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Macromycetes of permanent plots in cultural forests in the Moravskoslezské Beskydy Mts. and Vsetínské vrchy hills (Czech Republic)

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The mycoflora of cultural (artificial and managed subnatural) forests (i.e. beech, spruce and mixed forests) was studied in 18 permanent plots in the Moravskoslezské Beskydy Mts. and the adjacent part of the Vsetínské vrchy hills (Czech Republic) during the years 1998–2000. Altogether, 314 species of macromycetes were recorded. The highest number of species was recorded in plots in a young spruce forest on a former meadow (72 species) and a waterlogged spruce forest (67 species). Mycorrhizal fungi were the dominant group in older spruce forests (44.2 %), waterlogged spruce forests (43.3 %) and alder forest (45.6 %). A high percentage of terrestrial saprophytes was found in the young forest on a former meadow (43 %). Generally, common species prevailed. The main factor which influenced the species composition of all trophic groups was the composition of the tree layer. These results are compared with results from similar plots in the Czech Republic and neighbouring countries.

Key words: Czech Republic, macromycetes, cultural beech and spruce forests, mycocoenology, permanent plots, ecology

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V letech 1998–2000 byla studována mykoflóra kulturních lesů (bukové, smrkové a smíšené porosty) na 18 trvalých plochách v jižní části Moravskoslezských Beskyd a přilehlé oblasti Vsetínských vrchů. Celkem bylo zaznamenáno 314 druhů makromycetů. Druhově nejbohatší se jevily plochy v mladém smrkovém lese na bývalé louce (72 druhů) a v podmáčené smrčině (67 druhů). Mykorhizní druhy převládaly ve starších smrkových lesích (44.2 %), podmáčených smrkových lesích (43.3 %) a olšině (45.6 %), naopak vysoké procento terestrických saprofytů bylo zjištěno v mladém smrkovém lese na bývalé louce (43 %). V druhovém složení převažovaly běžné, ekologicky nepříliš specifické druhy. Hlavním faktorem ovlivňujícím druhové složení všech ekologických skupin bylo složení stromového patra. Výsledky jsou srovnávány s výsledky studia obdobných trvalých ploch v ČR a sousedních zemí.

INTRODUCTION

Cultural (artificial and managed subnatural) forests prevail in the landscape of the Czech Republic. It is assumed that the mycoflora of these forests is reduced in

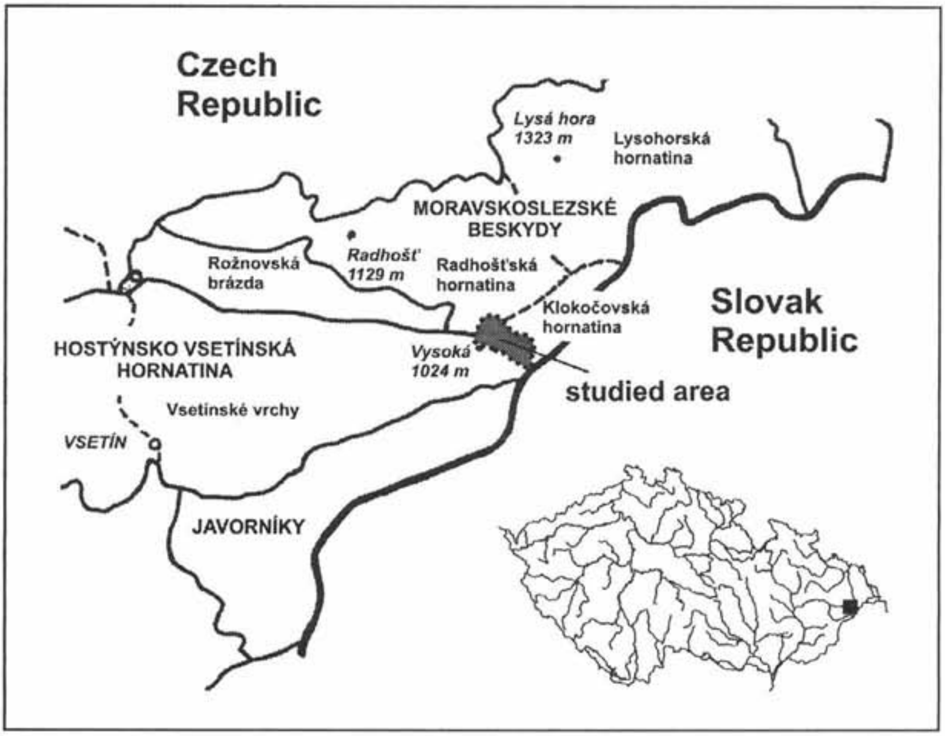

Fig. 1. Delimitation of the study area.

comparison with the mycoflora of natural forests. No details are known about this problem, because cultural types of forests have been studied only marginally (Pilát 1969; Holec 1992 – 1 plot; Hlůza 1988; Šmarda 1972, 1973) in the Czech Republic. In Central Europe cultural forests were studied mainly by Meisel-Jahn and Pirk (1955), Höffler (1955), Ricek (1981), and a review was given by Kost (1992).

This paper is based on my master's (MSc.) thesis. I studied permanent forest plots that were situated in two geomorphological subunits of the Západní Beskydy Mts. (in the southern part of the Moravskoslezské Beskydy Mts. and in the northern part of the Hostýnsko-vsetínská hornatina Mts.) about 690–930 m a.s.l. (Fig. 1). According to the phytogeographical division of the Czech Republic (Skalický 1989), they are situated in the Carpathian Oreophyticum (99a. Radhošťské Beskydy). The average annual temperature is 11.5 °C (station Bílá) to 12.3 °C (station Horní Bečva), the average annual precipitation 1144 mm (station Bílá) and 1101 mm (station Horní Bečva). The geological structure is dominated by Carpathian flysch; dominant soils are brown and acid soils. According to the map of potential vegetation (Neuhäuslová et al. 1998), the natural vegetation of the area was beech woodland of the *Dentario enneaphylli-Fagetum* association. The major part of the area was deforested during the last 400 years due to intensive grazing (Wallachian colonisation). Gradual afforestation by spruce monocultures was started in the 19th century. Nowadays, these spruce monocultures are dominant, whereas managed beech and mixed stands are confined to limited areas. The original beech-fir forests form a small percentage of the forests in the area and are protected by law in a few small reserves (Salajka, Razula). The mycoflora of these fragments of near-natural beech-fir forests is partly known (e.g. through mycofloristic research by Kuthan 1990). The managed subnatural and artificial forests have not yet been studied in this area.

The aim of this study was to contribute to the knowledge of macromycetes of cultural forests in the Moravskoslezské Beskydy Mts. and the Vsetínské vrchy hills and to evaluate and compare species richness, percentage of trophic groups and species composition on permanent plots with data from similar cultural or natural forest communities. Records of some rare and interesting species are published elsewhere (Vašutová 2004).

Methods

Permanent plots were established in 1998 and 1999 in different types of forests in the Moravskoslezské Beskydy Mts. and the adjacent part of the Vsetínské vrchy hills in order to cover most of the cultural (artificial, managed subnatural) forest types in the studied region (Table 1). The terms artificial forests and managed subnatural forests are used as follows. Artificial forests are made up by tree species allochthonous to the studied area (*Picea abies, Larix decidua*). Managed subnatural forests are made up by autochthonous tree species, but their age structure is homogeneous.

Three plots (60 × 60 m; I, II and III) in beech, mixed and spruce stands were visited at two-week intervals (from the second half of August to the first half of October at about one-week intervals) over a period of three years (60 visits). These visits contributed to a detailed study of fructification (Vašutová 2001). Later on, 15 additional plots of smaller area (50 × 50 m), which is comparable to plots of other Czech authors (Fellner 1985; Holec 1992, 1997; Lepšová 1988; Fellner and Soukup 1991), were established (plots 1–15). These plots were visited at approximately four-week intervals over a period of two years (10 visits: 1999: 18–7, 21–8, 5–9, 2–10; 2000: 1–6, 14–7, 23–8, 10–9, 20–9, 12–10). Only species that were found in plots I-III during ten visits (see above) were used for comparison between plots I-III and plots 1–15. These reduced plots are called Ir-IIIr.

Occurrence of macromycetes, i.e. fungi with sporocarps larger than c. 1 mm, was studied in the permanent plots. The following taxonomical groups (according to Kirk et al. 2001) were included: Agaricales, Russulales (p.p.), Boletales (p.p.), Polyporales (excl. small corticioid fungi), Cantharellales, Hymenochaetales, Thelephorales, Phallales, Dacrymycetales (p.p.), Tremellales (p.p.), Auriculariales (p.p.), Pezizales, Xylariales (p.p.), Sordariales (p.p.), Hypocreales (p.p.), Helotiales (p.p.), Diaporthales (p.p.), Rhytismatales (p.p.). The concept of macromycetes is different in studies by various authors (see Arnolds 1992). In order to be able to compare the results, Agaricales s.l. (Agaricales; Russulales – *Russulaceae*; Boletales – *Boletaceae, Suillaceae, Paxillaceae, Hygrophoropsidaceae*) were separated from the other macromycetes.

Each plot was characterised by the total number of species, percentage of trophic groups and species composition. Macromycetes were classified into three main trophic groups: mycorrhizal, saprophytic and parasitic. Saprophytic fungi were divided into lignicolous species and terrestrial species (saprophytic species growing on moss, fungi sporocarps, cones etc. are placed in this group). Parasitic fungi represented only an inconsiderable part of all fungi and in some cases they have an ambiguous trophic behaviour. Therefore they were classified under saprophytic terrestrial fungi in the analysis. Each species of macromycetes was attributed to a trophic group based of the criteria by Kreisel (1987).

