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Litter decomposition of red oak, larch and lime tree and its effect on selected soil characteristics

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ABSTRACT: This study was designed to estimate the effect of the introduced *Quercus rubra* L. on the habitat (soil) quality because only poor vegetation appears under the stands of this tree which was planted in monocultures on abandoned old fields in Prague 30 years ago, similarly like other tree species. Leaf litter decomposition rates were compared for red oak, *Quercus rubra* L., larch, *Larix decidua* Mill. and lime tree basswood, *Tilia cordata* Mill., using the litter-bag method, under constant temperature and moisture in the laboratory conditions. Each kind of leaf litter and cellulose were exposed on each soil taken from the respective stands of the tree species, and on a sand for control. Mass loss was measured four times in 59-day intervals. The leaf litter was also tested for such qualities as water absorbency, specific leaf mass, and for the content of the main elements (C, N, P) and phenols. The soil on which the leaf material decomposed for 118 days was analyzed to assess the ratio of humic to fulvic acids in the soils, from the Q4/6 quotient. Leaf litter production and its decay rate were also estimated in the field for the particular stands. Cellulose decomposition rates were repeatedly followed in the field, using the litter-bag technique. It was found that leaf litter of *Quercus rubra* was decomposing very slowly, owing to its quality such as low water absorbency, high specific mass and high C/N ratio, but no adverse effect on the soil quality was observed. The low cover of the ground-layer vegetation is probably caused by a high production of hardly decomposable material which accumulates on the soil and creates a mechanical barrier preventing light to reach the plant seedlings. Lime-tree litter was decomposed very quickly in the field, though the lime-tree soil showed some restriction to the decay rate, probably due to a high phenol content in the lime-tree litter. Larch litter showed a slow decay though there was not observed any adverse effect of the larch soil on the litter decay rates of the trees studied, neither in the lab nor in the field where the cellulose decomposed very fast. The ground-layer vegetation was most abundant on the larch site. A practical conclusion from this work would be the recommendation to plant mixed cultures preferably to monocultures, to balance the different adverse effects of the leaf litters of the component species.

Keywords: *Quercus rubra*; *Tilia cordata*; *Larix decidua*; litter; decomposition; soil; herb layer; physical and chemical properties of litter and soil

Plant litter is the basic source of energy and nutrients for the detritic part of nutrient chain through which both nutrients and energy contained in living tissues re-enter the cycles in the ecosystem. Decomposition as the main process in soil formation is of crucial importance both for plants and animals. Litter quality and quantity influences not only decomposition rates, but also soil quality and conditions for seed germination and growth of plants (SYDES, GRIME 1981). The between-year litter production varies according to many factors, such as stand species composition, stand productivity and age (JENSEN 1974; BRAY, GORHAM 1964 in JENSEN 1974; SKLENÁŘ 1994; OLSON 1963). There is a mutual connection between litter production and its decay described in the decomposition models (JENY 1949 in ÚLEHLOVÁ 1989; OLSON 1963, etc.).

Decomposition rate depends most of all on soil microclimate and on physical and chemical characteristics of the decomposing litter. Many papers show that the process of decomposition is affected by litter quality (DAUBENMIRE 1963; JENSEN 1974; KOVÁŘOVÁ 1984; SKLENÁŘ 1994 and others) and some papers brought evidence that even the underlying soil may involve the decomposition process (HADINCOVÁ et al. 1990; KOVÁŘOVÁ 2000).

The initial litter quality affects the decomposition rate in a substantial way (see e.g. GILLON et al. 1994).

Soil (humus layer) formation in the process of decomposition depends on decomposition rate and quality of the decomposing material (PELÍŠEK 1962). The contents and change of humic substances, esp. humic and fulvic acids, in the process of decomposition, indicate humus quality and also physical and chemical soil processes (POSPÍŠIL 1978; PELÍŠEK 1962; PFLUG, ZIECHMANN 1981; KELTING et al. 1998).

The aim of this study was to compare decomposition rates of leaf litter of three woody species – lime tree (*Ti-

lia cordata L.), larch (*Larix decidua* Mill.) and the introduced red oak (*Quercus rubra* Mill.), under constant temperature and moisture in laboratory chambers, with selected chemical and physical characteristics of the litter and assess the effect of litter quality on its degradability. At the same time, the effect of soil substrate on decomposition of the litters was estimated, as well as the effect of decay products on the balance of soil humic and fulvic acids.

Besides the description of herb and shrub vegetation, the field part of the study also includes the annual litter production and the measurements of cellulose decomposition rates in the stands studied.

MATERIALS AND METHODS

SITE DESCRIPTION

The studied area is E of the edge of Nature Reserve Chuchelský háj in Prague 5. The area is covered with forest cultures, the elevation is ca 300 m a.s.l., sum of precipitation 530 mm/year, average annual temperature 8.1°C. The bedrock is limestone (Silurian) with overlying layer of eolian clay and loam.

The studied localities are covered with even-aged monocultures of red oak, lime tree and larch on a flat terrain, each of ca 1,000 m² area. These stands were planted on abandoned fields and were 40 years old in 2000.

The herb and shrub layer analysed by ecological factors with indication values (ELLENBERG 1979) shows the occurrence of forest mesophilous and rather nitrophilous plants of medium warmth and suboceanic distribution. In lime tree and red oak monocultures, the herb layer was composed of shade-tolerant and slightly acid-tolerant species.

LABORATORY EXPERIMENT

Litter decomposition

The following experiment was designed to compare the effects of decomposition rates of the various litter types and to estimate the effect of soil substrate on the decomposition of litters under constant moisture and temperature in lab chambers. Leaf litter of the studied species and cellulose (control) were exposed in nylon litter bags (BOCOCK, GILBERT 1957) of 1 mm mesh size, on the soil and sand (control) in a design combining all possible pairs of substrate and litter types. The decomposition rates were followed at four intervals, each 59 days long, with four replications. The decay rate of the decomposing material was expressed both as weight loss (WL) and as LDR (litter disappearance rate in mg/g/day, according to SUFFLING, SMITH 1973):

$$WL = \frac{(I - F) \times 100}{I}$$

$$LDR = \frac{1,000 \times (I - F - S)}{I \times T}$$

where: I – initial weight (g),
F – final weight (g),
S – total spillage (or correction for impurities),
T – total number of days of exposure.

The substrate on which the litter was decomposed for 118 days was analysed and the ratio of humic to fulvic acids (as Q 4/6 quotient according to KRÁLOVÁ et al. 1991) was assessed and compared with the same ratio in the substrate at the start of the experiment.

Chemical and other analyses
Litter

Total N (Kjeldahl), C (oxidimetry – wet combustion), CN elemental (Heraeus), total P (colorimetry after wet digestion with HNO_3 and $HClO_4$, 2:1), water-soluble polyphenols (KUITERS 1987), pH (electrometry) and ash content (after heating at 500°C for 3 hours) were analysed in the litter. Water absorbency and content of water soluble substances (WSS) were estimated according to GILLON et al. (1994). Specific litter mass (SLM) was calculated as the weight of leaf litter area. Leaves were weighed and their copy was fabricated. Leaf area was calculated by means of the program LEAF AREA – Jiří Janáček.

Soil

The upper humus horizon was analysed for total N, oxidizable C, pH (both in KCl and H_2O), and for the humic to fulvic acid ratio (see above).

FIELD INVESTIGATIONS

Cellulose decomposition rates were repeatedly assessed on the plots studied, using the litter-bag method, cellulose (filter paper) and 1 mm mesh size. The bags were randomly distributed in 10 replications per plot and repeatedly left to decay for 56-day periods, replacing the old set by a new one six times from 9. 4.1999 to 11. 3. 2000. The cellulose decomposition rates were expressed like in the case of litter decomposition (see above).

The annual leaf production by the monoculture stands and the balance between import and disappearance were estimated by collecting the litter (from three separate square meters on each plot), immediately after the leaf fall. The fresh litter was separated from the old one and the two counterparts were dried (at 85°C) and weighed. Decomposition constants k, k', $T_{(0.5)}$ and $T_{(0.95)}$ were calculated from these data using the following formula:

1. $k = X/X_0 = e^{-kt}$ (OLSON 1963)

where: X – litter weight in time t (old litter),
X_0 – litter weight in time 0 (fresh litter),
t – time in years.

2. $k' = X_0/X + X_0$ (JENY 1949)

3. $T_{(0.5)}$ and $T_{(0.95)}$ (OLSON 1963) is decomposition time of 50 and 95% litter respectively.

The constant was not determined for larch leaf litter.

Data from both laboratory and field measurements were subject to statistical analysis (ANOVA and Dun-

Table 1. Initial characteristics of oak, lime-tree and larch leaf litter. Values in rows marked with the same letter do not differ significantly at $P < 0.05$

Litter Initial characteristics		Quercus rubra				Larix decidua				Tilia cordata		
		Mean	Std. dev.	n		Mean	Std. dev.	n		Mean	Std. dev.	n
SLM (g/m^2)		66.6		4		130.3		130		54.3		15
Absorbency (%)	a	166	35	4	b	237	18	4	c	332	13	4
WSS (%)	a	6.2	1.4	4	c	31.9	0.78	4	b	22.7	2.65	4
pH in leachate	a	4.97	0.2	4	a	4.93	0.01	4	a	4.99	0.2	4
N (%) Kjeldahl	a	0.47	0.16	3	b	1.19	0.24	4	a	0.59	0.15	4
N (%) elem. an.	a	0.67	0	2	c	1.9	0.57	2	b	1.01	0.01	2
Cox (%)	a	42.4	2.4	4	a	42.9	3.5	4	a	45.1	3.9	4
C (%)	a	47	0.14	2	a	47.6	0.14	2	a	47.25	0.21	2
C/N	c	70.2	0.14	2	a	25.05	0.78	2	b	46.85	0.21	2
P (mg/g)	b	0.79	0.02	2	c	1.3	0.03	2	a	0.69	0.01	2
Phenols (mg/g)	a	887.2	22.3	4	b	992.8	76	4	c	2,335.3	77.6	4
Ash (%)	a	3.82	0.06	5	c	5.73	0.11	5	b	6.72	0.3	5

Explanatory notes: SLM – specific litter mass; WSS – water soluble substances (GILLON et al. 1994); n – number of replications

can's test). Indication values were calculated by Kruskal-Wallis and Mann-Whitney tests.

RESULTS AND DISCUSSION

LITTER CHARACTERISTICS

Leaf litter characteristics are shown in Table 1.

Red oak leaf characteristics indicate the highest resistance to decay – the lowest ability to absorb water and the lowest amount of leachable matter which well correlates with the highest content of structural elements like cellulose and lignin in the cell wall and with the lowest N content and highest C/N ratio. The remaining measured characteristics were of medium range. Low polyphenol content suggests low or no allelopathic effects on decomposers and/or germination of forest floor plants.

Lime-tree leaf litter with lowest specific mass and highest water absorbency shows a better disposition to decay whilst the chemical characteristics (medium N and C/N ratio, low P contents, very high water-soluble polyphenol contents) suggest a worse disposition to decay and high allelopathic effect.

Larch leaf litter showed the best characteristics for decay rate contrary to the statement that coniferous needle litter is less subject to decay than the broadleaf litter (ABER et al. 1990). Larch deciduousness shifts this coniferous tree closer to the broadleaf tree group. The only characteristic of this litter favouring slow decay is its high specific mass connected with the relatively large surface of needles enriched with relatively heavy substituents like cutins and waxes and higher lignin content in the cell walls (DAUBENMIRE 1963). However, high N and P contents as well as low C/N ratio and high water-soluble substances increase palatability and vulnerability to leaching (BERG, STAAF 1987).

SOIL CHARACTERISTICS

Soil analyses are given in Table 2. Soil acidity and N contents are quite similar for all the soils tested. The soils differ only in Cox (and, of course, in C/N ratio) with higher values for the soil under larch, which probably reflects a slower decay in the upper soil resulting in a layer of undecomposed litter in this stand. The HA:FA ratio is lower here than in the other stands due to increased fulvic acids.

Table 2. Several soil chemical characteristics of organic Ah horizon from the oak, lime-tree and larch monocultures studied. Values in columns marked with the same letter do not differ significantly at $P < 0.05$

	n	pH (KCl)		n	pH (H$_2$O)		n	Cox (%)		n	N (%)	Cox/N		n	HK:FK	
Q. rubra	2	5.18 ± 0.3	a	2	5.47 ± 0.25	a	4	5.11 ± 0.62	a	3	0.25 ± 0.06 a	20.44		2	0.32 ± 0.0	a
L. decidua	2	4.22 ± 0.21	a	2	4.99 ± 0.42	a	4	6.49 ± 0.42	b	3	0.25 ± 0.07 a	25.96		2	0.23 ± 0.01	b
T. cordata	2	5.31 ± 0.34	a	2	5.83 ± 0.66	a	4	4.31 ± 0.48	a	2	0.21 ± 0.01 a	20.52		2	0.38 ± 0.04	a
Sand	2	8.63 ± 0.31	b	2	9.24 ± 0.23	b	1	0	c	3	0.05 + 0.0 b					

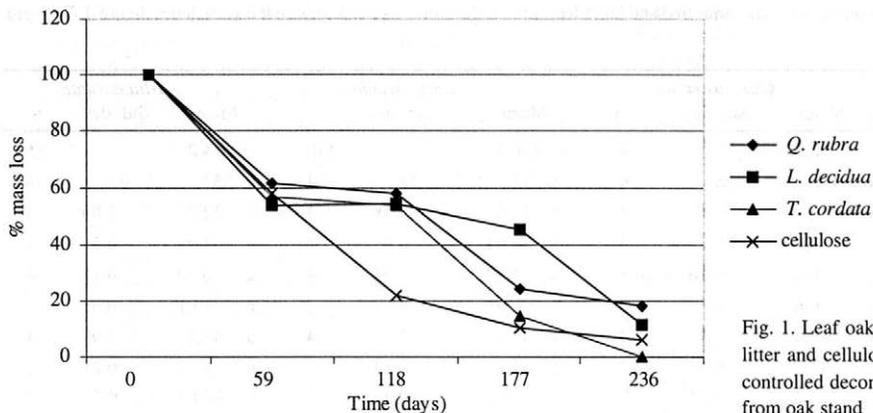Explanatory notes: n – number of replications

Fig. 1. Leaf oak, lime tree and larch litter and cellulose mass loss during controlled decomposition on the soil from oak stand

LITTER DECOMPOSITION

The rate of decomposition of the particular leaf litters and cellulose on different soil substrates in the lab is given in Figs. 1–4. Cellulose shows the highest decomposition rates followed by lime tree, larch and red oak. Fast decay of lime-tree leaf litter compared to other deciduous trees and conifers was reported e.g. by COTE and FYLES (1994). Among the many leaf litters, they found the slowest decay with red oak. Similarly, ABER et al. (1990) report the lowest decay rates for conifers and red oak. They also found a high index of lignin/cellulose ratio for the red oak leaves which is indirectly correlated with decomposition rate.

The detailed analysis showed the fastest decomposition of all kinds of leaf litter on red oak soil and the fastest decomposition of cellulose on lime-tree soil.

Red oak litter decomposition was slowest on larch soil and on the sand (here also larch litter and cellulose). Lime-tree litter was however decomposed most slowly on "its own" lime-tree soil, which may reflect the high concentration of water-soluble polyphenols both in the soil and in the litter that cannot be leached out from the soil samples in the lab like in the wood and may inhibit the activity of decomposers (OLSEN et al. 1971).

The time course of decomposition showed no or small differences between the particular litters (except for cellulose) on the first two sampling dates. Also, after the fast initial mass loss, there was a lag between the first and the second sampling date. The litters differ in decomposition rates since the third sampling (177 and 236 days of exposure). Cellulose was losing its weight gradually since the beginning (except on sand).

A comparison of the effects of soil substrate on litter decomposition rates indicated that the red oak soil enhanced the decay more than the other soils while decomposition on sand was very slow. The oak, larch and lime-tree soils largely accelerated the decay of cellulose but on sand, it was the lime-tree leaf litter that lost most mass.

On red oak soil, similarly like on larch soil, the most slowly decomposing litter was that of red oak and larch. Lime-tree soil does not support the decay of any type of litter, except for cellulose. Sand was least favourable for cellulose decomposition.

The course of decomposition shows that the effect of soil substrate on the particular LDR curves is not distinct except for red oak soil which promoted decomposition of red oak, larch and lime-tree litters after 177 and 236 days of exposure. On lime-tree soil, there was a retardation of
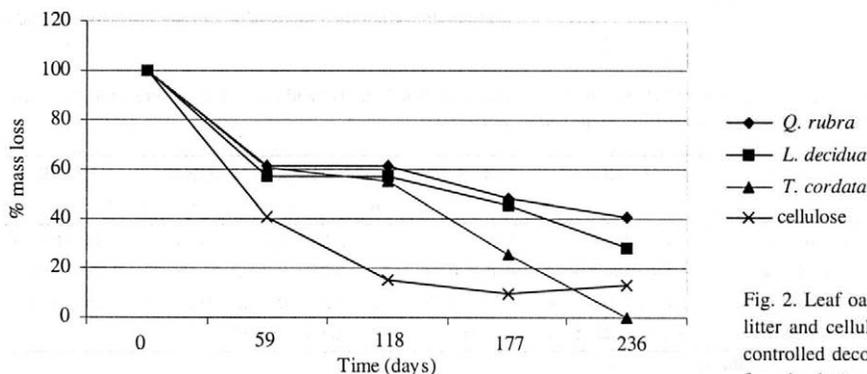
Fig. 2. Leaf oak, lime tree and larch litter and cellulose mass loss during controlled decomposition on the soil from larch stand
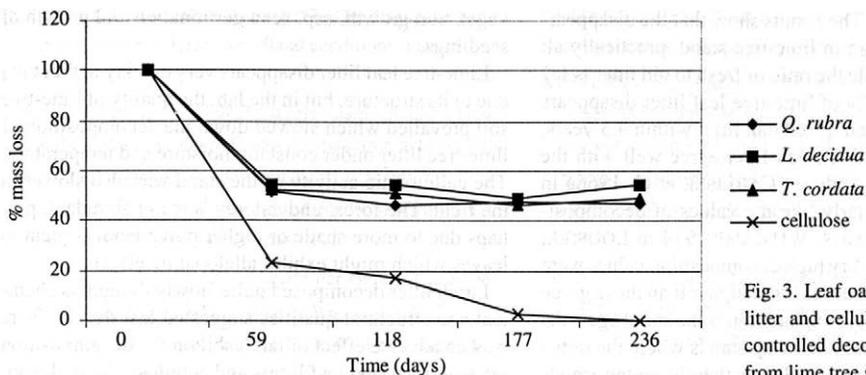
Fig. 3. Leaf oak, lime tree and larch litter and cellulose mass loss during controlled decomposition on the soil from lime tree stand

Table 3. Old and fresh leaf litter mass and decomposition constants for oak, lime-tree and larch monocultures studied

	Trees	n	Mean	Minimum	Maximum	Std. dev.	Standard error
Fresh litter (t/ha)	Q. rubra	3	2.49	2.32	2.6	0.15	0.09
	T. cordata	3	1.24	1.11	1.32	0.12	0.07
	L. decidua	3	2.08	1.87	2.25	0.19	0.11
Old litter (t/ha)	Q. rubra	3	2.47	1.7	2.91	0.67	0.39
	T. cordata	3	0.01	0	0.01	0	0
k'	Q. rubra	3	0.51	0.45	0.6	0.08	0.05
	T. cordata	3	1	0.99	1	0	0
k	Q. rubra	3	0.72	0.6	0.92	0.17	0.1
	T. cordata	3	5.8	4.99	7.01	1.07	0.62
$T_{(0.5)}$	Q. rubra	3	1	0.75	1.15	0.21	0.12
	T. cordata	3	0.12	0.1	0.14	0.02	0.01
$T_{(0.95)}$	Q. rubra	3	4.31	3.27	4.97	0.92	0.53
	T. cordata	3	0.53	0.43	0.6	0.09	0.05

Explanatory notes: n – number of replications

decay after the initial loss of soluble matter, except for cellulose.

CHANGE OF HUMIC TO FULVIC ACID RATIO

There was no significant change in the humic to fulvic acid ratio after 118 days of exposure compared with the initial one, with any of the experimental pairs of soil substrate and litter.

LITTER PRODUCTION

Table 3 gives data on the annual balance of leaf litter import and disappearance, incl. decomposition constants

Fig. 4. Leaf oak, lime tree and larch litter and cellulose mass loss during controlled decomposition on the sand

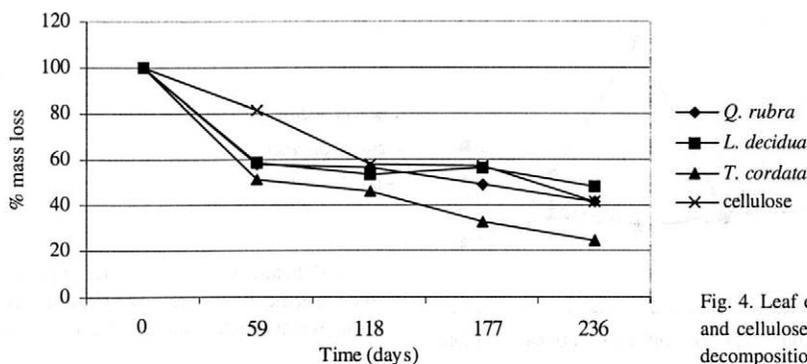k, k', $T_{(0.5)}$ and $T_{(0.95)}$. The results show that the disappearance rate is very high in lime-tree stand, practically all the litter is fresh while the ratio of fresh to old litter is 1:1 in red oak stand. 95% of lime-tree leaf litter disappears within 6.5 months and of red oak litter within 4.3 years. The amounts of shed red oak litter agree well with the data given by other authors (CARLISLE et el. 1966a in JENSEN 1974), similarly like the values of decomposition constants (AUSMUS, WITKAMP 1974 in LOUSIER, PARKINSON 1976). Very high decomposition values were estimated for lime-tree leaf litter, higher than those given in literature. A possible explanation is the stand age – the data are reported from grown-up stands where the nutrient and energy turnover is slower than in young stands such as the studied one.

DECOMPOSITION OF CELLULOSE IN THE FIELD

Fig. 5 shows the relative cellulose decomposition rate in the studied stands. Lime-tree stand appeared to be less active in cellulose decomposition. There might be some inhibition by polyphenols or low protection of the soil surface against frost and desiccation. The greatest cellulose loss was in larch stand with a thick layer of leaf litter and moss *Atrichum undulatum*. The enhancement of cellulose decomposition was most remarkable in dry summer months and in winter. Also, larch crowns let more light penetrate to the ground, which brings about higher temperatures. Cellulose RDR in red oak stand is a medium one, perhaps due to the leaf litter layer creating a specific microclimate.

CONCLUSION

Red oak litter decomposes slowly but the process of its decay runs well and is not harmful either to soil quality or to cellulolytic activity and decomposition of the litters of other tree species. The high annual leaf litter production, along with its slow decay, causes accumulation of litter into a thick layer which restricts the forest floor

vegetation growth, esp. seed germination and growth of seedlings.

Lime-tree leaf litter disappears very quickly in the stand due to its structure, but in the lab, the quality of lime-tree soil prevailed which slowed down the decomposition of lime-tree litter under constant moisture and temperature. The cellulolytic activity of the stand was also slower in the field. The forest understorey was not abundant, perhaps due to more shade or higher polyphenol content in leaves which might exhibit allelopathic effects.

Larch litter decomposed quite slowly though its chemical and structural qualities suggested fast decay. There was no adverse effect of larch soil on the decomposition rates of the tested leaf litters and cellulose. Also, the understorey was most abundant in larch stand, perhaps due to a high amount of penetrating light and warmth.

It is however necessary to keep in mind that this study was devoted to young, growing stands with high metabolic activity where the cycling of nutrients and energy is faster than in the old ones.

As a practical conclusion, the idea appears that in the case of tree plantations, it is better to plant mixtures of different tree species rather than monocultures, also from the viewpoint of litter decomposition. By mixing the litters of different quality, the adverse effect of one type of litter – either due to its structure or chemistry – might be avoided. This would help to avoid the worsening of forest soil quality and to support development of more natural forest-floor flora and fauna and thus achieve a desired balance of mass and energy of the whole stand.

