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ALIEN FUNGI IN LITHUANIA: LIST OF SPECIES, CURRENT STATUS AND TROPHIC STRUCTURE

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Abstract

Motiejūnaitė J., Markovskaja S., Kutorga E., Iršėnaitė R., Kasparavičius J., Kačergius A., Lygis V., 2017: Alien fungi in Lithuania: list of species, current status and trophic structure. – Bot. Lith. 23(2): 139–152.

A comprehensive inventory of alien fungi (excluding fungi-like oomycetes) recorded in Lithuania since the 19th century was performed. The compiled list includes 142 fungal species, the major part of which are plant pathogens (125 species), while mycorrhizal and saprotrophic fungi (eight and nine species, respectively) are much less represented. The distribution within country and current status of non-native fungi were assessed. Large part of alien fungus species (58) are considered as established, three species (*Auricularia auricula-judae*, *Aureoboletus projectellus*, *Lecanosticta acicola*) are currently spreading, three species (*Serpula lacrymans*, *Synchytrium endobioticum*, *Tilletia caries*) are decreasing, one (*Laricifomes officinalis*) is considered to be extinct, five saprotrophic species are ephemeromycetes with few records almost exceptionally indoors and not surviving in outside conditions. Status of more than half of the listed species (73) is categorized as unknown as their records are few, suitable habitats and/or hosts are uncommon. The peak of alien fungus recording in Lithuania was in 1980–2000, apparently reflecting an increased frequency of international carriages and the highest peak of national mycological activities. Based on climate change scenarios for Lithuania, further increase of the numbers of alien species is being forecasted.

Keywords: fungi, invasive species, mycorrhizal, plant pathogens, saprobic.

INTRODUCTION

Because of ecological and socio-economic significance, and a huge number of species, fungi represent an essential component of biodiversity, albeit one of the most understudied (Blackwell, 2011). Though the marked impact of fungal introductions on ecosystems is being recognized (Vitousek et al., 1996; Richardson et al., 2000; Wingfield et al., 2001; Nuñez & Dickie, 2014), the general knowledge about geographical distribution and spread patterns of alien fungi is far from complete (Kreisel, 2006; Desprez-Loustau et al., 2010; Santini et al., 2013) and needs continuous updating.

In Lithuania, first records of fungi that are at least in part vouchered by herbarium collections date back to the first half of the 19th century; however, active mycological studies started in 1930's (full review on history of mycological investigations in the country has been provided by Kutorga (2004)). First records of alien fungi are found in the earliest mycological reports: e.g. *Serpula lacrymans* and *Ustilago nuda* mentioned by Jundziłł (1830). Since then the records of new alien species have continuously been reported in the country. Numerous reports on new, previously undetected alien taxa have appeared during the last two decades. In the late 1980's and the beginning of 1990's, along with the fall of the Iron Curtain, increasing quantities and diversity of imported goods (Vilpišauskas, 2000), including plants and plant-derived commodities combined with changing climatic conditions, have likely evoked an emergence and spread of the alien fungi.

In the present paper we aimed to summarize and revise all known information on alien fungi (in the strict sense, excluding chromistan oomycetous fungal analogues) in Lithuania, and to compile a comprehensive list of non-native fungal species belonging to all trophic and ecological groups. The initial list of Lithuanian alien fungi includes 95 species (Kutorga, unpublished data); however, in the present study a number of the records, especially those of microfungi, were critically revised and either retained or excluded from the list because of poorly studied areas of their distribution, generally undefined biology (after Desprez-Loustau et al., 2007, 2010) or uncertain status in Lithuania and neighbouring countries.

MATERIALS AND METHODS

All available literature on Lithuanian fungi and fungal collections of the herbaria BILAS (Herbarium of the Nature Research Centre, Institute of Botany, Vilnius) and WI (Herbarium of Vilnius University) (about 600 specimens of alien fungus species) were used to review existing records on alien fungal taxa in Lithuania. Arbitrary and by other means unreliable references or verbal records were disregarded.

To avoid ambiguity of the status (native vs. alien), large portion of the fungal species recorded on indigenous hosts were excluded, for example such species as *Ascochyta tenerrima* Sacc. & Roum., which is found mainly on cultivated plants of *Viburnum* and *Lonicera*, but also occurs on native *V. opulus* L. and *L. xylosteum* L., or *Sphaeropsis sapinea* (Fr .) Dyco & Sutton and *Dothistroma septosporum* (Dorogin) M. Morelet (also occurs on native conifers), which alien status is doubtful (Desprez-Loustau et al., 2010; Drenkhan et al., 2013, 2016; Mullet et al., 2015). Thus, only the pathogens of indigenous plants with a confirmed and well-documented alien status in Europe were considered in this paper.

The current status of every alien fungus was determined following these categories: a) established – the first record dates back to more than 15 years; currently found in various parts of the country and hosts are common; b) spreading – the first record dates back to less than 15 years; recorded localities of occurrence are numerous or, alternatively, recorded more than 10 years ago, but the number of localities has started to increase only during the last decade; c) decreasing – the first record dates back to more than 15 years, records have been less frequent during the last decade or fungus is not found at present; d) ephemeromycete – records are few, the fungus does not survive in natural conditions (after Kreisel & Scholler, 1994; Scholler, 1999); e) unknown – records are few, suitable habitats and/or hosts are uncommon, distribution is unknown (not investigated).

