

# Macrofungal diversity of greenhouses at the Warsaw University Botanic Garden

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**Abstract.** In 2019–2020 (for 13 months), 21 macrofungi species, both native (14) and inadvertently introduced from warmer regions (7), were found in greenhouses at the Warsaw University Botanic Garden. These included 13 species recorded for the first time in Polish greenhouses. Descriptions and photographs are given for 5 species identified, which are new to Poland (*Gymnopus luxurians*, *Hemimycena ignobilis*, *Leucoagaricus meleagris*, *L. rubrotinctus*, and *Xylaria arbuscula* s.l.). The highest variety of species was found in the greenhouses with the collection of tropical and succulents and cacti, with 11 and 8 species, respectively. The number of species ranged from five to four in other greenhouses. The current results increase the number of species reported from greenhouses in Poland to approximately 50. None of the identified species has a negative impact on the growth and health of plants in the greenhouses at the Warsaw University Botanic Garden and at present none of them are indicated as potentially invasive.

**Keywords:** alien fungi, ecology, Poland, *Gymnopus luxurians*, *Hemimycena ignobilis*, *Leucoagaricus meleagris*, *Leucoagaricus rubrotinctus*, *Xylaria arbuscula*.

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## 1. Introduction

Fungi are some of the most numerous and diverse organisms on Earth. Until recently, fungi were not included in invasion ecology studies, primarily due to insufficient knowledge of fungal biodiversity, biogeography, and ecology (Desprez-Loustau et al., 2007). According to Desprez-Loustau (2009), 688 non-native fungal species, including 84 alien invasive species, occur in Europe; against the background of a changing climate, increased global trade and tourism, as well as intensified agriculture and horticulture, this number is likely to increase (Seebens et al., 2017; Vellinga, 2004). In Poland, 94 alien fungi (belonging to the kingdoms of Fungi

and Chromista), including 11 macrofungal species, have been reported (Alien Species in Poland, 2021).

In Europe, a relatively high number of species from warmer regions have first been observed as inadvertently introduced in greenhouses, with some of them later spreading into the surrounding environment, such as *Leucocoprinus brinbaumi* and *Gymnopus luxurians* (Desprez-Loustau, 2009).

In Poland, greenhouses are rarely sites of long-term research on fungi (Szczepkowski et al., 2014). The first reports about macrofungi found in greenhouses in Poland date back to the late 19th century (Błoński, 1896; Chełchowski, 1888, 1898; Schroeter, 1889). Several dozen macrofungal taxa were recorded in greenhouses in Polish botanical gardens before

this study, both native and inadvertently introduced from warmer regions (Szczepkowski et al., 2014). Some species of fungi found in greenhouses were also noted in rooms heated all year round or at least in winter, such as supermarkets, offices, and flats, e.g., *Leucocoprinus lilacinogranulosus* (Henn.) Locq. (Gierczyk & Dubiel, 2014). The colonization of greenhouses and other buildings by the thermophilous, exotic species is the first step in spreading to new areas. Progressive climate changes result in the possibility of their further expansion into outdoor areas, e.g., gardens, parks, lawns, or woodlands (Kreisel, 2009; Wojewoda & Karasiński, 2010; Vellinga, 2004; Větrovský et al., 2019).

This paper aims to assess the species composition of macrofungi in greenhouses at the Warsaw University Botanic Garden as the place of the potential source of alien and invasive fungal taxa in Poland.

## 2. Material and methods

### 2.1 Location and description of greenhouses

Warsaw University Botanic Garden is located at 4 Aleje Ujazdowskie (52°13'15" N; 21°1'49" E) in the central part of Warsaw, Poland. The entire complex of greenhouses, open to visitors, covers an area of about 1070 m<sup>2</sup> and is composed of four greenhouses (Table 1). In 1818, Warsaw University was given over 20 ha of land for the newly established Botanic Garden. This area already contained orangeries, built at the time of King Stanisław August (the second half of the 18th century). One of them – „*trebhauz*” (K) – has remained in the Garden until today and was renovated in the years 1994–1995 and 2011. It holds a rich collection of succulents and cacti. There have always been several orangeries/greenhouses

in the Botanic Garden, but the existing greenhouses were built between 1990 and 2005 (Bielska, 2002; Werblan-Jakubiec & Zych, 2013; Werblan-Jakubiec et al., 2018).

