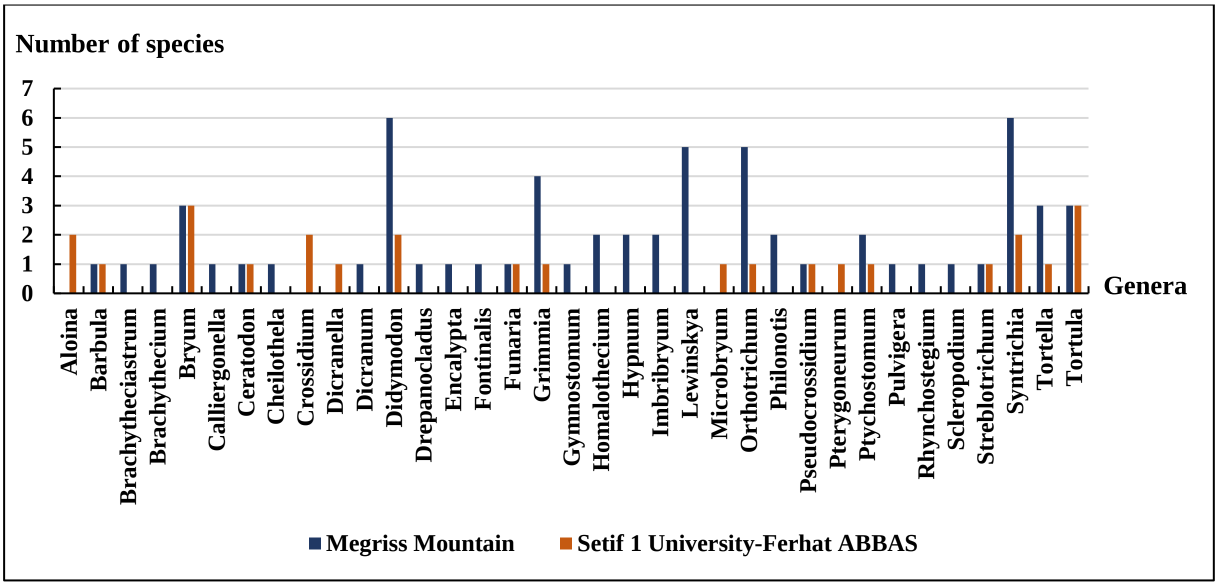

Figure 39. Number of species recorded for each genus at Megriss Mountain and Setif 1 University - Ferhat ABBAS.

5.3. Biotypes

The examination of moss biotypes from Megriss Mountain and Setif 1 University - Ferhat ABBAS revealed a higher prevalence of acrocarpous mosses compared to pleurocarpous mosses. Notably, there was a total absence of pleurocarpous mosses at Setif 1 University - Ferhat ABBAS (Figure 40).

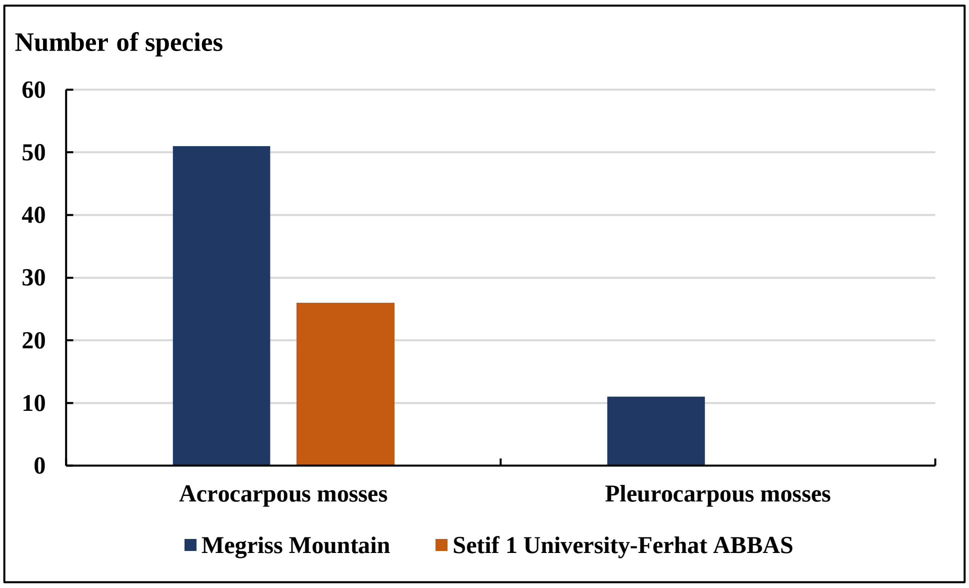

Figure 40. Biotypes of moss species collected from Megriss Mountain and Setif 1 University - Ferhat ABBAS.

6. Role of bryophytes in both study areas

Mosses play a crucial role in maintaining the biodiversity of both study areas by significantly contributing to various ecosystem processes and functions. Our understanding of their role is based on observations made during field and laboratory work, along with relevant literature.

Mosses absorb and retain large amounts of water from rain and fog, slowly releasing moisture into the air and helping to create a more humid microclimate in the regions where they thrive. For example, in Megriss Mountain, there are several cedar forests that are separated from each other. Some of these forests have a high coverage of mosses on their trunks and branches, while others have less moss coverage. The moss-rich forests exhibit higher humidity levels compared to those with less moss coverage.

Furthermore, mosses enhanced the biodiversity of the ecosystem by serving as habitats for a variety of organisms such as tardigrades, rotifers, *Alternaria* spores, etc (Figure 41).

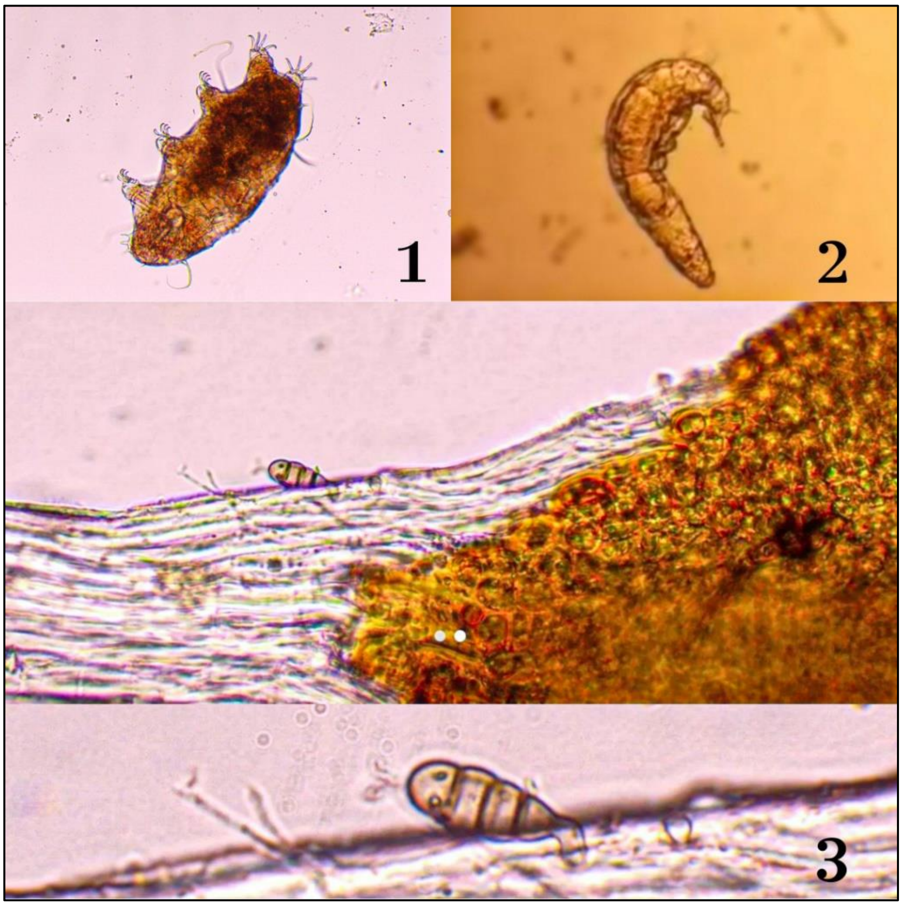

Figure 41. Diverse organisms inhabiting different mosses (Microphotographs by Mazari Amira); 1- Tardigrades (moss piglets), 2- Rotifers, 3- Spores of Alternaria.

Mosses add an extra layer of vegetation, contributing to the "vertical stratification", which increases habitat complexity by creating more spaces and resources for other organisms to live, grow, and interact.

They accumulate nutrients from the atmosphere and rainwater, storing them in their tissues. When they decompose, they release these nutrients into the soil, enriching it for other plants, and contributing to a more diverse ecosystem.

During the winter period, when trees are bare of leaves and soils lack colorful vegetation, mosses persist and promote biodiversity in ecosystems. They flourishing on soils, trees, walls, and rooftops, providing an aesthetically pleasing environment.

Among the identified moss species, *B. unguiculata*, *B. argenteum*, *Ceratodon purpureus* (Hedw.) Brid., *F. antipyretica*, *Funaria hygrometrica* Hedw., and *T. squarrosa*, have been used for ethnomedical purposes (Frahm, 2004; Chandra *et al.*, 2016; Motti *et al.*, 2023).

II. Discussion

The results revealed that the count of moss species on Megriss Mountain surpassed the number found at Setif 1 University - Ferhat ABBAS. This difference can be primarily attributed to the surface area of the both sites, as Setif 1 University - Ferhat ABBAS is much smaller compared to Megriss Mountain. Additionally, the presence of a wide variety of habitats at Megriss Mountain is likely a key factor in its capacity to host a larger diversity of moss species in comparison to Setif 1 University - Ferhat ABBAS. This observation is supported by Gignac & Dale (2005), who highlight that habitat heterogeneity increases bryophyte diversity. Furthermore, even if there are different types of substrates in urban areas, they are usually characterized by a low number of bryophytes. This is due to unfavorable environmental conditions, particularly water or air pollution (Wolski *et al.*, 2012).

Liverworts and hornworts generally require more moist and sheltered microhabitats compared to mosses. The lack of liverworts and hornworts observed in the study areas may be attributed to unfavorable environmental conditions, such as insufficient moisture, high soil dryness, inadequate shading, or excessive light exposure, which can inhibit their growth and development (Glime, 2017c, 2017e; Ruklani & Rubasinghe, 2021; Song *et al.*, 2023). Alternatively, their absence may be due to insufficient sampling efforts rather than their actual absence from the study areas, especially in Megriss Mountain.

Within Megriss Mountain, there is a significant dominance of the Pottiaceae, Orthotrichaceae, Bryaceae, and Brachytheciaceae. This dominance has been observed in various regions with a Mediterranean climate, as supported by several studies conducted in

Morocco (Cano *et al.*, 2002; Ahayoun *et al.*, 2016; Laouzazni *et al.*, 2018; El Harech *et al.*, 2020; Fadel *et al.*, 2020; Zaza *et al.*, 2020, 2021; Laouzazni *et al.*, 2021), France (Hugonnot & Celle, 2013), and Spain (Ros & Guerra, 1987; Rams *et al.*, 2014).

The Pottiaceae is recognized as the largest family within Bryopsida in terms of genera diversity (Zander, 1993). Moreover, the majority of moss species belonging to this family demonstrate exceptional adaptability to harsh environments, particularly arid conditions typical of open montane areas (Zander, 1993; Gradstein *et al.*, 2001). This, combined with the first observation, suggests that arid regions of North Africa (Ben Osman *et al*., 2021) or coastal regions of the Mediterranean could serve as suitable habitats for the Pottiaceae.

Moreover, the Orthotrichaceae stands as the second most diverse family in terms of species richness. All species inventoried within this family at Megriss Mountain were previously attributed to a single genus, *Orthotrichum*. This genus is recognized as one of the most abundant within the Orthotrichaceae (Lara *et al.*, 2016), with a global count of 163 species (Medina *et al.*, 2013) and 40 species specifically in the Mediterranean region (Ros *et al.*, 2013). The majority of these species are known to be epiphytic (Lara *et al.*, 1994, 2016; Lara & Mazimpaka, 2001).

Our investigation revealed that ten out of 11 species of Orthotrichaceae were thriving on trees, aligning with findings from previous studies by Draper *et al.* (2003, 2005, 2006), which highlighted the dominance of the family Orthotrichaceae and the genus *Orthotrichum* in the epiphytic bryoflora of various regions in Morocco, confirming their ecological significance in the Mediterranean region (Lara *et al.*, 1994; Lara & Mazimpaka, 2001). However, in recent years, there has been a significant taxonomical revision of the genus *Orthotrichum* (Draper *et al.*, 2021). European and Mediterranean species have been reclassified into three distinct genera: *Pulvigera* which includes *P. lyellii* (Hook. & Taylor) Plášek, Sawicki & Ochyra (*Orthotrichum lyellii* Hook. & Taylor) (Plášek *et al.*, 2015), *Lewinskya* for the phaneroporous and monoicous taxa of *Orthotrichum*, and *Orthotrichum* s.s. for the rest of species (Lara *et al.*, 2016).