RESULTS AND DISCUSSION

Species diversity

Our analysis showed that a total of 142 species of fungi that occur in natural and anthropogenic ecosystems can be regarded as alien in Lithuania. These species are listed in Table 1 and include the anamorphic and teleomorphic *Ascomycota* (92 species), *Basidiomycota* (49 species), and *Chytridiomycota* (1 species). Most of the listed species are plant pathogens (125), while saprotrophic and mycorrhizal fungi make only a small part of the total analysed material (nine and eight species, respectively). The status of more than half of the listed species (73) fall into the category of ”unknown”, of these, high fraction of fungi are pathogens of economically less important ornamental plants. Five species (*Agaricus bisporus*, *Leucoagaricus bresadolae*, *Leucocoprinus birnbaumii*, *L. cepistipes*, *Peziza ostracoderma*) are ephemeromycetes casually found indoors and occasionally occur also in outdoor environment, but do not overwinter. A considerable number of species (58) that belong to all trophic groups can be regarded as established in Lithuania, although only a few are found in natural habitats. Three species (*Auricularia auricula-judae*, *Aureoboletus projectellus*, *Lecanosticta acicola*) are currently intensively spreading; three species (*Serpula lacrymans*, *Synchytrium endobioticum*, *Tilletia caries*) are decreasing due to improved control methods, and one species (*Laricifomes officinalis*) has not been found again since its first record in 1966 (Kutorga et al., 2013; Ruzgas & Liatukas, 2009; Wrzosek et al., 2017, unpublished data by R. Iršėnaitė and S. Markovskaja).

Table 1. List of alien fungi in Lithuania, their status, the year of first record and first published reference (for the definition of species status see Materials and Methods)

Fungus species	Status	Year of first record and first published reference
Agaricus bisporus (J.E. Lange) Imbach	Ephemeromycete	1975 (Urbonas, 1999)
Ascochyta actaeae (Bres.) Davis	Unknown	1987 (Treigienė, 2009)
Ascochyta aristolochiae Sacc.	Unknown	1987 (Treigienė, 2009)
Ascochyta caraganae (Vestergr.) Melnik	Established	1987 (Treigienė, 2009)
Ascochyta funkiae-sieboldianae Punith.	Unknown	1987 (Treigienė, 2009)
Ascochyta phlogis Voglino	Unknown	1991 (Markevičius, 1992)
Ascochyta rubiae Bubák	Unknown	1980 (Treigienė, 2009)
Auricularia auricula-judae (Bull.) Quél.	Spreading	1959 (Mazelaitis, 1962)
Blumeriella jaapii (Rehm) Arx	Established	1960 (Minkevičius, 1962)
Aureoboletus projectellus (Murill) Halling	Spreading	2007 (Motiejūnaitė et al., 2011)
Boletinus cavipes (Opat.) Kalchbr.	Unknown	1994 (Urbonas, 1997a)
Camarosporium amorphae Sacc.	Unknown	1996 (Treigienė, 2009)
Camarosporium caragana P. Karst.	Established	1995 (Treigienė, 2009)
Camarosporium elaeagnellum Fairm.	Unknown	1998 (Treigienė, 2009)
Camarosporium incrustans (Sacc.) Sacc.	Unknown	1999 (Treigienė, 2009)
Camarosporium robiniae (Westend.) Sacc.	Unknown	1987 (Treigienė, 2009)
Camarosporium spiraeae Cooke	Established	1996 (Treigienė, 2009)
Clathrus archeri (Berk.) Dring	Unknown	2011 (Motiejūnaitė et al., 2016)
Coleosporium clematidis Barclay	Unknown	1936 (Szakien, 1937)
Colletotrichum acutatum J.H. Simmonds	Unknown	2001(Jovaišienė & Taluntytė, 2002)
Colletotrichum lindemuthianum (Sacc. & Magnus) Briosi & Cavara	Established	1927 (Ignatavičiūtė & Treigienė, 1998)
Cronartium ribicola J.C. Fisch.	Established	1926 (Minkevičius, 1937)
Cumminsiella mirabilissima (Peck) Nannf.	Established	1931 (Melamėdaitė, 1932)
Cylindrosporium pseudoplatani (Roberge ex Desm.) Died.	Established	1987 (Ignatavičiūtė & Treigienė, 1998)
Diaporthe caraganae Jacz.	Unknown	1983 (Minkevičius & Rukšėnienė, 1987)
Didymascella thujina (E.J. Durand) Maire	Unknown	2000 (Jovaišienė & Sabas, 2004)
Diploceras parasiticum (Dearn. & House) Nag Raj	Unknown	1996 (Ignatavičiūtė & Treigienė, 1998)
Diplodia aesculi Lév.	Established	1998 (Treigienė, 2009)
Diplodia cydoniae Sacc.	Unknown	1997 (Treigienė, 2009)
Diplodia ilicicola Desm.	Unknown	1998 (Treigienė, 2009)
Diplodia ligustri Westend.	Unknown	2000 (Treigienė, 2009)
Diplodia mori Westend.	Unknown	1995 (Treigienė, 2009)
Diplodia profusa De Not.	Unknown	1997 (Treigienė, 2009)
Diplodia rhois Sacc.	Unknown	1997 (Treigienė, 2009)
Diplodia siphonis Henn.	Unknown	1998 (Treigienė, 2009)
Diplodia symphoricarpi Sacc.	Unknown	1995 (Treigienė, 2009)
Diplodia tulipiferae Died.	Unknown	1998 (Treigienė, 2009)
Elsinoë ampelina Shear	Unknown	1975 (Ignatavičiūtė & Treigienė, 1998)
Entyloma calendulae (Oudem.) de Bary	Established	1959 (Brundza, 1961)
Entyloma dahliae Syd. & P. Syd.	Unknown	1934 (Michalski, 1936)
Entyloma gaillardianum Vánky	Established	1956 (Ignatavičiūtė, 1975)
Entyloma ludwigianum Syd.	Unknown	1970 (Ignatavičiūtė, 1975)
Erysiphe alphitoides (Griffon & Maubl.) U. Braun & S. Takam.	Established	1909 (Minkevičius, 1927)
Erysiphe azaleae (U. Braun) U. Braun & S. Takam.	Unknown	2003 (Grigaliūnaitė & Pribušauskaitė, 2006)
Erysiphe flexuosa (Peck) U. Braun & S. Takam.	Established	2004 (Grigaliūnaitė et al., 2005)
Erysiphe magnicellulata U. Braun	Established	1933 (Brundza, 1934)
Erysiphe palczewskii (Jacz.) U. Braun & S. Takam.	Unknown	2010 (Stankevičienė & Snieškienė, 2013)

