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Genetic variation of European silver fir (*Abies alba* MILL.) in the Western Carpathians

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ABSTRACT: Genetic structure of 26 populations of silver fir from the Western Carpathians and 4 reference populations from Moravia (Bohemian Quadrangle) was studied by means of isozyme gene markers. Polymorphisms of 18 isozyme gene loci were surveyed. Allele frequencies at 5 loci – *Idh-B, 6Pgd-A, Per-A, Lap-A, Aco* – revealed geographic clines in the East-West direction. Another 4 genes (*Aco-A*$_4$, *Got-A*$_1$, *Got-B*$_1$ and *Dia-A*$_1$) appeared to be area-specific. The Western-Carpathian populations showed average heterozygosity (H_o) of 0.101–0.110, expected heterozygosity (H_e) 0.104–0.120, and effective number of alleles per locus (υ) 0.122–0.137. The corresponding parameters were somewhat lower in Moravia ($H_o = 0.097$, $H_e = 0.099$, $\upsilon = 1.108$). Geographic distribution of genetic parameters in the studied populations can be explained by different Postglacial phylogeny of silver fir in the Western Carpathians and Bohemian Quadrangle, and by adaptation to specific site and climatic conditions.

Keywords: European silver fir; isozyme gene markers; genetic variation; delineation of seed zones

Especially in relation to the long-term dieback, the European silver fir belongs to the most intensively studied forest tree species of Central Europe. Its dieback is interesting also from the point of view of the populations genetics. Following LARSEN (1986) the basic reason for the decline of silver fir is its insufficient genetic diversity in Central Europe, resulting in the reduced adaptability compared to other forest tree species. Its genetic variation was likely reduced during complicated Postglacial migration from refuges in the Apennine and Balkan peninsulas. Many eco-physiological studies aimed at the variation in the tolerance to frost, raised concentrations of SO_2, needle senescence, intensity of assimilation (LARSEN 1986; LARSEN et al. 1988; LARSEN, MEKIĆ 1991) support this hypothesis. The same applies to the studies aimed at the phenotypic (e.g. MEKIĆ, DOHRENBUSCH 1995; SVOLBA 1995; AAS et al. 1994), biochemical (WOLF 1992; LANG 1994) and isozyme variation. They all reveal reduced genetic variability of the Central-European populations of silver fir affected by the dieback, which is contrasting to the high genetic diversity of the same species in the southwestern, southern and southeastern parts of its natural range. Especially the isozyme studies of BERGMANN and KOWNATZKI (1988) and BERGMANN et al. (1990) documented close relationships between the genetic diversity and adaptability of silver fir, and supported LARSEN's hypothesis on the genetic background of its dieback. In the most comprehensive study of KONNERT and BERGMANN (1995), 54 population samples of silver fir from almost all of the natural range were analyzed. The area-specific genes allowed them to separate provenances with different phylogeny from the Pyrenees, Massif Central, Alps, Apennines and the Balkan Peninsula. The genetic structure of silver fir from the Bohemian Quadrangle and Western Carpathians appears to have a transitory position between the Eastern-Carpathian and Eastern-Alpine populations according to these authors.

In the regional studies of European silver fir in Germany, SCHROEDER (1989) revealed clinal variation in *Idh-B* and *6Pgd-A* in the southwest-northeast direction. The heterozygosity in *6Pgd-A* correlated with the altitude while in *Idh-B* with the growth rate of seedlings. KONNERT (1992) proved the phylogenetic fixation of regionally-specific alleles in *Dia-A* (syn. *Mnr-B*) that allowed to distinguish the provenances of silver fir from southwestern and southeastern Germany. The same author (1993) revealed a correlation between the level of defoliation and genotypes in *Got-C* and *Idh-B*. Particularly the allele *Got-C*$_3$ had a negative effect on the vitality of its carrier. LLAMAS GÓMEZ (1995) analyzed the remnant populations of fir in Saxony and concluded that they may represent the northwestern limit of the transition between the Eastern-Alpine and Carpathian Postglacial migration route. His results were applied to the delineation of seed zones and regional rules for the transfer of reproduction material. In a similar study of 11 seminatural populations of silver fir in Switzerland, HUSSENDÖRFER and MÜLLER-STARCK (1994) reported considerable genetic effects of different Postglacial migration routes. Their information was used in the designing of the national network of gene pool forests. In Austria, BREITENBACH-DÖRFER et al. (1997) revealed significant East-West clines in the allele frequencies of *Idh-A,-B*, *Lap-A* and *6Pgd-A*. They ascribed them to the Postglacial migration of silver fir into the Alps via two different migration routes. But BERGMANN and GREGORIUS (1993) proved that the clinal variation patterns of *Id-B* in the North-South direction are directly related to different thermostability of isozymes encoded by different alleles in this locus.

