BIOMASS OF EPIGEIC SPOROCARPS IN SUBMOUNTAIN BEECH STANDS EXPOSED TO DIFFERENT IMMISSION LOAD

IVAN MIHÁL, KATARÍNA BUČINOVÁ

Institute of Forest Ecology of the Slovak Academy of Sciences, Štúrova 2, 960 53 Zvolen, Slovak Republic; e-mail: mihal@sav.savzv.sk, bucinova@sav.savzv.sk

Abstract

Mihál I., Bučinová K.: Biomass of epigeic sporocarps in submountain beech stands exposed to different immission load. Ekológia (Bratislava), Vol. 26, No. 2, p. 201–210, 2007.

In this contribution we evaluate the production dynamics of epigeic sporocarps in saprophytic macromycetes growing in submountain beech monocultures. The studied research plots have been exposed to different immission load. On all three plots, we have determined a total number of 121 macromycetes species, 70 of them were involved into the evaluation of the biomass production. The species with the highest biomass production were: on the Research monitoring plot (RMP) Žiar nad Hronom: *Marasmius rotula, Rhodocollybia butyracea f. asema, Clitocybe brumalis, Agrocybe praecox*; on the Permanent research plot (PRP) Jalná: *Strobilomyces strobilaceus*, *Hypholoma fasciculare, Clitocybe nebularis, Xerocomus chrysenteron*; on the Experimental and ecological stationary (EES) Kováčová: *Lycoperdon pyriforme, Lactarius piperatus, Clitocybe nebularis, Hygrophorus eburneus*. We have recorded an increasing trend in biomass production in ectomycorrhizal macromycetes from the most loaded RMP Žiar nad Hronom to the lowest loaded plot EES Kováčová. At the same time, we have found an increase in sporocarp biomass of saprophytic macromycetes and simultaneously the lowest occurrence of ectomycorrhizal ones on the plot RMP Žiar nad Hronom. Relatively low values of the sporocarp biomass production on all three plots were caused by unfavourable microclimatic conditions during the study period and poor species composition of phytocoenoses in beech monocultures.

Key words: beech, *Fagus sylvatica* L., macromycetes, biomass of epigeic sporocarps, immission load, Slovakia

Introduction

In 1996, beech forest stands represented 30.3% of the total timber land area in the Slovak Republic. Consequently, beech is the woody plant number one of the Slovak forests and its importance for landscape ecology and forest management is indisputable. Up to the most recent time, biotic factors – insect attacks and infection by pathogenic fungi – have been considered only low significant in relation to beech decline (Korpeľ et al., 1991). However, there is evident a steep increase in damage to beech trees caused by biotic factors in the last years. This is also true for fungal diseases – mycoses. Mycoses are frequently chronic. Their distribution can range from a local attack to an epiphytocia.

Macromycetes growing in beech forest stands represent an intricate ecotrophic-ecotopic system connected with beech and the associated environment. The most important indicators distinctive for a given mycocoenosis involve the production of fruiting bodies (or epigeic sporocarps) of the individual macromycetes species. The problems of determination, of abundance and production of sporocarps in macromycetes in beech stands were in Slovakia studied by Janík, Mihál (1995) and Mihál (1995a, b, 1997, 1998), in abroad by Holec (1994), Jennings, Lysek (1996), Matsuda (1994), Murphy, Miller (1993), Salerni, Perini (2004). Several authors also examined the species diversity, dominance and succession of macromycetes in beech stands. In Slovakia was the last issue studied by e.g. Mihál (1995c, 2002) and Pavlík (1997), in abroad e.g. by Adamczyk (1995), Andersson (1995).

In this contribution we evaluate the dynamics of production of epigeic sporocarps in macromycetes growing in submountain beech forest stands. The studied research plots are exposed to different immission load with the impact on the species diversity, dominance and succession of macromycetes as well as on the production dynamics of their epigeic sporocarps.

Material and methods

The research into the epigeic sporocarp biomass production was carried out in three beech monocultures exposed to different grades of immission load with origin from an emission source – the aluminium plant in Žiar nad Hronom. The detailed description of the research plots is summarized in Table 1.

