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Contribution to study of the pyrophilous fungi of Ukraine

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ABSTRACT:
The paper reports data on pyrophilous ascomycetes collected in 2017-2019 during a mycological survey in the Holosiivskyi National Nature Park (Kyiv, Ukraine). Sixteen species belonging to the Pezizomycetes were found. Among them, *Tricharina praecox* and *Octospora similis* were collected in Ukraine for the first time. Substrates, localities, data on general distribution and some notes about these species are presented. Ecological peculiarities of all species are briefly discussed.

Keywords:
biodiversity, distribution, Holosiivskyi National Nature Park, new records, Pezizales, post-fire fungi

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INTRODUCTION

Pyrophilous fungi are an ecologically interesting, highly specialised group of organisms that occur in areas heated by fire and steam or on fresh volcanic ejecta mixed with organic material. The adjective 'pyrophilous' was applied by Seaver (1909) and has mainly been used by certain authors (El-Abyad & Webster 1968; Kirk *et al.* 2008). The same group of fungi are also referred to as anthracophilous fungi (Moser 1949), fireplace fungi (Petersen 1970), carbonicolous fungi (Wicklow 1975), phoenicoid fungi (Carpenter & Trappe 1985) or post-fire fungi (Claridge *et al.* 2009). The group includes saprotrophic, mycorrhizal and parasitic (root-pathogenic) fungi. Among them are species which occur exclusively on burnt ground, as well as ones that may also occur on disturbed unburnt substrates (Petersen 1970; Dougoud 2001). High temperature stimulates germination of the spores of a number of terrestrial fungi fruiting on charcoal, ash, heated soil or partially burned organic debris, in addition to various dung fungi whose spores are lying dormant in the soil (Dix & Webster 1995). Most pyrophilous fungi belong to the Ascomycota, primarily operculate discomycetes, which dominate forest bonfire sites, but Basidiomycota (mostly agarics) and Mucoromycota are also represented in such places (Claridge *et al.* 2009).

Growth and fruiting of fungi in post-fire areas are affected by various factors. These include response to environmental changes, resistance to chemical changes in the soil following burning and adaptation to physico-chemical properties of post-fire habitats such as high temperatures and pH values, low water retention capacity of burnt substrates, etc.(Petersen 1970; Dix & Webster 1995; Claridge *et al.* 2009). Restriction of this group of fungi to burnt ground can also be explained by their inability to compete with other microorganisms on non-burnt substrates.

The role of pyrophilous fungi in the regeneration of surfaces destroyed by fires and their ability to form

new mycorrhizal relationships with trees soon after the fire have attracted attention of mycologists around the world (Egger & Paden 1986; Vrålstad *et al.* 1998; Dahlberg 2002; Mcmullan-Fisher *et al.* 2011; Raudabaugh *et al.* 2020), including specialists in Ukraine. However, post-fire fungi are usually mentioned only in general lists of fungi of selected regions in Ukraine, with some exceptions (Scherbakova & Dzhagan 2013).

The present article provides data on pyrophilous discomycetes that were collected in 2017–2019 during our mycological survey in the Holosiivskyi National Nature Park, Ukraine. Although the species diversity of ascomycetes from this territory was investigated recently (Zykova & Dzhagan 2011), only seven species of pyrophilous ascomycetes were reported and this does not fully reflect the species richness of carbonicolous discomycetes in the reserved park area.

Holosiivskyi National Nature Park is the only one in Ukraine, and it is one of several national parks in the world located within megacities (Fig. 1). The park is a protected remnant of forest surrounded by the urban area of the city of Kyiv. Its total area is 10.988,14 hectares, of which 1.888,18 hectares are in permanent use. The park area belongs to the forest-steppe zone, with its main area covered by forest (more than 90% of the park´s territory). The northern part of the park includes tracts with predominance of deciduous forests containing numerous age-old oaks, and the southern part of the park is a sandy outcrop of the Dnieper covered with pine forests (http://nppg.gov.ua).

A variety of landscapes, significant biodiversity, the presence of lakes and wetlands and the fact that it contains a number of historical, cultural and ethnographic monuments make the park's area highly important for scientific research, ecosystem monitoring and conservation.