The genetic variation of silver fir in the eastern part of its natural range was only fragmentarily documented by the mid-1990's. The studies of BERGMANN et al. (1990) and KONNERT and BERGMANN (1995) included only 10 population samples including 25–60 trees each. The isozyme variation of silver fir in Slovakia was studied by KORMUŤÁK et al. (1982) and MATÚŠOVÁ (1995), and in Poland by MEJNARTOWICZ (1996). The genetic structure of 6 Romanian populations was analyzed using monoterpene and isozyme markers by LUCĂU-DĂNILĂ (1995). She found clear differentiation between the Romanian silver fir and reference populations from France.

The objective of this paper is to analyse the isozyme variation and genetic structure of European silver fir in the Western Carpathians. It is a part of a study aimed at the analysis of genetic variation of European silver fir based on isozyme gene markers and evaluation of provenance experiments. Its outputs will be applied to the management of genetic resources of the studied species.

MATERIAL AND METHODS

The analysis covers 26 populations of European silver fir from the Western Carpathians and 4 reference populations from the eastern part of the Bohemian Quadrangle. These populations belong to 6 geographic groups. The Western Beskids are represented by 5 populations, Northern Slovakia (the Tatras) by 5, Eastern Beskids by 10, Central Slovakia by 6, Eastern-Central Slovakia by 3 and Moravia by 4 populations (Fig. 1). Semi-natural (26) or natural (4) populations were analyzed.

The mean population sample included 50 randomly chosen trees, growing at a minimum distance of 30 meters from each other. Branchlets with dormant buds (8–12 buds per tree) were collected for laboratory analyses.

Table 1. Enzyme systems and gene loci surveyed

Enzyme system	E.C. code	Loci surveyed
Aconitase	1.1.1.1	*Aco*
Glutamate dehydrogenase	1.4.1.3	*Gdh*
Glutamate-oxalacetate transaminase	2.6.1.1	*Got-A,-B,-C*
Isocitrate dehydrogenase	1.1.1.42	*Idh-B*
Leucine aminopeptidase	3.4.11.1	*Lap-A (Aap-A)*
Malate dehydrogenase	1.1.1.37	*Mdh-A*
Menadion reductase	1.6.99.2	*Mnr-B*
NADH-dehydrogenase	1.6.99.2	*Ndh-A*
Peroxidase	1.11.1.7	*Per-B,-C*
Phosphoglucoso-isomerase	5.3.1.9	*Pgi-A,-B*
6-Phosphogluconate dehydrogenase	1.1.1.44	*6Pgd-A,-B*
Shikimate dehydrogenase	1.1.1.25	*Skd-A,-B*

Genetic structure and differentiation was studied in 18 enzyme loci (Table 1). The genetic control (codominant inheritance and stability of expression) of the isozymes in *Aap-A, -B, -C -D, Dia-A (= Mnr-A), Got-A,-B, -C, Idh-A,-B, Mdh-A, -C, 6Pgd-A,-B, Ndh-A* (= *Mnr-B*), *Pgi-A,-B, Pgm-A,-B* and *Skd-A* was verified by HUSSENDÖRFER et al. (1995). The interpretation of isozymes in *Skd-B* was described by VICARIO et al. (1995), and in *Per-B* and *-C* by LUCĂU-DĂNILĂ (1995). The laboratory procedures were similar to CONCKLE et al. (1982) and KONNERT (1992).

