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First contribution to the study of lichen diversity in the Tlemcen National Park (Case of the Hafir Forest)

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Abstract

The objective of this work is the inventory of lichens in the Hafir forest, which is part of a wider project aiming to study the lichen flora of the Tlemcen region. The Hafir forest is one of the last Algerian mountainous cork oak forests belonging to the Bético Rifain complex. The study area presents a Mediterranean climate, subhumid with cool winters. Based mainly on random sampling, giving particular importance to the different types of substrate, 68 species of lichens have been identified, belonging to 16 families and 3**8** genera. Among these, *Parmeliaceae* is the most dominant family with 18 species, followed by *Physciaceae* with 13 species, and *Lecanoraceae* with 12 species. The thallus physiognomy shows the presence of six lichen morphologies: crustose, foliose, fruticose, gelatinous, leprose and composite. According to their substrate preferences, corticolous lichens dominate with 46 species, followed by saxicolous with 13 species, terricolous with six, and the less common are lignicoles and muscicoles with two species each. 18 species protected by Algerian law have been identified among inventoried lichens. The Hafir forest hosts a very interesting lichen diversity that deserves to be protected, which requires immediate intervention to reduce the anthropogenic pressure that can disturb this natural environment.

Keywords: Lichen - Biodiversity-Sampling- Inventory- Tlemcen.

الملخص

الهدف من هذا العمل هو جرد الأشنات في غابة حفير ، وهو جزء من مشروع أوسع يهدف إلى دراسة نباتات الأشنة في منطقة تلمسان. غابة حفير هي واحدة من آخر غابات البلوط الجزائرية الجبلية التي تنتمي إلى مجمع Bético Rifain. تتميز منطقة الدراسة بمناخ البحر الأبيض المتوسط ,شبه رطب مع شتاء بارد. بناءً على أخذ العينات العشوائي، مع إعطاء أهمية خاصة لأنواع مختلفة من الركيزة ، تم تحديد 68 نوعًا من الأشنات ، تنتمي إلى 61عائلة و 38 جنسًا. ومن بين هذه الفصيلة،Parmeliaceae هي الأسرة الأكثر انتشارًا مع18 نوعًا تليهاPhysciaceaeمع 13 نوعًا و Lecanoraceaeمع 12 نوعا. يُظهر وجود ستة أشكال حزازية: قشرية ، ورقية ، شجيرية ، هلامية ، ومركبة. وفقًا لتفضيلات الركيزة الخاصة بهم ، تهيمن الأشنات corticoleمع46 نوعًا ، تليها saxicoles مع13 نوعًا ، و terricolous بستة أنواع ، والأقل شيوعًا هي lignicoles و muscicoles مع نوعين لكل منهما. تم تحديد 18 نوعًا محميًا بموجب القانون الجزائري بين الأشنات التيتم جردها. تستضيف غابة حفير تنوعًا مثيرًا للاهتمام من الأشنات يستحق الحماية ، الأمر الذي يتطلب تدخلاً فوريًا لتقليل الضغط البشري الذي يمكن أن يضر بهذه البيئة الطبيعية.

الكلمات المفتاحية: حزاز - التنوع البيولوجي - أخذ العينات - الجرد - تلمسان

Introduction

Lichenology is one of the least known branches of botanical sciences compared to other fields of botany in Algeria (Bendaikha, 2018). The study of lichens in Algeria began more than a century ago (Ait hammou 2011, Hamralaine 2019), with a current list of 1050 taxa (Amrani, 2018). It should be pointed out that lichen diversity worldwide amounts to 20,000 species (Yannick, 2021), and research is uninterrupted because of the great importance of this biota in ecological, pharmacological, industrial

and biotechnological fields (Chermat 2019).