Correlations between quantitative parameters and environmental data (number of visits, degree of naturalness of the forest, tree composition, age of stand, shrub, bush and tree cover, slope inclination, orientation of plot, presence of high groundwater level, heterogeneity of plot surroundings, disturbance in plot, number of plants and substrate types – for explanation see Table 1) were tested using the Spearman rank correlation coefficient. Correlations between number of visits and quantitative parameters were analysed with complete data from plots I-III; in the other cases reduced data from plots I-III were used. The Mann-Whitney test was used to statistically evaluate the differences between percentages of single trophic groups in spruce and beech forests. These analyses were carried out using the STATISTICA 6 package. The presence of species in plots (each trophic group separately) and environmental data were analysed by multivariate statistical methods using the programme CANOCO (ter Braak and Šmilauer 1998). Because of the amount of environmental data and their high reciprocal correlation, only the environmental data that most correlated with the main canonical axis were used for the final analysis (detrended correspondence analysis (DCA) with additional correlation of environmental data, covariable data: plot area).

The nomenclature of macromycetes follows Hansen and Knudsen (2000) and Kreisel (1987). Unidentified sporocarps which appeared to be separate species were labelled by numbers. Herbarium specimens are deposited in the author's private herbarium or at the Department of Botany, Moravian Museum, Brno (BRNM). The nomenclature of phytocoenological units follows Moravec et al. (1995).

LOCALISATION OF PERMANENT PLOTS

I – Vsetínské vrchy hills, Horní Bečva, spruce forest on N slope of Mt. Vysoká (1024 m), about 0.9 km WNW of the top, c. 810 m a. s. l.; 49°24'44"N, 18°21'18"E; **II** – Vsetínské vrchy hills, Horní Bečva, mixed forest on N slope of Mt. Vysoká (1024 m), about 1.2 km WNW of the top, c. 760 m a. s. l.; 49°24'48"N, 18°21'13"E; **III** – Moravskoslezské Beskydy Mts., Bílá, beech forest on W slope of Malý Čistý hill (865 m), about 0.6 km W of the top, c. 790 m a. s. l.; 49°24'23"N, 18°24'32"E; **1** – Moravskoslezské Beskydy Mts., Bílá, beech forest on E slope of Mt. Vysoká (1024 m), about 1.2 km NE of the top, c. 790 m a. s. l.; 49°24'34"N, 18°22'23"E; **2** – Moravskoslezské Beskydy Mts., Bílá, beech forest, about 0.8 km WSW of the top of Okrouhlice hill (743 m), c. 740 m a. s. l.; 49°24'20"N, 18°23'35"E; **3** – Vsetínské vrchy hills, Horní Bečva, Bečvice, beech forest on N slope of Mt. Vysoká (1024 m), by spring of the Rožnovská Bečva river, about 0.4 km NE of the top, c. 930 m a. s. l.; 49°24'16"N, 18°21'51"E; **4** – Moravskoslezské Beskydy Mts., Bílá, beech forest on the top of Čistý hill (749 m), about 0.7 km SE of the top of Malý Čistý hill (865 m), c. 750 m a. s. l.; 49°24'41"N, 18°24'35"E; **5** – Vsetínské vrchy hills, Horní Bečva, Bečvice, mixed forest on N slope of Mt. Vysoká (1024 m) about 1.4 km WNW of the top, c. 700 m a. s. l.; 49°24'53"N, 18°21'09"E; **6** – Vsetínské vrchy hills, Horní Bečva, Bečvice, mixed forest with larch about 1.6 km N of the top of Mt. Vysoká (1024 m), c. 700 m a. s. l.; 49°25'05"N, 18°21'33"E; **7** – Moravskoslezské Beskydy Mts., Horní Bečva, Bečvice, alder forest surrounded by spruce forest on E slope of Mt. Kladnatá, about 0.4 km SW of the top (918 m), c. 860 m a. s. l.; 49°26'02"N, 18°21'19"E; **8** – Vsetínské vrchy hills, Horní Bečva, Bečvice, spruce forest about 1 km ENE of the top of Mt. Vysoká (1024 m), c. 760 m a. s. l.; 49°24'44"N, 18°21'52"E; **9** – Moravskoslezské Beskydy Mts., Horní Bečva, Bečvice, waterlogged spruce forest in the spring area of the Sergač brook on N slope of Mt. Grapa (892 m) about 0.3 km WNW of the top, c. 860 m a. s. l.; 49°25'59"N, 18°21'25"E; **10** – Vsetínské vrchy hills, Horní Bečva, Bečvice, spruce forest on N slope of Mt. Vysoká (1024 m), about 0.7 km WNW of the top, c. 890 m a. s. l.;

Tab. 1. Vegetation and habitat characteristics of the permanent plots.

Number of plot	Vegetation	Forest naturalness	Tree composition (%)	Age	Tree /Bush/ Herb cover	Inclination	H. g. level	Char. of plot surroundings	Disturbance	Number of plant species	Number of substrate types
I	Secondary spruce stand	1.5	P (100)	85	80/20/85	12.5	–	2	3	24	12
II	Degradation stage of the *Dentario enneaphylli-Fagetum*	2	F (30), P (30), A (30), (S), (Ac)	59	80/0/15	8	–	2	3	21	33
III	*Dentario enneaphylli-Fagetum Salvietosum glutinosae*	3	F (100)	76	80/0/25	16	–	1	3	59	19
1	*Dentario enneaphylli-Fagetum*	2	F (90), P (10)	76	80/0/20	22	–	1	2	17	25
2	*Dentario enneaphylli-Fagetum*	2	F (100)	76	80/0/10	16	–	1	2	24	18
3	*Dentario enneaphylli-Fagetum Impatientetosum*	3	F (100), (P)	34	70/5/25	28.5	–	2	1	59	21
4	*Dentario enneaphylli-Fagetum Salvietosum glutinosae*	3	F (100)	55	80/0/45	9	–	2	1	32	18
5	Degradation stage of the *Dentario enneaphylli-Fagetum*	2	F (55), P (40), A (5), (Ac), (B)	56	80/0/8	6	–	2	2	16	25
6	Secondary mixed stand with larch	1	P (40), L (30), F (20), (Ac)	51	75/2/15	9	–	1	3	25	23
7	*Arunco silvestris-Alnetum glutinosae Crepidetosum paludosae*	3	P (50), Ai (25), Ag (25)	46	90/5/90	8	+	3	1	53	18
8	Secondary spruce stand	1.5	P (95) L (5), (A)	103	75/5/60	13	–	2	3	16	12
9	Secondary spruce stand resembling the *Mastigobryo-Piceetum*	3	P (100), (A)	83	60/0/75	6.5	+	1	2	29	18
10	Secondary spruce stand	1	P (100)	87	80/5/70	16	–	1	3	16	14
11	Secondary spruce stand	1	P (100), (A)	97	75/0/40	19	–	1	2	11	13

Tab. 1. – continuation.

Number of plot	Vegetation	Forest naturalness	Tree composition (%)	Age	Tree /Bush/ Herb cover	Inclination	H. g. level	Char. of plot surroundings	Disturbance	Number of plant species	Number of substrate types
12	Degradation stage of the *Luzulo-Fagetum descham-psietosum flexuosae*	1	P (100)	97	70/0/75	24	–	1	2	11	14
13	Young secondary spruce stand originated from natural seeding and later planting on the meadow of the *Arrhenatherion*	1	P (100), (F, S, B, Ac)	13	80/30/90	13	–	3	3	41	18
14	Secondary spruce stand	1	P (100), (A)	36	75/0/15	16	–	1	2	19	19
15	Secondary spruce stand resembling the *Equiseto-Piceetum deschampsietosum caespitosae*	2	P (100)	99	80/0/90	5	+	1	3	50	16

Legend: Degree of forest naturalness: 1 – artificial forest, 1.5 – artificial forest with subnatural elements, 2 – artificial/managed subnatural forest, 3 – managed subnatural forest; tree composition: P – *Picea abies*, F – *Fagus sylvatica*, A – *Abies alba*, B – *Betula pendula*, S – *Sorbus aucuparia*, Ag – *Alnus glutinosa*, Ai – *Alnus incana*, Ac – *Acer pseudoplatanus*, tree species in parentheses mean that the occurrence was lower than 5 %; H. g. level = high groundwater level. Character of plot surroundings: 1 – homogeneous, i.e. plot is surrounded by a similar type of forest, 2 – partly heterogeneous, 3 – heterogeneous, i.e. plot is surrounded by a different type of forest. Disturbance, i.e. timber cutting on plot or nearby or presence of forest road or forest edge near plot: 1 – no disturbance, 2 – some disturbance, 3 – high disturbance.

49°24'35"N, 18°21'24"E; **11** – Moravskoslezské Beskydy Mts., Horní Bečva, Bečvice, spruce forest on S slope of Mt. Grapa (892 m), about 0.9 km SE of the top, c. 810 m a. s. l.; 49°25'33"N, 18°21'03"E; **12** – Moravskoslezské Beskydy Mts., Horní Bečva, Bečvice, spruce forest on S slope of Mt. Kladnatá (918 m), about 0.6 km NW of the top, c. 800 m a. s. l.; 49°25'54"N, 18°20'58"E; **13** – Vsetínské vrchy hills, Horní Bečva, Bečvice, young spruce forest on N slope of Mt. Vysoká (1024 m), about 1.5 km NNW of the top, c. 700 m a. s. l.; 49°24'57"N, 18°21'12"E; **14** – Moravskoslezské Beskydy Mts., Bílá, spruce forest about 2.3 km S of the top of Lučovec hill (908 m), c. 690 m a. s. l.; 49°24'57"N, 18°23'29"E; **15** – Moravskoslezské Beskydy Mts., Bílá, spruce forest with small peat bogs about 1.3 km NE of the top of Mt. Vysoká (1024 m), c. 720 m a. s. l.; 49°24'52"N, 18°22'06" E.