The following genetic parameters of populations were computed from single-tree genotypes:

1. Allelic and genotypic frequencies.
2. Mean expected (H_e) and observed (H_o) heterozygosity, and genetic diversity (υ).
3. Genetic multiplicity depicted in the total number of alleles (*M*), proportion of polymorphic loci (*PP*), maximum genotypic multiplicity (G_M) and hypothetical gametic di-

Fig. 1. Geographic origin of studied populations

versity (υ_{gam}). G_M results as the product for all loci of the number of genotypes that can arise for a specified number of alleles (BERGMANN et al. 1990), while υ_{gam} equals the product of single locus genetic diversities (υ) and measures the diversity that would result from the given allelic frequencies under a linkage equilibrium at each locus (GREGORIUS 1978).

The genetic differentiation was analysed by means of the pairwise homogeneity χ^2 tests of allelic and genotypic frequencies at $P > 95\%$, and Nei's (NEI 1978) genetic distances. Correlations between the geographic position and allele frequency in populations were tested using the SPEARMAN's non-parametric test at $P > 95\%$.

The allele frequencies, genotype frequencies and genetic distances were computed using the PC programme BIOSYS-1 (SWOFFORD, SELANDER 1981). The Principal Coordinates Analysis (GOWER 1966) using the PC programme SYN-TAX III (PODANI 1988) was employed for interpretation of the matrices of genetic distances.

RESULTS

The genetic multiplicity depicted in the total number of alleles across all 18 loci, proportion of polymorphic loci and genotypic multiplicity (G_M) are very similar across the provenance regions (Table 2). The Western Beskids with higher gametic diversity values seem to be the only exception.

Table 2. Genetic multiplicity of silver fir characterised by the total number of alleles (*M*), proportion of polymorphic loci (*PP*) and hypothetic genetic multiplicity (G_M)

	Moravia	W. Beskids and Tatras	Central Slovakia	Eastern Beskids	Eastern Carpathians
M	37	37	36	36	38
PP	77.8	77.8	77.8	77.8	88.9
G_M	255×10^6	510×10^6	170×10^6	102×10^6	306×10^6

AREA-SPECIFIC POLYMORPHISMS

For the evaluation of area-specific genes, which reflect the phylogenetic relationships of regional populations with much higher probability than the frequencies of common, functionally important genes (KONNERT, BERGMANN 1995), the populations were pooled on the geographical basis. This enabled to achieve sample sizes that would guarantee with 95% reliability conclusions about the presence or absence of area-specific genes with frequency lower than 0.5–0.8%. Fig. 2 provides a review of geographic distribution of such area-specific alleles, including information about the Eastern Carpathians adopted from LONGAUER (1996). The populations from Western Beskids and Central Slovakia differ from Eastern-Beskids

Provenance region	α (P ≥ 95%)	*Aco-A*$_4$	*Got-A*$_3$	*Got-B*$_1$	*Dia-A*$_1$	*Nadh-A*$_3$
Moravia	1.2%	■			▧	■
Western Beskids + Tatras	< 0.8%		▧		▧	■
Central + Central-Eastern Slovakia	< 0.8%	▧	▧		▧	■
Eastern Beskids	< 0.8%			▧		▧
Romanian Eastern Carpathians	< 0.8%			▧	▧	

Fig. 2. Distribution of area-specific alleles. Symbol ■ indicates the frequency of area-specific alleles above and ▧ below 0.5%, α is a frequency at which the presence or absence of an area-specific allele can be confirmed with 95% probability

in 3 area-specific alleles: *Aco-A*$_4$, *Got-A*$_1$, *Got-B*$_3$. Another allele, *Dia-A*$_l$, is typical of all populations except of those from the Eastern Beskids (LONGAUER 1996).

GENETIC DIVERSITY AND DIFFERENTIATION

The allele frequencies in populations grouped according to the geographic regions are presented in Table 3. The correlations ($P > 95\%$) between allele frequencies and geographic position of a population were detected in 5 loci: *Aco*, *Idh-B*, *Aap-A*, *Px-B* and *6Pgd-A* (Fig. 3).