### 2.2 Methods

Field studies were conducted from July 2019 to July 2020. Once a month, greenhouses were inspected in search of macrofungal sporocarps, with 13 visits in total. The records from each visit describe in which greenhouse and near which plant species the sporocarps were found. Plant species were named according to their labels (placed on or near the plants) or according to information from the greenhouse staff. The collected specimens were identified using standard mycotaxonomical methods (Clemençon, 2009), using the following monographs: *Chlorophyllum*, *Cystolepiota*, *Lepiota*, *Leucoagaricus*, *Leucocoprinus* (Knudsen & Vesterholt, 2012; Noordeloos et al., 2001), *Conocybe* (Hausknecht, 2009), *Coprinellus*, *Henningsomyces*, *Phallus*, *Psathyrella* (Knudsen & Vesterholt, 2012), *Gymnopus* (Antonín & Noordeloos, 2010), *Hemimycena* (Antonín & Noordeloos, 2004), *Polyporus* (Ryvarden et al., 2017), *Stereum*, *Trechispora* (Bernicchia & Gorión, 2010), *Xylaria* (Fournier, 2014).

The nomenclature of basidiomycetous fungi according to Funga Nordica (Knudsen & Vesterholt, 2012) was used, along with the abovementioned monographs.

Dried specimens were deposited in the fungarium of the Department of Forest Protection of the Warsaw University of Life Sciences – SGGW (WAML) and the private fungarium of B. Gierczyk (BGF).

Abbreviations: FD – forest district, LP – landscape park, NP – national park; res. – nature reserve.

**Table 1.** Description of the investigated greenhouses at the Warsaw University Botanic Garden

Greenhouse	Year of erection	Area (m <sup>2</sup> )	Temperature in winter/summer (°C)	Humidity in winter/summer (%)	Major collections (genera or families)
Subtropical (S)	1990	360	20–24/above 24	50–70/60–80	<i>Asplenium</i> , <i>Platyserium</i> , <i>Selenicereus</i> , <i>Nymphaea</i> , <i>Aristolochia</i> , <i>Passiflora</i> , <i>Persea</i> , <i>Coffea</i> , <i>Zingiber</i> , <i>Vanillia</i>
Palm house (P)	2005	200	18–20/above 24	50–70/60–80	<i>Ficus</i> , <i>Musa</i> , <i>Strelitzia</i> , <i>Ravenala</i> , <i>Howea</i> , <i>Kentia</i> , <i>Livistona</i>
Tropical (T)	1997	250	20–24/24–28	60/70–90	<i>Araceae</i> , <i>Bromeliaceae</i> , <i>Cycadaceae</i> , <i>Orchidaceae</i>
Succulents and cacti (K)	before 1818	260	10–12/above 20	40–60/30–50	<i>Aloe</i> , <i>Alluaudia</i> , <i>Cactaceae</i> , <i>Ficus</i> , <i>Laurus</i> , <i>Punica</i> , <i>Welwitschia</i>
Nursery (N)	1995	120	20–24/above 24	60–70/60–80	Representatives of the plant taxa mentioned above

### 3. Results

In the greenhouses at the Warsaw University Botanic Garden, 21 species of macrofungi (1 Ascomycota and 20 Basidiomycota) were recorded. The highest diversity of species was found in the greenhouses with the collection of tropical species (T) and succulents and cacti (K), with 11 and 8 species, respectively. In the subtropical greenhouse (S) and seedbed (N), 5 species were found in each. The fewest species (4) were found in the palm house (P). No species were recorded in more than two greenhouses. One species, *Leucocoprinus heinemannii*, was dominant in greenhouses in terms of the number of basidiomata and the length of their occurrence. Basidiomata of this species were the most abundant and were found during 10 inspections.

