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A study of the diversity and distribution of ascomycetes across selected ecological zones of Morocco

Nour ID Elhakkar[1*], Ali Outocoumit[1], Karima Selmaoui[1], Najoua Mouden[1], Moulay Abdelaziz El Alaoui[1], Amina Ouazzani Touhami[1], Allal Douira[1]

[1] Laboratory of Botany, Biotechnologies, and Plant Protection, Faculty of Sciences, Ibn Tofail University, Kenitra, Morocco

* Corresponding author's e-mail: nour.idelhakkar@uit.ac.ma

ABSTRACT

Fungi play a central role in terrestrial ecosystems, where they contribute to organic matter decomposition, nutrient cycling, and symbiotic interactions with plants. Among them, macro-ascomycetes remain under-documented in North Africa despite their ecological and biotechnological importance. The objective of this study was to investigate the diversity and ecological distribution of macro-ascomycetous fungi in Morocco, focusing on contrasting ecosystems ranging from Mediterranean cork oak and Eucalyptus forests to cedar forests of the Middle Atlas. Field surveys were conducted between 2007 and 2022 across six major regions (Mamora, Khmis-es-Sahel, Lalla Mimouna, Rif, Oulmes, and Middle Atlas). Sampling was carried out systematically along predefined transects during fruiting seasons. A total of 19 species belonging to 8 genera and 5 families were identified, including several taxa newly reported for Morocco or for the studied regions, such as Geopora arenosa, Otidea umbrina, and Peziza echinospora. Morphological analyses revealed a wide variety of traits related to their ecological strategies, ranging from saprotrophy on woody debris to possible ectomycorrhizal associations in forest soils. The results highlight both the richness of Moroccan macro-ascomycetes and the ecological specificity of certain taxa, particularly within the Pyronemataceae. This updated inventory provides the first integrative overview of macro-ascomycete diversity in these Moroccan habitats. It emphasizes the need for further research combining molecular tools and ecological approaches to clarify taxonomic boundaries and functional roles. Protecting forest ecosystems where these fungi occur is essential for preserving their biodiversity and the critical ecological processes they sustain.

Keywords: Pyronemataceae, Geoglossaceae, Helvellaceae, Pezizaceae, diversity, ecology, Morocco.

INTRODUCTION

Fungi play a fundamental role in the functioning of terrestrial ecosystems. They form species-rich communities across a wide range of habitats, from forests and grasslands to deserts and marine environments (Frąc et al., 2018; Tedersoo et al., 2014; Hawksworth and Lücking, 2017; Hyde et al., 2018). Among these habitats, forest ecosystems harbor the highest fungal diversity, where fungi perform key functions in organic matter decomposition, nutrient cycling, and the structuring of plant communities (Mueller, 2019; Bosso et al., 2017; Yakop et al., 2019). Within the fungal kingdom, Ascomycetes represent the largest phylum, with approximately 93,000 described species (Clark et al., 2018; Catalogue of Life, 2021)

Their morphological, phylogenetic and ecological diversity renders their classification particularly complex, especially due to the presence of numerous cryptic and microscopic species (Yarza et al., 2017) Recent advances in molecular phylogeny notably through the use of multigene markers and the integration of morphological and ecological data were contributed to clarifying the evolutionary relationships within this group.

For instance, recent phylogenomic studies have revealed a previously unrecognized lineage, the Lichinomycetes, which includes lichenized, mycorrhizal, and endophytic forms (Prieto et al., 2022), thus enriching our understanding of fungal diversification. Despite this complexity, mycological research has historically favored Basidiomycetes, which are more conspicuous, to the detriment of macro-Ascomycetes, whose small size, rarity, or cryptic nature make them difficult to detect (Maharachchikumbura et al., 2021; Wijayawardene et al., 2022; Wanasinghe et al., 2022). However, certain Ascomycete species hold significant ecological and economic importance. They actively contribute to organic matter degradation, establish mycorrhizal symbioses, and can serve as bioindicators of habitat quality. Their biotechnological potential is increasingly recognized, notably in the production of enzymes, natural antibiotics, and high-value compounds (Hyde et al., 2019; Liu et al., 2021). In Morocco, the diversity of macro-Ascomycetes remains largely under-documented.

Early studies, mainly descriptive, date back to Maire and Werner (1937) and Malençon and Bertault and were limited to species lists without detailed morphological descriptions. Subsequent research (Abourouh, 2000; Khabar, 2002; El Assfouri, 2006; Larouz, 2007) has expanded knowledge but remained localized and partial, with particular focus on truffle species (T erfezia, Tirmania, Picoa, Tuber) and some Pezizales. Recent studies have identified new species, such as *Tirmania sahariensis* in arid zones, highlighting the potential for fungal speciation linked to bioclimatic conditions in the region (Cherkaoui et al., 2023). Other work has emphasized the biotechnological interest of Moroccan desert truffles, both for their antimicrobial properties and their symbiotic associations with host plants (El Khalloufi et al., 2024).

Nevertheless, these data remain insufficient to establish a representative inventory of Moroccan fungal diversity, especially considering the country's broad ecological diversity including Mediterranean cork oak forests, Middle Atlas cedar forests, and semi-arid zones which are likely to harbor a rich and largely unexplored fungal flora. In the absence of recent systematic inventories and due to insufficient available data, the true diversity of Moroccan macro-Ascomycetes remains largely unknown. This gap hinders not only the evaluation of their ecological role in local ecosystems but also the valorization of their biotechnological potential.

The objective of this study is to address this knowledge gap by conducting an updated inventory of macro-Ascomycete diversity in several ecologically contrasting regions of Morocco (Mamora, Khmis-es-Sahel, Lalla Mimouna, Rif, Oulmes, Middle Atlas). The study aims to document their distribution, assess their ecological importance, and identify species with potential biotechnological interest.

MATERIALS AND METHODS

Ascomycete samples were collected during field campaigns conducted across several ecologically diverse regions of Morocco (Figure 1), namely the Mamora plain at the location with coordinates 34°N, 6°W; altitudes between 100 and 200 m), Khmis-es-Sahel (34.7°N, 6.1°W; 150 m), Lalla Mimouna (34.3°N, 5.9°W; 120 m), the Rif mountain range (between 35°N and 36°N, 4°W to 5°W; altitudes ranging from 300 to 800 m), Oulmes (33.5°N, 5.3°W; 700 m), and the Middle Atlas (33.5°N–34°N, 5°W–6°W; altitudes between 900 and 1400 m). These sites were selected to represent a variety of habitat types, including Mediterranean forests, semi-arid zones, and diverse substrates such as forest soils, grasslands, and leaf litter. The sampling protocol consisted of systematic collections conducted along predefined transects, repeated seasonally during the periods favorable to fruiting (from autumn to spring) (Ajana et al., 2020a, 2020b; Lotfi et al., 2019, 2020; El Kholfy et al., 2021a, 2021b; Nmichi et al., 2021). In the field, a set of equipment is required for the study of higher fungi, specifically macro-ascomycetes. This includes recording all relevant information concerning the surveyed area and the morphological features of the ascocarps, in addition to photographing and collecting specimens. The material used comprised:

- A field notebook for noting essential information such as the collection date, vegetation type or substrate, and the dimensions of the collected ascocarps;
- A high-resolution camera equipped with a macro function to photograph the different parts of the ascocarps and capture fine morphological details;
- A metal blade or pocket knife to extract or detach specimens from woody substrates;

- A graduated ruler to measure the dimensions of various ascocarp structures; and several cardboard boxes used to store the collected specimens prior to their transfer to the laboratory.

For ascocarp collection, we followed a random sampling approach by surveying different locations within the study areas. No estimation of the surface area surveyed was performed due to the difficult climatic conditions, which strongly influence fungal development. In some cases, multiple transects had to be explored to obtain ascocarps at different developmental stages, which are necessary to complete both macroscopic and microscopic examinations. Additionally, one or two ascocarps were set aside for preservation in the Herbarium of Ibn Tofail University or deposited in the Herbarium of the Institut Scientifique of Rabat (Morocco).

In the laboratory, macroscopic characteristics are studied by observation with the naked eye, while microscopic characteristics are studied by:

- Making thin sections of the hymenial layer of a fresh ascocarp, mounting them between a slide and cover slip with a dye, and observing them to characterise the shape and types of asci (clavate, globular, bitunicate or unitunicate) and the number of spores they contain.
- Using dyes such as cotton blue lactic acid (0.05 g cotton blue, 30 g lactic acid), as this highlights the spore ornamentation of most ascomycetes and also colours the cell walls.
- Use potassium hydroxide (KOH), diluted to 2, 5 or 10%, which is considered a catalyst for the amyloid reaction of asci. It causes a coloured reaction in certain paraphyses, certain hairs or flesh.
- Use Lugol's reagent (1 g iodine, 1–3 g potassium iodide, dissolved in 100–300 g water), which causes a more or less red colouration of the apical ring of the asci of certain inoperculate fungi.
- Take photographs of each microscopic preparation at magnifications of 100×, 200×, 400× and 600×.
- Provide a detailed description of the macroscopic and microscopic characteristics of each species.
- Compare the macroscopic and microscopic descriptions with bibliographic data (mycological bibliography, Index of Fungorum, 2018).
- Consult the specific identification keys for Ascomycetes (Hansen and Knudsen, 2012; Skrede et al., 2017; Melo et al., 2020) to determine the species name.

RESULTS

Geoglossaceae

Trichoglossum hirsutum (Persoon: Fries) Boudier, 1907

New species for the Lalla Mimouna region (Le Gharb). Collected on 15 February 2009 and 2022, under *Quercus suber* (Lalla Mimouna) (Figure 2). The sporocarps (1.5 to 9 cm high) are clavate and black in colour. The head (0.5–2.5

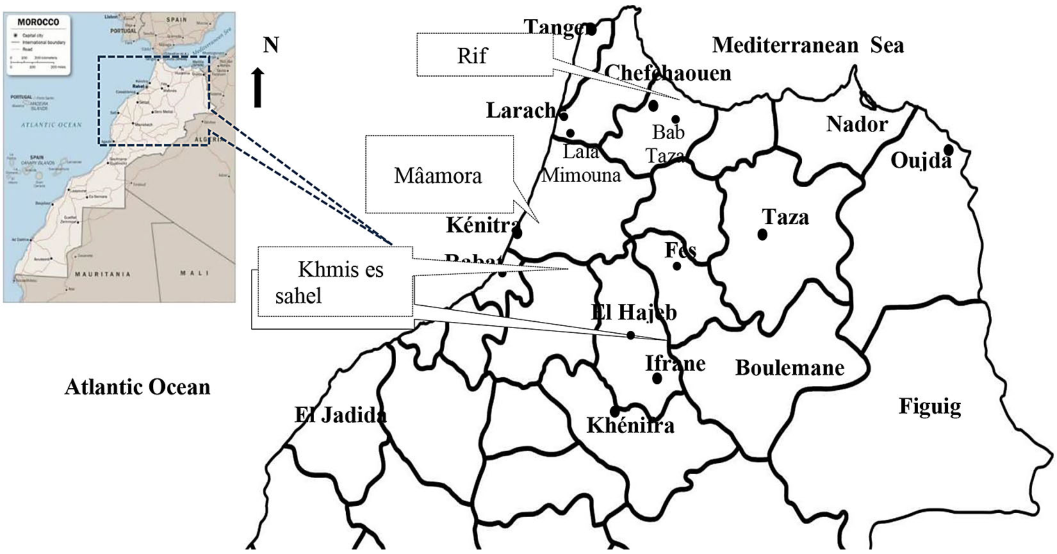

Figure 1. Geographical location of the collection areas of the fungal species studied

cm high × 0.2 to 5 mm wide and 0.2 mm thick) is the fertile part of the fruiting body and may be swollen, flattened, oblong, shovel-shaped, spatula-shaped or club-shaped. It may also be velvety with fine hairs. The foot (1 to 2.5 cm in diameter) is equal, cylindrical and concoloured with the head. It is pubescent or furfuraceous. The hairs are stiff and visible to the naked eye. They are black, opaque and end in a fine point. The asci (90–130 (220) × 20 um) are inoperculate, thin-walled, octosporic, clavate and perpendicular to the axis of the head. The paraphyses are slender, septate and their apical cells are slightly swollen and curved. The spores (90–150 × 4–7 um) are brown in water, dark brown in iodised water and dark grey in KOH (5%). They are filiform and their ends are attenuated. They are also septate (usually 15 to 16 septa).