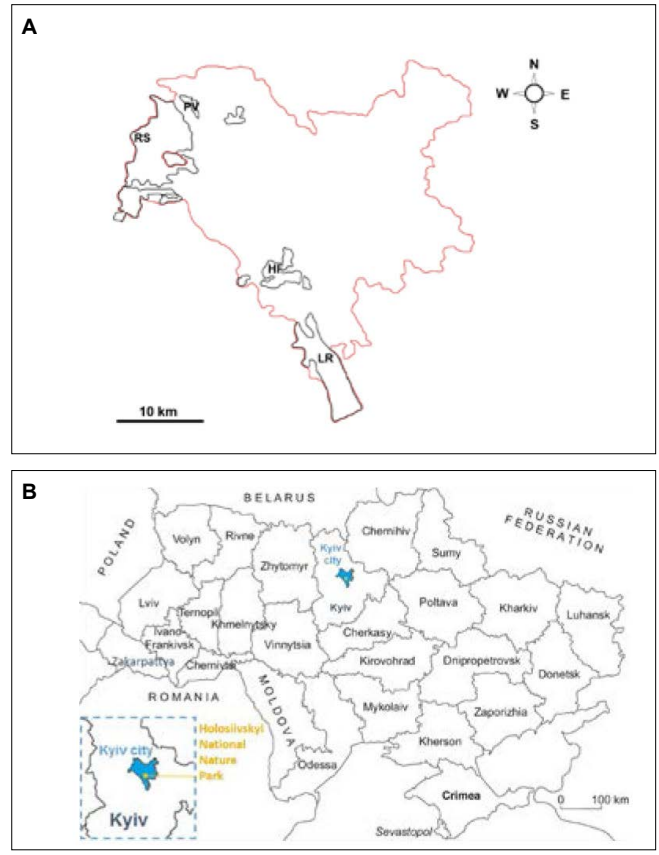

Fig. 1. (a) Location of main protected areas of the Holosiivskyi National Nature Park (HF -Holosiiv Forest; LR – Lisnyky Reserve; PV – Pushcha-Vodytsia; RS – Romaniv swamp). Red line – borders of the city of Kyiv, black line – borders of the Holosiivskyi National Nature Park; (b) Location of the Holosiivskyi National Nature Park within territory of the city of Kyiv (inset) and Ukraine.

MATERIALS AND METHODS

Samples were collected in the Holosiivskyi National Nature Park (Ukraine) between autumn of 2017 and summer of 2019. Four protected areas were included in this survey: Holosiiv Forest – the central part of the park, which is the part most anthropogenically affected, the Pushcha-Vodytsia landscape reserve, the Romaniv swamp and the Lisnyky Reserve (Fig. 1).

Sites of past fires with various burn intensities were examined. Specimens from burnt sites were collected with substrate, dehydrated and deposited in the herbarium of the Taras Shevchenko National University of Kyiv (KWU).

Macro- and microstructures were observed in fresh material. Notes on morphological and ecological characteristics of the fruit bodies were made before collection. Macrophotographs were taken with Sony Cyber-shot DSC-H3 8.1 MP and Canon PowerShot SX40 HS 12.1 MP digital cameras. Identification of species was performed using an MBS-10 stereomicroscope (JSC "LZOS", Russia), an XY-B2T light microscope (Ulab, China) and a Zeiss Primo Star light microscope (Carl Zeiss, Germany). Hand-made sections of fruit bodies were studied in tap water, 3% KOH, Melzer's reagent (MLZ), Congo Red (CR) and Lactophenol Cotton Blue (LPCB).

Dimensions of fungus structures were measured using AxioVision Rel. 4.8 (Carl Zeiss Imaging Solutions, Germany). Around 50 ascospores and other microstructures (asci, paraphyses, excipular cells, hairs) were measured. The quotient of spore length and width (Q), as well as the average quotient (Q_{av}), were calculated.

Digital microphotographs were made with a Canon PC 1089 Power shot G6 digital camera.

Species were identified using various synoptic keys, monographs and other relevant literature (Breitenbach & Kränzlin 1984; Schumacher 1990; Ellis & Ellis 1998; Hansen & Knudsen 2000; Dougoud 2001).

Fig. 2. Discomycetes from post-fire sites in the Holosiivskyi National Nature Park. A – *Anthracobia maurilabra*; B – *Ascobolus carbonarius*; C – *Humaria hemisphaerica*; D – *Iodophanus carneus*; E – *Peziza echinospora*; F – *Peziza tenacella*; G – *Plicaria endocarpoides*; H – *Pseudombrophila merdaria*; I – *Pyronema domesticum*; J – *Rhizina undulata*; K – *Scutellinia crinita*; L – *Sphaerosporella brunnea*; M – *Tarzetta cupularis*; N – *Trichophaea hemisphaerioides*. Scales: A, B, D, H, I, K, L = 5 mm; C, E, F, G, J, M, N = 1 cm. Photos: Yu. Shcherbakova & A. Atamanchuk.

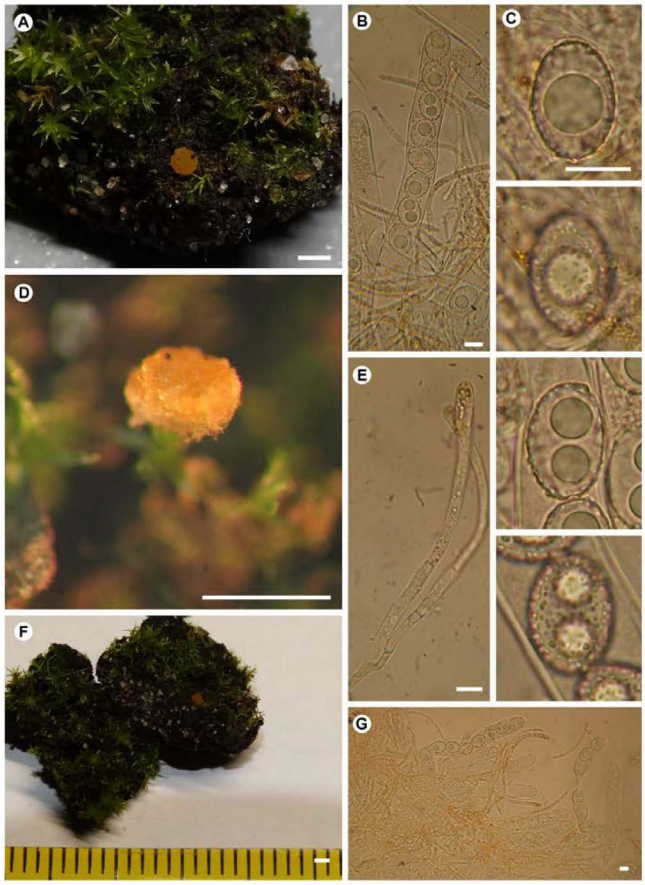

Fig. 3. *Octospora similis*. A, D, F – ascomata attached to moss on substrate; B – mature ascus with eight ascospores (H_2O); C – ascospores (H_2O); E – paraphyses (H_2O); G – asci and paraphyses (H_2O). Scales: A, D, F – 1 mm; B, C, E, G = 10 μm. Photos: Yu. Shcherbakova & A. Atamanchuk.

