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Ectomycorrhizal and saprotrophic macrofungi associated with woody plants in the Borova hora arboretum

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Abstract: A survey of macrofungi in collections of woody plant species in the Borova hora arboretum (Central Slovakia) which are originally grew in natural forests of Slovakia was conducted during both Systematic botany and Mycology courses within vegetation periods 2010-2015. List of all recorded ectomycorrhizal and saprotrophic macrofungi is presented. A total of 211 macrofungal species were recorded. Of that 205 were Basidiomycota and 6 Ascomycota. These were represented by 103 species of ectomycorrhizal symbionts, 24 species of saprotrophic wood-decaying fungi and 84 species of saprotrophic terricolous fungi. Data as to types of fruitbodies recorded as well as case dichotomous identification key of chosen species are also given.

Keywords: Borova hora arboretum, macromycetes, woody plants, education

Introduction

The Borova hora arboretum is an important research and educational object, belonging to the Technical University in Zvolen (Central Slovakia). The planting

of woody plants started here in 1965. It is aimed, above all, at the protection and conservation of genetic resources of Slovak dendroflora (STAŠIOV et al. 2012). Students of the Faculty of Ecology and Environmental Sciences of the Technical University in Zvolen make use of the Borova hora arboretum collections in the courses of their Master´s degree study programme „Ecology and biodiversity conservation" as well as within the practical training. The Systematic botany and Mycology courses within vegetation periods 2010-2015 were attended by more than 150 students and the results of our mycological research are presented in this paper. List of all recorded ectomycorrhizal and saprotrophic macrofungi is presented. Morphological types are given of all recorded fruitbodies. Finally, dichotomous identification key for twenty chosen species is available.

Material and methods

The Borova hora arboretum is located near the middle reach of the Hron River, about 3 km NW from the centre of Zvolen. It lies on the SW foot of the Zvolenská pahorkatina hills, which belongs, from the viewpoint of phytogeography to the Zvolenská kotlina basin. The arboretum has a hilly character with the range of altitudes 290 m (NW part) to 377 m in the eastern part (LUKÁČIK et al. 2005, STAŠIOV et al. 2015). The town of Zvolen belongs to the warm region and warm, moderately humid district with cold winters. The mean annual temperature of this region is +8.8℃, the mean temperature in the vegetation period is +15.6℃. Mean annual amount of precipitations is 640 mm, 399 mm in the vegetation period (STAŠIOV et al. 2012).

A survey of macrofungi in the arboretum was conducted during both Systematic botany and Mycology courses within vegetation periods 2010-2015. Nomenclature of fungi follows Index fungorum (Index Fungorum. http://www.indexfungorum.org. Accessed November 2015).

Results

During both Systematic botany and Mycology courses within vegetation periods 2010-2015 at Borova hora arboretum 211 macrofungal species were recorded. Of that 103 were ectomycorrhizal symbionts, 24 saprotrophic wood-decaying fungi and 84 saprotrophic terricolous fungi.

The list of recorded species

Ectomycorrhizal macrofungi: *Amanita citrina* Pers., *Amanita crocea* (Quél.) Singer, *Amanita excelsa* (Fr.) Bertill., *Amanita fulva* Fr., *Amanita muscaria* (L.) Lam., *Amanita pantherina* (DC.) Krombh., *Amanita phalloides* (Vaill. ex Fr.) Link, *Amanita rubescens* Pers., *Amanita vaginata* (Bull.) Lam., *Boletus edulis* Bull., *Boletus erythropus* Pers., *Boletus reticulatus* Schaeff., *Boletus subtomentosus* L. = *Xerocomus subtomentosus* (L.) Quél., *Butyriboletus regius* (Krombh.) Arora & J.L. Frank = *Boletus regius* Krombh., *Cantharellus cibarius* Fr., *Clitopilus prunulus* (Scop.) P. Kumm., *Cortinarius alboviolaceus* (Pers.) Fr., *Cortinarius caerulescens* (Schaeff.) Fr., *Cortinarius hinnuleus* Fr., *Cortinarius torvus* (Fr.) Fr.,