Fungus species	Status	Year of first record and first published reference
Erysiphe syringae Schwein.	Unknown	2009 (Žeimavičius et al., 2011)
Erysiphe thermopsidis R.Y. Zheng & G.Q. Chen	Unknown	1990 (Grigaliūnaitė, 1997)
Erysiphe vanbruntiana var. *sambuci-racemosae* (U. Braun) U. Braun & S. Takam.	Established	1978 (Grigaliūnaitė, 1984)
Euoidium chrysanthemi (Rabenh.) U. Braun & R.T.A. Cook	Established	1934 (Brundza, 1934)
Euoidium lycopersici (Cooke & Massee) U. Braun & R.T.A. Cook	Established	1983 (Grigaliūnaitė, 1997)
Exobasidium japonicum Shirai	Unknown	1936 (Brundza, 1961)
Gloeosporium aroniae Kill.	Unknown	1975 (Ignatavičiūtė & Treigienė, 1998)
Gloeosporium orbiculare (Berk.) Berk.	Established	1936 (Michalski, 1936)
Gomphidius maculatus (Scop.) Fr.	Established	1956 (Urbonas, 1997a)
Guignardia aesculi (Peck) V.B. Stewart	Established	1987 (Grigaliūnaitė et al., 2010)
Gymnosporangium sabinae (Dicks.) G. Winter	Established	1935 (Minkevičius, 1937)
Hendersonia hirta (Fr.) Curr.	Established	2001 (Treigienė, 2009)
Hygrophorus lucorum Kalchbr.	Unknown	1971 (Urbonas, 1997a)
Hymenoscyphus fraxineus (T. Kowalski) Baral, Queloz & Hosoya	Established	1996 (Juodvalkis & Vasiliauskas, 2002)
Hymenoscyphus rokebyensis (Svrček) Matheis	Unknown	1990 (Kutorga, 1993)
Kabatina thujae R. Schneid. & Arx	Established	1996 (Ignatavičiūtė & Treigienė, 1998)
Lachnellula occidentalis (G.G. Hahn & Ayers) Dharne	Unknown	1991 (Kutorga & Raitviir, 2006)
Lachnellula willkommii (Hartig) Dennis	Established	1933 (Minkevičius, 1936)
Lactarius blennius (Fr.) Fr.	Established	1998 (Urbonas, 2001)
Laricifomes officinalis (Vill.) Kotl. & Pouzar	Decreasing	1966 (Gricius & Matelis, 1996)
Lecanosticta acicola (Thüm.) Syd.	Spreading	2009 (Markovskaja et al., 2011)
Leucoagaricus bresadolae (Schulzer) Bon & Boiffard	Ephemeromycete	1985 (Urbonas, 1999)
Leucocoprinus birnbaumii (Corda) Singer	Ephemeromycete	1968 (Urbonas, 1999)
Leucocoprinus cepistipes (Sowerby) Pat.	Ephemeromycete	2005 (Motiejūnaitė et al., 2016)
Marssoniella juglandis (Lib.) Höhn.	Established	1989 (Ignatavičiūtė & Treigienė, 1998)
Marssonina clematidis Allesch.	Unknown	1974 (Ignatavičiūtė & Treigienė, 1998)
Melampsoridium hiratsukanum S. Ito ex Hirats.	Established	1997 (Markovskaja, 2013)
Melanconium oblongum Berk.	Unknown	1995 (Ignatavičiūtė & Treigienė, 1998)
Microdiplodia coggygriae Zerova	Unknown	1997 (Treigienė, 2009)
Microsphaeropsis hellebori (Cooke & Massee) Aa	Unknown	1987 (Treigienė, 2009)
Mutinus ravenelii (Berk. & M.A. Curtis) E. Fisch.	Established	1991 (Kutorga, 2004)
Myxocyclus cenangioides (Ellis & Rothr.) Petr.	Unknown	1987 (Treigienė, 2009)
Ophiostoma novo-ulmi Brasier	Established	2010 (Motiejūnaitė et al., 2016)
Ophiostoma ulmi (Buisman) Nannf.	Unknown (may be already replaced by *O. novo-ulmi*)	1952 (Žuklys, 1958)
Oidium hortensiae Jørst.	Established	1961 (Grigaliūnaitė, 1997)
Peziza ostracoderma Korf	Ephemeromycete	1996 (Kutorga, 2000)
Phellinus hippophaëicola H. Jahn	Unknown	1965 (Mazelaitis, 1976)
Phloeospora maculans (Sandri) Allesch.	Unknown	1914 (Siemaszko, 1914)
Phloeospora robiniae (Lib.) Höhn.	Established	1973 (Ignatavičiūtė & Treigienė, 1998)
Phomopsis caraganae Bondartsev	Established	1996 (Treigienė, 2000)
Phomopsis juglandina (Sacc.) Höhn.	Unknown	1997 (Treigienė, 2000)
Phomopsis leptostromiformis (J.G. Kühn) Bubák	Established	1912 (Strukčinskas, 1971)
Phomopsis liriodendri Grove	Unknown	1998 (Treigienė, 2000)
Phomopsis oncostoma (Thüm.) Höhn.	Established	1997 (Treigienė, 2000)
Phomopsis stictica (Berk. & Broome) Traverso	Unknown	1998 (Treigienė, 2000)
Phomopsis vaccinii Shear	Unknown	2002 (Kačergius et al., 2004)