Ecologically, lichens are true pioneers (Ait Hammou 2015, Asta 2019). They are found in inert environments with extreme conditions (Boutabia 2016), where they cause pedogenesis and favor the appearance of plant cover (Hassani 2013). Within forest ecosystems, lichens provide food and refuge for other organisms and influence forest hydrology (Belguidoum 2021). Lichens are used as indicators of air quality par excellence (Fadel 2009, Semadi 1995, Ghennam 2011). Their use for biomonitoring is more effective compared to the Physico-chemical methods given the speed and the reduced costs (Maatoug 2010, Sarmoum 2014). On the other hand, lichens have important therapeutic properties such as antiviral, antioxidant, antifungal, antibacterial, and cytotoxic effects (Ramya 2017). The recent discovery of lichen antifreeze proteins for frozen foods and the degradation power of bioplastics and the prevention of dehydration would have a big impact on the food industry (Oksane 2006).

Lichenological studies in Algeria were initiated by Montagne in 1784, who inventoried 180 species including two genera and 18 species new to science at that time. In 1896, Flagey published a catalog of Algerian lichens, which has remained up to the present the most complete collection of Algerian lichens. After these works no flora, catalog, or even checklist from Algeria has been produced (Amrani, 2015). However, many contributions have been made in recent years focusing on floristic inventories of lichens in several Algerian regions and natural sites: (from east to west) El-Kala National Park (Slimani, 2013), Gouraya National Park (Rebbas, 2011), Djurdjura National Park (Chaker, 2021), Chréa National Park (Yahia, 2019), and Teniet el Had Park (Khdime, 2018). Nevertheless, no study has been established for the Tlemcen National Park, which is a real hot spot (Medjahedi, 2018). The lichen flora of this park has never been studied before, hence the interest of our contribution.

In this work we have centered our inventory on the forest of Hafir, the integral zone of the park, representing the core of the Park and its central part. The forest is an old cork oak stand of 200 to 250 years old (Bouhraoi, 2003). It is the largest cork oak forest in the wilaya of Tlemcen in terms of area. Unfortunately, this forest has suffered several fires; in 2002 a wild fire ravaged dozens of hectares of cork oak (Berrichi, 2015). And severe anthropogenic disturbances in recent years, which imposes the immediate justification for a conservation strategy based primarily on inventory studies in order to identify endemic species and preserve the natural patrimony.

Presentation of the study area

The Hafir forest, at the National Park of Tlemcen, is located in the northwest of Algeria in the wilaya of Tlemcen, municipality of Terni (fig.1). The Hafir forest is a mountainous area (part of the Monts de Tlemcen) ranging between 800 and 1418 m and extends over 32 km from east to west and 13 km from north to south (Sauvagnac, 1956). The dominating soils are deep brown forest soils 30 to 70 cm deep. The pH is slightly acidic with a value of 6.1 (Gaouar, 1980). The bioclimate is sub-humid Mediterranean with cool winters. Rainfall varies between 600 to 900 mm/year depending on altitude. The area is characterized by a fairly high atmospheric humidity which can reach 70% on average (Taibi, 2016), with an average annual temperature of 16°C. January is generally the coldest month, with average temperatures varying between 5.8 and 6.7°C. While July and August are the hottest months with temperatures of 24 to 26°C on average (Bouchaour-Djabeur, 2016).

The vegetation of the Hafir forest is a heterogeneous stand composed mainly of three oak species (*Quercus suber L*., *Quercus ilex* subsp. *ballota* (Desf.) Samp. And Quercus *faginea* subsp. *broteroi* (Cout.) A. Camus), wild olive tree (*Olea europaea* L. subsp. *europaea*) and an ash trees (*Fraxinus angustifolia* author subsp. *oxycarpa* (Willd.) Franco & Rocha Afonso) (Taibi, 2016). At low altitude *appears* the prickly cedar (*Tetraclinisarticulata* (Vahl) Mast.) and oxycedar juniper (*Juniperus oxycedrus* L. subsp. *oxycedrus*) (Mostefai, 2011). The Aleppo pine (*Pinus halepensis* Mill.), the pinion pine (*Pinus pinea* L.), the common cypress (*Cupressus sempervirens* L.), and *eucalyptus* meet in certain degraded cantons, where they were introduced during the last reforestation programs (Bouharoua, 2003).