Cortinarius triumphans Fr., *Cortinarius trivialis* J.E. Lange, *Craterellus cornucopioides* (L.) Pers., *Chalciporus piperatus* (Bull.) Bataille, *Chroogomphus rutilus* (Schaeff.) O.K. Mill., *Cyanoboletus pulverulentus* (Opat.) Gelardi, Vizzini & Simoini = *Boletus pulverulentus* Opat., *Geastrum triplex* Jungh., *Gomphidius glutinosus* (Schaeff.) Fr., *Gomphidius maculatus* (Scop.) Fr., *Gyrodon lividus* (Bull.) Sacc., *Hebeloma crustuliniforme* (Bull.) Quél., *Hebeloma mesophaeum* (Pers.) Quél., *Hebeloma sinapizans* Paulet) Gillet, *Hygrophorus agathosmus* (Fr.) Fr., *Hygrophorus chrysodon* (Batsch) Fr., *Hygrophorus eburneus* (Bull.) Fr., *Hygrophorus hypothejus* (Fr.) Fr., *Hygrophorus lucorum* Kalchbr., *Hygrophorus piceae* Kühner, *Hygrophorus pustulatus* (Pers.) Fr., *Imleria badia* (Fr.) Vizzini = *Xerocomus badius* (Fr.) E.-J. Gilbert, *Inocybe corydalina* Quél., *Inocybe geophylla* (Bull.) P. Kumm., *Laccaria tortilis* (Bolton) Cooke, *Laccaria laccata* (Scop.) Cooke, *Laccaria amethystina* Cooke, *Lactarius blennius* (Fr.) Fr., *Lactarius circellatus* Fr., *Lactarius deliciosus* (L.) Gray, *Lactarius deterrimus* Gröger, *Lactarius glyciosmus* (Fr.) Fr., *Lactarius necator* (Bull.) Pers., *Lactarius pinicola* Smotl. ex Z. Schaef., *Lactarius piperatus* (L.) Pers., *Lactarius porninsis* Rolland, *Lactarius pubescens* Fr., *Lactarius quietus* (Fr.) Fr., *Lactarius rufus* (Scop.) Fr., *Lactarius salmonicolor* R. Heim & Leclair, *Lactarius scrobiculatus* (Scop.) Fr., *Lactarius torminosus* (Schaeff.) Gray, *Lactarius vellereus* (Fr.) Fr., *Lactarius volemus* (Fr.) Fr., *Leccinum duriusculum* (Schulzer ex Kalchbr.) Singer, *Leccinum pseudoscabrum* (Kallenb.) Šutara, *Leccinum scabrum* (Bull.) Gray, *Paxillus involutus* (Batsch) Fr., *Pseudocraterellus undulatus* (Pers.) Rauschert, *Ramaria abietina* (Pers.) Quél., *Rheubarbariboletus armeniacus* (Quél.) Vizzini, Simonini & Gelardi = *Xerocomus armeniacus* (Quél.) Quél., *Russula amethystina* Quél., *Russula aeruginea* (L.) Fr., *Russula aurea* Pers., *Russula cyanoxantha* (Schaeff.) Fr., *Russula chloroides* (Krombh.) Bres., *Russula emetica* (Schaeff.) Pers., *Russula foetens* Pers., *Russula integra* (L.) Fr., *Russula mustelina* Fr., *Russula nigricans* Fr., *Russula olivacea* (Schaeff.) Fr., *Russula queletii* Fr., *Russula virescens* (Schaeff.) Fr., *Russula xerampelina* (Schaeff.) Fr., *Scleroderma verrucosum* (Bull.) Pers., *Suillellus luridus* (Schaeff.) Murrill = *Boletus luridus* Schaeff., *Suillus collinitus* (Fr.) Kuntze, *Suillus granulatus* (L.) Roussel, *Suillus grevillei* (Klotzsch) Singer, *Suillus luteus* (L.) Roussel, *Thelephora terrestris* Ehrh., *Tricholoma atrosquamosus* Sacc., *Tricholoma fulvum* (DC.) Bigeard & H. Guill., *Tricholoma imbricatum* (Fr.) P. Kumm., *Tricholoma portentosum* (Fr.) Quél., *Tricholoma saponaceum* (Fr.) P. Kumm., *Tricholoma scalpturatum* (Fr.) Quél., *Tricholoma sejunctum* (Sowerby) Quél., *Tricholoma sulphureum* (Bull.) P. Kumm., *Tricholoma terreum* (Schaeff.) P. Kumm., *Tricholoma vaccinum* (Schaeff.) P. Kumm., *Xerocomellus chrysenteron* (Bull.) Šutara = *Xerocomus chrysenteron* (Bull.) Quél., *Xerocomellus pruinatus* (Fr. & Hök) Šutara = *Boletus pruinatus* Fr. & Hök.