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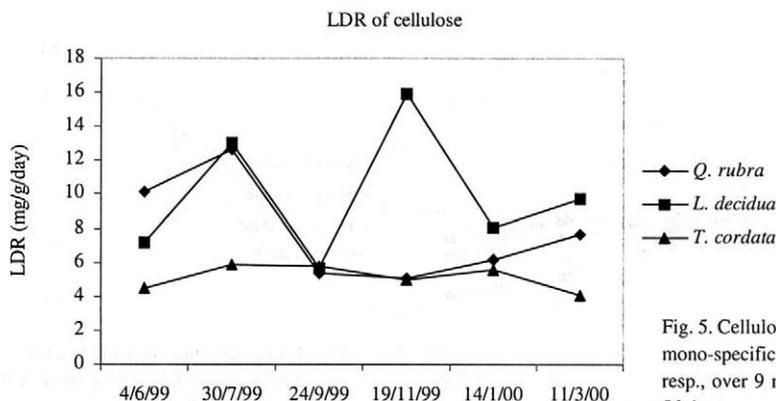
LDR of cellulose

Fig. 5. Cellulose relative decomposition rates in mono-specific stands of oak, lime tree and larch, resp., over 9 months with the sampling period 56 days

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Dekompozice opadu dubu červeného, modřínu opadavého a lípy srdčité a její vliv na vybrané půdní vlastnosti

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ABSTRAKT: V monokulturách tří dřevin – dubu červeného (*Q. rubra* L.), lípy srdčité (*T. cordata* Mill.) a modřínu opadavého (*L. decidua* Mill.) byla sledována rychlost dekompozice jejich listového opadu, a to jednak přímo na stanovištích, jednak kombinačním pokusem za kontrolovaných podmínek v laboratoři. Dále byla na stanovištích sledována rychlost dekompozice celulózy a stanovena roční produkce listového opadu. Byly také provedeny analýzy vybraných fyzikálních a chemických vlastností jak půdy, tak listového opadu dřevin. Výsledky ukazují, že listový opad červeného dubu se díky svým vlastnostem rozkládá v našich podmínkách pomalu, ale procesy dekompozice probíhají příznivě a nezhoršují půdu na stanovišti. Nízká pokryvnost podrostu je pak pravděpodobně způsobena vysokou produkcí těžko rozložitelného opadu, který se na stanovišti hromadí a představuje mechanickou a pro světlo nepropustnou překážku pro semenáče rostlin. Lipový opad se na stanovišti rozkládá velmi rychle, ale v laboratorních podmínkách se lipová půda projevuje jako brzdící pro procesy dekompozice. Modřínový opad vykazoval pomalý rozklad, nebyl však prokázán nepříznivý vliv půdy ze stanoviště modřínu na rychlost dekompozice opadu studovaných dřevin ani celulózy jak v laboratoři, tak v terénu, kde se celulóza rozkládala nejrychleji. Také podrost na stanovišti modřínu byl nejbohatší a vykazoval nejvyšší pokryvnost. Z práce vyplývá doporučení vysazovat spíše smíšené porosty než monokultury.

Klíčová slova: *Quercus rubra*; *Tilia cordata*; *Larix decidua*; opad; dekompozice; půda; podrost; chemické a fyzikální vlastnosti půdy a opadu

Rostlinný opad je základním energetickým zdrojem pro detritový potravní řetězec. Jeho dekompozice je pak hlavním procesem směřujícím k tvorbě půdy jako prostředí důležitého pro rostliny i půdní živočichy.

Cílem práce bylo porovnat rychlost dekompozice listového opadu tří druhů lesních dřevin – lípy srdčité (*Tilia cordata*), modřínu opadavého (*Larix decidua*) a introdukovaného dubu červeného (*Quercus rubra*) v podmínkách konstantní teploty a vlhkosti v laboratoři a porovnáním se zjištěnými vybranými chemickými a fyzikálními charakteristikami opadu odhadnout kvalitu opadu těchto dřevin a jeho potenciální rozložitelnost. Zároveň bylo zjišťováno, jak se různé druhy listového opadu rozkládají v závislosti na půdním substrátu a jak se různé kombinace substrátu a opadu podílejí během dekompozice na změně poměru huminových kyselin a fulvokyselin.

Terénní část práce zahrnovala kromě zhodnocení bylinného a keřového patra také zjištění roční produkce listového opadu na stanovištích monokultur zkoumaných dřevin a sledování rychlosti dekompozice celulózy na jednotlivých stanovištích.

Studované území se nalézá východně od hranice Přírodní rezervace Chuchelský háj v Praze 5. Sledované lokality jsou tvořeny stejnověkými monokulturami dubu červeného, lípy srdčité a modřínu opadavého.

Bylinné a keřové patro vykazuje podle analýzy ekologických faktorů pomocí indikačních hodnot (ELLENBERG 1979) na všech třech lokalitách vlastnosti lesních mezofilních, spíše nitrofilních rostlin středně teplých poloh a sub-

oceánského rozšíření. Na lokalitě modřínu opadavého byl zjištěn podle analýzy podrostu posun k jeho bazifilnějšímu charakteru a slunnějším stanovištím.

Pro porovnání vlivu jednotlivých druhů opadu a jednotlivých substrátů na rychlost dekompozice listového opadu dřevin byl ve standardních laboratorních podmínkách exponován kombinačním způsobem jejich listový opad a filtrační papír (celulóza) v plastových detritových sáčcích (TESAŘOVÁ 1987). Byla sledována rychlost dekompozice ve čtyřech časových odběrech po 59 dnech. Ta byla vyjádřena jak úbytkem hmotnosti opadu (WL), tak i relativní rychlostí rozkladu LDR (litter disappearance rate) (SUFFLING, SMITH 1974).

Substrát, na kterém byl 118 dní (2. odběr) rozkládán listový materiál a celulóza, byl podroben analýze poměru huminových kyselin a fulvokyselin a výsledek byl porovnán s poměrem HK : FK v substrátu na počátku dekompozičního procesu.

Dále byly stanoveny vybrané fyzikální a chemické vlastnosti listového opadu studovaných dřevin, a to: celkový obsah dusíku, celkový obsah uhlíku, obsah oxidovatelného uhlíku, celkový obsah fosforu, obsah vodorozpustných polyfenolů, specifická hmotnost listu (SLM), schopnost listů absorbovat vodu (absorbancy), obsah vodorozpustných látek (WSS) a obsah popelovin.

Humusový Ah horizont půd byl podroben analýze celkového obsahu dusíku, obsahu oxidovatelného uhlíku, pH (KCl/H_2O) a poměru huminových kyselin a fulvokyselin.

Sledování rychlosti rozkladu celulózy (filtrační papír) na jednotlivých lokalitách studovaných dřevin bylo

prováděno metodou detritových sáčků (TESAŘOVÁ 1987) při expozici 56 dní. Celkem bylo provedeno šest odběrů. Výsledná rychlost rozkladu celulózy byla vyjádřena jako relativní rychlost rozkladu (LDR).

Roční produkce listového opadu v jednotlivých monokulturách sledovaných dřevin a bilance jeho přísunu a odstraňování byla zjištěna jednorázovým odběrem opadu bezprostředně po jeho spadu. Z výsledných hmotností byly vypočteny dekompoziční konstanty k (OLSON 1963), k' (JENY 1949), $T_{(0,5)}$ a $T_{(0,95)}$ (OLSON 1963). V případě modřínového porostu nebyly dekompoziční konstanty určeny.

Z výsledků analýz listového opadu studovaných dřevin (tab. 1) vyplývá, že opad červeného dubu má vzhledem k rozložitelnosti nejméně příznivé vlastnosti jak fyzikální (nejnižší schopnost absorpce vody a nejméně vodorozpustných látek), tak chemické (nejnižší obsah dusíku a nejméně příznivý poměr C/N). Allelopatické účinky opadu jsou vzhledem k nízkému obsahu polyfenolů málo pravděpodobné.

Opad lípy vykazuje vlastnosti listu o něco lepší, spíše však po stránce fyzikální (nejnižší specifická hmotnost listu a nejvyšší schopnost absorbovat vodu). Chemické vlastnosti opadu mají neutrální (obsah N, poměr C/N) nebo nepříznivý (obsah P a polyfenolů) vztah k dekompozici.

Celkově nejpříznivější vlastnosti vykazuje opad modřínu. Jediná zjištěná nepříznivá vlastnost tohoto druhu opadu je jeho vysoká specifická hmotnost. K atraktivitě jehlic modřínu pro dekompozitory by mohl přispívat zejména vysoký obsah N, P a příznivý poměr C/N, rychlost rozkladu může podporovat také vysoký obsah vodorozpustných látek.

Analýza humusového Ah horizontu studovaných stanovišť ukázala (tab. 2), že – vyjímaje písek – se v případě pH půdy a obsahu dusíku jednotlivé půdy neliší; v dalších charakteristikách se odlišuje pouze půda pod modřínem, která vykazovala vyšší obsah Cox, a tím méně příznivý poměr C/N.

Z výsledků rychlosti dekompozice opadu a celulózy v laboratoři (obr. 1–4) vyplývá, že ze všech exponovaných materiálů se nejrychleji rozkládá celulóza, dále lipový opad a nejdéle odolává rozkladu opad modřínu a červeného dubu. Podrobnější analýzou bylo zjištěno, že všechny druhy listového opadu se nejlépe rozkládají na půdě ze stanoviště červeného dubu (dále dubová půda), pouze celulóza je nejrychleji dekomponována na půdě z lipového porostu (dále lipová půda).

Rozklad opadu červeného dubu probíhá nejpomaleji na půdě z modřínového porostu (dále modřínová půda) a na písku, na písku se také nejhůře rozkládá modřínový opad a celulóza. Lipový opad pak podléhá dekompozici nejpomaleji na vlastní (tj. lipové) půdě.

Z hlediska časového průběhu dekompozice bylo zjištěno, že při prvním a druhém časovém odběru se rych-losti dekompozice mezi jednotlivými druhy opadu, s výjimkou celulózy, příliš neliší. Rychlosti rozkladu se rozrůznují až při třetím a čtvrtém odběru.

Při srovnání vlivu použitých substrátů na rychlost dekompozice jednotlivých druhů opadu bylo zjištěno, že dekompozici nejvíce urychluje půda ze stanoviště červeného dubu, zatímco nejpomaleji probíhá rozklad na písku.

Dubová, modřínová a lipová půda nejvíce urychlují rozklad celulózy, na písku pak největší úbytek hmotnosti vykazuje opad lípy.

Na dubové půdě se nejhůře dekomponuje opad červeného dubu a modřínu, velmi podobná situace nastává na modřínovém substrátu. Lipová půda není příznivá rozkladu žádného druhu listového opadu, podporuje pouze rozklad celulózy. Na písku se nejhůře rozkládá celulóza.

Z časového průběhu dekompozice lze zjistit, že vliv půdního substrátu na jednotlivé křivky LDR v čase není výrazný, výjimku tvoří dubová půda, která přispívá u opadu červeného dubu, modřínu a lípy k rychlejší míře rozkladu při třetím a čtvrtém odběru z termoboxu. Zbrzdění procesu dekompozice bylo zjištěno u lipové půdy.

Změna poměru huminových kyselina fulvokyselin před dekompozicí a po 118 dnech dekompozice opadu na substrátech v termoboxu nebyla prokázána u žádné z kombinací substrátu a opadu.

Z výsledků ročního spadu listového opadu a bilance jeho přísunu a odstraňování vyplývá (tab. 3), že rychlost úbytku opadu je v porostu lípy srdčité velmi vysoká, 95 % listového opadu lípy zmizí ze stanoviště asi za 6,5 měsíce, opad červeného dubu pak asi za 4,3 roku.

Výsledky sledování relativní rychlosti dekompozice celulózy na stanovištích studovaných monokultur je znázorněn na obr. 5. Stanoviště s porostem *T. cordata* se projevilo jako nejméně příznivé k rozkladu celulózy. Může to být způsobeno buď inhibičním účinkem vysoké koncentrace polyfenolů, nebo nedostatečnou ochranou povrchu půdy vůči vysychání a mrazu.

Nejvyšší rychlost rozkladu celulózy u modřínového porostu naznačuje příznivé půdní vlastnosti pro tento proces. Navíc je porost modřínu prosvětlenější a je zde tedy patrně příznivější mikroklima.

Při hodnocení výsledků práce je však nutné mít na paměti, že se zabývá porosty nedospělými, které stále rostou, takže tyto závěry nemusí již platit pro porosty vyššího stáří, neboť vlivem růstu a vývoje porostu může dojít ke změně ekologických faktorů. Navíc se v případě červeného dubu a modřínu jedná o jejich okrajová stanoviště.

Jako praktický závěr práce se nabízí myšlenka, že pokud je nutné vysazovat nepůvodní dřeviny do našich přírodních podmínek, je lépe vytvářet směsi dřevin, neboť míšením různých druhů opadu se omezují do jisté míry vlivy jak nepříznivých charakteristik opadu, tak i vlivy metabolitů jejich rozkladu na lesní půdu.

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Influence of different treatment on Wild Cherry seedling performance

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ABSTRACT: A trial plantation of two years old seedlings of Wild Cherry (*Prunus avium* L.) was established in the framework of research project. Three different treatments with three replicates were laid out randomly. The used treatments were: mycorrhiza inoculum applied to seedling roots, hydrocolloid covering of seedling roots when planted and combination of both methods. An evaluation of the plantation was done regularly. No statistically significant differences were found between the treatments in terms of total mortality or above-ground biomass. The most important finding is that the ground biomass (root system) of treated seedlings was significantly stronger and heavier than the ground biomass of the control.

Keywords: noble hardwood; artificial regeneration; plantation treatment; mycorrhiza; hydrocolloid; above-ground biomass; ground biomass

Wild Cherry *(Prunus avium* L.) is reintroduced to forest stands for many good reasons. However, there has not been very much information on its site demands and requirements for artificial regeneration until now.

The Wild Cherry growing in Europe is a spontaneous hybrid of different origins spread through the whole area mostly without any help of man (FERKL 1958). It prefers warm sandy soils on warm southern exposures (FERKL 1958). The actual area is the whole Europe apart from Scandinavia (FÉR 1994). Wild Cherry is growing from oak vegetation zone up to beech vegetation zone, i.e. from 100 up to 700 m above sea level. Wild Cherry prefers bottom parts of valleys and the bases of deep slopes. It is a partly shade-tolerant species, in other words it needs some sunshine in the vegetation period. It seems to be quite tolerant to air pollution; on the other hand, it is sensitive to frost. Long drought could heavily damage the plantation. Wild Cherry is not very demanding for nutrients. It is very sensitive to mechanical injuries but it is quite stable against windstorms. On the other hand, Wild Cherry is not resistant to biotic damage.

Wild Cherry has a life span between 60–80 years, which is not very long in comparison to other trees. Its regeneration potential is rather low (ČÍŽKOVÁ, BENEDÍKOVÁ 1999). It is spread in the whole territory of the country, preferring the thermophytic and mesophytic zones. The actual main growing areas are Central Bohe-mia, Southern Moravia and Slovakia. Wild Cherry was originally growing most probably only in Slovakia and Southern Moravia and it has spread to Central Bohemia.

DESCRIPTION OF THE PLOTS AND METHODS USED

Trial plantations of two years old Wild Cherry seedlings were established at the locality called Na Americe in April 1999. Generative bare root seedlings of local origin were used as the planting stock. Site quality could be described by the Czech typological system as 2K0, which is defined as a not very rich in terms of soil nutrients but quite warm site. The site is not the best for Wild Cherry but it is quite good for successful growing. The trial plantation was carried out in one day on 20th April 1999. There are twelve trial subplots into which the whole research plot is divided. The size of subplots is 10 by 10 m, which makes the total size 40 by 30 m, that means the total area of 0.12 ha. The bare root seedlings were planted manually into 25 by 25 cm sockets about 30 cm deep. There are 16 Wild Cherry plants on each subplot with the 2 by 2 m spacing. Though the trial has not a very large amount of plants and some generalization could be done only with caution, we think the results could be of interest because not very much data have been published on Wild Cherry plantations until now.

Table 1. Type of seedling treatment and its identification

Identification	Treatment description
M	Mycorrhizal granulate added to seedling socket
H	Covered seedling roots with hydrocolloid
HM	Covered seedling roots with hydrocolloid and mycorrhizal granulate added to seedling socket
C	Control (no seedling treatments)

Table 2. Quality evaluations of seedlings and used coding

Code	Quality description of seedlings
1	Plant in good condition with clear height increment
2	Plant with stem damage or multi-stem plant
3	Plant with damaged terminal (top bud) or/and damaged top
4	Dead plant

The chosen plot was weed grown and reforested with two-year beech seedlings (ten thousand per hectare) one year ago (1998). The situation on the plot gives us the chance to study also the influence of weed competition on the Wild Cherry plantation. The Wild Cherry seedlings were planted at a regular 2-m distance between beech seedlings.

There were three types of treatments made at the time of planting and no treatment (control) in the trial. The treatments were three times repeated. The position of partial plots with specific treatment was given by generating random numbers. The type of treatment and its identification are given in Table 1.

The tested mycorrhizal granulate was prepared by the Institute of Chemistry and Technology in Prague. An application for product protection by the patent has been filed. Therefore the type and composition of mycorrhiza cannot be specified for the time being. The same applies to the specification of hydrocolloid which has the role of root protection in the post-planting period.

The plot is fenced to protect the plantation against game damage. As stated above, the plants were exposed to strong weed competition. The depth of weed rhizosphere ranges from 10 to 17 cm with average height of *Calamagrostis epigeos* (L.) about 70 cm. Routine protection of seedlings by weed reduction was done once a year to improve growing conditions for plants.

All planted seedlings were identified by metal label with given number. Measurements of plants and their qualitative evaluation were carried out regularly in the autumn. The quality evaluation was done using the following codes given in Table 2.

Stem damage means in most cases that the part of the stem is dead with new sprouts starting from the bottom part of the plant. A similar situation is with code 3. The top of the stem is dead and new sprouts are growing from the lower part of the stem. There was no evident damage on the aboveground part of the plant by insects or animals and it was difficult to identify the harmful factor. Most probably the weed pressure would be the main reason for the damage.

The height of a plant is defined as the vertical distance between the ground and the tallest living part of the plant. The diameter of a plant is defined as a stem diameter measured just above the ground (where the stem comes into the ground and changes its colour). The root architecture was also evaluated by sample plants taken from each partial plot in the autumn 2000. The root system was separated into fine roots (with diameter less than 1 mm) and the others. Biomass volume and weight in fresh and dry conditions were assessed separately for above-ground and underground parts of the plant. Plant desiccation was done in a drying chamber at a temperature of 105°C for 24 hours.

RESULTS AND DISCUSSION

The planted Wild Cherry seedlings were under a strong pressure of weed competition (*Calamagrostis epigeos* L.). Although Wild Cherry is as a young, partly shade-

Table 3. Quality of seedlings after one growing season after planting (in total)

Code	Quality description	Number of plants	Relative number of plants (%)
1	Plants in good condition	151	78.7
2	Plants with stem damage	10	5.2
3	Plants with damaged top	6	3.1
4	Dead plants	25	13.0
	Total	192	100.0

tolerant tree species, the weed pressure has clearly deteriorating impacts on seedlings. This statement is obviously supported by empirical data collected on the plot. Table 3 gives the summarized data on quality evaluation of seedlings, one growing season after planting, that means in autumn 1999. The data are summarized for all types of treatment.

Two plants were not found in autumn 1999 and therefore they were considered as dead. They are not taken into account for further calculations as we were not able to follow their status.

The data show that total mortality was acceptably low (only 13% – much lower than average mortality in artificial regeneration in this country, the latest data indicate 19.6%, ANONYMOUS 2000). But another 8% of plants were damaged either on the bottom or upper part of the stem. As no damage was observed due to insects or small vertebrates (neither due to game), it could be supposed the damage was due to weed competition.

A more complex picture of quality development in the next year is given in the following tables and graph. The seedlings are divided into two groups depending on the quality status in 1999:
– undamaged plants,
– damaged plants.

The plant quality was registered in autumn 2000 using the same coding as given in Table 2 and data are given separately depending on the 1999 status of the plant. Table 4 gives data on control subplots.

The high mortality (42%) of the damaged seedlings on control subplots (with no special treatments) is not very surprising but more than a half (53%) of newly damaged plants among those that were not damaged a year ago is really high. The results show how difficult the weed competition at the beginning of their existence in the field is for Wild Cherry seedlings (like for many broadleaved species). On the other hand, no mortality of undamaged plants shows how important the good starting situation of planted trees is for their survival.

What was the quality development of specially treated seedlings? Here are the data given together with untreated plants (control subplots) in Fig. 1.

There are not any statistically significant differences between the groups with different treatments. Slightly worse results of hydrocolloid treatment could hardly be explained. An obvious fact is that control subplots had the same results as specially treated subplots, thus no evident positive influence of any treatment on avoiding damage after planting could be found out.

Table 5 gives the data on development of quality status in seedlings damaged in 1999.

Again, the worst results were obtained for seedlings treated with hydrocolloid but no statistically significant differences in mortality for damaged trees in one year after the first damage appeared.

Height and its increment are very important as quantitative indicators. A good height increment gives the plant a chance to earlier escape the weed competition. The visible height increment is one of the parameters required by Forest Act for secured plantations. The data on height increment is given in Table 6.

Only the seedlings with mycorrhiza had statistically significantly better height increments than untreated seedlings (control). The other treatments also had slight-
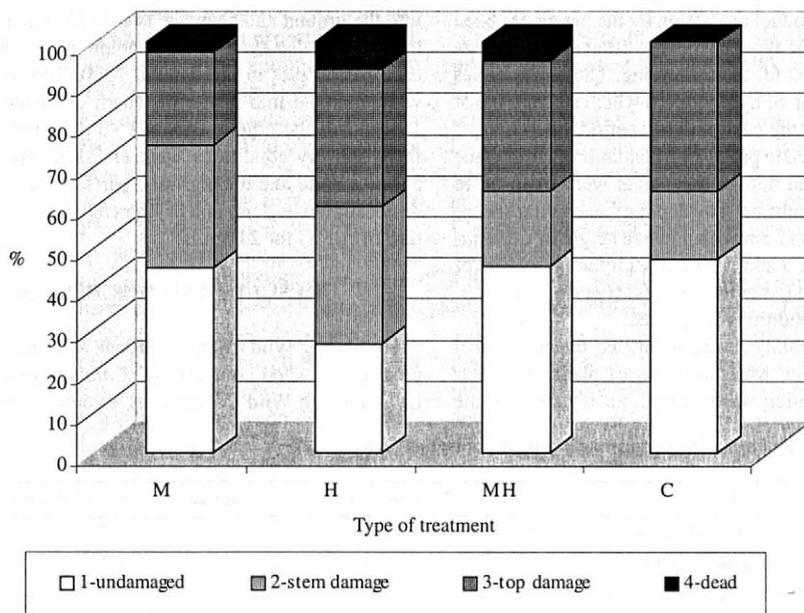

Fig. 1. Quality status in 2000 for undamaged plants in 1999 according to their treatments

Table 4. Seedling quality in 2000 according to their 1999 status – control subplots

Starting 1999 status	(1) Undamaged plants	(2) Plants with stem damage	(3) Top damaged plants	(4) Dead plants	Total
Undamaged in 1999	17	6	13	0	36
Damaged in 1999	0	5	2	5	12
Total	17	11	15	5	48

Table 5. Seedling quality in 2000 according to 1999 status – damaged plants in 1999

Treatments	(1) Undamaged plants	(2) Plants with stem damage	(3) Top damaged plants	(4) Dead plants	Total
Mycorrhiza	1	1	2	4	8
Hydrocolloid	0	2	2	12	16
Mycorrhiza and hydrocolloid	0	2	0	2	4
Control	0	5	2	5	12
Total	1	10	6	23	40

ly better height increment in comparison with control subplot but these differences were not significant.

Table 7 gives the most exciting results of the trial. While the differences in the aboveground parts of seedlings are not significantly different from control (with one exception of height increment of mycorrhized seedlings), the ground biomass shows significant differences at probability level 95% in all types of treatments. The differences are significant both in fresh and dry condition. The weight of fine roots was also significantly higher for treated seedlings than for control but the proportion, i.e. the ratio to the whole weight of roots, was not significantly different.

The differences are still larger in Table 8 where the ratio of under-ground to above-ground biomass is given. All type of treatments are significantly different from the control reflecting the fact the ground biomass was much more developed than the above-ground biomass of seedlings.

The ground biomass is the most important part of seedlings and it is a crucial part for success or failure of seedling performance. Particularly the seedlings with mycorrhiza and hydrocolloid treatment show significantly higher ground biomass than seedlings with no treatment (Table 8) but all treated seedlings have statistically significantly higher ground biomass.

Table 6. Seedling heights and their increment in the growing season 2000

Treatments	Height 1999 (cm)	Height 2000 (cm)	Height increment (cm)
Mycorrhiza	39.9	41.0	1.1*
Hydrocolloid	41.4	42.4	1.0
Mycorrhiza and hydrocolloid	42.0	42.9	0.9
Control	38.7	39.4	0.7

* Statistically significantly different from the control at probability level 95%

Table 7. Data on the above- and under-ground parts of seedlings two growing seasons after planting

Treatments	Weight of above-ground part (g)		Weight of ground part (g)		Proportion of fine roots	
	fresh	dry	fresh	dry	dry (g)	% of total roots
Mycorrhiza	8.73	4.57	13.33*	5.53*	0.57	6.7
Hydrocolloid	10.23	5.23	13.99*	6.06*	0.65	10.7
Mycorrhiza and hydrocolloid	10.18	5.25	18.71*	8.22*	0.68	8.3
Control	9.48	5.26	8.28	3.95	0.3	7.6

*Statistically significantly different from the control at probability level 95%

Table 8. The ratio of under- to above-ground parts of seedlings two growing seasons after planting

| Treatments | Ratio of under- to above-ground parts | |
	fresh	dry
Mycorrhiza	1.5*	1.2*
Hydrocolloid	1.4*	1.2*
Mycorrhiza and hydrocolloid	1.8*	1.6*
Control	0.9	0.8

*Statistically significantly different from the control at probability level 95%

CONCLUSIONS

Wild Cherry seedlings were planted on a trial plot at Kostelec nad Černými lesy in spring 1999. Since then regular measurements have been carried out on the plots. The plot is divided into twelve research subplots where three different treatments were applied. Together with control subplots it makes three replications on the trial plot. The treatments were: mycorrhiza, hydrocolloid, combination of both methods, i.e. hydrocolloid and mycorrhiza, and no treatment (control). Mycorrhizal grains were added to the root sockets, and/or hydrocolloid covered the seedling roots just before planting (Table 1). The trial plot is fenced giving good protection against game damage. On the other hand, the plot is densely overgrown with the weed *Calamagrostis epigeos*.

Weed competition was definitely the main harmful factor influencing the plantation. Our assessments made twice a year did not find any other harmful factors in the plantation. Routine protection of seedlings by weed reduction was done once a year to improve the growing condition for plants.