Helvellaceae

Helvella leucomelaena (Pers.) Nannf. 1941

Collected in February 2008, 2009 and 2022. (Figure 3). The ascocarps are solitary or in groups on the sandy soil, among the grasses under *Pinus pinea*, in the Kenitra region. The harvesting site is very shady and very humid. The apothecia (2–4 cm high and 2 to 3 cm in diameter) are cup-shaped or perfectly goblet-shaped or sometimes more or less compressed with a veined pseudostipe. The outer surface is smooth, pale greyish to greyish, more or less dark to blackish in the upper part and lighter towards the stipe. The inner surface is pale to buff grey, sometimes very dark. The margin is more or less regular and whole or toothed; it may split irregularly in places. The flesh (around 4 mm thick) is elastic, brittle and whitish in colour. The asci (up to 400 × 20 um) are cylindrical and non-amyloid; they have an enlarged apex and a conical base. Paraphyses are cylindrical with an enlarged apex. The cytoplasm of the paraphyses contains a brown pigment in water and sometimes small guttules. The spores (18–22 × 12–14 um or 19.0 to 22.5 × 10–13 m) are hyaline, broadly elliptical, smooth and contain a single large oily drop.

Helvella lacunosa Afzel. 1783

Collected in January and February, 2009, 2018 and 2022 under *Quercus suber* in the Oulmes region (Figure 4). The ascocarps (up

Figure 2. *Trichoglossum hirsutum* (Persoon: Fries) Boudier 1907 – macroscopic criteria – ascocarps in situ (a), ascocarp morphology (b and c) and hairs on part of the apothecia, (c) – microscopic criteria – hymenium showing asci and paraphyses (e) with swollen and curved apices (× 100); small paraphysis asci with blue tip in iodine and sporulation (f) (× 400) and segmented ascospores (16 segments). Mounting liquid observations in iodine water.

Figure 3. *Helvella leucomelaena* (Pars.) Nannf. Macroscopic characters – one specimen top view in situ (a) and side view (b), hymenium in iodinated water × 100, (c) asci and paraphyses (d) and spores with oily drops (d) and (e) observations in water × 400*)*

to 15 cm) have a cap and a foot and develop on the ground. The cap (1–10 cm) is fertile, irregularly lobed and cerebriform or sometimes saddle-shaped. The colour of the fertile head (cap) is black, with the margin attached to the foot in several places. The flesh is thin, fragile and chambered. The foot (3–15 × 1–3 cm) is whitish in young specimens and may be greyish or black. It has deep veins and intersecting ribs. The asci (350 × 18–20 um) are inoperculate and non-amyloid. The paraphyses (3–8 um in diameter) are cylindrical or clavate. Spores (17.5–20 × 11 to 13 um) are smooth, elliptical, non-amyloid and contain an oily drop.

Figure 4. *Helvella lacunosa* Afzel. 1783: An ascocarp with a multi-lobed and more or less cerebriform cap (a); the same ascocarp with a white, ribbed foot with deep veins and a margin joined to the foot by its edges (b), hymenium with asci with eight ascospores and paraphyses (× 100) (c), top of an asci and a paraphysis (d) and ascospores (e), (c and d × 400). The mounting was carried out in iodine water

Helvella sulcata Afzel. 1783

Harvested in February and March 2009, 2017 and 2021, under *Quereus suber*, Lalla Mimouna region (Figure 5).

The ascocarps rarely exceed 6 cm. The cap (3 to 5 cm) is fertile, composed of 2 to 3 lobes that are misshapen, curled or saddle-shaped; it is dark grey to blackish-grey in colour, sometimes evenly spotted with whitish. The flesh is gelatinous. The foot (3 to 6 cm) is straight or sinuous, even slightly twisted, with protruding veins and moderately thick ribs; it is solid and concoloured on the cap. The asci (320 × 18–20 um) are inoperculate and non-amyloid, the paraphyses (up to 8 m in diameter) are cylindrical or clavate and the spores (17 to 18 × 10–12) are elliptical, non-amyloid and contain an oily drop.

Pezizaceae

Peziza ammophila Durieu et Montagne 1847

Peziza ammophila Durieu et Montagne 1847 (= *Sarcosphaera ammophila* Durieu et Mont. Moesz): New species for Morocco. Harvested in February, March and April, 2008 2009, 2015, 2019 and 2022 on Mamora sand (Figure 6).

Peziza ammophila Durieu et Montagne (*Peziza*, Pezizaceae, Pezizales, Pezizomycetidae, Pezizomycetes, Ascomycota, Fungi) (Kirk et *al.*, 2008) was found in two different locations at the same station on two occasions in February 2008 and February 2009. The ascocarps form almost aligned groups. Each group is composed of 2 to 6 specimens. The ascocarps (0.55 cm in diameter before fruiting) are neck-shaped. Initially, they are hypogeous, then become semi hypogeous. When the fruiting bodies emerge from the sand,

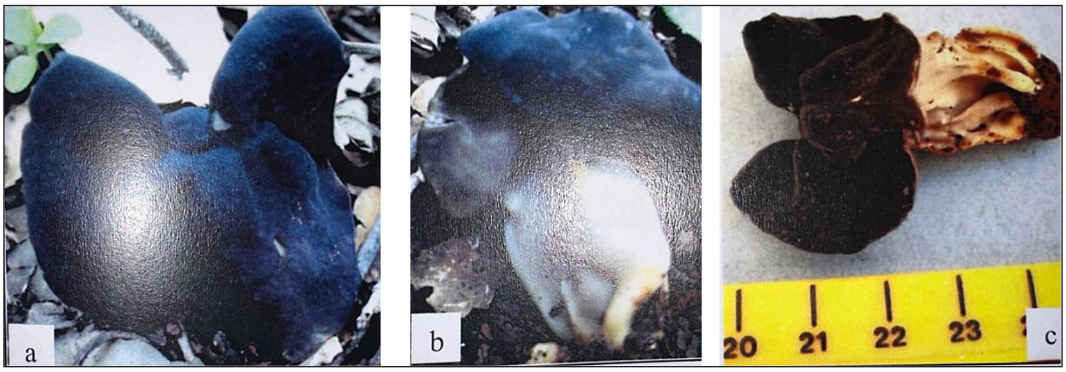

Figure 5. *Helvella sulcata* Afzel. *1783:* Ascocarp with three-lobed head (a), the same ascocarp with weakly ribbed foot and free cap margins (b) and ascocarp with three-lobed cap, not cerebriform, with ribbed foot and deep veins (c)

they open with a star-shaped tear. Gradually, the apothecia spreads and flattens out almost parallel to the substrate. The ascocarps have a pseudostype (about 3–4 cm high × 0.5 cm in diameter). The pseudostype remains embedded in the substrate. It is generally cylindrical, axial and attenuated at the base or sometimes flattened along its entire length. The excipulum and margin are covered with short hairs that stick to the sand. The flesh is greyish-cream and brittle. The hymenium is greyish to cream with 8 ascospores.

The asci (about 200 × 20 um) are amyloid-topped, inoperculate and the paraphyses (10 um diameter) are straight with slightly enlarged tapering tops, thin-walled and without lipid globules. Ascospores (17.5–19 × 12.5 m) are smooth, broadly ellipsoidal, with solitary or gregarious tips.

Peziza badia Pers. 1800

Harvested in December, January 2008, 2015, 2020 and 2022 on soil in Khmis-es-Sahel (Figure 7). The apothecia (3–8 cm in diameter) are sessile, more or less cupuliform, but irregularly so, being wavy in shape in older specimens. The outer surface is reddish, brown and rough, especially towards the margin. The hymenial surface is olive-brown to reddish-brown, becoming darker in dried specimens. The flesh is thin, pale brown or reddish brown. It exudes an aqueous juice. The asci (up to 330 × 15 µm) are octospores with a top that turns blue in iodine. The paraphyses are straight and slightly clavate. The spores (17 to 20 × 9–12 m) are elliptical with two oil drops, but often one is larger than the other. They have short ridges that tend to unite to form an irregular reticulum. The spores are smooth and then verrucose.

New species for Morocco. Collected in February and March 2008, 2016, 2019 and 2021, on a recent fire place in the Mamora (Figure 8).

Peziza echinospora grows solitarily on sandy soil in a recent fire place, in a plantation of Eucalyptus sp. near the town of Kenitra (Mamora forest). The apothecia (2 to 6 cm in diameter) are sessile cupuliform at first and may later flare to a dark disc. The outer surface is creamy brown and rough. The margin is curved and toothed. The inner surface is smooth and hazelnut brown to dark reddish brown. The flesh is fine brown to brown with a pale greenish tinge. The excipulum is stratified into two or more different cell layers. The asci (260–300 × 14–17 um) are capped and contain & ascospores. The tips of the asci turn blue under the action of iodinated water. The paraphyses are of two types; some are straight, slightly clavate, tapered and with a slightly swollen top and the other paraphyses are forked. The spores (14–18 × 8–10 um) are oblong, elliptical or fusoid, hyaline to pale brownish and warty; they may or may not contain lipid droplets.

Periza saniosa Schrad. 1799

A rare species, new to the Mamora. Collected in January, February and March 2008, 2012, 2018 and 221 under *Quercus suber* in the Mamora (Figure 9).

