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Full Length Research Paper

Distribution and ecology of the superior mushrooms of the Aulnaie of Ain Khiar (El Kala National Park, Northeastern Algeria)

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The macro-ecology of the superior mushrooms in the peat land of the El Kala National Park (Algeria) is totally unknown. The research presented here aims at determining the environmental factors which might explain the distribution of mushrooms and contribute to the knowledge of the mycofloristic composition of this particular environment. For that purpose, we selected a protected site in the El Kala National Park, classified RAMSAR since 2002 as: "the Peat land of Ain Khiar". The carpophores of mushrooms were exhaustively recorded on a monthly basis from November, 2003 until May 2008, and several environmental factors which might determine the distribution of the species such as altitude, acidity of the ground, the degree of humidification of peat land, floral composition of the vegetation were also recorded. The site of Ain Khiar is part of 60 sites studied at the El Kala National Park, which will be the subject of future other publications. Twenty two species were collected on the site, among which 6 species (25 %) were found to be unique to this site. A differentiated analysis according to functional groups of macrofungi showed that the 15 saprotrophs species are determined by several factors of comparable importance; while the ectomicorrhizal are mainly determined by the most dominant species. A more relevant analysis of the ecology of the fungal communities is thus obtained by distinguishing the functional groups, their specific composition being determined by different environmental factors.

Key words: Macrofungi, inventory, Peat Land of Ain Khiar, trophic status, distribution.

INTRODUCTION

The macro-ecological study of mushrooms was introduced by the works published by Maire (1907), which were mainly carried out in the forests of Baïnem (Algiers). At the level of El Kala National Park (Northeastern Algeria), no study of inventory was published until our days, as well as for the mycological inventories concerning the peaty milieu.

More generally, with the exception of the most characteristic or the most symbolic species, the precise information on the ecology and the biogeographical distribution of macrofungi associated with peat land milieu is very rare. The unique bibliographical reference base as for the knowledge and the ecology of the species of mushrooms in North Africa (Algeria, Tunisia and Morocco) consists in the herbarium elaborated by Malencon and Bertault (1970, 1975), kept at the Museum of Natural History of Montpellier (France); unfortunately this last one, does not supply quantitative indication on the ecological spectra of the species.

Our study, dedicated to the fungal communities of the Peat land of Ain Khiar within the El Kala National Park, a wet zone classified RAMSAR site since 2002 (Boumezber and Bouteldji, 2002), is divided into two additional parts. The first part consists of a macroscopic and microscopic description of the species recorded at the level of the chosen site, whereas the second part aims to describe more exactly the ecology of these mushrooms by analyzing in the mean time the distribution of the species according to the environmental conditions

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Figure 1. Location of the Aulnaie of Ain Khiar with regard to the PNEK (Source: Google Earth, 2010).

(synecology) and the fungal communities as descriptors of these conditions (mycocoenological study).

MATERIAL AND METHODS

Choice of the site

A peaty site was chosen at the level of the El Kala National Park as representative of the peat land of the northeastern of Algeria, namely the Peat Land of Ain Khiar. The Peat land of Ain Khiar, also called Aulnaie of Ain Khiar, is a wet zone classified site RAMSAR site "1" since 2002 with the Lac Noir (PNEK). Situated in the Municipality of Ain Khiar, Daïra d' El Tarf, Wilaya d' El Tarf (Figure 1), the site is located at an altitude ranging from 0 to 3 m above sea level (latitude 36° 40'N, longitude 8° 20'E); its area is 180 ha.

Description

The main peculiarity of the El Kala National Park, the aulnaie-ripisylve, is extremely rare to be found somewhere else in Algeria; it is characterized by a floral composition based of *Alnus glutinosa, Fraxinus oxyphylle, Populus nigra, Salix babylonica*, a tree stratum demanding high humidity. The Peat land of Ain Khiar is situated between the dunal shoreline cord and the agricultural plain of El Tarf. By receiving, in winter, waters of the floods of the Oued El Kebir that drains the entire region, it is transformed into a swampy zone. This small ecosystem has a considerable biological and scientific value in the Maghreb. It is an extremely rare environment of natural wet zone of the Mediterranean region, and can be considered a site of international importance. The fact of being a peaty area as well, not studied, increases the indisputable intrinsic value of the site (Boumezber and Bouteldji, 2002).