Tab. 2. Number of species within each ecological group in the permanent plots. I-III: main permanent plots (60 visits); Ir-IIIr: reduced main permanent plots (10 visits); 1–15: additional plots (10 visits); Tot. no. Ag.: total number of Agaricales s. l.; Tot. no. macr.: total number of all macromycetes.

	I	Ir	II	IIr	III	IIIr	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Agaricales s. l.																					
Mycorrhizal	31	22	30	16	18	9	8	8	13	15	3	8	21	14	26	10	15	9	16	16	25
Sapr. lign.	19	11	21	10	21	11	6	8	10	9	5	4	7	4	13	9	5	0	7	8	7
Sapr. terr.	12	6	21	8	18	11	3	3	11	12	5	9	10	4	6	3	3	0	31	7	10
Sapr. others	7	4	4	1	4	1	0	0	3	0	0	2	1	1	6	0	1	1	5	1	4
Tot. no. Ag.	69	43	76	35	61	31	17	19	37	36	13	23	39	23	51	22	24	10	59	32	46
Other groups of macromycetes																					
Mycorrhizal	2	0	2	1	1	0	0	0	0	1	0	1	0	0	1	0	2	1	1	0	1
Sapr. lign.	15	4	45	29	46	32	26	17	18	20	11	11	5	5	13	6	9	6	10	11	8
Sapr. terr.	1	1	1	1	1	0	0	0	4	0	0	1	2	0	1	1	0	2	0	1	0
Sapr. others	2	0	4	0	3	2	0	0	1	0	0	1	0	0	1	0	0	0	2	0	0
Parasitic	1	1	1	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	1
Tot. no. macr.	90	49	129	66	112	65	43	36	61	57	24	37	46	29	67	29	35	19	72	44	56

RESULTS

Number of species and percentage of trophic groups in the permanent plots

The number of species collected in each plot is shown in Table 2 and Fig. 2, the correlation coefficients with environmental data in Table 3. A high number of species was found in plots I, II and III (90, 129, 112 species of all macromycetes; 69, 76, 61 species of Agaricales s.l.). These plots were visited 6 times more frequently than the others. The number of species of macromycetes, of Agaricales s.l. and all trophic groups of macromycetes is positively correlated with visit frequency, whereas no correlation was found between visit frequency and percentage of single trophic groups.

When only species found in plots I-III during ten visits (Ir, IIr, IIIr) were used to compare with plots 1–15, the number of species in the permanent plots fell about 42–49 % (49, 66, 65 species of macromycetes). The number of species of

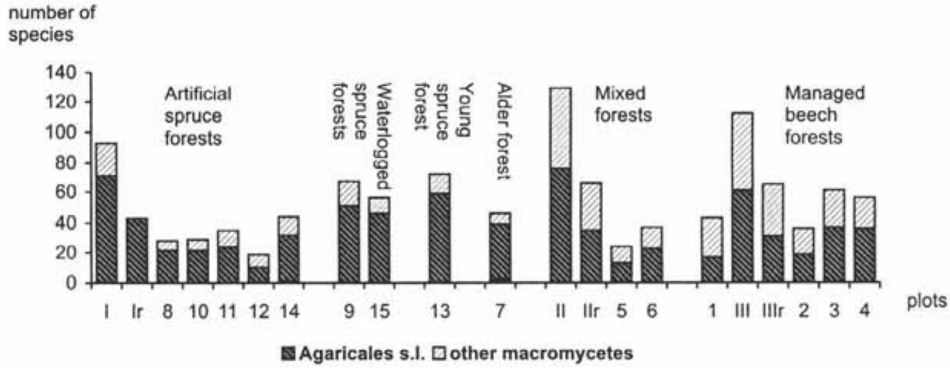

Fig. 2. Number of macromycete species in the permanent plots. Ir, IIr, IIIr – number of macromycete species recorded in plots I, II and III while visiting additional plots 1–15.

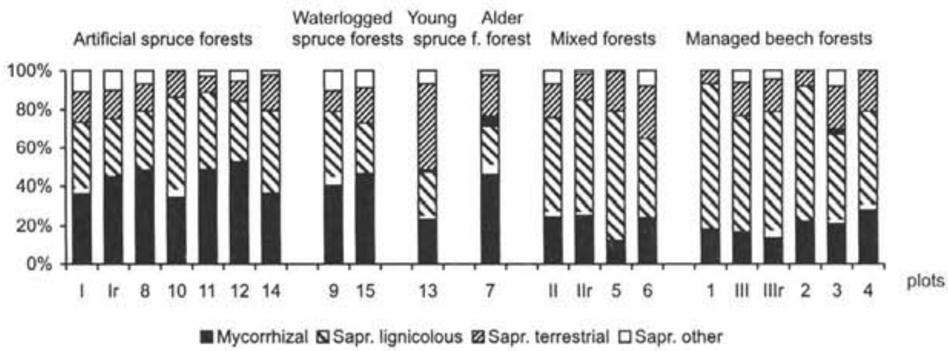

Fig. 3. Percentage of trophic groups in the permanent plots. Ir, IIr and IIIr – percentage of trophic groups recorded in plots I, II and III while visiting additional plots 1–15.

macromycetes was positively correlated with number of plant species and degree of naturalness of the forest; the number of species of Agaricales s.l. with herb cover, high groundwater level and number of plant species. The species richest plots were in the young spruce forest on a former meadow site (plot no. 13: 72 species) and in the waterlogged spruce forests (plots no. 9: 67 species; no. 15: 56 species). A high number of other macromycetes was found in the beech and mixed forest plots I, II and 4. The poorest in species were plots in the old spruce forest on steep slopes (plot no. 12: 19 species) and in the mixed forest (plot no. 5: 24 species).

The percentage of trophic groups in permanent plots is shown in Fig. 3; the correlation coefficients with environmental data are given in Table 3. The

Tab. 3. Correlation between quantitative parameters and environmental data.

	macr	ag	m%	n-m	l%	n-l	s%	n-s
Shrub cover					–0.49		0.58	
Herb cover		0.59	0.59	0.66	–0.83		0.50	
Presence of spruce			0.68		–0.67	–0.61		
Presence of beech			–0.78		0.76	0.72		
Age			0.57					
High groundwater level		0.53		0.62	–0.47			
Heterogeneity of surrounding							0.48	
Degree of naturalness of the forest	0.48					0.54		
Number of plant species	0.75	0.75					0.72	0.84
Number of substrate types			–0.77		0.58	0.68		
Number of visits	0.65	0.64		0.56		0.67		0.56

Legend: macr – number of macromycetes; ag – number of Agaricales s.l.; m% – percentage of mycorrhizal fungi; n-m – number of mycorrhizal fungi; l% – percentage of lignicolous fungi; n-l – number of lignicolous fungi; s% – percentage of saprophytic terrestrial fungi; n-s – number of saprophytic terrestrial fungi. Only factors that significantly correlated with quantitative parameters (r_S, n=18, $p < 0,05$) are shown.

percentage of mycorrhizal fungi was positively correlated with presence of spruce, herb layer cover and age of trees and inversely with presence of beech and number of substrate types. The percentage of lignicolous fungi was positively correlated with presence of beech and number of substrate types and inversely with presence of spruce, herb and shrub cover and high groundwater level. The percentage of saprophytic terrestrial fungi was positively correlated with herb and shrub cover, degree of naturalness of the forest and heterogeneity of the plot surroundings.

There are statistical differences between percentages of mycorrhizal and lignicolous fungi in spruce and beech forest plots ($p < 0.05$). Mycorrhizal species were the most important group in permanent plots in older artificial spruce (44 %), waterlogged spruce (43 %) and alder forests (46 %). On average, in plots in beech and mixed forests, mycorrhizal species made up 21 % of macromycetes. A high percentage of terrestrial saprophytes (43 %) was observed in the young spruce forest. Lignicolous species were the dominant group of macromycetes in all beech and some mixed plots.

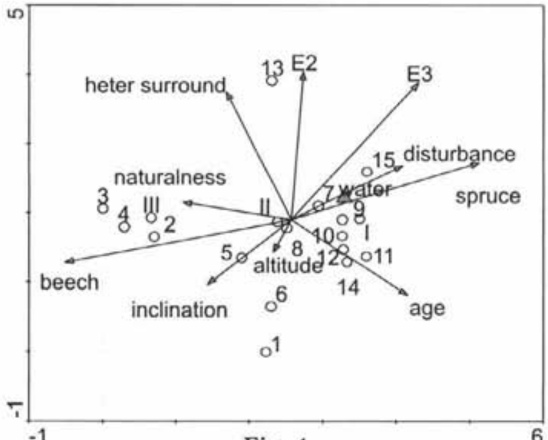

Fig. 4

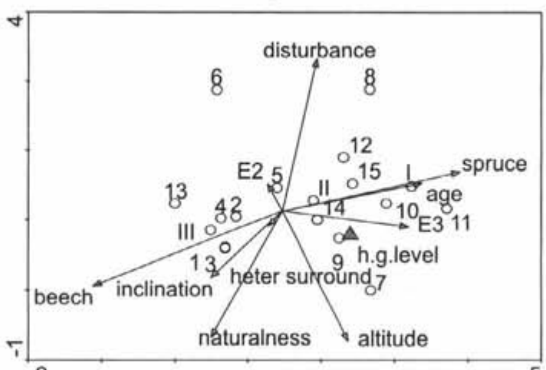

Fig. 5

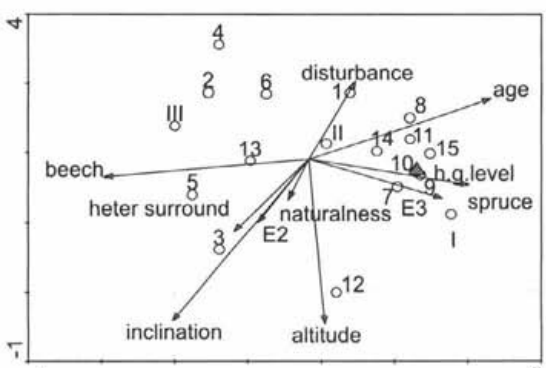

Fig. 6

Fig. 4–6. Biplot of DCA ordination of species composition (mycorrhizal, lignicolous and saprophytic terrestrial species) in 18 permanent plots. Vectors indicate additional correlation of the DCA axis with environmental data. For an explanation of the environmental data see Table 1 (heter surround = heterogeneity of surrounding; water, h. g. level = high groundwater level).