Several specimens have been found on woody debris under Quercus suber in Mamora. The apothecia (1–1.5 cm in diameter) are urn-shaped at first, but soon become enlarged and flattened. The outer surface is brownish-grey to dark brown and rough. The margin is entire and wrinkled on the outside. The disc is greyish blue to purplish blue. When cut, a

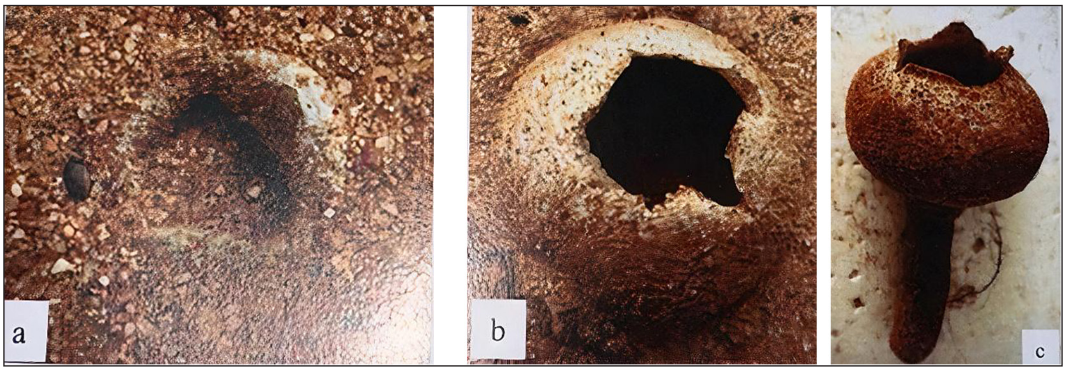

Figure 6. *Peziza ammophila* Durieu et Montagne: hypogeous stage, ascoma observable after removal of the sand covering the specimen (a); semi hypogeous stage (b) (a and b: photos in situ) and a specimen with its pseudostipe (c)

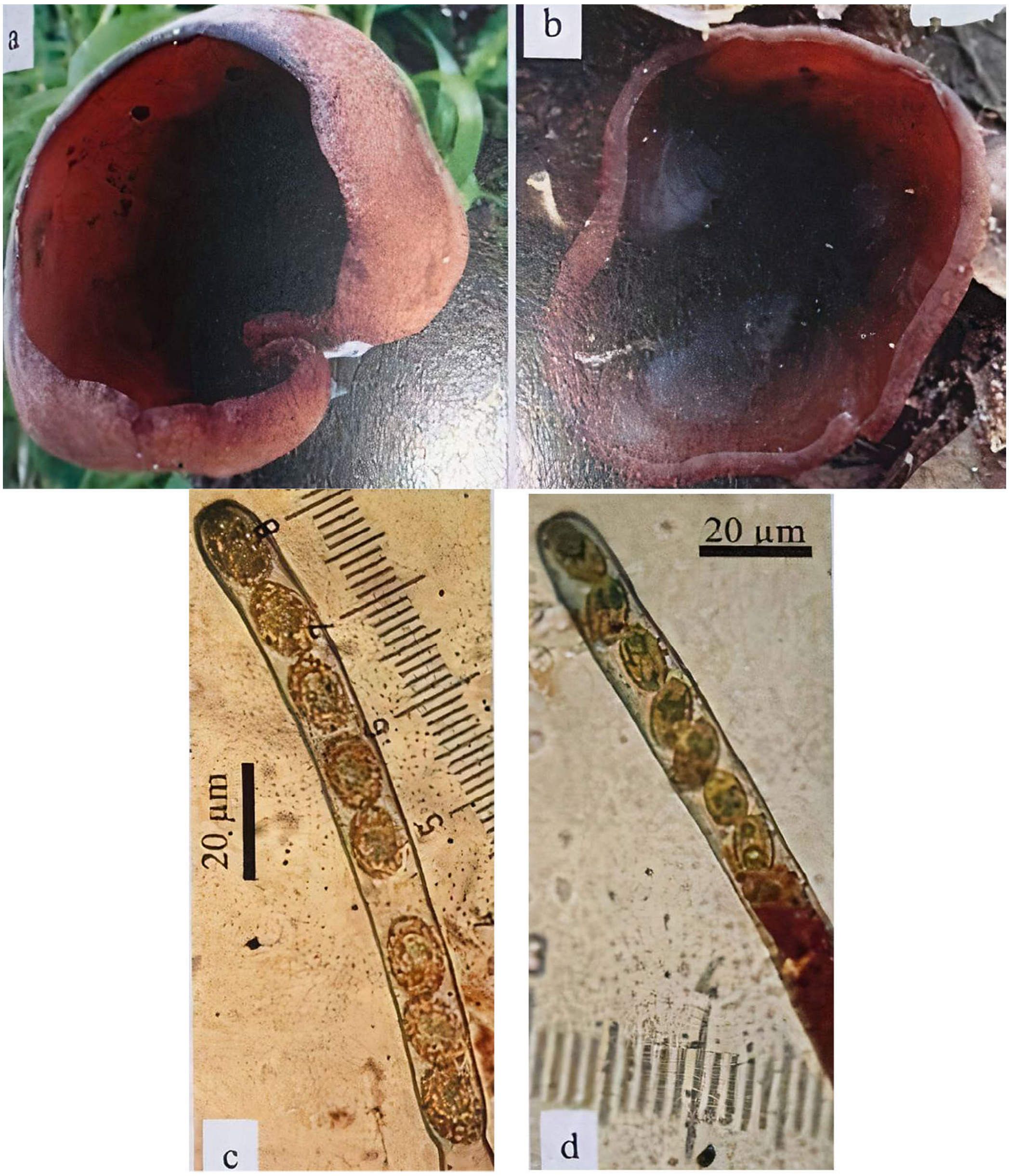

Figure 7. *Peziza badia* Pers. An ascocarp (in situ) (a and b); asci in water: the spores are ornamented (c); asci in iodised water: the spores are bigutullate and the top of the asci turns blue(d) (c and d × 400).

Peziza echinospora P. Karst. 1869

purplish-bluish latex oozes out. The cytoplasm of the asci (about 250 × 13 um) is brownish. The paraphyses are straight, colourless and have an enlarged apex. The spores (14–15.5 × 7–9 um) are coarsely verrucose and contain two oily drops. *P. saniosa* grows on the ground or on soil. It is a non-edible species (Dennis, 1968). *Peziza saniosa* Schrad. 1799 (= *Galactinia saniosa* (Schrad.) Sacc.) (Pezizaceae, Pezizales, Pezizomycetidae, Pezizomycetes, Ascomycota, Fungi) (Kirk et al., 2008) was found only once in 1958 by Malençon and Bertault under *Quercus suber* in Cherf-El-Akab (Tangier) (Malençon, 1958) ts range has thus far been limited to Tangiers. Our collection is the second for this species in Morocco and the first outside Tangiers. It appears to be a rare species and is new to the Mamora.

Peziza succosa Berk. 1841

Collected on 12 December 2010 and 2021 in the Mamora (Figure 10). *Peziza succosa* grows solitary on the ground in a damp depression under *Quercus suber*. The fruiting body (2–5 cm) is cup-shaped, flared and unstipulated. The outer surface is greyish to olive-brown and finely granular. The margin is slightly crenellated. The flesh is whitish to greyish; when pressed or cut, it exudes a latex which is initially greenish yellow and contrasts with the outer surface, rapidly turning yellow on paper or a handkerchief. The inner surface is dark. The asci (approximately 350 × 18–20 um) are octospores, operculate, uniseriate and their commets turn blue in iodine. The paraphyses are straight, colourless and slightly aviform. The apex of the paraphyses (5–7.5) is slightly swollen. The spores (17 to 22 × 9–12

Figure 8. *Peziza echinospora* Karsten 1869: Greenish-coloured ascocarp on a recent fire-place (a), crenate margin (b), sessile apothecium with rough surface (c), hymenium with octosporate asci and straight or forked paraphyses × 100 (d), apex of asci bluish in iodinated water and operculum × 400 (e), an echinulate ascospore and diagram (f) (microscopic observations in iodinated water).

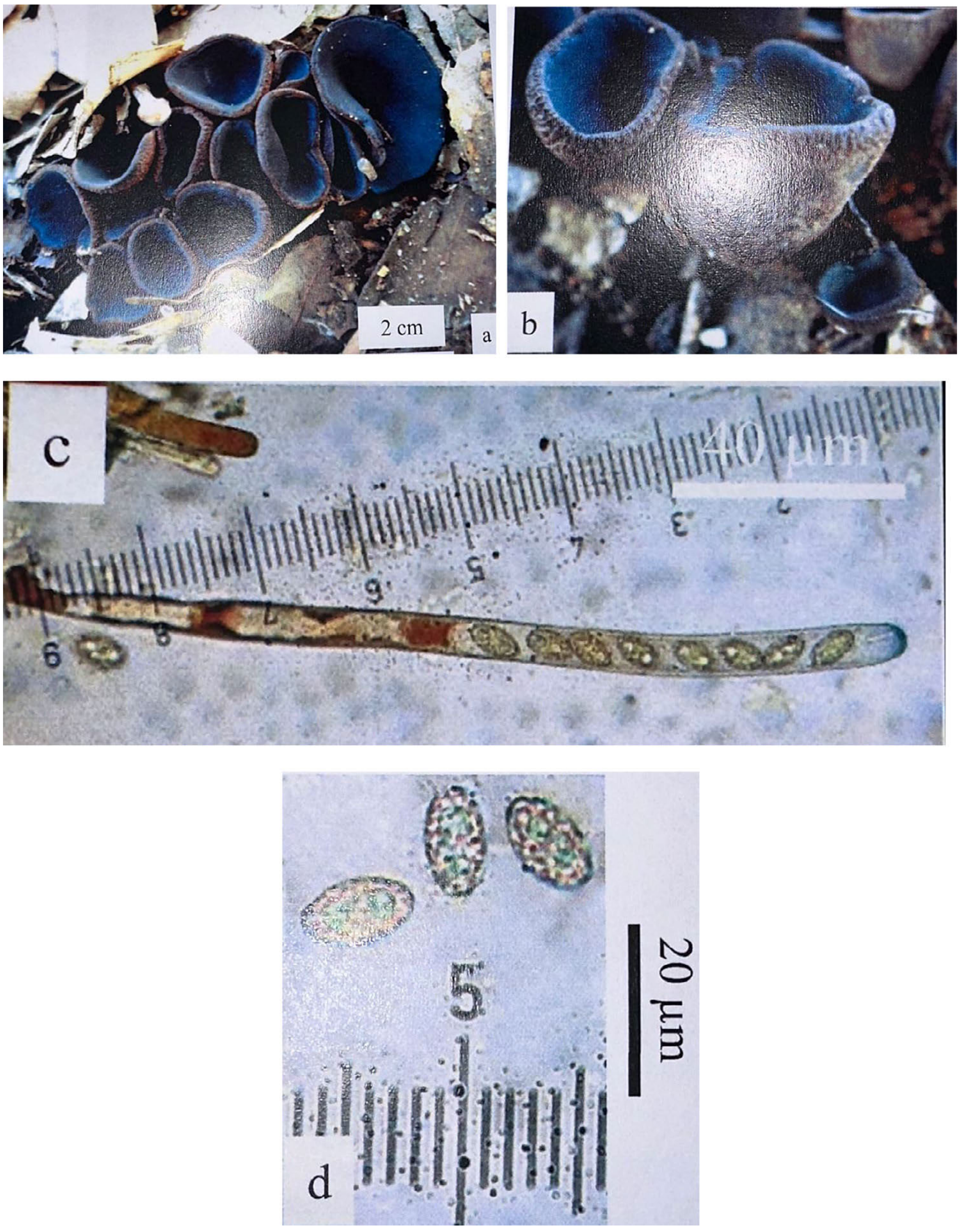

Figure 9. *Peziza saniosa* Schrad: Ascocarps on woody debris of *Quercus suber* with bluish-indigo inner surface, twisted margin (a), purplish-brown outer surface and wrinkled edge of opening (b), an asca with bluish top in iodinated water (c) x 100 and coarse verrucose spores ey containing oily drops (d)× 400

um) are elliptical and contain two large oily drops, they are ornamented by coarse warts and ephemeral ridges. The Galactinia lineage includes a group of species in the *Peziza* genus that contain a whitish or yellowish milky substance that is exuded by the ascocarp after cutting. They form the Succosa clade (Hansen and Pister, 2006). *P. succosa* is a saprophytic species, but has recently been suggested as a mycorrhizal species. *Peziza succosa* has been reported in the Middle Atlas (Malençon, 1958) in the Mamora forest (El Assfouri et al., 2003).

