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ECOLOGICAL IMPORTANCE OF BRYOPHYTES IN THE CORK OAK FOREST OF MAMORA (MOROCCO)

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Abstract

Located in northwest Morocco, the Mamora forest was at the beginning of the XXth century a real reservoir of Flora and Fauna biodiversity. Today, this biodiversity is considerably reduced as a result of the strong anthropozoological pressure it faces. The bryological biodiversity of the area has been estimated at around 70 species. The objectives of this work are to assess the ecological importance of this flora and to compare the three cantons studied. Thus, for each species surveyed, a cover index was assigned, which made it possible to calculate the Index of Ecological Significance (IES). Using this index, five groups of species were identified: very rare species (29 taxa), rare species (28 taxa), moderately abundant species (10 taxa), abundant species (2 taxa) and a single dominant species (*Ptychostomum cappillare*) with an IES of 336. The species with xerophilic character are the most abundant because the suberaie (Cork Oak Forest) is a fairly an open plant formation and the soil is very sunny. There is a decrease in species richness and abundance of bryophyte species from Canton A (West) to Canton C (East) along an increasing continental gradient, with a slight increase from Canton B to Canton C. This last variation can be explained by the fact that Canton C is characterized by a profusion of temporary pools and Canton B is heavily anthropized. The three cantons studied are *Quercus suber* ecosystems whose generally similar environmental conditions explain the similarity b*et*ween the three sites evaluated at 70% using the Sørensen Index. The similarity b*et*ween the cantons taken in pairs, as assessed by the Jaccard index, is 89% b*et*ween A and C, 61% b*et*ween A and B and 58% b*et*ween B and C. These values show that the effect of continentality is impacted at Canton B by the strong anthropic pressure on the site.

Key words : Bryophytes, biodiversity, abundance, similarity, Mamora, Morocco.

Introduction

The Mamora forest, located in the northwest of Morocco, is a large expanse of cork oak that spreads from the Atlantic coast in the west to the vicinity of around he city of Tifelt in the east over a length of nearly 70 km and a width of nearly 30 km. At the beginning of the XXth century, this forest formation was a real reservoir of biodiversity, both Fauna and Flora. Today, the ecosystems that make up the Mamora forest have been considerably impoverished due to the anthropic pressure they have been subjected to since the beginning of the century. In a large part of Mamora, the soils are compacted by overgrazing and are less and less hospitable to the regeneration of the suberaie and its shrubby undergrowth; the undergrowth is no longer formed except by undemanding therrophytes. Under these conditions, the census of the bryological diversity of the cork oak forest of the Mamora made it possible to establish a list of 70 species including 44 Mosses, 22 liverworts and 4 hornworts (El Harech *et al.,* 2020). This biodiversity is important for the functioning of the cork forest ecosystem.

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Indeed, observations throughout the forest have shown the correlation between the presence of these species and the germination of cork oak acorns (El Harech *et al.*, 2020).

In this context, the objective of the present work is to assess the ecological importance of bryological diversity in the three cantons A, B and C of Mamora using the Index of Ecological Significance (IES). This Index was designed by Lara and Mazimpaka in 1998 and used in particular by Albertos *et al.*, (2000 and 2001); Marques *et al.*, *(*2005); Ezer *et al.*, (2009); Ezer and Kara (2013); Medina *et al.*, (2013); Ezer (2017).

Materials and Method

1. Study area

The part of Mamora concerned by this study is limited to the three cantons A, B and C (Fig. 1). Cantons E and D have been left out because they contain many private enclaves, access to which is not always easy or authorized. The three invested cantons are located between three major conurbations (Rabat the capital, Salé and Kénitra). Canton A, bordered to the west by the Atlantic Ocean, has a subhumid bioclimate with temperate variant. Canton C, located further east, has a semi-arid bioclimate. There is therefore a gradient of West-East continentality which causes precipitation to decrease and temperatures to rise towards the East. The three cantons are underlain by a geological bedrock formations marl, sand or sandstone Pliocene (HCEFLCD, 2011), on which sandy-clayey soil develops.

