INVENTORY AND ECOLOGY OF MACROFUNGI AND PLANTS IN A NORTHWESTERN ALGERIAN FOREST

Mesfek, F., Z. Fortas and S. Dib

Laboratoire de Biologie des microorganismes et Biotechnologie, Département de Biotechnologie, Faculté des Sciences de la Nature et de la Vie, Université Oran 1 (Algérie)

Abstract

In Algeria, forest ecosystems bring together a diversity of fungal species and little data is currently available on forest macrofungi. This preliminary study focuses on the distribution and ecology of macrofungi in two sites in Northwester of Algeria. The mycological surveys carried out for the first time during two successive years made it possible to determine the fungal and floristic diversity as well as the climatic parameters and the physicochemical characteristics of the soil. The results indicate a good relation between the appearance of fungi and environmental factors. The fungal inventory carried out in the two study sites reveals a diversity of macrofungi comprising 44 taxa (84.09% basidiomycetes and 15.9% ascomycetes) distributed in 24 genera and 17 families. This diversity of the macrofungi identified is also linked to the density of the plant cover made up of three strata: tree, shrub and herbaceous.

***Keywords*:** Fungal diversity; Macrofungi; Oued Rhiou Forest; Climatic factors; Floristic survey.

INTRODUCTION

Studies on fungal diversity in forest ecosystems are numerous after 2000 (Richard *et al.* 2005, Azul *et al.* 2010, Aponte *et al*. 2010, Fernandez-Brime *et al.* 2014). A total of 1.5 million fungal species is estimated to populate our planet and only about 5-10% are identified and described (Zervakis and Venturella 2007). In North Africa, the only basic bibliographic reference on the ecology and knowledge of macromycetes are the work of Maire (1906), Malençon and Bertault (1975), Bertault (1980). The current knowledge available on fungal diversity in the Maghreb is presented either in the form of a bibliographic inventory in Morocco on the basidiomycetes of Tangier (Outcoumit *et al*. 2014) and of a checklist of macrofungi in Tunisia (Ouali *et al.* 2020), or in the form of studies relating to the synecology of macrofungi in the region. We can cite the study of the mycoflora of El Kala in northeastern Algeria, the myco-ecology of cork groves in northeastern Algeria (Adouane 2011). The documents relating to Algerian mycoflora are scattered. The most important fungal inventory in the historical literature is that of Maire (1916) concerning the mushrooms of the surroundings of Algiers and the works of Malençon and Bertault (1975) which report some descriptions of mushrooms collected in Algeria.

The study of the mycoflora of the Chréa cedar grove in the Djurdjura massif in Algeria allowed the identification of 100 species of macrofungi including 48 genera belonging to the Tricholomatales (Cortinariales and Russulales) (Nezzar-Hocine *et al.* 1996). The preliminary inventory of cork oak russules from northeastern Algeria based on bibliographic data and classical mycological methods made it possible to describe six species of *Russula* (Chekireb *et al*. 2013). The work on the ecology of macrofungi and their distribution in the alder groves of El Kala National Park (North-East of Algeria) carried out by Djelloul (2014) led to the identification of 67 species including 10 species specific to the study site and 45 species specific to the type of environment (alder groves). The inventory of

macrofungi carried out in the cedar groves of Belezma National Park in Batna (50 species) of Basidiomycetes and one species of Ascomycete according to Boukerker and Boumedjane (2018). However, these methods still lack the finesse of molecular analysis; there is little work in the Maghreb using molecular tools to identify forest fungi. For example, the phylogenetic study of the fungi of a Moroccan cork grove carried out by useing the techniques of restriction fragment length polymorphism (RFLP) and those of Benazza-Bouregba (2017) in Algeria who studied the diversity of saprophytic and mycorrhizal basidiomycetes fungi of the cork grove of the forest of M'sila (Wilaya Oran). The analysis of 127 ITS rDNA sequences enabled the author to identify 29 genera and 50 species (ectomycorrhizal and saprophytic), 4 of which are potentially new (*Inocybe. Aff. Tigrina* (I. Pn. sp.), *Cortinarius* Pn. sp., *Macrolepiota* aff. *phaeodisca* (M. Pn. Sp.), *Boletopsis* Pn. sp. 1, never described and 22 species including (*Hebeloma limbatum*) already known but never reported in Algeria. *T. caligatum* identified for the first time in North Africa by molecular tools belongs to the group of *Matsutake* known for their high gastronomic value (Benazza-Bouregba *et al.* 2016). This work made it possible to enrich for the first time an herbarium referenced MPU of the University of Montpellier, France by Algerian macrofungi with molecular data and illustrations of certain samples and also to enrich bases of international data (GenBank, Unite) with sequences from the ITS zone of rDNA of little-known fungal species from the Mediterranean rim.

These works show that the mycological inventories carried out in certain Algerian forest ecosystems are scattered and often remain incomplete or nonexistent in several regions not yet explored, hence the interest of preliminary study on the distribution and ecology of macrofungi in the forest of Oued Rhiou, in the Northwest of Algeria (Wilaya of Relizane) where no fungal inventory has been made yet.