Among the most common understory species, we cite *Hedera helix* L. subsp. *helix,Lonicera implexa* Aiton, *Smilax aspera* L., *Rubus ulmifolius* Schott, *Daphne gnidium* L., *Arbutus unedo* L., *Ruscusaculeatus* L., *Erica arborea* L., *Rosmarinus officinalis* L. and *Pteridium aquilinum* (L.) Kuhn subsp.*aquiline.* In the degraded, warmer areas, we can find more secondary species such as *Quercuscoccifera* L. and *Juniperus oxycedrus* L. subsp. *oxycedrus*, and also cistus (*Cistus albidus* L.,

Cistusladanifer L., *Cistus monspeliensis* L., *Cistus salviifolius* L. and *Cistus creticus* L.), *Ampelodesmosmauritanicus*(Poir.) T. Durand & Schinz and *Chamaerops humilis* L. (Haffaf, 2011)

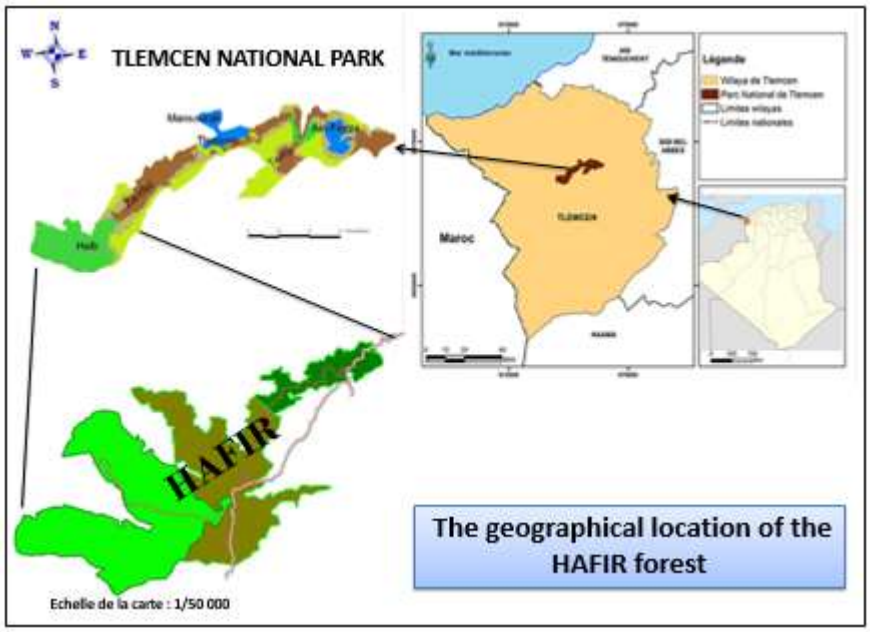

Figure 1: Location of the study area

Material and methods

Sampling

In order to consider all the ecological situations, the variability of the main ecological factors such as the nature of the substrate, type of the plants' formation, topography, and exposure, was considered Sampling was carried out between 2015 and 2020. Seven plots were defined and limited mainly by ridgelines, tracks, and reliefs (Figure 2). In each plot, we recorded the geographical coordinates, the slope, the exposure, and the nature of the substrate.

Lichen diversity was studied in all the available substrates: trees, rocks, and soil. Epiphytic lichens were collected on trunks up to 2 m in height, including branches.

The sampled lichens were individually wrapped in paper envelopes on which the survey number, date of collection, site and type of substrate are noted.