The research was realised in vegetation periods 2003 and 2004 at intervals of three to five weeks (in 2003 on 28.5., 11.6., 15.7., 5.8., 10.9., 1.10., 11.11.; in 2004 on 19.5., 16.6., 13.7., 10.8., 23.9., 13.10., 8.11.).

In field surveys we recorded on research plots the macromycetes species diversity together with the abundance of their fruiting bodies. The evaluation of the biomass production was carried out with average samples (1–50 examples) of sporocarps of the relevant species. The sampled material was weighed in fresh and oven-dry state. The calculated average weight of one fruiting body was multiplied by the total abundance of exemplars of the given species identified over the whole study period (in $kg.ha^{-1}$). A more detailed description of the in-field method can be found in Mihál (1995a).

It is necessary to add that in some cases we only succeeded to find one single fruiting body of certain species over the whole period of study (e.g. *Inocybe rimosa, Pholiota adiposa, Scleroderma citrinum, Tricholoma sulphureum* and others). Such a fruiting body represented at the same time the average weight for the given species. Also fruticose and resupinate fruiting bodies of lignicolous species were excluded from the evaluation of the production because it was not possible to determine the number of their fruiting bodies precisely (e.g. *Bisporella citrina, Calocera viscosa, Hypoxylon multiforme, Trametes versicolor* and others). This has influenced the abundance of the species involved into the evaluation. For example, on all the three research plots we determined 121 macromycetes species; on the other hand, only 70 species (i.e. 57.9% from the total species number) were involved into the production evaluation. There were the following total numbers of the production-evaluated species: on the RMP 29 species (47.5% from the total number of 61 species determined on the RMP), on the PRP 39 ones (50.0% from the 78 ones identified on PRP) and at the EES 46 ones (67.6% from 61 ones at the EES).

The problems connected with the methods correspond to the experience of other authors who studied the issue of biomass determination for epigeic sporocarps. For example, Gáper (1992) describes problems connected with

T a b l e 1. Characteristics of the research plots.

Characteristics	RMP Žiar nad Hronom	RPP Jalná	EES Kováčová
Orographic unit	Štiavnické vrchy Mts	Štiavnické vrchy Mts	Kremnické vrchy Mts
Code of DFS	7479a	7479b	7380
Area [ha^{-1}]	0.15	0.25	0.15
Exposition	NW	W	W
Altitude [m]	470	610	470-490
Age of stand [years]	75-80	80-90	95-100
Stocking	0.7	0.8-0.9	0.8 – 0.9
Parent rock	ryolites tufits	andesite, tufits	andesite, tufits
Soil type	cambisol luvisol,	cambisol	cambisol
Forest type groups	Fagetum pauper	Querceto-Fagetum	Fagetum pauper inferiora
Average annual temperature [°C]	7.6	6.2	6.8
Average annual precipitations [mm]	750	850	778
Distance from emmission source [km]	2	7	18
Wet deposition*(in 1994) [$kg.ha^{-1}$]			
SO_4^{2-}	26.3	not done	18.1
F^-	2.5	not done	0.4

Notes**:** RMP – Research monitoring plot Žiar nad Hronom, PRP – Permanent research plot Jalná, EES – Ecological and experimental stationary Kováčová, Code of DFS – mapping grid of Database of Fauna of Slovakia
*– results of wet deposition taken from Dubová, Bublinec (1994)

methods of exact determination of biomass of ectomycorrhizal macromycetes from the viewpoint of determination of mycelium biomass and of persistence and frequency of occurrence of the fruiting bodies in the forest stand. Similarly, Holec (1994) studied the abundance and biomass production in the fruiting bodies and drew a conclusion that the absence of fruiting bodies in several years is not an exact demonstration about the absence of mycelium in the soil. The biological activity of the species is also influenced by the thickness of the litter layer and by the humus form. On the other hand, the biological activity does not need to be connected with the abundance of the macromycetes fruiting bodies.