Fungus species	Status	Year of first record and first published reference
Pithya cupressina (Batsch) Fuckel	Established	1979 (Kutorga, 2000)
Puccinia asparagi DC.	Unknown	1937 (Minkevičius, 1937)
Puccinia chrysanthemi Roze	Unknown	1936 (Michalski, 1936)
Puccinia helianthi Schwein.	Established	1903 (Szakien, 1926)
Puccinia hordei G.H. Otth	Established	1926 (Minkevičius, 1937)
Puccinia horiana Henn.	Unknown	1996 (Kutorga, 1997)
Puccinia komarovii Tranzschel	Established	1936 (Szakien, 1937)
Puccinia malvacearum Bertero ex Mont.	Established	1926 (Szakien, 1926)
Puccinia pelargonii-zonalis Doidge	Unknown	1986 (Minkevičius & Ignatavičiūtė, 1993)
Puccinia sorghi Schwein.	Unknown	1942 (Minkevičius, 1949)
Rhabdocline pseudotsugae Syd.	Established	1959 (Žuklys & Vitkūnas, 1991)
Seiridium cardinale (W.W. Wagener) B. Sutton & I.A.S. Gibson	Unknown	1997 (Ignatavičiūtė & Treigienė, 1998)
Septoria aesculi (Lib.) Westend.	Unknown	1929 (Brundza, 1930)
Septoria argyraea Sacc.	Unknown	1975 (Markevičius & Treigienė, 2003)
Septoria buxicola D.N. Babajan & Simonyan	Unknown	1987 (Markevičius & Treigienė, 2003)
Septoria echinocystis Ellis & Everh.	Unknown	1994 (Markevičius & Treigienė, 2003)
Septoria helenii Ellis & Everh.	Unknown	1997 (Markevičius & Treigienė, 2003)
Septoria heterochroa Roberge ex Desm.	Unknown	1998 (Markevičius & Treigienė, 2003)
Septoria kaznowskii M.I. Nikol.	Established	1963 (Markevičius & Treigienė, 2003)
Septoria lavandulae Roberge ex Desm.	Unknown	1998 (Markevičius & Treigienė, 2003)
Septoria maydis Schulzer & Sacc.	Unknown	1979 (Markevičius & Treigienė, 2003)
Septoria melissae Desm.	Unknown	1998 (Markevičius & Treigienė, 2003)
Septoria oleandrina Sacc.	Unknown	1914 (Siemaszko, 1914)
Septoria penstemonis Ellis & Everh.	Unknown	1990 (Markevičius & Treigienė, 2003)
Septoria petroselini Desm.	Established	1965 (Markevičius & Treigienė, 2003)
Septoria phlogis Sacc. & Speg.	Unknown	1970 (Markevičius & Treigienė, 2003)
Septoria rudbeckiae Ellis & Halst.	Unknown	1986 (Markevičius & Treigienė, 2003)
Septoria zeae G.L. Stout	Established	1978 (Markevičius & Treigienė, 2003)
Serpula lacrymans (Wulfen) J. Schröt.	Decreasing	1830 (Jundziłł, 1830)
Sirococcus spiraea (Lebedeva) Petr.	Established	1978 (Treigienė, 2009)
Sphacelotheca reiliana (J.G. Kühn) G.P. Clinton	Established	1956 (Ignatavičiūtė, 1975)
Sphaerotheca mors-uvae (Schwein.) Berk. & M.A. Curtis	Established	1926 (Minkevičius, 1927)
Sporisorium sorghi Ehrenb. ex Link	Unknown	1936 (Ignatavičiūtė, 2001)
Stagonosporopsis curtisii (Berk.) Boerema	Unknown	1984 (Juronis & Baliūnienė, 1990)
Stropharia rugosoannulata Farl. ex Murrill	Unknown	2011 (Motiejūnaitė et al., 2016)
Suillus grevillei (Klotzsch) Singer	Established	1953 (Urbonas, 1997a)
Suillus viscidus (L.) Roussel	Established	1953 (Urbonas, 1997a)
Synchytrium endobioticum (Schilb.) Percival	Decreasing	1938 (Brundza, 1961)
Thecaphora oxalidis (Ellis & Tracy) M. Lutz, R. Bauer & Piątek	Unknown	1936 (Lepik, 1937)
Tilletia caries (DC.) Tul. & C. Tul.	Established	1830 (Jundziłł, 1830)
Tricholoma psammopus (Kalchbr.) Quél.	Unknown	1996 (Urbonas, 1997b)
Uncinula necator (Schwein.) Burrill	Unknown	1934 (Brundza, 1934)
Urocystis occulta (Wallr.) Rabenh.	Established	1912 (Vilkaitis, 1937)
Uromyces appendiculatus F. Strauss	Established	1936 (Minkevičius, 1982)
Uromyces caraganicola Henn.	Established	1975 (Minkevičius, 1982)
Uromyces lupinicola Bubák	Established	1969 (Minkevičius, 1982)
Ustilago hordei (Pers.) Lagerh.	Established	1913 (Ignatavičiūtė, 1975)
Ustilago maydis (DC.) Corda	Established	1936 (Minkevičius, 1951)
Ustilago nuda (C.N. Jensen) Rostr.	Established	1830 (Jundziłł, 1830)