The paired χ^2-tests revealed 21 heterogeneities of allelic and genotypic frequencies in the Western Carpathians. In the loci, the allele frequencies were heterogeneous 4-times in *Got-C*, 3-times in *Px-B* and *Idh-B*, and once in *6Pgd-A*. The number of heterozygous individuals differed 5-times in *Got-C*, 3-times in *Px-B* and twice in *Aco*. The deviations from Hardy-Weinberg equilibrium were detected in 10 cases. They concentrate to those loci where the correlation was detected between the allelic frequencies and geographic position of a population. Between the provenance regions, 12 differences were between the northern (Western Beskids, Tatras, Eastern Beskids) and southern (Central and Central-Eastern Slovakia) part of the natural range of silver fir in the Western Carpathians. A surprisingly high number of differences in allelic frequencies (6) was found between the Central and Central-Eastern Slovakia, which are merged into the same seed zone according to valid legislation for the forest reproductive material. Deviations from Hardy-Weinberg equilibrium concentrate in the northern part of Western Carpathians (Western Beskids, Tatras, Eastern Beskids).

Most of the characteristics of genetic variability reveal the West-East clines with the minimum in Moravia and maximum in the Eastern Beskids (Table 4). The populations from Central Slovakia revealed somewhat reduced heterozygosity and genetic diversity.

Nei's genetic distances between the groups of regional populations (Table 5 and Fig. 4) correspond well with the geographic clines in the allelic frequencies and genetic diversity. The populations from Moravia differed clearly from the Carpathian populations.

Table 3. Allelic frequencies in populations grouped according to their geographic origin

Locus		Moravia	Western Beskids	Tatras	Eastern Beskids	Central Slovakia	Central-Eastern Slovakia
Sample size		222	182	256	461	252	140
PER-A	*1*	0.995	0.997	0.998	0.999	0.982	0.996
	2	0.005	0.003	0.002	0.001	0.018	0.004
PER-B	*1*	0.016	0.088	0.115	0.111	0.052	0.096
	2	0.984	0.912	0.885	0.889	0.948	0.904
ACO	*1*	0.066	0.042	0.040	0.026	0.034	0.007
	2	0.070	0.084	0.107	0.131	0.093	0.082
	3	0.859	0.874	0.854	0.843	0.873	0.907
	4	0.005	0.000	0.000	0.000	0.000	0.004
LAP-A	*1*	0.016	0.031	0.041	0.056	0.018	0.018
	2	0.948	0.944	0.947	0.926	0.932	0.964
	3	0.036	0.025	0.012	0.019	0.050	0.018
6PGD-A	*1*	0.438	0.394	0.424	0.345	0.427	0.339
	2	0.562	0.606	0.576	0.655	0.573	0.661
6PGD-B	*1*	0.982	0.967	0.975	0.958	0.974	0.986
	2	0.014	0.027	0.021	0.035	0.026	0.014
IDH-B	*1*	0.261	0.500	0.471	0.487	0.429	0.454
	2	0.739	0.500	0.529	0.513	0.571	0.546
GOT-A	*1*	0.007	0.008	0.006	0.008	0.006	0.004
	2	0.993	0.992	0.992	0.992	0.994	0.996
	3	0.000	0.000	0.002	0.000	0.000	0.000
GOT-B	*1*	0.000	0.000	0.000	0.001	0.000	0.000
	2	0.961	0.984	0.982	0.970	0.994	0.996
	3	0.039	0.016	0.018	0.029	0.006	0.004
GOT-C	*1*	0.108	0.103	0.151	0.190	0.080	0.143
	2	0.835	0.830	0.791	0.762	0.878	0.829
	3	0.057	0.067	0.058	0.048	0.042	0.029
MDH-A	*1*	0.007	0.000	0.016	0.005	0.016	0.011
	2	0.986	0.981	0.973	0.978	0.966	0.964
	3	0.007	0.019	0.012	0.016	0.018	0.025
GDH	*1*	0.005	0.011	0.010	0.009	0.012	0.007
	2	0.995	0.989	0.990	0.991	0.988	0.993
DIA-A	*1*	0.002	0.000	0.004	0.000	0.002	0.000
	2	0.998	1.000	0.996	1.000	0.998	1.000
NDH-A	*1*	0.989	0.986	0.990	0.998	0.994	0.996
	2	0.011	0.014	0.010	0.002	0.006	0.004
PGI-A	*1*	1.000	1.000	1.000	1.000	1.000	1.000
PGI-B	*1*	1.000	1.000	1.000	1.000	1.000	1.000
SKD-A	*1*	1.000	1.000	1.000	1.000	1.000	1.000
SKD-B	*1*	1.000	1.000	1.000	1.000	1.000	1.000