Saprotrophic wood-decaying macrofungi: *Abortiporus biennis* (Bull.) Singer, *Auricularia auricula-judae* (Bull.) Quél., *Bjerkandera adusta* (Willd.) P. Karst., *Calocera viscosa* (Pers.) Fr., *Coprinellus micaceus* (Bull.) Vilgalys, Hopple & Jacq. Johnson, *Cyathus striatus* (Huds.) Willd., *Daedalea quercina* (L.) Pers., *Flammulina velutipes* (Curtis) Singer, *Fomes fomentarius* (L.) Fr., *Hypholoma*

fasciculare (Huds.) P. Kumm., *Hypholoma lateritium* (Schaeff.) P. Kumm. = *Hypholoma sublateritium* (Fr.) Quél., *Lenzites betulina* (L.) Fr., *Lycoperdon pyriforme* Schaeff., *Panellus serotinus* (Pers.) Kühner, *Piptoporus betulinus* (Bull.) P. Karst., *Polyporus lipsiensis* (Batsch) E.H.L. Krause = *Ganoderma lipsiense* (Batsch) G.F. Atk., *Schizophyllum commune* Fr., *Steccherinum ochraceum* (Pers.) Gray, *Stereum hirsutum* (Willd.) Pers., *Stereum rugosum* Pers., *Tapinella atrotomentosa* (Batsch) Šutara = *Paxillus atrotomentosus* (Batsch) Fr., *Trametes hirsuta* (Wulfen) Lloyd, *Trametes versicolor* (L.) Lloyd, *Xylaria hypoxylon* (L.) Grev.

Saprotrophic terricolous macrofungi: *Agaricus arvensis* Schaeff., *Agaricus campestris* L., *Agaricus semotus* Fr., *Agaricus sylvaticus* Schaeff., *Agaricus urinascens* (Jul. Schäff. & F.H. Møller) Singer = *Agaricus macrosporus* (F.H. Møller & Jul. Schäff.) Pilát, *Agaricus xanthodermus* Genev., *Aleuria aurantia* (Pers.) Fuckel, *Ampulloclitocybe clavipes* (Pers.) Redhead, Lutzoni, Moncalvo & Vilgalys = *Clitocybe clavipes* (Pers.) P. Kumm., *Bolbitius titubans* (Bull.) Fr. = *Bolbitius vitellinus* (Pers.) Fr., *Bonomyces sinopicus* (Fr.) Vizzini = *Clitocybe sinopica* (Fr.) P. Kumm., *Bovista plumbea* Pers., *Calocybe gambosa* (Fr.) Donk, *Chlorophyllum rachodes* (Vittad.) Vellinga = *Macrolepiota rachodes* (Vittad.) Singer, *Clavulina cinerea* (Bull.) J. Schröt., *Clavulina rugosa* (Bull.) J. Schröt., *Clitocybe dicolor* (Pers.) Murrill, *Clitocybe gibba* (Pers.) P. Kumm., *Clitocybe nebularis* (Batsch) P. Kumm., *Clitocybe odora* (Bull.) P. Kumm., *Clitocybe phyllophila* (Pers.) P. Kumm., *Clitocybe vibecina* (Fr.) Quél., *Coprinellus disseminatus* (Pers.) J.E. Lange = *Coprinus disseminatus* (Pers.) P. Kumm., *Coprinellus domesticus* (Bolton) Vilgalys, Hopple & Jacq. Johnson = *Coprinus domesticus* (Bolton) Gray, *Coprinus comatus* (O.F Müll.) Pers., *Cuphophyllus pratensis* (Fr.) Bon = *Hygrocybe pratensis* (Fr.) Murrill, *Cystoderma amianthinum* (Scop.) Fayod, *Cystoderma carcharias* (Pers.) Fayod, *Entocybe nitida* (Quél.) T.J. Baroni, Largent & V. Hofst. = *Entoloma nitidum* Quél., *Entoloma clypeatum* (L.) P. Kumm., *Entoloma porphyrophaeum* (Fr.) P. Karst., *Gliophorus psittacinus* (Schaeff.) Herink = *Hygrocybe psittacina* (Schaeff.) P. Kumm., *Gymnopus brassicolens* (Romagn.) Antonín & Noordel., *Gymnopus confluens* (Pers.) Antonín, Halling & Noordel., *Gymnopus dryophilus* (Bull.) Murrill, *Gymnopus perforans* (Hoffm.) Antonín & Noordel. = *Marasmiellus perforans* (Hoffm.) Antonín, Halling & Noordel., *Gymnopus peronatus* (Bolton) Gray, *Helvella elastica* Bull., *Helvella lacunosa* Afzel., *Hygrocybe ceracea* (Sowerby) P. Kumm., *Hygrocybe coccinea* (Schaeff.) P. Kumm., *Hygrocybe conica* (Schaeff.) p. Kumm., *Hygrocybe punicea* (Fr.) P. Kumm., *Infundibulycibe geotropa* (Bull.) Harmaja = *Clitocybe geotropa* (Bull.) Quél., *Lacrymaria lacrymabunda* (Bull.) Pat., *Leotia lubrica* (Scop.) Pers., *Lepista flaccida* (Sowerby) Pat. = *Clitocybe inversa* (Scop.) Quél., *Lepista nuda* (Bull.) Cooke, *Lepista personata* (Fr.) Cooke, *Lepiota clypeolaria* (Bull.) P. Kumm., *Lepiota cristata* (Bolton) P. Kumm., *Leucoagaricus leucothites* (Vittad.) Wasser, *Leucoagaricus nympharum* (Kalchbr.) Bon = *Macrolepiota puellaris* (Fr.) M.M. Moser, *Leucocybe connata* (Schumach.) Vizzini, P. Alvardo, G. Moreno & Consiglio = *Lyophyllum connatum* (Schumach.) Singer, *Lycoperdon excipuliforme* (Scop.) Pers., *Lycoperdon molle*