Results and discussion

All the macromycetes species involved in the evaluation of the biomass production in sporocarps are listed in Table 2, together with their production values on the individual research plots. The summary of the biomass of sporocarps in years 2003 and 2004 is in Table 3. Taxonomic nomenclature of the macromycetes follows Marhold, Hindák (1998) and Škubla (2003). The complete list of macromycetes species determined on all three research plots is presented by Mihál (1995b, c, 2002), Mihál, Bučinová (2005).

It is necessary to point out that the given values of the sporocarps production reflect the overall status of the mycocoenoses on the research plots. In the case of more favourable

T a b l e 2. Production of macromycetes in individual research plots during investigated period (fresh biomass of sporocarps [kg.ha^{-1}].

Species of fungi	RMP	PRP	EES	Total
Agrocybe praecox (P e r s.) F a y o d	2.494		0.499	2.993
Amanita vaginata (B u l l.) L a m.	1.012			1.012
Cantharellus cibarius F r.			0.326	0.326
C. pallens P i l á t			0.169	0.169
Clitocybe brumalis (F r.) P. K u m m.	4.020			4.020
C. metachroa (F r.) P. K u m m.	0.035			0.035
C. nebularis (B a t s ch.) P. K u m m.		1.225	1.020	2.245
C. odora (B u l l.) P. K u m m.			0.012	0.012
Coprinus micaceus (B u l l.) F r.	0.573	0.02	0.007	0.6
Cortinarius sp.			0.130	0.130
Cyathus striatus (H u d s.) W i l l d.	0.217	0.008		0.225
Entoloma rhodopolium f. nidorosum (F r.) N o o r d e l.			0.093	0.093
Gymnopilus penetrans (F r.) M u r r i l l	0.117	0.070		0.187
Gymnopus erythropus (P e r s.) A n t o n í n et al.	0.947			0.947
G. peronatus (B o l t o n) A n t o n í n et al.			0.134	0.134
Hebeloma crustuliniforme (B u l l .) Q u é l.		0.164		0.164
Hygrophorus eburneus (B u l l.) F r.	0.058	0.035	0.865	0.958
Hypholoma fasciculare (H u d s.) P. K u m m.	0.436	1.657		2.093
Inocybe rimosa (B u l l.) P. K u m m.			0.036	0.036
Laccaria amethystina (H u d s.) C o o k e	0.064	0.051	0.318	0.433
L. laccata agg.			0.064	0.064
Lactarius blennius (F r.) F r.	0.007			0.007
L. chrysorrheus F r.			0.013	0.013
L. piperatus (L.) G r a y	0.246	0.739	13.288	14.273
Lycoperdon lividum P e r s.	0.415			0.415
L. perlatum P e r s.	0.207	0.093	0.052	0.352
L. pyriforme S ch a e f f.			24.425	24.425
Marasmius alliaceus (J a c q.) F r.		0.026	0.679	0.705
M. rotula (S c o p.) F r.	11.209			11.209
Megacollybia platyphylla (P e r s.) K o t l. et P o u z a r		0.292	0.243	0.535
Mycena alcalina agg	0.021	0.022	0.006	0.049
M. citrinomarginata G i l l e t		0.097		0.097
M. galericulata (S c o p.) G r a y		0.194	0.041	0.235
M. galopus (P e r s.) P. K u m m.		0.005		0.005
M. haematopus (P e r s.) P. K u m m.	0.002	0.01	0.002	0.014
M. pura (P e r s.) P. K u m m.	0.018	0.141	0.09	0.249
M. polygramma (B u l l.) G r a y		0.016	0.036	0.052
M. renati Q u é l.		0.32	0.005	0.325
M. rosella (F r.) P. K u m m.		0.023	0.003	0.026
Panellus stipticus (B u l l.) P. K a r s t.	0.144			0.144
Peziza arvernensis B o u d.		0.449	0.514	0.963
Pholiota adiposa (B a t s ch) P. K u m m.			0.099	0.099
P. squarrosa (W e i g e l) P. K u m m.		0.060		0.060
Pleurotus ostreatus (J a c q.) P. K u m m.		0.353		0.353
P. pulmonarius (F r.) Q u é l.			0.211	0.211
Pluteus cervinus (S ch a e f f.) P. K u m m.	0.932	0.429	0.155	1.516
P. salicinus (P e r s.) P. K u m m.	0.015		0.001	0.016
Psathyrella piluliformis (B u l l.) P.D. O r t o n	0.993	0.123		1.116
P. spadiceogrisea (S ch a e f f.) M a i r e		0.142	0.079	0.221
Psilocybe inquilina var. crobula (F r.) H ř i l.	0.009			0.009