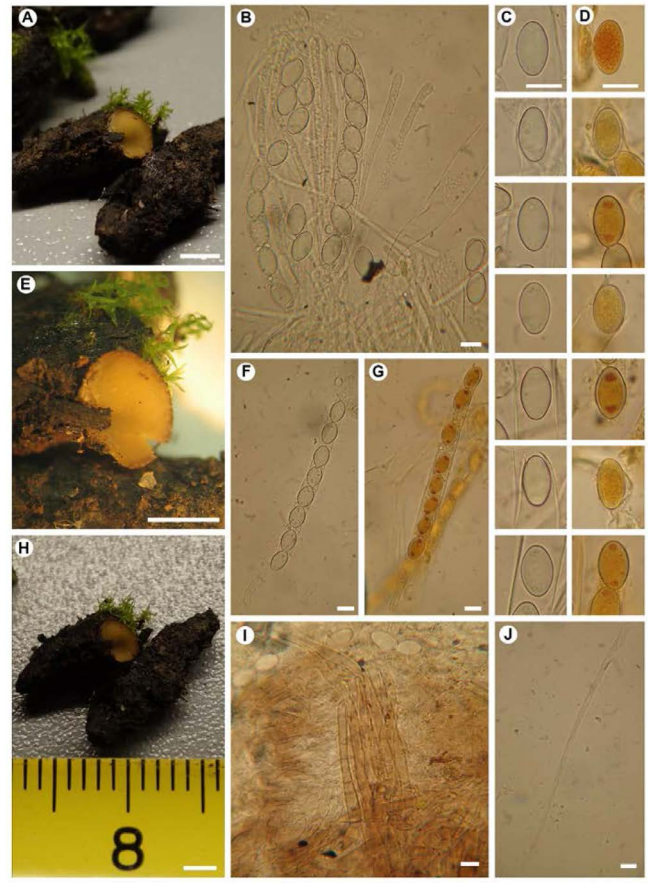

Fig. 4. *Tricharina praecox*. A, E, H – ascomata on substrate; B – mature asci with ascospores and paraphyses (H_2O); C – ascospores (H_2O); D – ascospores (MLZ); F – mature ascus with ascospores (H_2O); G – mature ascus with ascospores (MLZ); I – hairs (H_2O); J – paraphysis (H_2O). Scales: A, E, H = 2 mm; B, C, D, F, G, I, J = 10 μm. Photos: Yu. Shcherbakova & A. Atamanchuk.

Analysis of the general distribution of species is based on data from published sources (Breitenbach & Kränzlin 1984; Barseghyan & Wasser 2013; Beug *et al.* 2014) and on critically revised open Internet resources (GBIF 2020). The taxonomic position of species is presented according to Wijayawardene *et al.* (2018). The floristic novelty of species records for the Holosiivskyi National Nature Park and for Ukraine was established in accordance with previously published papers (Smitska 1980; Minter & Dudka 1996; Dudka *et al.* 2009, 2019; Zykova & Dzhagan 2011; Scherbakova & Dzhagan 2013).

RESULTS

During the conducted mycological survey, sixteen species of pyrophilous discomycetes were identified from post-fire sites in the Holosiivskyi National Nature Park (Fig. 2). Eleven of the species were not previously reported for this park. *Tricharina praecox* (P. Karst.) Dennis and *Octospora similis* (Kirschst.) Benkert were found in Ukraine for the first time. Brief descriptions of these two species are given below. Digital illustrations of their macro- and microstructures are presented in Figs. 3-4.

An annotated list of the collected species with citations in published lists, bibliographies, localities and some notes is provided below. The taxa are listed in alphabetical order together with their brief descriptions, habitats, localities, collection dates, herbarium numbers, general distribution in Ukraine and worldwide, notes on their morphological characters and ecological peculiarities. Species not previously recorded for the Holosiivskyi National Nature Park are marked with an asterisk (*), ones new for Ukraine with two asterisks (**).

Anthracobia maurilabra (Cooke) Boud. (Pyronemataceae), Histoire et Classification des Discomycètes d'Europe: 65. 1907. (Fig. 2A)

Specimen data: Holosiiv Forest, near the Expocenter of Ukraine, N 50.373539°, E 30.486122°, 20 May 2019, leg./det. A. Atamanchuk, (KWU210519/2), on burnt soil of a former bonfire 120 cm in diameter.
Distribution in Ukraine. Kyiv, Ternopil, Volyn and Zakarpattya Regions (Smitska 1980; Minter & Dudka 1996; Scherbakova & Dzhagan 2013; Dudka *et al.* 2019).
General distribution. Australia, Europe, North America (Hansen & Knudsen 2000; GBIF 2020).
Notes. The species is quite rare in Ukraine, previously known only from its western part. *Anthracobia maurilabra* is among species that occur exclusively on burnt sites as early as 7 weeks after burning, but which do not fruit later than 80 weeks after burning (Dix & Webster 1995; Dougoud 2001). Species of *Anthrocobia* are presumed saprotrophs that may act as important post-fire soil stabilisers. According to Claridge *et al.* (2009), after fire masses of *Anthracobia* spp. fruit-bodies associated with thick mats of white mycelium on and within the soil at such microsites and accompanying algae and bryophytes perform a key role in helping bind the soil in the absence or near absence of plant rootlets, humus and leaf litter. Thus, mycelium of *Anthracobia* near or at the soil surface may play a role in stabilising soil. A recent study suggested that *Anthrocobia* species can form associations with lichens and be an endophyte of mosses (Raudabaugh *et al*. 2020). *Anthracobia maurilabra* is considered as conspecific with *A. melaloma* by some taxonomists (Yao & Spooner 1995). However, we prefer to use the name *A. maurilabra* for this taxon, which differs from *A. melaloma* in having larger ascospores (19-22 × 9-11 µm) and an almost black colour of the dried apothecia. These species are also treated as separate taxa in the Index Fungorum online database (http://www.indexfungorum.org/).