#### List of species of macrofungi recorded in greenhouses at the Warsaw University Botanic Garden

*Chlorophyllum brunneum* (Farl. & Burt) Vellinga: in S on the ground, under/among *Piper nigrum*, *Saccharum officinarum*, *Vasconcella quercifolia*; single or two basidiomata; March, April, September, October, November; in P on the ground, under *Alectryon tomentosum*; single; September and October.

**Notes:** In Poland, this species is known from approximately 10 localities (Kujawa, 2020). It was also reported from greenhouses in Warsaw-Powsin (Szczepkowski et al., 2014).

*Conocybe hexagonospora* Métrod ex Hauskn. & Enderle: in N on the ground in a flowerpot with *Philodendron ilselmanii*; gregarious; February and July.

**Notes:** Species rarely reported from Poland. It is known from the Świętokrzyskie Mts (Łuszczynski, 2007, 2008; Hausknecht, 2005, 2009), Pogórze Karpackie (Gierczyk et al., 2018a), and the Bieszczady Mts (Gierczyk et al., 2019).

*Coprinellus disseminatus* (Pers.) J.E. Lange: in K on the ground, under *Castanospermum australe*, *Acacia sphaerocephala*, and *Sterculia diversifolia*; gregarious; January, August, September, and December.

**Notes:** This species is highly common in Poland (Kujawa, 2020; Wojewoda 2003). Hitherto, it was reported from greenhouses at the Warsaw University Botanic Garden (Szober, 1965).

*Cystolepiota cystidiosa* (A.H. Sm.) Bon: in T on the ground, under *Cyrtomium falcatum*; single and gregarious; January, February, March, April, and May.

**Notes:** Extremely rare species, in Poland hitherto reported from Otowo, Poznań, the vicinity of Parchatka (Gierczyk et al., 2011), Cieszyn (Chachuła et al., 2015), a greenhouse in the Polish Academy of Sciences Botanical Garden – Centre

for Biological Diversity Conservation in Warsaw-Powsin (Szczepkowski et al., 2014) and Stare Urbanowo (Gierczyk & Ślusarczyk, 2020).

*Gymnopus impudicus* (Fr.) Antonín, Halling & Noordel.: in S on the ground, under *Ficus benjamina*, *Pandanus veitchii*, *Sobralia* sp. *Tectaria cicutaria*; gregarious; July.

**Notes:** Saprobic species growing on the ground, in litter, in different types of forests, such as forests with *Larix*, *Ribes nigri-Alnetum*, and other deciduous forests as well as mixed coniferous forests. The species is rare in Poland, reported from the Świętokrzyskie Mts (Domański, 1997; Łuszczynski, 2008), Łochowskie Forests (Domański, 1997), Jelonka res. (Kałużka, 2009), near Olkusz (Mleczo & Beszczyńska, 2015), Gryżynski LP (Ślusarczyk, 2019), and Poznań (Gierczyk & Ślusarczyk, 2020).

*Gymnopus luxurians* Peck (Murill) (Fig. 1): in T on the ground under *Crossandra infundibuliformis*, *Dianthera candidans*, and *Hemigraphis alternata*; several dozen basidiomata; July.

**Description:** Basidiomata medium-sized, pilei 1–4 cm in diameter, convex to applanate, concave when old, dark brown in the center, paler (brownish, ochre to cream-colored) at margins, smooth to radially fibrillose, not hygrophanous, not striate. Stipe 3–5 cm high, cylindrical, white or cream-colored with pinkish to brownish hue, fibrillose-striate. Lamellae crowded, white, narrowly adnate. Basidia four-spored. Spores 7–9.5 × 4–5 μm, ellipsoid, hyaline, smooth, without iodine reaction, germ pore absent. Cheilocystidia (sub)cylindrical, narrowly clavate to narrowly utriform, somewhat irregular, sometimes with coralloid excrescences. Pleurocystidia absent. Pileipellis a cutis, composed of cylindrical, rarely diverticulate hyphae, sometimes with excrescences, pigment incrusting. Terminal elements narrowly clavate to subcylindrical. Caulocystidia oblongly pyriform, clavate to broadly fusoid. Clamps present. **Specimens studied:** Warsaw University Botanic Garden, 2020.07.29, (BGF0008246, WAML1086).