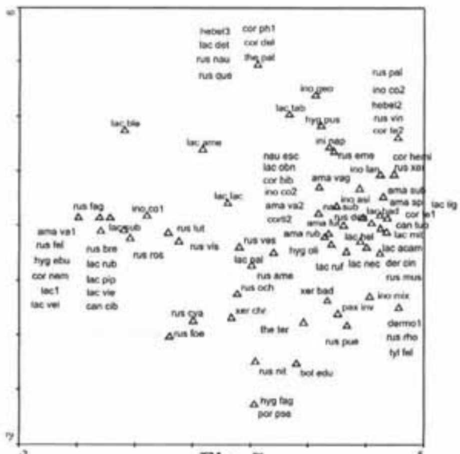

Fig. 7

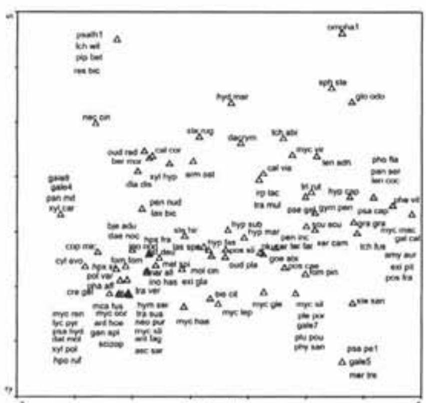

Fig. 8

Fig. 9

Fig. 7–9. DCA ordination diagrams showing the position of mycorrhizal, lignicolous and saprophytic terrestrial species. Species codes are 5–6 letter abbreviations.

Species composition in permanent plots

Altogether 314 species of macromycetes (Agaricales s.l.: 211) were recorded in the permanent plots. Only 16 species of macromycetes (Agaricales s.l.: 13) were present in more than 10 plots, 129 species of macromycetes (Agaricales s.l.: 90) were found in one plot only (Table 4).

Species composition of the different trophic groups in the permanent plots was compared by means of DCA, additionally correlated with environmental data. Plot area was used as covariable data (Figs. 4, 5 and 6). After filtering out the influence of plot area, the first two main canonical axes explained 24.8 % of the data variability of mycorrhizal species composition, 21.5 % of the data variability of lignicolous species composition, and 23.4 % of the data variability of saprophytic terrestrial species composition. In all cases, the first canonical axis expressed the tree composition gradient, from beech to spruce. It is the most important in mycorrhizal fungi composition, whereas in the case of saprophytic fungi, the first canonical axis also expresses the age gradient and presence of water. The second canonical axis is determined by the gradient of herb cover, shrub cover and heterogeneity of plot surroundings in the ordination of mycorrhizal fungi, by the gradient of disturbance and forest naturalness in the ordination of lignicolous fungi, and very slightly by altitude in the ordination of saprophytic terrestrial fungi (Figs. 3–5). Details of the relationship between macromycete composition and environmental factors were not discovered because of the high reciprocal correlation of environmental factors and the lack of data on soil characteristics.

In the case of mycorrhizal fungi (Figs. 4 and 7), DCA separated two distinct groups of species strongly linked to beech or spruce trees. The first group in the left part of the ordination diagram was formed by species associated with beech (e.g. *Amanita* sect. *Vaginatae* 1, *Lactarius subdulcis, L. ruginosus, Russula faginea, Hygrophorus eburneus*), that occur in at least two of the plots III, 2, 3 and 4. The second group in the right part was dominated by species associated with spruce (e.g. *Amanita rubescens, Lactarius necator, Lactarius rufus, Lactarius helvus*), that occur in the majority of plots I, 9, 10, 12, 11 and 14. The main dissimilarities are found in the species composition of young forest plot 13 and the other plots. It is caused by the presence of species associated with spruce young forests, e.g. *Lactarius deterrimus, Russula queletii* and *R. nauseosa*, and by the absence of *Russula ochroleuca*. The mycorrhizal species composition in beech plot 1 and spruce plot 8 resembled more the mycorrhizal species composition in mixed forest plots than that in the other beech or spruce forest plots.

In the case of lignicolous fungi (Figs. 5 and 8), DCA distinguished a compact cluster of species associated with beech (e.g. *Marasmius alliaceus, Fomes fomentarius, Inonotus nodulosus*) occurring in all beech plots (III, 1, 2, 3 and 4). A similar lignicolous species composition was found in young forest plot 13. It is

Tab. 4. Occurrence of macromycetes in permanent plots in cultural forests. +, number of plots in bold: species was noted on plot; +, number of plots: species was noted in plot, but not included in ordination.

	I	II	III	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Mycorrhizal species – Agaricales s. l.																		
Russula ochroleuca	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	.	+	+
Xerocomus chrysenteron s.l.	+	+	+	+	+	+	+	.	+	.	+	+	+	.	+	.	+	.
Hygrophorus olivaceoalbus	+	+	.	+	.	.	.	.	.	+	.	+	+	+	+	+	+	+
Laccaria laccata agg.	+	+	+	.	.	+	+	.	+	+	.	+	.	+	.	+	.	+
Amanita rubescens	+	+	.	.	.	.	.	+		+	+	+	.	+	+	.	+	+
Amanita vaginata s.l.	+	+	+	.	.	.	.	.	+	+	+	+	+	.	.	+	.	+
Xerocomus badius	+	+	.	+	.	.	.	.	.	+	+	+	+	.	+	.	+	+
Laccaria amethystea	.	+	+	.	+	+	+	.	.	+	.	+	.	.	.	+	.	+
Russula emetica	.	+	.	.	.	.	.	.	.	+	+	+	.	+	+	+	.	+
Inocybe napipes	.	+	.	.	.	.	.	.	.	+	+	+	+	.	.	+	+	+
Lactarius turpis	+	.	.	.	.	.	.	.	.	+	.	+	+	+	+	.	+	.
Lactarius rufus	+	+	.	.	.	.	.	.	.	+	.	+	.	+	+	.	+	.
Russula cyanoxantha	+	+	+	+	+	.	+	.	.	.	+	.	.	.	.	.	.	.
Amanita fulva	+	+	.	.	.	.	.	.	.	.	+	+	.	+	.	.	.	+
Lactarius blennius	.	+	+	.	+	+	+	.	.	.	.	.	.	.	.	+	.	.
Russula viscida	.	+	+	.	+	.	+	+	.	.	+	.	.	.	.	.	.	.
Amanita spissa	+	+	.	.	.	.	.	.	.	.	.	+	.	.	.	.	+	+
Hygrophorus pustulatus	+	+	.	.	.	.	.	.	.	.	.	+	.	.	.	+	.	+
Lactarius subdulcis	.	+	+	.	+	+	+	.	.	.	.	.	.	.	.	.	.	.
Russula puellaris	+	+	.	.	.	.	.	.	+	.	.	.	.	+	.	.	+	.
Russula vesca	+	+	.	.	.	.	+	.	.	.	+	.	.	.	.	.	+	.
Boletus edulis	+	+	.	+	.	.	.	.	.	.	.	+	.	.	.	.	.	.
Lactarius camphoratus	.	.	.	.	.	.	.	.	.	.	.	+	.	+	+	.	.	+
Lactarius helvus	.	.	.	.	.	.	.	.	.	+	.	+	+	+	.	.	.	.
Lactarius lignyotus	+	.	.	.	.	.	.	.	.	.	.	+	.	+	.	.	.	+
Paxillus involutus	+	.	.	.	.	.	.	.	+	.	.	+	.	.	.	.	+	.
Inocybe assimilata	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+
Amanita cf. *submembranacea*	+	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	+
Amanita sect. *Vaginatae* 1	.	.	+	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.
Inocybe lanuginosa	.	.	.	.	.	.	.	.	.	+	.	+	.	.	.	.	.	+
Lactarius mitissimus	+	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.
Lactarius tabidus	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	+	.	.
Russula brevipes	.	+	+	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.

Tab. 4. – continuation.

	I	II	III	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Russula densifolia	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	+	+
Russula fellea	.	+	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.
Russula vinosa	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+

Species present in only 1–2 plots: *Cortinarius hemitrichus:* **9**, **15**; *Dermocybe cinnamomea:* **I**, **14**; *Hygrophorus eburneus:* III, **3**; *Inocybe geophylla:* **13**, **15**; *Lactarius* sp. 1: III, **3**; *Lactarius ruginosus:* III, **4**; *Russula amethystina* I, **II**; *Russula faginea* **III**, **4**; *Russula foetens* **III**, **6**; *Russula lutea* **II**, **III**; *Russula mustelina* **I**, **14**; *Russula nigricans* I, II; *Russula rosea* II, **3**; *Russula xerampelina* **I**, **15**; *Inocybe* sect. *Cortinatae* 1: **3**, **7**; *Inocybe* sect. *Cortinatae* 2: I, **7**; *Amanita* sect. *Vaginatae* 2: **7**; *Cortinarius* sp. 1: I; *Cortinarius* sp. 2: **7**; *Cortinarius bibulus* **7**; *Cortinarius delibutus* **13**; *Cortinarius* cf. *nemorensis:* **3**; *Cortinarius* subgen. *Phlegmacium* 1: **13**; *Cortinarius* subgen. *Telamonia* 1: **9**; *Cortinarius* subgen. *Telamonia* 2: **15**; *Dermocybe* sp. 1: **11**; *Hebeloma* sp. 1: I; *Hebeloma* sp. 2: **15**; *Hebeloma* sp. 3: **13**; *Hygrophorus* cf. *fagi:* **1**; *Inocybe mixtilis*: **14**; *Inocybe* sect. *Cortinatae 3*: **15**; *Lactarius badiosanguineus*: **9**; *Lactarius deterrimus*: **13**; *Lactarius obscuratus*: **7**; *Lactarius pallidus*: **8**; *Lactarius piperatus*: **4**; *Lactarius vellereus*: **3**; *Lactarius vietus*: **4**; *Alnicola melinoides*: **7**; *Naucoria submelinoides*: **7**; *Porphyrellus pseudoscaber*: **1**; *Russula* cf. *fragilis*: I; *Russula integra*: II; *Russula nauseosa*: **13**; *Russula nitida*: **6**; *Russula paludosa*: **15**; *Russula queletii*: **13**; *Russula rhodopoda*: **11**; *Tylopilus felleus*: **11**