Physical characteristics

Geology and geomorphology: The territory where the Aulnaie of Ain Khiar is located is characterized by a relatively complex geology. Generally speaking, we distinguish, according to a North-south fictitious line, big geomorphologic sets and low hills formations from 30 to 310 m as Djebel El Korsi with an average of 100 m of height.

Hydrology: The Aulnaie of Ain Khiar is a part of the plain of El Tarf near Oued El Kebir and near the pond overturning of the dam of Mexna. It is fed by Khelidjes and Châabets (small brooks and rivulets) of Boukchrida, El Aloui and Tchaouf and receives in winter period the floods of the Oued El Kebir. Being a part of the low plain, it remains sometimes flooded even in summer period, especially when late rains fall in April and May.

Climate

This particular ecosystem benefits from special conditions or

Figure 2. The Aulnaie of Ain Khiar (Photo taken by R. Djelloul).

microclimate. Commonly, according to the classification of Emberger (1955), the zone is located in the sub humid bioclimatic floor characterized by a cold and wet winter and a warm and dry summer. The volume of rain varies from 717.2 to 944 mm per year; January being the rainiest month. This considerable volume is due to the absence of topographic obstacles as well as to the nearness of the sea and the surrounding lakes of the wet complex of the region of El Kala. The thermal variations show that August month is the warmest month, the minimal of the average temperatures are of 8°C and the maxima of 29.7°C.

Type of ground

Grounds are mainly composed of silt; widely present developed in the swamps and flooded lowland; the impermeability of the basement is connected to the extension of clays of Numidia.

Ecological characteristics

The Aulnaie of Ain Khiar shelters vegetation cover is characterized by the presence of *Fraxinus* sp., *A. glutinosa, Populis* sp., *Salix* sp., a tree stratum that requires high humidity. Trees composing the Aulnaie are essentially deciduous broad leaves, with 20 m height in average (Figure 2). The important canopy, can reach 100% in certain places, with an 80% average. The presence of old trees and/or died trees as well as the bryophytes facilitates the installation of specific fungi species of ecological interest (Boumezber and Bouteldji, 2002).

Sampling method and determination of carpophores

The site of Ain Khiar is considered as ecologically homogeneous as for its vegetation. Considering the large extension of the site and its homogeneity, we studied a small spot with an area of 5000 m^2, according to the method of laminated sampling suggested by Rodwell et al. (1991), for the study of the vegetation in a peaty environment. This corresponds to the estimation of minimal area of sampling for the superior mushrooms (between 500, 1000 and 5000 m^2) calculated by Arnolds (1992).

The chosen sampling method, which appeared best to fit our objectives, is the 'unpredictable transects' method of Favre (1948). Carpophores were exhaustively counted on the site during monthly visits from November, 2003 till May, 2008. The number of carpophores per unit of surface (5000 m^2) was converted into index of frequency:

1 = A carpophore with spot distribution;
2 = 0.04 - 0.50, 2 - 5 carpophores / 5000 m^2 ;
3 = 0.51 - 1.0, 6 - 10 carpophores / 5000 m^2;
4 = 1.1 - 2.0, 11 - 20 carpophores / 5000 m^2;
5 = 2.1, > 20 carpophores / 5000 m^2.

The identification of mushrooms was performed on the basis of on reference guides and identification keys: Malencon and Bertault (1970, 1975), Bouchet (1979); Montegut (1980), Becker (1980), Bon (1988), Thibault (1989), Courtecuisse and Duhem (1994), Romagnesi (1995), Slezec (1995), and Roux (2006). Identification was confirmed as often as necessary by microscopic examination. The specimens of most of the definite species were sent to the Laboratory of Cryptogamy, Faculty of Pharmacy, Henry Poincaré 1 university-Nancy for confirmation of the identification, and are currently kept as exsiccata in the personal collection of R. djelloul.