METERIAL AND METHODS

Surveys were carried out in 2011 and 2012 in the North West of Algeria in two sites located in the state forest of Oued Rhiou (Wilaya of Relizane) located in the South East of the commune of Ain Tarik (Fig. 1a, b). The 1st site is located in the locality of Kherrarba (canton of Tafrent) and the 2nd site in the locality of Tidda (canton Ain Dalia). This forest has an area of approximately 3521.71 ha, its topography is hilly with a slope of 30 % and a North-East and North-West exposure and its altitude varies between 171-990 m. It presents a diversity of plants, forest species mainly *Pinus halepensis*, *Quercus ilex*, *Quercus coccifera*, *Tetraclinis articulata* and an undergrowth represented mainly by *Cistus* sp. and *Pistacia lentiscus* (Fig. 1c, d, e). The region is characterized by a sub-humid to semi-arid climate, with average monthly temperatures from 26 to 27°C (maximum temperature 28.5°C in March and April and minimum temperature 9.15°C in December and January). The average annual rainfall is 429 mm. The characteristics of the two sites studied are presented in Table 1.

Data on the study region were collected in the Wilaya of Relizane from the Forest Conservation Department of the Wilaya of Relizane, the Circonscription of Ammi Moussa as well as the District of Ain Tarik.

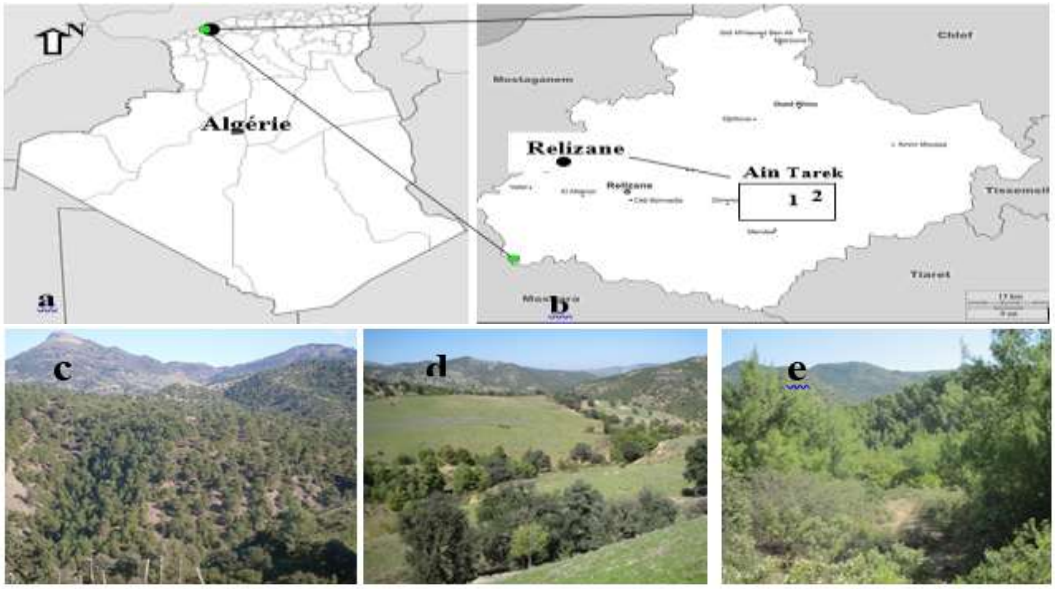

Fig.1. a = Location of Relizane province in northwestern Algeria, **b** = Location of the two studied sites Kherraba (**1**) et Tidda (**2**) in the commune of Ain Tarik, **c** = Oued Rhiou State Forest Overview**, d=** Kherrarba Site Overview, e = Tidda Site Overview.

Table 1. **Characteristics of the two sites studied in Oued Rhiou State Forest of Ain Tarik municipality according the Conservation of Forests of Relizane province and Ain Tarik District.**

Locality sites	Cantons	Geographical coordinates	Area (ha)	Altitude (m)	Dominant vegetation
Kherrarba	Tafrent	X1: 366,5 X2: 368 Y1: 273,5 Y2: 274,5	873	626 -761	*Pinus halepensis*, *Quercus ilex* (espèce indigène) very abondant et *Quercus coccifera, Tetraclinis articulata, Pistacia lentiscus*
Tidda	Ain Dahlia	X1: 363 X2: 364 Y1: 275 Y2: 276	863	461 -606	*Pinus halepensis* (espèce introduite) with some *Quercus ilex, Quercus coccifera, Tetraclinis articulata, Pistacia lentiscus*

Sampling

Samples were collected and recorded from November to April during two successive study years 2011 and 2012 in the two Kherrarba and Tidda sites of the Oued Rhiou national forest. The samples collected were macromycetes forming sporophores directly observable *in situ* (epigeal or semi-hypogeal). Fruit bodies were harvested mainly in November - December rarely in March-April in a random manner without special statistical methods allowing a strict correlation between the number of surveys carried out in the forest and the number of taxa recorded. When the fruiting of the fungi was visible, two or three samples of the same fungal species were collected. The harvested sporophores were photographed *in situ* before their harvest, taking care to note their natural substrate (mosses, dead tree, under the trunk or near a living tree), their mode of development "social character of fungus" (alone or in group) and certain characters that are immediately recorded such as color, diameter of the cap,

presence or absence of ring or volva, smell, etc.). Each collected sample is placed separately in a paper bag and transported to the laboratory for further examinations.