	I	II	III	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Mycorrhizal species – other groups of macromycetes																		
Thelephora terrestris	+	+	+	.	.	.	.	.	+	.	.	+	.	+	.	.	.	.
Cantharellus tubaeformis	+	+	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	+

Species present in only 1–2 plots: *Cantharellus cibarius*: **4**; *Thelephora palmata*: **13**

	I	II	III	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Saprophytic terrestrial species – *Agaricales* s.l.																		
Mycena galopus	+	+	+	.	.	+	+	+	+	+	+	+	+	+	.	+	+	+
Clitocybe vibecina	+	+	.	+	.	.	.	.	+	+	+	+	.	.	.	.	+	+
Cystoderma amiantinum	+	+	.	+	.	+	.	.	.	+	+	+	.	.	.	.	+	+
Marasmius androsaceus	+	+	.	.	.	.	+	.	.	+	.	+	+	+	.	.	+	+

Tab. 4. – continuation.

	I	II	III	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Collybia butyracea var. *asema*	.	+	+	.	+	+	+	+	+	.	.	.	.	.	.	+	.	.
Micromphale perforans	+	.	.	.	.	.	.	.	.	+	+	+	.	+	.	+	+	+
Collybia peronata	.	+	+	+	+	.	+	.	+	.	.	.	.	.	.	+	.	.
Mycena sanguinolenta	.	+	+	.	+	+	.	+	+	.	.	.	.	.	.	+	.	.
Collybia dryophila	.	.	+	.	.	+	+	.	+	.	.	+	.	.	.	.	.	.
Mycena rorida	+	+	.	.	.	.	.	.	.	+	.	.	+	.	.	.	.	+
Clitocybe ditopa	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+
Marasmius bulliardii	.	.	+	.	.	+	+	+	.	.	.	.	.	.	.	.	.	.
Mycena pura	.	.	+	.	.	.	+	.	+	.	.	.	.	.	.	+	.	.
Psathyrella murcida	.	+	+	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.
Cystoderma carcharias	.	+	.	.	.	+	.	+	.	.	.	.	.	.	.	.	.	.
Entoloma conferendum	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	+	+	.
Galerina pumila	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.
Marasmius wettsteinii	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	+	.	+
Mycena capillaris	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.

Species present in only 1–2 plots: *Clitocybe gibba*: **III**, **13**; *Collybia confluens*: **4**, **13**; *Entoloma cetratum*: II, **6**; *Entoloma rhodopolium*: III, **3**; *Lepista gilva*: **4**, **13**; *Mycena amicta*: **4**, **13**; *Mycena cinerella*: II, **13**; *Mycena crocata*: **III**, **4**; *Mycena epipterygia*: II, **13**; *Mycena metata*: **7**, **13**; *Mycena stylobates*: **3**, **5**; *Mycena zephirus*: II, III; *Pholiota lenta*: II, **III**; *Stropharia aeruginosa*: II, **III**; *Phaeocollybia arduennensis*: I; *Agrocybe praecox*: III; *Bolbitius vitellinus*: **13**; *Clitocybe* cf. *brumalis*: I; *Clitocybe clavipes*: **13**; *Collybia* sp. 1: **3**; *Collybia maculata*: **II**; *Conocybe* sp. 1: **6**; *Conocybe* sp. 2: **13**; *Flammulaster* sp. 1: **13**; *Galerina* sp. 1: **I**; *Galerina* sp. 2: **13**; *Galerina* sp. 3: **7**; *Hemimycena delectabilis*: **13**; *Hemimycena gracilis*: **15**; *Marasmius setosus*: **13**; *Mycena* sp. 1: I; *Mycena* sp. 2: **3**; *Mycena acicula*: **13**; *Mycena aurantiomarginata*: **13**; *Mycena* cf. *flavoalba*: **13**; *Mycena* cf. *vitilis*: **13**; *Mycena fagetorum*: II; *Mycena vulgaris*: **15**; *Naucoria* sp.: III; *Panaeolus acuminatus*: **13**; *Phaeomarasmius erinaceus*: II; *Psathyrella* sp. 1: III; *Tubaria* sp.: **13**

	I	II	III	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Saprophytic terrestrial species – other groups of macromycetes																		
Clavulina cinerea	+	+	.	.	.	+	.	.	.	+	.	+	+	.	+	.	+	.
Clavulina cristata	.	.	+	.	.	+	.	.	.	.	.	.	.	.	+	.	.	.

Species present in only 1–2 plots: *Leotia lubrica*: **3**, **7**; *Phallus impudicus*: **6**; *Clavulina rugosa*: **3**

Tab. 4. – continuation.

	I	II	III	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Saprophytic lignicolous species – *Agaricales* s. l.																	
Armillaria obscura	+	+	+	.	.	+	+	+	+	.	.	+	.	.	.	+	+	+
Hypholoma capnoides	+	+	+	.	.	.	.	.	.	+	+	+	+	+	.	.	+	+
Mycena galericulata	+	+	+	+	+	+	.	.	.	+	.	+	+	.	.	.	+	.
Mycena viridimarginata	+	+	+	.	.	.	+	+	.	.	+	+	+	.	.	.	+	+
Pluteus cervinus	+	+	+	+	+	+	+	.	.	.	.	+	+	+	.	.	.	.
Megacollybia platyphylla	+	.	+	+	+	+	+	+	.	.	.	+	.	.	.	.	+	.
Hypholoma marginatum	+	+	+	.	+	+	.	.	.	.	.	+	+	.	.	+	.	.
Tricholomopsis rutilans	+	+	.	.	.	.	.	.	+	+	.	+	+	.	.	.	.	+
Hypholoma fasciculare	.	+	+	.	+	.	+	.	.	.	.	+	.	.	.	.	+	.
Marasmius alliaceus	.	.	+	+	+	+	+	.	.	.	.	.	.	.	.	.	+	.
Oudemansiella radicata	.	+	+	.	+	+	+	.	+	.	.	.	.	.	.	.	.	.
Xeromphalia campanella	+	+	+	.	.	.	.	+	.	.	.	.	+	+	.	.	.	.
Gymnopilus penetrans	+	+	.	.	.	.	.	+	.	.	.	.	+	.	.	.	+	.
Mycena haematopus	.	.	+	.	+	.	+	.	.	+	.	.	.	.	.	.	.	.
Mycena leptocephala	.	.	.	.	.	+	.	.	.	+	.	.	.	.	.	+	.	+
Coprinus micaceus	.	.	+	.	.	.	+	.	.	.	.	.	.	.	.	+	.	.
Hypholoma sublateritium	.	+	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	+
Mycena oortiana	.	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Mycena silvae-nigrae	+	+	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.
Panellus mitis	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.
Pleurocybella porrigens	+	.	+	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.

Species present in only 1–2 plots: *Hydropus marginellus*: **III**, **8**; *Kuehneromyces mutabilis*: II, III; *Lentinellus cochleatus* **I**, III; *Mycena maculata*: II, **11**; *Mycena picta*: II, III; *Mycena rubromarginata*: I, II; *Pluteus* cf. *pouzarianus*: II, **9**; *Pholiota subochracea*: I; *Crepidotus applanatus*: I, *Galerina calyptrata*: **11**; *Galerina* sp. 4: **13**; *Galerina* sp. 5: **7**; *Galerina* sp. 6: II; *Galerina* sp. 7: **9**; *Galerina* sp. 8: **13**; *Lentinus adhaerens*: **15**; *Mycena* sp. 24: **3**; *Mycena stipata*: **1**; *Mycena renati*: **III**; *Omphalina* sp. 1: **8**; *Panellus serotinus*: **I**; *Pholiota flammans*: **I**; *Psathyrella* sp. 1: **6**; *Psathyrella* cf. *caput-medusae*: **10**; *Psathyrella hydrophila*: **III**; *Psathyrella* sect. *Pennatae* 1: **7**

Tab. 4. – continuation.