In the Megriss Mountain, out of the 63 taxa inventoried, two species—*O. diaphanum* and *L. acuminata*—were widely spread within the *C. atlantica* forest. These species are common epiphytic mosses in the Mediterranean area, and their prevalence likely indicates the predominantly temperate conditions of the forests, which feature a well-developed epiphytic stratum (Draper *et al.*, 2006).

Other species were also observed to be widespread across the area: *D. insulanus*, *G. pulvinata*, and *T. squarrosa*. This common distribution has also been noted in some Moroccan mountain regions (Draper *et al.*, 2006; Laouzazni *et al.*, 2021). This similarity may be attributed to the comparable climatic and edaphic conditions of both Algeria and Morocco (Mazari & Boulaacheb, 2023).

At Setif 1 University - Ferhat ABBAS, the Pottiaceae and Bryaceae were the most prominent. According to Zuo *et al.* (2013), some species belonging to these families demonstrate a capacity to thrive in environments with high levels of heavy metal pollution, which may explain their prevalence in our urban study area. Moreover, both the Bryaceae and the Pottiaceae are expected to be prevalent and widely distributed groups. These families include cosmopolitan species that can thrive in urban areas as well as in challenging environmental conditions (Floyed & Gibson, 2012; Yu *et al.*, 2019).

Furthermore, out of the 26 species surveyed at Setif 1 University - Ferhat ABBAS, three species—*B. argenteum, O. diaphanum,* and *T. muralis*—were found to be widely distributed. These species are commonly found in areas with high levels of urbanization and traffic (Kirmaci & Ağcagil, 2009). Specifically, *B. argenteum* and *T. muralis* are recognized for exhibiting higher resistance to air pollution compared to other species (Inglis & Hill, 1974), while *O. diaphanum* has been characterized as tolerant to high temperatures and aridity (Dierssen, 2001). The prevalence of these three species is also noted in other studies conducted in urban areas (Fudali, 2006; Isermann, 2007; Kirmaci & Ağcagil, 2009; Marka & Zaloshnja, 2017; Fudali, 2019). Additionally, *C. purpureus*, *Didymodon vinealis* (Brid.) R.H.Zander, *F. hygrometrica*, and *G. pulvinata*, are also recognized for their widespread presence in urban environments (Isermann, 2007; Barbottin, 2016), indicating their capacity to withstand high levels of pollutants. This may explain their presence in both study areas. Notably, *C. purpureus* and *F. hygrometrica* produce sporophytes under highly polluted conditions (Bahuguna *et al.*, 2013).

According to Magill (1976), species belonging to the genera *Aloina* and *Crossidium* typically thrive in areas with direct sunlight and receive little moisture. Similarly, the genera *Microbryum* and *Pterygoneurum* prefer dry environments, as indicated by Brinda *et al.* (2011) and Alvarez & Suárez (2023). This characteristic may account for their absence in Megriss Mountain.

The results reveal that Megriss Mountain exhibits a greater prevalence of acrocarpous mosses compared to pleurocarpous mosses, whereas Setif 1 University - Ferhat ABBAS has no occurrences of pleurocarpous mosses. The disparity in the prevalence of acrocarpous mosses over pleurocarpous mosses may be attributed to the ability of acrocarpous mosses to adapt to regions with varying degrees of moisture and sunlight. In contrast, pleurocarpous mosses typically thrive in humid and shaded environments (Govindapyari *et al.*, 2012; Mazari &

Boulaacheb, 2023). Megriss Mountain, as a subhumid region with relatively high levels of precipitation compared to the Setif 1 University - Ferhat ABBAS, provides favorable conditions for pleurocarpous mosses to thrive. However, pleurocarpous mosses are sensitive to both pollution and extended periods of dryness, making them rare or even completely absent in urban areas (Gerdol *et al.*, 2002). The study of Isermann (2007) conducted at the Urban Area "Campus of the University of Bremen" supports these findings regarding the scarcity of pleurocarpous mosses in an urban environment.

In terms of habitats, terrestrial mosses exhibited the highest prevalence, followed by epilithic mosses and terrestrial-epilithic mosses. The predominance of terrestrial mosses at Megriss Mountain and Setif 1 University - Ferhat ABBAS can be attributed to the abundance of terrestrial substrates, which are more widespread and easily accessible for bryophytes. The higher occurrence of epilithic mosses is likely influenced by specific ecological factors such as the abundance of stones, boulders, and rocky substrates, particularly in Megriss Mountain. Furthermore, the dominance of moss species that thrive in both soil and rock substrates supports these observations.

Epiphytic bryophytes are highly sensitive to variations in humidity and temperature, necessitating shaded environments with consistent moisture levels (Kutnar *et al.*, 2023). In urban areas, where precipitation is often polluted and water is scarce, this creates a significant stress for epiphytes (Fojcik *et al.*, 2015). Their vulnerability to global warming is amplified by their tight coupling to atmospheric conditions (Gradstein *et al.*, 2009). However, epiphytic *Orthotrichum* species exhibit heightened sensitivity to even low levels of pollutant compared to other types of moss (Slack, 2011). This may explain the absence of epiphytic mosses, with the exception of *O. diaphanum*, at the Setif 1 University - Ferhat ABBAS. Bryofloristic data indicate that urban areas are typically devoid of epiphytic bryophytes, with this ecological group mainly persisting in large parks and urban forests (Fudali, 2019).

The genus *Grimmia* predominantly thrives on rocks (Delgadillo-Moya, 2015). However, there are few species within this genus, such as *G. pulvinata*, which we have observed growing on both rocks and trees in Megriss Mountain. This species has been also found growing as an epiphyte in various areas throughout Morocco (Draper *et al.*, 2003, 2005, 2006; Zaza *et al.*, 2021).

According to the literature, *D. sinuosus* thrives in moist environments, typically on basic rocks near streams and rivers (Smith, 2004; Guerra *et al.*, 2006), as well as on protected limestone soils (Guerra *et al.*, 2006). The corticolous habitat is uncommon (Zander, 1978), but it can occasionally be found on *Q. ilex*, *Ulmus* (Guerra *et al.*, 2006). Additionally, it was collected from the bark of a mulberry tree in Greece (Zander, 1978). Notably, the saxicolous habitat of this species has not been observed in North Africa, as indicated by our study and other studies conducted in Morocco (Zaza *et al.*, 2020, 2021), where it was found to thrive exclusively in soils.

According to the checklist of Ros *et al.* (2013) and considering the recent nomenclature by Hodgetts *et al.* (2020), Algeria was known to have nine species of *Didymodon* and one subspecies. However, with the recent discovery of new species within this genus, the total count of *Didymodon* species in Algeria has now increased to ten.

Syntrichia calcicola is commonly recognized as a terrestrial species found on basic soils or as a saxicolous species on limestone or sandstone substrates, occasionally inhabiting crevices or gaps in rocks with soil deposits (Casas *et al.*, 2006; Guerra *et al.*, 2006). Our research, alongside a study conducted in the Republic of Macedonia (Papp *et al.*, 2016), has demonstrated the capacity of *S. calcicola* to thrive even on concrete surfaces.

Algeria was previously documented to have 11 species and three varieties of *Syntrichia* (Ros *et al.*, 2013), Nevertheless, following the identification of new species within this genus, the overall number of *Syntrichia* species in Algeria has increased to 12.

Orthotrichum cupulatum var. *cupulatum* is typically found on limestone rocks (Guerra *et al.*, 2014; Plášek *et al.*, 2023) or stones in exposed habitats (Plášek *et al.*, 2023). It can also be found as an epiphyte on the bark of various trees, such as *Juglans regia* L., *Juniperus oxycedrus* L., *J. thurifera* L., *Olea europaea* L., and *Q. ilex* subsp. *ballota* (Desf.) Samp. Its habitat is primarily in Mediterranean regions (Guerra *et al.*, 2014). In our study, the species was observed growing for the first time on *C. atlantica* tree; an endemic species of Northern Africa that holds significant ecological importance within the Mediterranean mountain regions (Demarteau *et al.*, 2007).

On the other hand, the *O. macrocephalum* specimen, collected in Ain Guelou locality was found growing on the lower part of the bark of *F. angustifolia* alongside other epiphytic mosses such as *O. diaphanum*, other species of the Orthotrichaceae, and *Syntrichia laevipila* Brid. This species is known to thrive on the trunks of flowering plants, particularly those belonging to the Fagaceae family (*Quercus canariensis* Willd., *Q. faginea* Lam., *Q. ilex*, *Q. suber* L.) and the Oleaceae family (*F. angustifolia*) (Lara *et al.*, 1994; Garilleti *et al.*, 1997), within an elevation range of 1,000 to 2,600 m (Draper *et al.*, 2006). In a specific locality, Oued El Bordj, *O. macrocephalum* was also observed growing on *C. atlantica* for the first time.

Interestingly, the xerophytic moss *O. macrocephalum* (Draper *et al.*, 2006) and the occasional epiphytic moss *O. cupulatum* var. *cupulatum*, which typically grows in exposed habitats, seem to thrive in the humid environment of cedars. This new habitat provides an opportunity to gain insight into the ecology of the *Orthotrichum* genus, which generally grows in dry, sunny habitats as epiphytes on the bark of deciduous trees or shrubs (Plášek & Ochyra, 2020). Furthermore, this finding can contribute valuable information on the tolerance and ecological requirements of Mediterranean epiphytes.

Recent research has revealed that *O. scanicum*, previously classified as a rare and threatened species in Europe and listed on the global red list of bryophytes, is actually widespread and commonly found in regions surrounding the Mediterranean Sea, such as Morocco (Blockeel, 2012), where it has been observed growing at elevations between 1,050 and 1,950 m. This species can be found in various types of forests, growing on the bases, branches, and trunks of different phorophytes (Draper *et al.*, 2003).

According to the checklist of Ros *et al.* (2013) and the recent nomenclature (Hodgetts *et al.*, 2020), a total of 17 species and one variety of the genus *Orthotrichum* s.l. have been reported from Algeria. This includes *Pulvigera lyellii* (Hook. & Taylor) Plášek, Sawicki & Ochyra, six species of *Lewinskya*, and ten species plus one variety of *Orthotrichum* s.s. The discovery of two new species—*O. macrocephalum* and *O. scanicum*—has increased the number of *Orthotrichum* species in Algeria to 12.

Numerous recent studies have made substantial contributions to the understanding of the Orthotrichaceae; however, global knowledge and diversity within this family remain only moderately understood (Draper *et al.*, 2022). Lara & Mazimpaka (2001) indicate that the high species diversity observed in *Orthotrichum* s.l. suggests that the Mediterranean region could represent a center of diversity for this group. Algeria, as a large Mediterranean country characterized by its varied geography and climate, can considerably contribute to this context.

The discovery of four new species demonstrates that exploring previously unstudied regions allows for the expansion of the bryophyte catalog of Algeria. Unfortunately, the absence of historical data from these study regions hinders our ability to compare the current moss flora with past records. This lack of previous information poses a challenge in evaluating any changes or patterns in the composition of bryophyte species over time.

Conclusion and perspectives

The inventory of bryophytes in various regions of Algeria represents a significant contribution to understanding the Mediterranean bryophyte flora. The Algerian climate and landscapes are highly variable, which can give rise to the richness and diversity of bryophytes. These bryophytes, thriving in a broad spectrum of habitats, emerge as a vital component of the biodiversity of the country. Despite this, there are limited historical studies on this group in Algeria, with only one recent study available. In this context, recent surveys conducted in Megriss Mountain and Setif 1 University - Ferhat ABBAS aimed to establish a preliminary understanding of moss diversity in both peri-urban and urban areas. Additionally, these surveys sought to elucidate the key relationships between these species and their environment, shedding light on how environmental factors impact the distribution of various moss taxa. The results of these investigations revealed a list of 89 moss taxa. As a preliminary inventory, this represents an important aspect of biodiversity that reflects the diversity of the ecosystems and vascular flora of both study areas.

The survey conducted in the peri-urban area, Megriss Mountain, has identified 63 moss species, including 14 families and 30 genera. Amon these, 52 species were acrocarpous, while the remaining 11 were pleurocarpous. In contrast, in the urban area, Setif 1 University - Ferhat ABBAS, a total of 26 moss species have been identified, distributed among seven families and 18 genera, all of which were acrocarpous.