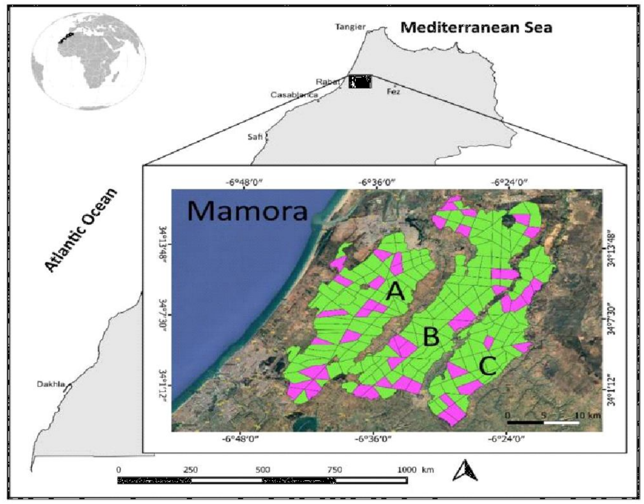

Fig. 1: Geographical location of Mamora (Cantons A, B and C). Sampled plots are in red.

2. Sampling and data analysis

The sampling adopted is stratified random sampling with 50 stations selected from the 245 plots in the 3 cantons on a random basis, taking care to exclude plots containing private enclaves (Fig. 1). Proportional stratified random drawing is performed in Excel using the function *alea* and taking the cantons as stratum. Random points are generated at the rate of one point per plot drawn.

Sample collection took place during the fall and spring of the years 2015, 2016 and 2017. At each station and for each species sampled, an index is assigned corresponding to the coverage class. This index will allow the calculation of the IES (Index of Ecological Significance). The Index/Coverage Class correspondence scale is as follows :

Index	0,5	1	2	3	4	5
Class	<1%	1% à 5%	6% à 25%	26% à 50%	51% à 75%	> 75%

In the IES index, coverage and frequency, which are the 2 parameters of abundance, are combined to best reflect any changes in species abundance (Albertos *et al.*, 2001). IES values are combined with frequency classes as follows: very rare (IES<25), rare (26-50), moderately abundant (51-100), abundant (101-200) and dominant (> 200).

Index of Ecological Significance (IES)

The relative frequency was estimated using the Index of Ecological Significance (IES) (Lara & Mazimpaka, 1998; Albertos *et al.*, 2001), whose mathematical expression is as follows:

$$IES = F\ (1 + C)$$

F is the relative frequency; $F = 100 * x / n$, where *x is* the number of samples containing the species and *n is* the total number of samples;

C: average coverage; *C=" ci / x*, where *ci* represents the coverage class assigned to the species in each sample.

Sørensen Index

In order to compare sites from the point of view of similarity, several indices are used including the Sørensen index (Magurran, 2004; Diserud and Odegaard, 2006). Cantons A, B and C are the three sites to be compared in our case;

so T = 3 sites;

a: number of species in Canton A; b: number of species in Canton B and c: number of species in Canton C.

C_S^T ab: number of species in common between sites A and B; ac: number of species in common between sites A and C; bc: number of species in common between sites B and C; abc: number of species in common between all sites of A, B and C.

: Sørensen Index

$$C_S^T = \frac{T}{T-1} * \frac{ab + ac + \mathbf{bc} - \mathbf{abc}}{a + b + c}$$

Jaccard index

To compare the cantons two by two, the Jaccard index is recommended (Magurran, 2004; Diserud and Odegaard, 2006).

$$I_{Jaccard} = \frac{ab}{a + b - 2ab} \times 100$$

where A and B are the two sites to be compared; a: number of species in site A; b: number of species in site B; ab: number of species in common b*et*ween A and B.