Identification

The identification of taxa follows the usual procedures based on morphological and chemical characters (AFL, 2022). Morphological characters were observed using a binocular stereo-microscope, and microscopical features were examined using a transmission microscope. Chemical characters were based on the reactions of selected parts of specimens to different reagents: chlorine (Cl), potassium hydroxide (KOH) and para-phenylenediamine (P).

The identification of the collected material we carried on by consulting several references Kirschbaum & Wirth (1997), Haluwyn et al. (2009), Krzewicka et al. (2009), Aptroot (2009), Aptroot & Schumm (2008), Jahns (2007), Serusiaux et al. (2004), Hale (1990), Boistel (1986) and Ozenda & Clauzade (1970).

The identified specimens are kept in a herbarium, where they can be used as a reference for further studies.

Results

The current lichen catalog of the Hafir forest consists of 68 species.

1. *Acrocordia gemmata (*Ach.*)* A.Massal.
2. *Amandinea punctata (*Hoffm.*)* Coppins et Scheid.
3. *Anaptychia ciliaris (*L.*)* Körb.
4. *Athallia pyracea (*Ach.*)* Arup,Frödén et Søchting
5. *Blennothallia crispa (*Huds.*)* Otálora, P.M. Jørg. & Wedin

6. *Caloplaca cerina (*Hedw.*)* Th. Fr
7. *Candelariella reflexa (*Nyl.*)* Lettau
8. *Candelariella vitellina (*Hoffm.*)* Müll Arg.
9. *Candelariella xanthostigma (*Ach.*)* Lettau
10. *Cladonia foliacea (*Huds*)*Willd
11. *Collema nigrescens (*Huds.*)* DC.
12. *Diplochiste scruposus (*Schreb.*)* Norman
13. *Enchylium tenax (*Sw.*)* Gray
14. *Evernia prunastri (*L.*)* Ach.
15. *Flavoparmelia caperata (L.)* Hale
16. *Heterodermia spciosa(*Wulfen*)* Trevis
17. *Hypogymnia tubulosa* (Schaer.) Hav
18. *Hypogymnia farinaceae* Zopf
19. *Hypogymnia physodes (*L.*)* Nyl.
20. *Hypotrachyna horrescens (*Taylor.*)* Krog &Swinscow
21. *Hypotrachyna pulvinata (*Fée.*)* Hale
22. *Lecania fuscella (*Schaer.*)* A. Massal.
23. *Lecanora allophana (*Ach.*)* Nyl
24. *Lecanora argentata (*Ach.*)* Malme*(syn. L. subfusca, & var. argentata, Parmelia subfusca*
25. *Lecanora caesiirubella (*Ach.*)*
26. *Lecanora campestris (*Schaer.*)* Hue
27. *Lecanora chlarotera* (Nyl.)
28. *Lecanora conizaoides Cromb.*
29. *Lecanora expallens (*Ach.*)*
30. *Lecanora intumescens (*Rebent.*)* Rabenh
31. *Lecanora pulicaris (*Pers.*)*Ach.
32. *Lecanora strobilina(*Spreng*)*Kieff
33. *Lecidella elaochroma (*Ach.*)* M. Choisy
34. *Lepra. amara (*Ach.*)* Hafellner
35. *Lepraria incana* (L.) Ach.
36. *Melanelixia glabra (*Schaer.*)* O.Blanco et al.
37. *Myriolecis dispersa (*Pers.*)* Śliwa, Zhao Xin et Lumbsch
38. *Myriolecis hagenii (*Ach.*)* Śliwa, Zhao Xin & Lumbsch
39. *Parmelia pastilifera (*Harm.*)* Hale
40. *Parmelia saxatilis* (L.*)* Ach
41. *Parmelia sulcate* Taylor
42. *Parmelina carporrhizans (*Taylor.*)* Poelt & Vězda
43. *Parmelina quercina (*Willd.*)* Hale
44. *Parmelina tiliacea (*Hoffm.*)* Hale
45. *Parmotrema reticulatum (*Taylor.*)* Choisy
46. *Parmotrema robustum (*Degel.*)* Hale
47. *Peltigera collina (*Ach.*)* Schrad.
48. *Peltigera practextata (*Sommerf.*)*Zopf
49. *Pertusaria hymenea (*Ach.*)*Schaer.
50. *Phaeophyscia ciliate (*Hoffm.*)* Moberg
51. *Phaeophyscia orbicularis (*Neck.*)* Moberg
52. *Physcia adscendens (*H.*)* Olivier
53. *Physcia aipolia (*Humb.*)* Fürnr.
54. *Physcia biziana (*A. Massal.*)* Zahlbr.
55. *Physcia caesia (*Hoffm.*)* Fürnr.
56. *Physcia dubia (*Hoffm.*)* Lettau
57. *Physcia stellaris (*L.*)* Nyl.
58. *Physcia tenella (*Scop.*)* DC.
59. *Physconia grisea (*Lam.*)* Poelt
60. *Physconia perisidiosa (*Erichsen*)* Moberg