Environmental factors

The altitude of the site was pointed out from the topographic maps. The measurement of soil acidity, the pH of the water of the peat land was measured using an electronic pH-metre at 15°C, on 4 samples, at two different soil depths 0 to10 cm and 10 to 20 cm. The rate of humification (dosage of the carbon) of the peat land was estimated by the method Walkley-Black modified for both soil depth levels (Sidari et al., 2008).

The floral composition of the phanerogamous vegetation as well as the bryophytes was determined and compared with other studies previously carried out within the El Kala National Park (Belair, 1990; Friberg et al., 2009).

Data analysis

The relations between the environmental factors found on the identified spot and the abundance of carpophores were analyzed. The maximal frequency index of every species (observed during monthly visits) was used as measure of its abundance in the spot. This indication being an ordinal variable, its association with the environmental factors was analyzed by tests of correlation of K-Pearson (tests of Chi-deux). According to these tests, the hypothesis H_0 representing the abundance of the carpophores of the species independent from the tested factor is rejected for P < 0. 05.

The significant correlations (P < 0.01) for the quantitative environmental variables (pH and altitude) and the rate of humification were divided into positive or negative correlations, as the specie is associated with the high or low values of the analyzed environmental variable. The relations with the vegetative cover (collection) were analyzed specie by specie wise.

To determine if the relative influence of the various environmental factors on the fungal populations differs according to the functional groups of mushrooms, four biological statuses were distinguished: Ectomicorrhizal species, saprotrophes on humus, saprotrophes on

Table 1. List of species listed out by indicating their trophic status and frequency index.

Species	Trophic status	Frequency index
Alnicola bohemica (Vel.) Kühner and R. Maire*	Mycorrhizic (*Alnus*)	2
Amanita rubescens Pers. : Fr.	Mycorrhizic	2
Armillaria mellea (Vahl: Fr.) Kummer	Parasitic (*Alnus*)	2
Auricularia auricular-judae (Bull.: Fr.) Wettst	Saprotrophic lignicolouse (*Alnus*)	2
Clitocybe candicans (Pers. : Fr.) Kummer	Saprotrophic humicolouse	2
C. decembris Singer	Saprotrophic humicolouse	2
Coprinus disseminatus (Pers. : Fr.) Gray	Saprotrophic lignicolouse (*Alnus*)	3
Cortinarius sp. *	Mycorrhizic	2
C. variabilis (Pers. :Fr.) Kumm.	Saprotrophic lignicolouse (*Salix*)	2
Galerina sp. *	Bryotrophic	2
G. coockeianum Nannf.	Saprotrophic humicolouse	2
H. mesophaeum (Pers.) Quelet**	Mycorrhizic (*Alnus* ?)	2
Hygrocybe reae (Maire) Lange	Saprotrophic humicolouse	2
Hypholoma fasciculare : (Hudson : Fr.) Kummer	Saprotrophic lignicolouse	2
Laccaria lateritia Malençon	Mycorrhizic	3
M. littoralis var. *microsporus* (Maire) Josserand	Saprotrophic humicolouse	2
Pluteus sp. *	Saprotrophic lignicolouse	2
Psathyrella candolleana (Fr. :Fr.) Maire	Saprotrophic lignicolouse (Salix)	3
Sarcoscypha coccinea (Scop. : Fr.) Lambotte	Saprotrophic lignicolouse	2
Schizophyllum commun Fr. : Fr.	Saprotrophic lignicolouse	3
Tubaria romagnesi ((Maire ex Kühn.) *	Saprotrophic humicolouse	2
T. quisquiliaris (Fr. :Fr.) P. Hennings*	Saprotrophic (Ptéridophytes)	2

* Species specific for the site of study; * * species harvested at high altitude > 500 m at other sites.

Table 2. Number of fungal species correlated to the altitude, for all the species as well as for four functional groups.