Total mortality for all types of treatments was 13%, which is better than the average level in the whole country. There were no significant differences in mortality between different treatments. The result supports the thesis that Wild Cherry seedlings were not particularly more sensitive to mortality when planted with a sufficient level of care.

The weed competition clearly damaged the seedlings when 52% suffered some injuries. The typical reaction of Wild Cherry seedlings is alternative shoots or stems. This phenomenon shows a good potential of Wild Cherry seedlings to recover from stem injuries.

Whereas the aboveground biomass did not show any significant differences for different treatments (and no significant difference as compared with control seedlings), the ground biomass was much more developed than the control. This applies to fresh biomass as well as to dry biomass. The most pronounced differences are expressed by the ratio of under to above-ground parts of seedlings which is given in Table 8. All values belonging to special treatments are significantly different from control data.

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Vliv různého ošetření sazenic třešně ptačí na jejich ujímavost

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ABSTRAKT: V rámci výzkumného projektu byly založeny v dubnu 1999 pokusné výsadby dvouletých sazenic třešně ptačí (*Prunus avium* L.). Na plochách byly použity tři různé způsoby ošetření sazenic ve třech replikacích náhodně opakovaných. Byla použita tato ošetření: inokulace sazenic přidáním inokulátu do jamky při výsadbě, obalení kořenů sazenic hydrokoloi-

dem při výsadbě a kombinace obou ošetření. Jako kontrola slouží výsadba sazenic bez ošetření. Hodnocení výsadeb bylo prováděno každoročně. Mezi jednotlivými způsoby ošetření nebyly zjištěny žádné statisticky významné rozdíly v mortalitě sazenic a v hmotnosti nadzemní biomasy. Signifikantní rozdíly byly zjištěny v hmotnosti kořenového systému.

Klíčová slova: cenné listnáče; umělá obnova; ošetření sazenic; mykorhiza; hydrokoloid; nadzemní biomasa; biomasa kořenového systému

Třešeň ptačí je z mnoha rozumných důvodů znovu vysazována v našich porostech. Bohužel však chybí dostatek relevantních informací o způsobech přirozené a umělé obnovy a pěstování této dřeviny. Ani její původ není zcela jasný. Poměrně dost informací máme o jejich ekologických nárocích.

V rámci výzkumného záměru byly na Školním lesním podniku v Kostelci nad Černými lesy založeny výzkumné plochy výsadeb třešně ptačí. Jednalo se o prostokořenné dvouleté generativní sazenice místního původu, které byly vysazovány do jamek o velikosti asi 25 × 25 cm. V rámci výzkumného záměru byly během výsadby použity tři různé způsoby ošetření. V první řadě byl do jamky při výsadbě přidán mykorhizní granulát, ve druhé variantě byly kořeny ošetřeny ponořením do hydrokoloidu, ve třetí variantě byla obě ošetření zkombinována a čtvrtá (kontrolní) varianta byla bez speciálního ošetření. Mykorhiza byla připravena pracovištěm Vysoké školy chemicko-technologické v Praze (preparát je podán k patentování a proto jeho složení nemůže být přesněji specifikováno). Hlavním cílem ošetření hydrokoloidem bylo ochránit kořenový systém během povýsadbového šoku. Celkem bylo vysázeno 12 dílčích arových ploch po 16 sazenicích ve sponu 2 × 2 m. Celková výměra pokusné plochy je 30 × 40 m. Plocha je v oplocence, takže je dobře chráněna před škodami zvěří. Původní paseka byla rok předtím zalesněna bukovými dvouletými prostokořennými sazenicemi. Celá plocha je silně zabuřeněná *Calamagrostis epigeos*.

Sazenice byly každoročně hodnoceny jak po stránce kvantitativní (výška nadzemní části a tloušťka kořenového krčku), tak po stránce kvalitativní. Kvalita sazenic byla hodnocena podle tab. 2. Data v tab. 3 ukazují značný stupeň poškození sazenic útlakem buření (celkem 21 %). Zajímavý výsledek je ilustrován na obr. 1, ze kterého je zřejmé, že způsob ošetření sazenic v podstatě nijak neovlivnil ujímavost a kvalitu sazenic. Neošetřené (kontrolní) sazenice byly rok po výsadbě ve stejném stavu jako sazenice ošetřené. Výškový přírůst v druhém roce po výsadbě je velmi malý (tab. 6) pravděpodobně jako výsledek povýsadbového šoku. Ošetření hydrokoloidem nemělo žádný pozitivní vliv na zmenšení tohoto šoku právě tak jako ošetření mykorhizou.

Ve stavu kořenového systému byl naproti tomu výrazný rozdíl. Všechny typy ošetření měly statisticky signifikantní vliv na rozvoj kořenového systému, jehož hmotnost byla významně vyšší (jak v čerstvém stavu, tak ve stavu dehydrovaném – tab. 7). Rovněž podíl jemných kořínků na hmotnosti celého kořenového systému je výrazně vyšší (tab. 7), což je velmi důležité z hlediska stavu výživy rostliny. Ačkoliv je zřejmé, že uměle vnesená mykorhiza je v prostředí lesa brzo překryta místní mykoflórou, pozitivní vliv mykorhizního inokulátu (ale i hydrokoloidu) je zřetelný.

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Extended methods of automatic processing of multispectral airborne images of forest stand

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ABSTRACT: This study deals with the application of sophisticated methods of airborne multispectral images with high spatial resolution to describe the forest stand of Josefov valley. Quite a large part of suggested methods was extended and developed. The study determined the possibilities of polynomial transformation of four bands from MSK 4 camera to the identical position and use of subtractive color model according to the proposed sequence of channels to display a synthesis of these channels in natural colors. Classification of tree species was proposed for application by soft classifiers in Idrisi system. The edge detection method in gradient direction was improved by the iterative morphological operations to detect object boundaries as well as the methods of preliminary tree top and crown detection were applied and improved.

Keywords: remote sensing; aerial photographs; tree detection; image processing; anisotropy diffusion

The needs of forest inventory concerning the most accurate and objective characteristics of forest ecosystem are generally known. Multispectral images are sources of information on the landscape for forest planning. Nowadays their application under current conditions is bounded by both the visual interpretation and by the computer supervised and unsupervised classifications. There is no doubt about the methods being suitable for the needs of forest planning because of their objective resultant information (it means information without witness's personal evaluation) on the forest stand.

Images with high spatial resolution can provide further detailed information on the texture, shape, area, and mutual influence of the particular tree crowns and thus contribute to the high-quality processing and investment valorization of the image acquirement. A basic unit for this information is just an individual tree whose visual, automatic or semiautomatic identification serves as a key for approximation of the real tree characteristics.

Operators dealing with data obtained from remote sensing in current working conditions are often limited in their image processing work by the use of commercial software that offers only basic algorithms of image data processing. There are no special methods for forest images at their disposal, such as tree top or crown detection, spe-cial edge detectors, etc. The situation is caused by the algorithm nature representing an intelligence property and a form of expertise for the subject or the cost of implementation of these technologies is too high for common users. This was the reason to implement some of these algorithms into a software product that would facilitate tree top and crown detection as well as other processing steps being rarely available by common software.

The aim of this paper is to present and apply advanced methods for image processing especially designed for the needs of forest planning, such as edge detection, tree species recognition and individual tree top and crown estimation.

MATERIAL AND METHODS

The selected area was situated in the northern part of the Josefov valley reservation called Purkyně reservation and adjacent northern part of the forest stand. The locality is situated 5 km to the north-east of Adamov and in the locality represented by deciduous forests of the protected natural area Moravian Karst. A major part of the area is represented by the formation of 4D3 *Fageta dealpina*, 1CD3 *Corni-acereta campestris* and 3BC3 *Querci-fageta tiliae-aceris*.

Table 1. Basic properties of MSK4 camera sensor (ŠMIDRKAL 1989)

	Half of the view angle (°)		F	Negative dimensions	Number of bands
α_x	α_y	α_{max}	(mm)	(mm)	
12.43	17.93	21.37	125	55 × 80	4

Table 2. View of the spectral bands of the MSK 4/II camera

Channel	Spectral band name	Wavelength (μm)	Filter (nm)
1	Blue	0.460–0.500	480
2	Green	0.520–0.560	540
4	Red	0.640–0.680	660
6	Near IR	0.790–0.890	840

Airborne images were made for Nature Protection Agency on 23. 7. 1990 in the daytime at 12.45–14.30 at the flying height of 4,500 m with forward 60% and lateral 30% overlap. The area was scanned in four spectral bands by MSK4 camera sensors. Tables 1 and 2 show the basic data on the camera. Due to this scale, the area covers 2.75 km² (1,375 m × 2,000 m). The area size without overlap is 0.77 km² (550 m × 1,400 m) and covers 28% of the total image surface. The northern part of Josefov valley is one square kilometer in size, Purkyně reservation takes 0.5 km² and is situated in the just forward overlap of scene number 535 28 and 535 29.

TRANSFORMATION AND COLOR SYNTHESIS

Each image of spectral band was digitized in spatial resolution of 600 dpi and intensity resolution of 256 levels of gray. In such resolution, there were approximately 90–120 pixels per one crown. Individual channels were transformed into identical position because of distortion of spectral cameras of MSK 4 sensors. Channels No. 4, 1, 6 were transformed into the position of channel No. 2. To fulfill this task projective and polynomial transformation of the third order was used with the nearest neighbor interpolation. The first one, projective transformation, requires six reference points at least and it does not compensate distortion caused by the area relief and camera lens displacement. The second one, polynomial transformation of 3rd degree, takes 10 reference points at least. It is suitable for distortion compensation caused by the area relief and camera lens displacement. If such a transformation takes place, a regular grid of reference points needs to be placed to avoid image distortion due to the higher order polynomial transformation effects.

The Descartes software for MicroStation was used for the transformation process due to the high performance features. The number of reference points was visually estimated to be between 15–20 locations regularly placed in the transformed area. Transformation accuracy was calculated according to the root mean square:

$$RMS(xy) = \sqrt{\frac{\Sigma(\Delta x^2 + \Delta y^2)}{(n-k)}}$$

$$\Delta x^2 = (x_1 - x_{orig})^2$$
$$\Delta y^2 = (y_1 - y_{orig})^2$$

where: x_1, y_1 – computed horizontal and vertical coordinates according to the transformation model,

x_{orig}, y_{orig} – horizontal and vertical coordinates of the original reference points,

n – number of reference points,

k – minimum number of reference points for transformation model.

COLOR SYNTHESIS

Color synthesis is an important part of the image pre-processing for the creation of training sets and multispectral classification. The number and type of synthesis components represent the number of spectral channels in the primary phase, and in the next one there can be some transformation channels of different modifications, for example vegetation indices, images from principal components analysis, etc. The Adobe Photoshop tool was used for color synthesis from the transformed images providing a suitable environment for image manipulation and visual interpretation. This platform makes it possible to create all possible combinations of the four channels in the RGB additive color model and provides a tool called Filter Factory for script programming. To this point a simple script for quickly changing the RGB channel order was developed for color synthesis variations. But the RGB color model can be composed of three bands only. To avoid this limitation of four channel images a subtractive color model CMYK was proposed together with subsequent transformation into RGB model. There is a review of all formed color models in Table 3.

VEGETATION INDICES COMPUTING

Once chlorophyll degenerates, its light absorption decreases in the red and near infrared bands causing yellow and red pigments to dominate. This is the opposite of the

Table 3. Review of the multispectral image color synthesis

	• RGB synthesis			
	Description	R	G	B
NAT I	Natural colors	4	2	1
NAT II	Health state synthesis	4	6	(1)
FALS I	False color	6	2	1
FALS II	False color synthesis II	6	2	4

	• CMYK composition			
	Description	C	M	Y	K
NAT III	Natural colors	4	6	1	2

reason for the increasing light reflectance in the band of 0.68 μm when defoliation takes place. Hence we use the 0.66 μm band as a red channel in RGB color model and 0.84 μm band in the green one; the increasing damage of trees causes a lower amount of the green component while increasing the red one (FAIMAN 1986). This principle forms a basis for vegetation indices computing. Their use is reduced by the spectrum variability of objects, which is caused by the factors of exposure, slope, illumination etc. Vegetation indices allow to discern vegetation from non-vegetation objects. This is the way to create a mask covering the vegetation only to make a classification process more precise. To fulfill this task a special script was formed in the Filter Factory environment to compute modified normalized vegetation indices according to the following equation:

$$VI_2 = \frac{(NIR - RED) \cdot S}{(NIR + RED) + A} + L$$

where: NIR, RED – channels No. 6 and 4.

The process of modification is based on the addition of the constants S, A, L for variable extension of brightness rate in the output image.

EDGE DETECTION

The edges represent both the boundaries of the current object demarcation (for example road construction) and a significant primary division of image segments. Edge detection and processing may optimize the whole classification process as well. Besides the specific spectral reflectance a closed segment boundary can provide some other characteristics, for example symmetry, orientation, texture characteristics, length of boundary, etc. and thus it contributes to the process of classification *per region*.

Edge detection was subdivided into three stages:
1. Image smoothing
2. Edge detection
3. Edge arrangements

1. Image smoothing by diffusion

A raw captured remote sensed image contains a number of minute edges being of no significance for detection on a certain scale. Therefore different degrees of Gaussian image smoothing are often used to reduce detail unnecessary information. A disadvantage of such linear filters is however a smoothing of important edges too. This paper benefits from the new anisotropy diffusion smoothing presented in the paper of MALIK, PERONA (1990). They proposed the anisotropy diffusion filter as a diffusion process that encourages intraregion smoothing while preserving interregion smoothing. They suggested the following equation in which the conduction coefficient c is not constant in space, but it is a function of the magnitude of the intensity gradient of the image:

$$\frac{\partial}{\partial t} I(x,t) = \nabla \cdot \Phi(x,t)$$

$$\Phi(x,t) = c(x,t)\nabla I(x,t)$$

$$c(x,t) = f(|\nabla I(x,t)|)$$

where: $I(x,t)$ – the image,
x – refers to the image axes,
t – refers to the iteration steps,
$\Phi(x,t)$ – the flow function,
$c(x,t)$ – the diffusion function.

By this process the amount of diffusion at each point in the image space is modulated by the function $c(x,t)$ and the image gradient at that point. They choose to make $c(\cdot)$ a monotonically decreasing continuous function of the image gradient magnitude. Evaluation of this function in a moving window process makes it possible to define a smoothing amount for the central pixel according to the diffusion results of the eight closest neighboring pixels. An exponential function was used in this study as a decreasing function, but an inverse function of image gradient could be used as well:

$$c_1(x,t) = \exp\left(-\left(\frac{|\nabla I(x,t|}{K}\right)^2\right)$$

$$c_2(x,t) = \frac{1}{1+\left(\frac{|\nabla I(x,t|}{K}\right)^{1+\alpha}} \mid \alpha > 0$$
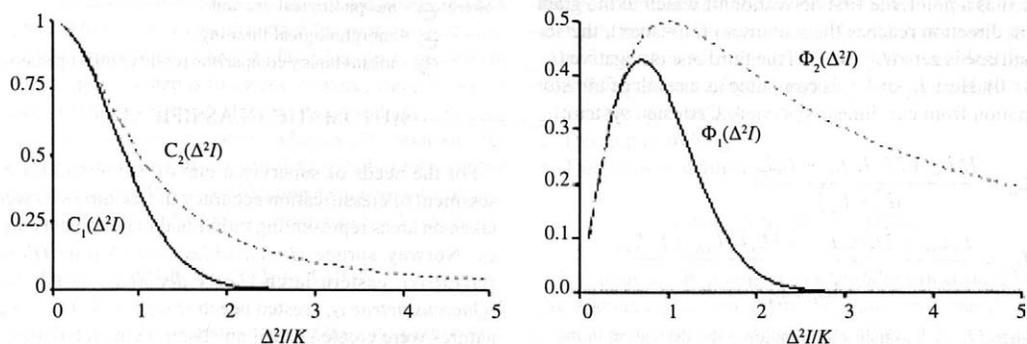
Fig. 1a) Dependence of the diffusion function on the image gradient. 1b) Dependence of the flow function on the image gradient

K is referred to as the diffusion constant. The function increases with the gradient to the point where $|\nabla I| \cong K$, and afterwards it decreases to zero. This function behavior implies that the diffusion process maintains homogenous areas where $|\nabla I| \ll K$ since the flow function is small in sections where $|\nabla I| \ll K$.

The highest flow is reached when the image gradient magnitude approximates to the value of K. Hence the coefficient K is applied to reflect to gradient magnitude produced by noise. The diffusion process can be used to decrease noise in images.

In this study a discrete implementation of the anisotropy diffusion was derived according to (GERIG et al. 1992):

$$I(t + \Delta t) = I(t + \Delta t \frac{\partial}{\partial_T} I = I(t) + \Delta t (\Phi_e - \Phi_w + \Phi_n - \Phi_s)|$$
$$\Delta t < -1$$

where: $\Phi_e, \Phi_w, \Phi_n, \Phi$ – denominate a flow function for pixels located in the n directions from the central pixel,

Δt – the integration constant.

To compute diffusion implies the increment of pixel flow located in the neighborhood of the processed pixel (Fig. 2).

2. Edge detection

The goal of the edge detection is to determine the pixels in the image in correspondence to the object boundaries seen in the captured scene. It is natural to define the edges as those points where the gradient magnitude assumes a maximum in the gradient direction. Thus the edges are defined by a differential geometric approach (LINDBERG 1993), also known as non-maximum suppression. For the purpose of the method explanation, it is possible to consider, for instance, an ideal tree crown in the sphere or cone shape supposing the illumination is vertically perpendicular to it. Then the tree crown is built up of isosurfaces (contours) gradually increasing from the tree top center. Next we introduce a new orthonormal coordinate system (u, v) at any image point where v-axis is parallel to the gradient direction of the pixel intensity L at the given point, and u-axis is perpendicular to it. It means u-axis is almost parallel to the tangent of the corresponding isosurface (Fig. 3):

$$(\cos\alpha, \sin\alpha) = (L_x, L_y) / (L_x^2 + L_y^2)^{1/2}.$$

The local directional derivative operators in this curvilinear coordinate system are as follows:

$$\partial_v = \cos\alpha \, \partial_x + \sin\alpha \, \partial_y; \qquad \partial_u = \sin\alpha \, \partial_x + \cos\alpha \, \partial_y.$$

At an arbitrary image point the gradient magnitude is equal to $\partial_v L$, marked as L_v below. The edge can be iden-
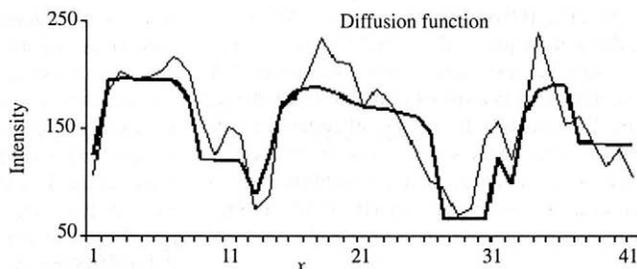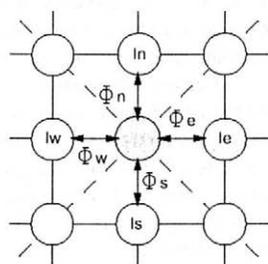

Fig. 2. On the left: A dependence of the computing of central pixel diffusion in the moving window on the value of the flow function of neighboring pixels. In, Iw, Ie, Is are the intensities of the adjacent pixels, adopted by GERIG et al. (1992). On the right: 1D diffusion function demonstration (a bold line) $K = 6$, $\Delta t = 0.1$, by 100 iterations

fied as a point, the first derivation of which in the gradient direction reaches the maximum (L_v = max), the second one is zero ($L_{vv} = 0$) and the third one is negative ($L_{vvv} \ll 0$). Here L_{vv} or L_{vvv} is computed as a result of transformation from curvilinear system to Cartesian system:

$$L_{vv} = \frac{L_x^2 L_{xx} + 2 L_x L_y L_{xy} + L_y^2 L_{yy}}{\left(L_x^2 + L_y^2\right)}$$

$$L_{vvv} = \frac{L_x^3 L_{xxx} + 3 L_x^2 L_y L_{xxy} + 3 L_x L_y^2 L_{xyy} + L_y^3 L_{yyy}}{\left(L_x^2 + L_y^2\right)^{\frac{3}{2}}}$$

where: L_x, L_y and their combination – the derivation in the x, y directions.

Two passes of the moving window process realize edge detection. In the first pass the derivation values are calculated and in the second one an image gradient value is only displayed in areas satisfying the criteria mentioned above. Thus output edges from the process are marked by one of the 256 brightness values corresponding to the gradient magnitude rather than to be displayed only as binary image. In such a way significant edges can be detected easily from those of less importance, for instance by the method of thresholding.

3. Edge arrangements

The edge segments obtained by the differential geometric approach are obviously very often discontinued due to the heterogeneous nature of their adjacent regions. Then the complete object boundary delineation consists of composition of the different edge gradient values. This is the reason why the threshold method cannot detect the object boundary entirely. Thus morphological and conditional operators were introduced to be used in task of continuous object boundary linking:
– Joining nearly linked pixels;
– Removing small, isolated groups of pixels;
– Morphological thinning until the remaining edges are only one pixel wide;
– Optionally systematically removing the unconnected segments.

Joining nearly linked pixel is based on the filling of the gaps located between single pixels in eight directions counting the central pixel in the moving window. Morphological thinning is based on the binary comparison of structural elements sequence $B_{(i)} = \{B_{i1}, B_{i2}\}$ with the image where i signifies a sequence and B_1 is a subset of X (image objects) and B_2 is a subset of X^c (inversed image, it means the background). In the spot of coincidence of a structural element and the image, reducing by one pixel takes place. For one sequence, it is possible to express the operation in the following way (HLAVÁČ, ŠONKA 1992):

$$X \otimes B = (X \ominus B_1) \cap (X^c \ominus B_2)$$

$$X \ominus B = X \,|\, (X \otimes B)$$

where: $\ominus$ – morphological erosion,

$\ominus$ – morphological thinning,

$\otimes$ – means binary comparison (or hit or miss operation).

AUTOMATIC CLASSIFICATION

For the needs of supervised classification and for assessment of classification accuracy the training sets were taken on areas representing individual major object classes: Norway spruce *(Picea abies)*, Scots pine *(Pinus sylvestris)*, eastern larch *(Larix decidua)*, sessile oak *(Quercus petraea)*, crested beech *(Fagus sylvatica)*. Signatures were created based on spectral characteristics of those training objects for supervised classification. Idrisi system with applied signature formation facilitates advanced fuzzy signature creation. This process provides better understanding of object nature as well as a new concept of signature creation. A traditional way defines the signature as a spectral representative of the only one and unique object, while fuzzy signatures allow the creation of inhomogeneous signatures with relations to other objects. The following classifications were undertaken over the processed area of interest. The Idrisi module names are in the parentheses:
1. Unsupervised classification (CLUSTER, ISOCLUST)
2. Maximum probability basic classifier (MAXSET)
3. Supervised hard classification (MAXLIKE)
4. Supervised soft classification (BAYCLASS, BELCLASS).

While unsupervised and supervised classifications are commonly known, a very interesting role is played by a MAXSET hybrid classifier. Maximum Basic Probability Classifier belongs to the transition area between supervised and unsupervised classification. Although it is run as if it were a supervised classifier requiring training site data, in the end it behaves as if it were an unsupervised classifier because it can assign a pixel to a class for which no exclusive training data have been supplied (EASTMAN 1997).

The module is based on assigning the highest probability to the class involved in Dempster-Shafer theory of the class hierarchic structure. Dempster-Shafer theory defines the probability of an object occurrence in the area (hypothesis) according to the hierarchic structure derived from the basic frame of object resolution. The basic resolution can be an individual, relatively homogeneous entity such as spruce, pine, larch etc. Other objects under consideration are a combination of these basic classes, for example spruce-pine, spruce-larch etc. ranged in a hierarchic way. The complete hierarchic structure of these classes is taken into account by this classification using different class combinations. The classifier evaluates the probability of a pixel being in one of the classes defined in such a way. It can give rise to the image whose composition is formed not only by the classes defined in an unambiguous way but also by those classes the user did not consider thus providing information on missing training sites. MAXSET module belongs to the hard clas-

sifiers set but it can directly discern mixed pixels and this feature is one of the most important for an in-process classification assessment. Once a classification is processed, a very important step is to assess the percentage of occurrences of the composed classes. If the indicator is very high, it is necessary to find out whether all-important signatures have been defined and if they truly represent the object reflection. Post-classification arrangements run into the modal filter in Idrisi with a matrix of 5×5 pixels.

TREE IDENTIFICATION

Numerous theses were involved to the automatic crown identification mainly for forest management purposes. Among others essential methods need to be stated: POLLOCK (1996) proposed synthetic crown templates with respect to the crown shape and size, angle of sun illumination, and quantity of received and reflected light. These crown templates were then correlated to the forest image. LARSEN, RUDEMO (1998) enhanced the crown template to the camera scanner angle. GOUGEON (1995) adopted the method of tracing spectral minima located between crowns, known as "valley following". WALSWORTH, KING (1998) proposed to find the tree crown top as a union of "ridges" lines obtained by the double aspect technique in four directions. Tree crowns were estimated by the cost surface generation. CULVENOR et al. (1998) detected tree tops as the local brightest pixel and the region growing technique delineated tree crown. Similarly, DRALLE, RUDEMO (1996) understood the problem of tree top searching. Their activity lied in research on optimal image smoothing for tree counting providing best correspondence to the ground truth. BRANDTBERG (1999) studied the dependence of two-dimension variograms for texture detection and identified tree crowns by differential geometric operators. KORPELA (2000) determined tree tops from image stereopairs.