Results

The specific richness of the bryological flora of the Mamora forest has been evaluated at 70 species belonging to 38 genera and 21 families (El Harech *et al.*, 2020). This richness in cantons A, B and C is of 60, 31 and 40 taxa respectively. The results of the d*et*ermination of the Index of Ecological Significance (IES) for each species in each of the three cantons are presented in (Table 1).

Thus, 5 groups of species were identified by matching the values of this index to the frequency classes (Fig. 2).

The species is very rare if IES≤25, rare if 26<IES≤50, moderately abundant if 51<IES≤100, abundant if 101<IES≤200 and dominant if IES>200. These groups are presented below. For each group, species are listed in order of increasing IES (values in brack*et*s).

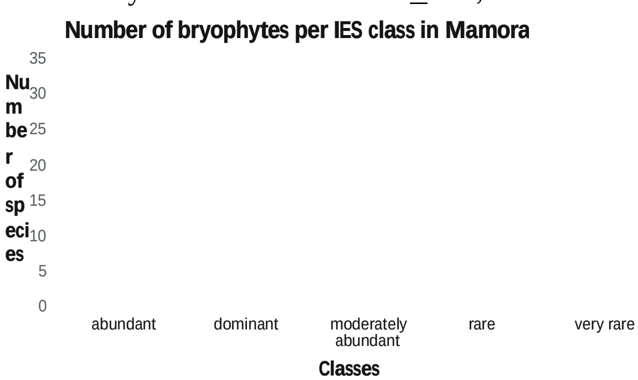

Fig. 2: Ecological importance of bryophyte species in the Mamora forest.

Very rare species (29 taxa)

Funariella curviseta (3), *Entosthodon fascicularis* (4), *Zygodon viridissimus* (4), *Frullania dilatata* (4) *et Riccia crozalsii* (4), *Fossombronia caespitiformis subsp. Multispira* (4), *Riccia fluitans* (4), *Riccia huebeneriana* (4), *Riccia lamellosa* (4), *Riccia macrocarpa* (4), *Sphaerocarpus michellii* (4), *Bryum radiculosum* (6), *Cheilothela chloropus* (6), *Anthoceros punctacus* (6), *Phymatoceros bulbiculosus* (6), *Orthotrichum anomalum* (8), *Didymodon tophaceus* (8), *Targionia lorbeeriana* (8), *Fossombronia pusilla* (8), *Entosthodon pulchellus* (9) , *Campylopus pilifer* (12), *Tortella nitida*(14), *Physcomitrium pyriforme* (14), *Riccia cavernosa* (14), *Trichostomum crispulum* (16), *Riccia sorocarpa* (16), *Riccia warstorfii var. subinermis* (16), *Tortula marginata* (18) , *Orthotrichum lyellii* (24).

Of these species, only one is aquatic, *Riccia fluitans* (Fig. 3). It was observed in Canton A.

Rare species (28 taxa)

Scorpiurium circinatum (26), *Rhynchostegium megapolitanum* (26), *Fabronia pusilla* (26), *Didymodon vinealis* (26), *Brachythecium velutunum*(26), *Isothecium alopecurioides* (26), *Fissidens bryoides* (26), *Bryum argentum* (26), *Timmiella barbuloides* (26), *Lunularia cruciata* (26), *Bryum dichotomum* (28), *Didymodon fallax* (28), *Syntrichia ruralis* (28), *Riccia crystallina* (28), *Anthoceros agrestis* (28), *Aloina ambigua* (30), *Corsinia coriandrina* (30), *Syntrichia laevipila* (32), *Fossombronia caespitiformis* (32), *Oxymitra incrassata* (32), *Riccia canaliculata* (32), *Targionia hypophylla* (34), *Pleuridium subulatum* (34), *Campylopus introflexus* (34), *Phaeoceros laevis* (42), *Sematophyllum substrumulosum* (42), *Barbula unguiculata* (44) and *Tortula muralis* (46).