**Notes:** Species new to Poland. It is known from Europe (Austria, Czech Republic, Denmark, France, Germany, Hungary, Italy, Netherlands, Spain, Switzerland), Africa (Benin), Asia (Pakistan, South Korea), and America (USA, Hawaiian Island, Costa Rica, Dominican Republic, Panama, Argentina, Brasil), albeit rare (Antonín & Henrik, 1999; Mata et al., 2006; Mata & Ovrebo, 2009; Antonín & Noordeloos, 2010; Lukács et al., 2010; Ludwig, 2012; Jang et al., 2015; Martínez & Lechner, 2021). It is probably a North American species, introduced and spreading worldwide (Mata et al., 2006; Antonín & Noordeloos, 2010). It has been reported from greenhouses in Austria, the Czech Republic, Germany, and Hungary (Antonín & Noordeloos, 2010; Lukács et al., 2010).



**Figure 1.** Basidiomata of *Gymnopus luxurians*; photo by A. Szczepkowski, July 29, 2020



**Figure 2.** Two basidiomata of *Hemimycena ignobilis* (arrow) on the root collar *Zamia furfuracea*; photo by A. Szczepkowski, January 23, 2020

*Hemimycena cucullata* (Pers.) Singer: in K at the base of the stem of *Erythrina crista-galli* growing in a pot; September, October; a few basidiomata; in T on the roots of *Alpinia purpurea*; two basidiomata; January.

**Notes:** In Poland, it is known from approximately 20 historical and contemporary localities (Kujawa, 2020; Wojewoda, 2003), including one greenhouse (Wojewoda, 2003).

*Hemimycena ignobilis* Joss. ex Bon (Fig. 2): in T on the root collar of *Zamia furfuracea*; five basidiomata; January.

**Description:** Basidiomata small, fragile. Pileus 3–10 mm in diameter, first campanulate then concave, thin, white, with a glabrous surface. Stipe cylindrical, 5–20 mm long, < 1 mm broad, white, glabrous, hygrophanous. Lamellae white, distant, decurrent. Basidia four-spored. Spores 7.5–13 × 4.5–

6.5 μm, broadly fusiform, hyaline, smooth, without iodine reaction. Cheilo-, pleuro-, caulo-, and pileocystidia absent. Pileipellis a cutis composed of smooth, cylindrical hyphae. Clamps abundant. **Specimens studied:** Warsaw University Botanic Garden, 2020.01.23 (BGF0005832); vicinity of Rosnówko, Wielkopolski NP, 2020.09.06 (BGF0005960); vicinity of Krynki, 2015.05.31 (BGF0006199).

**Notes:** Species new to Poland. In Poland, it has also been collected in Wielkopolski NP and in the vicinity of Krynki Village (Gierczyk, unpublished materials). This species has been hitherto reported from Europe (Austria, Belgium, Czech Republic, Denmark, France, Germany, Norway, the Netherlands) and Morocco (Antonín & Noordeloos, 2004; Læssøe & Elborne, 2012). It is easily recognized because of its hemimycenoid habit, absence of hymenial cystidia, and smooth pileipellis elements.

*Henningsomyces* aff. *candidus* (Pers.) Kuntze: in T on wet construction wood partially buried in the ground; several dozen basidiomata; January, February, March, April, May, June; in P on wet construction wood partially buried in the ground; several hundred basidiomata; January, February, March, April, May, and June.

**Notes:** In Poland (without localities), the first record dates back to 1961 (Cooke, 1961). Recently, it was reported from Wigierski NP (Halama & Romański, 2010), Ochojec res. (Karasiński, 2009), Kampinoski NP (Karasiński et al., 2015), Cieszyn (Chachuła et al., 2015), the Western Sudety Mts (Gierczyk et al., 2018b), Pogórze Karpackie (Gierczyk et al., 2018b), Puszcza Knyszyńska Forest (Kujawa et al., 2019), and a greenhouse in the Polish Academy of Sciences Botanical Garden – Centre for Biological Diversity Conservation in Warsaw-Powsin (Szczepkowski et al., 2014).