In spite of all the above mentioned the tree top and crown identification is still rather an unknown field in the current conditions of the Czech Republic. A set of basic methods for tree top identification was put forward in the present paper. No single algorithm is able to solve the complete task of tree finding and species classification (PINZ 1998). It is necessary to apply a hybrid approach of several stages. Based on these and other

reasons mentioned in the introduction the majority of the methods were implemented to "Kernel Processor" (KP) software system forming a framework for tree identification. The problem of tree identification can be subdivided into two partial tasks:
a) Tree top searching,
b) Tree crowns delineation.

TREE TOP DETECTION

The main assumption for tree top identification is that the spectral reflectance (in the study only beech and spruce were considered) is higher than the rest of the crown and that the imagery was captured in the time of highest solar elevation. Under such conditions reflectance is decreasing downwards the tree top, thus the crown is presented in form of cone or oval shape. In such a way the tree top corresponds to the brightest crown point (NIEMANN et al. 1998) (Fig. 4). Tree crowns on high spatial resolution images usually do not represent ideal geometric shapes (spheres or cones) that could simplify tree top detection. This is the reason for the image to undergo homogenization by the smoothing process. Gaussian linear filter was applied to solve this problem.

The actual process of the tree crown searching was modified in this study. The main part of the algorithm is based on a filter in the moving window choosing the pixel with the brightest reflectance located in its center. In such a way, smaller or larger tree tops can be identified depending on the window size. The supplemental finer conditions were added to define the possible crown reflectance disproportion, for instance, an incorrect pixel in different places of an illuminated part of the crown. Furthermore, threshold values for the central pixel were determined to eliminate some amount of defectively demarcated crown tops. Finally, the algorithm enables to smooth the pixels outside the crown top:

$$
S\,f(p) \quad
\begin{cases}
S\,f(p) = f(p) + K & max(q) <= f(p) \\
S\,f(p) = f(p) - K & min(q) => f(p) \\
S\,f(p) = G\,f(p)
\end{cases}
$$

where: max – function for searching a pixel with maximum reflectance in the moving window,
min – function for searching a pixel with minimum reflectance in the moving window,
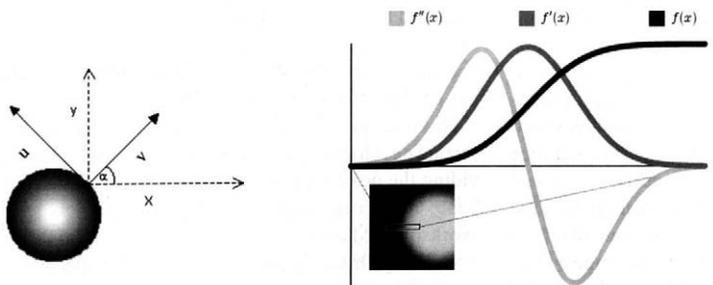

■ $f''(x)$ ■ $f'(x)$ ■ $f(x)$

Fig. 3. Left: An orthonormal coordinate system u, v positioned on the outer isosurface (contour). Right: Relation of derivation to an edge, adopted from KINDLMANN, DURKIN (1998)

$Gf(p)$ – function for smoothing, for example Gaussian smoothing,

$f(p)$ – central pixel in the moving window,

$f(q)$ – neighboring pixels in the moving windows,

K – constant to highlight a tree crown top.

Some tree tops might not be detected by the steps described, as either they lie in shadow, or their color properties do not match the given condition of the brightest central pixel. However, their number is quite low in comparison with tree tops detected by the above algorithm. An area-based template matching technique can look up such tree tops. This method determines the correspondence between a sample image (t) and the original image (f) according to the similarity of their gray level values. The sample (template) is derived from the original image where the tree tops were not yet identified. Thus this step is semi-automated. The size of sample image is either 3×3 or 5×5 pixels. The template matching between the sample and the compared part of the image is done by a normalized cross correlation formula:

$$\rho = \frac{\sum\limits_{x,y}\left[f(x,y) - \bar{f}_{u,v}\right]\left[t(x-u, y-v) - \bar{t}\right]}{\sqrt{\sum\limits_{x,y}\left[f(x,y) - \bar{f}_{u,v}\right]^2 \sum\limits_{x,y}\left[t(x-u), y-v) - \bar{t}\right]^2}}$$

where: f – the image,

$\sum$ – the sum of pixel values computed according to the size and actual location of the template t positioned in u, v of the image,

$\bar{f}_{uv}$ – arithmetic mean $f(x,y)$ at the place of the template actual location,

$\bar{t}$ – arithmetic mean of the template.

The values of relevant template matching should vary from 0.90 to 0.97 in locations where tree tops were found. The tree top was chosen from all correlation values using the method of the brightest pixel, it means the best correlation. In the case of duplicity in tree top identification a new filter was introduced performing duplicity removal. This filter application realized similarly by the moving window is based on the resultant image adaptation with special attention to the side effect of complementary conditions that can produce duplex tree top identification.

TREE CROWN DELINEATION

For the tree crown delineation the methods of spectral minima tracing and cost surface generation were adopted. The first one, also known as "valley following" (GOUGEON 1995), works as a filter in the moving window. In each processed area a procedure is run testing if the central pixel (i.e. the starting pixel for tracing) interferes with any neighboring pairs of minimum pixels. (In total four tests are run for horizontal, vertical, and two diagonal neighboring pixels.) If the condition is accomplished, the program recursively continues tracing in four main directions and tests and marks pixels using the same conditions. As the algorithms are incorporated into the moving window, all image pixels are tested as starting pixels for tracing. The individual steps of the entire process are outlined as follows:

1. Visual thresholding of image to separate the forest areas from the non-forested areas.
2. Scanning the image with 3×3 moving window to find local spectral minima.
3. For each found pixel to perform region growing for those areas satisfying the spectral minima criteria.
4. Joining nearly-linked crowns segments.
5. Morphologically thinning the image until the remaining crown segments are only one pixel wide.
6. Systematic removing of unconnected crown segments.

The second method of cost generation is linked to the preceding tree top detection. Located tree tops are used as a starting point for the crown filling, thus delineating its borders. For this filling a CostPush/CostGrow algorithm from the Idrisi for Windows software package was used. This algorithm uses a crown reflectance surface and calculates a cost distance surface. The movement from the tree top is realized in eight directions; it means that circular rings of distances are created around each tree top, depending on the (friction) crown surface (EASTMAN 1989). The output crown cost surfaces were then processed by the valley – following the above-mentioned algorithm.

IMAGE MANAGEMENT AND PROCESSING SOFTWARE DEVELOPMENT

The current software products facilitating remote sensing image processing result sometimes without any possibility to run special operations. The task of the user in such a case consists in further software development by him. Thus the software called "Kernel Processor" was developed for Windows NT platform, performing all necessary operations for the presented research. The software architecture is designed as complement enriching image processing operations and functions (e.g. Idrisi32 of the Clark Labs, Worcester, Ma). A basic module provides input/output operations into several image formats such as BMP, TIFF, and the format for Idrisi system – RST. The image processing functions are encapsulated into DLL libraries, which comply with a certain standard of the coding being similar to the user code applied in the ER-Mapper program. There is a user interface over this basic unit being able to cooperate with Excel office software and Idrisi system. Kernel Processor is a freeware; it can be installed without fee from an official page of the regional center IDRISI for the Czech and Slovak Republics or from the Links page of idrisi.com.

The management of raster data is maintained by the second developed application named Image Storage, providing the possibility to store raster files in Oracle database, allowing long transactions with the help of Workspace Manager and finally localizing raster positions using Oracle Spatial Cartridge. Workspace Manager provides a long transaction event framework built on

Table 4. Accuracy assessment of the channel transformation into the position of channel No. 2

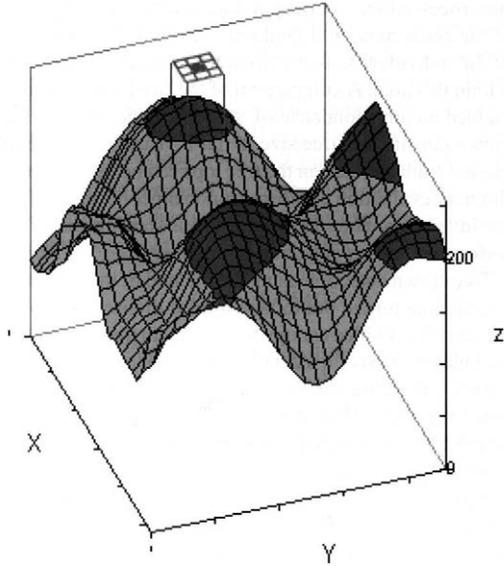| Channel	Transformation Model	Number of points	STD			RMS		
			X	Y	XY	X	Y	XY
1	Polynomial-3	20	0.0564	0.1878	0.1801	0.1231	0.3769	0.3965
4	Projective	19	0.3113	0.3407	0.3388	0.5293	0.5384	0.7550
4	Polynomial-3	21	0.1378	0.1019	0.1187	0.3203	0.2398	0.4001
6	Polynomial-3	15	0.0214	0.0190	0.0264	0.6436	0.4857	0.8063

Fig. 4. Plot of image in 3D, where reflectance corresponds to z-axis. The moving window selects brightest pixels

the workspace management system. It uses a series of short transactions and multiple data versions to implement a complete long transaction event that maintains atomicity and concurrency (ORACLE 2001).

Both developed softwares were written in C++ language using MFC library, Visual Basic and Java.

RESULTS AND DISCUSSION

The accuracy of projective transformation using 19 reference points was acceptable from the visual point of view, but it is not the most accurate according to the root

mean square (RMS). Therefore more accurate results from the polynomial transformation of the 3rd degree were used for further processing. In Table 4 both deviation indicator and RMS for particular transformed channels are shown being divided according to the axis. The lowest RMS was achieved by the first channel due to an easy identification of the reference points. A higher deviation in the sixth channel is on the contrary caused by a more difficult identification, for the sixth channel was of higher degree of brightness.

The color composition by a subtractive color model CMYK facilitated to make a synthesis out of all four channels. This untraditional way of synthesis turned out very advantageous for creating the training set with an observation possibility of object spectral characteristics in all four bands at the same time. Moreover, this synthesis allowed a natural visualization of objects in the image and provided a robust foundation for digital visual interpretation. The image quality of post-transformation of the CMYK synthesis into RGB color model did not lose quality and this transformation allowed to reduce four channels into three. This process presented a more natural way of visual interpretation and training set formation in comparison with channel number reduction by principal components analysis where the resulting components were not obviously radiometrically identical to the original channels. Computing of the normalized vegetation indices and synthesis of the state of health allowed to separate the vegetation cover from the non-vegetation land cover.

Detected edges by Laplacian operator of 9 × 9 pixels with subsequent threshold performance provided only rough boundaries of the main objects of the scene. Edge detection by a differential geometric approach especially in the gradient direction provided detection of more detailed object boundaries, but their discontinuity degraded the result. Therefore, other proposed operations of
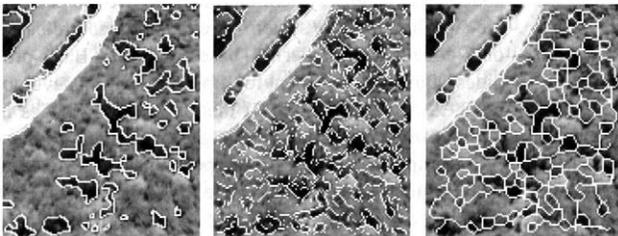

Fig. 5. Left: Detected edges by Laplacian operator of 9 × 9 pixels. In the middle: Edges detected by a differential geometry approach in gradient direction without arrangement. Right: Detected edges after proposed arrangement

morphological thinning, connection and elimination of small segments of the edges manifested to be useful for the final edge determination and achievement of a higher number of closed polygons (Fig. 5).

In the course of signature formation and spectral reflectance analysis in four spectral channels the larch class turned out to be difficult to be discerned from spruce. Neither was the separation of the oak signature from the beech one successful.

Unsupervised classification by ISOCLUST module facilitated the basic assessment of spectral groups of objects. These groups can be considered as basic objects of the image, suitable for further detailed identification, and can represent frames for basic object recognition for the MAXSET classifier. Results of this classification provided data of interest on the way of pine differentiation from spruce.

Hybrid classification by MAXSET module turned out very successful for the beginning of searching of different classes and for data acquisition on the assessed object signature accuracy. The resulting MAXSET classifier proved that the training sites for classes were well chosen because the representation of derived combinations reached only 6%.

BAYCLASS soft classifier tended to be the most accurate one based on Bayess theorem of probability. BAYCLASS reached 89% of success in the whole process of classification. Using this module it was possible to discern spruce with the classification accuracy of 98% and pine with 84%. In the case of particular classification of oak and beech the results get worse due to the different degree of crown reflectance, where some parts of the crown closure were overlapped in the spectral image. On the basis of the above mentioned, these two species were integrated in a mixed oak-beech class. This mixed class demonstrated 90% accuracy.

Generally, the whole classification by MAXLIKE module of maximum probability was of 87% and manifested only the slightest percentage of success compared with BAYCLASS module. The Larch indicated indiscernibility in the course of spectral reflectance characteristics. Thus this class was integrated with spruce.

BELCLASS classifier based on Dempster-Shafer theory did not bring about any significant differences in the accuracy compared with BAYCLASS and MAXLIKE ones.

Tree top detection based on the brightest pixel method tended to be very useful for tree crown identification. The image smoothing represents a very important feature. The main purpose of the crown smoothing is an approximation of the crown surface to a cone (in the case of spruce) or to a sphere (in the case of beech). Crown top searching with the use of iterative process proved to be very successful starting with the 7 × 7 pixels moving window which later diminishes to 5 × 5 and 3 × 3 pixels, followed by the process of further search refining according to the added conditions. The template method searching of tree tops provided solid foundations for generic tree identification. A disadvantage of the method consists in manual selection of tree crown samples from the input image serving as a template. The proposed highest correlation marking of resultant image allowed to identify those tree tops that were not identified by the previous method. According to the template size a preliminary tree crown size was set and delineated.

The accuracy of automatic detection of tree tops compared with manual detection depends on canopy thickness, tree species, image quality and smoothing quality. To assess the accuracy of the approach a subsample of the processed area, corresponding to approximately 10% of the entire area, was randomly selected. The locations of the individual tree crowns were manually interpreted within this area. A comparison of the two interpretations yielded a correspondence of 88–95%, depending on the crown density and tree size. After a visual revision and ground truth calibration the tree tops can be used for preliminary evaluation of the tree number per hectare in forest inventory. They can represent a starting point for further tree crown detection in this way.

Tree crown detection using the method of tracing spectral minima turned out to be a logical division of crown canopy. The divided canopy together with tree crown tops provides the basis for a detailed objective analysis of tree crown – it means analysis of both spectral and spatial characteristics. Thus image segmentation takes place where the proper segmentation process is a priori accommodated to the image scene character with a forest stand. For example it is possible to classify, cluster and create a layer of crown canopy for forest geoinfomation systems. It is worth paying attention to the relation between the edge detection, tree top and tree crown. If the tree top is formed by the brightest pixels and the crown contour is formed by the darkest ones, detected edges of tree crowns represent the highest changes in crown intensity from its darkest part to the brightest. Delineation of tree crown by means of crown cost surface production from its top was found to be a suitable method for assessment of the minimum surface the crown can occupy. The method depends on the full tree top detection (Fig. 6).

The problem for future development lies in assessment of the accuracy of image-based crown delineation algorithms. For this purpose special equipments like Field Map need to be used for ground truth estimation of the real crown shape.

Created applications were an important part of the whole project. Kernel Processor was a very successful and useful tool for verifying algorithms written in the user code. Compatibility of those codes with the user code of Er-mapper system facilitates to use the accessible algorithms of the system. A code architecture based on C code and user interface based on Visual Basic provides a quick environment for rapid application development. A negative feature of this application resides in unoptimized performance for large data amounts. Image Storage application is a prototype of hi-tech raster data management. Raster data storage in database via special database cartridge using a long transaction model and
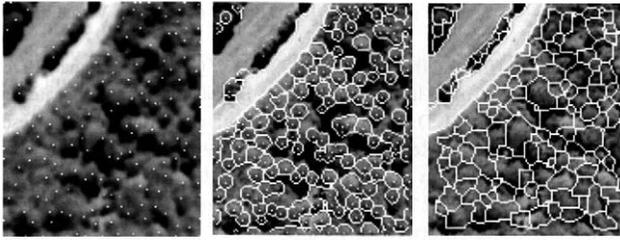
Fig. 6. Left: Detected tree tops. In the middle: Thresholded cost surface. Right: Crown delineation using the valley following method

spatial database operations for localization solved the problem of effective and safe image manipulation. Long transactions by Workspace Manager proved by its performance the suitability for image processing where it is possible to store individual stages of processed images in versioned tables. Oracle database in version 8.1.7. proved to be prepared for raster reading and storing directly from the database without any expressive time consumption compared to the file system.

CONCLUSION

This paper pointed out a possibility of extended processing of multispectral airborne forest images specially focused on edge detection and individual tree detection. Based on the presented results it is possible to draw the following conclusions:
- polynomial transformation provides more suitable results for misalignment elimination of MSK 4 multispectral camera than the projective one;
- a subtractive color model facilitates to make a synthesis of all four spectral bands in natural colors, being a valuable basis for training set selection and visual classification;
- normalized vegetation indices allowed to discern vegetation from non-vegetation objects, which is a promotion of successful picture segmentation;
- edge detection in the directional gradient of pixel intensities shows an applicable result of further morphological operation;
- it was not possible to classify larch successfully from a summer photograph. For larch classification it is obviously necessary to make a photograph during the spring season;
- separation of oak and beech classes was unsuccessful due to their common course of reflectance in all four channels and the characters of a mixture growth, so it was not possible to create a mask for only one type of species;
- automatic detection of tree crown tops by the method of the brightest pixel represents a significant contribution to tree number and location assessment. This detection should be supervised in a visual way or complemented by missing crowns and confronted with a real forest situation for example by GPS;
- crown delineation by tracing the spectral minima facilitates a logical segmentation of the image preparing the basis for more accurate object pixel classification,

- tree delineation by applied assessment methods constitutes a basis for further more convenient tree crown contours analysis;
- special image processing is hardly possible in the framework of the current software products for image processing; that is why it is necessary to apply these methods by help of the user's own experience. In order to fulfill this target it is possible to apply C/C++ programming language, providing quick processing and a possibility of using the resources of accessible library codes;
- any type of photographs (airborne or satellite) forms an important part of geoinformation systems. Thus the storage of all spatial data including its semantic characteristics will get on importance. We may also suppose that the long transactions in those databases will be essential for preserving the intermediate steps of image processing;
- the output of all steps of image processing results using these extended methods promises new possibilities of application of multispectral airborne images to the needs of forestry planning.

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Rozšířené metody automatického zpracování multispektrálních leteckých snímků lesních porostů

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ABSTRAKT: Studie se zabývá využitím a aplikováním rozšířených metod zpracování obrazu pro multispektrální snímky s vysokým prostorovým rozlišením na příkladu snímku lesního porostu Josefovské údolí. Významná část těchto metod byla rozšířena a naprogramována do vlastního softwaru. Studie poukázala na možnosti transformovat snímky z kamery MSK 4 do shodné polohy pomocí polynomické transformace a výsledné kanály sestavit podle navrženého pořadí do subtraktivního barevného modelu. Metoda detekce hran ve směru gradientu byla rozšířena o iterativní morfologické operace. Klasifikace druhového složení proběhla v systému Idrisi za použití měkkých klasifikátorů. Pro multispektrální snímek byla také navržena metoda detekce vrcholů a obrysů korun stromů.

Klíčová slova: dálkový průzkum Země; letecké snímky; detekce stromů; anizotropní difuze

Potřeba stanovení co nejpřesnějších a objektivních charakteristik lesního ekosystému pro lesnické plánování je obecně známá. Jedním z informačních zdrojů o území, které se při plánování používají, jsou letecké analogové multispektrální snímky. Tato studie navrhuje a aplikuje rozšířené metody zpracování těchto multispektrálních snímků, které mimo běžně využívané spektrální klasifikace spočívají v detekci hran, vrcholů a korun stromů.

Vybrané území pro zpracování leteckého snímku se nachází v severní části rezervace Josefovské údolí – rezervace Purkyňova a přiléhající severní část porostů. Lokalita se nachází asi 5 km na severovýchod od Adamova v listnatém porostu, který patří do CHKO Moravský kras.

Území bylo nasnímáno ve čtyřech spektrálních pásmech komorou MSK4/II v roce 1990. Negativy snímků byly digitalizovány s rozlišením 600 dpi při 256 odstínech šedi. Jednotlivé senzory kamery MSK 4 jsou nesouosé, proto byla věnována značná pozornost metodě geometrické transformace jednotlivých spektrálních kanálů do shodné polohy. Pro tento úkol byla navržena polynomická transformace za použití softwaru Descartes běžící na platformě MicroStation. Transformované kanály byly netradičně sestaveny do navržené sestavy v subtraktivní barevné syntéze, což přineslo možnost zobrazení všech čtyř kanálů místo tří kanálů, které se běžně používají v modelu RGB. Tento nový způsob syntézy se ukázal jako výhodný při tvorbě trénovacích množin, kdy byla možnost sledovat pohyb spektrálních charakteristik objektů ve všech čtyřech pásmech současně. Tato syntéza navíc umožnila přírodní zobrazení objektů na snímku, a tím i plnohodnotný podklad pro vizuální interpretaci

Významná diskontinua v intenzitách pixelů na zdigitalizovaném snímku se v této studii chápou nejen jako hranice běžně vylišitelných objektů, ale také jako ohraničení relativně homogenních segmentů snímku, které mohou mimo spektrální charakteristiky navíc poskytovat další informace, a tím významně přispět k procesu klasifikace *per region*. Pro snímek byla navržena metoda detekce hran ve směru gradientu intenzity pixelů spolu s vyhlazením metodou anizotropní difuze. Tato metoda umožnila stanovit detailní hranice, nicméně jejich diskontinuálnost velmi degradovala celkový výsledek. Z tohoto důvodu se navržené následné operace ztenčení, spojování a rušení malých segmentů hran ukázaly jako velmi přínosné pro stanovení konečných hran a dosažení většího počtu uzavřených polygonů. Nad snímkem proběhla detekce hran také pomocí Laplaceova operátoru o rozměrech 9 × 9 pixelů s následnou operací prahování. Tyto výsledky ovšem poskytovaly pouze hrubé obrysy hlavních objektů na snímku.

Spektrální klasifikace proběhla v systému Idrisi za použití jednak poměrně nových tzv. měkkých klasifikátorů založených na Dempster-Shaferově teorii (např. MAXSET, BELCLASS), jednak za použití klasických neřízených a řízených klasifikací. Výsledek neřízené klasifikace provedený modulem ISOCLUST poskytl zajímavé údaje z hlediska rozlišení borovice od smrku. Jako neodlišitelná dřevina se ukázal modřín, který průběhem odrazivostí v jednotlivých pásmech splýval se smrkem. Klasifikace modulem MAXSET se projevila jako velmi vhodný začátek pro zjištění neodlišitelnosti některých tříd a získání údajů o přesnosti definovaných signatur objektů. Výsledek klasifikátoru MAXSET prokázal, že definované trénovací množiny pro třídy byly dobře stanoveny, neboť zastoupení odvozených kombinací dosahovalo pouze 6 %. Neřízená klasifikace umožnila základní

rozlišení spektrálních skupin objektů. Klasifikátor BELCLASS nepřinesl významné rozdíly v přesnosti oproti klasifikátoru BAYCLASS. Při klasifikaci se ukázal jako nejpřesnější měkký klasifikátor BAYCLASS založený na Bayesově teorému pravděpodobnosti, který dosáhl celkové 89% úspěšnosti klasifikace. Tímto modulem se podařilo odlišit smrk s přesností klasifikace 98% a borovici s 84% přesností. Výsledky jednotlivých klasifikací dubu a buku byly zhoršeny různým stupněm odrazivosti koruny, kdy část korun těchto dřevin se spektrálně překrývala. Z tohoto důvodu byly tyto dvě dřeviny sloučeny do třídy smíšení dub–buk.

Snímky s vysokým prostorovým rozlišením mohou mimo jiné podávat další informace týkající se textury, tvaru, rozlohy a vzájemného ovlivnění jednotlivých korun stromů, a tím přispět ke kvalitnějšímu zhodnocení investic do pořízených leteckých snímků. Základní jednotkou pro tyto informace je právě koruna stromu, jejíž ať už vizuální, automatická nebo poloautomatická identifikace je klíčem k aproximaci skutečných taxačních charakteristik porostu. Klasifikací jednotlivých korun stromů lze docílit také zpřesnění výsledků řízené klasifikace a vůbec zkvalitnění celkové segmentace obrazu. Pro detekci jednotlivých stromů byla navržena a rozšířena metoda nejsvětlejšího pixelu s použitím přídavných podmínek a metoda porovnání se vzorem následovaná výběrem nejvyšší korelace mezi vzorem koruny a snímkem. Kardinální význam pro úspěšnou detekci mělo prvotní vyhlazení snímku. Detekované vrcholy korun mohou být – po jejich vizuální revizi a doplnění o pozemní šetření – využity v lesnickém plánování pro předběžné zjištění počtu stromů na hektar. Dále mohou sloužit jako výchozí bod pro následnou detekci obrysů korun.

Pro detekci obrysů korun byly navrženy metody trasování frekvenčním minimem s následnou úpravou pomocí morfologických operací a metoda založená na vytvoření akumulačního povrchu koruny. Tyto detekce obrysů korun umožnily logicky segmentovat snímek, a tím připravit základ pro přesnější objektovou klasifikaci pixelů. Tyto prototypy obrysů korun mohou být východiskem pro zpřesnění reálného tvaru koruny.