Moderately abundant species (10 taxa)

Riccia gougetiana (52) , *Tortella squarrosa* (54) *et Homalothecium sericeum* (54) , *Orthotrichum diaphanum* (60) , *Funaria hygrometrica* (63), *Barbula convoluta* (64) *et Ptychostomum torquescens* (64), *Tortella flavovirens* (68) , *Riccia ciliifera* (74) , *Bryum caespiticium* (78).

The abundant species (2 taxa)

Brachythecium rutabulum (104) and *Pleuridium acuminatum* (150).

The only species considered to be dominant is *Ptychostomum capillare* with an IES of 336.

Similarity b*et*ween cantons A, B and C of the Mamora forest using the Sørensen index

The comparison of similarity b*et*ween cantons of Mamora according to Sørensen index is evaluated as follows:

Species number matrix (number of species per

Table 1: IES for taxa in cantons A, B and C of Mamora.

Index of Ecological Significance (IES)			
Species	**Canton A**	**Canton B**	**Canton C**
Aloina ambigua	_	_	30
Barbula convoluta	8	12	44
Barbula unguiculata	16	12	16
Bryum argentum	12	6	8
Bryum caespiticium	30	40	8
Bryum dichotomum	22	6	_
Bryum radiculosum	3	_	3
Brachythecium rutabulum	32	36	36
Brachytheciumvelutunum	14	_	12
Campylopus introflexus	6	8	20
Campylopus pilifer	_	4	8
Cheilothela chloropus	_	_	6
Didymodon fallax	14	14	_
Didymodon tophaceus	4	4	_
Didymodon vinealis	12	14	_
Entosthodon fascicularis	4	_	_
Entosthodon pulchellus	9	_	_
Fabronia pusilla	6	20	_
Fissidens bryoides	12	_	14
Funaria hygrometrica	26	11	26
Funariella curviseta	3	_	_
Homalothecium sericeum	36	18	_
Isothecium alopecurioides	_	8	18
Orthotrichum anomalum	8	_	_
Orthotrichum diaphanum	18	12	30
Orthotrichum lyellii	_	16	8
Physcomitrium pyriforme	14	_	_
Pleuridium acuminatum	36	48	66
Pleuridium subulatum	20	14	
Ptychostomum capillare	138	110	88
Ptychostomum torquescens	40	24	_
Rhynchostegium megapolitanum	26	_	_
Scorpiurium circinatum	26	_	_
Sematophyllum substrumulosum	30	12	_
Syntrichia laevipila	18	_	14
Syntrichia ruralis	12	6	10
Timmiella barbuloides	16	_	10
Tortella flavovirens	18	18	32
Tortella nitida	8	6	_
Tortella squarrosa	40	_	14
Tortula marginata	6	_	12
Tortula muralis	12	6	28
Trichostomum crispulum	8	_	8
Zygodon viridissimus	4	_	_
Corsinia coriandrina	8	6	16

Table 1 contd....

canton):

The index formula is:

$$C_S^T = \frac{T}{T-1}\frac{ab+ac+bc-abc}{a+b+c}$$

	A	**B**	**C**
A	60		
B	25	31	
C	32	19	40

therefore:

$$C_S^T = \frac{3}{2} * \frac{61}{131} = 70\%$$

Thus, there is 70% of similarity between the canton A, B and C.

Similarity between the cantons of the Mamora forest considered two by two using the Jaccard index

Cantons A and B:

Species number matrix

thus the similarity as computed by Jaccard index is of:

$$I_{Jaccard} = \frac{25}{41} = 61\%$$

	A	**B**
A	60	
B	25	31

Cantons A and C:

Species number matrix

thus the similarity as computed by Jaccard index is of:

$$I_{Jaccard} = \frac{32}{36} = 89\%$$

	A	**C**
A	60	
C	32	40

Cantons B and C:

Species number matrix

thus the similarity as computed by Jaccard index is of:

$$I_{Jaccard} = \frac{19}{33} = 58\%$$

Table 1 contd....