61. *Pleurosticta acetabulum (*Neck.*)* Elix & Lumbsch
62. *Polycauliona candelaria* (L.) Frödén, Arup & Søchting
63. *Polycauliona polycarpa (*Hoffm.*)* Frödén, Arup, & Søchting
64. *Porina chlorotica (*Ach.*)* Müll.Arg
65. *Pseudovernia furfuracea* (L.) Zopf
66. *Ramalina farinacea* (L.) Ach.
67. *Variospora flavescens* (Huds.) Arup, Frödén et Søchting
68. *Xanthoria parietina* (L.*)*Th. Fr

Taxonomic notes

The 68 species so far identified represent 38 genera and belong to 16 families. The most abundant family is *Parmeliaceae* with 13 species in ten genera, followed by *Physciaceae* with 13 species in five genera, and *Lecanoraceae* with 12 species in two genera. These three families account for 60% of the catalog. Seven families are represented by just one species: *Caliciaceae*, *Cladoniaceae*, *Graphidaceae*, *Monoblasteniaceae*, *Lecideaceae*, *Porinaceae,* and Sterocaulaceae.

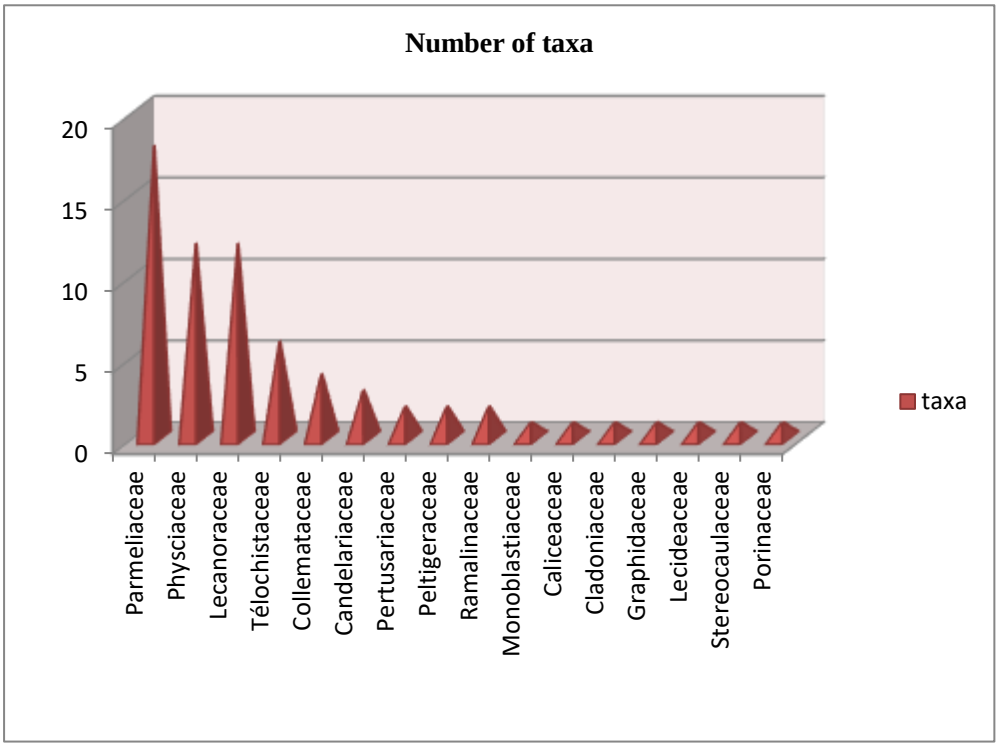

Figure.3: Diversity of lichens taxa observed in Hafir forest arranged by families

Morphological traits

The lichen diversity of the Hafir forest in the Tlemcen National Park shows six different thallus biotypes: crustose, foliose, fruticose, gelatinous, leprose and composite. The lichen catalog is dominated by foliose biotypes, 32 species have been observed representing almost the 50% of the taxa. Crustose lichens are also well represented by 27 taxa. Fruticose, composite, gelatinose, and leprose are scarcely pictured with four, three and one representatives each.

The type of lichens by nature of substrate

The identified lichens are mainly corticolous (67, 6%), followed respectively by saxicolous and terricolous lichens (19% and 8,8%), and muscicolous lichens represent (3%).

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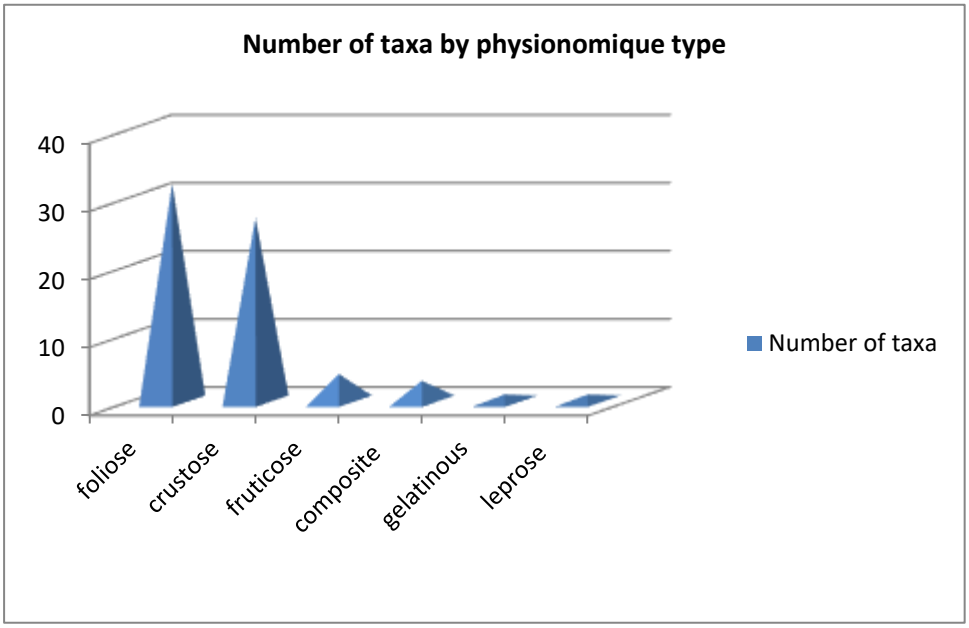

