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Changes of hypogeous funga in the Carpathian-Pannonian region in the past centuries

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The exploration of hypogeous fungi in the Carpathian-Pannonian region speeded up in the past decades, owing to the widespread of truffle hunting with dogs. As a result, not only several new species were found in the region, but our view of the frequency of truffles also changed fundamentally. It became evident that *Tuber aestivum*, *T. brumale*, *T. macrosporum*, *T. magnatum*, *T. mesentericum* and *Mattirolomyces terfezioides* can be collected in commercial quantity. Among the dog preferred hypogeous fungi (DPH) several species, earlier believed to be rare like *Octaviania asterosperma* and *Stephensia bombycina*, also occurred. The taxonomic alterations and revisions brought about changes in the list of hypogeous fungi, and further changes are expected from molecular taxonomy research on a number of genera at present.

Key words: list of underground fungi, mycota, distribution, dog preferred hypogeous fungi, Hungary

INTRODUCTION

There are only few publications which have focused on the distribution of hypogeous fungi in European regions (Ławrynowicz 1989, 1990, 1992; Montecchi, Sarasini, 2000; Riousset et al. 2001). The Carpathian-Pannonian region is considered as one of the best known biogeographical regions of the hypogeous funga. This is partly because a number of manuscripts have reported and described hypogeous fungi since the 16th century, but mainly because two world-famous researchers, László Hollós (1911) and László Szemere (1965) made a detailed inventory of hypogeous fungi in the past nearly 200 years in their books. During his work Hollós published roughly 460 data of 52 hypogeous fungi in the Carpathian Basin. Szemere (1970) reported on 86 species in his book. Such richness of the hypogeous funga may be attributed to the varied landscape, the superposition of several climatic effects and the diversity of soil types in the Carpathian-Pannonian biogeographic region (Stanners, Bourdeau 1995).

Following the hardships of the last century, at the end of it, truffle hunting with dogs became popular in a number of countries in the region. The mapping and preservation of hypogeous fungi in fungaria also progressed by the leadership of professional organisations and societies. Collections in the past decades did not only reveal species new to the region, but modified our knowledge on the frequency of occurrence and ecological requirements of some species. Although the practice of using dogs for collection produced a large amount of data, it was evident that species with the most preferable odour were overrepresented. As collection for commercial purposes became general, collectors started to focus on certain forest types or landscapes, and dog owners often discouraged their dogs from finding non-commercial species. Consequently, data from dog-aided collections can be considered representative only for species of commercial importance and their accompanying species. It is worth mentioning that these very data could have laid the foundations of the legal regulations for truffle collecting. The assessment of the distribution of other hypogeous species raises further questions in terms of sampling and collecting.

Being aware of the above mentioned diverse collecting methods and aims, in this paper we aim at reassessing the frequency of occurrence of hypogeous fungal species in the region and unrevealing the likely causes of changes and the possibilities of utilization and protection.

MATERIALS AND METHODS

In cooperation with collectors of the First Hungarian Truffle Society (EMSzE), we compiled a fungarium of 4224 preserved specimens of hypogeous fungi in the past three decades. Data on collection and available habitat descriptions were organised in a database (Merényi et al. 2010). Present study compares the occurrence data of species in the database with the published data of Hollós (1911) and Szemere (1970).

RESULTS AND DISCUSSION

Table 1 shows the species used for comparison. Some taxa in Table 1 appear with genus names only as their classification at species level is still unclear, and they are under molecular taxonomic investigations. For simplicity, species will be discussed in three large groups.