Trophic status	Low altitude (< 500 m)	High altitude (> 500 m)
Ectomycorrhizic species	4	1
Saprotrophic humicolous species	6	0
Saprotrophic no humicolous species	10	0
Bryotrophic	1	0
All types of species	21	1

wood and bryotrophic species.

RESULTS

General distribution of the fungal species

Twenty two species of macrofungi were collected of the Ain Khiar site (Table 1). Among these, 6 species were found to be site specific (indicated in table by *), that is, were not harvested at any other sites of the El Kala National Park.

The species indicated in the table by **, are species which were only harvested at other sites at high altitude (> 500 m).

Correlations between the fungi communities and the environmental variables

The altitude of the experimental plots we have sampled varies from 0 to 3 m. Comparing our data with those obtained studying the macrofungal flora at 60 different sites within the El Kala National Park, 21 species out of the 22 species listed out and analyzed here, were found to be correlated, as for their occurrence, to the altitude (that is, they were more frequent at low altitude) (Table 2). Three species only were found to be ubiquitarious, with a similar frequency at both high and low altitude.

Therefore, the fungal variety average at the level of this

Table 3. Number of fungal species correlated to the acidity of the ground in the superficial soil (0 to 10 cm) and the lower soil (10 to 20 cm), for the four functional groups.

Trophic status	Superficial soil	Lower soil
Ectomycorrhizic species	2	4
Saprotrophic humicolous species	5	6
Saprotrophic no humicolous species	4	2
Bryotrophic	1	1
All types of species	12	13

Table 4. Number of associated fungal species influenced by the rate of humification in the superficial horizon (0 to 10 cm) and the lower horizon (10 to 20 cm), for all the species as well as for four functional groups.

Trophic status	Superficial soil	Lower soil
Ectomycorrhizic species	4	4
Saprotrophic humicolous species	5	6
Saprotrophic no humicolous species	0	0
Bryotrophic	1	0
All type of species	10	10

site (peaty milieu at low altitude), is superior to that of high altitude milieu, with 21 species growing at less than 500 m and 1 specie growing at more than 500 m of altitude.

The acidity of the soil (pH of water of the peat soil) at the study site varied from 6 to 6.5. Most of the species whose abundance was connected to the pH of the superficial soil layer (0 to 10 cm) also correlated to the pH of the deepest layer (10 to 20 cm). Certain species however were correlated only to the superficial pH (Table 3). Only two ectomicorhizal species (*Hebeloma mesophaeum* and *Cortinarius* sp.) and a saprotrophic species on humus *(Clitocybe decembris)* associated to the deepest layer, which suggests a distribution of the mycelium deeper than that of the other species.

The amount of the total organic carbon at the level of the peat soil of Ain Khiar was found to be rather an important factor influencing macrofungal occurrence/ frequency. According to the analysis of modified Walkley-Black, 60% of organic matter was determined. Only 10 species were found to be significantly influenced by the rate of humification (Table 4), among which four ectomicorrhizal species that were associated with a high rate of decomposition as well as the species saprotrophic on humus. The single bryotrophic species was found to be influenced by a high rate of humification of the superficial horizon.

All the species correlated to the level of humification of the lower horizon are also correlated to that of superficial horizon; not surprisingly, the only occurring bryotrophic species, was found to be correlated only to humification of the superficial horizon.

The collection of the lignicolous species, linked to the tree stratum, is an important factor for the distribution of more than a half of the studied species (Table 5). The analysis revealed a strong influence of *Alnus* on the ectomicorrhizical composition of the mycoflore and on the general specific variety. The same happens for *Salix,* each tree genus possessing a small contingent of exclusive ectomycorrhizal species.