Specializované zpracování obrazu není většinou v možnostech běžných softwarových produktů pro zpracování obrazu, proto je často nutné tyto metody aplikovat vlastními silami. Z tohoto důvodu byl vytvořen speciální software „Kernel Processor", který umožnil jednotlivé algoritmy sestavit a realizovat v prostředí operačního systému Windows.

Snímky, ať už letecké, nebo družicové, jsou součástí geoinformačních systémů. Jestliže se v současné době uplatňuje ukládání prezentačních, sémantických a vektorových prostorových dat do databází, lze předpokládat, že význam ukládání a správy rastrových dat v těchto databázích také poroste. Dlouhé transakce hrají v těchto databázích významnou úlohu pro uchování jednotlivých stavů zpracování snímku. Pro tento účel byl vytvořen druhý nástroj s názvem „Image Storage", který využívá

nejmodernější technologie pro ukládání snímků do databáze Oracle s využitím dlouhých transakcí a prostorových operací pro lokalizaci. Oba produkty jsou volně šiřitelné a na vyžádání dostupné.

Výsledky ze všech procesů zpracování využívající tyto rozšířené metody prokázaly nové možnosti využitelnosti těchto snímků pro potřeby lesnického plánování.

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Results of beech stump inoculation with antagonistic fungi

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ABSTRACT: Non-decayed beech stumps remain in the forest stand for 20 years after a cutting intervention. The paper investigates decay intensity of beech stumps after an artificial infection by *Pleurotus ostreatus* (JACQ.: FR.) KUMM. In addition, its fruit bodies are suitable for the pharmaceutical and food industries. The fungi succession was evaluated in the 4th, 5th and 6th year after artificial infection. After fifteen years of research, the results of stump decay after artificial infection by Oyster fungus (*Pleurotus ostreatus* [JACQ.: FR.] KUMM.) demonstrate the possibility of shortening the stump decay period approximately by a half. The most intensive decay continues in the fifth year after infection due to fungi succession with prevalence of *Trametes versicolor* (L.) PILÁT and in the sixth year after infection with prevalence of *Trametes gibbosa* (PERS.) FR. and *Trametes hirsuta* (WULFEN) PILÁT.

Keywords: *Fagus sylvatica* L.; *Pleurotus ostreatus* (JACQ.: FR.) KUMM.; Oyster fungus; stump decay; wood-destroying fungi succession

Stumps left in forest stands after felling remain non-decayed up to 20–25 years, inhibit stand regeneration, and, due to a slowly proceeding decay, delay the nutrient supply into the soil substrate. From this point of view, several wood-destroying fungi have important roles in the natural material cycle. Decomposing dry branches and stumps these fungi are important agents in the humification process. Dead trees and wooden remnants, so-called "dead" wood, are taken from the biological and ecological viewpoint in connection with living conditions as necessary for many organisms, vertebrates and invertebrates, cryptogams and higher plants, and for a great amount of fungi. Decaying dead trees and wooden mass in forest stands ensure the rich species variability of forest ecosystems. In production forests, however, the dead trees can also be the resource of infection and the focus of distribution of harmful pests (JANČAŘÍK 2000).

The cultivation of edible mushrooms on wood was studied e.g. in Hungary (KISS 1977; FARKAS 1983; ERDÖS, CSORDÁS 1984). The first grower in the former Czechoslovak Republic was LÓRI (1970). GINTEROVÁ (1985) proposed methods of cultivation of the Oyster fungus on straw substrate and on substrate from shredded corn stalks and husks. Some information on artificial infection of stumps came from Germany (PŘÍHODA 1953), but this way of stump removal from stands was neglected by 1980. The first research papers dealing with this problem were published in the 1980s by KODRÍK J. (1979), KODRÍK M. (1981), KODRÍK J. and VANÍK

(1989), who studied artificial infection of stumps by the fungus *Pleurotus ostreatus* (JACQ.: FR.) KUMM. The fruit bodies of this fungus can be used in the food as well as pharmaceutical industry. A significantly shortened period of stump decay by means of artificial infection is important from the biological as well as economic point of view, which cannot be neglected when seeking more effective ways of forest management.

MATERIAL AND METHODS

The studied locality is situated on a south-exposed slope within the School Forest Enterprise of the Technical University in Zvolen in the upper part of the valley Sielnica. The experiment was established at a site where felling of beech trees was carried out in the preceding period (area about 2.5 ha). The stand (221a) grows at 700 m a.s.l. on Cambisol very rich in minerals, with a favourable moisture regime and belongs to the forest type group *Fap* (ZLATNÍK 1959). The conditions in the stand are highly favourable namely for the fungus *Pleurotus ostreatus* (JACQ.: FR.) KUMM. The stand was fenced with wire netting to prevent the game from access.

The studied beech stumps were infected in the following manner: holes were bored into each stump, and either vaccine alone or vaccine mixed with sawdust was pressed into the key and covered with the sawn block of wood. During the first four years we tried to find the best

way of infection introduction and fungi production. Also the following succession of wood-destroying fungi and their antagonistic relations were studied.

An inoculum was obtained from the artificial cultivation farm of Oyster fungus in Pezinok. Millet was a supporting inoculum. Its production is described by GINTEROVÁ (1985).

Considering restricted possibilities of work in laboratory we focused primarily on macroscopic observations that consisted of the following steps:
- from each observed series a stump was selected from which three 3 cm thick disks were cut,
- each disk was weighed and its weight was expressed through percentage loss compared with the non-infected stumps,
- for the above-mentioned controls or series the mean values were calculated in the 4th, 5th and 6th year after infection had been introduced,
- fungi succession was evaluated, the species as well as their abundance were determined,
- antagonistic relations have been observed only directly on the infected stumps up to present – without additional analysis in laboratory.

The infection was introduced on 15 series of stumps (each series containing 10–15 stumps) with diameter 20–60 cm. Four disks were cut from five stumps with the scope to study on them decay progression and intensity. These cuts were selected according to the decay intensity gradation with the aim to observe the progress and intensity of the rot spreading process. After the first production of fruit bodies of *Pleurotus ostreatus* (JACQ.: FR.) KUMM. the neighbouring trees were artificially damaged to enable to detect also a possible parasitization.

RESULTS AND DISCUSSION

EVALUATION OF STUMP DECAY

The evaluation of stump decay showed that the fungus *Pleurotus ostreatus* (JACQ.: FR.) KUMM. together with succession of wood-destroying fungi did not damage all stump parts in the same measure. Patches of less decomposed wood were frequent. According to the present fruit bodies of the individual fungal species, the fastest decay was observed on stumps with abundant sporophores of *Trametes versicolor* (L.) PILÁT and *Trametes hirsuta* (WULFEN) PILÁT and the slowest with *Schizophyllum commune* FR. Table 1 summarizes the values of wood weight reduction due to the rot attack. It is evident from the review that the weight losses during the fourth year since the stump infection ranged from 43.9% to 53.2%. In the fifth year these values were 59.4–71.3%. The highest values of weight reduction were detected in the sixth year after the infection had been introduced (75.2–90.7%).

Evaluation of differences in stump decay caused by differences in the vaccine application showed significant differences between the stumps in the fourth year after infection, nevertheless, these were equalized during the

following year. Variability in stump weight losses was detected by assessment of stump age. The younger the age of the stump, the lower the percentage of decay. The highest decay degree was observed on stumps older than 120 years with 50.0–53.4% in the fourth year, 66.4–71.3% in the fifth year and in the sixth year all the stumps showed the decay percentage higher than 85.0%.

Assessment of rot spread in the infected stumps showed that the activity of wood-destroying fungi was remarkably influenced by several abiotic (physical) and biotic factors. The moisture in wood is neither uniformly nor continuously distributed (JURÁSEK, RYPÁČEK 1954). According to these authors, differences in wood moisture content between the adjacent parts can be fairly remarkable (up to 100%). These parts are always separated by a dark well-visible zone about 1 mm in width. We can suppose that namely this zone reduces the water evaporation, primarily in June and July, creating favourable conditions for the growth of wood-destroying fungi. The evaluation of infected stumps showed that the optimum conditions for the wood-destroying fungi were found in wood in central parts of stumps, where the most intensive growth of fungi was detected. We could often observe mycelia at sites with dry upper layers, nevertheless, at these sites the intensity of fungal growth as well as wood decomposition were low. In our opinion, these mycelia inhibited water evaporation from the deeper stump layers. By the evaluation of sample stumps the ratio of wood moisture content to air content in wood was proved to be a highly significant factor for the metabolic processes of wood-destroying fungi (RYPÁČEK 1953). If the wood was too much soaked with water with only low air content or too much dried, then the wood decay was interrupted. It is possible to explain in this way why several of stumps were not uniformly decomposed or why the above-ground stump parts were decomposed to higher degree than the corresponding roots.

Based on the observations on infected stumps it can be supposed that immediately after felling the wood in lower-root stump parts has the highest moisture content. The moisture content in the upper stump parts rapidly decreases, frequently also under the limit which is necessary to be maintained for the growth of wood-destroying fungi. So it is possible to explain why several stumps of younger trees turned dark very soon and no succession was formed on them.

EVALUATION OF WOOD-DESTROYING FUNGI SUCCESSION

On the stumps infected with *Pleurotus ostreatus* (JACQ.: FR.) KUMM. fruit bodies of *Schizophyllum commune* FR. (in average 18 fruit bodies per stump) could be observed as the first, followed by *Trametes versicolor* (L.) PILÁT (on several stumps up to 22 fruit bodies), *Trametes hirsuta* (WULFEN) PILÁT (7 fruit bodies per stump) and *Trametes gibbosa* (PERS.) FR. The occurrence of other fungi is shown in Table 2.

Table 1. The values of wood weight reduction (w. w. r.) due to the rot attack (in per cent)

Sample	Ring layer	w. w. r. in the 4th year	Arithmetical mean	w. w. r. in the 5th year	Arithmetical mean	w. w. r. in the 6th year	Arithmetical mean
1	A	44.7		61.2		77.3	
	B	42.2		59.3		75.0	
	C	49.3	45.4	57.8	59.4	73.2	75.2
2	A	48.7		63.2		79.1	
	B	45.3		65.6		82.1	
	C	47.2	47.1	64.2	64.3	80.3	80.5
3	A	41.5		67.1		81.0	
	B	49.3		63.5		83.7	
	C	47.2	46.0	64.1	64.9	80.3	81.6
4	A	47.3		67.1		85.8	
	B	51.3		68.3		88.3	
	C	50.2	49.6	65.8	67.1	95.2	86.4
5	A	47.3		69.3		83.2	
	B	48.2		66.5		87.1	
	C	49.3	48.3	67.2	67.6	80.3	83.5
6	A	42.7		67.7		85.1	
	B	43.8		58.3		78.3	
	C	47.5	44.7	66.3	64.1	75.3	79.6
7	A	49.3		59.2		78.8	
	B	52.2		65.3		80.0	
	C	53.1	51.5	63.2	62.6	81.5	80.1
8	A	49.2		61.7		80.3	
	B	46.3		63.2		80.5	
	C	45.8	47.1	65.2	63.4	76.8	79.2
9	A	47.3		60.0		78.8	
	B	51.3		59.3		79.4	
	C	50.2	49.6	64.2	61.2	84.1	80.8
10	A	49.3		61.8		88.2	
	B	47.2		65.3		85.0	
	C	43.1	46.5	69.2	65.4	89.3	87.5
11	A	51.3		73.2		87.0	
	B	52.7		71.2		91.2	
	C	53.5	52.5	69.5	71.3	87.3	88.5
12	A	49.9		69.2		88.3	
	B	46.1		65.2		85.2	
	C	48.2	45.8	58.3	61.6	75.2	80.5
13	A	49.9		69.2		88.3	
	B	48.2		67.3		85.2	
	C	49.1	49.1	61.8	66.1	81.0	84.8
14	A	51.2		70.8		90.0	
	B	53.5		69.3		88.2	
	C	55.6	53.4	73.8	68.9	87.1	88.4
15	A	47.3		59.3		79.1	
	B	48.3		71.3		83.1	
	C	45.5	47.0	65.3	65.3	85.8	82.7
16	A	51.8		70.8		85.4	
	B	53.7		72.3		89.3	
	C	54.1	53.2	69.8	71.0	88.2	87.6

Table 1. to be continued

17	A	48.2		63.5		85.5	
	B	47.2		65.0		83.0	
	C	50.1	48.5	59.5	62.7	77.3	81.9
18	A	44.5		67.7		83.0	
	B	43.2		65.2		82.6	
	C	50.3	46.0	59.5	64.1	79.5	81.7
19	A	48.7		61.8		80.0	
	B	45.0		62.9		79.3	
	C	48.3	47.3	64.3	63.0	80.5	79.9
20	A	49.3		69.8		80.2	
	B	51.2		68.3		79.3	
	C	54.1	51.5	61.5	66.5	81.0	80.2
21	A	43.3		63.2		83.3	
	B	44.5		58.4		88.8	
	C	47.2	45.0	57.1	60.0	76.3	82.8
22	A	43.1		64.2		87.0	
	B	42.2		66.2		86.1	
	C	48.5	44.6	65.0	65.1	85.0	86.0
23	A	42.7		70.5		90.0	
	B	44.8		69.3		89.3	
	C	51.3	46.3	73.5	71.1	90.0	89.8
24	A	51.2		70.1		90.1	
	B	48.2		66.3		86.1	
	C	45.5	48.3	62.8	66.4	82.8	86.4
25	A	41.6		71.2		91.3	
	B	49.0		72.3		92.5	
	C	45.0	45.2	68.2	70.6	88.4	90.7
26	A	49.2		61.5		86.2	
	B	46.3		62.8		82.8	
	C	44.0	46.5	64.6	63.0	84.8	84.6
27	A	43.2		60.1		81.8	
	B	46.0		58.4		80.3	
	C	45.8	45.0	63.8	60.8	82.3	81.5
28	A	47.0		69.7		79.0	
	B	51.8		70.8		88.0	
	C	50.2	50.0	71.4	70.6	91.4	86.1
29	A	47.2		62.3		84.1	
	B	49.2		59.8		79.0	
	C	43.1	46.5	63.7	61.9	82.0	81.7
30	A	44.3		73.2		91.2	
	B	40.1		73.0		90.0	
	C	47.3	43.9	67.2	71.1	87.0	89.4

Non-infected control stumps turned black without wood-destroying fungi. Only in few cases could *Schizophyllum commune* FR. be observed. No symptoms of decay were detected, with the exception of two stumps on which decay caused by *Fomes fomentarius* (L.: FR.) KICKX. could be identified already during felling.

The checks made in summer and at the beginning of autumn in the course of the study on production of *Pleurotus ostreatus* (JACQ.: FR.) KUMM. showed that the fungus production began to decrease in the fourth year. However, the checks made around the 15th October revealed an expansion of production primarily on the

Table 2. Qualitative and quantitative composition of wood-destroying fungi growing on the infected stumps in the 4th year after the introduction of artificial infection

Species	Frequency of occurrence
Pleurotus ostreatus (JACQ.) P. KUMM.	231
Schizophyllum commune FR.	103
Trametes versicolor (L.) PILÁT	71
Trametes hirsuta (WULFEN) PILÁT	67
Trametes gibbosa (PERS.) FR.	51
Xylaria hypoxylon (L.) GREV.	41
Lycoperdon pyriforme SCHAEFF.	22
Ustulina deusta (HOFFM.) LIND	11

stumps where the fungus could be found also in the preceding year. We can give an interesting example of a stump with 73 fruit bodies weighing together 5.1 kg. This record was also supported by moist, rainy weather. The above-mentioned succession of wood-destroying fungi also kept growing on the same stumps. The controls uninfected with *Pleurotus ostreatus* (JACQ.: FR.) KUMM. showed no occurrence of wood-destroying fungi. For this reason we can conclude that the infection with the fungus *Pleurotus ostreatus* (JACQ.: FR.) KUMM. prepared favourable conditions for the succession of other wood-destroying fungi which started to decompose the beech stumps. Out of these species we could observe the fluctuating occurrence of *Trametes hirsuta* (WULFEN) PILÁT reaching the abundance of up to 8 fruit bodies on some stumps, and only 1–2 bodies on others.

Table 3. Qualitative and quantitative composition of wood-destroying fungi growing on the infected stumps in the 5th year after the introduction of artificial infection

Species	Frequency of occurrence
Trametes versicolor (L.) PILÁT	97
Trametes gibbosa (PERS.) FR.	38
Pholiota aurivella (BATSCH) P. KUMM.	37
Xylaria polymorpha (PERS.) GREV.	37
Pleurotus ostreatus (JACQ.) P. KUMM.	28
Fomitopsis pinicola (SW.) P. KARST.	21
Polyporus squamosus (HUDS.: FR.)	19
Bjerkandera adusta (WILLD.) P. KARST.	18
Coniophora puteana (SCHUMACH.) P. KARST.	11
Ischnoderma resinosum (FR.) P. KARST.	11
Ganoderma applanatum (PERS.) PAT.	11
Trametes unicolor (BULL.) PILÁT	8
Trametes confragosa (BOLT. ex FR.) JÖRST	8
Laetiporus sulphureus (BULL.) MURRILL	7
Chondrostereum purpureum (PERS.) POUZAR	5
Meripilus giganteus (PERS.) P. KARST.	4

We also studied carefully the occurrence of *Armillaria mellea* (VAHL) KUMM. s. l. It is interesting that not even a single case of occurrence was detected on the infected stumps, in spite of the fact that this fungus could be found in the experimental stand. Similarly, we could detect no presence of *Pleurotus ostreatus* (JACQ.: FR.) KUMM. on stumps that in the period of introduced infection showed evident signs of decay caused by *Fomes fomentarius* (L.: FR.) KICKX., *Pleurotus ostreatus* (JACQ.: FR.) KUMM. We found out by detailed research that its mycelium completely stopped growing on these stumps. We suppose in both cases that there is a certain antagonism. It is necessary to verify it in laboratory conditions.

In the fifth year after the infection had been introduced, quantitative and qualitative changes in wood-destroying fungi succession were revealed. No fruit bodies of *Schizophyllum commune* FR. could be found on stumps with formerly abundant *Schizophyllum commune* FR. in the simultaneous presence of the species *Trametes versicolor* (L.) PILÁT and/or *Trametes hirsuta* (WULFEN) PILÁT. It is interesting that both species occupied almost all the infected stumps and were dominant in terms of fruit body abundance. Compared with the preceding year a significant increase in the occurrence of *Trametes gibbosa* (PERS.) FR. was detected. Qualitative and quantitative composition of wood-destroying fungi growing on the infected stumps is illustrated in Table 3.

The checks of wood-destroying fungi succession made in the sixth year after infection identified some changes again. The most frequent and the most abundant was the fungus *Trametes gibbosa* (PERS.) FR., followed by *Trametes hirsuta* (WULFEN) PILÁT. *Schizophyllum commune* FR. and *Trametes versicolor* (L.) PILÁT were absolutely absent. On the other hand, the following species started to grow: *Hypholoma fasciculare* (HUDS.), *Merulius tremellosus* SCHRAD.: FR., *Megacollybia platyphylla* (PRES.) KOTL. et POUZ.), *Ganoderma applanatum* (PERS.) PAT. Quantitative and qualitative composition of wood-destroying fungi growing on the infected stumps in the sixth year after the introduction of infection is summarized in Table 4.

Only singular occurrence of several wood-destroying fungi was detected on the non-infected stumps. The most frequent of them were the species *Exidia planna* (WIGG.: SCHLEICH.) DONK, *Xylaria hypoxylon* (L.) GREV., *Xylaria polymorpha* (PERS.) GREV.

The described observations show that the stump surfaces in stands remain undamaged for a long time. The blackened cut surfaces do not accommodate favourable conditions for development of wood-destroying fungi. The occurrence of these fungi, if any, is very rare in the first 5–6 years. A hypothesis can be proposed on the presence of communities of other organisms that inhibit the growth of wood-destroying fungi. This opinion can also be supported by facts from literature dealing with detailed micro-biological analysis of surfaces of wood species decomposed under natural conditions (HEJTMÁNEK,

Table 4. Qualitative and quantitative composition of wood-destroying fungi growing on the infected stumps in the 6th year after the introduction of artificial infection

Species	Frequency of occurrence
Trametes gibbosa (PERS.) FR.	87
Trametes hirsuta (WULFEN) PILÁT	77
Hypholoma fasciculare (HUDS.) P. KUMM.	33
Pholiota squarrosa (WEIGEL) P. KUMM.	22
Merulius tremellosus SCHRAD. ex FR.	22
Flammulina velutipes (CURTIS) SINGER	21
Pluteus cervinus (SCHAEFF.) P. KUMM.	18
Mycena alcalina (FR.) P. KUMM.	17
Pluteus leoninus (SCHAEFF.) P. KUMM.	14
Crepidotus mollis (SCHAEFF.) STAUDE	12
Megacollybia platyphylla (PERS.) KOTL. et POUZAR	12
Ganoderma applanatum (PERS.) PAT.	12
Chlorosplenium aeruginascens (NYL.) P. KARST.	11
Hydnum cirrhatum PERS. ex FR.	6
Inonotus radiatus (SOWERBY) P. KARST.	3
Trametes versicolor (L.) PILÁT	3
Hericium coralloides (SCOP.) GRAY	2
Heterobasidion annosum (FR.) BREF.	2

RYPÁČEK 1953). In addition to lower fungal species, there were identified also 84 species of bacteria and Actinomyceta. They were tested on agar-malt substrate to study their coexistence with the fungi *Serpula lacrimans* (WULFEN) J. SCHRÖT., *Gleophyllum sepiarium* (WULFEN) P. KARST., *Fomitopsis pinicola* (SW) P. KARST., *Schizophyllum commune* FR. Antagonistic reactions were identified for 22 of these micro-organisms.

Similarly, the non-infected control stumps covered with lichens showed neither signs of the presence of rot nor of wood-destroying fungi. Also in this case we can suppose a certain antagonistic influence of lichens due to some products of their metabolic activities. The antibiotic influence of lichens on pathogenic micro-organisms and soil bacteria was detected by FLOREY (1949 in RYPÁČEK 1953). RYPÁČEK (1953), who studied several metabolic products of lichens, confirmed their fungistatic properties by tests with the fungus *Heterobasidion annosum* (FR.) BREF.

In Tables 2, 3 and 4 it is possible to see the discussed fungi succession even if within a narrow time scale. We can detect regression of the individual species in the presence of another species on the same stump. In the fourth year after infection the best symbiotic relations were indicated for the species *Trametes versicolor* (L.) PILÁT with *Pleurotus ostreatus* (JACQ.: FR.) KUMM. and with *Trametes gibbosa* (PERS.) FR. In the fifth year after infection no occurrence of *Schizophyllum commune* FR. was detected and with *Trametes versicolor* (L.) PILÁT the best symbiotic relations were observed for *Trametes*

gibbosa (PERS.) FR. The poorest symbiosis with *Trametes versicolor* (L.) was indicated for the fungus *Trametes hirsuta* (WULFEN) PILÁT. In the sixth year the most frequent symbiosis was observed between *Pleurotus ostreatus* (JACQ.: FR.) KUMM. and *Trametes hirsuta* (WULFEN) PILÁT and between *Hypholoma fasciculare* (HUDS.) P. KUMM. and *Merulius tremellosus* SCHRAD.: FR., with the entire absence of *Trametes versicolor* (L.) PILÁT. In the sixth year a considerable increase in *Trametes hirsuta* (WULFEN) PILÁT was also detected, which in the fifth year was present only at low amounts on stumps occupied simultaneously by *Trametes versicolor* (L.) PILÁT.

EVALUATION OF DAMAGED STANDING STEMS

Not a case of *Pleurotus ostreatus* (JACQ.: FR.) KUMM. growing in stem wounds was revealed by checks performed each year. As this fungus need not fructify immediately after the infection, it is not possible to make final conclusions and further study of the problem is necessary in the future. To provide complete information, we must add that the checks carried out in the second year after the infection detected on two injured stems the fungi *Polyporus squamosus* (HUDS.: FR.), on two other stems *Laetiporus sulphureus* (BULL.) MURRILL, on five stems *Schizophyllum commune* FR., and, finally, on one stem *Inonotus radiatus* (SOWERBY) P. KARST. These species could be found only in the second year after the injury, with the exception of *Inonotus radiatus* (SOWERBY) P. KARST, which appeared only in the fourth year after the injury. All the fruit bodies were growing on stems older than 100 years. Preliminary results allow us to conclude that the fungus *Schizophyllum commune* FR. seems to be the most dangerous. One year old fruit bodies of this fungus were growing on the same stems for 3 years and caused moderate wood decomposition. It should be mentioned that the fungus was also found on other standing stems damaged due to frost cracks or solar heat. Such stems were situated primarily on the uncovered stand edge exposed to SW. Similar was the case of fungus *Polyporus squamosus* (HUDS.: FR.), which was found on two stems damaged during felling. Based on these facts we can conclude that the species cultivated in laboratory is less aggressive than the species growing in beech stands under natural conditions. If this hypothesis is confirmed by further research, it will be possible to cultivate *Pleurotus ostreatus* (JACQ.: FR.) KUMM. with the aim to increase the rate of beech stump decomposition and simultaneously to be also used in the food and pharmaceutical industry.

CONCLUSION

– According to the results obtained until now the Oyster fungus can be successfully cultivated on stumps left after felling, i.e. on clear cuts in beech stands.