The high number of herein considered alien species in Lithuania (Table 1) could be explained by comparatively large portion of alien plants (558 species) (Gudžinskas, 2011, 2017) in the flora of Lithuania (1360 species of indigenous vascular plants have been recorded in the country (Bukantis et al., 2008)), and a specific geographical position of the country: i) Lithuania is at the intersection of important bioclimatic zones and geographical populations (Ahti et al., 1968; Jaarola & Searle, 2002; Navasaitis et al., 2003; Heuertz et al., 2006); ii) a major bird migration route (White Sea-Baltic Sea) crosses the western part of the country and birds are known to be an important vector of long-distance dispersal of various organisms (Viana et al., 2016); and iii) Lithuania is a transit country, where sea, rail and road transportation of goods is intensive. Another explanation may be due to an outstanding collection, identification and reporting effort of local mycologists (Kutorga, 2004). The cumulative graph of the number of records of alien fungi in Lithuania (Fig. 1) is somewhat similar to that published by Desprez-Loustau (2009) for alien fungi in Europe and by Santini et al. (2013) for invasive forest pathogens in Europe. The large number of alien species' records made in 1980–2000 possibly reflects a combination of two phenomena: an increased frequency of international carriages after the fall of the Iron Curtain and the highest peak of national mycological activities. As shown in Fig. 1, the number of new records increased only slightly in 2010–2016, which coincides with a decreasing number of active taxonomy experts in Lithuania.

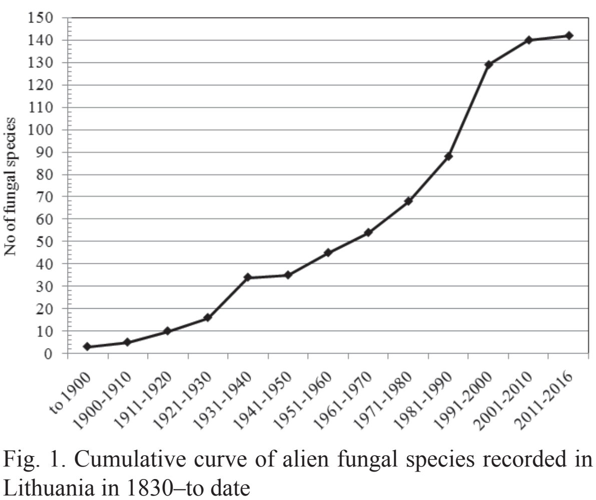

Fig. 1. Cumulative curve of alien fungal species recorded in Lithuania in 1830–to date