Ascobolus carbonarius P. Karst. (Ascobolaceae), Notiser ur Sällskapets pro Fauna et Flora Fennica Förhandlingar 11: 202. 1870. (Fig. 2B)
Specimen data: 1) Pushcha-Vodytsia, N 50.538613°, E 30.405191°, 21 October 2017, leg. Yu. Shcherbakova, det. A. Atamanchuk, (KWU211017/20), on burnt soil of a former bonfire 286 cm in diameter; 2) Pushcha-Vodytsia, N 50.538906°, E 30.402979°, 21 October 2017, leg./det. Yu. Shcherbakova, (KWU211017/25), on burnt soil of a former bonfire 206 cm in diameter; 3) Pushcha-Vodytsia, N 50.538769°, E 30.405516°, 21 October 2017, leg./det. Yu. Shcherbakova, (KWU211017/27), on burnt soil of a former bonfire 276 cm in diameter; 4) Holosiiv Forest, near the Expocenter of Ukraine, N 50.372482°, E 30.492098°, 29 May 2018, leg./det. A. Atamanchuk, (KWU290518/4), on burnt soil of a former bonfire 160 cm in diameter.
Distribution in Ukraine. Zakarpattya and Kyiv Regions (Smitska 1980; Minter & Dudka 1996; Scherbakova & Dzhagan 2013, Dudka *et al.* 2019).
General distribution. Worldwide (Dix & Webster 1995; Hansen & Knudsen 2000; Dougoud 2001; GBIF 2020).
Notes. In contrast to most species of the genus *Ascobolus*, which are coprophilous, *A. carbonarius* is known to occur exclusively on burned ground and wood, and is a cosmopolitan post-fire ascomycete (Lisiewska 1992; Dix & Webster 1995; Dougoud 2001). The thickened irregularly warted episporium ornamentation at the poles of the spores separates it well from all other species.

Humaria hemisphaerica (F.H. Wigg.) Fuckel (Pyronemataceae), Jahrbücher des Nassauischen Vereins für Naturkunde 23–24: 322. 1870. (Fig. 2C)
Specimen data: Romaniv swamp, N 50.504352°, E 30.271175°, 4 October 2017, leg./det. A. Atamanchuk, (KWU041017/15), on burned wood.
Distribution in Ukraine. Cherkasy, Chernihiv, Chernivtsi, Ivano-Frankivsk, Kharkiv, Kherson, Khmelnytskyi, Lviv, Poltava, Rivne, Sumy, Ternopil, Volyn and Zakarpattya Regions (Smitska 1980; Minter & Dudka 1996; Dudka *et al.* 2009, 2019; Zykova & Dzhagan 2011; Yatsiuk 2017).
General distribution. Asia, Europe, North America (GBIF 2020).
Notes. In some literature on the Ukrainian mycobiota, this species is mentioned as *Lachnea hemisphaerica* (F.H. Wigg.) Gillet or *Peziza hemisphaerica* F.H. Wigg. (Smitska 1980; Minter & Dudka 1996). The species is more common in unburnt areas (rich soil, plant debris) and is an optionally pyrophilous form (Dougoud 2001).

Iodophanus carneus (Pers.) Korf (Pezizaceae), American Journal of Botany 54(1): 19. 1967. (Fig. 2D)
Specimen data: Holosiiv Forest, near the Expocenter of Ukraine, N 50.375514°, E 30.481335°, 19 October 2017, leg. Yu. Shcherbakova, det. A. Atamanchuk, (KWU191017/20), on burnt soil of a former bonfire 220 cm in diameter.
Distribution in Ukraine. Zakarpattya, Kyiv, Chernivtsi, Kharkiv, Kherson, Luhansk, Poltava and Sumy Regions (Smitska 1980; Minter & Dudka 1996; Dudka *et al.* 2009, 2019; Zykova & Dzhagan 2011; Scherbakova & Dzhagan 2013).
General distribution. Worldwide (Doveri 2004; Beug *et al*. 2014; GBIF 2020).
Notes. *Iodophanus carneus* is a widespread and one of the most common of coprophilous discomycetes, but in addition to animal excrements, it is also known to occur on decaying vegetable matter, soil, cloth, wet rags and burned ground (Beug *et al*. 2014). It is a rather variable species whose morphological features (colour of apothecia, episporic ornamentation, spore size and shape) are greatly influenced by environmental conditions (Doveri 2004).

