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RESEARCH ARTICLE

New for Azerbaijan records of agaricoid fungi collected in Shaki District

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Abstract. The article provides information about new for Azerbaijan records of agaricoid fungi collected during the field trips in 2016–2019. In particular, 18 taxa (*Agaricus porphyrizon*, *Amanita strobiliformis*, *Aureoboletus gentilis*, *A. moravicus*, *Clavulina cinerea*, *C. coralloides*, *Clitocybe martiorum*, *Lactarius acerrimus*, *L. evosmus*, *L. mairei*, *Ramaria formosa*, *Russula aurora*, *R. heterophylla* f. *adusta*, *R. melitodes*, *R. melliolens*, *R. velenovskyi*, *Scleroderma areolatum*, *Tricholoma columbetta*, *T. fracticum*) belonging to ten genera, eight families, and five orders are reported. The data on the distribution patterns and habitats for each taxon are provided. The recorded mushrooms belong to two ecological groups: humus saprotrophs are represented by three species (*Agaricus porphyrizon*, *Clavulina coralloides*, and *Clitocybe martiorum*) while the remaining 14 species and one form are mycorrhizal. Data on conservation status in the European countries for *Amanita strobiliformis*, as well as for representatives of the genera *Aureoboletus, Russula*, *Tricholoma*, and *Lactarius*, are provided.

Keywords: Agaricomycetes, agaricoid fungi, diversity, ecological groups, Greater Caucasus, mycorrhiza, rare species, taxa

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Introduction

The Caucasus is one of the botanically diverse regions representing one of the twenty-six "biodiversity hotspot" areas worldwide (Ali-zade, Shulkina, 2018). The area has rich flora and fauna; its conditions are favorable for agaricoid fungi as well. The mushroom diversity of the Greater Caucasus within Azerbaijan has been studied mainly in the second half of the 20th century. Initial information regarding edible species, such as *Morchella esculenta* (L.) Pers., *Fomitopsis officinalis* (Vill.) Bondartsev & Singer, *Tuber magnatum* Picco, *T. melanosporum* Vittad. along with a few lichens belonging to the genera *Lecanora* Ach., *Roccella* DC., and *Usnea* Dill. ex Adans. dates back to the medieval manuscripts written by physicians of those times (Alakbarli, 2006). Few fungal specimens were collected and reported by foreign botanists such as Voronov in 1922–1923, Kolenati in 1858, Gelesnov in 1869, etc. (Aghayeva, 2018). Until the 1960s, data on species diversity of macrofungi in the country was based on randomly collected specimens. In 1960–2010, Sadigov made a significant contribution in fungal diversity studies in Azerbaijan (Opredelitel..., 1985; Sadigov, 2007; Qambarov et al., 2012). As a result, 130 edible and 9 poisonous species were recorded across the country (Sadigov, 2007). Currently, 827 agaricoid fungi species belonging to 210 genera are known in Azerbaijan, based on herbarium materials kept at the Mycological herbarium (BAK) of the Institute of Botany, ANAS (Aghayeva, 2018).

The diversity of Agaricomycetes in the area along the Greater Caucasus in Azerbaijan has been studied more extensively during the last seven years; thus, over 140 taxa of fungi have been recorded, with 30 taxa reported