*Lepiota rubella* Bres.: in T on the ground, under *Alpinia purpurea*; January; single; in N on the ground in a pot with *Asplenium nidus*; a few basidiomata; February, and March.

**Notes:** Species described from the Botanical Garden in Berlin, native to South America and the Caribbean islands. In Europe, rarely found in botanical gardens and greenhouses (Gierczyk et al., 2011). It is extremely rare in Poland, hitherto reported only from Poznań, City Palm House, where it grows gregariously in large groups on the fragments of severely decayed wood and rich soil in the greenhouse with tropical plants (Gierczyk et al., 2011).

*Leucoagaricus meleagris* (Gray) Singer (Fig. 3): in K on the ground, under *Agave guttata*, *Cryptanthus glaziovii*, a few basidiomata; July; in N on the ground, under *Aloe ciliaris*; over a dozen basidiomata; July.

**Description:** Basidiomata medium-sized. Pileus 20–45 mm in diameter, first hemispherical, then broadly campanulate, plano-convex; background white, changing to dirty red with age or when handled, minutely fibrillose, covered with radially arranged, brownish or reddish coarse fibrils and squamules. Stipe clavate, up to 6 cm long, white, fibrillose, becoming brownish red when old or bruised, with ascending, fugacious white annulus with reddish squamules on its underside. Lamellae white, crowded, free, discoloring similarly to other parts of the basidioma. Basidia four-spored. Spores ellipsoid, hyaline, smooth, 8–10 × 6–8 μm, somewhat thick-walled, with inconspicuous germ pore with plug, dextrinoid. Cheilocystidia clavate, fusiform to sub-cylindrical, with moniliform apical excrescence. Pleurocystidia absent. Pileus covering made of cylindrical elements; terminal elements irregular, narrowly clavate, cylindrical or narrowly fusoid, in the majority with an abrupt appendix. Clamps absent. **Specimens studied:** Warsaw University Botanic Garden, 2019.07.30 (BGF0004690, BGF0004691, BGF0004693).

**Notes:** Species new to Poland. Widespread and reported from Europe (Denmark, Finland, Germany, Great Britain, Hungary, Italy, Sweden, the Netherlands), Asia (India, Japan), Australia, South America (Brazil), and North America (Canada, USA) (Cabrera, 2015; Candusso & Lanzoni, 1990; Lange, 2012; Legon & Henrici, 2005; Ludwig, 2012; Vellinga, 2001a; Vrinda et al., 2003; ALA database, 2021). In temperate regions, it occurs in greenhouses. Other reddening *Leucoagaricus* species differ from *L. meleagris* by smaller, thin-walled spores without germ pore or stouter basidiocarps and a different shape of the terminal elements of pileus covering.



**Figure 3.** Basidiomata of *Leucoagaricus meleagris*: younger specimen on the left, older specimens on the right; photo by A. Szczepkowski, July 30, 2019

*Leucoagaricus rubrotinctus* (Peck) Singer (Fig. 4): in S on the ground, under *Fittonia verschafeltii*; single; September, October; in P on the ground, under *Antigonon leptopus*; six basidiomata; February.

**Description:** Basidiomata small. Pileus 2–2.5 cm in diameter, campanulate to plano-convex, with orange to pinkish-orange, distinctly darker at the center, coarsely fibrillose to fibrillose-squamulose, sometimes radially cracked covering on white, almost completely covered background. Stipe clavate, white, with an indistinctly fibrillose surface, 2–4 cm long. Annulus ascending, white, with minute orange warts on its lower surface. Lamellae white, crowded, free. Basidia four-spored. Spores amygdaliform, often with apical papilla, 7–10 × 4–5.5 μm, smooth, hyaline, without germ pore. Cheilocystidia clavate, utriform, subspherical to broadly fusoid. Pleurocystidia absent. Pileipellis a cutis with cylindrical to fusoid terminal elements, with incrusting pigments. Clamp connections absent. **Specimens studied:** Warsaw University Botanical Garden, 2019.09.30, 2020.02.21 (BGF0005061, BGF0005822).