***Octospora similis** (Kirschst.) Benkert (Pezizales genera *incertae sedis*), Agarica 14 (no. 23): 51 (1996). (Fig. 3)
Description. *Apothecia* 1 mm in diameter, rounded, orange, attached to moss. *Asci* eight-spored, operculate, non-amyloid, cylindrical, 150–200 × 15–20 µm. *Ascospores* uniseriate, broadly ellipsoid, ornamented with hemispherical warts, with one (seldom two) globose guttule, 14.2–17.8 × 10.2–13.7 µm (Q = 1.18–1.56). *Paraphyses* 3–4 µm in diameter, with a broader apex, straight to slightly bent, septate, branched, containing orange pigment.
Specimen data: Pushcha-Vodytsia, N 50.538906°, E 30.402979°, 21 October 2017(KWU211017/05), leg./det. Yu. Shcherbakova, on soil among *Ceratodon purpureus* and *Pohlia nutans* on a former bonfire 97 cm in diameter.
Distribution in Ukraine. Previously not recorded for Ukraine.
General distribution. Europe, North America, also known from Antarctica (Richter 2011; http://octospora.de/Osimilis.htm).
Notes. Bryoparasitic species, occurs in association with *Bryum, Ceratodon, Pohlia* and other mosses, mainly in damp, sandy soil. *Octospora similis* grows from May to November and is classified as "endangered" in the German Red Book (Richter 2011).

***Peziza echinospora** P. Karst. (Pezizaceae), Notiser ur Sällskapets pro Fauna et Flora Fennica Förhandlingar 10: 115. 1869. (Fig. 2E)
Specimen data: 1) Pushcha-Vodytsia, N 50.538613°, E 30.405191°, 21 October 2017, leg./det. Yu. Shcherbakova, (KWU211017/16), on burnt soil of a former bonfire 286 cm in diameter; 2) Pushcha-Vodytsia, N 50.538769°, E 30.405516°, 21 October 2017, leg. Yu. Shcherbakova, det. V. Dzhagan, (KWU211017/26), on burnt soil of a former bonfire 276 cm in diameter; 3) Holosiiv Forest, near the Expocenter of Ukraine, N 50.372482°, E 30.492098°, 29 May 2018, leg./det. A. Atamanchuk, (KWU290518/1-2), on burnt soil of a former bonfire 160 cm in diameter.
Distribution in Ukraine. Kyiv, Volyn and Zakarpattya Regions (Smitska 1980; Minter & Dudka 1996; Scherbakova & Dzhagan 2013; Dudka *et al.* 2019).
General distribution. Asia, Australia, North and South America; also widespread in Northern, Western, Southeast and Central Europe (Hansen & Knudsen 2000; Barseghyan & Wasser 2013; GBIF 2020).
Notes. Occurs exclusively on burned ground, wood and charcoal in early stages of succession and is one of the largest of pyrophilous discomycetes (Breitenbach & Kränzlin 1984; Dougoud 2001). It takes 10-50 weeks to appear on bonfire sites and persists for 130-200 weeks (Dix & Webster 1995; Hansen & Knudsen 2000).

***Peziza tenacella** W. Phillips (Pezizaceae), Grevillea 15(76): 100. 1886. (Fig. 2F)
Specimen data: Pushcha-Vodytsia, N 50.538906°, E 30.402979°, 21 October 2017, leg./det. Yu. Shcherbakova, (KWU211017/17), on burnt soil of a former bonfire 206 cm in diameter.
Distribution in Ukraine. Zhytomyr, Kyiv and Poltava Regions (Smitska 1980; Minter & Dudka 1996).
General distribution. Asia, Australia, Europe, Tasmania (Barseghyan & Wasser 2013; GBIF 2020).
Notes. Occurs exclusively on burned ground, among mosses, grasses and coal remnants (Dougoud 2001). This species is a common mycorrhizal ascomycete after fire (McMullan-Fisher *et al.* 2011), one which fruits 10-150 weeks after burning (Hansen & Knudsen 2000). *Peziza subviolacea* is now considered by many taxonomists to be synonymous with *P. tenacella* (Barseghyan & Wasser 2013).

***Plicaria endocarpoides** (Berk.) Rifai (Pezizaceae), Verhandelingen Koninklijke Nederlandse Akademie van Wetenschappen Afdeling Natuurkunde 57(3): 255. 1968. (Fig. 2G)
Specimen data: 1) Pushcha-Vodytsia, N 50.530514°, E 30.401011°, 21 October 2017, leg./det. Yu. Shcherbakova, (KWU211017/14), on burnt soil of a former bonfire 97 cm in diameter; 2) Pushcha-Vodytsia, N 50.538906°, E 30.402979°, 21 October 2017, leg. Yu. Shcherbakova, det. A. Atamanchuk, (KWU211017/16.), on burnt soil of a former bonfire 206 cm in diameter; 3) Lisnyky Reserve, N 50.284444°, E 30.575035°, 20 June 2018, leg./det. A. Atamanchuk, (KWU200618/11), on burnt soil among mosses.
Distribution in Ukraine. Kharkiv, Kyiv and Zakarpattya Regions (Dudka *et al.* 2009, 2019; Zykova & Dzhagan 2011; Yatsiuk 2017).
General distribution. Asia, Australasia, Europe, North and South America (GBIF 2020).
Notes. Occurs exclusively on burned ground, especially on sandy heaths (Dougoud 2001), 20-130 weeks after the fire (Hansen & Knudsen 2000).

***Pseudombrophila merdaria** (Fr.) Brumm. (Pezizales genera incertae sedis), Libri Botanici 14: 45. 1995. (Fig. 2H)
Specimen data: Holosiiv Forest, near the Expocenter of Ukraine, N 50.375248°, E 30.481243°, 12 October 2017, leg./det. A. Atamanchuk, (KWU121017/50), on burned cardboard in a former bonfire 150 cm in diameter.
Distribution in Ukraine. Sumy Region (Yatsiuk 2017).
General distribution. Europe and North America (Brummelen 1995; GBIF 2020).
Notes. *Pseudombrophila merdaria* is a cosmopolitan and quite common species. It is rather variable with respect to its habitat and morphological features. occurring on various kinds of dung (that of both herbivores and carnivores), as well as on compost; especially frequent on decaying sterns and leaves of plants; more rarely appear-

ing on rotting materials (paper, millboard, cloth); also on soil contaminated with dung, on burnt ground and animal cadavers (Brummelen 1995). *Pseudombrophila merdaria* was identified as new in Ukraine in 2017 on burned soil (Yatsiuk 2017).