DISCUSSION

GENETIC DIVERSITY AND PHYLOGENESIS OF SILVER FIR

Information about Postglacial dissemination of silver fir in the Western Carpathians and Bohemian Quadrangle comes from several paleobotanic studies. SZAFER (1959) provides information about 150 pollen profiles from Poland and Western Ukraine. KRIPPEL (1986) reviewed 47 pollen profiles and findings of macro-remnants in Slovakia. SAMEK (1967) and OPRAVIL (1976) documented the Postglacial history of silver fir in the Czech Republic.

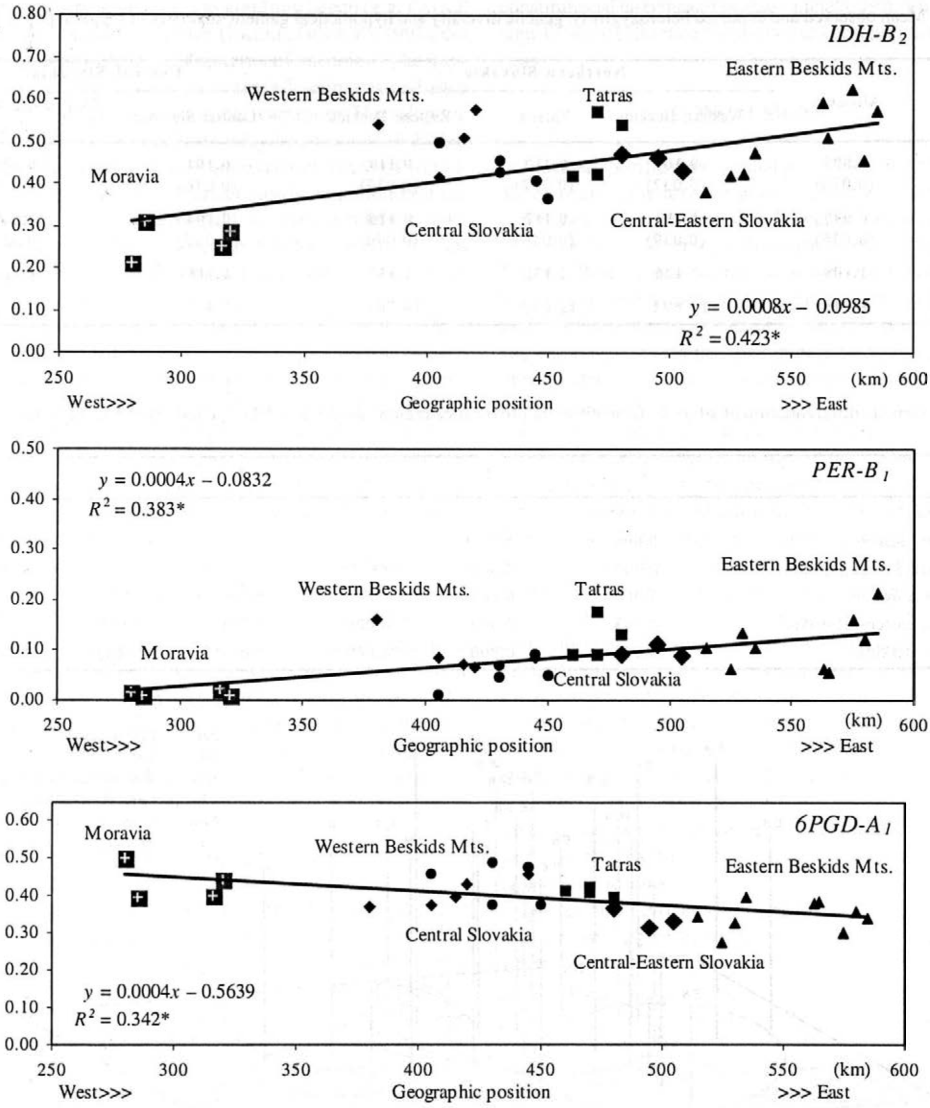

Fig. 3. Correlations between allelic frequencies in *Idh-B*, *Per-B* and *6Pgd-A*, and geographic position of populations from the northernmost point of the natural range of silver fir (* – correlation coefficients statistically significant at $P > 95\%$)

KRIPPEL (1986) dates the first Postglacial presence of this species in the Western Carpathians to Preboreal. It is evident from the continuous presence of 3–8% of fir pollen in the Hypkaňa bog, the Vihorlat Mts., in Eastern Slovakia. This conclusion is in agreement with the Polish studies (ŚRODOŃ 1983) which indicate 3–5% of fir pollen in the southeast Poland in the first half of Boreal. The inner part of the Western Carpathians was re-colonised by silver fir in two streams. The Northern one is documented by high concentrations of its pollen in the Spiš basin eastwards of the High Tatras. In the South, fir pollen exceeded 10% at 3 localities