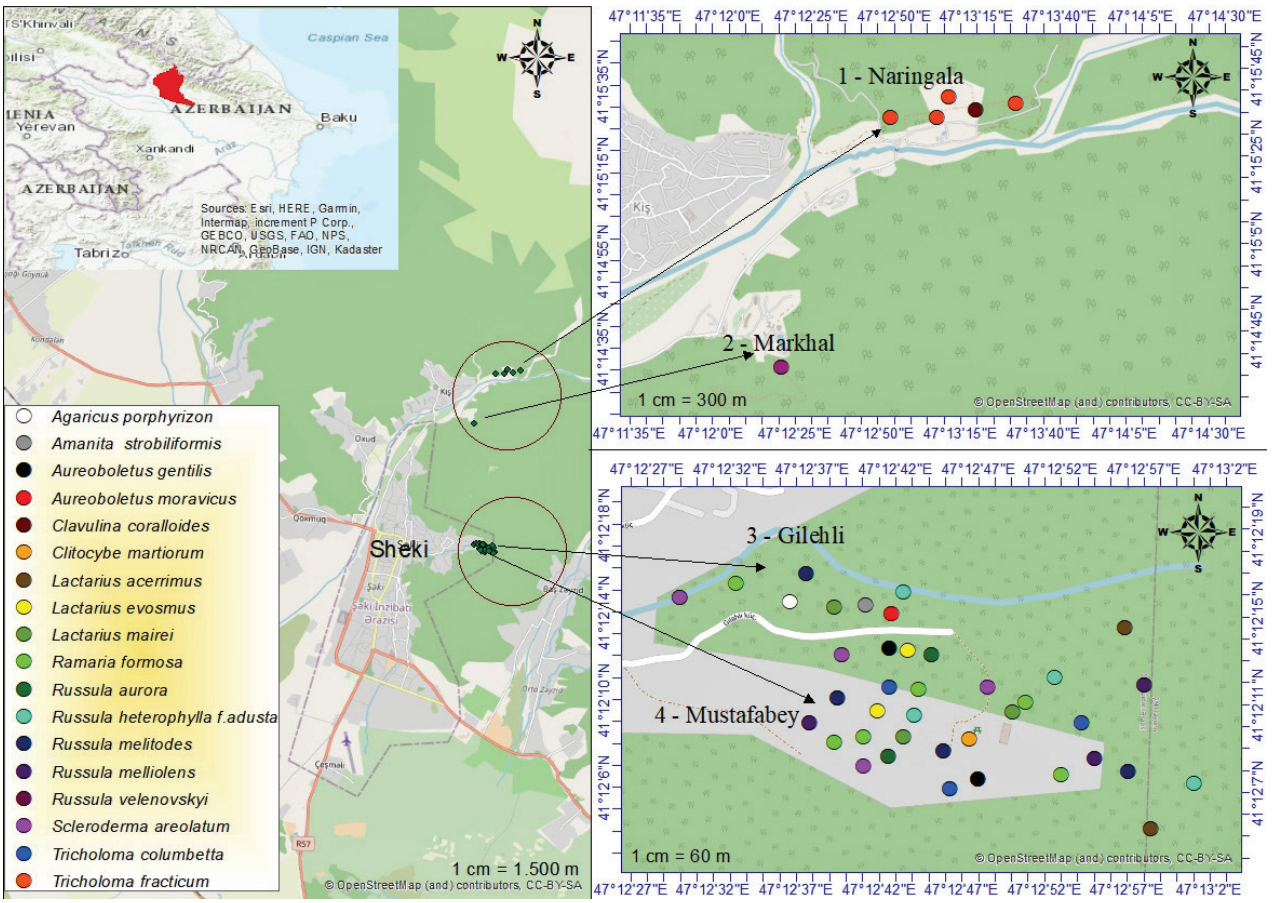

Fig. 1. Schematic map of the collection sites: 1 – Naringala pine forest; 2 – Markhal resort complex; 3 – Gilehli hazelnut forest; 4 – Mustafabey oak-beech, chestnut-beech forest. Species names of the fungi are indicated in the map

as new for the territory of the country (Mustafabayli, Aghayeva, 2019a, b; Mustafabayli, 2020; Mustafabayli et al., 2020a, b). Few edible species were also observed during the study of macromycetes of the southern part of the Greater Caucasus (Aghayeva, Sadigov, 2008; Mustafabayli, Aghayeva, 2019a, b). In recent years, interest in edible mushrooms in the country continues to grow; at the same time, the number of cases of mushroom poisonings increased and even mortality incidences in the northern regions were registered.

In this article, we report 18 new for Azerbaijan fungi taxa (17 species and one form); their distribution patterns, ecological features, and occurrence are also discussed.