Trophic groups

Plant pathogens

Thanks to emerging disease symptoms they cause, plant pathogens are among the most often recorded and the best investigated alien fungi (Desprez-Loustau et al., 2007; Vellinga et al., 2009), however, identification of the causal agent often tails away from the record of symptoms of a new disease. The good recent example is ash dieback, which was for the first time recorded in Poland in early 1990's (Kowalski & Lukomska, 2005) (in Lithuania reported in 1996 (Juodvalkis & Vasiliauskas, 2002)), while the causal agent of the disease, pathogenic *Hymenoscyphus fraxineus* (anamorph *Chalara fraxinea* T. Kowalski), was described only in 2006 (Kowalski, 2006; Baral et al., 2014). In Lithuania, plant pathogens also make a major fraction (125 species) of all recorded alien fungi (Table 1). Most of these are narrowly specialized pathogens of non-indigenous crops or ornamental plants; while other pathogens such as *Ustilago nuda* or *U. hordei* have been known for several centuries in Lithuania. The emergence of others (i. e. *Ustilago maydis* (on *Zea mays* L.) or *Coleosporium clematidis* (on *Clematis* spp.)) coincided with introduction and/or spread of their hosts in the 20th century (see Table 1 for references). The economic importance of the herein considered alien pathogens varies from high, causing serious losses in agriculture, forestry or for growers of ornamental plants, i. e. *Blumeriella jaapii* on *Prunus* spp., *Colletotrichum lindemuthianum* and *Uromyces appendiculatus* on *Phaseolus vulagaris*, *H. fraxineus* on *Fraxinus excelsior*, *Lachnellula willkommii* on *Larix* spp., *Gymnosporangium sabinae* on *Juniperus* spp. and *Pyrus* spp., etc.; to the lowest, causing only minor damage to some garden or park plants, i.e. *Entyloma gaillardianum* on *Gaillardia* spp., *Erysiphe magnicellulata* on *Phlox* spp., *Erysiphe azaleae* and *Exobasidium japonicum* on *Rhododendron* spp., *Kabatina thujae* on *Chamaecyparis* spp., *Juniperus* spp. and *Thuja* spp.).

Only few alien pathogens are recorded on indigenous plants, exclusively on woody species and most of these fungi constitute serious threat to native forest communities. For example, powdery mildew caused by *Erysiphe alphitoides* on *Quercus* spp. was recorded at the beginning of the 20th century (Table 1) and since has become widespread all over the country (Dabkevičius et al., 2006). Dutch elm disease caused by *Ophiostoma ulmi* s. str. on *Ulmus* spp., recorded in the '50s of the 20th century (Žuklys, 1958) has likely been replaced by a closely related, more aggressive species – *O. novo-ulmi*, which has become established (Motiejūnaitė et al., 2016). Some pathogens, namely *Lecanosticta acicola*, *Melampsoridium hiratsukanum* and *Hymenoscyphus fraxineus* have emerged only recently, but have caused a very serious concern to foresters, environmentalists and broader society (Markovskaja et al., 2011; Pliūra et al., 2011; Markovskaja, 2013; Lygis et al., 2014).

Several alien to Lithuania plant pathogens of little or no economic importance are noteworthy as examples of border extensions for rare fungal species. For example, aphyllophoroid fungus *Phellinus hippophaëicola* inhabits hosts of *Elaegnaceae* family (predominantly *Hippophae rhamnoides* L.), and, though its hosts are widely distributed and not uncommon in Eurasia, the fungus is generally rather rare (Wilga & Wantoch-Rekowski, 2013). The distribution borders of its principal host *H. rhamnoides* lay close to Lithuania (Kaliningrad region of Russia), but the shrub does not occur in the country naturally, although it is widely cultivated and grows as an escapee in various dry and sun-exposed habitats (Gudžinskas, 1998). Nevertheless, *P. hippophaëicola* has been found only in the environs of Juodkrantė (western Lithuania), where it is abundant (Gricius & Matelis, 1996). Another aphyllophoroid fungus, *Laricifomes officinalis,* an agent of brown heart rot of several coniferous species (most commonly found on *Larix* spp.) requires old trees and stands of old age, and is becoming rare in a number of countries (Chlebicki et al., 2003; Gregori, 2013). Considerable part of lowland European records of this fungus have been made in an anthropogenic environment (Chlebicki et al., 2003), as in Lithuania, where it has been found on old larch in a city park (Mazelaitis, 1976). *Auricularia auricula-judae*, a weak facultative parasite commonly developing as saprobe on woody plants of temperate to tropical distribution, was for the first time recorded in Lithuania in 1959 on *Sambucus nigra* L. (Mazelaitis, 1962). Since that time no new records of this species have appeared for the next five decades; however, recently its population has started to expand its range in Lithuania along with a spread of its alien hosts – *Acer negundo* L. and *Sambucus* spp., especially in disturbed and eutrophicated environment (e.g. in a forest affected by cormorant colony) (Kutorga et al., 2013). A distinct increase of frequency and spreading of *A. auricula-judae* was noted in the second half of the 20th century in Denmark, southern Sweden, the Netherlands, Germany and Poland (Kreisel, 2006). Changes in host range, abundance and fruiting time of *A. auricula-judae* have been reported in the United Kingdom, probably as a response to global warming (Gange et al., 2010). High nutrient availability, e.g. increased nitrogen levels and dust deposition, may be an alternative factor explaining the expanded distribution of the species (Heilmann-Clausen & Læssøe, 2012).