In Megriss Mountain, the dominant families were the Pottiaceae, Orthotrichaceae, Bryaceae, and Brachytheciaceae. In contrast, at Setif 1 University - Ferhat ABBAS, the prevalent families were the Pottiaceae and Bryaceae. Notably, the Pottiaceae family is recognized for its ability to tolerate drought conditions.

The genera *Didymodon*, *Syntrichia*, *Lewinskya*, and *Orthotrichum* exhibited the highest diversity in Megriss Mountain. On the other hand, at Setif 1 University - Ferhat ABBAS, *Bryum* and *Tortula* are the most diverse genera.

The discovery of four new species of mosses belonging to the Othrotrichaceae and Pottiaceae families in Megriss Mountain indicates a significant lack of knowledge regarding moss diversity in Algeria. This highlights the urgent need for further surveys to collect and identify more species in Algeria, update the bryoflora of the country, and contribute to a better understanding of the ecology and distribution of the Orthotrichaceae and the Pottiaceae in general and the species *D. sinuosus*, *O. macrocephalum*, *O. scanicum* and *S. calcicola* in particular. Further studies should be conducted to characterize bryophyte species and verify their geographical distribution and conservation status.

Unfortunately, the lack of historical data from both study areas prevents a comparison of the current bryophyte flora with past records. This absence of previous information makes it challenging to assess any changes or trends in bryophyte species composition over time. Nevertheless, this study represents a significant and recent addition to the extensive research conducted in diverse Mediterranean countries such as France, Greece, Italy, Spain, and Morocco.

Much work still needs to be carried out to achieve a thorough understanding of the mosses of Megriss Mountain and Ferhat Abbas University. Several unexplored locations remain in Megriss Mountain, suggesting the possibility of discovering a significantly higher number of species than currently identified. Furthermore, many new species identifications are expected, as well as the possibility that nearly all species found in Morocco and southern Spain will also be present in Algeria, given their shared climatic, vegetation, and physical characteristics.

Additionally, many ecological observations are required in the field to better interpret the spatial distribution of species and to assess the long-term effects of climate change on them. This is essential for identifying vulnerable species and developing conservation strategies. Long-term observations also provide valuable insights into the ecological requirements, behaviors, and interactions of species within their natural habitats, which is crucial for successfully cultivating them in controlled settings, such as laboratories. This is especially important if we aim to utilize their chemical compounds, as distinguishing one species from another in the field can be challenging, especially when some species are often mixed with algae and fungi. Bryophytes are frequently used as biological indicators globally, making them valuable for assessing pollution levels. Thus, they should be included in future studies addressing pollution.

Finally, the collaboration with researchers on an international scale promotes the exchange of information, the development of techniques, and conservation strategies for our bryophyte heritage.

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Annexes

Glossary

All challenging terms referenced in this dissertation have been explained in the glossary provided below. This glossary was compiled based on the works of (Vanderpoorten & Goffinet, 2009).

Archegonium (pl. archegonia): female sex organ composed of a stalk, a venter holding a single egg and a neck that is hollow and open at maturity, and provides the gateway for the sperm cell to reach the egg.

Autoicous: male and female organs on the same plant but in distinct inflorescences.

Bud: structure produced by the protonema.

Bulbil: vegetative bud-like propagule.

Calyptra: membranous structure derived at least in part from the modification of the archegonium following fertilization.

Capsule: spherical or elongate structure enclosing the spore-producing tissue.

Columella: axial sterile tissue in mosses and hornworts surrounded by sporogenous tissue.

Crenulate: with rounded teeth.

Dioicous: relative to a unisexual plant (archegonia and antheridia on separate plants).

Diploid: 2n, contains sets of chromosomes (organ, tissue, cell, …).

Elater: single elongated cell in the sporangium of liverworts, and hence of endothecial origin, with a wall that is reinforced by a spiral thickening, which accounts for the hygroscopic movement of the cell upon dehydration.

Elliptical: ellipse-shaped.

Emergent: referring to the capsule, only partly projecting beyond the tips of perichaetial leaves.

Endostome: in the arthrodontous mosses, inner peristome.

Excurrent: nerve that extends beyond the leaf apex.

Exostome: relative to an arthrodontous capsule, outer peristome.

Exothecial cells: outer cells of the capsule wall.

Gametangium (pl. gametangia): sex organ borne on the haploid gametophyte.

Gamete: haploid reproductive cell.

Gametophyte: multicellular haploid stage developing the sex organs.

Gemma (pl. gemmae): specialized asexual reproductive propagule.

Guide cells (eurycystes): large cells filled with a vacuole found in the costa (nerve, midveins) of some mosses.

Habit: general appearance of a plant.

Hair-point: long, fine point often formed by the excurrent nerve.

Haploid: 1n, one set of chromosomes.

Heteroicous: polyoicous, with several types of gametangia on the same plant.

Hyaline: colorless and transparent or translucent.

Hydroid: conductive cell, elongated and with thin and concave walls, present in the central strand or in the costa of some bryophytes.

Immersed: 1. Referring to a capsule exceeded by the perichaetial leaves. 2. Referring to the stomata below the epidermis of capsule.

Lanceolate: lance-shaped.

Leptoid: specialized cell in the central strand of the stem, the costa and the seta of some mosses involved in the conduction of photosynthate and thus analogous to the sieve cells of angiosperms.

Lignin: polymer impregnating the cell walls of water conducting cells in vascular plants.

Lingulate: tongue-shaped.

Meiosis: two successive nuclear divisions leading to the reduction of the number of chromosomes in the cell, from the diploid (2n) mother-cell to the haploid (n) daughter cells.

Monoicous: with antheridia and archegonia on the same plant, bisexual.

Monophyletic: refers to a group defined by a single common ancestor and all of its descendants.

Oblong: rounded at both ends, longer than broad and wider in the middle.

Oil body: in some liverworts, in a cell, structure limited by a membrane and containing particular terpenes.

Operculum (lid): flat to conical lid of the capsule of mosses and some liverworts that is shed upon dehiscence.

Ovate: outline of an egg with base broader than apex.

Papillae: cell ornamentation, small protuberance.

Papillose: with one or several papillae per cell.

Paraphyllium (pl. paraphyllia): photosynthetic filamentous or foliose cauline appendages in mosses, likely involved in external water conduction.

Paraphysis: sterile hyaline or yellowish hair intermixed with antheridia and archegonia.

Paroicous: monoicous plant with antheridia and archegonia on the same inflorescence but non mixed, located in different bracts.

Perichaetial leaves: specialized leaves surrounding archegonia.

Peristome: circular structure (one or two rows of teeth) present at the mouth of a moss capsule.

Phenotype: appearance characters of a species resulting from the interaction of genotype and the environmental conditions.
Pluripapillose: relative to a cell, which has several papillae.
Propagule (Pl. propagules): body serving for vegetative reproduction of the plant, with the appearance of a reduced bud, branch, or leaf.
Protonema (pl. protonemata): first multicellular stage following the germination of a spore or an asexual propagule.
Pseudo-elater: uni- or multicellular filamentous structure produced within the sporangium of hornworts.
Recurved: curved backwards, downwards.
Rhizoid: filament that affixes to substratum (multicellular in mosses, unicellular in liverworts).
Segment: the main division of the endostome.
Seta (pl. setae) (axis): stalk of the sporophyte terminated by the sporangium in liverworts and mosses.
Spinose, spiny: with sharp teeth, or with high or sharp papillae or mamillae.
Sporangium (pl. sporangia): specialized region of the sporophyte of land plants within which spore mother-cells are formed and undergo meiosis to yield haploid spores.
Spore: haploid cell produced by meiotic division of sporangial cells.
Sporophyte: multicellular stage of the life cycle of plants characterized by a diploid genome and producing spores in a specialized tissue, the sporangium.
spreading: relative to a habit of leaves or branches, more or less horizontal and perpendicular to the axis (an angle of 45° or more with the axis).
Stereid: thick-walled cell supporting the costa or stem in some mosses.
Stoma (pl. stomata): opening formed in between two differentiated epidermal cells (the guard cells).
Synoicous: with antheridia and archegonia mixed in the same inflorescence.
Theca (urn): spore bearing portion of the capsule.
Tuber: underground vegetative propagule.
Vaginula: minute sheath surrounding the base of the seta, derived from the wall of the archegonium, remaining after the separation of the calyptra.
Zygote: first stage of the diploid phase of the life cycle, resulting from the fusion of a sperm cell with an egg.

List of publications

1- **Mazari, A**., & Boulaacheb, N. (2023). Contribution to the knowledge of the mosses of Megriss Mountain (Algeria). *Biosystems Diversity*, *31* (4), 542–547. https://doi.org/10.15421/012364

2- **Mazari, A**., Boulaacheb, N., & Ros, R. M. (2024). A new moss record for Algeria: *Orthotrichum macrocephalum* F. Lara, Garilleti & Mazimpaka. *Egyptian Journal of Botany*, *64* (2), 547–554. https://doi.org/10.21608/ejbo.2023.199586.2279

List of communications

1- **MAZARI Amira**, ROS Rosa Maria, and BOULAACHEB Nacira. Les bryophytes et leur place dans les écosystèmes des Hautes Plaines Sétifiennes (Algérie du Nord). Poster presentation. International Seminar on Biodiversity, Valorization and Conservation of Urban and Forest Ecosystems: (In support of sustainable development). April 28-29, 2021.

2- **MAZARI Amira** and BOULAACHEB Nacira. Etude de la diversité des Pottiaceae dans les Hautes Plaines Sétifiennes : famille résistante à la sécheresse. Poster presentation. Premier Séminaire National en Biologie Végétale et Environnement « SNBVE 2021 ». November 24-25, 2021.

3- **MAZARI Amira** and BOULAACHEB Nacira. Bryophytes of the Setifian High Plains: An ethno-medical review. Poster presentation. The 1st International Forum of Pharmaceuticals Sciences. May 6, 2023.

4- **MAZARI Amira** and BOULAACHEB Nacira. Mosses diversity within urban areas: case study of Ferhat Abbes University Setif 1 (Algeria). Poster presentation. 1st International Seminar on Ecology and Biotechnology, in Mediterranean Atmosphere Climate (ISEBMCE’23). November 14-15-16, 2023.

5- **MAZARI Amira** and BOULAACHEB Nacira. The use of bryophytes of Jbel Megriss as bioindicators of pollution: a literature review. Poster presentation. The Second National Seminar on Environment & Gestion Durable (HYBRID-SNEGD’23). December 09-10, 2023.

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A New Moss Record for Algeria: *Orthotrichum macrocephalum* F. Lara, Garilleti & Mazimpaka

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THE BRYOFLORA of the Setifian High Plains, which situated in the Northeastern region of Algeria is poorly known. Megriss Mountain is one of the most important ecosystems in this region. The examination of Orthotrichaceae samples collected during bryophytes diversity investigations in the northern part of Megriss resulted in the identification of the epiphytic species; *Orthotrichum macrocephalum* F. Lara, Garilleti & Mazimpaka. The identification was made based on its leaves with rounded or obtuse apices, recurved margins, pluripapillose laminal cells, the presence of propagules, emergent capsule with eight longitudinal orange ribs and star-shaped mouth when dry, scarcely constricted below the mouth, immersed stomata in the capsule wall and the papillose endostome segments. This acrocarpous moss with a marked affinity for the Mediterranean climate has never been recorded in the Algerian bryoflora. A comprehensive description, microphotographs, and distribution map in Algeria of this species are provided. Moreover, its ecology is also discussed.

Keywords: Algeria, Mediterranean Region, Megriss Mountain, Orthotrichaceae, Setifian High Plains.

Introduction

Bryophytes are a group of non-vascular plants (Patiño & Vanderpoorten, 2018; Das et al., 2022) that include mosses, liverworts, and hornworts (Mishler, 2001). Approximately 18,000-25,000 species of bryophytes have been identified globally (Sabovljević et al., 2022), which makes them considered as the most diverse group after the flowering plants (Mishler, 2001; Renzaglia et al., 2007; Goffinet et al., 2009; Bahuguna et al., 2013; Chandra et al., 2016). Among the bryophytes, mosses are the most diverse in terms of species richness (Crandall-Stotler & Bartholomew-Began, 2007), with about 12,000 (Vanderpoorten & Goffinet, 2009) and 14,000 (Asakawa & Ludwiczuk, 2017; Das et al., 2022) species worldwide. Moreover, bryophytes are ubiquitous plants (Hodgetts et al., 2019) that can occupy a variety of habitats (Crandall-Stotler & Bartholomew-Began, 2007; Budke et al., 2018; Taha, 2020; Dziwak et al., 2022) compared to vascular plants (Sabovljević et al., 2022). Due to their structure, bryophytes are very sensitive to environmental conditions (Sabovljević et al., 2022), which makes them good indicators for environmental changes (Hallingback & Hodgetts, 2000; Mishler, 2001; Das et al., 2022), especially the epiphytic bryophytes which are predictably sensitive to global warming because of their direct connection to atmospherical conditions (Gradstein, 2008).