**Notes:** Species new to Poland. This widespread species is known from several European countries (France, Germany, Italy), where it occurs mainly in greenhouses, Africa (Ethiopia, Republic of South Africa), Australia, Asia (India, Japan, South Korea), South America (Brazil, Columbia), and North America (Canada, Mexico, USA) (de Albuquerque et al., 2010; Dejene et al., 2017; Després, 2002; Franco-Molano et al., 2000; Imazeki et al., 1988; Jang, 2017; Ludwig, 2012; Pérez-Moreno, 2008; Verma et al., 2018; Peck, 1884; ALA database,



**Figure 4.** Basidioma of *Leucoagaricus rubrotinctus*; photo by A. Szczepkowski, September 30, 2019

2021). The macroscopically similar *L. rubroconfusus* Migl. & Coccia has distinct pileocystidia and ellipsoid or amygdaloid spores without apical papilla.

*Leucocoprinus birnbaumii* (Corda) Singer: in K on the ground, under *Alluaudia procera*, *Euphorbia epiphyllodes*, *E. tirucalli*, *Kalanchoe fedtschenkoi*, *Sedum rubrotinctum*, *Senecio herreanus*, *Welwischia mirabilis*; single and gregarious, 23 basidiomata; June; in N on the ground in the pot with *Monstera karwinskyi*; six basidiomata; June.

**Notes:** This tropical species (Africa, South and Central America) does not occur in the temperate zone. In Poland, the first record of this species dates back to 1960. It was reported from a few localities: a greenhouse, a supermarket, a private apartment, and rooms of a university (Szczepkowski et al., 2014; Wojewoda & Karasiński, 2010; Żurawlew, 2014). In June 2020, a few basidiomata were found growing in a flowerpot with *Epipremnum aureum* in the Institute of Forest Sciences of the Warsaw University of Life Sciences SGGW (leg. A. Giedrowicz, det. A. Szczepkowski, unpublished data).

*Leucocoprinus cepistipes* (Sowerby) Pat.: in K on the ground, under *Aloe ciliaris*, *Cryptanthus glaziiovii*, *Puya laxa*, *P. chiensis*; 11 basidiomata; June; in T on the ground, under *Aechmea* sp.; single; June.

**Notes:** Cosmopolitan fungus known from Africa, Australia, Asia, Europe, and the Americas. A species of tropical origin, but the range of its natural distribution is not known. Found both indoors (greenhouse) and outdoors on rich soils, compost heaps, and wood chips (Birkebak, 2010; Vellinga, 2001b). In Poland, it was reported from six sites in greenhouses, one in a private apartment (Szczepkowski et al., 2014; Wojewoda & Karasiński, 2010), and one outdoors in Gdańsk (Gierczyk et al., 2011).

*Leucocoprinus heinemannii* Migl.: in S on the ground, under *Rauwolfia serpentina*; single; March; in T on the ground, under *Fittonia gigantea*, *Hedychium gardnerianum*, *Maranta leuconeura*, *Megaskepasma erythrochlamys*, *Phyllodendron elegans*, *Stangeria eriopus*, *Strongylodon macrobotrys*, *Thunbergia laurifolia*, and *Zamia furfuracea*; several dozen basidiomata; January, February, March, April, May, June, July, and August.

**Notes:** Saprotrophic on soil and litter, in greenhouses and indoors. Known from scattered localities in Europe (e.g., Netherlands, France, Italy, Germany, and Hungary) and western North America. Species of tropical origin (Lukács et al., 2011; Vellinga, 2001b). In Poland, it is known only from a greenhouse in the Polish Academy of Sciences Botanical Garden – Centre for Biological Diversity Conservation in Warsaw-Powsin (Szczepkowski et al., 2014).



Figure 5. Stromata of *Xylaria arbuscula* s.l.; photo by A. Szczepkowski, January 23, 2020

*Phallus hadriani* Vent.: in K on the ground, under *Commiphora abyssinica* and on the ground in a crack in the concrete floor; a few basidiomata; May, November.