Mycorrhizal fungi

Invasions by ectomycorrhizal macromycetes to other continents or otherwise new areas have been reported since the first half of the 20th century (Vellinga et al., 2009; and references therein); however, economic and ecological importance of alien mutualistic species has been acknowledged only lately (Richardson et al., 2000; Vellinga et al., 2009; Nuñez & Dickie, 2014). In Lithuania, alien ectomycorrhizal fungi were for the first time reported in 1950's (Urbonas, 1997a). At present, eight mycorrhizal macromycetes could be included into the list of alien species (Table 1). Most of these fungi are associated with *Larix* spp., which are thought to be the earliest introduced (ca. 200 years ago) conifers in Lithuania, and are widely grown as ornamental plants or in forest plantations (Navasaitis, 2004). One species – *Lactarius blennius* is associated with *Fagus sylvatica* L. which is non-native as well. Recently recorded *Aureoboletus projectellus* is associated with two pine species – alien *Pinus mugo* Turra and indigenous *P. sylvestris* L. (Motiejūnaitė et al., 2011). The latter fungus is also the only one mycorrhizal species of extra-European origin found in the country and the only one showing invasive tendencies: it spreads rapidly, fructifies abundantly and forms association with novel ectomycorrhizal partners, including the indigenous one (Wrzosek et al., 2017), thus showing similarity to the expansion of introduced ectomycorrhizal *Amanita phalloides* in western North America (Pringle et al., 2009).

Saprobic fungi

Economic and ecological impact of alien saprobes is in most cases the least known among all trophic groups of fungi. The alien saprobes are thought to impact decomposition cycles by interacting (outcompeting) with native decomposers (Desprez-Loustau et al., 2007). There are no direct studies supporting these presumptions, but known interactions of soil saprotrophs and mycorrhizal fungi reviewed by Cairney & Meharg (2002) would imply that disturbance of existing community ties through introduction of novel saprobic species may have a wider impact than is known at present. Of the nine alien saprobes recorded in Lithuania (Table 1), only one species indoors wood-decaying *Serpula lacrymans* has been documented to have economic importance. In Europe, this fungus has already been known for a long time, although in the natural environment it has been found only once (Kotlaba, 1992). Recent study by Skrede et al. (2013) has confirmed the hypothesis that *S. lacrymans* is an introduced species in Europe.

Other recorded alien saprobes are of no economic, and, apparently, of little environmental impact, since none of them was found in natural ecosystems and most do not overwinter outdoors (see above). Except for *Agaricus bisporus*, all other species have been introduced unintentionally with soil, potted plants or wood chips. *Agaricus bisporus* has been in cultivation for over 300 years in Europe (Kerrigan, 1995), and while in some European countries its origins and alien status are under discussion (Voglmayr & Krisai-Greilhuber, 2002), in Lithuania, this macromycete is non-indigenous according to the definition of its distribution by Desprez-Loustau (2009). It is widely cultivated in the country, but apparently it has not spread as an escapee: outside the farms, the presence of fruitbodies of *A. bisporus* has been reported correctly only once (on dung in a garden) (Urbonas, 1999). All other reports proved to be erroneous as collections contained indigenous four-spored species of *Agaricus* (J. Kasparavičius, unpublished data). A soil saprobe *Mutinus ravenelii*, native to North America, was first noted in Berlin, Germany in 1942 (Kreisel, 2006). It is regarded as a recent newcomer to Lithuania (Table 1). This fungus is the only one among alien soil saprobes widely spread in the country. Two recent additions to the Lithuanian alien saprobe list – *Clathrus archeri* and *Stropharia rugosoannulata* have been found only once (Motiejūnaitė et al., 2016). Seemingly, these fungi have not spread further from the places of their first occurrence as they have never been observed again, despite that both species form large and very conspicuous fruitbodies, which tend to attract public attention.

Hosts of the alien fungi

During the present study, a total of 86 plant genera were found to be associated with alien fungi in Lithuania; of those, only seven genera (all woody plants: *Alnus*, *Fraxinus*, *Pinus*, *Pyrus*, *Quercus*, *Ribes* and *Ulmus*) include also indigenous species. Only 27 of all considered host plant genera are associated with more than one species of the alien fungi (Fig. 2). The highest number of alien fungal taxa (nine species), both mutualists and pathogens, are associated with *Larix* spp.

Plant host genera associated with the highest numbers of alien fungal taxa are cultivated on a large scale (e.g. *Zea mays*, *Caragana arborescens* Lam.) and/or are common as naturalized escapees (e.g. *Robinia pseudoacacia* L., *Lupinus* spp.) (Fig. 2), but on the other hand, various commonly grown plants are associated with a single alien fungus (e.g. *Gloeosporium orbiculare* on *Cucumis*, *Entyloma dahliae* on *Dahlia*, etc.). Neither the time since their introduction, nor the scale of cultivation of the host plants seem to correlate with the numbers of associated alien fungal taxa. For example, wheat and barley have been cultivated since the Bronze Age in Lithuania (Grigalavičienė, 1995), but only one alien species has been found to be associated with the wheat and three – with the barley. Alternatively, five species of alien fungi are associated with corn and nine spe-