Despite the progress of research for this group in general and epiphytes in particular, there remains a paucity of knowledge regarding their ecology and geographical distribution, mainly in countries where they are understudied or

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neglected, the case of Algeria. Indeed, vascular plants are extensively studied and updated. In contrast, except for the only study conducted in northeastern Algeria by Boukhatem et al. (2017), all bryological explorations in Algeria are very ancient (Jelenc, 1955, 1967). Ros et al. (1999) summarized all available sources to compile an annotated bryophyte checklist of North Africa that was also updated in the Mediterranean checklists of liverworts and mosses (Ros et al., 2007, 2013). To update the Algerian bryoflora, particularly that of the northern part of the Setifian High Plains, Megriss Mountain was chosen to be explored, which is considered one of the most interesting and important ecosystems in terms of biological and landscapes diversity (Boulaacheb, 2013). This landscape diversity allows the creation of microhabitats and offers favorable conditions for the growth of bryophytes, such as trees on which epiphytic bryophytes develop. According to Bahuguna et al. (2013), epiphytic bryophytes play a crucial role in water balance and humus formation in habitats, specifically in gymnosperm forests.

The present work aims to provide knowledge on the geographical distribution and the ecology of an epiphyte moss reported for the first time in Algeria. Knowledge of the distribution and ecological conditions is very important for the future conservation of the species in general and for those rare and threatened in particular. Their survival and existence depend on the preservation of their habitat.

Materials and Methods

Study area

Megriss Mountain culminates at 1737m elevation. It is a part of the Setifian High Plains, which are situated in northeastern Algeria on latitude 36°19'54" N and longitude 5°21'14" E (Fig. 1). It is characterized by a sub-humid bioclimatic stage with a cold winter variant. Average annual rainfall is 500 mm, of which an important quantity falls as snow; the warmest month is August, with a maximum of 26.4°C, while January is the coldest one, with a minimum of -0.6°C (Boulaacheb, 2013).

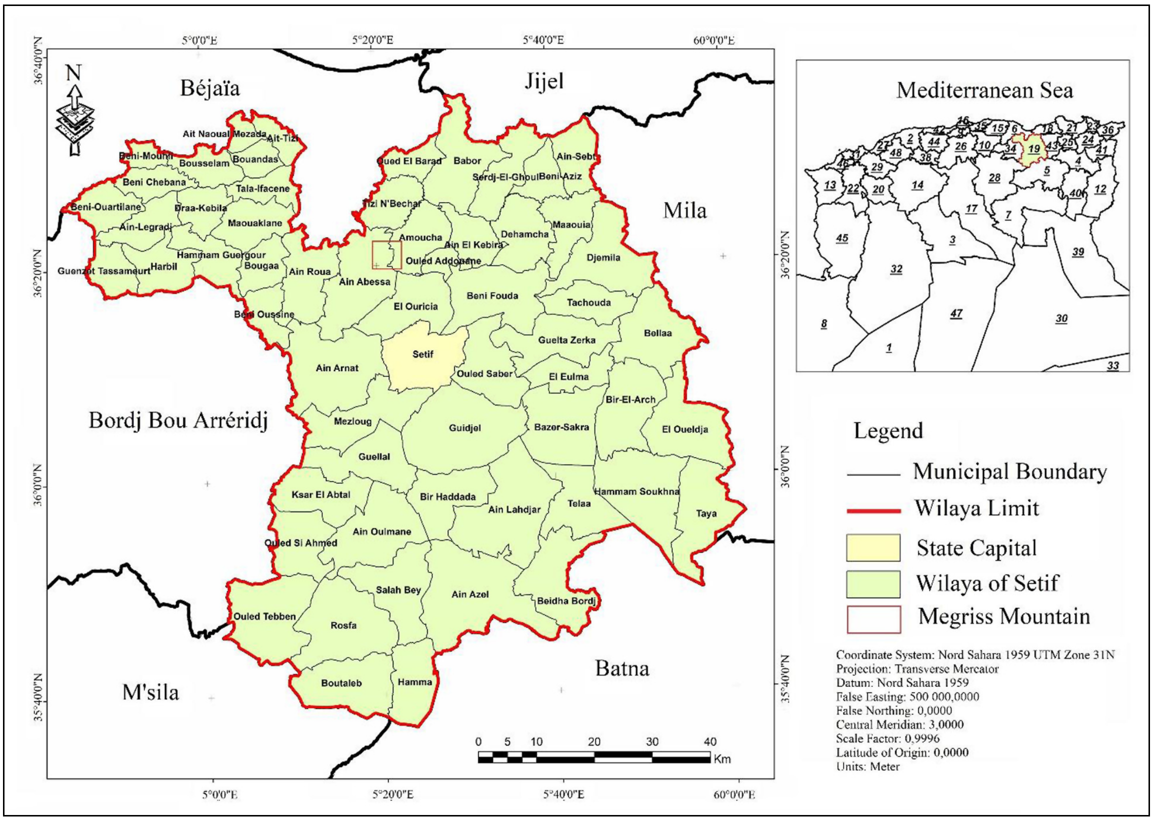

Fig. 1. Study area location in Northern Algeria [Megriss Mountain belongs to the Wilaya of Setif (number 19 in the upper right map), situated northwards of the city of Setif (the base map is from GeoJamal website with the permission of the author)]

The study area constitutes a heterogeneous ecosystem (lowlands, grasslands, streams, temporary pools, matorral of *Quercus ilex* L. *and reforestation* of *Cedrus atlantica* (Endl.) Manetti ex Carrière (Boulaacheb, 2013). Additionally, there are a few species of trees such as *Fraxinus angustifolia* Vahl, *Populus alba* L., and *Salix alba* Kern (Boulaacheb, 2009).

Data collection

The collection of samples was carried out in the northern part of Megriss Mountain on two ecologically different localities; the first one is a private property next to a gabion by the road side characterized by a more or less dry soil and temperate atmosphere and the second one is a forest of *Cedrus atlantica* with a rich soil on organic matter and a humid atmosphere (Fig. 2).

Samples were macroscopically and microscopically examined in the *laboratory of urban project, city and territory* (PUViT) which is affiliated with the Department of Architecture, team of Urban-Periurban Ecology and Biodiversity, using Zeïss stemi 2000-c stereomicroscope and Optika microscope**.** Photomicrographs of the studied samples were captured using Optika proview 4,8,15529 software. For mosses nomenclature, Hodgetts et al. (2020) was followed.

Results

During the fieldwork, a new Algerian record of Orthotrichaceae was found: *Orthotrichum macrocephalum* F. Lara, Garilleti & Mazimpaka.

Specimens studied

Algeria. Sétif: Djebel Megriss Mountain, Ain Guelou, 36°21’40.0”N 5°20’19.8”E, *ca* 1108 m a.s.l., on the lower part of the bark of *Fraxinus angustifolia*, 01.06.2021, *leg.* A. Mazari 11, Boulaacheb private herbarium n° 95; *Idem*, 04.10.2022, *leg.* A. Mazari 12, Boulaacheb private herbarium N° 67; Djebel Megriss Mountain, Oued El Bordj, 36°20’5.8”N 5°20’31.5”E, *ca* 1554 m a.s.l., on the lower part of the bark of *Cedrus atlantica*, 01.06.2021, *leg.* N. Boulaacheb 10, Boulaacheb private herbarium nº 66; *Idem*, 25.10.2022, *Leg*. N. Boulaacheb 03, Boulaacheb private herbarium N° 94.

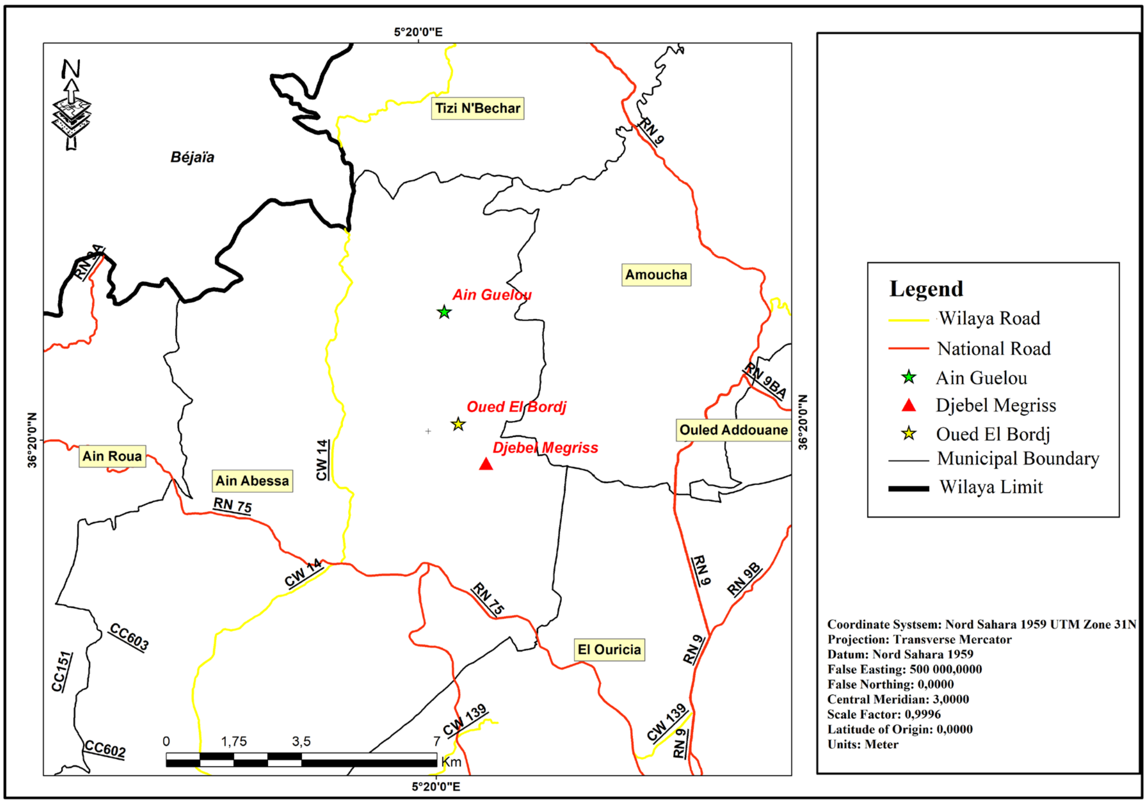

Fig. 2. Sampling localities in Megriss Mountain

Morphological characteristics

Orthotrichum macrocephalum was readily recognized as the samples showed all the diagnostic characteristics stated by Lara et al. (2009) and Lara & Garilleti (2014): small-sized plants, lingulate or lanceolate-lingulate leaves with rounded or obtuse apices and costa ending below the apex, recurved and unistratose margins, pluripapillose and unistratose laminal cells, cylindrical gemmae with 6 to 15 cells. Other morphological characters observed were the emergent capsule with eight longitudinal orange ribs and star-shaped mouth when dry, scarcely constricted below the mouth, immersed stomata in the capsule wall, and very papillose endostome segments (Fig. 3).