Coprobia granulata (Bull.) Boud. 1907

First encounter of *Coprobia granulata* (Bull.) Boud. in the Mamora forest. Collected on 20 November 2011, 2019, 2021 and 2022 under Eucalyptus sp. in the Mamora forest (Figure 11).

C. granulata fruiting bodies are gregarious and fimicolous or coprophilous saprophytes The apothecia (0.5 to 3 mm in diameter) are sessile cup-shaped, enlarged at the base and firmly attached to the woody debris. The disc is slightly concave and more or less dark orange-yellow in colour. The hymenophore has a hymenium that is

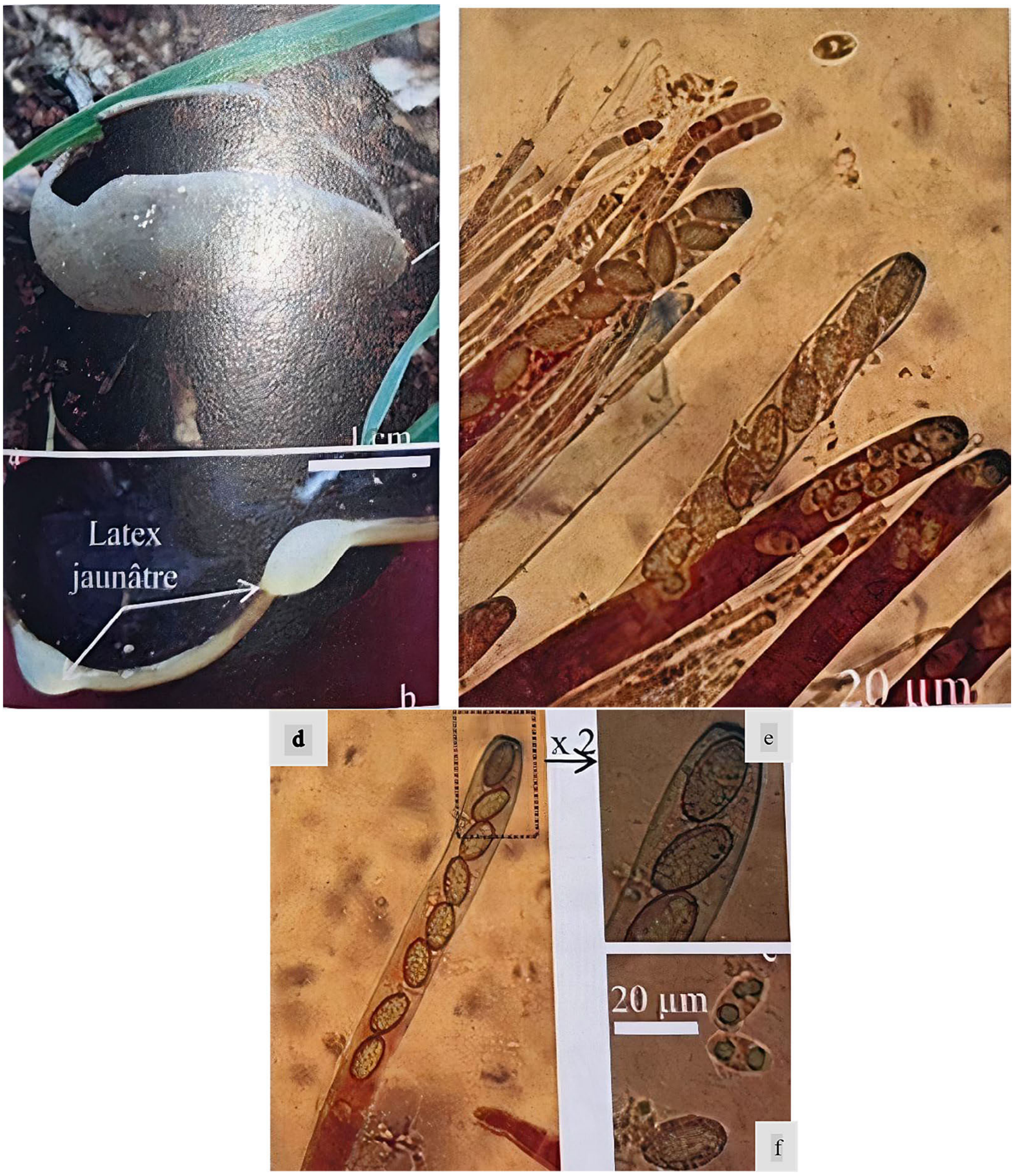

Figure 10. *Peziza succosa* Berk. An ascocarp (in situ) with a dark hymenial surface and a grey outer surface (a); the latex exuded by the yellowish-green flesh after cutting (b); part of the hymenium with asci and paraphyses in iodinated water (c); an octosporate and uniseriate asci (d), enlarged apex of the asci (e) and ornamented and bigutulate spores (f) Pyronemataceae

granular in appearance due to the prominent asci; the granules are brownish to blackish in colour and have brown or blackish tips corresponding to the ends of the asci protruding from the hymenium. Under the binocular magnifying glass, the margin is fringed with tiny whitish hairs. The outer surface appears slightly paler and has black tips corresponding to the ends of the asci that extend beyond the hymenium. The outer surface and margin are slightly flaky. The flesh is thick, soft and pale yellow. Under the microscope, the asci (200 × 15–17 m) are inoperculate and inamyloid; the paraphyses are spindly with clavate apices, the cells of the paraphysis apices up to 14 um in diameter. Spores (1517 × 7–10 km), on average are elliptical, smooth, uniseriate, moderately thick-walled and not guttulate.

Humaria hemisphaerica (F. H. Wigg.) Fuckel (1870)

Humaria hemisphaerica (F. H. Wigg.) Fuckel (1870) (= *Peziza hemisphaerica* Wigg.): New species for North-West Morocco. Collected on 16 February and March 2009, 2017 and 2021, in the vicinity of Lalla Mimouna (Figure 12).

Figure 11. *Coprobia granulata* (Bull.) Boud. 1907: Ascocarps in situ on undetermined waste, top right, details of apothecia with prominent asci (a); apices of paraphyses and asci (b) and smooth ascospores inside the asci (c) (microscopic observations in cotton blue× 400)

The fruiting bodies *of Humaria hemisphaerica* (F. H. Wigg.: Fries) Fuckel are found in groups among the various woody debris and dead leaves of Eucalyptus sp. on very damp, sandy clay soil. They are semi-hypogeous and sessile. The ascocarps (1 to 3 cm in diameter, 1 cm high and 1 to 1.5 cm open) are sessile, hemispherical at first, then open in cross-section. The inner surface is whitish, pale grey to bluish grey and smooth, while the outer surface is covered with stiff reddish-brown hairs (500 × 20 um). Under the magnifying glass, the margin is fringed with hairs about 1 mm long. The flesh is waxy and leathery. The asci (about 350 × 20 um) have eight ascospores and are supported by a 15 um high peduncle. The paraphyses (7 to 8 um in diameter) are tapered and have a slightly domed, colourless apex. The hyphae are curled. The spores (19–25 × 10–12 um) are elliptical and hyaline in water. They are largely verrucose and surrounded by a thick brown wall. The spores contain two oily drops. The lipid drops are initially crescent- shaped and then become round or ovoid. Sometimes the two drops merge to form a single large drop. *H. hemisphaerica* is a saprotrophic species that grows on rotten wood or soil. It is a non-edible species (Dennis, 1968).

Geopora sumneriana (Cooke) De La Torre 1895

Geopora sumneriana (Cooke) De La Torre 1895 (= *Sepultaria sumneriana* (Cooke) Massee 1887). Harvested on 19 April 2007, 2009, 2015 and 2021, under *Cedrus atlantica* (Manetti ex Endl.) Carr. at Ras-el-Ma, near Ifrane in the Middle Atlas (Figure 13).

The ascocarps of *Geopora sumneriana* (Cooke de La Torre) (1 to 7.5 cm) are solitary or gregarious, initially hypogeous and closed, then becoming semi hypogeous. They are dally sessile, globose or subglobose, hollow and cup-shaped. They open by random or star-shaped tears, forming irregular lobes on the surface of the ground. The outer surface of the ascocarp is brown, with whitish, bistratified flesh. The hymenium is whitish, creamy, pinkish or greyish. The spore is cream-coloured. The asci (320–360 × 18–20 um) are operculate, cylindrical, pleurodynous, octosporic and non-amyloid. The paraphyses (about 5 um wide) are hyaline, septate and often swollen at the apex. Ascospores (28–37 × 14–18 um) are uniseriate, hyaline, smooth, elliptical and usually bigutulate, with lipid droplets usually accompanied by small granulations.

Geopora arenosa (Fuckel) S. Ahmad 1978

New species for Morocco. Harvested in January 2011 and 2021, under *Pinus pinea* in the Mamora (Figure 14).