Pyronema domesticum (Sowerby) Sacc. (Pyronemataceae), Sylloge Fungorum 8: 109. 1889. (Fig. 2I)
Specimen data: 1) Holosiiv Forest, near the Expocenter of Ukraine, N 50.372048°, E 30.486591°, 12 October 2017, leg./det. A. Atamanchuk, (KWU121017/13),on burnt soil of a former bonfire 120 cm in diameter; 2) Holosiiv Forest, near the Expocenter of Ukraine, N 50.372482°, E 30.484320°, 19 October 2017, leg./det. A. Atamanchuk, (KWU191017/10),on burnt soil of a former bonfire 160 cm in diameter; 3) Holosiiv Forest, N 50.372730°, E 30.492517°, 29 May 2018, leg. N. Tsvyd, det. A. Atamanchuk (KWU290518/4, KWU290518/5), on burnt wood and soil of a former bonfire; 4) Lisnyky Reserve, N 50.284389°, E 30.575574°, 20 June 2018, leg./det. A. Atamanchuk (KWU200618/10), on burnt soil among mosses.
Distribution in Ukraine. Kharkiv, Kyiv, Ivano-Frankivsk, Volyn, Zakarpattya Regions (Smitska 1980; Minter & Dudka 1996; Scherbakova & Dzhagan 2013; Yatsiuk 2017; Dudka *et al.* 2019).
General distribution. Worldwide (Moore & Korf 1963; GBIF 2020).
Notes. The genus *Pyronema* occurs in burnt areas worldwide and produces apothecia fairly early after fires (Moore & Korf 1963; Peterson 1970; Dougoud 2011). The mycelia of these species grow very rapidly and are able to colonise large areas relatively quickly. *Pyronema domesticum* is one of two species of this genus to be registered in Ukraine. The other one is *P. omphallodes,* which is almost indistinguishable from *P. domesticum* morphologically, but in nutrient-rich culture only. *Pyronema domesticum* forms sclerotia (Moore & Korf 1963).

Rhizina undulata Fr. (Rhizinaceae), Observationes mycologicae 1: 162. 1815. (Fig. 2J)
Specimen data: Lisnyky Reserve, N 50.284389°, E 30.574444°, 20 June 2018, leg. /det. A. Atamanchuk, (KWU200618/1, KWU200618/3), on burnt soil in a tplace where a coniferous forest burned.
Distribution in Ukraine. Kyiv, Kherson, Rivne, Sumy, Volyn (Smitska 1980; Minter & Dudka 1996; Dudka *et al.* 2009, 2019; Scherbakova & Dzhagan 2013; Yatsiuk 2017).
General distribution. Worldwide (GBIF 2020).
Notes. A cosmopolitan post-fire pathogenic fungus on coniferous plant roots, one which commonly develops in fire-damaged pine forests growing on acid soil. The distinctive yellow mycelium occurs in the raw humus layer, but extends onto living conifer roots, causing illness and subsequent death of pine seedlings (Dix & Webster 1995; Dougoud 2001). On bonfire sites for up to 70 weeks after burning (Hansen & Knudsen 2000).

Scutellinia crinita (Bull.) Lambotte (Pyronemataceae), Mémoires de la Société Royale des Sciences de Liège, sér. 2 14: 299. 1887. (Fig. 2K)
Specimen data: Romaniv swamp, N 50.504361°, E 30.271175°, 4 October 2017, leg./det. Yu. Shcherbakova, (KWU041017/13), on burnt soil.
Distribution in Ukraine. Ivano-Frankivsk, Kharkiv, Kyiv, Lviv, Ternopil, Volyn, Zakarpattya and Zhytomyr Regions (Smitska 1980; Minter & Dudka 1996; Scherbakova & Dzhagan 2013; Yatsiuk 2017; Dudka *et al.* 2019).
General distribution. Africa, Asia, Europe, New Zealand, North America (Schumacher 1990; GBIF 2020).
Notes. The fungus is quite common in Europe as a forest saprotroph on a wide range of substrates, e.g., decaying wood, burnt ground, bare soil, dung and plant remnants (Schumacher 1990), and our finding it on burnt ground is rather unusual. It should be noted that we did not find any of the other *Scutellinia* species known in Ukraine in similar conditions.

Sphaerosporella brunnea (Alb. &Schwein.) Svrcek & Kubicka (Pyronemataceae), Ceská Mykologie 15(2): 65. 1961. (Fig. 2L)
Specimen data: 1) Holosiiv Forest, near the Expocenter of Ukraine, N 50.372860°, E 30.490030°, 10 August 2017, leg. Yu. Shcherbakova, det. A. Atamanchuk, (KWU100817/06), on burnt soil of a former bonfire 140 cm in diameter; 2) Lisnyky Reserve, N 50.283439°, E 30.574444°, 19 October 2018, leg./det. A. Atamanchuk, (KWU191018/3), on burnt soil of a former bonfire 130 cm in diameter.
Distribution in Ukraine. Kyiv and Zakarpattya Regions (Zykova & Dzhagan 2011; Dudka *et al.* 2019).
General distribution. Asia, Europe, North America (GBIF 2020).
Notes. This species is found on burnt ground and clayey soil. *Sphaerosporella brunnea* is a pioneer ectomycorrhizal ascomycete with facultative saprophytic capacities that produces cup-shaped apothecia often after rain or disturbance. The fungus forms ectomycorrhizae with *Larix*, *Pinus, Picea* and *Populus* (Dix & Webster 1995).