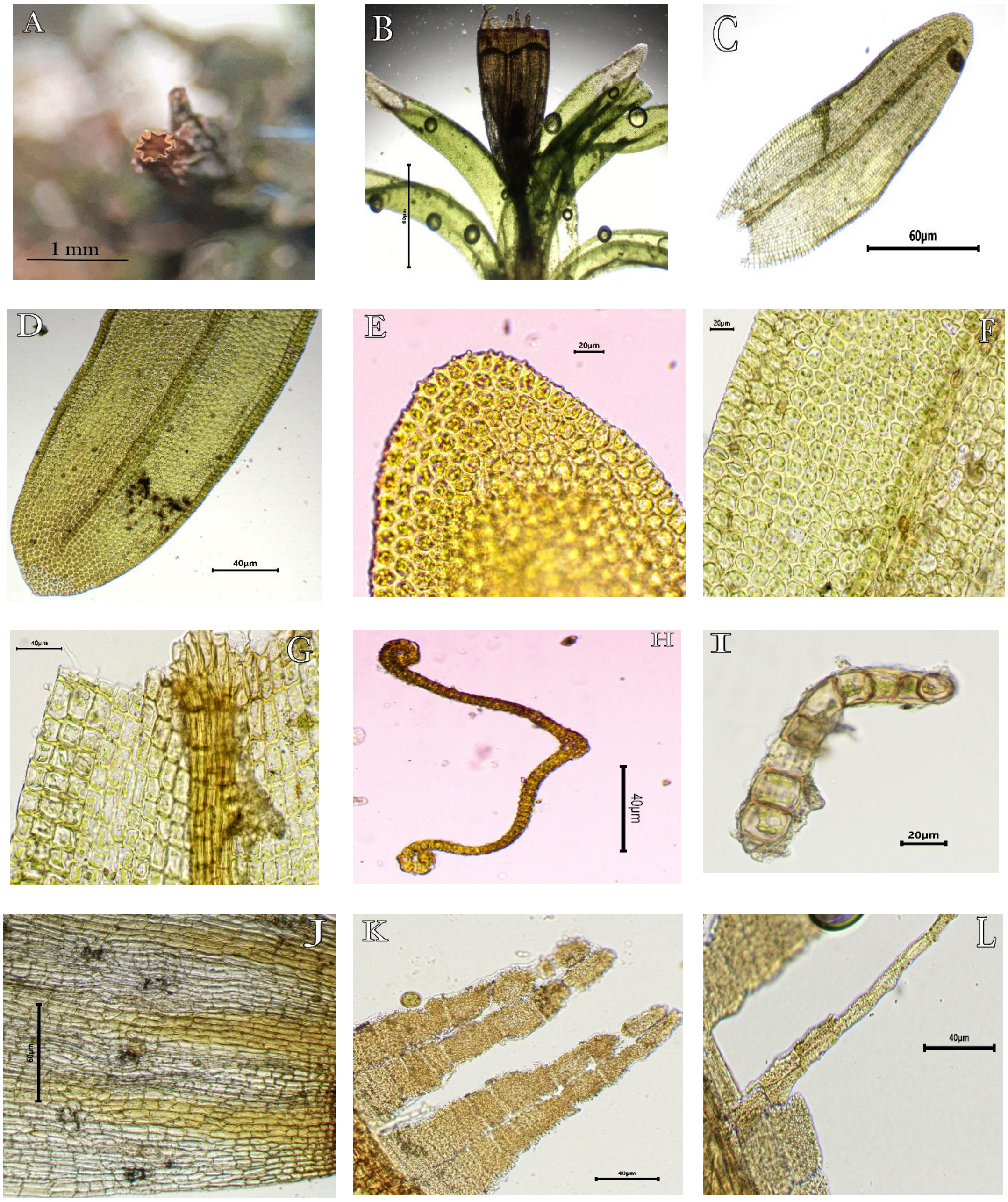

Fig. 3. Microphotographs of *Orthotrichum macrocephalum* from Djebel Megriss (Boulaacheb private herbarium nº 95 and n° 66) [(A) capsule showing the star-shaped mouth, (B) habitus of the plant, (C-D) leaves, (E) apical cells, (F) median cells, (G) basal cells, (H) leaf cross-section at the basal part, (I) gemmae, (J) capsule wall showing ribs and immersed stomata (K) exostome teeth, (L) endostome segment. A,B,J,K,L MAZ 11 C,D,E,F,G,H,I. BOU 10]

Discussion

Orthotrichum macrocephalum is a neutrophytic and toxitolerant epiphyte (Garilleti et al., 1997). It extends in Mediterranean climate areas, and it was known from Spain, Morocco, Tunisia, Corsica, Sicily, Greece, Turkey, and Cyprus (Lara & Garilleti, 2014), this species has now also been recorded in Algeria, as was expected by Garilleti et al. (1997).

The specimen collected in Ain Guelou locality was growing at 1108 m on the lower part of the bark of *Fraxinus angustifolia* with other epiphytic mosses such as *Orthotrichum diaphanum* Brid. and other Orthotrichaceae species, as well as *Syntrichia laevipila* Brid. while in Oued El Bordj, it was growing at 1554m on the lower part of *Cedrus atlantica bark*. According to Lara et al. (1994) and Garilleti et al. (1997), *O. macrocephalum* grows on the trunks of angiosperms, especially the Fagaceae (*Quercus canariensis* Willd., *Q. faginea* Lam., *Q. ilex*, *Q. suber* L.) and the Oleaceae (*Fraxinus angustifolia*). The species also grows on bases and trunks of different phorophytes between 1000 and 2600m (Draper et al., 2006). In Oued El Bordj locality, the species was observed to grow for the first time on *Cedrus atlantica,* one of the endemic Northern Africa species and which is ecologically the most important of the Mediterranean mountains (Demarteau et al., 2007). Probably this xerophytic moss (Draper et al., 2006) appears to thrive in the humid atmosphere of cedars. This new habitat provides an opportunity to gain insight into the ecology of the *Orthotrichum* genus generally, which typically grows in dry, sunny habitats as epiphytes on the bark of deciduous trees or shrubs (Plášek & Ochyra, 2020) and of the species *O. macrocephalum* particularly; Additionally, this finding can help to provide more information on the tolerance and ecological requirements of Mediterranean epiphytes. Unfortunately, the species may be endangered due to climate change threatening *Cedrus atlantica*.

O. macrocephalum can sometimes be confused with *Nyholmiella obtusifolia* (Brid.) Holmen & E.Warncke (*Orthotrichum obtusifolium* Brid.) due to their similar small size, compact habit, rounded leaf apex, and often with propagules. *O. macrocephalum* has, however, leaves with recurved margins and pluripapillose laminal cells while *N. obtusifolia* has erect-incurved margins with a single central papilla (Lara & Garilleti, 2014).

According to the checklist of Ros et al. (2013), a total of 16 species and one variety of the genus *Orthotrichum s.l.* were reported from Algeria, which at present correspond to *Pulvigera lyellii* (Hook. & Taylor) Plášek, Sawicki & Ochyra, five species of *Lewinskya*, and ten species and one variety of *Orthotrichum s.s*. The last one through this discovery reaches 11 species in Algeria, and the number may well increase if surveys further. Compared to the Grand Maghreb countries, *Orthotrichum s.l.* is well represented with 40% of the total 40 Mediterranean species. In order to update the Algerian bryoflora, it is necessary to widen the explorations, including all the geographical areas. With more collections and discoveries, our knowledge of the bryophytes of the country, especially the Orthotrichaceae, will be better.

Although numerous and recent studies have contributed significantly to the understanding of this botanic family, their knowledge and diversity worldwide are still moderately known (Draper et al., 2022). According to Lara & Mazimpaka (2001), the high species diversity exhibited by *Orthotrichum s.l.* suggests that the Mediterranean region may represent a center of the diversity of this group. Algeria, such a large Mediterranean country and characterized by its varied geography and climate, can considerably contribute to this context.

The variability of the Algerian climate and landscapes can give rise to the richness and diversity of bryophytes. The discovery of a new moss species pushes us to broaden surveys to update our bryoflora on the one hand and on the other hand to contribute to a better understanding of the ecology and distribution of the Orthotrichaceae in general and the species *O. macrocephalum* in particular.

Conclusion

This study identified new moss record of the family Orthotrichaceae in Algeria: *O. macrocephalum.* The leaves with rounded or obtuse apices, recurved margins, pluripapillose laminal cells, the star-shaped mouth of capsule when dry, scarcely constricted below the mouth are important distinguishing features of this new recorded species. Moreover, the study provides useful information to differentiate between the two morphologically similar species, *O. macrocephalum* and *N. obtusifolia* (*O. obtusifolium*). Further detailed bryological surveys in Algeria may reveal other interesting discoveries regarding bryophytes in the region.

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Conflicts of interest: The authors declare no conflict of interest.

Authors' contributions: Amira Mazari and Nacira Boulaacheb were responsible for collecting, analyzing, and interpreting the data, as well as writing the initial draft. Rosa María Ros contributed to interpreting the data, reviewing, and revising the final draft.

Ethics approval: Not applicable.

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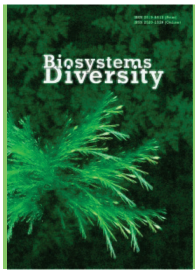
تسجيل نوع جديد من الحزازيات في الجزائر *Orthotrichum macrocephalum* F. Lara, Garilleti & Mazimpaka

أميرة مزاري [1، 2]، نصيرة بولعشب [3، 2]، روسا ماريا روس [4، 5]

[1] قسم بيولوجيا وبيئة النبات- كلية علوم الطبيعة والحياة- جامعة فرحات عباس سطيف 1- الباز- 19000 سطيف- الجزائر؛ [2] مخبر المشروع العمراني- المدينة والإقليم؛ [3] قسم الصيدلة- كلية الطب- جامعة فرحات عباس سطيف 1- الباز- 19000 سطيف- الجزائر؛ [4] قسم بيولوجيا النبات- كلية البيولوجيا- حرم إسبيناردو الجامعي- جامعة مورسيا- 30100- مورسيا- إسبانيا؛ [5] مخبر التصنيف الجزيئي- جغرافيا الأعراق والحفظ عند الطحالب.

إن النباتات الطحلبية الخاصة بالهضاب العليا لمنطقة سطيف، الواقعة في شمال شرق الجزائر غير معروفة بشكل جيد ويعتبر جبل مغرس أحد أهم النظم البيئية في هذه المنطقة. خلال الخرجات الميدانية والتي كان الهدف منها دراسة وجرد تنوع النباتات الطحلبية في الجزء الشمالي من جبل مغرس، أدى فحص عينات عائلة Orthotrichaceace إلى تسجيل نوع هوائي *Orthotrichum macrocephalum* F. Lara, Garilleti & Mazimpaka. وقد تم تحديده بناءً على أوراقه ذات القمم المستديرة أو المنفرجة والحواف المنحنية إلى الخارج، خلاياه الصفيحية أحادية الحليمة، وجود الجيمات، كبسولته المغطاة جزئيا مع ثمانية خطوط برتقالية طولية وفم على شكل نجمة عندما جفافها، تضيق بشكل خفيف أسفل الفم، ثغور مغمورة في جدار الكبسولة والأسنان الداخلية الحليمية. لم يتم تسجيل هذه الحزازية وحيدة التفرع ذو التقارب الملحوظ لمناخ البحر الأبيض المتوسط في النباتات الطحلبية الجزائرية من قبل. قد تم توفير وصف شامل وصور دقيقة وخريطة توزيع في الجزائر لهذا النوع. علاوة على ذلك، تمت مناقشة بيئتها أيضًا.



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Contribution to the knowledge of the mosses of Megriss Mountain (Algeria)

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Due to the limited knowledge on bryophytes in Algeria, this study aimed to update the Algerian bryophyte flora. Megriss Mountain (also called Jbel or Djebel Megriss), which is a part of the High Plains of Setif, was chosen as a study area for its interesting biological and landscape diversity. The inventory was carried out in different habitats (rocks, trees, soils and streams). Samples were collected from minimum survey areas of 100 cm^2 (from soil and rocks), but the sample area was sometimes increased depending on the availability of species; the trees were mostly sampled between heights of 1 and 2 meters. As a result, a preliminary list of 55 moss species were identified, including 44 acrocarpous and 11 pleurocarpous, belonging to 13 families and 29 genera. The most species-rich families were Pottiaceae, Orthotrichaceae, Brachytheciaceae, and Bryaceae, while the most diverse genera were *Lewinskya* and *Syntrichia*. Epilithic mosses were dominant, followed by terricolous mosses and finally epiphytic mosses. The most frequent species in the study area were *Orthotrichum diaphanum*, *Lewinskya acuminate*, *Didymodon insulanus*, *Grimmia pulvinata*, and *Tortella squarrosa*. The study also highlights the presence of a new species that had never been recorded in Algeria -*Orthotrichum scanicum*. A comprehensive description, microphotographs of the species are provided and its ecology is also discussed. This discovery will contribute to the enrichment of the Algerian bryophyte flora in general and of the Orthotrichaceae in particular,within the genus *Orthotrichum*, which now has a total of 11 species recorded in the country.

Keywords: biodiversity; Mediterranean bryophytes; *Orthotrichum scanicum*; Setifian High Plains.

Introduction

The bryophyte flora of Algeria has been the subject of a relatively extensive number of studies that started in the XIX century, but which has become more limited since the second half of the XX century; during the sessions of the Botanical Society of France, occasional collections of mosses from some Algerian provinces were presented by Pinoy, Klincksieck, Trabut, and Maire. As a result, Camus (1906) and Trabut (1914, 1927) identified a few species of bryophytes. Furthermore, the French bryologists Feódor Jelenc did much fieldwork in Algeria and published the first compilation of reports dealing with bryophytes from northern Africa (Jelenc, 1955, 1967). Moreover, Ros et al. (1999) synthesized all accessible references to create an annotated list of bryophytes in northern Africa, in which Algeria had the most significant number of taxa (648 taxa). This checklist was later updated in the Mediterranean checklists of liverworts and mosses (Ros et al., 2007, 2013). Also, Bischler (2004) included much data about Algerian hepatics without precise localities. Recently an inventory of the mosses of the Tonga watershed (Northeastern Algeria) was carried out by Boukhatem et al. (2017).