The apothecia (0.5–3.5 (4) cm in diameter) is spherical, cup-shaped and sessile. It is almost hypogynous at first, after opening. It is incised and forms lobes that spread out in an almost horizontal star shape on the substrate. The margin is ochraceous brown then greyish with age. The outer surface is ochraceous brown and densely covered with tangled pale brown hairs that clump together grains of sand. The hymenophore is smooth to slightly rough, cream, greyish, ochraceous to brownish in colour. The flesh (0.5 mm thick (excipulum and hymenium), always less than 1 mm thick) is thin, bistratified, brittle, whitish to cream-coloured and has a non-distinctive odour and flavour. The spore is white. The asci (240 × 14–20

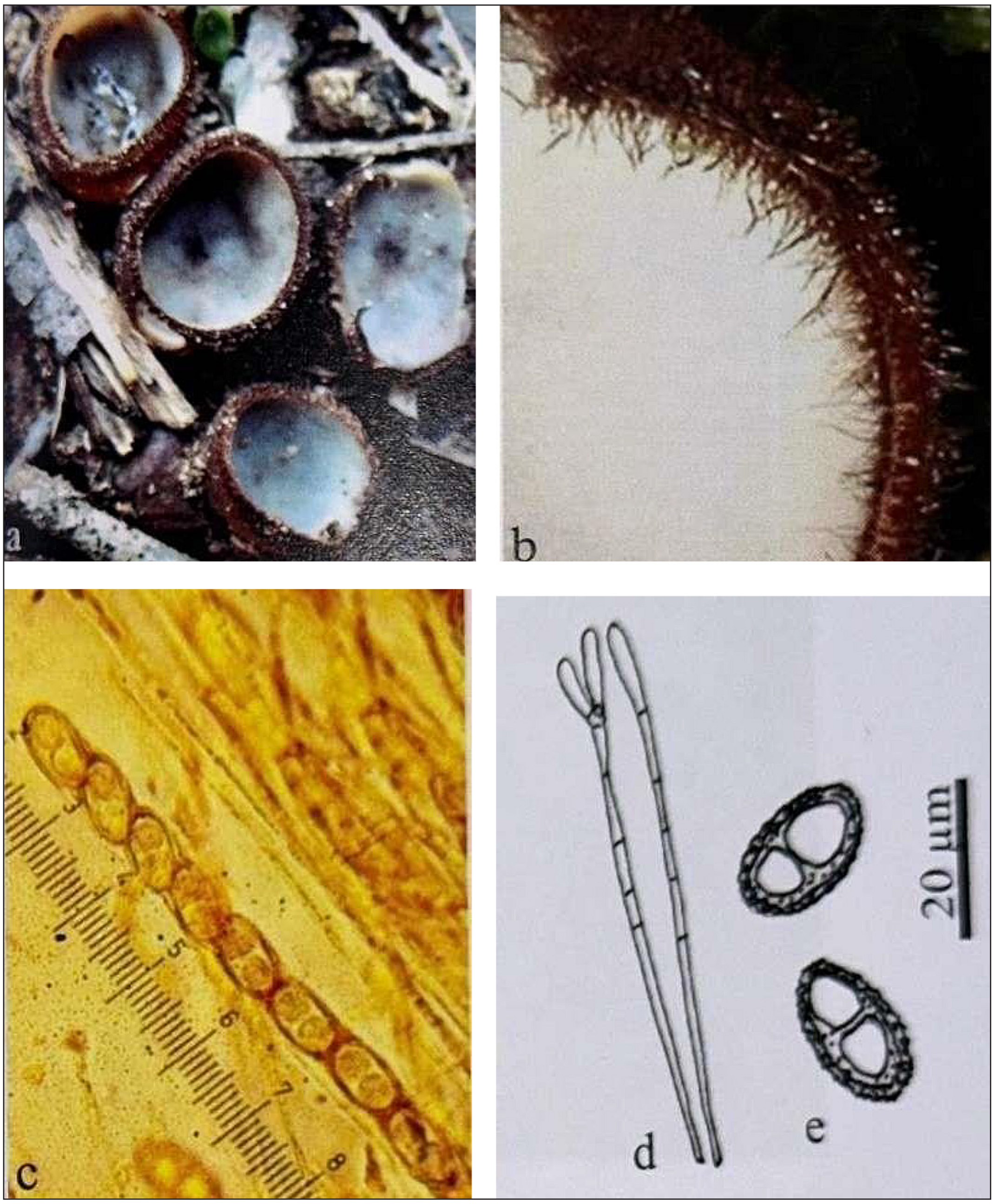

Figure 12. *Humaria hemisphaerica* (F. H. Wigg. Fries) Fuckel: Ascocarp on woody debris (a); margin fringed with stiff, pointed cilia (b); unoccluded asci with 8 ascospores (iodine water × 400) (c); pattern of segmented straight and forked paraphyses (d) and pattern of ornamented, bigutulate ascospores (e)

um) are cylindrical, inamyloid and have eight uniseriate spores. The paraphyses (6–9 um in diameter at the apex) are cylindrical, narrow, straight or slightly flexuous. They are sparsely septate with a branched base and contain one or two lipid droplets. The hairs on the outer surface (1000 × 5–10 um) are septate, aided, branched, thin-walled and brown in colour.

Geopora arenicola (Lev.) Kers 1974

Harvested in January and March 2011, 2018, 2020 and 2022, under *Pinus pinea* in the Mamora (Figure 15).

The apothecia (0.5–4 cm in diameter) is spherical, cupuliform, sessile and initially almost hypogynous before opening up and becoming semi hypogynous. The margin is incised, forming several lobes, and the outer surface is ochraceous

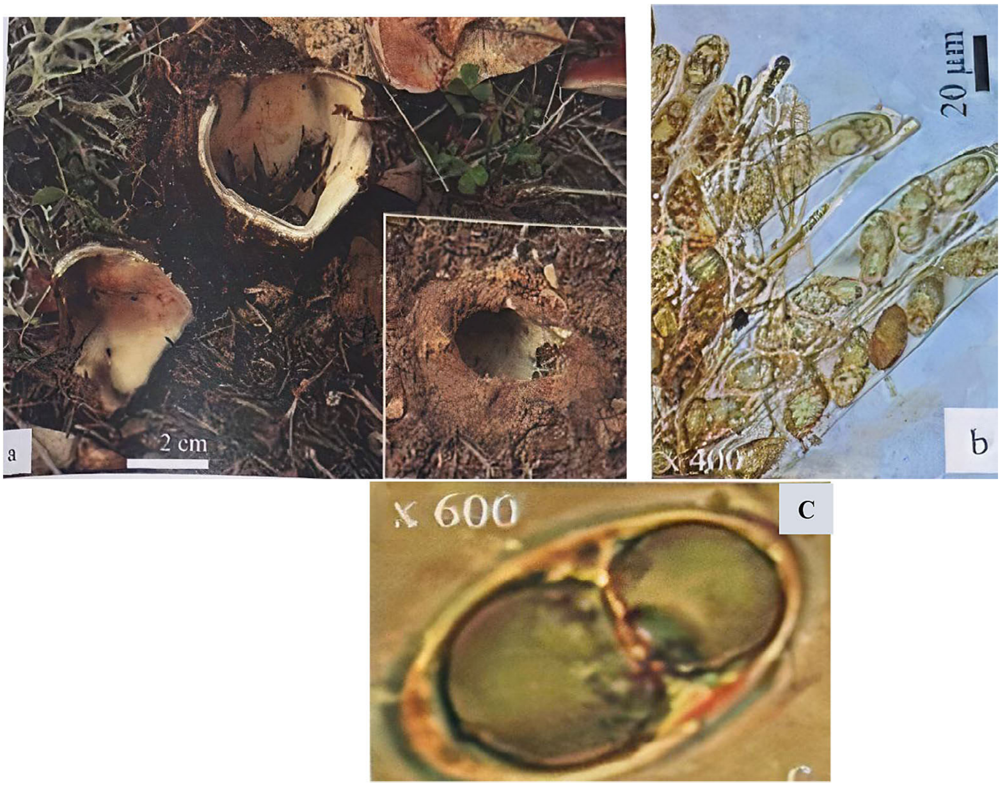

Figure 13. *Geopora sumneriana* (Cooke) Massee: Semi-hypogynous ascocarps with bistratified flesh (a and b), cylindrical asci with 8 ascospores and thin paraphyses with a swollen apex (c) and an ellipsoid bigutullate spore (in iodinated water)

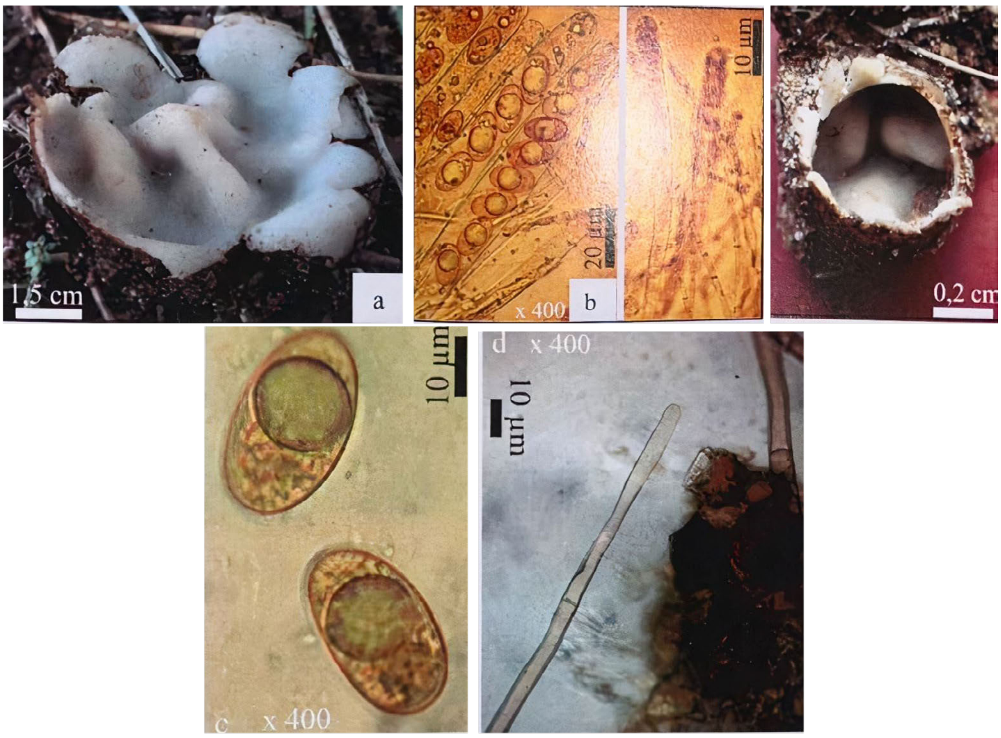

Figure 14. *Geopora arenosa* (Fuckel) S. Ahmad: Ascocarps semi hypogeous, at first closed then gradually opening and spreading horizontally, the margin incised, the hymenial surface whitish and the flesh bistratified (a); cylindrical asci with 8 ascospores and slender septate or swollen-topped paraphyses (b) ellipsoid spores with rounded margins and guttulate in iodinated water (c) and hairs on the outer surface in water; the hairs are felt and brown (d)

brown, densely covered with hairs that agglutinate grains of sand. The hymenophore is smooth to slightly rough, cream to ochraceous to brownish in colour. The flesh (excipulum and hymenium, about 1 mm thick) is bistratified and thin, brittle, whitish and with a non-distinctive odour and flavour. The spore is white. Asci (240 × 14–20 um) are cylindrical, inamyloid and have eight uniseriate spores. The paraphyses (6–9 um in diameter at the apex) are cylindrical, narrow, straight or slightly flexuous. They are sparsely septate with a branched base. Ascospores (19.5–23 × 10–13.5 m) are smooth, hyaline, elliptical with ficoid margins and contain one or two lipid droplets. The outer hairs (1000 × 10 um) are wavy, thick-walled, branched and have thin septa 6-.

Otidea umbrina (Pers.) Bres. 1898

Otidea umbrina (Pers.) Bres. 1898 (= *Otidea cochleata* Fuckel 1870): new species for the Lalla Mimouna region. Collected in February 2009 and 2022, under *Quercus suber* in the Ferjana forest (Lalla Mimouna). (Figure 16).