Figure 4: Diversity of lichensbased on the frequency of morphological traits

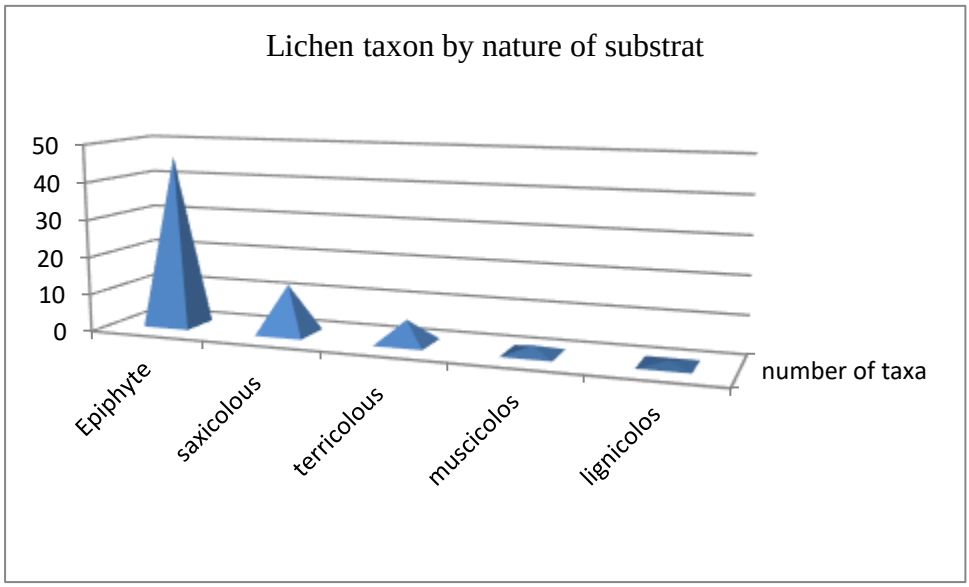

Figure 5: Lichen variability according to the nature of the substrate

Discussion

The lichen diversity in the Hafir forest is higher than other similar Algerian areas. Indeed, by comparing our data with the catalogs of the Gazoul forest in Tiaret with 30 species (Ait Hammou, 2011), Tessala forest in Sidi bel abbès with 53 species (Hamelaine, 2019), and the Ghoraya National Park with 50 species (Rebbas, 2011), it reflects the higher richness of our study. This is also comparable with larger covers such as the inventory of the Oran region yielding 68 species (Bendaikha, 2018) or the 70 species were identified for the entire Djurdjura National Park (Chaker, (2021). If we compare the lichen richness of Hafir forest in terms of altitudinal range, instead of cover, we can state that the potential lichen diversity is quite high. The lichen richness of our site, reaching 1400 m is very similar to the lichens found at Teniet el had which only counts 70 species with an altitude that reaches 1700 m (Khedim, 2018). Considering that lichen diversity increases with altitude (Belguidoum, 2021), the importance of the lichen diversity of Hafir forest, and the National Park of Tlemcen should be taken into consideration.

This demonstrates the importance of this area for this type of study. It should also be noted that in recent years, the forests of the Tlemcen region have suffered from drought and frequent fires (Berrichi, 2017).

The analysis of lichen diversity reveals the importance of Parmeliaceae, with 18 species and 26% of taxa inventoried. Our results are similar to those of Ait Hammou (2015) Boutabia (2018) and Merabti (2020). These are generally found in the natural environment, which confirms the cleanness of the atmosphere in the natural environment as well as the high altitude. According to Boutabia (2018), the majority of species in these genera require sunshine and humidity. The dominance of Parmeliaceae is probably due to its cosmopolitan distribution, it is among the most popular families worldwide. It should also be noted that the species of this family settle in a wide range of habitats (Thell, 2012).

The analysis of the morphological traits of the lichens (fig.4) shows us a clear dominance of foliose thallus with 32 species. This diversity in biotypes is similar to the results of Semadi (1989), Boutabia et al. (2015) and Ait Hammou (2015). The analysis of the diversity in morphological traits indicates a low diversity of lichen categories, given the rarity of the spectrum with leprous and gelatinous thallus. Lichens with foliose thallus are the most abundant; this is undoubtedly due to the dominance of *Parmeliaceae* and *Physciaceae*. Crustose biotypes are also very numerous, represented by 27 species. They are very common because of their great resistance to climatic and substrate influences thanks to their strong adhesion to substrates (Bendaikha, 2018). Fruticose lichens are scarce in number but they are more abundant, in terms of biomass, above 2 meters of the trunk. These parts were outside the harvesting area. Fruticose lichens characterize wet stands at an altitude above 200 m (Boutabia, 2018), which confirms the harmony of the suitability of the study environment.