in southern Slovakia. At the beginning of Atlanticum, its pollen was present in almost all spectra analysed in the Western Carpathians with the highest concentrations in the Inner-Carpathian basins (Spiš, Liptov, Orava), South-Slovakian basins, and in the Danube lowlands.

The succession of findings of fir pollen in the Bohemian Quadrangle and the Western Carpathians suggests a junction of its Western-Carpathian and Eastern-Alpine

Table 4. Mean observed and expected heterozygosity, genetic diversity and hypothetical gametic diversity of regional populations

	Moravia	Northern Slovakia			Central Slovakia	
		Western Beskids	Tatras	Eastern Beskids	Central Slovakia	Central-Eastern Slovakia
H_o	**0.099** (0.036)	**0.107** (0.037)	**0.110** (0.037)	**0.110** (0.037)	**0.101** (0.036)	**0.108** (0.039)
H_e	**0.097** (0.036)	**0.110** (0.039)	**0.117** (0.040)	**0.120** (0.040)	**0.104** (0.037)	**0.109** (0.038)
υ	**1.108**	**1.126**	**1.133**	**1.137**	**1.115**	**1.122**
υ_{gam}	8.546	11.692	12.619	14.701	11.431	11.222

Table 5. Genetic differentiation of silver fir from different provenance regions depicted in Nei's genetic distances at 18 loci

Region	1	2	3	4	5	6
1 Moravia	*****					
2 Western Beskids	0.004	*****				
3 Northern Slovakia (Tatras)	0.003	0.000	*****			
4 Central Slovakia	0.002	0.000	0.001	*****		
5 Central-Eastern Slovakia	0.003	0.000	0.000	0.001	*****	
6 Eastern Beskids	0.005	0.000	0.000	0.000	0.002	*****