To contribute to the knowledge of Algerian bryophyte flora, particularly that of the northern part of the Setifian High Plains, Megriss Mountain was chosen to be explored, which is considered one of the most interesting and important ecosystems in terms of biological and landscape diversity (Boulaacheb, 2013). Despite this interest, its bryoflora has not been deeply studied. Therefore, the present work aims to provide a preliminary list of the mosses of Megriss Mountain and to provide knowledge on the geographical distribution and ecology of an epiphyte moss reported for the first time in Algeria.

Material and methods

Study area. Megriss Mountain is a part of the Setifian High Plains, which are situated in northeastern Algeria at latitude 36°19'54" N and longitude 5°21'14" (Fig. 1), and culminates at 1737 m elevation. It is characterized by a sub-humid bioclimatic stage with a cold winter variant. The warmest month is August, with a maximum of 26.4 °C, while January is the coldest one, with a minimum of –0.6 °C. The average annual precipitation is 500 mm, of which an important quantity falls as snow (Boulaacheb, 2013).

Megriss Mountain contains diverse ecosystems which consist of grasslands, lowlands, streams, temporary pools, reforestation of *Cedrus atlantica* (Endl.) Manetti ex Carrière, also *Quercus ilex* L. woods (Boulaacheb, 2013). Additionally, there are a few species of trees such as *Fraxinus angustifolia* Vahl, *Populus alba* L., and *Salix alba* Kern. (Boulaacheb, 2008). The soils of Megriss Mountain are classified into two types: vertisols and leached soils (Lahmar et al., 1993).

Sampling methods. In 2012, the initial fieldwork was conducted. Years later, further fieldwork was carried out in April 2021, June 2021, and October 2022. In the course of this fieldwork, samples were collected at only ten stations (Table 1).

Wherever mosses were available on rocks and soils, a minimum survey area of 100 cm^2 (10 × 10 cm) was selected. However, this area could be increased depending on the availability of species. The trees were mostly sampled between heights of 1 and 2 meters.

The specimens collected were as complete as possible because fertile samples are easier to determine. Each sample was collected in a paper envelope indicating substrate type. When an epiphyte was being collected, it was important to mention whether it had been taken from the upper, the middle or the lower part of the tree trunk. All mosses collected were preserved and used in Boulaacheb's private herbarium collection as well as further identification.

Identification of the mosses. Moss samples were macroscopically and microscopically examined in the laboratory of the Urban Project, City and Territory (PUViT) which is affiliated with the Department of Architecture, team of Urban-Periurban Ecology and Biodiversity, using a Zeïss stemi 2000-c stereomicroscope and Optika microscope. Photomicrographs of the studied samples were captured using Optika proview 4,8,15529 software. Their identification was performed by determining the morphological character of each specimen with identification keys to bryophytes such as the Moss Flora of Britain and Ireland (Smith, 2004), the Handbook of mosses of the Iberian Peninsula, the Balearic Islands (Casas et al., 2006), all volumes of the series Flora Briofítica Ibérica (Guerra et al., 2006, 2010, 2014, 2018; Brugués et al., 2007; Brugués & Guerra, 2015) as well as website resources like Bryologia Gallica & Ultramarina (http://bryologia.gallica.free.fr/les-bryophytes-defrance.php) and the British Bryological Society (www.britishbryologicalsociety.org.uk) (Hodgetts et al., 2020) was followed for the mosses' nomenclature.

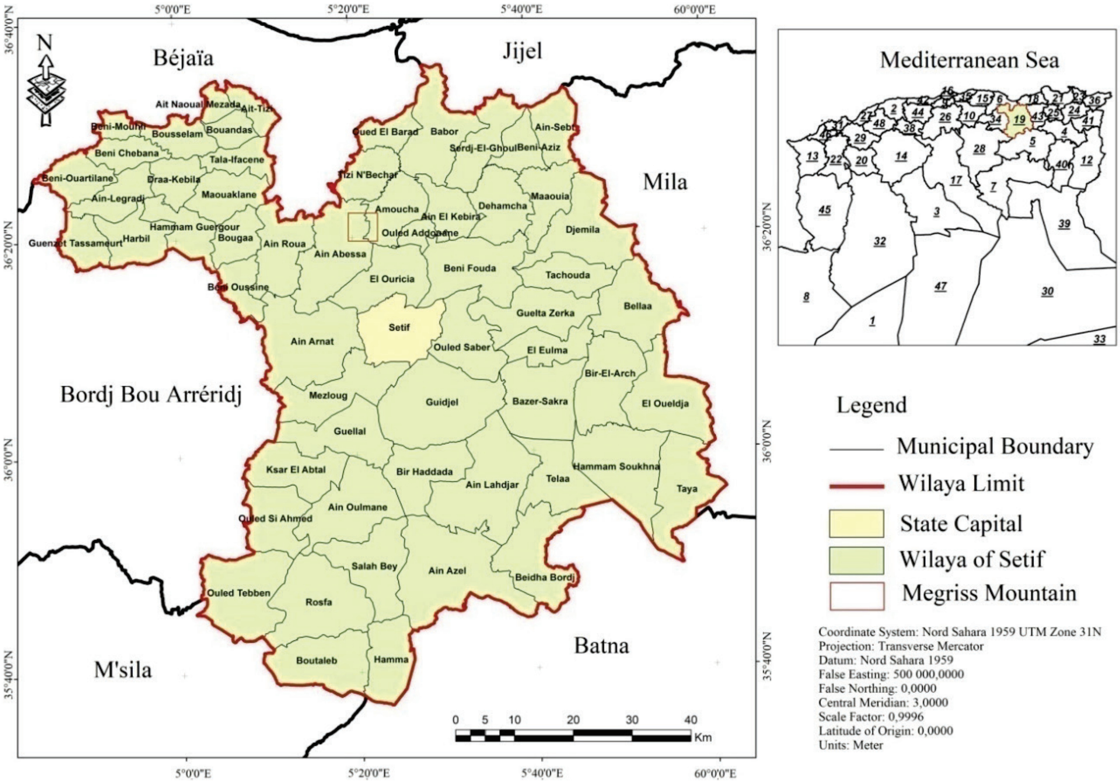

Fig. 1. Study area location in Northern Algeria: Megriss Mountain belongs to the Wilaya of Setif (number 19 in the upper right map), situated northwards of the city of Setif (the base map is from GeoJamal website with the permission of the author)

Table 1
Geographic coordinates of the sampled stations

Station	Latitude	Longitude	Altitude, m
1	36°21'15.4" N	5°22'39.6" E	1036
2	36°21'40.0" N	5°20'19.8" E	1108
3	36°20'05.5" N	5°20'34.8" E	1364
4	36°20'09.4" N	5°20'52.5" E	1525
5	36°20'01.9" N	5°20'14.4" E	1553
6	36°20'05.8" N	5°20'31.5" E	1554
7	36°20'00.7" N	5°20'14.1" E	1555
8	36°20'09.0" N	5°22'50.2" E	1565
9	36°19'52.9" N	5°20'42.9" E	1614
10	36°19'50.1" N	5°21'02.5" E	1686

Results

As a result of the current study, a total of 55 moss species were identified to their specific/generic level, including 11 pleurocarpous (20%) and 44 acrocarpous mosses(80%). These species are distributed in over 29 genera belonging to 13 families, among which four families reveal a remarkable specific richness; the Pottiaceae, represented by 17 species (i.e., 30.9%), the Orthotrichaceae with 10 species (18.2%), and then the Brachytheciaceae and the Bryaceae, which are each represented by six species (10.9%). The Grimmiaceae are represented by four species (7.3%) and the Hypnaceae by three species (5.5%). The Bartramiaceae and the Ditrichiaceae both are represented by two species (3.6%). The remaining five families are each represented by only one species (1.8%, Fig. 2).

At the generic level, *Lewinskya* F. Lara, Garilleti & Goffinet and *Syntrichia* Brid. are the most diverse, with five species each (Fig. 2).

Mosses of the study area were found inhabiting different types of habitats (Table 2); 20 species (36.4%) were epilithic, 13 species (23.6%) were terricolous, 9 species (16.4%) were epiphytic, of which 8 of them belong to the Orthotrichaceae family, and 2 (3.63%) were aquatic, of which *Drepanocladus aduncus* Hedw. was semi aquatic while *Fontinalis antipyretica* Hedw. was aquatic. Eight species (14.4%) were found growing on both soils and rocks, namely; *Homalothecium aureum* (Spruce) H. Rob., *Hypnum cupressiforme* Hedw. var. *lacunosum* Brid., *H. jutlandicum* Holmen & E. Warncke, *Scleropodium touretii* (Brid.) L. F. Koch., *Syntrichia ruralis* (Hedw.) F. Weber & D. Mohr var. *ruralis*, *Tortella squarrosa* (Brid.) Limpr., *Tortula inermis* (Brid.) Mont, and *T. subulata* Hedw. The remaining three species were growing on rocks and trees, namely: *Grimmia pulvinata* (Hedw.) Sm., *Orthotrichum cupulatum* Brid. and *O. diaphanum* Brid. although in our study area, *O. diaphanum* was found growing more on trees.

Based on the Checklist of the Mediterranean mosses (Ros et al., 2013), this study revealed one new species record for Algeria belonging to the Orthotrichaceae family, which is *Orthotrichum scanicum* Grönvall. A description of the species is provided below based on our observations and the literature.

Specimen examined. Algeria. Setif: Megriss Mountain, Ain Guelou, 36°21'40.0" N 5°20'19.8" E, ca 1108 m a.s.l., on the medium part of the bark of *Fraxinus angustifolia*, 25.10.2022, leg. A. Mazari 13, Boulaacheb private herbarium n° 92.

Morphological characteristics. The sample of *Orthotrichum scanicum* collected was easily identifiable based on the presence of the diagnostic characteristics stated by Lara et al (2009) and Guerra et al. (2014): leaves linear-lanceoloate to ovate-lanceolate with a costa ending below the apex, an acute and irregularly toothed apex, recurved and unistratose margins, unistratose laminal cells and, often with broad oval base. Leaves are also characterized by rounded upper cells, rectangular-elliptical median cells and rectangular basal cells (Fig. 3).

Orthotrichum scanicum collected in our area was also characterized by capsules broadly emergent and which contain eight ribs, immersed stomata located in the lower ½ of the urn, exostome with eight pairs of teeth and endostome with 16 segments (eight long segments interspersed with eight short ones), often appendiculate. Spores 18–19 µm in diameter (Fig. 4).