Polyporus brumalis (P e r s.) F r.		0.003		0.003
P. melanopus (S w.) F r.		0.003	0.002	0.005
P. varius (P e r s.) F r.	0.213	0.183	0.21	0.606
Rhodocollybia butyracea f. asema (F r.)A n t o n í n et al.	5.387	0.185	0.657	6.229
Russula amoenolens R o m a g n.			0.055	0.055
R. aurea P e r s.			0.324	0.324
R. cyanoxantha (S ch a e f f.) F r.			0.165	0.165
R. fellea (F r) F r.		0.033		0.033
R. firmula J u l. S ch a e f f.		0.066		0.066
R. foetens (P e r s.) F r.			0.055	0.055
R. galochroa (F r.) J.E. L a n g e			0.165	0.165
R. heterophylla (F r.) F r.		0.038		0.038
R. virescens (Schaeff.) F r.		0.033		0.033
Scleroderma citrinum P e r s.		0.017		0.017
Strobilomyces strobilaceus (S c o p.) B e r k.		3.503		3.503
Stropharia aeruginosa (C u r t i s) Q u é l.			0.10	0.10
Tricholoma sulphureum (B u l l.) P. K u m m.			0.293	0.293
Tubaria conspersa (P e r s.) F a y o d	0.015		0.015	0.03
Xerocomus chrysenteron (B u l l.) Q u é l.	0.604	1.209	0.201	2.014
Xerula melanotricha D ö r f e l t			0.269	0.269
X. radicata (Relhan) D ö r f e l t	0.523	0.6	0.238	1.361
Total	30.933	12.637	46.364	89.934

Abbreviations see in Table 1.

T a b l e 3. Production of macromycetes in individual research plots in 2003 and 2004 (fresh biomass of sporocarps [kg.ha^{-1}].

Years	RMP	PRP	EES	Total
2003	6.9975	2.27	3.8455	13.113
2004	23.9355	10.367	42.5185	76.821
Total	30.933	12.637	46.364	89.934

Abbreviations see Table 1.

microclimate changes, there should certainly have been recorded higher species diversity in macromycetes, together with higher abundance and production of the fruiting bodies. Unfavourable microclimatic conditions during the research period and poor species composition of the phytocoenoses in beech monocultures can be considered as the principal factors adversely influencing the mycocoenoses in these stands. For example, in dry years 1992 and 1993 we recorded in the stand on the PRP Jalná only 83 macromycetes species, which had produced only 817 sporocarps (Mihál, 1995b).

The highest biomass production on the RMP Žiar nad Hronom was recorded for the species: *Marasmius rotula, Rhodocollybia butyracea f. asema, Clitocybe brumalis, Agrocybe praecox*. In the case of the PRP Jalná there were: *Strobilomyces strobilaceus*, *Hypholoma fasciculare, Clitocybe nebularis, Xerocomus chrysenteron*, at the EES: *Lycoperdon pyri-*

Fig. 1. *Xerula radicata* (Relhan) Dörfelt – a very typical species of beech stands, occurring on all the three research plots (Photo: A. Cicák).

forme, Lactarius piperatus, Clitocybe nebularis, Hygrophorus eburneus. Fig. 1 illustrates a very typical species *Xerula radicata*, regularly occurring on all the three research plots, reaching, however, only low values of the fruiting bodies biomass production.