Ecological study of survey sites

Climatic parameters

Climatic data (temperature, rainfall, humidity) were collected from the National Water Resources Agency (ARNH) (Wilaya de Relizane) for the Gargar station, which is the closest meteorological station to our study region. To know the distribution of rainfall according to the seasons, we analyzed the average seasonal rainfall regime in the two study sites according to Musset (1935).

Physico-chemical analysis of soil samples

Five soil samples were taken at depths from 5 to 20 cm and at different places in each study site. They were then mixed according to the practical guide provided by the Fertial Laboratory in Annaba (Algeria) in order to constitute a significant sample for physico-chemical soil analyzes. Their physico-chemical analysis was carried out at the Regional Soil Analysis Laboratory of El-Matmar (Wilaya of Relizane) and at the FERTIAL Laboratory in Annaba.

Floristic survey

The samples of the most frequent plant species, within a radius of 2 m of the site of the sporophores were collected and photographed *in situ*. Their identification was carried out at the Laboratoire d'Ecologie Végétale according to the flora of Maire (1952-1987). The taxa nomenclature have been updated from the North Africa database of Dobignard and Chatelain (2010-2013).

Determination of fungal taxa

The harvested sporophores were dried as quickly as possible, especially fleshy specimens, such as *Boletus* to prevent decomposition of the flesh. Large mushrooms were cut into half for better drying. The dried sporophore samples were then stored in brown paper bags labeled with the sample number, date of harvest and *in situ* photographs.

The identification of the collected taxa was carried out mainly following macroscopic and microscopic methods. Certain macroscopic characters of the sporophores, collected and photographed in the field, were immediately recorded, such as color, diameter of the cap, presence or absence of ring or volva, odor, etc. Other additional observations were carried out in the Laboratory using a Leica stereomicroscope magnifying glass, in particular the dimensions of the cap and the stipe (length and diameter) as well as the insertion of the gills which is a diagnostic feature for the identification of macromycetes.

The microscopic observations of the spores (color, shape) and their dimensions were carried out using an Olympus CX22 microscope on dried collections and from fresh basidiospores. The sample is mounted between slide and coverslip in a drop 3% potassium hydroxide (KOH) for the examination of spores and in Congo Ammoniacal red for basidia and cystidia. The sizes of 30 spores were measured using a calibrated micrometer placed on the microscope. The sporic quotient (Q) was calculated by Q = Length / Width; this provides information on the shape of the spore.

All the macroscopic and microscopic characteristics of each sample were recorded on a descriptive sheet. The Identification of taxa was performed using the Index Fungorum (http://www.indexfungorum.rg/Names/Names.asp).

RESULTS AND DISCUSSION

Ecological characteristics of the study sites

Climatic parameters

A number of important factors in particular the climate, the composition and structure of the vegetation and the physicochemical nature of the soil exert an influence on the diversity of fungi. The sporophores were harvested in November-December 2011 and 2012 and in the spring of 2012 during the wettest seasons. The fruiting of forest mushrooms depends on certain climatic conditions, such as season, temperature, precipitation and relative humidity (Fig. 3). There was a slight variation in the average monthly temperatures between 2011 and 2012. The minimum temperatures were 10.55-13.05°C in January - February and 10.2-15°C in October-December; they were maximum in July-August (Fig. 3a). The highest rainfall was recorded in November 2011 with 88.6 mm and in April and December 2012 with 98.2 mm and 88.5 mm, respectively. The maximum precipitation was in 2011 in winter and autumn and in 2012 it was in winter and spring (Fig. 3b). The average seasonal rainfall in the two study sites was WASS (Winter-Autumn-Spring-Summer) in 2011 and SWAS (Spring-Winter-Autumn-Summer) in 2012 (Fig. 3c). The average values of relative humidity were 45.5-52.5% in November-December (Fig 3d).