**Notes:** Species not uncommon in Poland, known from over 20 localities (Kujawa, 2020; Wojewoda, 2003). Hitherto, it was not reported from greenhouses in Poland.

*Polyporus squamosus* (Huds.) Fr.: in N on the wood of a native deciduous tree species; single, July; in T on the wood of a native deciduous tree species; three basidiomata; April, May.

**Notes:** Although it is a highly common species (Kujawa, 2020; Wojewoda, 2003), hitherto, it was not reported from greenhouses in Poland.

*Psathyrella candolleana* (Fr.) Maire: in K on the ground, near the trunk of *Acacia heterophylla*; single; June.

**Notes:** A highly common species (Kujawa, 2020; Wojewoda, 2003), but hitherto not reported from greenhouses in Poland.

*Stereum hirsutum* (Willd.) Pers.: in P on the wood of a native deciduous tree; a few basidiomata; January, February, March, April, May, June, July, August, September, October, November, and December.

**Notes:** A highly common species (Kujawa, 2020; Wojewoda, 2003), but hitherto not reported from greenhouses in Poland.

*Trechispora nivea* (Pers.) K.H. Larss.: in T on the wood of a native deciduous tree; one basidioma; April, May, June; in K on wood of a native deciduous tree lying on the ground; one basidioma; June.

**Notes:** In Poland, it was reported from Warsaw (Błoński, 1896; Chełchowski, 1888, 1898), Cracow (Larsson, 1995 after Wojewoda, 2003), Kampinos NP (Karasiński et al., 2015), Polanów FD (Kudławiec, 2016), Białowieża NP (Holec et al., 2019), and Poznań (Gierczyk & Ślusarczyk, 2020). It is probably more common and widespread but may be confused with other *Trechispora* species.

*Xylaria arbuscula* s.l. (Fig. 5): in S on a stump of *Dracena fragrans*; a few stromata; January, February, March, April, May, June, July; in T on the wood of a native deciduous tree lying on the ground; a few stromata; February, March, April, May, June, and July.

**Description:** Stromata erect, up to 2–3 cm high, simple or branched, black, with a well-delimited, cylindrical stem ca. 1–2 mm broad and cylindrical to lanceolate fertile part (2–3 mm broad) ended with sterile, conical apex. Stromatal surface covered with carbonaceous crust (ca. 100 µm thick), forming elongated plaques and undulating furrows; perithecial contours not visible through the crust. Perithecia ca. 0.5 mm in diameter, subglobose, immersed, ostioles inconspicuous. Asci eight-spored, cylindrical, with amyloid apical-apparatus. Spores (13)14–16 (20) × 5–6(6.5) µm, ellipsoid with narrowly rounded ends, dark brown, with straight, ventral germ slit for ca. ¼ of the full spore length. Anamorph stage not studied. **Specimens studied:** Warsaw University Botanic Garden, 2020.01.23, (BGF0007659).

**Notes:** Species new to Poland. It is known from numerous localities worldwide, e.g., New Zealand, Asia (Taiwan, Thailand, Iran), and America (Mexico, USA) (Fournier et al., 2012; Hashemi et al., 2014), and has been reported from greenhouses in Europe in Germany, Italy, and the Netherlands (NMV, 2021; Fournier et al., 2012).

#### 4. Discussion and Conclusions

To date, only 40 taxa of macrofungi have been reported previously from greenhouses of botanical gardens and commercial greenhouses in Poland (Szczepkowski et al., 2014). In Central Europe, e.g., in the Czech Republic (Kuthan, 1992) or Germany (Gubitz, 2012), over 80 species have been found in a single greenhouse complex. Our study lasted only 1 year and was therefore considerably shorter than the cited studies (4 and 7 years, respectively).