Several species in Table 2 with the highest or relatively high biomass production of sporocaps have also been referred by other authors as dominant species, with frequent occurrence and reaching high values of biomass production in beech forests. For example, the species *Hygrophorus eburneus* is according to Mihál (1998) a species occurring in the conditions of the stand at the EES Kováčová with high values of the biomass production (from 1991 to 1994 fluctuated the values of the fruiting bodies biomass production in this species from 0.71 to 63.19 $kg.ha^{-1}$). Also Adamczyk (1995) reports about this species as one of the most dominant in beech forest stands. Analogically to *Marasmius rotula*, Adamczyk assigns (l.c.) to the most dominant macromycetes in beech stands. The taxonomically related species *Marasmius alliaceus* was classified by Tyler (1991) to the macromycetes with the highest biomass production of sporocarps in beech forests. The fruiting bodies biomass amount produced by this species on the EES plot in 1991–1994 ranged from 0.32 to 4.97 $kg.ha^{-1}$ (Mihál, 1998). The species *Rhodocollybia butyracea f. asema* belonged to the species with the highest production of sporocarp biomass, primarily on the plot RMP. Murphy, Miller (1993) found, that the taxonomically relative species *Collybia subnuda*, a dominant saprophytic fungus of deciduous forests produced from 390 to 930 sporocarps, converted to from 2.6 to 6.1 $kg.ha^{-1}$ of the fresh weight of the sporocarps. In the stand on the EES plot we evaluated the sporocarp biomass production for the saproparasitic species *Armillaria ostoyae* over the period 1991–1994. On the other hand, in years 2003 and 2004 the species was absent on all the research plots. The dynamics of fruiting bodies of this species at the EES in 1991–1994 ranged from 65.4 to 143.8 $kg.ha^{-1}$ of the fresh weight of sporocarps (Mihál, 1995a).

In addition to the direct evaluation of the dynamics of sporocarp biomass production, we studied at the EES the ratio between the dynamics of sporocarp biomass production ($kg.ha^{-1}$) and the dynamics of aboveground biomass production in herbs ($t.ha^{-1}$) in dependence on the stocking on the partial research plots. We have found that the dynamics of sporocarp biomass increased beginning with the clearcut plot to the plot with a stocking of 0.9; the trend in biomass of herbs was just opposite (Janík, Mihál, 1995). This phenomenon is connected with the microclimatic, trophic and topic conditions on the individual partial plots. Important factors are also: sufficient amount of dead wood substrate, the thickness of litter layer, the grade of weeding on the partial plots, stocking grade, etc. According to Holec (1994), the litter layer thickness and humus form are the factors controlling not only the abundance of saprophytic but also ectomycorrhizal fungi and their mutual ratio. For example, beech stands with mull humus form contain more saprophytic than ectomycorrhizal macromycetes. Murphy, Miller (1993) found that in deciduous forests was dominant also the saprophytic species *Collybia subnuda*. Tyler (1991) also examined the influence of litter removal on the production of macromycetes fruiting bodies. This author found that on the plot with litter layer was higher fruiting bodies production in the saprophytic species *Mycena cinerella, M. galopoda* and *Rhodocollybia butyracea f. asema*; the plots from which the litter had been removed, showed the highest production of ectomycorrhizal species from the genera

T a b l e 4. Proportion of sporocarps production of saprophytic macromycetes to production of ectomycorrhizal macromycetes on individual research plots (kg.ha^{-1} of fresh biomass of sporocarps).

Plots	LS	TS	ES	Total
RMP	4.945	24.141	1.845	30.931
PRP	2.531	3.822	6.284	12.637
EES	28.038	2.367	15.959	46.364
Total	35.514	30.33	24.088	89.932

Notes: LS – lignicolous saprophyte,
TS – terrestical saprophyte,
ES – ectomycorrhizal symbionts

Lactarius and *Russula*. On the other hand, Salerni and Perini (2004) studying the dynamics of the fruiting bodies of the ectomycorrhizal species *Boletus edulis* found the highest amount of fruiting bodies in this species namely on plots with sufficient litter layer.