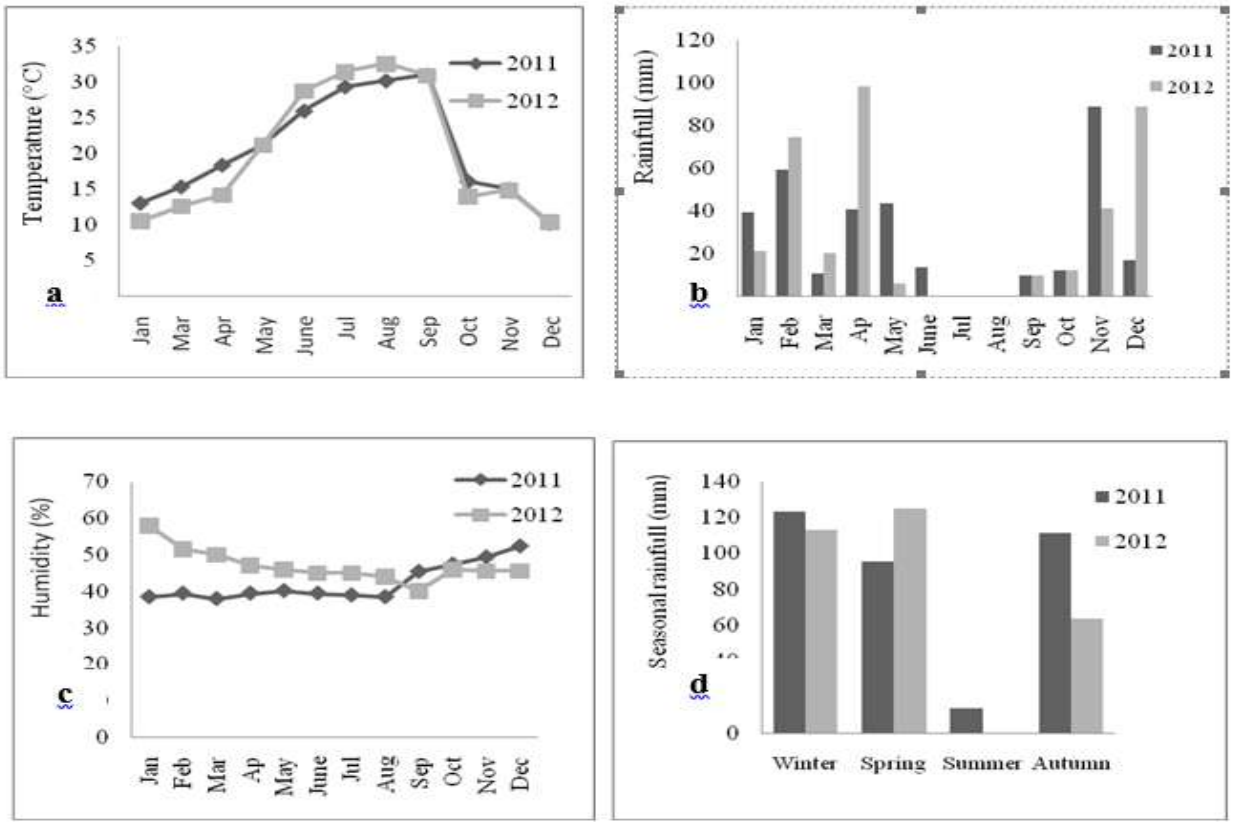

Fig. 3. Variations of climatic parameters in studied sites during 2011 and 2012. **a** = monthly variation of temperature; **b** = monthly variation of rainfall; **c** = monthly variation of relative humidity; d = variation of seasonal rainfall pattern.

Physico-chemical characteristics of the soil

The physico-chemical analysis of the soil reveals that the soil composition of the two study sites is not very different (Table 2). The soil texture is silty-sandy in the Kherrarba site and silty-clayey-sandy in that of Tidda. Silt is dominant (41.57-43.46%), sands represent 34.14-45.83% and clay 10.71-24. 29%. The electrical conductivity results show that the soil is unsalted (0.12-0.17mS / cm) according to the Herrmann salt scale. The soil of the two sites is at an alkaline pH (7.81-7.88), limestone containing a high content of organic matter (2.64%-3.27%) and low in nitrogen (0.15%-0.20%). It is poor in assimilable phosphorus (0.8-10.90%) and well supplied with magnesium and potassium.

Table 2. Soil physicochemical characteristics of macromycetes in studied sites.

Soil parameters	Site Kherrarba	Site Tidda
Clay (%)	10.71	24.29
Fine silt (%)	11.97	32.63
Coarse silt (%)	31.49	8.94
Fine sand (%)	11.01	6.85
Coarse sand (%)	34.82	27.29
pH	7.81	7.88
Total $CaCO_3$ (%)	0.42	8.49
Organic matter (%)	2.64	3.27
Electrical conductivity (Ms/cm)	0.12	0.27
N Kjeldahl (%)	0.15	0.20
Mg (meq/100g)	1.86	8.90
Na (meq/100g)	0.30	10.54
K (meq/100g)	0.27	1.20
Ca (meq/100g)	57.11	60.47
P Olsen (ppm)	10.90	0.80

Floristic statement

The floristic survey revealed the presence of 68 taxa distributed between 37 families and 60 genera in the two study sites. 56 taxa are represented by species of specific or sub-specific rank (Table 3). The vegetation covering the Tidda site is relatively higher than that of the Kherrarba site. The most represented families are Asteraceae (14 taxa, 20.58%), Papilionaceae, Borraginaceae, Rosaceae (4 taxa, 5.88%), Fabaceae (3 taxa, 4.42%), Brassicaceae, Caryophyllaceae, Cistaceae, Cupressaceae, Fagaceae, Lamiaceae and Poaceae (2 taxa, 2.94%). The rest of the families are represented by a single taxon (1.47%). The vegetation covering the sites studied (Table 3) is composed of a shrub layer, made up of *Quercus ilex*, *Quercus coccifera*, *Pinus halepensis* and *Tetraclinis articulata*. The underforestation consists mainly of *Pistacia lentiscus*, *Olea europea var. oleaster*, *Cistus albidus*, *Cistus monspeliensis*, *Arbutus* sp., *Arbutus unedo*, *Acacia saligna*, *Lavandula stoechas*, *Calycotome spinosa*, *Ampelodesma mauritanica*, *Tamarix gallica*. The herbaceous state consists of taxa, the majority of which are common or fairly common in Algeria because they are resistant, undemanding and ruderal. The installation of certain species is favoured as in the majority of Algerian forests by grazing, fires and an unfavorable climate (viz. *Anacyclus clavatus*, *Calendula arvensis*, *Carduus* sp., *Echinops* sp., *Marrubium vulgare*, *Malva sylvestris*, *Papaverrhoeas*, *Plantago lagopus*, *Anagallis monelli*, *Reseda alba).*