Species	Canton A	Canton B	Canton C
Fossombronia caespitiformis	16	_	16
Fossombronia caespitiformis	_	4	_
subsp. multispira			
Fossombronia pusilla	_	_	8
Frullania dilatata	3	_	_
Lunularia cruciata	26	_	_
Oxymitra incrassata	16	_	16
Riccia canaliculata	_	4	28
Riccia cavernosa	14	_	_
Riccia ciliifera	16	22	36
Riccia crozalsii	4	_	_
Riccia crystallina	14	_	14
Riccia fluitans	4	_	_
Riccia gougetiana	8	_	44
Riccia huebeneriana	_	4	_
Riccia lamellosa	4	_	_
Riccia macrocarpa	4	_	_
Riccia sorocarpa	16	_	_
Riccia warstorfii var. subinermis	8	_	8
Sphaerocarpus michellii	4	_	_
Targionia hypophylla	28	_	6
Targionia lorbeeriana	20	_	8
Anthoceros agrestis	14	_	14
Anthoceros punctacus	_	_	6
Phaeoceros laevis	16	_	26
Phymatoceros bulbiculosus	6	_	_

	B	C
B	31	
C	19	40

Discussion

The Index of Ecological Significance (IES) identified 5 groups of species: 29 very rare taxa, 28 rare, 10 moderately abundant, 2 abundant and 1 dominant. This can be explained by the fact that the Mamora forest is an open formation over almost all of its territory and the high level of sunshine in the clearings and voids makes it difficult for the bryophytes to establish themselves except where the humidity is maintained. Moderately abundant, abundant and dominant species are xerophilic species capable of withstanding the harsh conditions of the environment.

The most frequently encountered species in the study area is *Ptychostomum capillare* which is observed in almost all samples (about 92%). It has significant overlaps on sandy-clay soil and at the base of the cork oak trunks, its IES decreases from west to east along a continental gradient, it reaches respectively 138, 110 and 88 in cantons A, B and C. This species of the family Bryaceae has also been observed in the exotic gardens of Bouknadel (El Harech *et al.*, 2018) and in the archaeological site of Chellah (El Harech *et al.*, 2017), with higher cover rates than other bryophyte taxa. It has also been reported at high *altitudes* in Morocco by Ros *et al.*, (2000) on the edges and fissures of granitic and quartzite rocks and peaty soils, between 2100 and 3300 meters above sea level, in the Middle Atlas by (Mazimpaka *et al.*, 2004; Draper *et al.*, 2006; Fadel *et al.*, 2017) in the Rif and Tazzeka Mountains by (Draper *et al.* 2005); and in the Ouzoud Waterfalls in the High Atlas by (Chtaibi *et al.*, 2018).

Pleuridium acuminatum is also widespread in the Mamora forest (IES = 150). It has been observed in the Rif, precisely at the level of Jbel Bouhalla between 1220 and 1050 m a.s.l (Jiménez *et al.*, 2002), at the level of the Ouzoud waterfalls in the High Atlas (Chtaibi *et al.*, 2018) and in the Ouazzane region at the level of the Jbel Sidi Ali forest in the Izarène massif (Laouzazni *et al.*, 2018).

Among the liverworts, *Riccia ciliifera* is the most widespread species, it is quite common in Morocco. Already in 1955, Jovet-Ast reported it on the exempt margins of the Mamora dayas. It usually occurs in association with *Fossombronia* sp.

Phaeoceros laevis (Fig. 4e) is the most frequently encountered taxon among the hornworts. It colonizes the wet earthen slopes.

Funariella curviseta (Fig. 4a) is the rarest species (IES = 3). It was harvested in Canton A on wet earthy soil. In the Rabat region, it was also encountered in the archaeological site of Chellah on limestone (El Harech *et al.*, 2017). It is a species that is difficult to observe because of its elusive vegetation.