Corticolous lichens are the most dominant given the nature of the forest ecosystem where phorophytes cover more than 70% of the global surface. Epiphytic lichens require suitable substrates for their development and several factors such are the nature of the substrate, the climate, or the quality of air (Semadi, 1983; Bendaikha, 2006; Fadel et al., 2012). Related to their ecology there is a sort of biotype. Crustose lichens are more common in bark crevices; while foliose species prefer to grow on an exposed surface, a trend that has already been found in several habitats and bioclimates (Rose, 1974; Öztürk, 2010; Bendaikha, 2018).

Altitude plays a determining role in the distribution of lichen species (Charmat, 2019). Indeed, lichens are largely abundant on the same phorophyte where the altitudinal gradient varies between 800 and 1400 m. Lichen cover is denser when altitude increases (Bendaikha, 2018) those areas have an environment that is more humid, cool, and unpolluted. Therefore, altitude is a variable that affects the richness, species composition and diversity of lichens (Baniya et al. 2010; Vittoz et al., 2010; Bässler et al. 2016; Rodríguez et al. 2017 and Cleavitt et al. 2019).

Johansson et al. (2007) found that older trees are richer in lichens and harbor a greater number of species than younger trees. This agrees with Scheidegger and Clerc (2002), who highlighted the importance of old trees for the conservation of epiphytic lichens.

In terms of rarity, we have inventoried 18 species threatened with extinction in Algeria among the identified lichens They appear in the list of protected plant species according to executive decree n°12-03 of 10 Safar 1433 corresponding to January 12, 2012, of the journal Algerian official. They are*: Anaptychia ciliaris (L.) Koerb. Foli, Cladonia foliaceae (Huds) Willd, Evernia prunastri (L.) Ach., Hypogymnia physodes (L.) Nyl, Parmelia saxatilis (L.) Ach, Parmelia sulcata (Taylor), Parmelia tiliaceae (Hoffm) Hale, Peltigera practextata (Flörke ex Sommerf.), Physcia adscendens (Fr.) H.Olivier, Physcia aipolia (Ehrh. ex Humb.) Fürnr, Physcia biziana (A.Massal.) Zahlbr, Physcia caesia (Hoffm.) Hampe ex Fürnr, Physcia dubia (Hoffm.) Lettau, Physcia stellaris(L.) Nyl , Physcia tenella (Scop.) DC, Physconia grisea (Lam.) Poelt, Physconia perisidiosa (Erichsen) Moberg, Ramalina farinacea (L.) Ach*

Conclusion

This preliminary work provides a general idea of the distribution and diversity of lichens in the Tlemcen region and the Hafir forest in particular. The latter presents an important lichen flora where we have been able to identify 68 species with varied taxonomic groups and morphological traits.

This inventory will undoubtedly contribute to the development of lichenological knowledge of the

Tlemcen National Park and the Tlemcen region in particular, and of Algeria and North Africa in general. It will also make it possible to develop lichenological research in Algeria by providing the necessary information (taxonomic, chronological, and ecological) for the production of works to help future researchers in this field.

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Author's Contributions

MAAZOUZ Sarah The choice of subjects, the bibliographic research, the application of the working methodology of the collection of samples to the writing of the manuscript

AIT HAMMOU Mohamed The proposal of the methodology, the confirmation of the determination of the species studied.

BENDAIKHA Yassmina. Manuscript development monitoring

BENFRIHA Abderrazzak participation in collecting samples, writing the manuscript and checking the translation.

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