Ascocarps are solitary or densely gregarious but very abundant among herbaceous plants. The apothecia (3–4 (6) cm in diameter × 3–4 cm high) are solitary or in compact, spiral tufts. They are sessile, cupuliform, more or less elongated and split on one side. The outer surface of the ascocarp is glabrous or wrinkled, cinnamon brown to brown with a purple sheen. The margin is rolled, slightly irregular and crenellated or finely serrated. The flesh is elastic and brownish in colour. The hymenium is smooth, brownish to dark brown with reddish to vinous highlights. The asci (200–260 × 10–15 um) are capped, uniseriate and non-amyloid. The paraphyses are spiral-topped, thickened and more or less nodular. The ascospores are white; under the microscope, in water, the spores (14–15 (19) × 9–11 m) are smooth, hyaline, broadly ellipsoid and bigutulate.

Tarzetta cupularis (L.) Svroek 1981

Harvested under *Quercus suber* L. in January and February 2005, 2010, 2015 and 2022 in the Mamora (Figure 17).

The apothecia (1 to 2 cm) is ovoid, hemispherical to subglobose, cup- or beaker-shaped and cream to pale beige in colour. The ascocarp may be sessile or have a very short pseudostipe. The outer and inner surfaces are almost concoloured; the outer surface is slightly lighter and finely granular. The margin is irregular and finely toothed; it may be circular or slightly flared. The flesh is fine and brittle. The asci (300 × 15–20 um approximately) have 8 ascospores and do not show any blue staining under the action of iodine. The paraphyses are slightly thick-walled. The

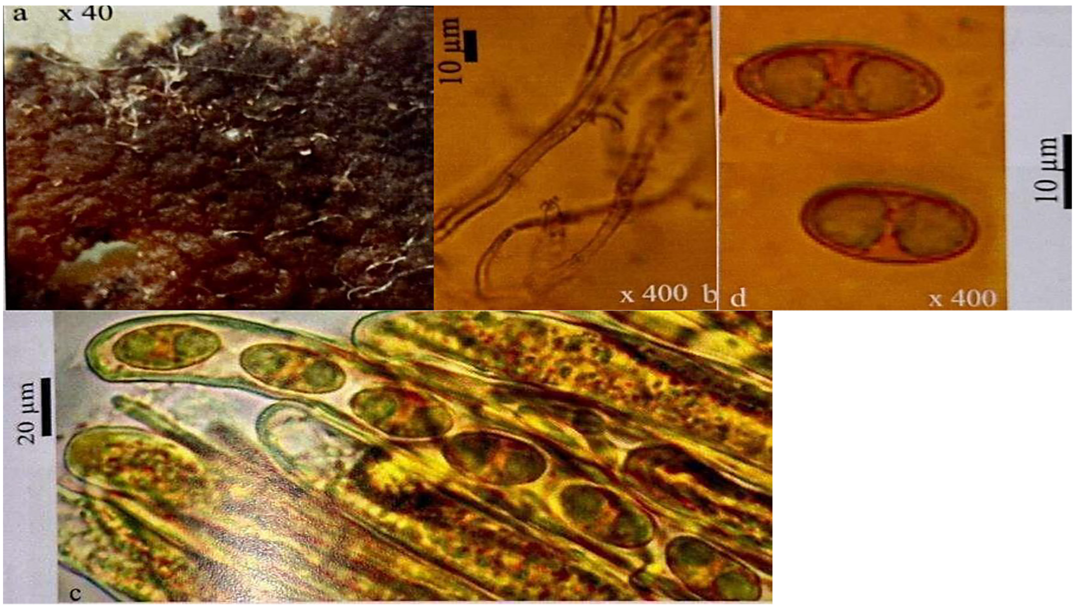

Figure 15. *Geopora arenicola* (Lev.) Kers: hairs on the outer surface under the magnifying glass (a) and under the microscope: the hairs are wavy and branched (b), cylindrical asci and spindly paraphyses (c) and elliptical-fusoid spores in iodinated water (d)

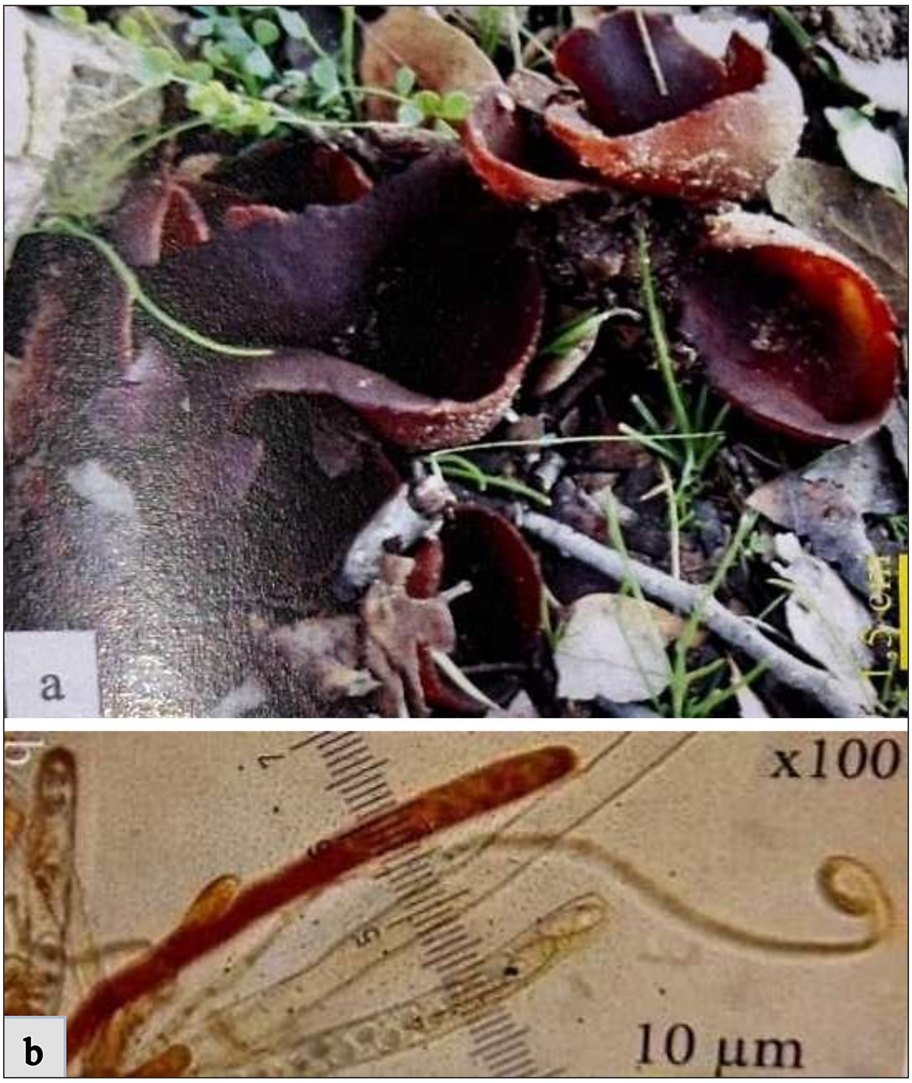

Figure 16. *Otidea umbrina* (Pers.) Bres. A clump of ascocarps in Quercus suber litter; asci and a spiral and nodular paraphysis (b)

spores (17–21 × 12.5–15 um) are smooth and elliptical and contain two large oily drops.

Scutellinia scutellata (L.) Lambotte 1887

Collected in April 2009, 2018 and 2020, on plant debris under *Cupressus arizonica* near Azrou (Middle Atlas) (Figure 18).

The apothecia (up to 10 mm in diameter) are cup-shaped. The disc is bright red, yellow or orange. The outer surface is stiff brown, dark brown or blackish. The flesh is bistratified. The hairs are 1000 um long and forked, with a base of around 40 um and tips 5 to 10 um thick. The asci (up to 300 × 25 um) are amyloid, the 10 mm thick paraphyses are clavate and their tips are stained green by iodine. Ascospores (17.5–20 × 10–12.5 mm) are elliptical. The ascospores (17.5 × 10 um) at the top of the asci are ornamented (maturation), while those at the base of the asci may be smooth. New species for the Rif and Gharb regions in the Ferjana forest (Lalla Mimouna) (Figure 19).

The fruiting bodies (0.8 to 2.4 cm in diameter × 0.5–2 cm in height) are intensely black cup- shaped, with greenish reflections when wet and brownish after drying. The outer surface has more or less regular longitudinal grooves and a mass of false foot composed of an abundance of black mycelium which spreads over the surface of the substrate where it is firmly attached. The flesh is dark green in fresh specimens and turns whitish grey in dried specimens; the inner surface of the apothecia is smooth and concoloured with the outer surface; the margin is circular or slightly flared and crenellated. The asci (400–550 × 15–21 m) are octosporous and do not show any blue staining under the action of iodine

Figure 17. *Tarzetta cupularis* (Holmsk.) Eckblad: Ascocarp among the leaves of *Q. suber* (a) and asci with smooth, non-amyloid, bigutullate spores × 400 in Congo red (b)

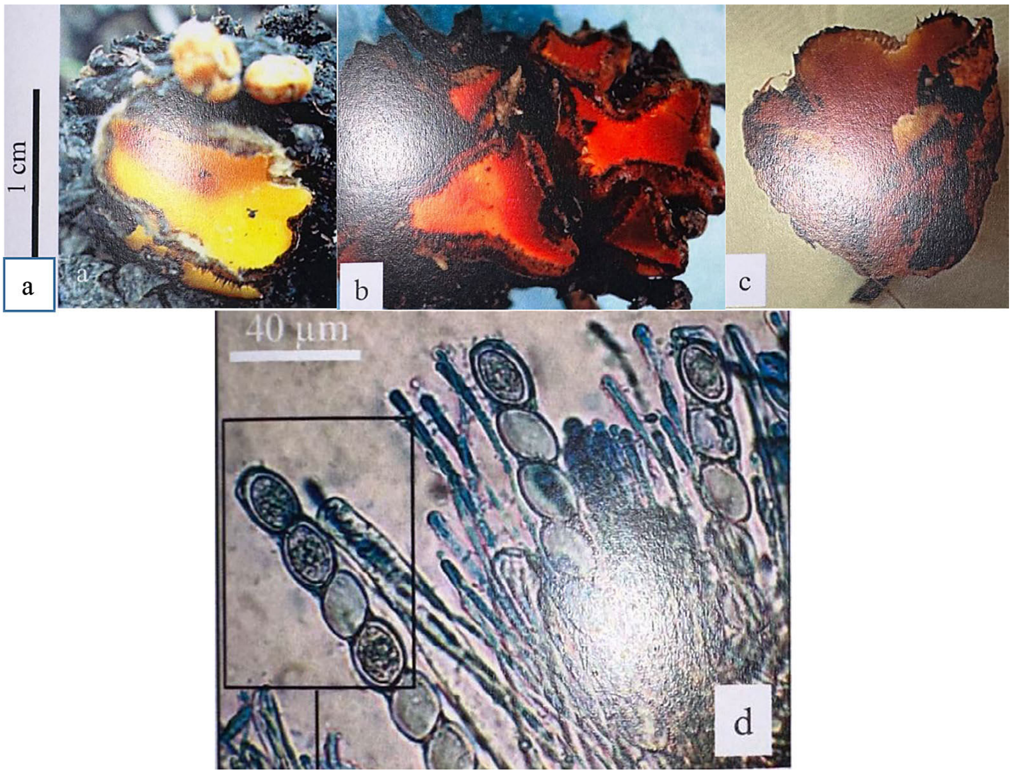

Figure 18. *Scutellinia scutellata* (L.) Lambotte: yellow, bright orange discoid ascocarps with ciliated margins (a, b and c); hymenium with amyloid asci, greenish paraphyses in iodine and smooth or ornamented ascospores, observed in iodinated water (d and e) *Plectania rhytidia (Berk.) Nannf. & Korf, 1957*

water. The paraphyses (1.2 to 2 um in diameter) are spindly, segmented with a straight apex that is not swollen or branched in the form of forks. Ascospores (21–26 × 10–13 um) are elliptical to fusiform or have one flat side and an arcuate other. They are hyaline in water.