	I	II	III	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Saprophytic lignicolous species – other groups of macromycetes																		
Calocera viscosa	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	.	+	+
Dacrymyces sp. div.	.	+	+	+	+	.	+	+	+	.	+	.	+	+	+	+	+	+
Fomitopsis pinicola	+	+	.	+	.	+	.	.	.	+	.	+	+	+	+	.	+	+
Calocera cornea	.	+	+	+	+	+	+	.	+	.	.	.	.	.	+	+	.	.
Diatrype disciformis	.	+	+	+	+	+	+	+	+	.	.	.	.	.	.	+	.	.
Postia caesia	+	+	.	+	.	.	.	+	.	+	.	+	.	.	+	.	+	+
Stereum hirsutum	.	+	+	+	+	.	+	+	.	.	.	+	.	.	.	+	.	+
Stereum rugosum	.	+	+	+	+	.	+	+	+	.	+	+	.	.	.	.	.	.
Xylaria hypoxylon	+	+	+	.	+	+	+	+	+	.	.	.	.	.	.	.	+	.
Hypoxylon fragiforme	.	+	+	+	+	+	+	.	.	.	.	.	.	.	.	+	+	.
Bertia moriformis	.	+	+	+	+	.	+	+	+	.	.	.	.	.	.	.	.	.
Bisporella citrina	.	+	+	+	+	.	+	.	.	+	.	+	.	.	.	.	.	.
Exidia plana	.	+	+	+	.	+	+	+	.	.	.	+	.	.	.	.	.	.
Melogramma spiniferum	.	.	+	+	+	+	+	+	.	.	.	.	.	.	.	.	+	.
Bjerkandera adusta	.	+	+	+	.	.	+	.	.	.	.	.	.	.	.	+	.	.
Daedaleopsis confragosa	.	+	+	+	.	.	+	.	.	.	.	.	.	.	.	+	.	.
Inonotus hastifer	.	+	+	+	.	+	+	.	.	.	.	.	.	.	.	.	.	.
Inonotus nodulosus	.	+	+	.	.	+	+	+	.	.	.	.	.	.	.	.	.	.
Mollisia cinerea	+	+	+	.	+	.	.	.	.	.	.	+	.	.	.	.	.	.
Phanerochaete affinis	+	+	+	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.
Pseudohydnum gelatinosum	+	+	.	.	.	.	.	.	.	.	.	.	+	.	.	.	+	+
Fomes fomentarius	.	.	+	+	+	.	+	.	.	.	.	.	.	.	.	.	.	.
Nectria cinnabarina	.	+	+	.	.	.	.	.	+	.	.	.	.	.	.	+	.	.
Postia stiptica	+	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	+	.
Schizopora sp.	.	+	+	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.
Sphaerobolus stellatus	+	.	+	.	.	.	.	.	.	.	+	.	.	.	.	.	.	+
Stereum sanguinolentum	.	+	.	.	.	.	.	.	.	+	.	.	.	+	.	.	+	.
Trichaptum fuscoviolaceum	.	+	.	.	.	.	.	.	.	.	.	+	+	+	.	.	.	.
Ustulina deusta	.	+	+	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.
Antrodiella hoehnelii	.	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ascocoryne sarcoides	.	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Gloeophyllum odoratum	+	.	.	.	.	.	.	.	.	.	+	.	.	.	+	.	.	.
Hymenoscyphus serotinus	.	.	+	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.
Lasiosphaeria spermoides	.	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.

Tab. 4. – continuation.

	I	II	III	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Physisporinus sanguinolentus	+	+	+	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.
Scutellinia scutellata	.	.	+	.	.	.	.	.	.	.	.	+	.	.	.	.	.	+
Trametes versicolor	.	.	+	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.

Species present in only 1–2 plots: *Antrodiella faginea*: II, **3**; *Cylindrobasidium evolvens*: **III**, **13**; *Datronia mollis*: II, **III**; *Exidia pithya*: II, **13**; *Ganoderma applanatum*: **III**, **3**; *Hypoxylon serpens*: **III**, **3**; *Merulius tremellosus*: III, **7**; *Mycoacia fuscoatra*: III, **1**; *Neobulgaria pura*: III; *Peniophora incarnata*: II, **9**; *Phellinus viticola*: **I**, **11**; *Polyporus varius*: III, **4**; *Trametes suaveolens*: **1**, **4**; *Trechispora farinacea*: **II**, **9**; *Trichaptum abietinum*: **II**, **12**; *Xylaria polymorpha*: II, **III**; *Aleurodiscus amorphus*: II; *Amylostereum areolatum*: I; *Antrodia heteromorpha*: II; *Ascotremella faginea*: III; *Creopus gelatinosus*: **III**; *Gloeophyllum abietinum*: **14**; *Grandinia alutaria*: I; *Grandinia granulosa*: **10**; *Grandinia nespori*: II; *Haplotrichum conspersum*: III; *Hyphoderma setigerum*: III; *Hypocrea lactea*: II; *Hypocrea rufa*: **III**; *Irpex lacteus*: **II**; *Lachnellula willkommii*: **6**; *Laxitextum bicolor*: **2**; *Lycoperdon pyriforme*: **III**; *Nectria ditissima*: III; *Peniophora nuda*: 2; *Peniophora* sp.: II; *Phellinus hartigii*: II; *Piptoporus betulinus*: **6**; *Postia fragilis*: **11**; *Resinicium bicolor*: **6**; *Trametes multicolor*: **II**; *Trechispora christiansenii*: I; *Xylaria carpophila*: **13**

	I	II	III	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Saprophytic other species – Agaricales s. l.																		
Galerina hypnorum	+	+	+	.	.	+	.	.	.	.	.	+	.	.	+	+	.	+
Collybia tuberosa	+	.	.	.	.	.	.	.	.	.	.	+	.	+	.	+	.	+
Rickenella fibula	.	+	.	.	.	.	.	.	+	.	.	.	.	.	.	+	+	.
Strobilurus esculentus	+	+	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	+
Baeospora myosura	+	+	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.
Galerina paludosa	.	.	.	.	.	.	.	.	+	.	+	.	.	.	.	.	.	+

Species present in only 1–2 plots: *Collybia cookei*: I, **9**; *Hypholoma elongatum*: **7**, **9**; *Stropharia semiglobata*: **I**, **III**; *Crepidotus epibryus*: III; *Flammulaster* sp. 2: 3; *Conocybe* sp.: I; *Galerina* sp.: III; *Mycena* cf. *lohwagii*: **3**; *Mycena pterigena*: **13**; *Rickenella setipes*: **13**

Saprophytic other species – other groups of macromycetes

Dasyscyphus bicolor: II, **III**, **3**; *Dasyscyphus virgineus*: II, III; *Rutstroemia bulgarioides*: I, II; *Hymenoscyphus scutula*: **13**; *Inermisia aggregata*: I; *Mitrula paludosa*: **9**; *Peziza* cf. *fimetii*: **III**; *Rhytisma acerinum*: 6; *Typhula erythropus*: II

Parasitic species

Sepedonium chrysospermum: 8; *Byssonectria luteovirens*: 15; *Cordyceps ophioglossoides*: **I**; *Polydesmia pruinosa*: II; *Cordyceps militaris*: 3

probably caused by the presence of beech wood rests and by a practical absence of lignicolous fungi on spruce. Spruce plots are more dispersed than the beech plots. The distinctive difference between plots 6 and 8 and the other plots is explained by the small number of lignicolous fungi and the presence of fungi associated with larch or birch (e.g. *Piptoporus betulinus, Lachnellula willkommii*).

Spruce forest plots create a more compact cluster than beech plots in the ordination diagram of saprophytic terrestrial fungi (Figs. 6 and 9). The common species for spruce forest plots are e.g. *Marasmius wettsteinii, Clitocybe vibecina* and *Marasmiellus perforans*. Beech plot 1 and mixed plot II are similar to these spruce plots. The group of beech plots is very dispersed and includes some mixed plots. The main differences in species composition in beech plots are between plots 3 and 4. The species composition of plot 13 is closer to the beech and mixed forest group than the spruce forest group and it is probably influenced by beech forest in the vicinity. This trophic group of fungi is practically absent in plot 12, which is therefore found by itself in the diagram.

DISCUSSION

Quantitative parameters

The number of species found in single permanent plots during a defined period of time is a basic parameter for species richness comparison. It is strongly influenced by the sampling procedure (Arnolds 1992). In the case of the studied plots, it was strongly correlated with visit frequency. The effect of area differences between the main plots I-III and additional plots did not appear to be very evident.

The hypothesis that more natural forest is more species-rich was partly confirmed except for the young spruce forest on a former meadow. Beech forests are better characterised by the presence of more groups of macromycetes than are spruce forests (see Table 2, Fig. 2). Species of Agaricales s.l. distinctively prevailed in spruce forests, where species richness is correlated to the presence of water and vascular plant species diversity. It can be stated that plots in artificial forests in the study area interesting from the floristic viewpoint are also interesting mycofloristically.

The percentage of trophic groups is an important indicator which characterises the state of mycoflora in forests. Mycorrhizal fungi, especially, are disappearing in pollution-impacted areas (Arnolds 1987, Schlechte 1987, Fellner and Soukup 1991). Contrary to the low number of species in the studied plots, the percentage of trophic groups does not correlate with visit frequency.

Fellner (1993) distinguishes three stages of disturbance of ectotrophic forest stability based on the percentage mycorrhizal and lignicolous macromycetes. According to this scale, plots 7, 11 and 15 are stable, plots I, 8, 9 and 12 are suffering latent disturbance of ectotrophic forest stability, plots II, 2, 3, 4, 6, 10 and 14 are acutely disturbed and plots III, 1 and 5 are lethally disturbed. Plot 13 is unclassified. These results are unlikely, because plots that are located near each other on the same hillside (5, II, I, 10) are classified in 3 different stages of ectotrophic forest stability. All beech forests plots are classified as acutely and lethally disturbed. In the plots studied, this classification expresses the natural differences between the mycoflora composition of spruce and beech forests more than the stage of ectotrophic stability. Fellner's scale is probably useful only for a small area and specific phytocoenoses, mainly spruce forests and acidic beech forests. Similar results not confirming Fellner's theory (1993) were reported from Italy, where the percentage of mycorrhizal fungi was most influenced by altitude (Laganà et al. 1999).

Characteristics of mycoflora of cultural forests in the studied area

Spruce forests

Artificial spruce forests substituting former beech forests of the *Dentario enneaphylli-Fagetum* association predominate in the study area. Their mycoflora was studied in six plots.

According to Kost (1992), the mycoflora of cultural spruce forests is reduced in species number when compared with natural forests. This reduction depends on the intensity of forestry management. Mycoflora reduction, especially in mycorrhizal fungi, appears in natural spruce forests in regions with extreme atmospheric pollution (Gulden et al. 1992), as well. Unfortunately, because of a lack of comparable results from natural forests in Beskydy Mts. and methodological differences in literature data, it is not possible to draw some definite conclusions about the state of artificial forests in Beskydy Mts.