Materials and methods

The territory of the Shaki District of Azerbaijan can be divided into three climatic zones (subtropical, temperate, and semi-arid) (Climate…, 2017). Soils and climate are favorable for the growth of a wide range of macromycetes. During 2016–2019, more than 65 field expeditions were conducted and sampling was performed based on route methods on the territory of Shaki District; as a result, more than 250 specimens were collected and identified. The main study sites were the following four areas: Naringala pine forest (N 41º15'32.60"; E 47º13'5.60", 1100 ± 50–70 m a.s.l.); along the Gilehli, hazelnut forest (N 41º12'14.29", E 47º12'40.01", 835–860 m a.s.l.); Markhal resort complex (N 41º14'34.85"; E 47º11'57.38", 960–1000 m a.s.l.) and Mustafabey oak-beech, chestnut-beech forest (N 41º12'09.06", E 47º12'52.03", 820–930 m a.s.l.). Schematic maps of the study sites were prepared using a GPS device, as well as Google Earth and ArcGIS 10.6 software (Fig. 1). In the study, the reference coordinate system WGS 1984 UTM 39N is used.

Photographs of fungal specimens were taken during field excursions; some peculiarities of carpophores (shape

and colour of stipe and cap, character of their surface, etc.) were also observed in the field using a magnifying glass. Such features as taste, odor and discoloration of mushroom flesh, as well as colour of spore print were recorded in the laboratory. Microscopic details of carpophore structure, in particular peculiarities of spores, basidia, hymenial cystidia, and dermatocystidia (their size, shape, colour, etc.) were observed using a Nikon microscope (Eclipse E100 Tokyo, Japan). Mushroom taxa were identified using several monographs and other special literature (Pilát, 1969; Dermek, Pilát, 1974; Zerova et al., 1979; Wasser, 1980; Opredelitel…, 1985; Arora, 1986; Dudka, Wasser, 1987; Breitenbach, Kränzlin, 1995; Bondartseva, 1998; Grunert, Grunert, 2002; Muñoz, 2005; Funga Nodrica, 2012; Climate…, 2017; Prance, Fechner, 2017; Kamel et al., 2017; Ali-zade, Shulkina, 2018; Heluta et al., 2019). For microscope slides, distilled water and Congo red solution were used. All specimens are deposited in the Mycological herbarium of the Institute of Botany of ANAS (BAK). Nomenclature and taxonomy correspond to *Index Fungorum* (http://www.indexfungorum.org/).

Results and discussion

In total, 17 species and one form belonging to 10 genera (one species of *Incertae sedis*), seven families and five orders of the Agaricomycetes are reported. Information on the taxa, including species names, localities and collection dates as well as BAK numbers of the specimens, is provided below.

BASIDIOMYCOTA

Agaricomycetes

Agaricales

Incertae sedis

Clitocybe martiorum J.Favre (Fig. 2, A)

Mustafabey oak-beech, chestnut-beech forest, solitary to scattered in forest, 05.10.2019 (BAK1681). Only three specimens of the species were found in the study area.

Agaricaceae

Agaricus porphyrizon P.D.Orton (Fig. 2, B)

Along the Gilehli, hazelnut forest, 06.10.2016 (BAK1672). The species was found several times as scattered or in small groups.

Amanitaceae

Amanita strobiliformis (Paulet ex Vittad.) Bertill. (Fig. 2, C)

Along the Gilehli, hazelnut forest, solitary under the *Corylus avellana* L., 11.06.2020 (BAK1716). In the Transcaucasian region the species has also been reported from Georgia and Armenia (Opredelitel…, 1985). It was recorded only twice in the study area.

Tricholomataceae

Tricholoma columbetta (Fr.) P.Kumm. (Fig. 2, D)

Mustafabey oak-beech, chestnut-beech forest, under *Carpinus betulus* L., *Fagus sylvatica* L., *Quercus iberica* M.Bieb., 18.11.2016 (BAK1691). The species was found several times as scattered or in small groups. In the Transcaucasian region the species has been reported from Armenia (Opredelitel…, 1985).

T. fracticum (Britzelm.) Kreisel. (Fig. 2, E)

Naringala pine forest, under *Pinus sylvestris* L., on forest soil, 18.11.2016 (BAK1691). This species forms large rings/groups of fruit bodies.