Pers., *Lycoperdon perlatum* Pers., *Lycoperdon pratense* Pers. = *Vascellum pratense* (Pers.) Kreisel, *Lycoperdon umbrinum* Pers., *Lycoperdon utriforme* Bull. = *Calvatia utriformis* (Bull.) Jaap, *Lyophyllum decastes* (Fr.) Singer, *Macrolepiota mastoidea* (Fr.) Singer, *Macrolepiota procera* (Scop.) Singer, *Marasmius oreades* (Bolton) Fr., *Melanoleuca grammopodia* (Bull.) Murrill, *Mutinus caninus* (Huds.) Fr., *Mycena aetites* (Fr.) Quél., *Mycena aurantiomarginata* (Fr.) Quél., *Mycena cinerella* (P. Karst.) P. Karst., *Mycena citrinomarginata* Gillet, *Mycena epipterygia* (Scop.) Gray, *Mycena galopus* (Pers.) P. Kumm., *Mycena pura* (Pers.) P. Kumm., *Mycena rosella* (Fr.) P. Kumm., *Mycena vulgaris* (Pers.) P. Kumm., *Mycetinis alliaceus* (Jacq.) Earle ex A.W. Wilson & Desjardin = *Marasmius alliaceus* (Jacq.) Fr., *Parasola plicatilis* (Curtis) Redhead, Vilgalys & Hopple = *Coprinus plicatilis* (Curtis) Fr., *Phallus impudicus* L., *Otidea onotica* (Pers.) Fuckel, *Pholiota gummosa* (Lasch) Singer, *Pseudoclitocybe cyathiformis* (Bull.) Singer, *Ramariopsis subtilis* (Pers.) R.H. Petersen = *Clavulinopsis subtilis* (Pers.) Corner, *Rhodocollybia butyracea* (Bull.) Lennox, *Rhodocollybia maculata* (Alb. & Schwein.) Singer, *Spathularia flavida* Pers.

Morphological types of fruitbodies recorded

A total of 14 morphological types of fruitbodies were recorded. Of that 12 were basidiocarps and 2 ascocarps. There are twelve morphological types of basidiocarps:

pilothecium: open basidiocarp is more or less clearly divided into pileus and stem (pileus and stem is missing only exceptionally), annual, without concentric layers, if it hits an obstacle during the growth, it pushes it away because everything is setteled already in primordium which is just increasing; hymenophore of various types is formed on the underside of the pileus (hymenophore is absent rarely):

pilothecium agaricoid: basidiocarp with distinct pileus and central stem, context of pileus and stem is clearly seperated (*Agaricus* spp., *Amanita* spp. and many others);

pilothecium canthareloid: basidiocarp with central stem, context of stem is not distinct from the context of pileus (e.g., *Cantharellus cibarius*);

pilothecium cypheloid: basidiocarp with diagonally upward facing stem, which is not connected to the hymenophore (*Piptoporus betulinus*);

pilothecium resupinate: basidiocarp without stem, pileus is attached to the substrate (*Schizophyllum commune*);

holothecium: basidiocarp without pileus and stem differentiation, hymenium is on the basidocarp's surface:

holothecium clavarioid: basidiocarp unbranched, cylindrical, spindle or clavate (e.g., *Calocera viscosa*);

holothecium ramarioid: basidiocarp is coral-like branched (e.g., *Clavulina rugosa*);

crustothecium: open basidiocarp, sometimes divided into the pileus and stem, concentrically layered, overgrowing obstacles:

crustothecium fomitoid: basidiocarp without stem, laterally attached to the substrate (*Fomes fomentarius* and others);