The numbers of species found in the studied plots are in the range noted by other authors (Table 5). The number of species recorded in plot I during 60 visits conforms to the number of species in a species-rich natural spruce forest recorded during 10 visits (Holec 1997). The numbers of species noticed in other spruce plots in the study area are comparable to results from the Krušné hory Mts. (Šteklová 1977, Fellner and Soukup 1991). The percentage of mycorrhizal fungi in studied plots is slightly higher than in plots in the Krušné hory Mts. and the Českomoravská vysočina hills. The number of lignicolous fungi corresponds to literature data and the number of saprophytic terrestrial fungi is lower.

Tab. 5. Comparison of results of studies of similar permanent plots in spruce forests
Numbers in brackets refer to the total number of macromycetes noted

	Area	Type of forest	Altitude	Number of visits	Period of study	Size of plot (m^2)	Number of fungal taxa	Number of mycorrhizal fungal taxa	Percentage of mycorrhizal fungal taxa	Number of lignicolous fungal taxa	Number of saprophytic terrestrial fungal taxa
Šmarda (1972)	Českomoravská vrchovina (ČR)	Artificial forest (*Picea* + + *Abies*)	610	39	1961–63	2000	–	70(72)	–	–	63(74)
		Artificial spruce forest	600	35	1961–63			70(72)			40(47)
			625	34	1961–63			54(56)			42(50)
			575	50	1960–63			106(109)			40(46)
		Artificial spruce forest	650	51	1961–65			89(93)			24(30)
			650	47	1961–65			96(99)			32(35)
			590	31	1960–62			71(75)			22(23)
		Bazzanio-Piceetum	710	35	1962–65			112(118)			44(50)
			630	18	1964–65			117(122)			38(48)
Gulden et al. (1992)	Black Forest (Germany)	*Vaccinio-Abietetum*	970	20	1987–89	10 x 225	(122)	(68)	(55.7)	(18)	(34)
Šteklová (1977)	Krušné hory (ČR)	*Calamagrostio villosae-Piceetum*	1029	2-week intervals	1975–76	900	36(37)	9	25	7(8)	18
			1030		1975–76		28(31)	10	35.7	5(8)	13
			1030		1975–76		25(26)	7	28	4(5)	14
Lepšová (1988)	Šumava (ČR)	Artificial spruce forest	900	8	1988	2500	–	28(31)	–	–	–
		Calamagrostio villosae-Piceetum	1190	12	1987–88	2500		20(21)			
			1300	11	1987–88	3 x 900		17			
			1300	11	1987–88	3 x 900		20			
			1140	8	1987–88	2 x 900		20(21)			
		Athyrio alpestris Piceetum	1350	8	1987–88	3 x 900		15			

Tab. 5. – continuation.

	Area	Type of forest	Altitude	Number of visits	Period of study	Size of plot (m^2)	Number of fungal taxa	Number of mycorrhizal fungal taxa	Percentage of mycorrhizal fungal taxa	Number of lignicolous fungal taxa	Number of saprophytic terrestrial fungal taxa
Fellner and Soukup (1991)	Šumava (ČR)	spruce stands	590–1300	(2)3–4 week intervals	1986*	2500	(89), (41), (58), (79) (115),	–	(34.5), (18.5), (23.5), (40.9), (43.6),	–	–
	Krušné hory (ČR)						(27), (27),		(26.6), (27.9)		
	Českomoravská vysočina (ČR)						(22), (60), (58)		(23.6) (27.8), (25.9)		
Holec (1997)	Šumava (ČR)	*Calamagrostio villosae-Piceetum*	1190–1210	11	1994–96	2500	63(84)	30(32)	47.6(38.1)	13(16)	20(36)
Vašutová (this study)	Vsetínské vrchy (ČR)	Artificial spruce forest	810	60	1998–2000	3600	69(90)	31(33)	44.9(38.1)	19(34)	19(22)
	Beskydy (ČR)	Artificial spruce forest	760	10	1999–2000	2500	23(29)	14	60.9(48.2)	4(9)	5
			890	10		2500	22(29)	10	45.5(34.5)	9(15)	3(4)
			810	10		2500	24(35)	15(17)	62.5(48.6)	5(14)	4
			800	10		2500	10(20)	9(10)	90(50)	0(7)	1(3)
			690	10		2500	32(44)	16	50(36.3)	8(19)	8(9)

* only the year when the study was started is mentioned

The number of species recorded by Šmarda (1972) in plots in the Českomoravská vysočina hills is distinctly higher. His plots were established in forests close to artificial ones, in lower altitudes than the plots of other authors and they were visited more often than most other ones, but his results are hard to explain by these dissimilarities. They could be explained by a higher species diversity in the past than at present, but results from the Českomoravská vysočina Mts. from 1963–1968 (Hlůza 1988) are comparable with those published by other authors.

The mycoflora of the studied cultural spruce forests was relatively homogenous, especially the species composition of saprophytic terrestrial fungi and widespread lignicolous fungi. It included most of the typical species of cultural forests according to Kost (1992): e.g. *Russula ochroleuca, Hygrophorus pustulatus, Inocybe assimilata, Lactarius necator, Cystoderma amiantinum, Mycena galopus, Mycena pura, Clavulina cristata, Marasmiellus perforans, Marasmius androsaceus, Clitocybe ditopa* and *Clitocybe vibecina*. Because of the high altitude of the studied plots, the mycoflora was enriched by some mountainous species: *Lactarius lignyotus* and *Russula mustelina* (typical species of mountain spruce forests according to Kost 1992), *Hygrophorus olivaceoalbus, Hygrophorus pustulatus, Mycena viridimarginata* and *Phellinus viticola* (mountain elements according to Šteklová 1977), *Pholiota subochracea* and *Pleurocybella porrigens* (typical species of climax spruce forests according to Holec 2000).

Cultural forests in the Czech Republic were mycocoenologically studied by Šmarda (1973). He recognised three mycoassociations. It was not possible to compare the mycoflora of the studied plots with his mycosociological units, because in the spruce forest plots in the Beskydy Mts. and the Vsetínské vrchy hills, the characteristic, subcharacteristic and abundant species of the genera *Cortinarius*, *Hebeloma* and *Tricholoma* were practically absent.

The main differences in species composition between artificial spruce forests in the Beskydy Mts. and climax spruce forests in the Šumava Mts. (Holec 1997) are the small number of species of the genera *Cortinarius, Russula* and *Galerina* and the presence of species not clearly associated with spruce in cultural forests. This can be caused by heterogeneity of the neighbouring forests and the effect of previous tree species composition described by Watling (Watling in Nantel and Neumann 1992).

Artificial waterlogged spruce forests

Two plots in waterlogged spruce forests were studied. The mycoflora of waterlogged spruce forests is richer than the mycoflora of other cultural spruce forests. This observation agrees with the results of Fellner and Soukup (1991). This may be caused by the high groundwater level and lack of slope of the studied plots. In addition, the massive occurrence of *Sphagnum* can be an advantage in dry periods. Percentages of trophic groups and species composition are very close to those of other artificial spruce forests. Except for the cultural spruce forest species and some mountainous forest species, several species characteristic of waterlogged spruce forests (Lazebníček 1989) were observed here: *Galerina paludosa, Hypholoma elongatum, Lactarius helvus, Mitrula paludosa, Russula emetica, Russula paludosa* and *Tephrocybe palustris*.

Young spruce forests

Young spruce forests were studied in one plot only. They are the most species rich forests in the studied area. The high percentage of saprophytic species and different species composition in comparison with old spruce forests are very interesting. The succession of fungi in newly forested plots was studied by Ricek (1981). He observed that an association of meadow fungus species (previously terrestrial saprophytes) completely changed into an association of fungi of mature forests over a period of 30 years. Rapid succession is typical of this type of forest. Newly planted forest creates densely closed stands, suitable for species of mature forest. In that stage, small grassy plots can persist, and they can form a niche for forest margin species and some less sensitive meadow species having broader ecological valence. Other micro-habitats are formed by ferns and herbs.

Some of the species characteristic of these types of forest (according to Ricek) were recorded here: *Lactarius deterrimus, Russula queletii, Russula nauseosa, Cortinarius delibutus, Laccaria laccata, Laccaria amethystea, Collybia confluens, Marasmiellus perforans, Mycena epipterygia, Hemimycena delicatula, Mycena rosella, Mycena aurantiomarginata, Marasmius androsaceus, Ramaria cristata, Clitocybe gibba, Collybia asema* and *Marasmius bulliardii*. Some fungi of mature forests which prevail in later stages (affter about 40 years) have been noticed sporadically, for example: *Hygrophorus pustulatus, Clitocybe ditopa and Hygrophorus olivaceoalbus.*

Beech forests

Beech and mixed forests are natural climax vegetation in the studied region (Neuhäuslová et al. 1998). They were very rich in number of macromycete species. A total of 220 species of macromycetes were found during 27 years of extensive study (Kuthan 1990) in a fir-beech forest in Salajka Nature Reserve. Recent managed subnatural beech forests of the *Dentario enneaphylli-Fagetum* association were studied in five plots. They show low substrate diversity (stumps, logs and trunks only) in comparison with natural forests.

Tab 6. Comparison of the results of studies in similar permanent plots in beech forests. Numbers in brackets refer to the total number of macromycetes noted.