Bryophytic are strongly correlated in the mycofloristique composition of the studied environment. These correlations concern at the same time species of mushrooms directly associated with mosses (*Galerina* sp.) and saprotrophic humus species associated with the organic matter

The ectomycorrhizal species (Figure 3a) depend, first of all, on tree cover and on the degree of humification of the ground, with almost equal proportions (20%) of significant correlations. The saprotrophic non humus species (Figure 3c), for the greater part associated with died wood and ligneous fragments, depend mainly on the nature of the ligneous substratum (60%). On the other hand, saprotrophic on humus (Figure 3b) are determined by other factors of equivalent importance, namely, the acidity (Lower soil 18%, Superior soil 21%). The bryophytic species (Figure 3d) are mainly determined by the composition of stratum muscinale (25%), but also by the degree of humification of the soil (25% of the correlations) and by the degree of acidity of the soil.

We can thus recapitulate the data in Table 6.

DISCUSSION

With this exhaustive inventory, the El Kala National Park

Table 5. Number of fungal species associated with the collection of botanical species as well as four functional groups.

	All	EM	SH	SnH	B
Aborscented stratum					
A. glutinosa	10	4	0	6	0
Salix sp.	3	0	0	3	0
Fraxinus sp.	1	0	0	1	0
Strate muscinale	7	0	6	0	1
All types included	21	4	6	10	1

EM: Ectomicorrhizal; SH: Saprotrophic on humus; SnH: Saprotrophic not on humus; B: Bryophytic.

administrators will then have an evaluation of the macro-fungal component of this remarkable peaty area. This study should be extended and completed by repeated works in the future.

These analyses showed a significantly different influence of various environmental factors on the respective composition of the various fungal communities, that is, ectomicorrhizal species, saprotrophic and bryophytic species (Figure 2). These comparisons notably show a dominating influence of the tree cover over the ectomicorrhizical composition, and of the nature of muscinales strata, as well as the altitude (strongly significant on the various sites studied on the whole research), on the bryophytic composition. This suggests a certain predictability of the composition of the fungal communities dominating the peat formations, as for what concerns the ectomicorrhizal communities and bryophytic species, knowing the nature of the vegetation and the altitude.

On the other hand, the saprotrophic communities seem to be determined by an association of co-dominant factors (floral composition, acidity, altitude, degree of humification) which do not allow, according to this analysis, to predict the specific composition of saprotrophic communities of a given environment. The reasons can be an ecological eclecticism of all the dominant species, or more probably a necessity of distinguishing various saprotrophic categories (Moreau, 2002).

If correlations between fungal species and environmental factors or botanical species were described in this work, no functional relation was envisaged here; such relations should be established in the other scales of study, the determination of an ectomicorrhizal relation is made either by direct observation of carpophors (Favre, 1948), or by identification of micorrhizes (Gardes et al., 1990; Rinaldi et al., 2008).

Also, the correlations between plants of herbaceous stratum and mushrooms (not exploited results considering that the correlations are not significant), describe only an ecological convergence, because no functional relation between these plants and the studied mushrooms is attested. We note in particular that *Salix* sp., that accompanies the afforestation of peat lands, is connected with the presence of mushrooms ectomicorrhizically linked to the nearby trees.

The correlations presented here concern only 21% of the total fungal variety. Among these species, we find species not indicated by Malencon and Bertault (1970, 1975), for example *Crepidotus variabilis, Geoglossum coockeianum* and *Typhula quisquiliaris.* It is thus a question of describing the main features of the environment, which define the ecological spectrum of the most representative fungal species. The study of the fungal associations (or "mycocoenology"), by means of multifactorial statistical analyses, allows us to take into account the less present species on 2 or 3 spots in comparison with the highly present species and the ecology of which is better defined (these results will be published in the future). These two complementary aspects of the ecology of carpophores, if they do not bring directly interpretable information about the biology of the species, suggest on the other hand to a very direct application in the inventory initiatives and bio-evaluation of the fungal communities (Arnolds, 1988; Courtecuisse et al., 2000; Gulden et al., 1992).

Conclusions

The present mycological study conducted within the El Kala National Park carries valuable information on the presence, the distribution, the ecology and the taxonomy of mushrooms in peat lands. Due to the lack of space, we could not accompany this publication with a descriptive part of the 21 of macrofungi collected on the site during these years of study.