Taxonomic changes and revisions. Following the publication of Szemere's book (1970), many researchers revised his fungarium. A detailed evaluation of these revisions is given by Bratek and Halász (2005). The following species were removed from Szemere's list by the revisions: *Choiromyces magnusii* (Matt.) Paoletti and *Endogone irregularis* Szem. New species on his list are: *Glomus caledonium* (Nicol. et Gerd.) Gerd. et Trappe, *Glomus fasciculatum* (Thaxt.) Gerd. et Trappe and *Hymenogaster remyi* Dodge et Zeller. All *Rhizopogon* species were merged into *Rhizopogon roseolus*

Table 1
The occurrence data of taxons found in the Carpathian-Pannonian region based on the published data of Hollós (1911), Szemere (1970) and on the actual database of First Hungarian Truffle Society (EMSzE)

Species	Hollós (1911)	Szemere (1970)	EMSZzE (2013)
Ascomycota			
Elaphomyces aculeatus Vittad.	8	2	26
Elaphomyces anthracinus Vittad.	5	3	2
Elaphomyces asperulus Vittad.	11	1	7
Elaphomyces decipiens Vittad.	-	-	6
Elaphomyces granulatus Fr.	9	-	31
Elaphomyces leveillei Tul.	1	-	2
Elaphomyces maculatus Vittad.	1	16	3
Elaphomyces muricatus Fr.	28	1	146
Elaphomyces persoonii Vittad.	-	-	4
Elaphomyces reticulatus Vittad.	-	-	10
Elaphomyces virgatosporus Holl.	-	-	11
Balsamia platyspora Bk.	-	-	2
Balsamia polysperma Vittad.	12	-	13
Balsamia vulgaris Vittad.	-	9	18
Balsamia sp. (undet.)	-	-	32
Hydnotrya cerebriformis Harkn.	-	-	2
Hydnotrya tulasnei Berk. et Br.	3	5	29
Choiromyces meandriformis Vittad.	84	-	77
Genea hispidula Berk. et Br.	-	-	4
Genea fragrans (Wallroth) Paoletti	-	-	11
Genea klotzschii Berk. & Broome	3	-	36
Genea lespiaultii Corda	5	1	11
Genea sphaerica Tul.	1	-	15
Genea verrucosa Vittad.	2	3	115
Genea sp. (undet.)	-	-	75
Stephensia bombycina (Vittad.) Tul.	1	-	139
Picoa carthusiana Tul.	2	-	3
Hydnobolites cerebriformis Tul.	3	2	21
Pachyphloeus spp.	3	13	95
Mattirolomyces terfezioides (Matt.) Fisch.	1	7	45
Tuber aestivum Vittad.	51	6	461
Tuber borchii aggr. (small white truffles)	20	6	227
Tuber brumale Vittad.	1	1	303
Tuber excavatum aggr.	22	2	485
Tuber lucidum Bonn.	-	-	5
Tuber macrosporum Vittad.	2	-	146
Tuber magnatum Pico	-	-	50
Tuber mesentericum (Vittad.) Fisch.	1	-	124
Tuber nitidum Vittad.	5	-	10
Tuber regianum Mont. et Lazz.	-	-	9
Tuber rufum Pico	19	29	458
Zygomycota			
Endogone flammicorona Trappe et Gerd.	-	1	9
Glomeromycota			
Glomus caledonium (T.H. Nicolson & Gerd.) Trappe & Gerd.	-	1	-
Glomus fasciculatum (Thaxt.) Gerd. et Trappe	-	2	4
Glomus fulvum (Berk. & Broome) Trappe & Gerd.	-	-	1
Glomus macrocarpum Tul.	-	6	10
Glomus microcarpum Tul.	-	6	6
Basidiomycota			
Leucogaster nudus (Hazsl.) Hollós	1	-	1
Melanogaster ambiguus (Vittad.) Tul.	15	3	75
Melanogaster broomeanus Berk apud Tul.	-	-	41
Melanogaster intermedius Berk. et Br	-	-	2

Table 1 – cont.