Table 3. **Abundance of plant species in Kherrarba and Tidda sites (Oued Rhiou forest, Algeria). Abundance classes: + = 0 - 10 %; I = 11 - 20 %; II = 21- 40 % (Gehu et Rivaz-Martinez 1981).**

Plant Family	Plant species	Kherrarba	Tidda
Aceraceae	*Adonis* sp.	I	+
Agavaceae	*Agave americana* L.	+	I
Anacardiaeaec	*Pistacia lentiscus* L. Ph., Méd.	II	II
Apiaceae	*Daucus carota* L. Hem., Cosm.	+	I
Apocynaceae	*Nerium oleander*	I	I
Asparagaceae	*Muscari comosum* (L.) Mill.)	+	I
Aspleniaceae	*Ceterach officinarum* L.	+	I
Asteraceae	*Carduus* sp.	II	II
	Chrysanthemum grandiflorum Ramat Ph., Méd	+	+
	Chrysanthemum coronarium L. Ph., Méd	II	II
	Hyoseris radiata L. Ph., Méd	II	+
	*Echino*ps sp.,	II	+
	Silybum marianum, (L.) Gaertn. Ch., Cosm.	II	+
	Pallenis spinosa (L.) Cass. subsp. spinosa Hem., Méd.	+	II
	Cantoria sp.	+	II
	Anacyclus clavatus (Desf.) Pers. Ph., Euro- Méd.	+	II
	Centaurea sp.	+	II
	Calendula arvensis (Vaill.) L	+	II
	Hertia cheirifolia (L.) Kuntze	+	+
	Bellis annua L. Ph., Méd.	+	+
	Bellis sylvestris Cirillo. Ph., Méd.	+	+
Boraginaceae	*Echium* sp.	II	II
	Echium confusum Coincy	+	II
	Anchusa azurea auct. Hem., Euro-Méd.	II	+
	Cynoghossum sp.	+	II
Brassicaceae	*Sinapis arvensis* L. Th., Paléo-Temp.	I	+
	Biscutella didyma L. Th., Méd.	I	+
Caryophyllaceae	*Silene* sp.	I	+
	Stellaria media L. Vill. Ph., Cosm	I	+
Cesalpiniaceae	*Ceratonia siliqua* L. Ph., Méd	I	I
Chenopodiaceae	*Spinacia oleracea* L.	+	I
Cistaceae	*Cistus albidus* L. Th., Méd	II	II
	Cistus monspeliensis L. Th., Méd	II	II
Convolvulaceae	*Convolvulus althaeoides* L. ssp. *typicus* Fiori. Hem. , Méd.	II	II
Cupressaceae	*Juniperus oxcedrus* L. subsp. *rufescens* (Link) Debeaux Ph.,	+	I
	Méd.	II	I
	Tetraclinis articulata (Vahl) Mast. Ph., Méd.		
Cyperaceae	*Delphinium* sp.	+	I
Ericaceae	*Arbutus* sp.	I	I
Euphorbiaceae	*Euphorbia helioscopia* L.subsp. *helioscopia* Th., Euras.	+	I
Fabaceae	*Acacia saligna* (Labill.) H.L. Wendl.,	I	I
	Cytisus arboreus (Desf.)DC ssp. *beaticus* (Webb) Ph.,Méd.	+	I
	Vicia faba major L.	+	I
Fagaceae	*Quercus coccifera L., Ph., Méd.*	II	I
	Quercus ilex L. var. *ballota* (Desf.) A. DC. Tab Morais. Ph.,	II	I
	Méd		
Lamiaceae	*Lavandula stoechas* L. Ph., Méd	II	+
	Marrubium vulgare L. Hem., Cosm	II	+
Malvaceae	*Malva sylvestris* L. Ph., Méd	I	I
Oleaceae	*Olea europaea* L. var. *oleaster* (Hoffm. & Link) Negodi. Ph.,	I	+
	Méd		
Papaveraceae	*Papaver rhoeas* L. Th., Com.	+	I