This report fits within the frame of a more complete and general inventory work and cartography of mushrooms conducted on a total of 60 sites within the El Kala National park, studied over 5 years, out of which the Peat land of Ain Khiar is just a small portion.

The results of the synecologic analysis of the mushrooms was very satisfactory and allowed us to define the influence of the different studied factors, both biotic and abiotic (altitude, pH, rate of degradation of the organic matter, vegetation) on each of the species listed out.

The mycocoenology analysis also was found applicable to our statements, in spite of the choice of a single peat land site in this study.

The system of mycocoenology we achieved is still incomplete, as regard to the use of the one single plot (for the realization of analysis in this publication), of the presence of mixed plots, and the presence of some disseminated flavorant in the opened milieus etc. Nevertheless, we think we were able to define, with coherence, the main associations of carpophores highlighted by the statistical analysis, and to replace them in a dynamic description of the environment.

The sampling system planned initially, and adapted

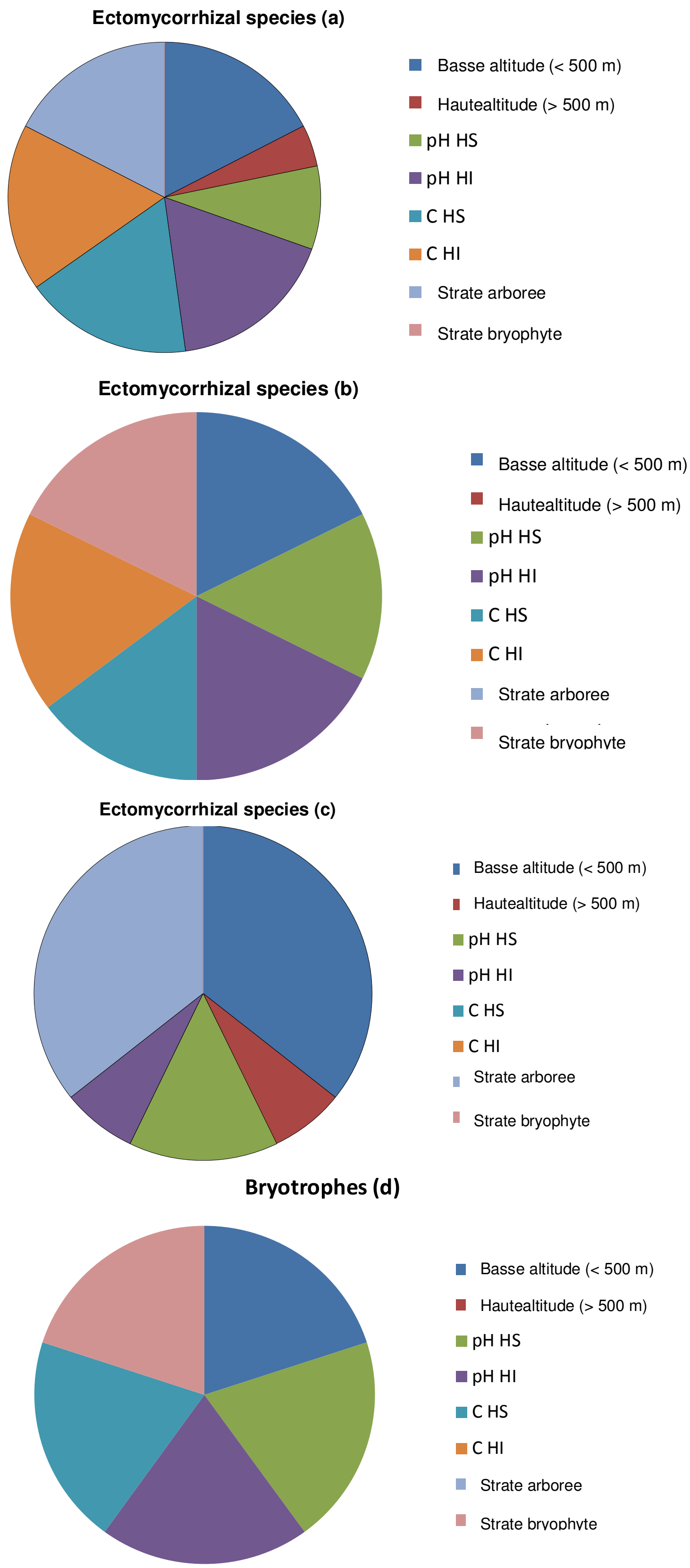

Figure 3. Relative influence of the various environmental factors studied on the specific composition of the fungal communities, given separately for four functional groups of basidiomycètes. (a, b, c, d).

Table 6. List of the fungal species listed out as well as the environmental variables in which its abundance was correlated.

Name	Var. abiotiques	Strate arborée	Muscinale stratum
C. variabilis (Pers.: Fr.) Kumm.	Alt.+, pH+	*Salix*	
Tubaria furfuracea ((Maire ex Kühn.) *	Alt+, pH+, CT+		+
S. coccinea (Scop. : Fr.) Lambotte	Alt.-, pH-	*Alnus*	
H. reae (Maire) Lange	Alt.+, pH+, CT.+		+
S. commun Fr. : Fr.	Alt.-, pH-, CT.-		
G. coockeianum Nannf.	Alt.+, pH+, CT.+		+
C. candicans (Pers. : Fr.) Kummer	Alt.+, pH+, CT.+		+
M. littoralis var. *microsporus* (Maire) Josserand	Alt.+, pH+, CT.+		+
C. decembris Singer	Alt.+, pH+, CT.+		+
Pluteus sp. *	Alt.+, pH-, CT.-	*Alnus*	