Boletales

Boletaceae

Aureoboletus gentilis (Quél.) Pouzar (Fig. 2, F)

Mustafabey oak-beech, chestnut-beech forest, solitary under *Quercus iberica*, 21.07.2017, 05.08.2019 (BAK1689). It was recorded only twice in the study area.

A. moravicus (Vaček) Klofac (Fig. 2, G)

Along the Gilehli, hazelnut forest, solitary under *Carpinus betulus* and *Corylus avellana*, 25.08.2018 (BAK1696). Only two specimens of the species were found.

Sclerodermataceae

Scleroderma areolatum Ehrenb. (Fig. 2, H)

Along the Gilehli, hazelnut forest, solitary or more often scattered, under *Carpinus betulus*, *Fagus sylvatica*, 05.10.2019 (BAK1678).

Cantharellales

Hydnaceae

Clavulina coralloides (L.) J.Schröt. (Fig. 2, I)

Naringala pine forest, in *Pinus sylvestris*, on soil, solitary, 06.10.2016 (BAK1676). A single specimen of the species was found.

Fig. 2. New records of fungi for Azerbaijan. A: *Clitocybe martiorum*; B: *Agaricus porphyrizon*, C: *Amanita strobiliformis*; D: *Tricholoma columbetta*; E: *T. fracticum*; F: *Aureoboletus gentilis*; G: *A. moravicus*; H: *Scleroderma areolatum*; I: *Clavulina coralloides*; J: *Ramaria formosa*; K: *Lactarius acerrimus*; L: *L. evosmus*; M: *L. mairei*; N: *Russula aurora*; O: *R. heterophylla* f. *adusta*; P: *R. melitodes*; Q: *R. melliolens*; R: *R. velenovskyi*

Gomphales

Gomphaceae

Ramaria formosa (Pers.) Quél. (Fig. 2, J)

Mustafabey oak-beech, chestnut-beech forest, solitary or in small groups, 10.05.2019 (BAK1690).

Russulales

Russulaceae

Lactarius acerrimus Britzelm. (Fig. 2, K)

Mustafabey oak-beech, chestnut-beech forest, in a small group, under *Fagus sylvatica* and *Quercus iberica*, 18.08.2018 (BAK1671). The species was found only once.

L. evosmus Hühner & Romang. (Fig. 2, L)

Mustafabey oak-beech, chestnut-beech forest, solitary or in small groups, under *Quercus iberica* and *Carpinus betulus*, 18.08.2018 (BAK1674).

L. mairei Malençon (Fig. 2, M)

Mustafabey oak-beech, chestnut-beech forest, under *Fagus sylvatica* and *Quercus iberica*, 03.07.2017 (BAK1682). The species was found once in a small group.

Russula aurora Krombh (Fig. 2, N)

Mustafabey oak-beech, chestnut-beech forest, under *Fagus sylvatica* and *Quercus iberica*, 03.07.2017 (BAK1687). The species was recorded several times, scattered or in small groups.

R. heterophylla* f. *adusta J.E.Lange (Fig. 2, O)

Mustafabey oak-beech, chestnut-beech forest, under *Fagus sylvatica*, *Quercus iberica*, 18.08.2018 (BAK1684). The species was recorded several times, scattered or in small groups.

R. melitodes Romagn. (Fig. 2, P)

Mustafabey oak-beech, chestnut-beech forest, under *Carpinus betulus*, *Corylus avellana* and *Quercus iberica*, 25.08.2018 (BAK1680). The species was recorded several times, scattered or in small groups.

R. melliolens Quél. (Fig. 2, Q)

Mustafabey oak-beech, chestnut-beech forest, under *Carpinus betulus*, *Corylus avellana*, *Fagus sylvatica* and *Quercus iberica*, 15.07.2018 (BAK1675). The species was recorded several times, scattered or in small groups.

R. velenovskyi Melzer & Zvára (Fig. 2, R)

Markhal resort complex, Mustafabey oak-beech, chestnut-beech forest, solitary, under *Betula pendula* Roth, *Quercus iberica*, 03.07.2017 (BAK1670). Two specimens were found only once.