Returning to the study site enabled us to adjust the specific numbers for Cantons B and C compared to El Harech *et al.*, (2020). Thus, the number of taxa is 60 in Canton A, 40 in Canton C and 31 in Canton B. The degree of similarity between cantons A, B and C in terms of specific richness, evaluated using the Sørensen index, is 70%. This similarity could be explained by the fact that the cantons involved in our study are *Quercus suber* ecosystems, which implies a relative similarity in

Fig. 3: a, b, c and d individuals of *Riccia fluitans* seen under binocular magnifying glass x20, x30 and x40; e and f microscopic observations of the surrounded areas x100; g thallus cross section x400.

environmental conditions. The 30% variation could be explained by the fact that Canton A is the closest to the Atlantic coast with a sub-humid bioclimate, Canton C holds relatively well preserved Cork oak forests even in a semi-arid bioclimate, and Canton B is characterized by a sparse forest, very poor undergrowth and compacted soil. The effect of continentality (West-East) is impacted by anthropogenic factors in Canton B. Thus, the variations noted in Canton B, where the species richness is relatively low compared to Canton C, which is more continental, can be explained by the strong anthropozoogenic pressure that the first canton has been facing since the beginning of the XXth century. In addition, in Canton C, the clay layer is close to the surface in several localities generating temporary puddles called dayas (Fig. 4b and c) which result in b*et*ter soil moisture maintenance. This is why the liverworts are more diversified in cantons A (18 species) and C (11 species) compared to B (5 species) since these plants are very sensitive to the moisture and quality of the soil. In the same context, hornworts are not observed in Canton B because they require aerated and moist soil. These conclusions are confirmed by the Jaccard index, which allows the evaluation of the degree of similarity b*et*ween the studied cantons considered two by two. Indeed, the rate of similarity b*et*ween Canton A and C is the highest (89%) when b*et*ween Cantons A and B is 61% and b*et*ween Cantons B and C is 58%. This clearly shows that the effect of continentality is modified by anthropic pressure and by the nature of soil.

In the Mamora forest, acorns have a high germination potential but the environmental factors such as soil compaction and drought hinder it. Germination is observed where the soil is covered with bryophytes because they maintain sufficient moisture levels to allow the acorns to produce new individuals.

Conclusion

The analysis of data collected in the Mamora during the autumn and spring of 2014, 2015 and 2016, enabled us to identify five groups of bryophyte species: very rare (29 taxa), rare (28 taxa), moderately abundant (10 taxa), abundant (2 taxa) and dominant (1 taxon). The species richness and cover rates or abundance of bryophytes are higher in Canton A where the bioclimate is sub-humid under the influence of the Atlantic Ocean and where temporary and permanent dayas are frequently encountered. The continental gradient affects the species richness and abundance of bryophytes, which decreases