- April or May are the most favourable months for infection introduction, the infection is applied to stumps left after winter felling on which the succession of other fungi has not started yet.
- The best method of stump infection is vaccine application into a key followed by inserting sawdust and the cut-out block of wood.
- The wood decay ranges from 43.9% to 53.2%, from 59.4% to 71.3%, and from 75.2% to 90.7% in the fourth, fifth and sixth year after infection, respectively.
- An enormous yield of *Pleurotus ostreatus* (JACQ.: FR.) KUMM. was in the fourth year after infection, on average 73 fruit bodies with total weight of 5.10 kg per one stump.
- During the whole research period *Armillaria mellea* (VAHL) KUMM. s. l. could not be found on any of the infected stumps, which points to antagonism between these fungi.
- On stumps with *Fomes fomentarius* (L.) J. KICKX F. the growth of mycelia as well as of fruit bodies of Oyster fungus was stopped.
- Certain antagonism can be supposed also for the presence of lichens because in such cases the wood-destroying fungi occurred very rarely.
- In total 43 species of wood-destroying fungi were identified growing on the infected stumps.
- During the period of study the mean Oyster fungus production per one stump was 8.35 kg.
- Not a case of infection with Oyster fungus could be detected on stems of living trees in the surrounding stand, not even on the stems artificially injured, with the exception of very rare growth of the following species: *Polyporus squamosus* (HUDS.: FR.), *Laetiporus sulphureus* (BULL.) MURRILL, *Schizophylum commune* FR. and *Inonotus radiatus* (SOWERBY) P. KARST.
- The experiments with artificial infection of beech stumps with Oyster fungus show that the decay period of stumps can be reduced to one half at least. The fungus can also be used in the food and pharmaceutical industry.

After fifteen years of research, the results of stump decay after artificial infection by Oyster fungus (*Pleurotus ostreatus* [JACQ.: FR.] KUMM.) demonstrate the possibility of shortening the stump decay period approximately by a half. The most intensive decay continues in the fifth year after infection due to fungi succession with prevalence of *Trametes versicolor* (L.) PILÁT and in the sixth year after infection with prevalence of *Trametes gibbosa* (PERS.) FR. and *Trametes hirsuta* (WULFEN) PILÁT.

As for the weight decrease, it is evident that the values ranged between 75.2% and 90.7% in all experiments performed in the sixth year after infection. However, in the seventh year after infection it was not possible to evaluate the stump remains due to decay intensity.

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Výsledky inokulácie bukových pňov antagonistickými hubami

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ABSTRAKT: Nerozložené pne po ťažbe ostávajú v poraste 20–25 rokov a prekážajú obnove porastov, ako aj pomalým rozkladom neskoro obohacujú pôdny substrát o živiny. Úlohou práce bolo urýchliť rozklad bukových pňov v poraste pomo-

cou umelo vyvolanej infekcie hubou *Pleurotus ostreatus* (JACQ.: FR.) KUMM. Boli testované rôzne spôsoby infekcie bukových pňov. V časovom intervale šiestich rokov sa sledoval rozklad infikovaných pňov, produkcia plodníc hlivy ustricovej a sukcesia ďalších drevokazných húb. V konečnom dôsledku sa podarilo skrátiť dobu rozkladu na polovicu, pričom plodnice hlivy ustricovej možno použiť v potravinárskom a farmaceutickom priemysle.

Kľúčové slová: *Fagus sylvatica* L.; *Pleurotus ostreatus* (JACQ.: FR.) KUMM.; hliva ustricová; rozklad pňa; sukcesia drevokazných húb

Po ťažbe ostávajú nerozložené pne buka v poraste ešte ďalších 20–25 rokov, čím bránia obnove porastu, ako aj spomaľujú návrat živín do pôdneho substrátu. Z tohto aspektu považujeme činnosť niektorých drevokazných húb v prírodnom kolobehu látok za pozitívnu. Rozkladaním suchých konárov ako aj pňov sa významným dielom podieľajú v procese humifikácie.

Rozklad pňov sme sa pokúsili urýchliť umelou infekciou vyvolanou hlivou ustricovou *Pleurotus ostreatus* (JACQ.: FR.) KUMM. Sledovali sme aj nasledujúcu sukcesiu drevokazných húb a ich antagonizmus.

Vzhľadom na skutočnosť obmedzených laboratórnych možností jadrom práce bolo makroskopické pozorovanie, ktoré pozostávalo z nasledujúcich krokov:
– z každej série pokusov bol vybratý peň, z ktorého sa odrezali tri kotúče o hrúbke 3 cm;
– kotúče boli vážené a ich hmotnosť bola vyjadrená úbytkom v percentách k nenainfikovaným pňom;
– z uvedených kontrol, resp. sérií sme vypočítali priemery v štvrtom, piatom a šiestom roku po nainfikovaní pňov;
– bola vyhodnotená sukcesia húb, určené druhy a množstvo;
– antagonistické vzťahy boli zisťované zatiaľ len na infikovaných pňoch bez laboratórnych rozborov.
Nainfikovaných bolo 15 sérií pňov (v každej sérii 10–15 pňov), ich priemery boli v intervale od 20 do 60 cm. Získané výsledky možno zhrnúť nasledovne:
– Doterajšie výsledky ukazujú, že hlivu ustricovú možno úspešne pestovať na opustených pňoch po ťažbe, t.j. na rúbaniskách v bukových porastoch.
– Najvhodnejšia doba na infekciu na pne po zimnej ťažbe je apríl alebo máj, kým sa na pňoch nevyskytuje iná sukcesia drevokazných húb.
– Najvhodnejší spôsob infekcie je aplikovanie očkovacej látky do nedorezu pňa za súčasného zakrytia pilinami a výpilkom zanechaným na pni po ťažbe.
– Hnilobnosť v štvrtom roku od infekcie podľa úbytku hmotnosti sa pohybuje od 43,9 % do 53,2 %, v piatom roku od 59,4 % do 71,3 % a v šiestom roku od 75,2 %

do 90,7 %. V siedmom roku sa už zbytky pňov pre intenzívny rozklad nedali vyhodnotiť.
– Rekordná úroda huby *Pleurotus ostreatus* (JACQ.: FR.) KUMM. bola v štvrtom roku od infekcie, a to v priemere 73 plodníc na peň, čo predstavovalo hmotnosť 5,10 kg.
– Sukcesia húb sa v priebehu výskumu menila. Konkrétne kvalitatívne a kvantitatívne vyhodnotenie tejto sukcesie v štvrtom, piatom a šiestom roku od infekcie je uvedené v tab. 2–4.
– Podpňovka obyčajná (*Armillaria mellea* (VAHL.) P. KUMM.) s.l. nerástla na žiadnom infikovanom pni po celý čas sledovania, čo poukazuje na antagonizmus týchto húb.
– Na pňoch, kde rástol *Fomes fomentarius* (L.) J. KICKX F., sa podhubie ako i rast hlivy ustricovej zastavil.
– Určitý antagonizmus je možné predpokladať aj pri prítomnosti lišajníkov, pretože výskyt drevokazných húb tu bol len minimálny.
– Spolu bolo identifikovaných 43 druhov drevokazných húb rastúcich na infikovaných pňoch.
– Produkcia hlivy ustricovej na jeden peň za sledované päťročné obdobie dosiahla priemernú hmotnosť 8,35 kg.
– Na stojacich živých kmeňoch okolitého porastu, aj keď boli umele poranené, neobjavila sa infekcia týchto rán hlivou ustricovou ani v jednom prípade. Len ojedinele bol zaznamenaný rast húb: *Polyporus squamosus* (HUDS.: FR.), *Laetiporus sulphureus* (BULL.) MURRILL, *Schizophylum commune* FR. a *Inonotus radiatus* (SOWERBY) P. KARST.

Zistené poznatky za 15-ročné sledovanie rozkladu pňov pri umelej infekcii hlivou ustricovou (*Pleurotus ostreatus* [JACQ.: FR.] KUMM.) dokazujú, že je možné podstatne skrátiť dobu rozkladu pňov približne o polovicu. Najintenzívnejšia hniloba pokračuje v piatom roku od infekcie, a to zásluhou sukcesie húb s prevahou *Trametes versicolor* (L.) PILÁT, a v šiestom roku pri prevahe húb *Trametes gibbosa* (PERS.) FR. a *Trametes hirsuta* (WULFEN) PILÁT.

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Exposure of tropospheric ozone in the region of the Beskydy Mountains, 1996–1999

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ABSTRACT: Air pollutants could be a major contributing factor to forest decline in Europe. The aim of this study is to determine the critical level for ozone in the region of the Beskydy Mts. at the Bílý Kříž station and the evolution observed in the ozone concentrations. The concept of AOT40 is chosen as an indicator for the exposure of ecosystems. The AOT40 values for forests in the period 1996–1999 are estimated according to the new revised critical levels for ozone in European Union (EU). To give an indication of exceeded critical levels, the AOT40 values of the Bílý Kříž region for forests are presented. A considerable increase in ozone values is observed for growing seasons and in summer periods from 1996 to 1999.

Keywords: ozone values; AOT40; forests; Beskydy Mts.

The air pollution in the Czech Republic, specially at the forested stations such as Bílý Kříž, has been the subject of many studies by national and international research groups during the past years (ROŽNOVSKÝ, BLAŽEK 1996a,b; KREJČÍ, ROŽNOVSKÝ 1998; ČERNÝ 1995, 1999; IMIP 1999; ZAPLETAL 1999a,b; HŮNOVÁ et al. 2000). The composition of atmosphere has been undergoing major changes since the beginning of the industrial revolution. Tropospheric ozone (O_3) is considered a major important pollutant over Europe, causing damage to human health, vegetation and materials (KRY-WULT, GODZÍK 1995; SEMENOV 1995; SZDZUJ 1995; EEA 1997; ZÁVODSKÁ et al. 1998; GRANT, WONG 1999; KALABOKAS et al. 1999; MOLNÁROVÁ 2000). The ozone-forming substances are emitted to the air from traffic, industrial processes, and power production. Ozone occurring in the troposphere has two sources: transport from stratosphere (ADEME 1998; ZÁVODSKÁ et al. 1998; MOLNÁROVÁ 2000) and complex photochemical reactions (APPA 1998; BECK et al. 1998; SCHWEITZER 1999; HŮNOVÁ et al. 2000). In the troposphere, its occurrence is influenced by several factors: ozone concentrations increase with altitude, unfavourable conditions (low temperature, high air humidity), low presence of photochemical precursors. The mechanism for ozone production is the oxidation of anthropogenic and biogenic volatile organic compounds (VOCs), methane (CH_4), ni-

trogen oxides (NO_x), carbon monoxide (CO) (ROŽNOVSKÝ, BLAŽEK 1996b; ADEME 1998; ZÁVODSKÁ et al. 1998; ČERNÝ 1999; JACKSON et al. 2000; MOLNÁROVÁ 2000). In urban areas, the photochemical production of ozone involves the oxidation of anthropogenic hydrocarbon compounds emitted by vehicular traffic and biogenic hydrocarbon compounds advected from surrounding rural areas. In rural areas, production of O_3 involves the oxidation of anthropogenic hydrocarbon compounds advected from nearby urban areas and biogenic hydrocarbon compounds emitted by vegetation (isoprene, terpenes) (GRANT, WONG 1999). Ozone concentrations in some areas may even be increasing. Increases in O_3 are of concern because of the important role of ozone in the chemical composition of the troposphere and climate (ZÁVODSKÁ et al. 1998). The ambient ozone concentration, a component of the ozone exposure of plants (MUSSELMAN, MASSMAN 1999), is a parameter used for the ozone critical levels (BECK et al. 1998; ZÁVODSKÁ et al. 1998; ZAPLETAL 1999a,b; HŮNOVÁ et al. 2000). In Europe, the highest ozone concentrations occur in summer, under stable high-pressure systems with clear skies (FALLY et al. 1995; ZÁVODSKÁ et al. 1998; VECCHI, VALLI 1999; HŮNOVÁ et al. 2000). Ozone has adverse effects on human health, agricultural crops, natural vegetation and materials. Ozone can cause troubles in the respiratory tract by inhalation, with in-

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creased risk of infection (reducing resistance to infection by bacteria and viruses). There are moreover indications that high ozone levels can lead to increased mortality (ADEME 1998; APPA 1998). The threshold values set for the protection of human health are exceeded regularly over large parts of Europe (FALLY et al. 1995; ADEME 1998; APPA 1998; BECK et al. 1998). The high ozone values can cause the corrosion of materials, monuments and sculptures (ADEME 1998; KALABOKAS et al. 1999). It is proven that ozone in the industrialized parts of the world causes damage to vegetation, crop yields and forests (FALLY et al. 1995; KRYWULT, GODZÍK 1995; KA-LABOKAS et al. 1999). Ozone enters the plant essentially through the stomata, reduces the photosynthesis process, damages the plasmatic membranes and the water regime (ROŽNOVSKÝ, BLAŽEK 1996; JACKSON et al. 2000). Ozone concentrations tend to be very high in some parts of Europe (EEA 1997; ADEME 1998).

MATERIAL AND METHODS

These results are selected from measurements at an experimental ecological station Bílý Kříž at 49°30'17'' northern latitude and 18°32'28'' eastern longitude (ROŽNOVSKÝ, BLAŽEK 1996a), in the region of the Beskydy Mts. at an altitude of 908 m (ČHMÚ 1998, 1999) in the Czech Republic.

The broken relief with steep extended slopes and deep valleys has a pronounced modification effect on the topoclimate in this area. The annual mean air temperature is 4.9°C, the mean annual precipitation is 1,100 mm and the mean annual air humidity is 80%. The region of the Beskydy Mountains, specially Bílý Kříž, is about 30–40 km from important emission sources in the regions Karviná and Ostrava (FORMÁNEK 2000).

The assessment of air pollution by ozone in the region of the Beskydy Mountains (eastern part of the Czech Republic) was based on the observation of an automated monitoring station (AMS) from February 1996 to De-

cember 1999. The mean of ozone concentration is measured every half-hour. The half-hour measures are calculated with the mean of values-minutes registered during 30 minutes. The ozone concentration measurement is based on ultraviolet absorption photometry, resting upon absorption of radiation with the wavelength of 254 nm by ozone in the analysed sample. The level of ozone pollution is characterized by half-hour average.

Assessment of the status of the air pollution is based on air pollution standards as specified by new European Union (EU) directive No. 0068/99 for tropospheric ozone published on 22 April 1999. The levels of pollution are characterized by daily average, monthly average, annual average and AOT40 values according to the new directives of air pollution standards in Europe.

The assessment of the state of ambient air pollution is based on air pollution standards set down by the new directives of EU. We calculated AOT40 for forests for vegetation period (from April to September) and in the period from May to July. The results of the Bílý Kříž station are compared with Jeseník and Karviná stations.

RESULTS AND DISCUSSION

ANNUAL CONCENTRATIONS

Fig. 1 shows that the annual concentrations were higher than the value of ozone annual limit of 40.0 $\mu g/m^3$ for the protection of materials. The annual ozone average varied between 68.6 (in 1996) and 78.6 $\mu g/m^3$ (in 1998). The annual ozone maximum ranged from 158.0 (in 1999) to 188.0 $\mu g/m^3$ (in 1998).

The annual mean concentrations increase at all measured stations (Bílý Kříž, Karviná and Jeseník) year after year from 1996 to 1999. The Karviná station registered lower ozone annual concentrations than the other stations with values ranging between 47 $\mu g/m^3$ in 1997 and 51 $\mu g/m^3$ in 1996. The Jeseník station registered annual values from 74 $\mu g/m^3$ in 1996 to 62 $\mu g/m^3$ in 1998. The
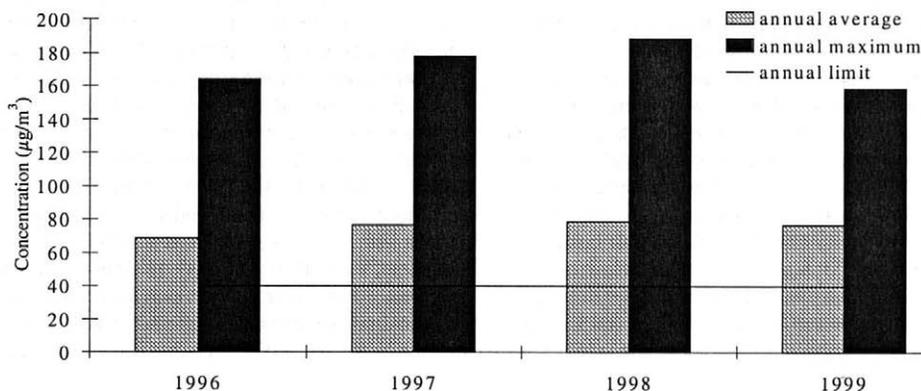

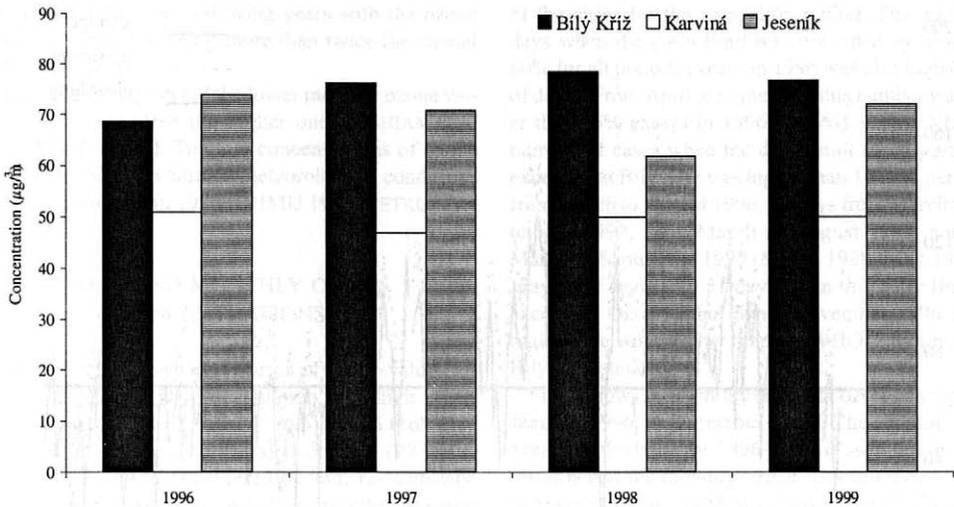Fig. 1. Annual ozone concentration from 1996 to 1999 with annual limit of 40 $\mu g/m^3$, Bílý Kříž

Fig. 2. Comparison of the Bílý Kříž station with other stations, annual concentration 1996–1999

Bílý Kříž station registered yearly values from 76 µg/m³ in 1996 to 78 µg/m³ in 1998. The observed situation was that the Bílý Kříž station registered higher ozone annual values than Karviná and Jeseník (Fig. 2).

The lowest annual concentration was registered in 1996 at the Bílý Kříž station, but on the other hand, the year 1996 registered the highest value at Karviná and Jeseník, as can be seen in Fig. 2. This difference is caused by faster destruction of ozone in the urban air and due to higher concentrations of nitrogen oxides, those of ozone precursors (ČHMÚ 1998, 1999).

The increase from 1996 to 1998 was found through the Czech Republic for the same time (ČHMÚ 1997, 1998,

1999; KREJČÍ, ROŽNOVSKÝ 1998; IMIP 1999; HŮNOVÁ et al. 2000; TSHIAMALA, ROŽNOVSKÝ 2000b) and through Europe (SZDZUJ 1995; ADEME 1998; APPA, 1998; BECK et al. 1998; MOLNÁROVÁ, MINĎÁŠ 1998; ZÁVODSKÁ et al. 1998). This situation can be explained by the fact that the meteorological conditions were unfavourable for ozone formation in 1996 and 1997 because of the lowest air temperature in summer (ČHMÚ 1998, 1999; PETRUŽELA et al. 1999; MOLNÁROVÁ 2000).

The annual limit of 40.0 µg/m³ for material was exceeded at the three measured Karviná stations for all periods (Fig. 2). The comparison of the measured period with the previous years shows that the last cited year was
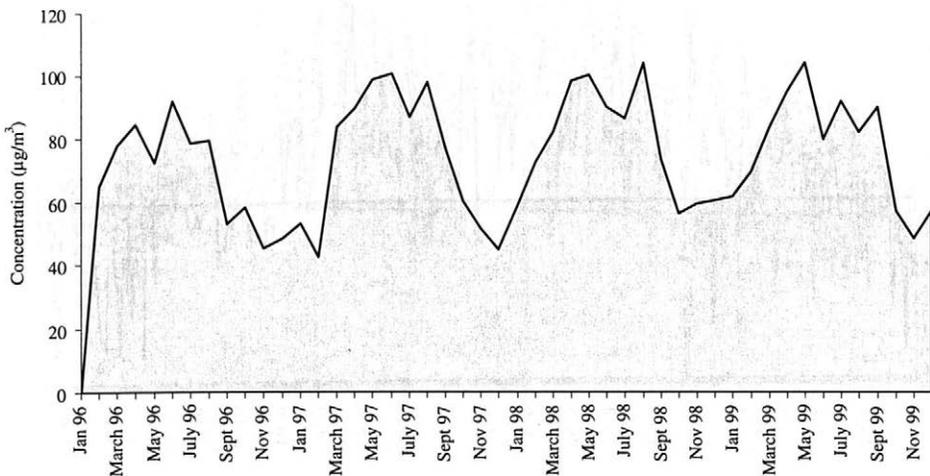
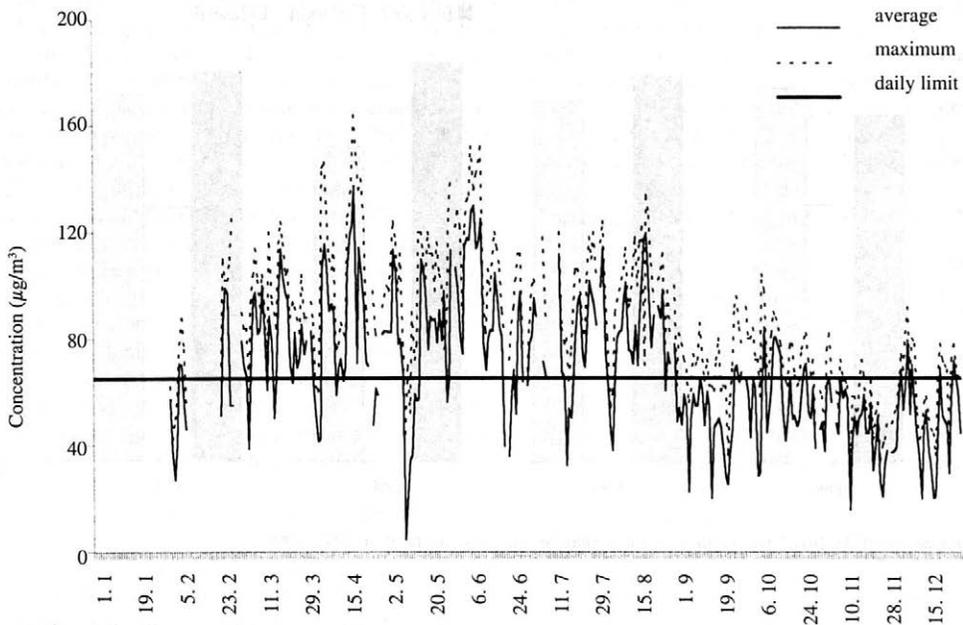Fig. 3. Monthly course of ozone average, Bílý Kříž 1996–1999
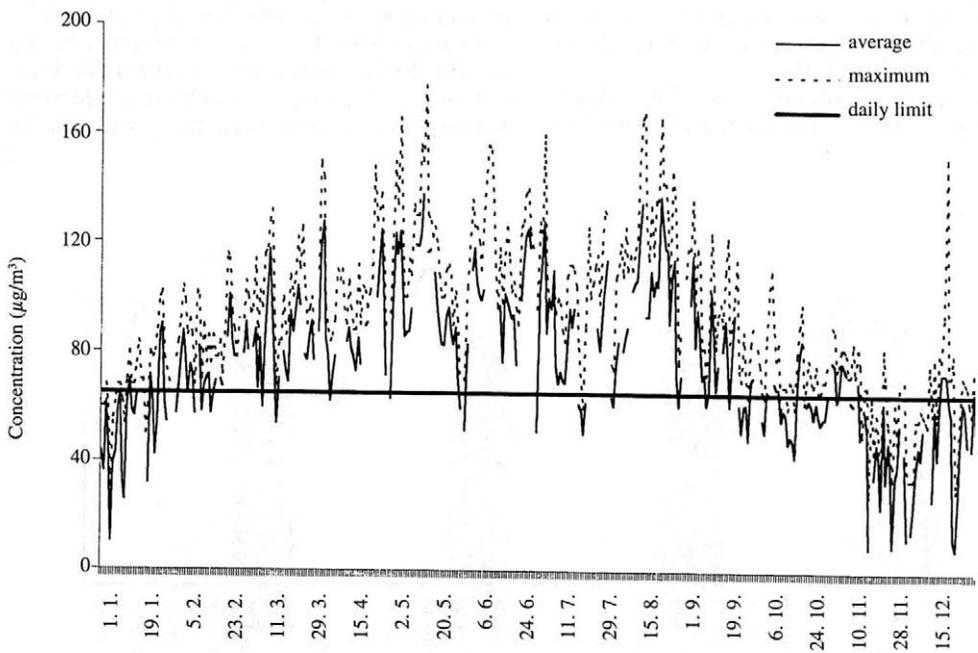
Fig. 4. Daily concentration with daily limit of 65 μg/m³, Bílý Kříž 1996

Fig. 5. Daily ozone concentrations with daily limit of 65 μg/m³, Bílý Kříž 1997

more harmful than the following years with the ozone annual concentration being more than twice the annual limit of 40.0 μg/m³.

The year 1996 registered the lower monthly ozone values and the year 1998 the higher ones (TSHIAMALA, ROŽNOVSKÝ 2000b). The low concentrations of ozone were due to the unfavourable meteorological conditions for ozone formation in 1996 (ČHMÚ 1999; PETRUŽELA et al. 1999).