DISCUSSION

Geoglossomycetes, commonly known as black earth tongues, represent a small class of ascomycetous fungi. According to Hustad et al. (2013), they are classified within the order Geoglossales, which includes six genera and approximately 50 species. This group has been recognized since the late 18th century (*Geoglossum*) and the 19th century (*Trichoglossum*), and is widely distributed and well-documented (Schoch et al., 2009; Hustad et al., 2011). The Index Fungorum (2018) records 23 species and 48 varieties globally, reflecting its diversity and broad biogeographic distribution.

Morphologically, members of the Geoglossaceae are terrestrial, stipitate, clavate or capitate, gymnocarpic black ascomycetes, characterized by inoperculate asci and typically septate, elliptical to cylindrical or clavate ascospores (Arauzo and Iglesias, 2014). Their apothecia, brown to black

Figure 19. *Plectania rhytidia f.* platensis (Speg.) Donadini 1985: Ascocarps found at Bab Taza (Chefchaouenne, Rif), black apothecia in section with a mycelial cord attaching the ascocarp to its woody substratum and the grooveson the outer surface (a); ascocarps found at Lalla Mimouna (gharb b) (b); the hymenium consisting of non- a12myloid octosporate asci and septate paraphyses that are spindly, forked or with rounded apices (observations in iodised water × 400) (c); diagrams of paraphyses (d) and spores (e)

when mature, arise from a stipe with a cartilaginous texture and can reach up to 10 cm in height. A key distinction between the genera *Geoglossum* and *Trichoglossum* lies in the dense, dark, velvety hairs covering the apothecia of the latter. However, species delimitation within *Trichoglossum* remains challenging; for instance, *T. hirsutum* and *T. tetrasporum* can only be reliably distinguished at maturity based on the number of spore septa.

Ecologically, *Trichoglossum hirsutum* (Pers.: Fr.) Boud. (1907) is a saprotrophic species that grows on decaying wood or leaf litter. Its ascocarps appear solitary, scattered, or clustered, often associated with mosses or decomposed hardwood (Dennis, 1968). In Morocco, *T. hirsutum* was previously reported from Tangier (Malençon and Bertault, 1956; 1960) and Larache (Bertault, 1964; 1967). In the present study, it is newly recorded from leaf litter in Ferjana Forest, located in the Lalla Mimouna region (Gharb), thereby expanding its known national distribution.

The genus *Helvella* comprises macroascomycetes characterized by saddle- or cup-shaped apothecia. These fungi are globally distributed and are known to play important ecological roles, particularly as ectomycorrhizal symbionts (Wang, 2019). One representative species, *Helvella leucomelaena* (Pers.) Nannf., also referred to by synonyms such as *Acetabula leucomelaena*, was first recorded in Morocco near Rabat under pine trees by Maire and Werner (1937), although no specific locality or substrate was provided. Subsequent records include observations in the Middle Atlas under *Pinus pinaster* (Malençon, 1958) as well as in Dayat Hachlaf and the Tangier region (Malençon and Bertault, 1956; Bertault, 1964).

The *Helvella lacunosa* species complex includes fungi with dark, lobed or convex apothecia and ribbed stipes. These species are primarily distributed in the Northern Hemisphere and fulfill critical ecosystem functions (Khalid et al., 2022; Hwang et al., 2015). Advances in molecular phylogenetics have significantly enhanced understanding of this group. Skrede et al. (2020) defined a monophyletic clade comprising *H. lacunosa* and its allied taxa, identifying 22 genetic lineages and designating epitypes or neotypes for several species (*H. atra*, *H. helvellula*, *H. nigra*, *H. pallescens*, *H. phlebophora*, *H. queletiana*, and *H. sulcata*). In China, the complex has been widely recorded across multiple provinces (Teng, 1963; Zhao and Hyde, 2019), with recent additions including newly described species such as *H. cysti*, *H. pseudolacunosa*, and *H. rugosa*. In Morocco, *Helvella lacunosa* Afzel. (1783) and *H. sulcata* Afzel. (1783) have been reported from various regions including Mamora, the Middle Atlas, Lalla Mimouna, Khmiss-es-Sahel, and Oulmès, typically growing on soil, particularly under oak trees. Larouz (2007) documented *H. lacunosa* in the Middle Atlas, although the measured spore sizes were smaller than those of our recent collections from Mamora, Oulmès, and Lalla Mimouna. While these species share many morphological traits, size appears to be the most consistent distinguishing feature. The taxonomic delimitation between *H. lacunosa* and *H. sulcata* remains unresolved. Both Courtecuisse and Duhem (2000) and Kirk et al. (2008) acknowledged the difficulty in distinguishing these taxa. Although Index Fungorum lists them as separate species, it also refers to *H. sulcata* as a variety of *H. lacunosa*. The anatomical differences described, such as size, color, and microscopic structures, appear insufficient to justify their status as distinct species. Similar intraspecific morphological variation has been documented in other fungal species, such as *Armillaria mellea*, *Agrocybe aegerita* (Outcoumit et al., 2005; 2007), *Lactarius rugatus*, and *L. volemus*. Based on these considerations, it seems plausible to treat *H. sulcata* as a morphological variety of *H. lacunosa*, a position initially proposed by S. Imai in 1954 (*Helvella lacunosa* var. *sulcata*).

The Pezizaceae family

The Pezizaceae family, one of the largest within the order *Pezizales*, comprises 31 genera and approximately 230 species (Kirk et al., 2008) These fungi play a fundamental ecological role in forest ecosystems, notably by contributing to the decomposition of organic matter and soil dynamics. However, the diversity and taxonomy of Pezizaceae in Morocco remain only partially explored, highlighting the need for in-depth studies.

The genus *Peziza*, which includes approximately 112 confirmed taxa (Jaklitsch et al., 2017) presents significant challenges in species delimitation due to the lack of reliable morphological characters such as hymenium color, external texture, or colored latex production (Dzhagan et al., 2020).In this context, *Peziza ammophila* Durieu and Montagne was recorded for the first time in the Mamora dunes in 2008 and 2009. This species, absent from both historical and recent Moroccan fungal inventories (Malençon and Bertault, 1971; Ait Aguil, 2005; El Assfouri, 2006; Haimed, 2007; Larouz, 2007), represents a new addition to the national mycobiota. Originally described in Algeria in 1847 Durieu and Montagne (Dennis, 1968), it is distinguished in this study by its larger spores, measuring 14–16 × 10 µm. Moreover, molecular analyses have led to its transfer to the family Sarcosphaeraceae, currently considered a section of Pezizaceae, under the name *Sarcosphaera ammophila* (Hansen et al., 2002). However, this synonymy has not yet been validated by the taxonomic reference work of Kirk et al. (2008) Phylogenetic analysis also revealed the presence of five taxa within the *P. ammophila* clade, indicating notable evolutionary complexity. Previous studies have reported the presence of *Peziza badia* in several Moroccan regions (Malençon, 1937; Malençon and Bertault, 1968) Since 2004, this species has been regularly observed in the forests of Mamora, Ferjana, and Khmis-es-Sahel. Its morphological similarity to other species, such as *Peziza badioconfusca* and *Galactinia linosa*, can lead to misidentification. Differentiation is primarily based on spore ornamentation: *P. badioconfusca* has finely warted spores (17–21 × 8–10 µm), while *G. linosa* features spores with elongated warts, lacking ridges, and is typically associated with clay-rich soils (Dennis, 1968).

Peziza echinospora P. Karst., a rarely edible species with numerous synonyms, primarily colonizes carbon-rich and often fire-affected soils. It was repeatedly observed at a Moroccan site, with spores exceeding previously reported dimensions. Several *Peziza* species exhibit ecological affinities for burned soils, notably *P. petersii*, which is characterized by smaller spores with fine ridges (Beug et al., 2014; Vizzini et al., 2016). Other species, such as *Peziza moseri*, *P. lobulata*, and *P. tenacella*, can be distinguished by specific spore features such as the presence of guttules, spore size, or ornamentation (Beug et al., 2014). Certain species present distinctive morphological traits that facilitate identification. For instance, *Peziza saniosa* exudes a bluish-purple latex when the hymenium is injured a rare feature within the genus *Peziza* (Moser, 1963; Dennis, 1968; Breitenbach and Kränzlin, 1984; Moreno and Remondo, 2003). This uncommon fungus grows in both deciduous and coniferous forests, on moss, litter, or decaying wood, and typically fruits from late spring to autumn. Although considered threatened in several European countries, recent observations indicate an increase in its frequency, possibly linked to improved climatic conditions (Ševčíková, 2017; Egertová, 2015). Finally, *Peziza succosa* is distinguished by strongly amyloid asci, showing an intense blue reaction at the apex, and exhibits a wide distribution across Europe, North America, and Asia (Hansen et al., 2001; Ashraf and Khalid, 2012). Overall, integrating morphological and molecular data significantly enhances current knowledge of Pezizaceae diversity and taxonomy in Morocco, providing new insights into their phylogenetic evolution and ecological roles in local forest ecosystems.

Within the order *Pezizales*, several genera of the family Pyronemataceae play an important ecological role and are characterized by remarkable morphological and ecological diversity. Among them, the genera *Coprobia*, *Humaria*, and *Geopora* represent key taxa, exhibiting both saprotrophic and, in some cases, potentially ectomycorrhizal lifestyles. This study provides updated data and comparative insights into these genera from various Moroccan habitats, including the Mamora forest, the Kénitra region, and the Middle Atlas.

The genus *Coprobia* includes three recognized species: *C. humana*, *C. hyphopila*, and *C. granulata*, the latter subdivided into two varieties: var. *granulata* and var. *minor* (Kirk et al., 2008) *Coprobia granulata* is typically a coprophilous species growing on the dung of herbivores such as cattle and sheep (Dennis, 1968). However, during fieldwork in the Kenitra region, ascocarps resembling *C. granulata* were collected on decaying woody debris rather than feces. This unusual substrate association suggests an unrecognized ecological behavior, an undescribed variety, or even a novel taxon, warranting detailed morphological and molecular investigation. Species similar to *C. granulata* and occupying comparable ecological niches belong to the genera *Anthracobia*, *Melastizia*, and *Ascophanus*. These taxa are generally characterized by specific microscopic traits such as cilia, iodine-reactive paraphyses, and guttulate ascospores, also present in *Coprobia* (Dennis, 1968). The morphological overlap among these genera further complicates identification based solely on traditional characters, thus reinforcing the importance of integrative taxonomy.