Tarzetta cupularis (L.) Svrcek (Pezizales genera incertae sedis), Ceská Mykologie 35(2): 88. 1981. (Fig. 2M)
Specimen data: Holosiiv Forest, near the Expocenter of Ukraine, N 50.369317°, E 30.489722°, 19 August 2019, leg. N. Tsvyd, det. A. Atamanchuk, (KWU190819/3), on burnt soil of a former bonfire.
Distribution in Ukraine. Ivano-Frankivsk, Kharkiv, Kherson, Kyiv, Ternopil, Volyn and Zakarpattya Regions (Smitska 1980; Minter & Dudka 1996; Dudka *et al.* 2009, 2019; Yatsiuk 2017).

General distribution. Worldwide (GBIF 2020).
Notes. In some literature on the Ukrainian mycobiota, this species is mentioned as *Geopyxis cupularis* (L.) Sacc. (Smitska 1975, 1980). The species occurs on burnt ground, but is more common in unburnt habitats, e.g., in mull or calcareous soil.

***Tricharina praecox* (P. Karst.) Dennis (Pyronemataceae), Kew Bulletin 25(2): 338. 1971. (Fig. 4)
Description. *Apothecia* 2–5 mm in diameter, sessile, spread at the end, hymenium ochraceous yellow, sometimes with dull orange tinges, external surface concolorous, covered by small brown hairs. *Marginal hairs* superficial, 50–90 × 8 µm, straight, apically sharp, more rarely obtuse, with a simple, slightly enlarged base, septate. *Asci* eight-spored, inamyloid, cylindrical, 160–180 × 11–15 µm. *Ascospores* uniseriate, ellipsoid, with somewhat tapered poles and bipolar spore granules, 11.9–15.9 × 6.6–9.5 µm (Q 1.73–2.09). *Paraphyses* hyaline, septate, not or slightly enlarged at the top, 4–5 µm in diameter, frequently forked at the apex.
Specimen data: Pushcha-Vodytsia, N 50.538906°, E 30.402979°, 12 October 2017, leg./det. Yu. Shcherbakova (KWU211017/19), on burnt soil of a former bonfire 206 cm in diameter.
Distribution in Ukraine. Previously not recorded for Ukraine.
General distribution. Asia, Europe, India, North America (Yang & Korf 1985; Hansen & Knudsen 2000; GBIF 2020).
Notes. This species occurs on limestone and burnt ground and fruits abundantly only after a fire (Dougoud 2011; Raudabaugh *et al.* 2020), mainly from late spring to early summer (Hansen & Knudsen 2000). According to Yang & Korf (1985), the species is probably the most common among species of *Tricharina* and is always associated with burnt sites, probably for the most part during the first or second year after fire.

**Trichophaea hemisphaerioides* (Mouton) Graddon (Pyronemataceae), Transactions of the British Mycological Society 43 (4): 689. 1960. (Fig. 2N)
Specimen data: Holosiiv Forest, near the Expocenter of Ukraine, N 50.372528°, E 30.494184°, 19 October 2017, leg. Yu. Shcherbakova, det. A. Atamanchuk, (KWU191017/19), on soil near a burned tree among *Ceratodon purpureus*.
Distribution in Ukraine. Chernihiv, Ivano-Frankivsk, Kyiv and Zakarpattya Regions (Smitska 1980; Minter & Dudka 1996; Scherbakova & Dzhagan 2013; Dudka *et al*. 2019).
General distribution. Europe and North America (GBIF 2020).
Notes. This species appears on recently burnt ground, often among mosses such as *Funaria*. However, it can also fruit on disturbed ground, especially where lime-rich materials such as building rubble, mortar and old plaster have been tipped (Dix & Webster 1995). On burnt areas, the species occurs 20-50 weeks after the fire (Hansen & Knudsen 2000).

DISCUSSION

Pyrophilous fungi are found throughout the kingdom Fungi, but most belong to the Pezizomycetes. Several categories of these fungi were indicated by Moser (1949) and by Petersen (1970), and they were later discussed in the works of Lisiewska (1992), Dix & Webster (1995), Raudabaugh *et al.* (2020). Petersen (1970) classified these fungi into four groups: species which occur exclusively on burnt ground (*group A*); species which occur under natural conditions exclusively on burnt ground, but which may also occur on somehow disturbed unburnt ground (*group B*); species which under natural conditions are common on burnt ground, but which in certain circumstances occur on unburnt ground (*group C*); and species which occur on burnt ground, but which are more common on unburnt (*group D*).

A similar division of post-fire fungi was presented by Raudabaugh *et al*. (2020). They distinguished four categories, viz., species that fruit only on burned soil (I); species that prefer burned soil conditions but may fruit elsewhere (II); randomly encountered species (III); and fire-intolerant fungi (IV).

Taking into account the aforementioned works, we divided pyrophilous discomycetes recorded in the Holosiivskyi National Nature Park into the following categories: ***obligate fireplace fungi*** (whose fruiting is observed only after a fire) and ***optional pyrophilous fungi*** (whose fruiting does not require a fire, but is frequently enhanced by fire, in comparison to that normally observed in unburnt areas). The largest number of species, as noted by Petersen (1970) and by Dix & Webster (1995), are ones belonging to the first category, in particular *Anthracobia maurilabra, Ascobolus carbonarius, Peziza echinospora, P. tenacella, Plicaria endocarpoides, Pyronema domesticum* and *Tricharina praecox*. These fungi are obligate pyrophilous forms and key species in the initial stages of forest regeneration after fires. Moser (1949) referred to this group as anthracobionts.