Based on our observations, the collected fungi belong to two ecological groups, humus saprotrophs and mycorrhizal fungi. The former group includes three species (*Agaricus porphyrizon*, *Clavulina coralloides*, *Clitocybe martiorum*), the latter one comprises 15 species (one represented by the form), namely *Amanita strobiliformis*, *Aureoboletus gentilis*, *A. moravicus*, *Lactarius acerrimus*, *L. evosmus*, *L. mairei*, *Ramaria formosa*, *Russula aurora*, *R. heterophylla* f. *adusta*, *R. melitodes*, *R. melliolens*, *R. velenovskyi*, *Scleroderma areolatum, Tricholoma columbetta*, and *T. fracticum*.

Through a search of the available publications, it was found that 12 of the reported here species are included in the Red Lists/Red Data Books of various European countries under several conservation categories. In particular, *Amanita strobiliformis*, *Aureoboletus gentilis*, and *A. moravicus* are listed in the *Red List of fungi in Bulgaria* as Endangered (EN) species (Gyosheva et al., 2006). *Lactarius acerrimus* and *Tricholoma fracticum* are included in the *Red Data Book of Lithuania* as Vulnerable (VU) species (Lajiene et al., 2007). *Tricholoma columbetta* is listed as a Vulnerable species in the *Red Data Book of Russia*, while *Amanita strobiliformis* is included there as a rare species with a narrow ecological confinement, given its occurrence only on calcareous soils (Krasnaya Kniga..., 2008). A number of species are included in the *Red List of mushrooms of Bavaria* (*Aureoboletus gentilis*, *Lactarius mairei*, *Russula aurora,* and *R. melliolens* as Endangered (EN), *Russula melitodes* as Critically Endangered (CR), *A. moravicus* as rare (R), *Lactarius acerrimus* and *Russula velenovskyi* as Vulnerable (VU), and *R. heterophylla* f. *adusta* as Near Threatened (NT) species) (Rote Liste..., 2010). Two of the reported species, *Aureoboletus gentilis* and *A. moravicus*, are listed in the *Red List of Fungi for Great Britain* as Near Threatened (NT) and Vulnerable (VU), respectively (Ainsworth et al., 2013). In the second edition of the *Red Data Book of the Azerbaijan Republic* (Red Data Book…, 2013), only 14 species of fungi are listed. We propose to include in the next edition of the national *Red Data Book* the following species: *Amanita strobiliformis*, *Aureoboletus gentilis*, *A. moravicus*, *Lactarius acerrimus*, *L. mairei*, *Russula aurora, R. melliolens*, *R. melitodes, R. velenovskyi, Tricholoma columbetta*, and *T. fracticum*.

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Реферат. Стаття містить інформацію про нові для Азербайджану види (а також одну форму) грибів, зібрані протягом польових виїздів, проведених у 2016–2019 рр. Зокрема були виявлені 18 таксонів (*Agaricus porphyrizon*, *Amanita strobiliformis*, *Aureoboletus gentilis*, *A. moravicus*, *Clavulina cinerea*, *C. coralloides*, *Clitocybe martiorum*, *Lactarius acerrimus*, *L. evosmus*, *L. mairei*, *Ramaria formosa*, *Russula aurora*, *R. heterophylla* f. *adusta*, *R. melitodes*, *R. melliolens*, *R. velenovskyi*, *Scleroderma areolatum*, *Tricholoma columbetta* та *T. fracticum*), які належать до десяти родів, восьми родин та шести порядків. Наведені дані про особливості їхнього поширення в регіоні досліджень та охарактеризовані місцезнаходження. Вказані гриби належать до двох екологічних груп, одна з яких (гумусові сапротрофи) представлена лише трьома видами (*Agaricus porphyrizon*, *Clavulina coralloides* і *Clitocybe martiorum*). Інші 14 є мікоризоутворювачами. Надано інформацію про природоохоронний статус у європейських країнах *Amanita strobiliformis*, а також представників родів *Aureoboletus*, *Russula*, *Tricholoma* та *Lactarius*.

Ключові слова: агарикоїдні гриби, Великий Кавказ, екологічні групи, мікориза, рідкісні види, різноманітність, таксони, Agaricomycetes