In conditions of submountain beech monocultures exposed also to immission load, are very important ratios between lignicolous, saprophytic and ectomycorrhizal macromycetes. The dynamics of sporocarp biomass in saprophytic and ectomycorrhizal macromycetes on the research plots is summarised in Table 4 showing the different values of biomass production in these ecotrophic groups on the individual plots. At the same time, we can see an increasing trend in biomass production of ectomycorrhizal macromycetes from the most immission-loaded plot RPM to the lowest loaded plot at the EES. This fact is very important for the forest health status and ecological stability of forest stands. The same trend was also observed at the EES over the period 1991–1994 (Mihál, 2002), primarily in ectomycorrhizal macromycetes (genera *Craterellus, Hygrophorus, Lactarius, Russula* and others). In a similar way, Matsuda (1994) studying the issue in thinned stands, found the highest abundance of sporocarps for the ectomycorrhizal genus *Russula*. It is necessary to aware that 30–35% of the assimilation products of a beech forest are metabolised by mycorrhizal macromycetes (Jennings, Lysek, 1996), and that the healthy beech trees have significantly higher numbers of vital mycorrhized roots compared to the declining trees (Power, Ashmore, 1996). From these facts it follows that the ectomycorrhizal symbionts on beech trees are crucially important for the health status of beech trees and ecological stability of beech stands.

The three research plots are exposed to different impact of immission load. The influence of airborne pollutants on the dynamics of the species diversity, abundance and distribution of fruiting bodies over the research plots has been discussed by Mihál (2002). These authors observed decreases in the species diversity, abundance and distribution of sporocarps on the plot RMP in comparison with the plots PRP and EES. At the same time, there were observed declines in abundance of ectomycorrhizal species and their sporocarp biomass on the plot RMP, in comparison with the plots PRP and EES. This phenomenon is also evident in Table 4. A conspicuous decrease in ectomycorrhizal symbionts on the plot RMP compared to the control (less immission-loaded plot) reports Pavlík (1997), at the same time observing an increase in abundance of saprophytic macromycetes, namely on the plot RMP. The observations of Pavlík (l.c.) have been confirmed by our evaluations of sporocarp biomass production on the examined plots. Table 4 shows evident that the biomass production was higher in saprophytic sporocarps compared to the biomass value in ectomycorrhizal macromycetes, namely on the plot RMP.

Conclusion

The research into biomass production in epigeic sporocarps was carried out in three stands of beech monocultures, each under different load by airborne pollutants. The pollutant source is the aluminium plant in Žiar nad Hronom. The research ran in the vegetation periods 2003 and 2004 at intervals of three to five weeks. In total, we have determined on all the research plots 121 macromycetes species, from this number, 70 species were involved into the evaluation of the production (i.e. 57.9% from the total species number). The species with the highest sporocarp biomass production were: on the RMP Žiar nad Hronom: *Marasmius rotula, Rhodocollybia butyracea f. asema, Clitocybe brumalis, Agrocybe praecox*; on the PRP Jalná: *Strobilomyces strobilaceus*, *Hypholoma fasciculare, Clitocybe nebularis, Xerocomus chrysenteron*; on the EES Kováčová: *Lycoperdon pyriforme, Lactarius piperatus, Clitocybe nebularis, Hygrophorus eburneus*. We have recorded an increasing trend in biomass production in ectomycorrhizal macromycetes from the most loaded RMP Žiar nad Hronom to the lowest loaded plot EES Kováčová. At the same time, we have found an increase in sporocarp biomass of saprophytic macromycetes and simultaneously the lowest occurrence of ectomycorrhizal ones on the plot RMP Žiar nad Hronom. Unfavourable climatic conditions during the research (drought) and poor species composition of the phytocoenoses of beech monocultures can be concluded as the main factors adversely influencing the mycocoenoses in such stands.

Translated by D. Kúdelová

Acknowledgements

The authors thank D. Kúdelová for translation of the paper. The study has been supported by the Grant Agency VEGA (Grant No. 2/4019/04).

References

Adamczyk, J., 1995: Ecological groups of macrofungi in beech forest on Częstochowa Uplands, Southern Poland. Feddes Repertorium, *106*: 303–315.

Andersson, H., 1995: Untersuchungen zur Pilzflora von *Fagus sylvatica* – Stubben. Zeitschrift fűr Mykologie, *61*: 233–244.