DAILY AND MONTHLY OZONE CONCENTRATIONS

Figs. 4–7 reveal the daily courses of ozone values for 1996 to 1999 at the Bílý Kříž station. The high ozone maximum was 163.7 (20th April 1996), 177.6 (16th May 1997), 187.6 (12th August 1998) and 157.7 (28th May 1999) μg/m³ for the considered period, respectively. These same data were recorded at the other stations through the Czech Republic (ČHMÚ 1998, 1999, 2000). The daily ozone averages ranged from 15.6 to 137.4, from 8.6 to 139.8, from 5.2 to 173.6 and 6.4 to 136.8 μg/m³ for 1996 to 1999 at the Bílý Kříž station.

The daily ozone concentrations were higher than the daily limit of 65 μg/m³ from March to September for all measured periods and the low concentrations were registered in November (TSHIAMALA, ROŽNOVSKÝ 2000a). The number of days when the ozone concentration was higher than the WHO limit 65 μg/m³ was more than 80%

of the cases for the vegetation period. The number of days when the daily limit was exceeded by more than 60% for all periods except in 1996 was also high (46.3% of days). From April to September this number was higher than 85% except in 1996 (64.6%) at Bílý Kříž. The number of cases when the daily limit of 65 μg/m³ was exceeded at Bílý Kříž was higher than 10 days per month from March to August 1996, 20 days from March to September 1997, from March to August 1998, and from March to September 1999. March 1998, May 1998 and May 1999 registered 31 days when this daily limit was exceeded. On the other hand, November 1996 did not register the value higher than the WHO daily limit at the Bílý Kříž station.

Fig. 3 shows the monthly course of ozone average from January 1996 to December 1999. The monthly ozone average calculated for 1996–1999 is seen in Fig. 8. The result is that the monthly ozone concentration was high in May (94 μg/m³) and low in November (51.2 μg/m³) at Bílý Kříž. The monthly values in μg/m³ ranged from 44.8 (November 1996) to 91.8 (June 1996), from 50.0 (December 1997) to 100.6 (June 1997), from 56.4 (October 1998) to 104.0 (August 1998), and from 48.4 (November 1999) to 104.2 (May 1999).

AOT40

The concept AOT40, Accumulated Ozone Exposure over 80 μg/m³, is chosen as an indicator for the exposure
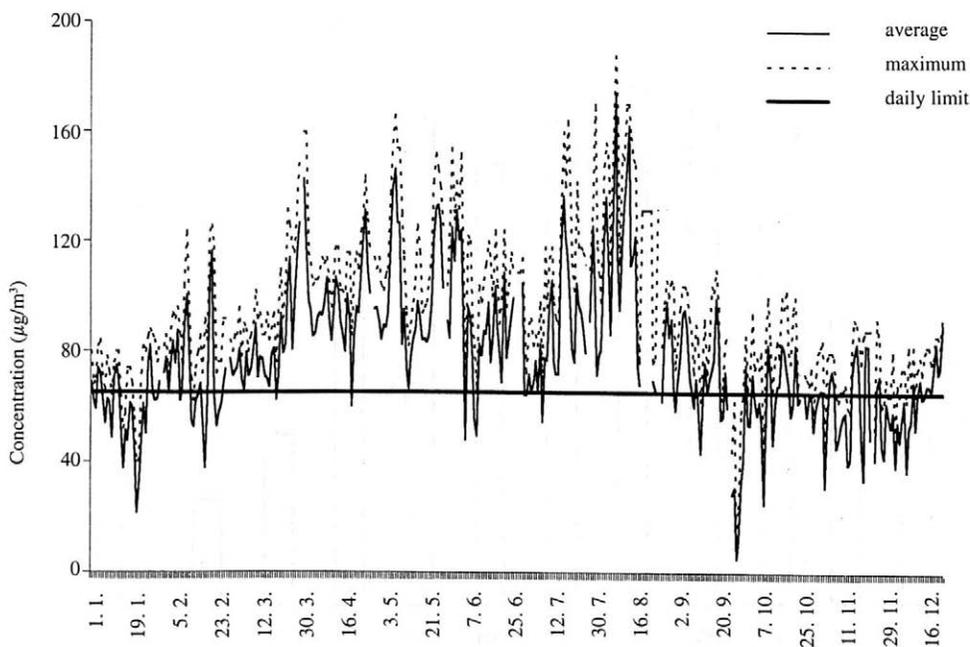

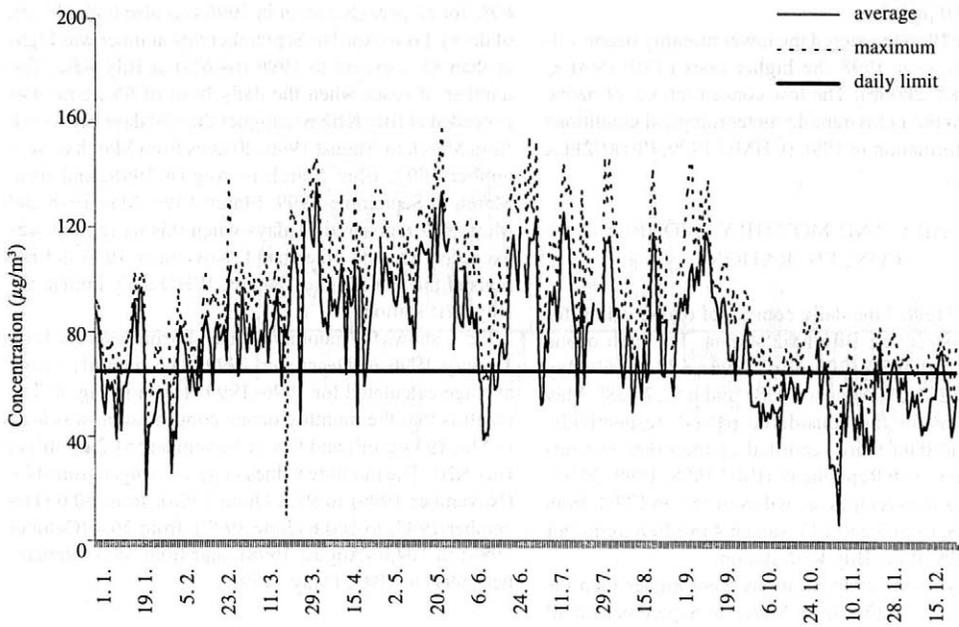Fig. 6. Daily ozone concentrations with daily limit od 65 μg/m³, Bílý Kříž 1998

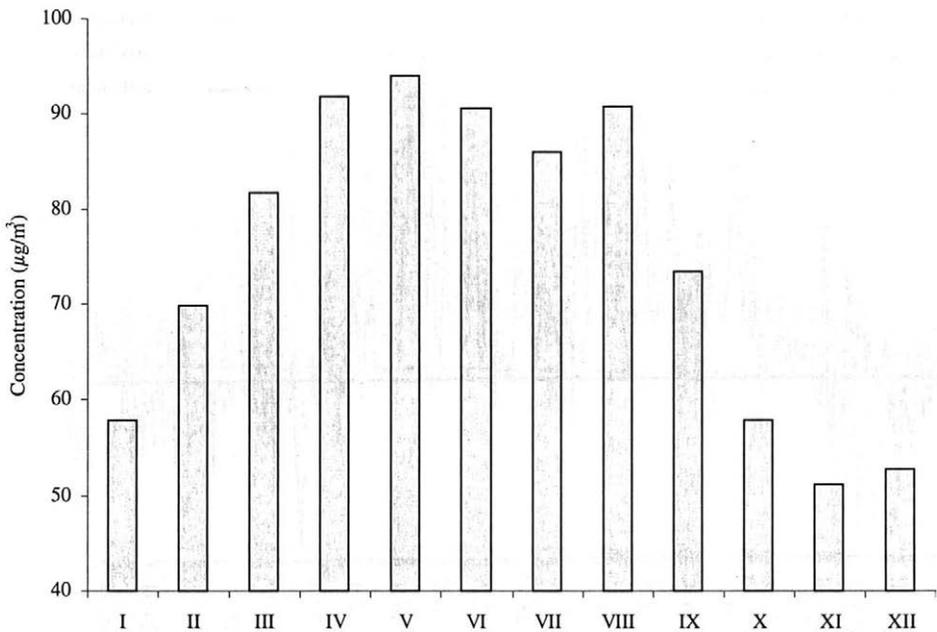Fig. 7. Daily ozone concentrations with daily limit of 65 µg/m³, Bílý Kříž 1999

Fig. 8. Monthly ozone average for 1996–1999, Bílý Kříž
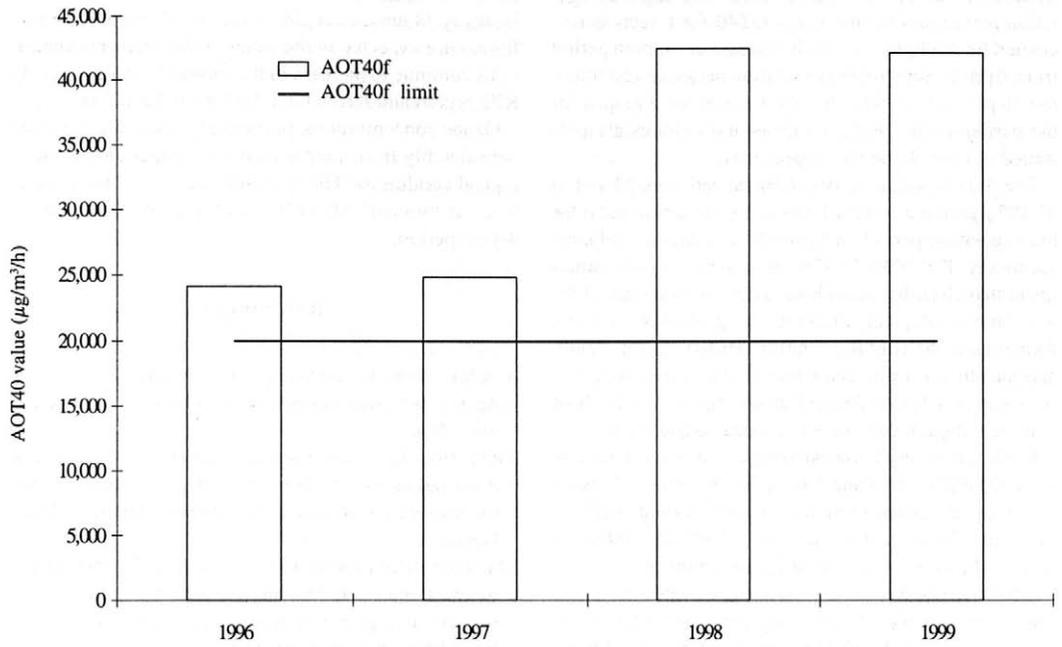
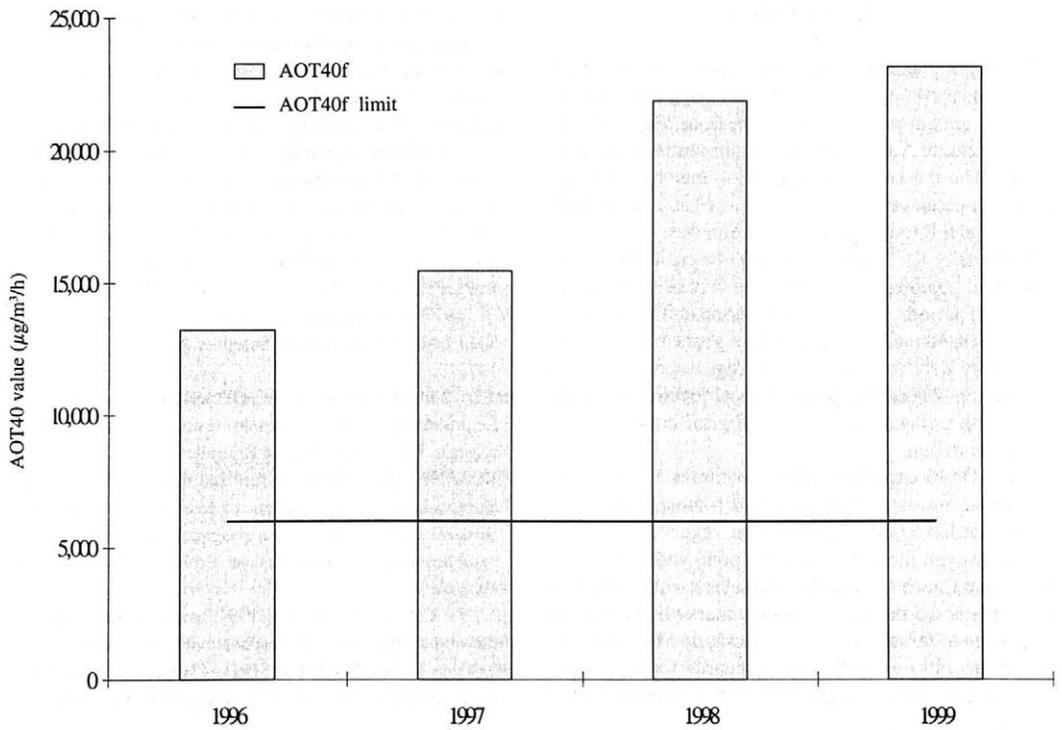Fig. 9. AOT40 for forest from April to September with limit of 20,000 $\mu g/m^3/h$, Bílý Kříž 1996–1999

Fig. 10. AOT40 for vegetation from May to July with limit of 6,000 $\mu g/m^3/h$, Bílý Kříž 1996–1999

of ecosystems such as forests, cultures during the vegetation period and in summer. AOT40 for forests is calculated for daylight hours only during a six-month period from April to September (vegetation period) and a three-month period from May to July. Critical level graphs for the period 1996–1999 for forests and cultures are presented in Figs. 9 and 10, respectively.

The AOT40 values at Bílý Kříž ranged from 24,144 to 42,407 µg/m³ per h and 13,248 to 23,214 µg/m³ per h for the vegetation period and period from May to July, respectively. The 1996–1997 registered the AOT40 values lower than the other years because of the existence of the worst meteorological conditions for ground-level ozone formation at the Bílý Kříž station (HŮNOVÁ et al. 2000) and the situation was encountered also in EU countries (BECK et al. 1998) and over Europe. Figs. 9 and 10 show that the critical levels were exceeded considerably.

In the years with lowest ozone concentrations and AOT40 values (1996 and 1997), the threshold values for forests are exceeded more than 1.2 to 2.6 times while in the years with highest ozone values (1998 and 1999), the threshold levels are exceeded 2.1 to 3.9 times.

A long-term exposure to high ozone concentrations can cause a decline of the forest ecosystem (BECK et al. 1998; MOLNÁROVÁ 2000). Rather high potential harmful impacts of ground-level ozone on forests at Bílý Kříž were observed every year with the high potential for toxic effects on vegetation.

CONCLUSION

During the investigation period from 1996 to 1999, ozone concentrations in forest stands of Bílý Kříž showed a typical annual pattern with the peak in May and secondary peak in August, and the minimum in November. Since 1996, the annual concentration increased considerably. The same situation was observed at other stations in the Czech Republic and in EU countries.

At the Bílý Kříž station, the AOT40 critical levels of 6,000 and 20,000 µg/m³ per h were exceeded during all measured periods in the summer period and the growing season, respectively. Results of the 4 years of monitoring at the Bílý Kříž station show that registered ozone concentrations exceed the annual critical level, even in the years with unfavourable meteorological conditions for ozone formation.

The AOT40 exposure index constitutes a useful tool for annual assessment of increased tropospheric ozone levels that have negative effects on vegetation and forests. However, these results correspond well with those from other Czech stations. Based on these concentrations of ozone, it can be stated that they markedly contribute to damage to forest stands of the Beskydy Mountains region from 1996 to 1999. The standards for vegetation and material protection are frequently exceeded at Bílý Kříž in all periods.

The high ozone concentrations and high AOT values can contribute to damage to forest lands and aggravate the forest decay at the forested station Bílý Kříž in the Beskydy Mountains region. Serious effects of ozone on forests are expected in the future if the ozone concentrations continue to increase in the forested areas in the Bílý Kříž region and throughout the Czech Republic.

Ozone concentrations, particularly peak values, varied considerably from year to year due to specific meteorologicał conditions. The AOT40f shows variations about a factor two and AOT40v about a factor three for the 4-year period.

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Hodnocení koncentrací troposférického ozonu na Bílém Kříži v letech 1996–1999

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ABSTRAKT: Znečišťující látky jsou důležitým faktorem poškozování lesů v Evropě, významnou úlohu má ozon. Cílem příspěvku je determinovat kritickou úroveň ozonu v Moravskoslezských Beskydech na stanici Bílý Kříž. Ukazatel AOT40, který se používá jako expoziční indikátor působení ozonu na lesní ekosystémy, byl vyhodnocen podle nových kritických úrovní stanovených v Evropské unii (EU). Předkládány jsou výsledky měření za roky 1996–1999. Pro lesy na Bílém Kříži bylo zjištěno překročení kritických úrovní koncentrací ozonu jak v letních obdobích, tak i během vegetačních období za sledované roky.

Klíčová slova: hodnoty ozonu; AOT40; lesy; Moravskoslezské Beskydy

Výskyt znečištění ovzduší je v podmínkách České republiky známý problém, který však dnes působí globálně, tedy nejen v průmyslových státech (KREJČÍ, ROŽNOVSKÝ 1998). Snížením některých druhů výroby, zánikem určitých podniků a instalací odlučovacích a odsiřovacích zařízení klesá znečištění našeho ovzduší mnoha škodlivinami. Jak však dokládají výsledky, na území ČR jsou vysoké koncentrace ozonu, který je označován za sekundární znečišťující látku v ovzduší. Vzniká chemickými reakcemi za účinku slunečního záření z prekurzorů, kterými jsou např. oxidy dusíku, organické látky apod. Koncentrace ozonu roste s nadmořskou výškou až po hranice lesa.

Troposférický ozon je plyn, který má negativní vliv na lidi, vegetaci i materiály. V rámci výzkumných projektů na ekofyziologickém pracovišti Bílý Kříž, spravovaném Ústavem ekologie krajiny AV ČR, probíhají v rámci měření meteorologických podmínek i měření koncentrací vybraných imisí včetně koncentrací ozonu. V příspěvku jsou uváděny výsledky z vyhodnocených měření koncentrací ozonu za roky 1996–1999.

Výsledky byly získány vyhodnocením kontinuálních měření koncentrací ozonu na stanici čistoty ovzduší na Bílém Kříži v nadmořské výšce 908 m na území Moravskoslezských Beskyd. Stanice je vzdálena 30–40 km od průmyslových regionů Karviné a Ostravy. K měření se používají UV analyzátory firmy Te Instruments, model 49. Stanice Bílý Kříž je součástí sítě stanic čistoty ovzduší ČHMÚ, tzv. automatického imisního monitoringu (AIM). Ke zpracování byly použity údaje o průměrných půlhodinových imisních koncentracích přízemního ozonu. Zvláštní pozornost byla zaměřena na index AOT40 (Accumulated Exposure Over Threshold of 80 $\mu g/m^3$), který se používá pro hodnocení vlivu ozonu na ekosystémy ve vegetační době. Roční koncentrace ozonu za období 1996–1999 ze stanice Bílý Kříž byly srovnávány s ročními koncentracemi na stanicích Karviná a Jeseník.

Obecně lze uvést, že v oblasti Bílého Kříže se vyskytují absolutní maximální koncentrace ozonu v měsíci srpnu. Měsíční průměrné koncentrace jsou nejvyšší v měsíci květnu, podružné maximum nacházíme v srpnu. Tato dvě maxima oddělují koncentrace měsíce června a července. V jednotlivých letech se výskyt maxim logicky od průměrného chodu liší a nemusí být vždy vyjádřena dvouvrcholová křivka. Pro rok 1998 je typické výrazné srpnové maximum a jednovrcholový tvar roční křivky narušuje o několik μg nižší koncentrace června a července jak u průměrů, tak i u měsíčních maxim.

Roční imisní limit pro protekci materiálů je 40 $\mu g/m^3$. Průměrné roční koncentrace přesahují 70 $\mu g/m^3$ a postupně stoupají. Podobně je to u ročních maximálních koncentrací, přesahujících 180 $\mu g/m^3$. K překročení ročního imisního limitu 40 $\mu g/m^3$ došlo během celé doby. Roční průměrná koncentrace ozonu na Bílém Kříži se pohybovala mezi 68,6–78,6 $\mu g/m^3$, v Karviné mezi 62,0–74,0 $\mu g/m^3$ a v Jeseníku mezi 47,0–51,0 $\mu g/m^3$. V období od března do srpna je průměrná koncentrace na Bílém Kříži nad 80 $\mu g/m^3$.

Na Bílém Kříži ve vegetačním období v letech 1996–1999 mělo více než 80 % dnů s měřeními koncentraci vyšší, než stanovuje Světová zdravotnická organizace (65 $\mu g/m^3$). V měsících květen až srpen byly zaznamenány výskyty denních maximálních koncentrací i nad 160 $\mu g/m^3$ (od 163,7 do 187,2 $\mu g/m^3$). V roce 1996, který měl nejnižší koncentrace ozonu za sledované období, bylo 46,3 % dnů s koncentracemi nad 65 $\mu g/m^3$.

Pro ochranu evropských lesů byla stanovena kritická úroveň ozonu AOT40f ve výši 20 000 $\mu g/m^3$ za h za období duben až září a pro ostatní vegetaci AOT40v ve výši 6 000 $\mu g/m^3$ za h za měsíce květen až červenec. Podle našich výsledků se na Bílém Kříži AOT40f pohybuje od 24 144,6 (1996) do 42 407 $\mu g/m^3$ za h (1998), AOT40v od 13 248,4 (1996) do 23 214,5 $\mu g/m^3$ za h (1999). V letech s nejnižšími koncentracemi ozonu a hodnotami AOT40 (1996 i 1997) byl překročen imisní limit pro ochranu lesů 1,2–2,6krát a v letech s nejvyššími koncentracemi (1998 i 1999) 2,1–3,9krát.

V průběhu roku má nejvyšší průměrnou koncentraci květen (90 $\mu g/m^3$), když jen o málo nižší průměrné koncentrace ozonu nacházíme u měsíců duben, červen a srpen. Nejnižší měsíční koncentrace má listopad.

Výsledky měření na Bílém Kříži vykazují v letech 1996–1999 dvakrát vyšší hodnoty AOT40 za vegetační období a třikrát více pro období květen až červenec, než uvádějí stanovené předpisy Evropské unie. To znamená, že koncentrace O_3 lesní porosty v oblasti Bílého Kříže poškozují.

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New or scarce Acalyptrate flies (*Diptera*) found in the forests of the Czech and Slovak Republics

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ABSTRACT: The author found other new species of the *Diptera*-Acalyptrata in the territory of the Czech and Slovak Republics, the occurrence of which has not been known until now; some of the species are rare in Central Europe. New species for the territory of the Czech Republic and also for the region of Bohemia are: *Suillia variegata* (LOEW) (fam. *Heleomyzidae*), *Sapromyza gozmanyi* PAPP and *Eusapromyza balioptera* CZERNY (fam. *Lauxaniidae*), *Loxocera* (*Platystyla*) *hoffmannseggi* MEIGEN and *Chamaepsila villosula* MEIGEN (fam. *Psilidae*) and *Herina germinationis* (ROSSI), *H. paludum* (FALLÉN) and *Cephalia rufipes* MEIGEN (fam. *Otitidae*). New species for the territories of Bohemia and Moravia are *Homoneura christophi* (BECKER) (fam. *Lauxaniidae*) and for Moravia *Suillia variegata* (LOEW) (fam. *Heleomyzidae*). New species for the southern and warm territory of the Slovak Republic is *Otites gradualis* CARLES-TOLRÁ, 1998. The author has found again some species being rare or markedly troglophilous in the territory of both republics.

Keywords: *Diptera*; *Heleomyzidae*; *Lauxaniidae*; *Otitidae*; *Psilidae*; faunistics; Czech Republic; Slovak Republic; new finds

In recent years (1984–2000) the author had an opportunity to identify a new extensive material of *Diptera* of some families of the group *Diptera*-Acalyptrata in the territory of the Czech and Slovak Republics. Besides his own finds the material originated mainly from the collection of Prof. Dr. Miroslav Barták (coll. of the Institute of Zoology and Fishery of the Czech University of Agriculture at Prague), Dr. Jindřich Roháček (coll. of Silesian Museum at Opava), Dr. Jan Máca (coll. of Agency for Nature and Landscape Protection at České Budějovice); other numerous specimens have been collected by Dr. Vladimír Košel (coll. of the Department of Zoology of the Faculty of Natural History of Komenský University at Bratislava), Prof. Rudolf Rozkošný (coll. of the Institute of Zoology and Ecology of the Faculty of Science of Masaryk University at Brno) and Dr. Bohuslav Mocek (coll. of Regional Museum of East Bohemia at Hradec Králové). In these extensive collections of *Diptera* the author has revealed some new finds of the species from the territory of both neighbouring republics hitherto unknown or generally rare in Central Europe.

New or scarce species were caught either by sweeping the plants (without marking), or by Malaise traps (= MT), yellow pan traps (= YPT), pitfall (= ET), or also by nets installed on the car in the course of rides to shorter distances (car trap = CT). Other abbreviations used in the text: coll. = collection, Bart. = Barták, Koš. = Košel, Mart.

= Martinek, Moc. = Mocek, Roh. = Roháček, Rozk. = Rozkošný, Woź. = Woźnica.