Moreover, the area of the examined greenhouses was much smaller than those examined in the Czech Republic and Germany, which also resulted in a much smaller number of taxa found. On the other hand, fewer species than those in greenhouses in the Czech Republic (Kuthan, 1992) and Germany (Gubitz, 2012) were found in the greenhouses at the Graz Botanical Garden during a 3-year study (Pidlich-Aigner & Hausknecht, 2001) and in the greenhouses at the Jena Botanical Garden during 2 years (Gminder, 2005) (37 and 33, respectively). This paper presents the results of the second Polish systematic observations of macrofungi in greenhouses at the Warsaw University Botanic Garden. Nine species (*Chlorophyllum brunneum*, *Coprinellus disseminatus*, *Cystolepiota fumosifolia*, *Hemimycena cucullata*, *Henningsomyces candidus*, *Lepiota rubella*, *Leucocoprinus birnbaumii*, *L. cepistipes*, and *L. heinemannii*) were previously reported in greenhouses from Polish botanical gardens (Szczepkowski et al., 2014). The other 8 species known in Poland from localities outside the greenhouses (*Conocybe hexagonospora*, *Gymnopus impudicus*, *Hemimycena ignobilis*, *Phallus hadriani*, *Polyporus squamosus*, *Psathyrella candolleana*, *Stereum hirsutum*, and *Trechispora nivea*) were recorded for the first time in Polish greenhouses. Five species (*Gymnopus luxurians*, *Hemimycena ignobilis*, *Leucoagaricus meleagris*, *L. rubrotinctus*, and *Xylaria arbuscula* s.l.) had never been recorded in Poland before. Seven species of the recorded taxa (*Gymnopus luxurians*, *Lepiota rubella*, *Leucoagaricus meleagris*, *L. rubrotinctus*, *Leucocoprinus birnbaumii*, *L. cepistipes*, *L. heinemannii*) are known from warmer climatic zones. In this study, all species found for the first time in Poland have previously been found in greenhouses in Europe (Breitenbach & Kränzlin, 1995; Gminder, 2005; Pidlich-Aigner & Hausknecht, 2001; Vellinga, 2001a). In temperate regions, some of them were recorded outdoors, e.g., *Gymnopus luxurians* (Desprez-Loustau, 2009). At present, none of these alien species are indicated as potentially invasive. They are known as ephemeromycetes casually found indoors and occasionally occur also in outdoor environment, but do not overwinter (Motiejūnaitė et al., 2017). The first systematic research in Poland was carried out in 2010 in greenhouses at the Polish Academy of Sciences Botanical Garden – Centre for Biological

Diversity Conservation in Warsaw-Powsin, where 17 species of macrofungi were found (Szczepkowski et al., 2014). The species composition of fungi in the greenhouses at the Warsaw University Botanical Garden is different from that in the greenhouses at the Botanical Garden in Warsaw-Powsin. Only six species (*Chlorophyllum brunneum*, *Cystolepiota fumosifolia*, *Henningsomyces candidus*, *Leucocoprinus birnbaumii*, *L. cepistipes*, *L. heinemannii*) were common to these two greenhouses. In contrast to the greenhouses at the Botanical Garden in Warsaw-Powsin, no representatives of genera such as *Agaricus*, *Asterostroma*, *Limacella*, *Mycenella*, and *Marasmius* were found in greenhouses at the Warsaw University Botanical Garden.

Among the identified species, one (*Phallus hadriani*) has been listed in the “Register of Protected and Endangered Fungal Species in Poland (GREJ)” (Kujawa et al., 2020). The current results increase the number of species reported from greenhouses in Poland to approximately 50. Moreover, our research can be a useful source of knowledge about alien fungi. For example, the knowledge of alien taxa distribution within greenhouses may be helpful in studies on their biology and spreading. It is worth emphasizing that none of the identified species has a negative impact on the growth and health of plants in the collection of the greenhouses at the Warsaw University Botanic Garden. Most of them (15) are terrestrial saprotrophic species, feeding on dead organic matter, having a positive effect on the soil and supporting the breakdown of complex organic compounds into simpler ones that are available for plants. The other six species are lignaceous fungi. Potentially ornamental woody plants may be threatened by only two parasitic/saprobic species i.e. *Polyporus squamosus* and *Stereum hirsutum*, but they have been present on the dead wood of native trees with which they have been brought into the greenhouses.

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