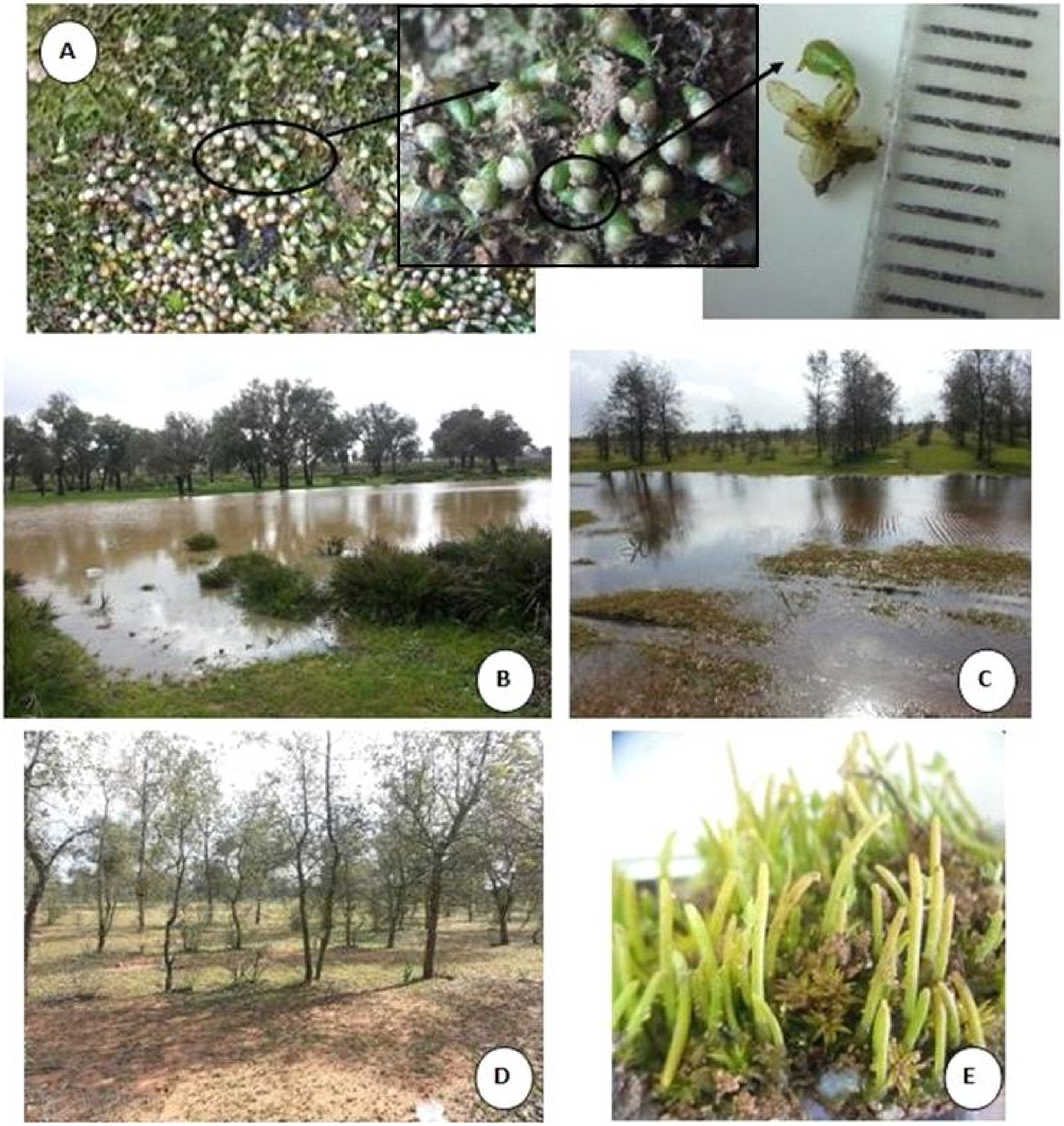

Fig. 4: A/ *Funariella curviseta* in situ and under binocular magnifying glass; B and C/ the Mamora Dayas; D/ General view in Canton A; E/ *Phaeoceros laevis* under binocular magnifying glass x 20.

from west to east, but Canton B has exceptions in some places as it undergoes high anthropozoogenic pressure and its soil is generally compacted by human visits and overgrazing. In Canton C, the soil is more consistently moist in several locations because the clay layer is close to the surface. For this reason, the highest cover classes are recorded in Canton A and C. The rarest species is *Funariella curviseta* and the most abundant is *Ptychostomum capillare.* The rate of similarity b*et*ween the three cantons studied remains fairly high (70%), which can be explained by the fact that the Mamora forest as a whole is a fairly homogeneous plant formation. The variations are relative to the effect of anthropisation and continentality. This is shown by the similarity rates of cantons two by two evaluated using the Jaccard index: 89% b*et*ween cantons A and C, 61% b*et*ween cantons A and B and 58% b*et*ween B and C.

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