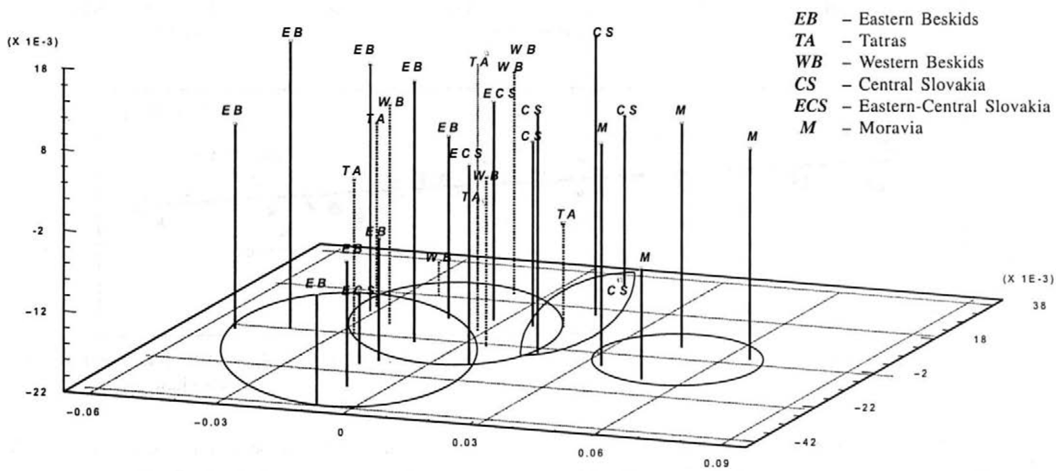

Fig. 4. Genetic differentiation of individual populations of silver fir. Principal Coordinates Analysis is based on Nei's unbiased estimates of genetic distance. Its first 3 axes display 85% of all differences revealed

migration routes in Northern Moravia in Subboreal (SAMEK 1967; KRIPPEL 1986). The Carpathian migration route may have progressed further northwards into the Hercynic system, however (LLAMAS GÓMEZ 1995; KONNERT, BERGMANN 1995).

The area-specific genes, statistically significant differences in allele frequencies, correlations between the geographic position and allele frequency, and differences in the total genetic variation are present especially in the East-West direction. But several significant paired differences were revealed also between populations from the Northern and Central Slovakia.

The correlation between geographic position in the West-East direction and allele frequencies was detected in 5 out of 18 surveyed loci: *Aco*, *Idh-B*, *Aap-A*, *Px-B* and *6PGD-A*. The analyses of other major tree species of the

Western Carpathians, such as common beech (e.g. PAULE et al. 1995) or Norway spruce (PAULE, GÖMÖRY 1993), did not reveal any analogical patterns of variation. The phylogeny but also adaptation to specific climates and sites may have contributed to clinal variation. The adaptive polymorphisms of isocitrate dehydrogenase (*Idh-B*) under different temperature regimes (BERGMANN, GREGORIUS 1993), *Got-B* and *-C* under mostly air pollution stress (KONNERT 1993), and peroxidase (*Per*) in relation to the water regime (SHEA 1989) and growth form in extreme sites (GRANT, MITTON 1977) were documented in silver fir or other *Abies* species.

A hypothesis about dissemination of fir into the Western Carpathians from East via two migration routes from East and South-East is supported by several area-specific alleles. *Aco-A4* and *GOT-A3* seem to be typical of the central and northwestern part of Slovakia. *Dia-A1* is present in the Northwest, North and Northeast of Slovakia but absent in the more southerly Western and Central Slovakia. *Got-B1* is present only in the populations from Northeastern Slovakia.

There are several area-specific genes shared by the populations from Moravia (Eastern-Hercynic Mts.), Western-Beskids and Central Slovakia. This fact indicates a broad introgression between the Western-Carpathian and Eastern-Alpine Postglacial migration routes of silver fir. This introgression may also have contributed to the high genetic multiplicity of populations from the Western Beskids. Higher values of corresponding parameters can be found only in the Eastern Carpathian populations from Romania (LONGAUER 1996).

PRACTICAL IMPLICATIONS

Numerous paired differences in the allele and genotype frequencies (21) were detected between the regional populations of silver fir in the Western-Carpathians. Their highest number (12) was found between the Northern (Western Beskids, Tatras and Eastern Beskids) and Central Slovakia (Central and Central-Eastern Slovakia). Only 3 differences were detected within the group of 3 provenance regions representing Northern Slovakia. Contrary to it, 6 such differences were detected between 2 regions representing Central Slovakia. The Central and Central-Eastern Slovakia are included in one seed zone (Slovak Ore Mts.) without any limitation for the transfer of forest reproductive material, however.