Melanogaster macrosporus Velen.	-	-	4
Melanogaster tuberiformis Corda	-	-	2
Melanogaster variegatus (Vittad.) Tul	22	2	12
Melanogaster sp. (undet.)	-	-	49
Rhizopogon roseolus sensu Martín	15	10	57
Rhizopogon villosulus Zeller	-	-	2
Octavianina asterosperma Vittad.	6	-	38
Phlyctospora fusca Corda	1	3	16
Gastroporium simplex Matt.	-	2	7
Hypogeic Russulales	2	1	36
Gautieria spp.	13	1	56
Hysterangium calcareum Hesse	-	-	2
Hysterangium clathroides Vittad.	21	-	2
Hysterangium coriaceum Hesse	-	-	3
Hysterangium crassum (Tul. & C. Tul.) E. Fisch.	-	-	27
Hysterangium membranaceum Vittad.	2	-	-
Hysterangium nephriticum Berk.	-	-	2
Hysterangium pompholyx Tul.	1	-	1
Hysterangium stoloniferum Tul.	11	2	29
Hymenogaster tener Berk.	3	4	3
Hymenogaster arenarius Tul.	2	7	8
Hymenogaster bulliardii Vittad.	-	-	35
Hymenogaster citrinus Vittad.	8	2	62
Hymenogaster griseus Vittad.	10	11	99
Hymenogaster hessei Soehner	-	-	28
Hymenogaster luteus Vittad.	-	1	103
Hymenogaster niveus Vittad.	-	-	41
Hymenogaster rehsteineri Bucholtz	-	-	23
Wakefieldia macrospora Hawker	-	-	2
Sclerogaster spp.	-	-	14

(Corda) T. M. Fr. (Martín, 1996). Species new to the list due to rearrangements are: *Glomus macrocarpum* Tul. and *Glomus microcarpum* Tul.

The revision of *Hymenogaster* species by the complex evaluation of molecular and morphological data, and using samples from the Carpathian-Pannonian region revealed that *Hymenogaster griseus* Vittad. 1831 (emend Stielow et al. 2010) includes the species *H. lilacinus* Tul. (probably), *H. lycoperdineus* Vittad., *H. muticus* Berk. et Br. (probably), *H. populetorum* Tul. and *H. vulgaris* Tul., while *Hymenogaster citrinus* Vittad. includes the species *H. olivaceus* Vittad.

Preliminary molecular biology studies have indicated that revision of the traditional species boundaries is needed in some genera. The following genera are being revised on molecular taxonomical basis: *Arcangeliella-Zelleromyces*, *Gautieria*, *Genea*, *Glomus*, *Hysterangium*, *Melanogaster*, *Pachyphloeus* and *Sclerogaster*. In other genera only certain species groups need to be revised by means of molecular taxonomy, such as *Elaphomyces muricatus/decipiens/reticulatus/asperulus*, *Hymenogaster niveus* aggr., *Hymenogaster rehsteineri* aggr., *Tuber rufum* aggr., *Tuber excavatum* aggr. and *Tuber borchii* aggr.

New species, extinct species and very rare species. Bratek et al. (1999) described sixteen species new to the Carpathian-Pannonian region including *Elaphomyces persoonii* Vittad., *Endogone flammicorona* Trappe et Gerd., *Hysterangium pompholyx* Tul., *Sclerogaster compactus* (Tul.) Sacc., *Tuber magnatum* Pico, *Tuber regianum* Mont. et Lazz. and *Wakefieldia macrospora* Hawker. But for *T. magnatum* and

Endogone flammicorona, which is often found in acidic conifer woodlands, all the above species are still regarded as very rare. *T. magnatum* has been collected in great quantities from the gallery forests of the southern Pannonicum in the past few years. In a habitat rich in *T. magnatum* today, Hollós used to collect other species. Moreover, Szemere collected plenty of hypogeous fungi in this county, too. All these facts may confirm the assumption that the distribution boundary of *T. magnatum* is shifting northwards as climate becomes warmer (Bratek 2008). However, its advance is limited as the majority of riverine oak-elm-ash woodlands were cut and disappeared in the last century.

During the above mentioned revision of *Hymenogaster*, two species new to the region: *H. megasporus* Soehner and *H. pruinatus* Hesse, and two species new to science: *H. intermedius* Stielow et al. 2010 and *H. huthii* Stielow et al. 2010 were also found (Stielow et al. 2011).