Such species as *Iodophanus carneus, Scutellinia crinita, Humaria hemisphaerica, Pseudombrophila merdaria, Sphaerosporella brunnea* and *Tarzetta cupularis* can grow in different ecotypes of "non-pyrogenic" origin, on various substrates, but they also often occur in post-fire areas. Fire frequently enhances their fruiting over that normally observed in unburned areas. We therefore consider them to belong to the category of optional or facultative pyrophilous fungi. They are also known as anthracophilous fungi, or fungi favoured by burning (Moser 1949).

Some species are difficult to place in one or another category due to peculiarities of their ecology and associative relations with plants. Thus, *Octospora similis* and *Trichophaea hemisphaerioides* form a separate group of species associated with pioneer plants, including mosses, which are the first to appear in post-fire areas.

Several authors have reported that such a conifer-pathogenic form as *Rhizina undulata* is an obligate pyrophilous species (Raudabaugh *et al.* 2020), but Petersen (1970) considered this fungus to be among species which under certain conditions can occur on unburnt ground. We also consider *Rh. undulata* to be an obligate pyrophilous species mainly found on old bonfires. However, we have sometimes noted this fungus in unburnt areas.

Post-fire recovery processes of forests have been thoroughly reviewed by many authors (Petersen 1970; Lisiewska 1992; Dix & Webster 1995). They distinguished the four groups (I-IV) of succession of fungi on fire sites according to which we have separated our species.

Group I consists of species appearing on the fire site as early as 7 weeks after the fire and occurring not later than 80 weeks after fire. This group, according to published data, includes *Anthracobia maurilabra* and *Pyronema domesticum*. These species were recorded in the first weeks after burning and are considered to be early post-fire fungi. According to Claridge *et al.* (2009), species of *Anthracobia* are pivotal in the early system recovery after disturbance, helping to minimise the movement of soil in the absence of plant roots. As plant root systems recover with the passage of time, the importance of these fungi in soil stabilisation may diminish. Other functional roles of this group of fungi might include nutrient acquisition, leading to the reestablishment of vegetation.

Group II is a heterogeneous group consisting of species occurring from 10 to 15 weeks after fire and fruiting abundantly in the first year, less so thereafter. The group includes such species as *Asobolus carbonarius, Peziza echinospora, Rhizina undulata, Sphaerosporella brunnea, Tarzetta cupularis* and *Tricharina praecox*.

Group III contains species appearing 20-50 weeks after fire and is comprised of only *Trichophaea hemisphaerioides* and *Plicaria endocarpoides,* which persist for 130-200 weeks.

Group IV is also heterogeneous and includes species occurring from 50 to 200 weeks after fire (appearing to the greatest extent in the third year). It is made up predominantly of agarics (species of *Psathyrella, Conocybe, Omphalina, Pholiota, Lyophyllum* and others) (Dix & Webster 1995; Raudabaugh *et al.* 2020), but also includes *Octospora similis, Humaria hemisphaerica* and *Peziza tenacella*, whose apothecia are generally associated with mosses. On such old fire sites overgrown with mosses and nitrophilous vascular plants *Rhizina undulata* also occurs abundantly (Lisiewska 1992).

Such species as *Iodophanus carneus*, *Scutellinia crinita* and *Pseudombrophila merdaria* rarely occur in burnt areas, so the possibility of their appearance on bonfire sites needs to be further investigated.

CONCLUSION

Sixteen species of pyrophilous discomycetes were identified from various post-fire sites of different ages in the Holosiivskyi National Nature Park. Eleven of the species were not previously reported for this park. *Tricharina praecox* and *Octospora similis* were found in Ukraine for the first time. Among the identified species, *Anthracobia maurilabra, Ascobolus carbonarius, Peziza echinospora, P. tenacella, Plicaria endocarpoides, Pyronema domesticum, Tricharina praecox* are obligate pyrophilous fungi, while *Iodophanus carneus, Scutellinia crinita, Humaria hemisphaerica, Pseudombrophila merdaria, Sphaerosporella brunnea* and *Tarzetta cupularis* can grow in different ecotypes and on various substrates in unburnt areas, but they also often occur in post-fire areas.

All these species disappear when their nutritional resources are exhausted or when changes occur in the composition of vegetation that is gradually being restored in the burnt areas.

Thus, the species composition of post-fire fungi can be a natural indicator of anthropogenic pressure on the studied territory. It can be asserted that ascertaining features and the potential role of pyrophilous fungi is highly relevant in studying processes of forest ecosystem restoration after disturbance.

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REZIME

Botanica SERBICA

Prilog poznavanju pirofilnih gljiva Ukrajine

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U radu su prikazani podaci o pirofilnim askomicetama, sakupljenim tokom mikoloških istraživanja u nacionalnom parku Holosiivskyi u periodu 2017-2019. Konstatovano je ukupno 16 vrsta koje pripadaju klasi Pezizomycetes. Među njima se nalaze i *Tricharina praecox* i *Octospora similis*, koje su prvi put nađene u Ukrajini. U radu su prikazani supstrati, lokaliteti, podaci o opštoj distribuciji, kao i neki dodatni podaci o ovim vrstama. Ukratko su razmatrane ekološke karakteristike svih vrsta.

Ključne reči: biodiverzitet, distribucija, nacionalni park Holosiivskyi, novi nalaz, Pezizales, gljive požarišta