Papilionaceae	*Calycotome spinosa* (L.) Link	II	II
	Anthyllis sp.	II	II
	Melilotus sp	II	+
	Coronilla valentina L. Ph., Méd	+	II
Pinaceae	*Pinus halepensis* Mill. Ph., Méd.	II	II
Plantaginaceae	*Plantago lagopus* L. Hem., Méd.	+	1
Poaceae	*Ampelodesmos mauritanicus*(Poir.Durand & Schinz. Ge., Méd.	I	I
	Avena sativa L. Ph., Méd	+	I
Primulaceae	*Anagallis monelli* L. Hem., Méd	+	I
Resedaceae	*Reseda alba* L. subsp. *alba* Th., Euras.	I	I
Rosaceae	*Rubus ulmifolius* Schott	II	II
	Prunus amygdalus Mill. Ph., Méd	+	I
	Prunus armeniaca L. Ph., Méd	+	I
	Eriobotrya japonica (Thunb.) Lindl.	+	I
Solanaceae	*Lycium intricatum* Boiss. Ph., Méd.	+	I
Tamaricaceae	*Tamarix gallica* L. Ph., Neo-Trop.	I	I
Thymeleaceae	*Thymelaea hirsuta* (L.) Ph., Méd.	I	I
Papilionaceae	*Calycotome spinosa* (L.) Link	II	II
	Anthyllis sp.	II	II
	Melilotus sp	II	+
	Coronilla valentina L. Ph., Méd	+	II
Pinaceae	*Pinus halepensis* Mill. Ph., Méd.	II	II
Plantaginaceae	*Plantago lagopus* L. Hem., Méd.	+	1
Poaceae	*Ampelodesmos mauritanicus*(Poir.Durand & Schinz. Ge., Méd.	I	I
	Avena sativa L. Ph., Méd	+	I

Fungal diversity

The surveys carried out in the two study sites of the Oued Rhiou State Forest have identified 25 taxa in the Kherraba site, of which 18 are Basidiomycetes (72%) and 7 Ascomycetes (28%); they are divided between 11 families and 15 genera. In the Tidda site, the 19 taxa collected are basidiomycetes (100%) distributed between 10 families and 11 genera, no ascomycete taxon was collected in this site during the two years of our study. All the fungal samples show a certain diversity of macrofungi comprising 44 taxa of which 37 are basidiomycetes (84.09%) and 7 are ascomycetes (15.9%) distributed between 24 genera and 17 families (Table 4 and Fig. 4). These families belong to Tricholomataceae Lotsy (10 taxa, 22.77%), Helvellaceae Fr. (6 taxa, 13.6%), Cortinariaceae R. Heim (4 taxa, 9%), Morchellaceae Rchb. and Hygrophoraceae Lotsy (3 taxa, 6.8%), Agaricaceae Chevall., Pezizaceae Dumort., Suillaceae Besl & Bresinsky, Sarcoscyphaceae Le Gal ex Eckblad, Strophariaceae Singer & A. H. Sm. and Psathyrellaceae Vilgalys, Moncalvo & Redhead (2 taxa, 4.5%), Russulaceae Lotsy, Boletaceae Chevall., Hymenochaetaceae Donk, Mycenaceae Overeem, Auriscalpiaceae Maas Geest. and Marasmiaceae Roze ex Kühner (1 taxon, 2%). The genera are represented by *Clitocybe* Fr. (7 taxa, 15.9%), *Helvella* L. (6 taxa, 13.63%), *Hygrocybe* (Fr.) P. Kumm. (3 taxa, 6.81%), *Morchella* Dill. ex Pers., *Peziza* Dill. ex Pers., *Sarcoscypha* (Fr.) Boud. and *Suillus* Gray (2 taxa, 4.54%). The rest of the genera listed contain one taxon (2.2%): *Agrocybe* Fayod., *Boletus* L., *Cortinarius* (Pers.) Gra, *Disciotis* Boud., *Hypholoma* (Fr.) P. Kumm., *Lactarius* Pers. , *Lentinellus* P. Karst. , *Lepiota* (Pers.) Gray, *Leucocoprinus* Pat., *Marasmius* Fr., *Melanoleuca* Pat., *Mycena* (Pers.) Roussel, *Myxomphalia* Hora, *Paxillus* Fr., *Phellinusn* Quélet, *Psathyrella* (Fr.) Quél., *Tricholoma* (Fr.) Staude.

Table 4. **List of macrofungi in Kherrarba and Tidda sites (Oued Rhiou forest, Algeria).**

Macrofungi genera	Class	Kherrarba	Tidda
Agrocybe Fayod.	Basidiomycetes	+	
Boletus L.	Basidiomycetes		+
Clitocybe Fr.	Basidiomycetes	+	+
Cortinarius (Pers.) Gra,	Basidiomycetes		+
Disciotis Boud.,	Ascomycetes	+	
Helvella L.	Ascomycetes	+	
Hygrocybe (Fr.) P. Kumm.	Basidiomycetes		+
Hypholoma (Fr.) P. Kumm.	Basidiomycetes		+
Lactarius Pers.	Basidiomycetes	+	
Lentinellus P. Karst.	Basidiomycetes		+
Lepiota (Pers.) Gray	Basidiomycetes		+
Leucocoprinus Pat.	Basidiomycetes	+	
Marasmius Fr.	Basidiomycetes		+
Melanoleuca Pat.	Basidiomycetes	+	
Morchella Dill. ex Pers.	Ascomycetes	+	
Mycena (Pers.) Roussel	Basidiomycetes		+
Myxomphalia Hora	Basidiomycetes	+	
Paxillus Fr.	Basidiomycetes	+	
Peziza Dill. ex Pers.	Ascomycetes	+	
Phellinus Quélet	Basidiomycetes	+	
Psathyrella (Fr.) Quél.	Basidiomycetes	+	
Sarcoscypha (Fr.) Boud.	Basidiomycetes	+	
Suillus Gray	Basidiomycetes		+
Tricholoma (Fr.) Staude	Basidiomycetes		+

The genus *Clitocybe* develops in the two study sites while 14 genera viz. *Agrocybe*, *Disciotis*, *Helvella*, *Lactarius*, *Leucocoprinus*, *Melanoleuca*, *Morchella*, *Myxomphalia*, *Paxillus*, *Peziza*, *Phellinus*, *Psathyrella* and *Sarcoscypha* were collected in the Kherraba site and 10 genera viz. *Boletus*, *Cortinarius*, *Hygrocybe*, *Hypholoma*, *Lentinellus*, *Lepiota*, *Marasmius*, *Mycena*, *Suillus* and *Tricholoma* in the Tidda site.