Closely related within the Pyronemataceae, the genus *Humaria* comprises cupulate fungi with elliptical, bi-guttulate ascospores. The type species, *H. hemisphaerica*, considered rare, has undergone multiple taxonomic revisions (Dennis, 1968; Kirk et al., 2008; Courtecuisse and Duhem, 2000). It was observed in this study on woody debris in the Lalla Mimouna region, a habitat consistent with previous Moroccan reports from the Mamora, Azrou, and Tamrabt forests (Maire and Werner, 1937; Malençon, 1966; El Assfouri et al., 2003). The identification of *H. hemisphaerica* at Lalla Mimouna constitutes a new record for this locality, thereby expanding its known geographical distribution. Interestingly, *Coprobia* and *Humaria* share several ecological and morphological traits, notably their saprotrophic behavior on decomposing organic matter and the presence of operculate asci and ornamented spores. Their coexistence with other ascomycetous and basidiomycetous taxa reflects the considerable ecological plasticity of these fungi. According to Tedersoo (2007), several genera of Ascomycota (e.g., *Humaria*, *Tricharina*, *Peziza*) as well as Basidiomycota (*Amanita*, *Ramaria*, *Tomentella*, etc.) may adopt various trophic strategies, including ectomycorrhizal symbiosis or saprotrophy, depending on environmental conditions.

Similarly, the genus *Geopora* presents complex ecological and taxonomic patterns. Initially defined by Harkness (1885) with the hypogeous species *G. cooperi* as the type species, the genus has since expanded to include semi-hypogeous and even epigeous species (Index Fungorum, 2020). Members of *Geopora* are characterized by operculate cylindrical asci, smooth hyaline spores, and hairy apothecia that often develop underground or partially buried in soil. These species are generally restricted to moist habitats, which explains their sporadic distribution and rarity in collections (Flores-Rentería et al., 2014; Saba et al., 2019).

In Morocco, *Geopora* is represented by three main species: *G. arenicola*, *G. sumneriana*, and *G. foliacea*. The latter, although reported from the Rif and the Middle Atlas, remains questionable due to imprecise descriptions and potential confusion with *G. arenosa* (Malençon and Bertault, 1961, 1967). *G. sumneriana* is a thermophilic species, mainly observed in calcareous cedar forests of the Middle Atlas, where it fruits in spring. Some authors consider it ectomycorrhizal (Abourouh and Najim, 1997), while others consider it to be specific to cedar forests without forming true symbioses (Lanier et al., 1978; Nezzar-Houcine et al., 1998). Morphologically, *G. sumneriana* is recognized by its ellipsoid to fusiform spores with one or two oil droplets and large, often clustered apothecia (Perić, 2011). *G. arenosa*, recently reported from the Mamora forest, is distinguished by its larger, yellowish apothecia, tufted external hairs, and relatively broad spores (Moser, 1963). It typically grows in moist coastal sandy areas under *Pinus pinea*. Often confused with *G. arenicola*, it can be differentiated microscopically by spore shape and excipulum hair morphology: *G. arenicola* has more branched, wavy hairs and slightly larger fusiform spores. It is important to note that morphological characters alone are often insufficient to distinguish species within the *Pezizales*, especially when diagnostic traits overlap. This issue is particularly evident in *Geopora*, where identification errors are frequent due to similar ascocarps and spore dimensions (Dzhagan et al., 2020). In conclusion, integrating molecular data with morphological and ecological observations is essential for resolving species boundaries and better understanding their functional roles in forest habitats.

The family Pyronemataceae (order Pezizales) comprises a diverse group of ascomycetous fungi, many of which are saprotrophic and exhibit a wide variety of ecological preferences, ranging from woody debris to burnt or humid soils. Several genera within this family *Otidea*, *Scutellinia*, and *Plectania* are particularly noteworthy for their morphological distinctiveness, ecological plasticity, and underexplored diversity in North African habitats. This study presents updated records and taxonomic insights on these genera based on collections from various Moroccan regions, including the Mamora forest, Lalla Mimouna, the Middle Atlas, and the Rif. Among these, *Otidea umbrina* is a known saprotroph that has been reported as potentially toxic (Gerhardt, 1999).

It was first documented in Morocco by Malençon in 1965, cited by El Assfouri (2003), with occurrences noted in the Mamora forest, the Jâaba forest, and under *Quercus faginea* in the Ifrane region (Middle Atlas). Larouz (2007) also recorded its presence under cedar trees in the Middle Atlas. The species is commonly observed during the spring season, with a notable preference for habitats dominated by Quercus suber, particularly in the Lalla Mimouna region, where it is newly reported. Taxonomic identification within *Otidea* is primarily based on the morphology and pigmentation of the apothecia (Kanouse, 1949; Dennis, 1968; Cao et al., 1990). A phylogenetic analysis by Liu et al. (2006) established two major clades within the genus: one comprising species with ear- or spoon-shaped apothecia, and another with discoid forms. While the shape and color of the apothecia are considered reliable characters, other features such as paraphyses and spore morphology are useful but often insufficient for accurate delimitation. Moreover, discrepancies between morphological traits and phylogenetic groupings further complicate identification.

A comparable ecological strategy is seen in the ascomycete *T. cupularis*, historically known under various synonyms (e.g., *Pustulina cupularis, Peziza cupularis*), which is a common saprophyte inhabiting diverse environments including gardens, woodlands, and burnt soils (Egli et al., 2003) Frequently encountered in the early months of the year, particularly January and February, this species has been observed in multiple Moroccan localities, including Mamora, Lalla Mimouna, and Khmis-es-Sahel.

Another representative genus of the Pyronemataceae with striking morphological traits is *Scutellinia*. Introduced by Cooke (1879) and elevated to generic status by Lambotte in 1887, *Scutellinia* is characterized by its bright orange or red apothecia and the presence of prominent, rigid hairs surrounding the hymenial surface (Choi et al., 2013). The taxonomic complexity of the genus has led to revisions over time, and species are often delineated based on spore shape and ornamentation as well as hair morphology (Bogacheva and Kullman, 2006; Donadini, 1983; Moravec, 1974; Schumacher, 1990) Two categories of hairs marginal and lateral are commonly used to aid species identification. Schumacher (1990) proposed the terms "differentiated" and "undifferentiated" to describe whether these hair types can be distinctly recognized. Such morphological criteria have proven valuable for delimiting cryptic species within this genus.

Scutellinia scutellata (L.) Lambotte, a widespread species in the Pyronemataceae, is primarily found on moist woody debris (Dennis, 1968) In Morocco, it has been recorded in Tangier, although the substrate was not specified. More detailed observations report its presence on damp wood of *Quercus pyrenaica* in the Rif and on wet *Quercetum* wood in the Middle Atlas (Malençon and Bertault, 1957–1959; Ait Aguil, 2005; Larouz, 2007). An additional observation from April 2009 reported its occurrence on *Cupressus arizonica* debris in the Middle Atlas. Such findings confirm its broad ecological amplitude and capacity to colonize a variety of hardwood substrates.

A remarkable case of fungal resilience is illustrated by the species *Plectania rhytidia*, observed in Bab Taza (Chefchaouen), where specimens stored under refrigeration for five months retained the ability to regenerate apothecia upon rehydration. This reviviscent behavior suggests adaptation to harsh environmental conditions, though field experiments are necessary to confirm this hypothesis. The genus *Plectania*, belonging to the Pezizomycetes, comprises 44 recognized species (Kirk et al., 2008). In Morocco, three taxa *Urnula melastoma, U. platensis,* and *U. japonica* have been identified. The genus was separated from Urnula by Le Gal in 1958 (Dennis, 1968), with new nomenclatural combinations introduced: Plectania melastoma, *P. platensis,* and *P. japonica*. Notably, *P. platensis*, originally reported by Malençon and Bertault (1956) under *Eucalyptus globulus* and *Quercus suber* in Tangier, corresponds to *Plectania rhytidia*. A recently discovered species of *Plectania,* recorded at Bab Taza and Lalla Mimouna (Rif and Gharb regions), further contributes to the known diversity of this genus in Morocco. Altogether, the genera *Otidea*, *Scutellinia,* and *Plectania* reflect the ecological and morphological richness of Moroccan Pyronemataceae, particularly in forested and humid habitats. Their records underscore the biogeographic value of Morocco as a reservoir of fungal diversity, while also highlighting the need for integrative approaches combining morphology, phylogeny, and ecology to resolve taxonomic ambiguities and uncover hidden diversity.

CONCLUSIONS

The Moroccan fungal flora is exceptionally rich and diverse, yet research on ascocarp-producing ascomycetes remains limited, and no comprehensive regional checklists have been published to date. In this study, nineteen species of Ascomycota were recorded from several localities across Morocco. *Trichoglossum hirsutum* was collected in Lalla Mimouna, while three species of *Helvella*: *H. leucomelaena*, *H. lacunosa*, and *H. sulcata* originated from the Mamora forest (Kenitra), Oulmès, and Lalla Mimouna, respectively. Five *Peziza* species were identified: *P. ammophila* in the Mamora dunes, *P. badia* in Khmis-es-Sahel, *P. echinospora* on burned soils of the Mamora, *P. saniosa* also in the Mamora, and *P. succosa* beneath cork oaks in the same forest. Additional Pyronemataceae were documented, including *Coprobia granulata* in the Mamora forest, *Humaria hemisphaerica* in Lalla Mimouna, and several species of *Geopora*. Among them, *G. sumneriana* was recorded in the Middle Atlas (Ras el-Ma, Ifrane), while *G. arenosa* and *G. arenicola* were associated with pine stands in the Mamora. *Otidea umbrina* was likewise collected in Lalla Mimouna, and *Tarzetta cupularis* was found in the Mamora forest. *Scutellinia scutellata* was observed near Azrou (Middle Atlas), and *Plectania rhytidia* was recorded both in the Rif (Bab Taza, Chefchaouen) and in Lalla Mimouna. Three species *Geopora arenosa*, *Peziza ammophila*, and *P. echinospora* constitute new records for the Moroccan mycobiota. Other taxa, including *Coprobia granulata*, *Humaria hemisphaerica*, *Otidea umbrina*, and *Plectania rhytidia*, are newly reported from the Mamora forest, northwestern Morocco, the Lalla Mimouna forest, and both the Rif (Ferjana forest) and the Gharb region. *Peziza saniosa* is presented here as a new and rare species for the Mamora forest. This study also provides, for the first time, detailed morphological descriptions of all recorded taxa.

Our observations indicate an expansion of the distributional ranges of several species, particularly *Plectania rhytidia*. Such patterns may reflect increased adaptive capacity, the establishment of new ecological associations, or shifts in climatic and environmental conditions. Microscopic examinations of ascocarps, asci, and ascospores revealed both consistencies and notable divergences from previously published accounts, raising questions regarding current taxonomic assignments. Nonetheless, these findings provide valuable new insights into the morphological variability of the species examined.

Overall, this study reinforces the importance of combining classical morphological approaches with modern molecular tools. It helps fill existing gaps in the knowledge of Moroccan fungal biodiversity and establishes a solid foundation for future research. Furthermore, it highlights the need for continued exploration of Moroccan forest ecosystems and adjacent habitats to deepen our understanding of these fungi and their essential ecological roles.

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