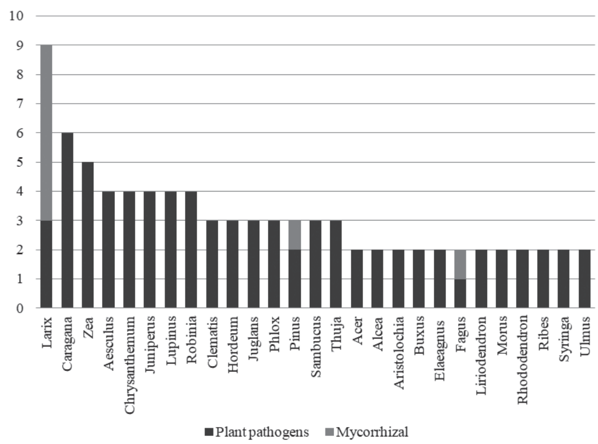

Fig. 2. Plant host genera associated with two or more species of alien plant pathogens and mycorrhizal fungi in Lithuania.

cies – with larches, the host plants, which were introduced to Lithuania relatively recently – in the 19th century (Jundziłł, 1830; Navasaitis, 2004).

Naturalization of alien plants is one of the most important factors that determine successful introduction and establishment of the associated fungal species in new areas, and vice versa – mutualistic mycobiota is essential for the success of invasive plants, as it has been demonstrated by the example of introduced species of pines and associated ectomycorrhizal fungi (Richardson et al., 2000). It is also known that the most successful invaders among plants have significantly fewer pathogens in their areas of naturalization when compared to their natural ranges (Mitchell & Power, 2003). Of the 18 species of most dangerous invasive plants in Lithuania (Anonymous, 2016), only four (*Acer negundo, Echinocystis lobata* (Michx.) Torr. & A. Gray*, Lupinus polyphyllus* Lindl. and *Robinia pseudoacacia*) are hosts to alien mycobiota (all plant pathogens), and none of these fungi cause any serious damage to their hosts.

Future scenarios for alien fungal species in Lithuania

Distribution and spread of fungi are commonly determined by distribution of their hosts (in case of plant pathogens and mycorrhizal species), but are strongly influenced by climatic conditions as well: Desprez-Loustau et al. (2010) have found existing positive relationship between the frequency of occurrence of alien fungi and average annual rainfall and mean air temperature. According to all scenarios of the climate change, rise of mean annual temperature in Lithuania is imminent with unchanged or increased annual precipitation (Ozolinčius et al., 2014). These changes may affect not only indigenous plants, but may also boost invasion of alien species. Changing climatic conditions will inevitably cause stress to local plant communities making them more prone to fungal invasions. On the other hand, milder climate will precipitate arrival and establishment of new fungal species, which sometimes could be harmful to the natural ecosystems and human society (Dukes et al., 2009; Santini et al., 2013). Thus, for planning preventive measures in agriculture, forestry and nature conservation, regular and intensive monitoring and detailed studies on occurrence, spread and invasiveness of the alien fungi are to be carried out continuously, and the present list of species is by no means a final one to Lithuania.

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LIETUVOS SVETIMŽEMIAI GRYBAI: RŪŠIŲ SĄRAŠAS, JŲ DABARTINIS STATUSAS IR TROFINĖ STRUKTŪRA

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Santrauka

Straipsnyje pateikiama išsami svetimžemių grybų (išskyrus į grybus panašius oomikotus) apžvalga, apimanti visas nuo XIX a. pradžios iki šių dienų Lietuvoje užfiksuotas rūšis. Pateikiamas 142 svetimžemių grybų rūšių sąrašas, kuriame daugumą sudaro biotrofai (125 rūšys), tuo tarpu mikorizinių (8 rūšys) ir saprotrofinių (9 rūšys) yra gerokai mažiau. Atliekant analizę, buvo įvertintas kiekvienos rūšies paplitimas Lietuvoje bei jų statusas. Didelė dalis svetimžemių grybų rūšių (58) laikomos įsitvirtinusiomis Lietuvoje, trys rūšys (*Auricularia auricula-judae, Aureoboletus projectellus, Lecanosticta acicola*) intensyviai plintančiomis, trijų rūšių (*Serpula lacrymans, Synchytrium endobioticum, Tilletia caries*) paplitimas mažėja, viena rūšis (*Laricifomes officinalis*) laikoma išnykusia. Penkios saprotrofinės grybų rūšys yra efemeromicetai, kurie randami retkarčiais, visada tik patalpose ir neišgyvena natūralioje aplinkoje. Daugiau kaip pusės svetimžemių rūšių (73) statusas yra nežinomas, kadangi jos aptiktos vos po kelis kartus, o joms tinkamų augaviečių mažai arba augalai šeimininkai šalyje reti. Daugiausia svetimžemių rūšių Lietuvoje buvo užregistruota 1980–2000 m., tas faktas atspindėjo padažnėjusį prekių transportavimą ir aktyviausią mikologų veiklos periodą šalyje. Remiantis klimato kaitos scenarijais Lietuvai prognozuojamas tolesnis svetimžemių grybų rūšių skaičiaus didėjimas.