	Area	Type of forest	Altitude	Number of visits	Periods of study	Size of plot (m^2)	Number of fungal taxa	Number of mycorrhizal fungal taxa	Percentage of mycorrhizal fungal taxa	Number of lignicolous fungal taxa	Number of saprophytic terrestrial fungal taxa
Šmarda (1973)	Českomoravská vrchovina (ČR)	Herb-rich beech forest	500 450 410	86 65 51	1960–65 1960–63 1960–63	2000	–	86 (89) 75 (77) 78 (83)	–	–	41 (48) 46 (60) 66 (85)
Hlůza (1988)	Českomoravské mezihoří (ČR)	Herb-rich beech forest	510 570 540	81 86 100	1963–68	3000	51 (68) 53 (67) 63 (88)	23 22 30	45.1 (33.8) 41.5 (32.8) 47.6 (34.1)	10 (22) 13 (23) 14 (27)	18 18 19
Fellner and Soukup (1991)	Krušné hory Českomoravská vysočina Křivoklátsko (ČR)	Beech forests	110–380	(2)3–4 week intervals	1986*	2500	(23) (85) (43), (44), (61), (43), (46), (27), (41), (33), (42)	–	(38.6) (10) (25.3), (22), (44.6), (19), (64), (65), (55.2), (80.9), (71)	–	–
Holec (1992)	Šumava (ČR)	*Dentario enneaphylli-Fagetum*	960–990 940 900–940 930–950 850–880 600–640	2–4 week intervals	1988–90 1989–90 1989–90 1989–90 1988–90 1988–90	2500	102 (107) 82 (88) 71 (74) 62 (66) 57 (61) 50 (55)	36 (37) 18 (19) 15 22 16 32 (35)	35.3 21.1 21.2 35.5 28.1 64	31 (32) 32 (33) 29 (31) 18 (19) 24 (25) 5	35 (38) 32 (36) 27 (28) 22 (25) 17 (20) 13 (15)
		Calamagrostio villosae-Fagetum	1110– –1120 1060– –1100		1988–90 1988–90		102 (108) 87 (91)	28 (30) 24	27.5 27.5	30 22 (23)	44 (48) 41 (44)

Tab 6. – continuation.

	Area	Type of forest	Altitude	Number of visits	Periods of study	Size of plot (m^2)	Number of fungal taxa	Number of mycorrhizal fungal taxa	Percentage of mycorrhizal fungal taxa	Number of lignicolous fungal taxa	Number of saprophytic terrestrial fungal taxa
Mihál (1993)	Kremnica uplands (SR)	Beech forest	450–475	29 29 29 29 29	1990–92	5000– –4100	(78) (58) (48) (68) (43)	(16) (11) (14) (14) (16)	(20.5) (19) (29.2) (20.6) (37.2)	(47) (40) (27) (35) (20)	(15) (7) (7) (19) (7)
Pavlík (1999)	Žiarská kotlina (SR)	Polluted beech forest	470		1994–1996	10 x 225	(88)	(32)	(36.4)	(31)	(25)
Vašutová (this study)	Moravskoslezské Beskydy (ČR)	*Dentario enneaphylli-Fagetum*	740 750	10 10	1999–2000	2500	19 (36) 36 (57)	8 (8) 15 (16)	42.1 35.1	8 (25) 9 (29)	3 (3) 12 (12)
	Vsetínské vrchy (ČR)	*Dentario enneaphylli-Fagetum*	790 930	60 10	1998–2000 1999–2000	3600 2500	61 (112) 37 (61)	18 (19) 13 (13)	29.5 41.7	21 (67) 10 (28)	22 (26) 14 (19)

* only the year when the study was started is mentioned

The mycoflora of these forests is more variable than that of artificial spruce forests. This variability is most expressed in terrestrial fungi composition and roughly agrees with the variability in vascular plant composition (Vašutová 2001). It supports results from roadside verges planted with beech in the Netherlands. Keizer (1993) found that the community of vascular plants corresponds with that of saprotrophs better than that of ectomycorrhizal fungi. The case of plot 1 is an interesting situation. The tree layer is dominated by beech with ten per cent spruce and the composition of lignicolous species is close to that of other beech plots. On the other hand, the floristic composition and composition of mycorrhizal and saprophytic terrestrial fungi is close to that of mixed plots. The number of species and percentage of mycorrhizal fungi found in the studied plots is within the range recorded by other authors (Table 6). The number of saprophytic terrestrial species is smaller than in the literature data, and comparable with results from the Kremnické vrchy Mts. (Mihál 1993). The number of lignicolous species is similar to results from the Českomoravské mezihoří hills (Hlůza 1988) and Žiarská kotlina (Pavlík 1999).

Characteristic species, which according to Lisievska (1972, 1974) are typical of beech forest, occur here: *Lactarius subdulcis, Lactarius vellereus, Russula fellea, Russula cyanoxantha, Collybia peronata, Collybia butyracea var. asema, Mycena stylobates, Marasmius bulliardii, Mycena galericulata, Oudemansiella radicata* and *Megacollybia platyphylla.*

There were no distinct differences between species composition of the studied plots and a polluted beech plot in Slovakia (Pavlík 1999). The observed differences were caused mainly by different altitudes and plant communities.

The main difference between species composition (Agaricales s.l.) of species-rich, managed subnatural forests (plots III, 3 and 4) and near-natural forests (two plots of the *Dentario enneaphylli-Fagetum* association) in Šumava (Holec 1992) is found in the number of species of all trophic groups, especially in the genera *Russula, Mycena* and *Psathyrella*. Expected differences in the number of lignicolous species between cultural (Vašutová 2001) and natural beech forest plots (Holec 1992) were not confirmed. According to Holec (1992) this may be due to the small area of the studied plots, in which natural forests cannot provide all the substrate types in various stage of decay needed for the growth of some lignicolous species, whereas substrate diversity in cultural forests is reduced because of forestry management.

Mixed forests

Mixed forests were studied in three plots. Although they were similar in floristic composition, they varied in mycofloristic composition. The main differences were observed in the overall number of macromycetes (129, 22, 37) and the composition of lignicolous fungi. Plot II was interesting because of the presence of fir. According to Pilát (1969) and Kałucka (1995), characteristic fir species are confined to dead fir wood. This was represented by some old stumps and one fresh branch. Only the characteristic fir species *Aleurodiscus amorphus*, *Trichaptum abietinum*, *Dacrymyces stillatus* and *Gymnopilus sapineus* were observed, and none of them are strictly confined to fir.

It is difficult to compare mixed forests because of their heterogeneity. The main differences between artificial mixed forests and natural ones are that artificial mixed forests have a homogeneous age structure and a deficient in wood substrates. But as can be seen in plot II, these forests can be very species rich. The mycoflora of these species-rich cultural forests and the mycoflora of a natural mixed forest in Šumava (Holec 1997) are different. Lignicolous fungi dominated in forests of both regions. There are more mycorrhizal fungi (especially from the genus *Russula*) in cultural forests, whereas saprophytic terrestrial fungi (especially in the genera *Clitocybe* and *Collybia*) are more important in natural mixed forests. But these differences can be more influenced by differences in environmental factors and plant communities.

Alder forests

Alder forests in the studied area are confined to wet terrain depressions and streams only and are surrounded by planted spruce forests. They probably replace former meadow springs after afforestation. They were studied in 1 plot. Its vegetation belongs to the *Arunco silvestris-Alnetum glutinosae* association (alliance *Alnion incanae*, suballiance *Alnenion glutinoso-incanae*).

A review of mycofloristical research in alder forests was given by Bujakiewicz (1992). Quantitative parameters were studied in Germany (Winterhoff 1993). The number of species noted in the plot in the Moravskoslezské Beskydy Mts. was lower than that in Winterhoff's study (1993). He recorded 89–159 species per plot in alder forests (association *Carici elongatae-Alnetum*), but his plots were 4000–5000 m^2 large and were visited 12–29 times. Lignicolous fungi were the dominant group (69–75.8 %). However, in the Moravskoslezské Beskydy Mts. the dominant group was formed by mycorrhizal fungi (46 %) in the cultural managed alder plot. This may have been caused by a deficient in wood substrates and the presence of mycorrhizal fungi on spruce. As in the case of the cultural spruce forest plots, the species composition in cultural alder plots was influenced by neighbouring forests and the species associated with them, and it was more similar to that of spruce forests than that of deciduous forests. No species characteristic of the *Carici elongatae-Alnetum* association were found in the studied plot and only 12 species were among those found in the alder plots studied by Winterhoff. Species characteristic of alder recorded in the studied plot were typical of the *Alnion glutinosae* alliance (according to Bujakiewicz 1992). On the other hand, species characteristic of the *Alnion incanae* alliance were absent. The studied community is obviously a transitional, very impoverished community.

Conclusions

The mycoflora of cultural (artificial and managed subnatural) forests (beech, spruce and mixed) was studied on 18 permanent plots in the Moravskoslezské Beskydy Mts. and Vsetínské vrchy hills (Czech Republic). A total of 314 species of mainly common macromycetes was recorded in 18 permanent plots. The most species-rich forest communities are young forests, waterlogged spruce forests and some mixed and beech forests. The number of species of macromycetes in individual plots varied from 19 to 129 and correlated slightly positively with the degree of naturalness of the forest.

Mycorrhizal fungi are the dominant group in old spruce and alder forest. The scale of disturbance of ectotrophic forest stability based on the percentage of mycorrhizal and lignicolous fungi does not seem to be suitable for an evaluation of these types of forests. The percentage of mycorrhizal fungi in the studied plots correlated positively most with the presence of spruce, and the percentage of lignicolous fungi correlated positively with the presence of beech.

Species composition (especially of mycorrhizal species) is most influenced by the tree layer composition. Regrettably, environmental variables describing soil characteristics were not measured. It seems that the mycoflora composition of spruce forests in the studied area is less variable (mainly in the case of mycorrhizal and saprophytic terrestrial fungi composition) than that of beech forests. Namely, the occurrence of saprophytic terrestrial fungi shows differences between various types of beech forests.

The main differences between natural forests and artificial forests are in species composition, especially in the occurrence of sensitive mycorrhizal genera (*Cortinarius, Russula*, etc.), rather than in quantitative parameters, which are influenced by the methods used in individual studies. It would be useful to study the relationships between quantitative parameters and species composition in plots with strictly defined vascular plant communities and environments, as well as to record characteristic species of single natural forest communities.

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