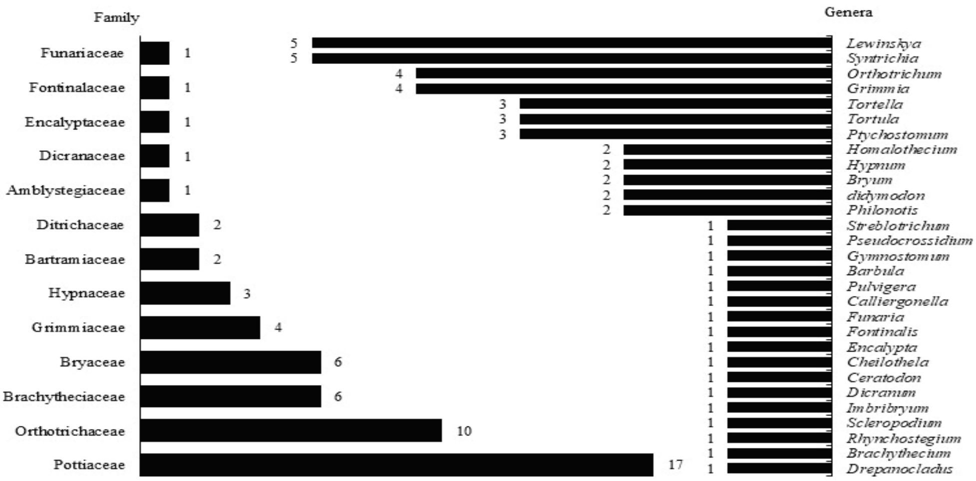

Fig. 2. Number of species recorded for each family and genus at the Megriss Mountain

Table 2
Mosses of Megriss Mountain: their families and substrate types

Species	Aquatic	Terrestrial	Epilithic	Epiphytic
Drepanocladus aduncus Hedw.	+	–	–	–
Philonotis calcarea (Bruch & Schimp.) Schimp.	–	+	–	–
Ph. tomentella Molendo	–	+	–	–
Brachythecium rutabulum (Hedw.) Schimp.	–	+	–	–
B. sp.	–	+	–	–
Homalothecium aureum (Spruce) H. Rob.	–	+	+	–
H. sericeum (Hedw.) Schimp.	–	+	–	–
Rhynchostegium megapolitanum (Blandow ex F. Weber & D. Mohr) Schimp.	–	–	+	–
Scleropodium touretii (Brid.) L. F. Koch.	–	+	+	–
Bryum argenteum Hedw.	–	+	–	–
B. radiculosum Brid.	–	–	+	–
Imbribryum mildeanum (Jur.) J. R. Spence	–	–	+	–
Ptychostomum capillare (Hedw.) Holyoak & N. Pedersen	–	–	+	–
P. pseudotriquetrum (Hedw.) J. R. Spence & H. P. Ramsay ex Holyoak & N. Pedersen	–	+	–	–
P. torquescens (Bruch & Schimp.) Ros & Mazimpaka	–	–	+	–
Dicranum scoparium Hedw.	–	+	–	–
Ceratodon purpureus subsp. *stenocarpus* (Brauch & Schimp. ex Müll. Hal.) Dixon	–	–	+	–
Cheilothela chloropus (Brid.) Broth.	–	+	–	–
Encalypta vulgaris Hedw.	–	–	+	–
Fontinalis antipyretica Hedw.	+	–	–	–
Funaria hygrometrica Hedw.	–	–	+	–
Grimmia funalis (Schwägr.) Bruch & Schimp.	–	–	+	–
G. orbicularis Bruch ex Wilson	–	–	+	–
G. ovalis (Hedw.) Lindb.	–	–	+	–
G. pulvinata (Hedw.) Sm.	–	–	+	+
Calliergonella cuspidata (Hedw.) Loeske	–	+	–	–
Hypnum cupressiforme Hedw. var. *lacunosum* Brid.	–	+	+	–
H. jutlandicum Holmen & E. Warncke	–	+	+	–
Lewinskya acuminate (H. Philib.) F. Lara, Garilleti & Goffinet	–	–	–	+
L. affinis (Schrad. ex Brid.) F. Lara, Garilleti & Goffinet	–	–	–	+
L. breviseta (F. Lara, Garilleti & Mazimpaka) F. Lara, Garilleti & Goffinet	–	–	–	+
L. rupestris (Schleich. ex Schwägr.) F.Lara, Garilleti & Goffinet	–	–	+	–
L. striata (Hedw.) F. Lara, Garilleti & Goffinet	–	–	–	+
Orthotrichum cupulatum Brid.	–	–	+	+
O. diaphanum Brid.	–	–	+	+
O. pumilum Sw. ex anon.	–	–	–	+
O. scanicum Grönvall	–	–	–	+
Pulvigera lyellii (Hook. & Taylor) Plášek, Sawicki & Ochyra	–	–	–	+
Barbula unguiculata Hedw.	–	–	+	–
Didymodon insulanus (De Not.) M. O. Hill	–	–	+	–
D. vinealis (Brid.) R H. Zander	–	–	+	–
Gymnostomum calcareum Nees & Hornsch.	–	–	+	–
Pseudocrossidium hornschuchianum (Schultz) R. H. Zander	–	+	–	–
Streblotrichum convolutum (Hedw.) P. Beauv. var. *convolutum*	–	–	+	–
Syntrichia laevipila Brid.	–	–	–	+
S. montana Nees var. *calva* (Durieu & Sagot ex Bruch & Schimp.) J. J. Amann	–	–	+	–
S. ruraliformis (Besch.) Mans.	–	+	–	–
S. ruralis (Hedw.) F. Weber & D. Mohr var. *ruralis*	–	+	+	–
S. virescens (De Not.) Ochyra	–	–	–	+
Tortella flavovirens (Bruch) Broth. var. *flavovirens*	–	+	–	–
T. nitida (Lindb.) Broth.	–	–	+	–
T. squarrosa (Brid.) Limpr.	–	+	+	–
Tortula inermis (Brid.) Mont	–	+	+	–
T. muralis Hedw.	–	–	+	–
T. subulata Hedw.	–	+	+	–

Discussion

The results of the current study indicate a higher number of acrocarpous mosses compared to the pleurocarpous mosses. Based in our observations during fieldwork and according to (Govindapyari et al., 2012), this may be due to the ability of acrocarpous mosses to colonize areas with more or less moisture and sunlight, while pleurocarpous mosses may be more common in areas with more moisture and shadow.

Our inventory shows a clear dominance of the Pottiaceae, the Orthotrichaceae, the Brachytheciaceae, and the Bryaceae. This dominance has been observed in many areas with Mediterranean climate, such as in several studies carried out in Morocco (Cano et al., 2002; Ahayoun et al., 2016; Laouzazni et al., 2018; El Harech et al., 2020; Fadel et al., 2020, 2021; Zaza et al., 2020, 2021), France (Hugonnot & Celle, 2013), and Spain (Ros & Guerra, 1987; Rams et al., 2014).

The Pottiaceae family is already known as the largest family within Bryopsida in terms of genera count (Zander, 1993). Moreover, a majority of Pottiaceae mosses show strong adaptation to harsh environments, specifically arid conditions like those found in open montane areas (Zander, 1993; Gradstein et al., 2001), confirming that significant arid areas of Northern Africa may provide a suitable habitat for the Pottiaceae (Ben Osman et al., 2021).

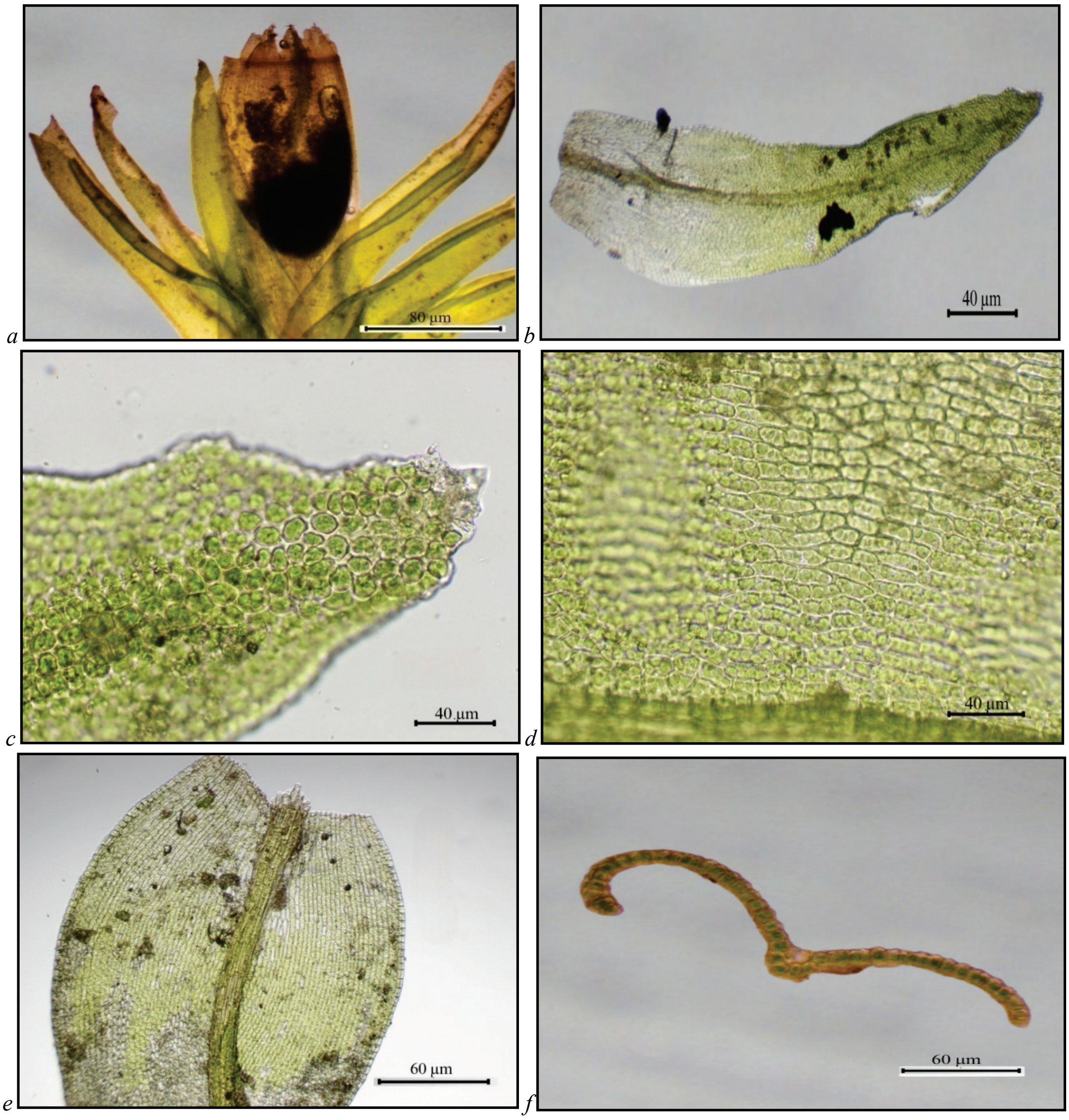

Fig. 3. Microphotographs of the gametophyte part of *Orthotrichum scanicum* from Jbel Megriss (Boulaacheb private herbarium nº 92): *a* – habitus of the plant; *b* – leaf; *c* – apex of leaf showing apical cells; *d* – median cells; *e* – base of leaf; *f* – leaf cross-section at base of leaf

Furthermore, the Orthotrichaceae family is the second most species-rich family. All species inventoried within this family in our study area were previously attributed to a single genus, *Orthotrichum* Hedw. This genus is considered to be one of the richest genera in the Orthotrichaceae (Lara et al., 2016), with 163 species in the world (Medina et al., 2013) and 40 species in the Mediterranean region (Ros et al., 2013). Most of these species are epiphytic (Lara et al., 1994; Lara & Mazimpaka, 2001; Lara et al., 2016). Our study found that nine out of ten species of Orthotrichaceae were growing on trees, which is similar to the results observed by (Draper et al., 2003; Draper et al., 2005; Draper et al., 2006), where they found that the Orthotrichaceae family and *Orthotrichum* genus were dominant in the epiphytic bryoflora of three areas in Morocco, confirming their ecological significance in the Mediterranean region (Lara et al., 1994; Lara & Mazimpaka, 2001). However, in recent years, there has been a significant taxonomical revision of the genus *Orthotrichum* Hedw. (Draper et al., 2021). The European and Mediterranean species were divided into three different genera. The genus *Pulvigera* Plášek, Sawicki & Ochyra which includes *P. lyellii* (Hook. & Taylor) Plášek, Sawicki & Ochyra (*Orthotrichum lyellii* Hook. & Taylor) (Plášek et al., 2015), *Lewinskya* F. Lara, Garilleti & Goffinet for the phaneroporous and monoicous taxa of *Orthotrichum* and *Orthotrichum* s.s. for the rest of species (Lara et al., 2016).