Dubová, M., Bublinec, E., 1994: Wet deposition and its chemisms (in Slovak). In Cicák, A. (ed.), Rámcové projekty ozdravných opatrení vo vytypovaných oblastiach – Žiar nad Hronom. Ref. úloha 15/PHÚ-OLH, ÚEL SAV Zvolen, 200 pp.

Gáper, J., 1992: Problems and possibilities of evaluation of ectomycorrhizal fungi biomass (in Slovak). In Metodológia v produkčnej ekológii. Proceedings, Arborétum Mlyňany – Ústav dendrobiológie SAV, Vieska nad Žitavou, p. 119–203.

Holec, J., 1994: Fungi of beech stands of the Šumava Mts. (in Czech). Živa, *2*: 52–54.
Janík, R., Mihál, I., 1995: The production of shoot biomass of herbage and selected terrestrial fungi in a beech ecosystem. Lesnícky časopis – Forestry Journal, *41*: 331–338.
Jennings, D.H., Lysek, G., 1996: Fungal biology – Understanding the fungal lifestyle. BIOS Scientific Publishers Limited, Guilford, United Kingdom, 156 pp.
Korpeľ, Š., Peňáz, J., Saniga, M., Tesař, V., 1991: Forest management (in Slovak). Príroda, Bratislava, 472 pp.
Marhold, K., Hindák, F., 1998: Check list of non-vascular and vascular plants of Slovakia (in Slovak). Veda, Bratislava, 687 pp.
Matsuda, Y., 1994: Seasonal occurrence and spatial distribution of fruitbodies of ectomycorrhizal fungi on the border of a man-made and naturally regenerated forest. Bulletin of the Nagoya University Forest, *13*: 109–118.
Mihál, I., 1995a: Abundance and production of *Armillaria ostoyae* (Romagn.) Herink in a fir-beech forest. Ekológia (Bratislava), *14*: 229–236.
Mihál, I., 1995b: Abundancy and distribution of fruitbodies of fungi under conditions of thinned beechwood (in Slovak). Lesnictví – Forestry, *41*: 218–223.
Mihál, I., 1995c: Príspevok k poznaniu mykoflóry bukových porastov severnej časti Štiavnických vrchov (in Slovak). Ochrana Prírody, *13*: 119–127.
Mihál, I., 1997: Produktionsverhältnisse der ausgewählten Basidiomyzeten in Bedingungen eines Tannebuchenwaldökosystem in dem Kremnické vrchy Gebirge. Folia Dendrologica, *23*: 111–120.
Mihál, I. 1998: Abundancy and production of selected Basidiomycetes in fir-beech forest stand of the Kremnické vrchy Mts (in Slovak). Folia Oecologica, *24*: 165–170.
Mihál, I., 2002: On the knowledge of mycoflora of the fir-beech forests in southern part of the Kremnické vrchy Mts (in Slovak). Ochrana Prírody, *21*: 196–206.
Mihál, I., Bučinová, K., 2005: Species diversity, abundance and dominance of macromycetes in beech forest stands. Journal of Forest Science, *51*: 187–194.
Murphy, J.F., Miller, O.K., 1993: The population biology of two litter decomposing agarics on a southern Appalachian Mts. Mycologia, *85*: 769–776.
Pavlík, M., 1997: Macromycetes species spectrum as a reflection of immission impact on beech forests (in Slovak). In Les – drevo – životné prostredie. Proceedings, TU Zvolen, p. 253–260.
Power, S.A., Ashmore, M.R., 1996: Nutrient relations and root mycorrhizal status of healthy and declining beech (*Fagus sylvatica* L.) in southern Britain. Water Air Soil Poll., *86*: 317–333.
Salerni, E., Perini, C., 2004: Experimental study for increasing productivity of *Boletus edulis* s.l. in Italy. Forest Ecology and Management, *201*: 161–170.
Škubla, P., 2003: Mycoflora Slovaca. Number of Copy 19 (in Slovak). Mycelium Edition, Bratislava, 1103 pp.
Tyler, G., 1991: Effects of litter treatments on the sporophore production of beech forest macrofungi. Mycological Research, *95*: 1137–1139.

Received 4. 4. 2005