The author thanks to all above-named collectors for the opportunity to publish the new data. The present contribution is a continuation of the preceding paper that was published in the journal Biológia (Bratislava) nearly 15 years ago (MARTINEK 1985). In the meantime, the author published other similar contributions in which finds of other new species in the territory of both republics are listed (MARTINEK 1993, 1994, 1997; MARTINEK et al. 1995, and others).

NEW SPECIES FOR THE CZECH REPUBLIC

FAMILY *HELEOMYZIDAE*

Suillia variegata (LOEW, 1862)

Boh. Occ. Sept.: Duchcov (50.36 N/13.43 E), floodplain forest (220 m), MT, 26.–30. 4. 1998 1 F*; Březno near Chomutov (50.24.24 N/13.23.21 E) near Hutná brook (285 m), MT, 1.–14. 5. 2000 1 M*; 27. 7.–25. 8. 2000 1 F* (Bart. leg. et coll., Mart. det.); Moravia Mer. Occ.: Šobes near Znojmo, Nat. Park Podyjí, steppe forest, YPT, 11. 6. 1995, 1 F* (Moc. leg. et coll., Mart. det.).

New species for the territory of the Czech Republic. Warm-loving southern species caught in maritime areas in Europe until now: Bulgaria – Varna, Italy – Trieste (all

coll. Mart.), Portugal (coll. Moc.), the Netherlands (ZUIJLEN et al. 1996). In Central Europe, this species was swept rarely in southern Slovakia near Kamenica nad Hronom most recently (MARTINEK 1993), PAPP (1981) reports it from the territory of Hungary. Now its catch near Duchcov (NW Bohemia) and in southern Moravia at Znojmo likewise in a lowland, obviously warm locality, may evidence the fact that this species occurs here and there also in inland Bohemia and Moravia due to temperature fluctuations. The species becomes obviously more abundant in the direction to the north.

FAMILY *LAUXANIIDAE*

Sapromyza gozmanyi (PAPP, 1981)

Boh. Centr.: Praha-Bohnice (50.08 N/14.24 E), sweeping on vegetation (250 m), 25. 6. 1988, 2 M* (Bart. leg., PAPP (1993) det., Mart. coll.).

New species for the territory of Bohemia and Czech Republic. A Mediterranean species described from Tunisia. It may also be an evidence of the spread of this warm-loving species to the north of Europe in the period of temperature fluctuations in the 80ies and 90ies.

Eusapromyza balioptera (CZERNY, 1932)

Boh. Or. Sept. (50.17 N/16.04 E); Zbytka Reserve, env. České Meziříčí near Dobruška (280 m), forest edge, 15.–22. 7. 1996, 1 F*; damp meadow, 22. 7.–31. 7. 1996, 1 M* (all in YPT), (Moc. leg. et coll.).

Rare species. This is the first record from Bohemia. In Moravia, it was caught by Landrock (1 M*) in the valley of the Bobrava river at Brno at the beginning of the 20th century (MARTINEK 1977a). A finding in Slovakia (Szaloncza = Slavnica) was published by SZILÁDY (1941). A thermophilous species showing increasing abundance, thus it can be found more easily during warmer periods. The finding of this species in the nature reserve Zbytka, besides many other rare animal and plant species, may stress the significance and value of this site in the flood plain of the Dědina river at foothills of the Orlické hory Mts.

Homoneura christophi (BECKER, 1895)

Boh. Centr.: Praha-Kunice near Říčany, CN, 30. 6. 1992 1 M* (Bart. leg., Mart. det. et coll.). Moravia Sept. Or.: Jablunkov – to Slovakian border, CN, 31. 7. 1992 1 F* (Bart. leg., Mart. det. et coll.).

New species for the fauna of the Czech Republic. Warm-loving species.

FAMILY *OTITIDAE*

Herina germinationis (ROSSI, 1790)

Boh. Or.: Střemošická stráň Reserve near Vysoké Mýto, 1. 7. 1998 1 F*; 2. 7. 1987 3 M*, 4 F*; 16. 7. 1997 1 F*, 20. 7. 1997 1 M*, 29. 7. 1997 2 F* (Moc. leg. et coll., Mart. det.).

The first find of this species in the territory of Bohemia. MARTINEK (1976a, 1978a) recorded it already in Moravia and Slovakia. Warm-loving species.

Herina paludum (FALLÉN, 1820)

Boh. Or.: Střemošická stráň Reserve near Vysoké Mýto, 2. 7. 1997 1 M*, 16. 7. 1997 2 M* 1 F*; 29. 7. 1997 1 M* 1 F* (Moc. leg. et coll., Mart. det.).

The first finding of this species in the territory of Bohemia. MARTINEK (1978a) recorded it already in Moravia and Slovakia (MARTINEK 1986). A warm-loving species. Both above-mentioned species of the genus *Herina* seem to considerably increase their abundance, so they may be more easily caught by sweeping regarding climatic fluctuations in recent decades.

Cephalia rufipes (MEIGEN, 1826)

Boh. Occ. Sept.: Březno near Chomutov (50.24 N/13.23 E), corridor of Hutná brook, MT, 18. 6.–27. 7. 2000, 1 M* (Bart. leg. et coll.).

First finding of this thermophilous South European species in the territory of Bohemia. In Moravia it was caught by O. Šustera in July 1943 at Brumovice near Břeclav (ROHÁČEK et al. 1986) and in Slovakia at Slovenské Nové Mesto (THALHAMMER 1899).

FAMILY *PSILIDAE*

Chamaepsila villosula (MEIGEN, 1826)

Boh. Or.: Střemošická stráň Reserve near Vysoké Mýto, forest edge, 12. 9. 1997 1 F* (Moc. leg. et coll., Mart. det.).

A new species for the territory of the Czech Republic and Bohemia as well, it has not been found in Moravia until now. In Slovakia it is known from Devín near Bratislava (MARTINEK 1984, 1986). Warm-loving species evidencing a warm locality!

Loxocera (Platystyla) hoffmannseggi (MEIGEN, 1826)

Boh. Occ. Sept.: Duchcov (50.36 N/13.43 E), floodplain forest (220 m), MT, 23. 7.–24. 8. 1998 1 F* (Bart. leg. et coll., Mart. det.).

A new species for the territory of Bohemia. J. Roháček (MARTINEK 1985) caught this species in southern Moravia (Radějov near Strážnice) in July and SOÓS (1946) caught it in Slovakia near Starý Smokovec. The species is a highly warm-loving one, occurring rarely and only here and there. For that reason it was possible to catch it only in the periods of higher summer temperatures in the last decades.

NEW SPECIES FOR THE SLOVAK REPUBLIC

FAMILY *OTITIDAE*

Otites gradualis (CARLES-TOLRÁ, 1998)

Slovakia Mer.: Modrý Kameň near Veľký Krtíš, 13. 5. 1959 1 F* (Ptáček leg., Carles-Tolrá det. et coll. – a holotype).

A recently described species from the territory of the Slovak Republic and Central Europe (CARLES-TOLRÁ 1998), obviously very warm-loving, belonging to south-

ern species. The preferred biotope cannot be precisely determined now, collection sites were warm oak forests in the environs of Veľký Krtíš. The present author saw one male of this species collected by Ptáček at the same locality in 1969 in the collection of the Slovak National Museum at Bratislava. This specimen was almost completely destroyed by an *Anthrenus*, mainly its abdomen including the genitalia. The preserved wings were extraordinarily broad (like in *Empis* (*Platyptera*) *borealis* L. of the *Empididae*) and uniformly brownish infuscated. Thanks to this character, the species may be distinguished at a glance. A new material from biotopes near Modrý Kameň (early in spring) and a catch of a male appear to be very desired for the description of male genitalia.

REPEATED FINDS OF RARE OR SCARCE SPECIES

FAMILY *HELEOMYZIDAE*

Eccoptomera infuscata (WAHLGREN, 1918)

Boh. Mer.: Šumava Mts., Spálenec (800 m), damp meadow, 15. 8. 1994 1 M* (Bart. leg., Mart. det. et coll.); Boh. Occ.: Krušné hory Mts., Jiřího návrší near Litvínov (850 m), 25. 8. 1960 1 M* (Mart. leg. et coll., Gorodkov det.), Krušné hory Mts., Cínovec (860 m), meadow wood, ET, 12.–16. 9. 1995 1 F* (Farkač leg., Mart. det. et coll.). Slovakia Sept.: Vysoké Tatry Mts., Štrbské Pleso, 1 km E (1,250 m), meadow, 20. 10. 1985 1 M* (Bart. leg., Mart. det. et coll.).

Mountain species distributed mainly in western Europe, more frequently in western Bohemia.

Scoliocentra (s. str.) *scutellaris* (ZETTERSTEDT, 1838)

Boh. Mer.: Šumava Mts., Plešné jezero, ET, 14. 5.–20. 6. 1991 1 M* 1 F*; Nová Hůrka, Hůrecký hill, ET, 14. 5.–19. 6. 1991 1 M* 1 F* (Chrudina leg., Mart. det. et coll.); Trojmezná Mt. (1,350 m), MT, 1 M* (Pavlíčko leg., Mart. det. et coll.). Slov. Centr.: Slov. Raj Reserve, Vlčia jaskyňa cave, 11. 1. 1992 (25–30 m), 1 M* (Koš. leg., Mart. det. et coll.).

A rare, rather West European species, collected for the first time in early spring by MARTINEK (1969) on a window of the Erlebach's chalet (1,150 m) beneath Špindlerovka mountain hut in the Krkonoše Mts. It is obviously mainly a mountain species, as proved also by new finds in the Šumava Mts. The species winters in caverns, earth caves, etc. (see e.g. Vlčia jaskyňa cave). Cavernicolous species.

Tephrochlaena halterata (MEIGEN, 1830)

Boh. Or.: Podlažice Altán, Chrudim district, xerotherm, 12. 5. 1995 1 F* (Moc. leg., Mart. det., Carles-Tolrá coll.).

This species may be rather a maritime one (cf. Woźnica – letter from 1996). For that reason it should not occur then in the inland part of Bohemia! Specimens caught

there indicate the obvious distribution 1 + 3 dc, and thus their genus status cannot be doubted. A repeated find from the territory of Bohemia (MARTINEK 1985).

Heleomyza serrata (LINNAEUS, 1758)

Boh. Mer.: Šumava Mts. (49.04 N/13.34 E), Zhůřské peat bogs (1,130 m), MT, 16. 6.–21. 7. 1999 1 M*; (49.00.59 N/13.25.05 E), Rokytecká peat bog (1,100 m), MT, 20. 8.–24. 9. 1999 1 M* (Bart., Kubík leg., Mart. det. et coll.).

Repeated finds from the mountain territory of Bohemia (MARTINEK 1969).

FAMILY *LAUXANIIDAE*

Calliopum albomaculatum (STROBL, 1909)

Boh. Mer.: Šumava Mts. (49.00.59 N/13.25.05 E), Rokytecká peat bog (1,100 m), MT, 18. 5.–16. 6. 1999 1 M*; (49.09. N/13.20 E) Nová Hůrka peat bog (870 m), MT, 18. 5.–16. 6. 1999 1 M* (all Bart., Kubík leg. et coll., Mart. det.).

Repeated finds from the Šumava Mts. (cf. ROHÁČEK et al. 1998).

Calliopum geniculatum (FABRICIUS, 1805)

Boh. Or.: Hradec Králové, 12 km N, Habřina – forest Vražba, edge of mixed forest, 21. 6. 1995 1 M* (Moc. leg., Mart. det., Carles-Tolrá coll.); MARTINEK (1977a) recorded this species in Moravia.

This species occurs rarely, it is of a smaller size than *C. aeneum* (FALLÉN).

Homoneura lamellata (BECKER, 1895)

Boh. Occ. Sept.: Vlčák env. Maxičky near Děčín, MT, 12. 5. 2000 1 M* (Kula leg., Mart. det. et coll.).

Repeated finds from the territory of Bohemia (cf. MARTINEK 1997).

Homoneura tesquae (BECKER, 1895)

Boh. Centr.: Praha-Holešovice, along the river (200 m), 14. 6. 1988 2 M* 1 F* (Bart. leg., Papp det., Mart. coll.).

Warm-loving, only rarely occurring species. The second find in the territory of Prague, for the first time recorded by MARTINEK (1982) from Džbán near the Šárka valley.

FAMILY *OPOMYZIDAE*

Geomyza annae (MARTINEK, 1978)

Boh. Centr.: Praha-Holešovice, river bank (200 m), 9. 8. 1984 1 M*; Praha-Šárka valley, damp meadow (300 m), 12. 9. 1985 1 M*; Pečky near Kolín, near a brook (200 m), 14. 6. 1985 1 M* (all Bart. leg., Mart. det. et coll.).

The second find of this species in Central Bohemia. It obviously occurs sporadically in the warmest lowland area in drying meadows. The first find of the species is from Lysá nad Labem from the grass cover of a steppe character on the railway embankment (MARTINEK 1978b). Warm-loving, obviously southern species.

Geomyza hendeli (CZERNY, 1928)

Boh. Occ. Sept.: Bílina-Holibka, near a pond (390 m), YPT, 8.–9. 8. 1998 1 F*; Bílina-Chloumek, hilltop steppe (480 m), MT, 13.–28. 5. 1998 1 F*; the same locality, MT, 24. 8.–23. 9. 1998 1 F*; (all. Bart. leg., Mart. det. et coll.). Chomutov – Černovický potok stream, 28. 5. 1998 1 F* (all Bart. leg. et coll., Mart. det.).

Further findings of this xerotherm species in Bohemia.

Geomyza virgata (CZERNY, 1928)

Boh. Occ. Sept.: Bílina-Lom, small pond (260 m), MT, 24. 8.–23. 9. 1998 1 M*; Bílina-Holibka, near a pond (390 m), YPT, 8.–9. 8. 1998 1 M* (all Bart. leg., Mart. det. et coll.).

The second find of this rarely occurring species in Bohemia. The first one was announced from Železná Ruda in the Šumava Mts. (cf. CZERNY 1928). This species is characteristic mainly by the 1 + 2 dc and the third segment of antennae being white coloured. Obviously warmloving and xerotherm species.

SPECIES USUALLY CONSIDERED AS EXCLUSIVELY TROGLOBIONTS, BUT IN REALITY OCCASIONALLY FLYING ALSO IN THE OPEN NATURE

Some species of the family *Heleomyzidae* were practically caught only at the adult stage on walls of caves, abandoned mining galleries, underground galleries, in burrows of rodents, etc. In recent years when modern collecting techniques are used (Malaise traps, yellow pan traps, etc.), it is clear that the species also live in the open nature, occurring there prevailingly rather in early spring and in late autumn (i.e. before and after wintering in underground covertures). All the species appear to be very cold-loving. It mainly applies to the following species:

Scoliocentra (s. str.) *amplicornis* (CZERNY, 1924)

Boh. Mer.: Šumava Mts., Horská Kvilda, damp meadow (1,000 m), 28. 6. 1992 1 F*; Jezerní peat bog (1,000 m), YPT, 2.–18. 6. 1995 1 M*; Malá niva peat bog (780 m), 21. 5. 1992 1 F* (all Bart. leg. et coll., Mart. det.); Mutná near Slavonice, 14. 4. 1994 1 M* (Máca leg. et coll., Mart. det.); Boh. Occ. Sept.: Bílina-Štěpánov, mixed wood near a brook (380 m), MT, 13.–28. 5. 1998 1 M*; Bílina-Chloumek, hilltop steppe (480 m), MT, 15.–25. 6. 1998 1 F*; Bílina-Lom, near a pond (270 m), MT, 30. 4.–14. 5. 1998 1 F* (all Bart. leg. et coll., Mart. det.); Ostrov env. Tisá near Děčín, MT, 29. 4. 1994 1 F*; Děčínský Sněžník (Letadlo) near Děčín, MT, 2. 5. 1997 1 F*, Kristin Hrádek near Děčín, ET, 17. 6. 1989 1 M* (all Kula leg., Mart. det. et coll.); Krušné hory Mts., Nové Město near Moldava (800 m), 20. 7. 1977 1 M* (Mart. leg., det. et coll.); Boh. Occ.: Blatno near Žlutice, 14. 7. 1967 1 M* (Mart. leg. et coll., Gorodkov det.); Boh. Centr.: Kunice near Říčany (430 m), MT, 11. 5. 1986 1 F*; Čelákovice near Lysá nad Labem, lowland wood (180 m), 14. 5. 1991 1 F* (all Bart. leg., Mart. det. et coll.); Žehuňská game

preserve near Chlumec nad Cidlinou, 5. 6. 1972 1 M* (Mart. leg. et coll., Gorodkov det.); Boh. Or. Sept.: Orlické hory Mts., Pěčín, 30. 5. 1981 1 F* (Moc. leg., Woźn. det. Mart. coll.); Dobrošov near Náchod, 30. 4. 1986 1 M*; Běstviny near Dobruška, Halín forest (290 m), 29. 6. 1965 1 F* (all Mart. leg., det. et coll.).

Clearly a troglophilous, not troglobiont, species.

Scoliocentra (*Gymnomus*) *caesia* (MEIGEN, 1830)

Boh. Mer.: Šumava Mts., Rakouská meadow (1,300 m), MT, 26. 6. 1989 2 M*; Trojmezná Mt. (1,350 m), MT, 3. 11. 1988 1 F* (Pavlíčko leg., Mart. det., Bart. coll.); Boh. Occ. Sept.: Bílina-Vršíček, mixed wood (410–440 m), MT, 24. 5.–1. 6. 1996 1 F*, 2. 4.–14. 5. 1998 1 M* 1 F*; 28. 5.–25. 6. 1998 1 F*; Bílina-Lom, small pond (270 m), MT, 13.–28. 5. 1998 1 M*, Bílina-Chloumek, hilltop steppe (480 m), MT, 13.–28. 5. 1998 1 M* (all Bart. leg. et coll., Mart. det.). Slovakia Sept.: Vysoké Tatry Mts., Trojhranné pleso (1,600 m), 12. 9. 1967 1 M* (Lauterer leg., Mart. det., see MARTINEK 1977b).

Clearly a troglophilous, not troglobiont, species.

Scoliocentra (s. str.) *dupliciseta* (STROBL, 1894)

Boh. Mer.: Šumava Mts., Nová Hůrka, on *Glyceria* (850 m), 18. 8. 1994 1 F* (Bart. leg. et coll., Mart. det.); Lutová near Třeboň, 5. 1987 1 M* (? leg., Mart. det.); Boh. Occ. Sept.: Bílina – poplar wood, sect. 2, YRT, 7.–15. 5. 1995 1 F*; Bílina-Vršíček, mixed wood (440 m), MT, 30. 4.–13. 5. 1998 1 F*; Duchcov, 4 km E, edge of oak wood (260 m), MT, 29. 4.–7. 5. 1996 1 M* (all Bart. leg. et coll., Mart. det.); Krušné hory Mts., Nové Město near Moldava, 12. 5. 1964 1 F*; 30. 7. 1970 1 F* (all Mart. leg. et coll., Gorodkov det.); Boh. Or. Sept.: Krkonoše Mts., Luční bouda, 13. 5. 1964 1 M*; 3. 7. 1967 1 F* (Mart. leg. et coll., Gorodkov det.), Chroustovice (res.) near Vysoké Mýto, steppe (250 m), 4. 5. 1989 1 F* (Bart. leg., Woź. det., Mart. coll.). Slovakia Sept.: Vysoké Tatry Mts., Štrbské pleso, meadow (1,250 m), 20. 10. 1985 1 F* (Bart. leg. et coll., Mart. det.).

This species mostly dwelling in the caves often flies also in the open air, so the species is troglophilous. The same applies to *Scoliocentra scutellaris* (ZETTERSTEDT) (see above).

Scoliocentra (*Gymnomus*) *czernyi* (PAPP et WOŹNICA, 1993)

Boh. Mer.: Šumava Mts., Trojmezná (1,350 m), MT, 3. 11. 1988 1 M* (Pavlíčko leg., Papp et Woź. det. (paratype), Mart. coll.); Boh. Centr.: Praha-Strahov, ET, 5.–11. 3. 1975 1 M* (Mart. leg. et coll., Papp et Woź. det.).

In fact, this cave species is also only troglophilous, not troglobiont.

Scoliocentra (*Gymnomus*) *europaea* (PAPP et WOŹNICA, 1993)

Boh. Centr.: Kopeč reserve near Neratovice, ET, steppe, 25. 4. 1973 3 F* (Mart. det. et coll.) – det. *S. ventricosa* (BECKER) (cf. MARTINEK 1976b); Ralsko near

Mimoň, mixed forest (650 m), 2. 7. 1962 1 M* (Mart. leg. et coll. – det. *S. ventricosa* (BECKER) (cf. MARTINEK 1974).

Clearly a troglophilous species.

Scoliocentra (Gymnomus) sabroskyi (GILL, 1962)

Boh. Or. Sept.: Orlické hory Mts., Pěčín, 20. 4. 1981 1 F* (Moc. leg., Woź. det., Mart. coll.).

Also this Holarctic cave species is actually only a troglophilous species, not a troglobiont.

Scoliocentra (Gymnomus) spectabilis (LOEW, 1862)

Boh. Centr.: Slapy near Štěchovice, MT (340 m), 10. 11. 1987 1 F* (Bart. leg. et coll., Mart. det.). Mor. Mer.: Znojmo, 4. 6. 1967 1 M* (T. Gregor leg. et coll., Mart. det.). Mor. Sept.: Žimrovice near Hradec near Opava, sweeping the undergrowth of deciduous forest, 16. 10. 1990 1 M* (Roh. leg., Mart. det., Woź. coll.); Opava, 17. 5. 1936 1 M* (Palásek leg., Gorodkov det., Mart. coll.). Slovakia Mer.: Hegy Farok, steppe (220 m), 16. 10. 1986 1 M* (Bart. leg., Woź. det. et coll.).

The listed finds show that this species known hitherto from the territory of Moravia and Slovakia only from caves, etc., occurs in the open landscape not only late in the autumn (October to November) but also early in the spring (May to June). So it is troglophilous, not a troglobiont.

Scoliocentra (s. str.) villosa (MEIGEN, 1830)

Boh. Mer.: Šumava Mts., Jezerní peat bog, MT, 5. 7.–5. 8. 1996 1 F*; Boh. Occ. Sept.: Bílina-Vršíček, mixed wood (440 m), MT, 2. 4.–14. 5. 1998 1 M* 1 F*; 30. 4.–13. 5. 1998 1 F*; 13.–28. 5. 1998 1 F*; 28. 5.–25. 6. 1998 1 M* 1 F*; Bílina-Štěpánov, edge of mixed wood (380 m), MT, 25. 6.–24. 7. 1998 1 M* (all Bart. leg. et coll., Mart. det.).

Also this cave species is in fact only troglophilous, not purely a troglobiont.

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Nové nebo vzácné druhy dvoukřídlého hmyzu (*Diptera*-Acalyptrata), zjištěné v lesích České a Slovenské republiky

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ABSTRAKT: Autor konstatoval v období let 1984–2000 na území ČR, případně i SR přítomnost některých dalších druhů skupiny *Diptera*-Acalyptrata, jejichž existence zde buď nebyla dosud zaznamenána, nebo jde o druhy všeobecně řídké až vzácné, dříve zde zachycené pouze sporadicky. Novými (tj. prvními) nálezy pro území Čech jsou *Suillia variegata* (LOEW) (čel. *Heleomyzidae*), *Sapromyza gozmanyi* PAPP a *Eusapromyza balioptera* CZERNY (čel. *Lauxaniidae*), *Loxocera* (*Platystyla*) *hoffmannseggi* MEIGEN a *Chamaepsila villosula* MEIGEN (čel. *Psilidae*), *Herina germinationis* (ROSSI), *H. paludum* (FALLÉN) a *Cephalia rufipes* MEIGEN (čel. *Otitidae*). Novým druhem pro území Moravy je dále druh *Suillia variegata* (LOEW) (čel. *Heleomyzidae*) a pro území celé ČR pak druh *Homoneura christophi* (BECKER) (čel. *Lauxaniidae*). Pro území SR je novým nově popsaný druh *Otites gradualis* CARLES-TOLRÁ, 1998 (čel. *Otitidae*), který byl uloven v okolí lokality Modrý Kameň, tj. na nejteplejším území Slovenska. Z druhů vzácných jsou svým druhým nálezem v Čechách potvrzeny např. dva druhy čeledi *Lauxaniidae* (*Calliopum geniculatum* [FABR.] a *Homoneura tesquae* [BECK.]), druh *Tephrochlaena halterata* (MEIG.) z čeledi *Heleomyzidae* a tři druhy (*Geomyza hendeli* CZERNY, *G. virgata* CZERNY a *G. annae* MARTINEK) z čeledi *Opomyzidae*. Dva druhy z čeledi *Heleomyzidae* (*Scoliocentra scutellaris* [ZETT.] a *Eccoptomera infuscata* WAHLGR.) se vzácně vyskytují jak v Čechách, tak i na Slovensku. Vedle uváděných nových a vzácných nálezů zjistil autor na území ČR a SR i jedince některých druhů, obvykle považovaných za úzce kavernikolní, či dokonce za troglobionty (např. *Scoliocentra spectabilis* [LOEW], *Sc. villosa* [MEIGEN], *Sc. scutellaris* [ZETT.], *Sc. czernyi* [PAPP et WOŹNICA], *Sc. sabroskyi* [GILL] atp.). Autor dokumentuje, že tyto druhy jsou vesměs troglophilní, neboť vedle svého pobytu v jeskyních, norách apod. poletují po delší časové údobí i ve volné přírodě.

Klíčová slova: dvoukřídlý hmyz (*Diptera*); *Heleomyzidae, Lauxaniidae, Otitidae, Psilidae*; faunistika; Česká republika; Slovenská republika; nové nálezy

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