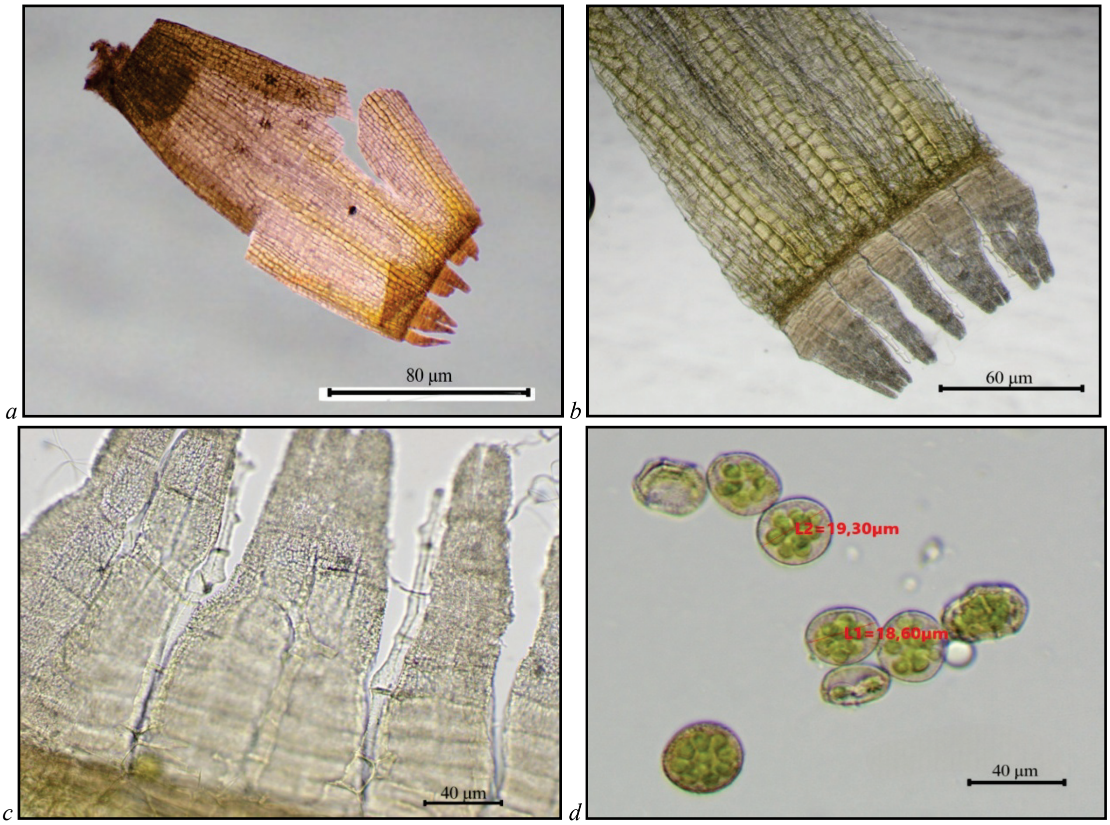

Fig. 4. Microphotographs of the sporophyte part of *Orthotrichum scanicum* from Jbel Megriss (Boulaacheb private herbarium nº 92); *a*, *b* – capsule wall showing ribs, immersed stomata and exostome teeth; *c* – endostome segments and exostome teeth; *d* – spores

Among the 55 species recorded in Megriss Mountain, two species were widely distributed in the *Cedrus atlantica* forest; *O. diaphanum* and *Lewinskya acuminate* (H. Philib.) F. Lara, Garilleti & Goffinet; both species are common epiphytic mosses in the Mediterranean area and their prevalence is likely an indication of the mainly temperate conditions of the forests with a well-developed epiphytic stratum (Draper et al., 2006). Other species were found to be widespread: *Didymodon insulanus* (De Not.) M. O. Hill, *Grimmia pulvinata* (Hedw.) Sm. and *Tortella squarrosa* (Brid.) Limpr. This common distribution has also been observed in some Moroccan mountain regions (Draper et al., 2006; Laouzazni et al., 2021). This might due the similarity of climatic and edaphic conditions of both Algeria and Morocco.

In terms of habitats, epilithic mosses were the most dominant. Twenty moss species were found exclusively in saxicolous habitats. This dominance may be explained by the presence of specific environmental conditions such as the profusion of stones and boulders and other rocky substrates. That was also observed by Zaza et al. (2021) in Morocco.

Orthotrichum scanicum: the new moss record, was previously believed to be a rare and threatened species in Europe and was placed on the world red list of bryophytes. However, recent studies have shown that it is actually widespread and locally common in countries around the Mediterranean Sea, such as Morocco (Blockeel, 2012), where it was found growing between altitudes of 1050 and 1950 m. This species can be found in various types of forests, growing on the bases, branches, and trunks of different phorophytes (Draper, 2003).

According to the checklist of Ros et al. (2013), a total of 16 species and one variety of the genus *Orthotrichum* s.l. were reported from Algeria, which at present correspond to *Pulvigera lyellii* (Hook. & Taylor) Plášek, Sawicki & Ochyra, five species of *Lewinskya*, and ten species and one variety of *Orthotrichum* s.s. The discovery of a new species: *O. scanicum*, has increased the number of *Orthotrichum* species in Algeria to 11, and this number may continue to increase with further surveys.

Conclusion

The Algerian climate and landscapes are highly variable, which can give rise to the richness and diversity of bryophytes. The discovery of a new moss species highlights the urgent need for further surveys to collect and identify more species on Megriss Mountain, to update the bryoflora of the country, and to contribute to a better understanding of the ecology and distribution of the Orthotrichaceae in general and the species *Orthotrichum scanicum* in particular. Further studies should be conducted to characterize species and verify their geographical distribution and status.

We would like to express our deepest gratitude to Francisco Lara for his valuable contribution in confirming the species *Orthotrichum scnanicum*. Additionally, we extend our thanks to Mr. Chaaouan Djamel for granting us permission to use the base map for our study location.

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Abstract

Due to the lack of knowledge about bryophytes in Algeria, this study was carried out to update the bryophyte flora of the region, highlight the influence of environmental factors on their distribution, and explore their role in maintaining the biodiversity of ecosystems. In this context, two areas of the High Plains of Setif with distinct environmental characteristics were selected for the study: the peri-urban area, Megriss Mountain and the urban area, Setif 1 University - Ferhat ABBAS. Bryophytes sampling was conducted across various habitats, including rocks, trees, soils, and streams. Ground and rock bryophytes were sampled from minimum survey areas of 100 cm² (10×10 cm), while epiphytic bryophytes were sampled from the trunk base up to nearly 2 meters above the ground, in all cardinal directions. The samples of bryophytes were examined macroscopically and microscopically in the laboratory of the Urban Project, City and Territory (LPUViT). A total of 89 moss taxa were identified from the two study areas, with 63 taxa recorded in Megriss Mountain and 26 species recorded at Setif 1 University - Ferhat ABBAS. Some species were found in both areas, while neither area included liverworts or hornworts. The 63 moss taxa recorded in Megriss Mountain include 52 acrocarpous and 11 pleurocarpous mosses, distributed among 14 families and 30 genera. In contrast, all the 26 moss species identified at the University were acrocarpous, belonging to 7 families and 18 genera. For Megriss, the most species-rich families are the Pottiaceae, Orthotrichaceae, Brachytheciaceae, and Bryaceae, while the most diverse genera are *Didymodon*, *Syntrichia*, *Lewinskya*, and *Orthotrichum*. On the other hand, the prominent families at the University are the Pottiaceae and Bryaceae, and the most diverse genera are *Bryum* and *Tortula*. In terms of habitats, terrestrial mosses are the most dominant, followed by epilithic mosses in both study areas. The study also highlights the presence of four new species for Algeria: *Didymodon sinuosus*, *Orthotrichum macrocephalum*, *Orthotrichum scanicum*, and *Syntrichia calcicola*. A comprehensive description and microphotographs of these species are provided, and their ecology is also discussed.

Keywords: Algeria, Bryophytes, Distribution, High Plains of Setif, Peri-urban environments, Urban environments.

Résumé

En raison du manque de connaissances sur les bryophytes en Algérie, cette étude a été réalisée pour mettre à jour la flore des bryophytes de la région, mettre en évidence l'influence des facteurs environnementaux sur leur distribution et explorer leur rôle dans le maintien de la biodiversité des écosystèmes. Dans ce contexte, deux zones des Hauts Plaines de Sétif avec des caractéristiques environnementales distinctes ont été sélectionnées pour l'étude : la zone péri-urbaine, Montagne de Megriss, et la zone urbaine, Université Sétif 1 - Ferhat ABBAS. L'échantillonnage des bryophytes a été effectué dans divers habitats, y compris les rochers, les arbres, les sols et les ruisseaux. Les bryophytes terrestres et saxicoles ont été prélevés sur des aires minimales d'échantillonnage de 100 cm² (10×10 cm), tandis que les bryophytes épiphytes ont été échantillonnés à partir de la base du tronc jusqu'à près de 2 mètres au-dessus du sol, dans toutes les directions cardinales. Les échantillons de bryophytes ont été examinés macroscopiquement et microscopiquement dans le laboratoire du Projet Urbain, Ville et Territoire (LPUViT). Un total de 89 taxons de mousses a été identifiés dans les deux zones d'étude, dont 63 taxons enregistrés dans la Montagne de Megriss et 26 espèces enregistrées à l'Université Sétif 1 - Ferhat ABBAS. Certaines espèces ont été trouvées dans les deux zones, tandis qu'aucune des deux zones ne comprenait de Marchantiophytes ou d'Anthocérotes. Les 63 taxons de mousses enregistrés dans la Montagne de Megriss comprennent 52 mousses acrocarpes et 11 mousses pleurocarpes, réparties en 14 familles et 30 genres. En revanche, toutes les 26 espèces de mousses identifiées à l'Université étaient acrocarpes, appartenant à 7 familles et 18 genres. Pour Megriss, les familles les plus riches en espèces sont les Pottiaceae, Orthotrichaceae, Brachytheciaceae et Bryaceae, tandis que les genres les plus divers sont *Didymodon*, *Syntrichia*, *Lewinskya* et *Orthotrichum*. D'autre part, les familles prédominantes à l'Université sont les Pottiaceae et Bryaceae, et les genres les plus divers sont *Bryum* et *Tortula*. En termes d'habitats, les mousses terrestres sont les plus dominantes, suivies par les mousses épilithiques dans les deux zones d'étude. L'étude met également en évidence la présence de quatre espèces nouvelle pour Algérie: *Didymodon sinuosus*, *Orthotrichum macrocephalum*, *Orthotrichum scanicum* et *Syntrichia calcicola*. Une description complète et des microphotographies de ces espèces sont fournies, et leur écologie est également discutée.

Mots-clés: Algérie, Bryoflore, Bryophytes, Distribution, Hautes Plaines de Sétif, Milieux Périurbains, Milieux urbains.

ملخص

نظراً لعدم وجود معلومات كافية عن النباتات الطحلبية في الجزائر، أُجريت هذه الدراسة لتحديث النباتات الطحلبية في المنطقة، ولتسليط الضوء على تأثير العوامل البيئية على توزيعها، ولاستكشاف دورها في الحفاظ على تنوع الأنظمة البيئية. وفي هذا السياق، تم اختيار منطقتين من هضاب سطيف العليا ذات خصائص بيئية مختلفة للدراسة: المنطقة شبه الحضرية، جبل مقرس والمنطقة الحضرية، جامعة سطيف 1 - فرحات عباس. تمت جمع عينات من النباتات الطحلبية عبر موائل مختلفة، بما في ذلك الصخور، والأشجار، والتربة، والجداول المائية. تم أخذ عينات من النباتات الطحلبية الأرضية والصخرية من مساحات لا تقل عن 100 سم² (10×10 سم)، بينما تم جمع النباتات الطحلبية الهوائية من قاعدة الجذع حتى ارتفاع يقارب مترين فوق سطح الأرض، في جميع الاتجاهات الرئيسية. تم فحص عينات الحزازيات مجهريا في مختبر المشروع الحضري، المدينة والإقليم. تم التعرف على إجمالي 89 نوع من الحزازيات في منطقتي الدراسة، حيث تم تسجيل 63 نوعًا في جبل مغرس و26 نوعًا في جامعة سطيف 1 - فرحات عباس. وُجدت بعض الأنواع في كلا المنطقتين، بينما لم تتضمن أي من المنطقتين النباتات الكبدية و النباتات الزهقرنية. تشمل الـ 63 نوعًا المسجلة في جبل مغريس 52 نوعًا من الحزازيات عمودية التفرع، و11 نوعًا من الحزازيات أفقية التفرع، موزعة على 14 عائلة و30 جنسا. بينما كانت جميع الأنواع الـ 26 التي تم تحديدها في الجامعة من الحزازيات عمودية التفرع، وتنتمي إلى 7 عائلات و18 جنسًا. في جبل مغرس، العائلات الغنية من حيث عدد النواع هي Pottiaceae، Orthotrichaceae، Brachytheciaceae، وBryaceae، بينما الأجناس الأكثر تنوعًا هي *Didymodon*، *Syntrichia*، *Lewinskya*، و*Orthotrichum*. بالمقابل، العائلات الغنية بالأنواع في الجامعة هي عائلتا Pottiaceae وBryaceae، والأجناس الأكثر تنوعًا هي *Bryum* و *Tortula*. من حيث الموائل، كانت الحزازيات الأرضية الأكثر سيادة، وتليها الحزازيات الصخرية في كلتا منطقتي الدراسة. كما أبرزت الدراسة وجود أربعة أنواع جديدة للجزائر، وهي *Didymodon sinuousus*، *Orthotrichum macrocephalum*، *Orthotrichum scanicum* و *Syntrichia calcicola*. تم توفير وصف شامل وصور مجهرية لهذه الأنواع وتمت مناقشة بيئتها أيضًا.

الكلمات المفتاحية: البيئات الحضرية، البيئات شبه الحضرية، التوزيع، الجزائر، النباتات الطحلبية، هضاب سطيف العليا.