crustothecium stereoid: basidiocarp partially fan-shaped, partially covering the substrate (*Stereum hirsutum* and others);

crustothecium corticioid: crust-like basidiocarp attached to the substrate (e.g., *Bjerkandera adusta*);

plectothecium: closed basidiocarp of Gasteromycetes with scattered or dispersed basidia, visible „veins“ in the section of gleba (*Scleroderma verrucosum*);

schizothecium: closed basidiocarp of Gasteromycetes with cavities of schizogen origin lined with hymenium (*Lycoperdon excipuliforme* and others);

clatrothecium: closed basidiocarp of Gasteromycetes, gleba is divided by coral-like branched plates and when mature it is hold on receptaculum (e.g., *Phallus impudicus*).

There are two morphological types of ascocarps:

apothecium: disk-shaped or cup-shaped ascocarp (e.g., *Aleuria aurantia*);

perithecium: flask-shaped ascocarp within the stroma (*Xylaria hypoxylon*).

Dichotomous identification key: a case study of twenty chosen species

1. a. Basidiocarp branched, usually forked near the tips.…..... *Calocera viscosa*
   b. Basidiocarp unbranched..... 2.
2. a. Basidiocarp with stem differentiation..... 3.
   b. Basidiocarp without properly formed stem..... 4.
3. a. Stem with ring..... 11.
   b. Stem without ring..... 15.
4. a. Gilled hymenophore..... *Schizophyllum commune*
   b. Different type of hymenohpore..... 5.
5. a. Smooth hymenohpore..... *Stereum hirsutum*
   b. Poroid hymenophore..... 6.
6. a. Maze-like pore surface..... *Daedalea quercina*
   b. Normal poroid surface..... 7.
7. a. Cap surface with sharply contrasting concentric zones of color…. *Trametes versicolor*
   b. Cap surface without contrasting zones..... 8.
8. a. Cap very densely hairy..... *Trametes hirsuta*
   b. Cap surface not hairy..... 9.
9. a. White context, corky texture..... *Piptoporus betulinus*
   b. Brown context, woody texture..... 10.
10. a. Basidiocarp with granular core..... *Fomes fomentarius*
    b. Basidiocarp without granular core..... *Polyporus lipsiensis*
11. a. Moveable ring..... 12.
    b. Non-moveable ring..... 13.
12. a. Flesh turns reddish when cut or bruised..... *Chlorophyllum rachodes*
    b. Flesh keeps the same color when cut or bruised..... *Macrolepiota procera*

13. a. Spore print chocolate brown..... *Agaricus arvensis*
    b. Spore print white..... 14.
14. a. Color of the cap is deep to bright red..... *Amanita muscaria*
    b. Color of the cap is pale greenish yellow, fading quickly to nearly white…. *Amanita citrina*
15. a. Spore print white..... 16.
    b. Spore print brown..... 17.
16. a. Gills not dense, odor radishlike..... *Mycena pura*
    b. Gills dense, without radishlike odor..... *Tricholoma imbricatum*
17. a. Poroid hymenophore..... *Leccinum scabrum*
    b. Gilled hymenophore..... 18.
18. a. Basidiocarps growing in clusters..... 19.
    b. Basidiocarps growing scattered or gregariously..... *Cortinarius trivialis*
19. a. Caps without reddish colors in the central part..... *Hypholoma fasciculare*
    b. Caps with brick-red to reddish center, on the edge yellow ocher… *Hypholoma lateritium*

Discussion

A great richness of dendroflora in the Borova hora arboretum, with ca. 1800 woody plant taxa, provides an oportunity for study the species spectrum of fungi and their associations with woody plants. Despite its very high biodiversity of plant and fungal taxa the arboretum is one of the less investigated suburban areas of Slovakia concerning mycology. The only one mycological research in this area was carried out by GLEJDURA (1997). He provides an overview of the identified rare fungal species. This article contains a list of the arboretum macrofungal taxa that have been classified as ectomycorrhizal or saprotrophic. Wood-decaying parasitic macrofungi, in contrast to the saprotrophs, are very scarce in this area. These results can benefit scientific workers in mycocoenological studies (MIHÁL 1993, MIHÁL & BUČINOVÁ 2005) and mycorrhizal applications (REPÁČ et al. 2011a,b). The results obtained can also benefit students of other universities, e.g., students of the Faculty of Natural Sciences of the Matej Bel University in Banská Bystrica also these results will be used in the course „Systematics of cyanobacteria, algae and fungi“ of their Bachelor´s degree study programe „Pedagogy of academy subjects“.

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