A. auricular-judae (Bull.: Fr.) Wettst	Alt.+, pH+, CT.-	*Alnus*	
Coprinus micaceus (Bull. : Fr.) Fr.	Alt.+, pH+, CT.-	*Salix*	
C. disseminatus (Pers. : Fr.) Gray	Alt.+, pH-, CT.-	*Alnus*	
H. fasciculare : (Hudson : Fr.) Kummer	Alt.+, pH+, CT.-	*Alnus*	
T. quisquiliaris (Fr. :Fr.) P. Hennings*	Alt.+, pH+, CT.-		
Galerina sp. *	Alt.+, pH+, CT.+		+
A. bohemica (Vel.) Kühner & R. Maire*	Alt.+, pH+, CT.+	*Alnus*	
H. mesophaeum (Pers.) Quelet	Alt.-, pH+, CT.+	*Alnus*	
Cortinarius sp. *	Alt.+, pH+, CT.+	*Alnus*	
A.rubescens Pers. : Fr.	Alt.+, pH+, CT.+	*Alnus*	
A.mellea (Vahl: Fr.) Kummer	Alt.+, pH+, CT.-	*Alnus*	

The codes of the environmental variables denote the significant correlations in P < 0,01, the other one, the significant correlations in P < 0,05 (test of K-Pearson). * Specific species in the site of study, Alt.: altitude, CT.: Carbon total.

specifically to the mosaic structure of the environment of study (variable-sized surface between 500 and 5000 m^2), was found effective and suitable to meet the initial objectives. This tailored method; using stratified sampling on homogeneous units of vegetation allowed us to have an almost exhaustive census of the species on plots spots as well as the comparison of 60 sites between them.

Finally, this work seems to open new perspectives of studies on the peaty milieu, a type of environment often neglected by mycologists. So, the alkaline afforestations reveal an extreme variety, of which the determinism varies according to the dominant flavorant.

The implications of our analysis on the conservatory management of the milieus are delicate to establish. The patrimonial evaluation represents the most direct application: The diversity of species, established type wise of vegetation, or even the characterization of mycocoenology, combined to the presence of species on red list, is enough to give an estimation of the patrimonial interest of a milieu. The alkaline afforestations (*Salix* and *Alnus* especially) are the most diversified, and deserve a conservation or a management suited to the preservation of this variety.

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