Stielow et al (2010) came across *Hydnotria michaelis* (Fischer) Trappe, a species new to the region in Sklene, Slovakia. Glejdura (2011) recorded *Stephanospora caroticolor*, also new to the region in the Lesser Fatra (Malá Fatra), part of the northwestern Carpathians. Montecchi et Sarasini (2000) reported on *Pachyphloeus prieguensis* Moreno-Arroyo, Gomez and Calonge, also new to the region, in the vicinity of Budapest. Similarly, specimens of the species *Rhizopogon villosus* Zeller turned up in an arboretum near Budapest (Bratek 2006), which had probably got there together with plant specimens from America.

The Red List compiled by Rimóczi et al. (1999), which assigns nature conservation values to macrofungi, contains most of the hypogeous fungi in Hungary. According to this Red List *Leucogaster nudus* is critically endangered, while *Gastrosporium simplex* and *Picoa carthusiana* are endangered. Our latest data confirm the validity of this categorization. Of the native hypogeous fungi only six black-peridium *Elaphomyces* species have so far received protection owing to their rarity (Siller et al. 2005). *E. pyriformis* Vittad. with also black peridium has not been found since Hollós (1911) and is supposed to have vanished from the funga of the region.

Species with highly changed frequency of occurrence. Table 1 contains a number of species whose frequency of collection has increased significantly or even by orders of magnitude. Based on their pronounced, strong odour, it is fair to assume that the widespread of collecting with dogs is responsible for an increase in their frequency of collection. Hence, we propose naming these species truffle dog preferred hypogeous fungi (DPH).

The number of fungarium data increased mostly for *T. brumale*, whose excellent odour places it among DPH species. Molecular studies have revealed genetic heterogeneity in the winter truffles of the region, confirming the hypothesis that *T. brumale* is not an invasive species in this biogeographical region, but has long been part of the hypogeous funga (Merényi et al. 2012). The same stands for *Tuber mesentericum*, whose genetic diversity has also been proved in the region (Sica et al. 2007). *Tuber macrosporum* also belongs here, as its rich localities have given the species commercial importance. We consider *Tuber aestivum* a DPH, too, since the number of its known localities has increased by more than one order of magnitude. The great majority of marketed *T. aestivum* originate from the high productivity woodlands of the Jászság region, thus making Hungary the most significant exporter of the species.

As of 2013, trufflers are obliged to keep records of the quantity of collected truffles in their collection notebook according to Hungarian legal regulations, which enables forestry authorities to follow any changes in the amount of collected *T. aestivum*. An opposing trend, a significant drop of records occurs for *Choiromyces meandriformis*. Earlier, the species was common in local market places (Hollós 1911), but has become rather unpopular in the European cuisine. At the same time, *Mattirolomyces terfezioides* has the potential to become a rising star in truffle gastronomy thanks to its prominent sweet taste. Besides a few records in other regions (Kovács 2009), its richest habitats are found in the Pannonicum, in black locust plantations growing on sand deposited by the Danube (Gógán et al. 2008).

Stephensia bombycina and *Octaviania asterosperma* are also DPH species that were classified as endangered due to the scarcity of data (Rimóczi et al. 1999), but are not considered as rare anymore.

In the above three chapters of the Discussion, we presented species whose frequency of occurrence could be estimated from collection data. However, the unearthing of the hypogeous fungi of the Carpathian-Pannonian region is far from being finished, as some regions/landscapes have only slightly or not at all been studied. Moreover, the mapping of surveyed species did not follow the most adequate method in all cases. The frequency estimation of DPH species appears to be the most reliable/straightforward. The adequacy of mapping methodology has outstanding importance in the case of other species. A further obstacle to the evaluation of hypogeous funga is the uncertainty of species boundaries in several genera, where intensive molecular taxonomic work is needed or is in progress. The relevance of such research lies in the fact that ecological studies and conservation assessments can only operate with stable species concepts. All the above results have the potential to further clarify and harmonize our understanding of the funga of the Carpathian-Pannonian region and its changes.

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