The mycological inventory carried out in the two sites of the State Forest of Oued Rhiou reveals a fungal diversity comprising 44 taxa of which 37 were basidiomycetes (84.09%) and 7 were ascomycetes (15.9%). The taxa collected are distributed between 17 families and 24 genera. The most dominant families are Tricholomataceae Lotsy (10 taxa, 22 .77%), Helvellaceae Fr. (6 taxa 13.6%), Cortinariaceae R. Heim (4 taxa, 9%), Morchellaceae Rchb. and Hygrophoraceae Lotsy (3 taxa, 6.8%) and the rest of the families are represented by 1 to 2 taxa (2%-4.5%). The genera with the highest number of taxa are represented by *Clitocybe* Fr. (7 taxa, 15.9 %), *Helvella* L. (6 taxa, 13.63%), *Hygrocybe* (Fr.) P. Kumm. (3 taxa, 6.81%), *Morchella* Dill. ex Pers., *Peziza* Dill. ex Pers., *Sarcoscypha* (Fr.) Boud. and *Suillus* Gray (2 taxa, 4.54%). The rest of the genera contains 1 to 2 taxa.

The global analysis of the mycological inventory reveals a diversity of macromycetes which group together 44 taxa distributed among 24 genera known in mycology The fungal richness in the study sites is linked to abiotic factors, such as temperature, rainfall, relative humidity, the physico-chemical composition of the soil and the characteristics of the plant cover.

The sporophores were harvested especially in autumn and even in spring after maximum rainfall. These seasonal periods are favorable to the development and abundance of forest fungi in most of the countries of the Mediterranean Basin (El-Assfouri *et al.* 2005, Martínez de Aragón *et al.* 2007).

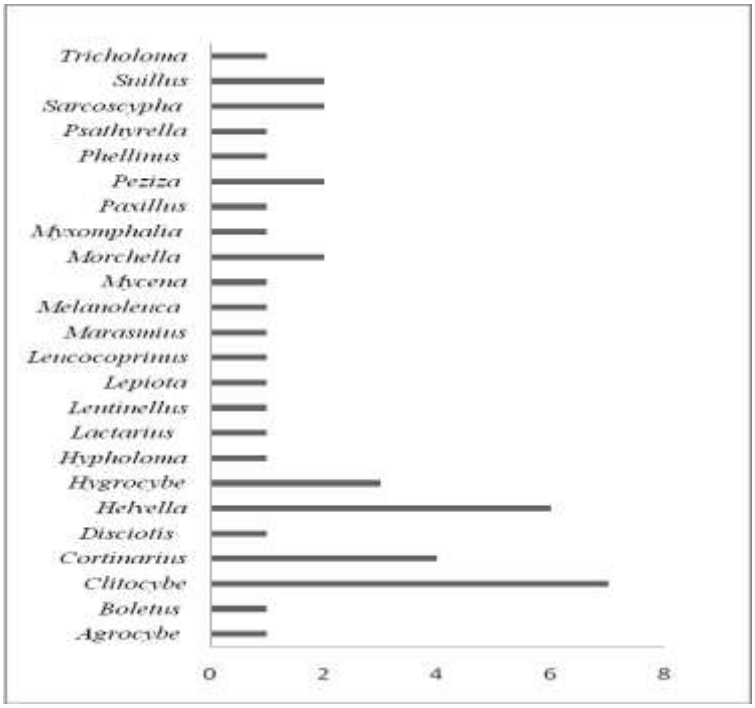

Fig. 4. Number of taxa per genus.

The pluviometry is a fundamental parameter because the mushrooms require rather important precipitations for their fruiting which continues for 15 days. A very high amount of water, the presence of adequate values of temperature and relative humidity promote the fruiting of fungi. Our observations agree with those of many authors who have shown that the abundance of precipitation would be an excellent indicator of the diversity and structure of fungal communities (O 'Dell *et al*. 1999); it is mainly important for initiating fruiting and increasing the productivity of fungi (Munguía *et al*. 2005).

The temperatures recorded in winter and autumn after rainy periods also play a role in the fruiting of forest mushrooms. Temperature and humidity are in fact the main factors conditioning the growth of carpophores in a forest environment. Air humidity has a direct effect on the evaporation of water from the soil and on transpiration. It plays an attenuating role in water deficit (Moore *et al.* 2008, Gévry and Villeneuve 2009). According to Martínez de Aragón *et al*. (2007), fungi require in the first stage of their development a minimum of precipitation and then appropriate temperatures for the appearance of sporophores. Similar data have been reported by many authors (El-Assfouri *et al*. 2005, Moore *et al*. 2008, Gévry and Villeneuve 2009 and Bâ *et al*. 2011).

The distribution and development of sporophores are also influenced by the physicochemical nature of the soil, the composition and structure of the vegetation. The pedological analysis reveals that the fungal taxa collected develop on a loamy-sandy or loamy-clayey-sandy soil, alkaline, unsalted, moderately provided with limestone, well provided with organic matter, and poor in available

phosphorus. These physicochemical characteristics allow the soil to retain a high quantity of water, favoring the fruiting of fungi. In the forest regions of Algeria, the soils are calcareous in the majority of wooded areas with variable textures, the alkaline pH of the soil is characteristic of the soils of semi-arid zones (Aimé 1991). Bonito *et al*. (2012) stated that some ectomycorrhizal fungi (ascomycetes and basidiomycetes) thrive in alkaline soils, but most ectomycorrhizal basidiomycetes prefer acidic soils. Garnica *et al*. (2005) reported the presence of Cortinarians on calcareous soil associated mainly with deciduous trees (*Fagus, Quercus*). Alvarado *et al.* (2015) showed that some agaricals with a whitish tone and slightly decurrent blades are present on calcareous soil.

The diversity of identified macromycetes is also linked to the density of the plant cover. The two study sites are characterized by a significant vegetation cover made up of three strata (viz. tree, shrub and herbaceous). The plant families and genera identified in the study sites have been inventoried by numerous authors in various forest and tellian pre-forest regions of Algeria (Medjahdi *et al.* 2009).

Most of the sporophores are collected from the tree stratum composed mainly of *Pinus halepensis, Quercus coccifera, Quercus ilex* and other trees, such as *Tetraclinis articulata* and a few plants of *Ceratonia siliqua*. Some genera of macromycetes collected (viz. *Boletus, Clitocybe, Cortinarius, Hebeloma, Hygrocybe, Inocybe, Lactarius, Paxillus, Russula Tricholoma*) are ectomycorrhizal and/or ectendomycorrhizal (Bâ *et al.* 2011). Forest species, such as *Pinus halepensis* and *Quercus* are recognized for their ability to form ectomycorrhizae with a significant diversity of fungi, mainly basidiomycetes but also Ascomycetes (Malençon and Bertault 1975).

Some fungal taxa develop in the shrub layer composed mainly by *Cistus albidus, Cistus monspeliensis, Pistacia leutiscus, Arbutus* sp. and more rarely in the herbaceous layer. The most dominant herbaceous species are Asteraceae, Borraginaceae and Papilionaceae. Various studies have shown that the distribution of macromycetes depends on forest species, their density (Munguía *et al*. 2005 and Gómez-Hernández and Williams-Linera 2011), fungal diversity and the structure of the forest cover (Richard *et al*. 2005). Indeed, O'Hanlon and Harrington (2012) have shown that in natural forests and areas with high forest cover, ectomycorrhizal fungi, wood decomposers and debris represent a high diversity while insufficient substrate (humus, tree trunks) or hosts can be a limiting factor. The structure of the forest cover (age, density of the cover) as well as the vegetation of the undergrowth are factors determining the richness and abundance of fungal species (Villeneuve 2000).

The Oued Rhiou forest is a rich area from a mycological and floristic point of view. The mycological inventory of macromycetes in the two study sites reveals a diversity of macromycetes comprising 44 taxa (84.09% basidiomycetes and 15.9% ascomycetes) distributed between 24 genera and 17 families known in mycology. This number of fungal taxa collected made it possible to construct a herbarium containing desiccated sporophores for subsequent taxonomic studies of molecular biology. The diversity of the macromycetes identified is linked to climatic conditions such as season, temperature, precipitation, relative humidity as well as the physicochemical characteristics of the soil and plant cover. The plant cover includes 68 taxa of specific or sub-specific rank, distributed among 36 families, 60 genera. The flora is occupied by four main forest species (*Quercus ilex, Quercus coccifera, Pinus halepensis* and *Tetraclinis articulata*), shrub species especially *Pistacia lentiscus* and herbaceous species common in forest ecosystems. The preliminary results of our work constitute a starting point for

evaluating the fungal and floristic biodiversity in the Forest of Oued Rhiou. The inventory of macromycetes still needs to be completed by other surveys because this forest could shelter other taxa and the study region is undergoing a notable bioclimatic change, precipitation has decreased and temperatures have increased. This change, already reported by many authors for the western region of Algeria (Quezel 2000) has clearly accentuated the dominant "arid" character of this region. The State Forest of Oued Rhiou like the majority of Algerian forests is degraded due to the increase in areas burned, overgrazing, drought raging over the past two decades and insufficient reforested areas (Meddour-Sahar and Derridj 2012). Meanwhile, the results of a random survey of 170 people in the study area found that over 53% of forest mushroom consumers are mostly wild edible mushroom enthusiasts. The organization of mycological awareness days among the local population by forest mushroom specialists will reduce the many poisonings among rural consumers of sometimes inedible mushrooms, according to the Oued Rhiou Prevention Service. Research on certain species of the macromycetes of gastronomic value which can be cultivated, in particular *Boletus*, *Lactaria* and morels, could represent a significant economic benefit in this semi-arid region.

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