It could be mentioned in relation to the value of presented results that significant and systematic differences revealed in a small number of marker genes indicate a chain of further differences in individual genomes and genetic structure of populations. In our case, variation in 18 non-linked isozyme gene loci was surveyed. In spite of their negligible number compared with the total genome of forest trees including 100–150 thousand loci, they revealed clear patterns of clinal geographic variation and area-specific polymorphisms. The second fact to be considered is that the surveyed isozyme loci belong to the group of constitutional enzymes of primary metabolism, which may significantly influence the individual and population fitness.

CONCLUSIONS

The area-specific genes, clinal geographic variation and differences in the level of genetic diversity confirm the correctness of currently valid delineation of seed zones in the west-east direction in the northern part of Slovakia: Western Beskids-Sub-Tatras (northwestern Slovakia) >> Tatras (northern Slovakia) >> Eastern Carpathians. The information obtained by means of isozyme gene markers and the results of provenance experiments suggest that the boundaries of 2 seed zones in Central Slovakia should be reconsidered:

1. A new, Central-Slovakian Seed Zone should be delineated southwards of the main ridge of the Veľká Fatra and Low Tatras Mts. The rest of the current Western-Slovakian Zone should be merged with the Western Beskids-Sub-Tatras Zone. Differentiation of populations from Northern and Central Slovakia was confirmed by 12 of 21 detected paired genetic differences between the studied regional populations of silver fir (Fig. 1). Suggested delineation of seed zones will allow to separate phylogenetically different populations originating in the Northeastern and Southeastern Postglacial migration routes of silver fir into the Western Carpathians.

2. Eastern part of the Slovak Ore Mountains could constitute a separate seed zone. The reason is that populations from Central Slovakia and Central-Eastern Slovakia revealed apparently more genetic differences than the group 3 northerly provenance regions covering much larger geographic area.

The results of provenance experiments with local silver suggest almost identical conclusions (LONGAUER et al. 1998).

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Genetická variabilita jedle bielej (*Abies alba* MILL.) v Západných Karpatoch

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ABSTRAKT: Analyzuje sa štruktúra genofondu jedle bielej zastúpenej 26 prirodzenými populáciami zo Západných Karpát a 4 referenčnými populáciami zo severozápadnej Moravy. Zo sledovaných 18 izoenzýmových lokusov sa až v piatich prípadoch (*Idh-B, 6Pgd-A, Per-A, Lap-A, Aco*) zistila štatisticky významná závislosť medzi alelickými frekvenciami a pôvodom populácie na transekte v smere západ – východ. Okrem toho boli nájdené štyri regionálne špecifické alely – $Aco\text{-}A_4$, $Got\text{-}A_1$, $Got\text{-}B_1$ a $Dia\text{-}A_1$. V Západných Karpatoch dosiahla priemerná heterozygotnosť (H_o) hodnoty 0,101–0,110, očakávaná heterozygotnosť (H_e) 0,104–0,120 a efektívny počet alel na lokus (υ) 0,122–0,137. V populáciách z Moravy bola úroveň genetickej variability nižšia ($H_o = 0{,}097$, $H_e = 0{,}099$, $\upsilon = 1{,}108$). Geografické trendy zistené pri jednotlivých genetických charakteristikách môžu súvisieť s migráciou jedle do Západných Karpát a Českého masívu z rôznych glaciálnych refúgií a tiež s adaptáciou jej populácií k rozdielnym stanovištným a najmä klimatickým podmienkam.

Kľúčové slová: jedľa biela; izoenzýmové genetické markéry; genetická variabilita; vylišovanie semenárskych oblastí

Kvôli svojmu dlhodobému ústupu a cyklicky gradujúcemu chradnutiu patrí jedľa biela medzi najsledovanejšie lesné dreviny. Platí to aj pre výskum genofondu. Po dlhom období dohadov a čiastkových vysvetlení totiž čoraz viac prác z tejto oblasti potvrdzuje hypotézu LARSENA (1986) o tom, že prvotnou príčinou chradnutia jedle je nedostatočná vnútropopulačná (genetická) variabilita. Jej dôsledkom je oslabenie celkovej adaptačnej schopnosti jedle v porovnaní s inými lesnými drevinami. Prejavy chradnutia jedle sa totiž obmedzujú na oblasť strednej Európy, kde k zníženiu jej genetickej variability prispelo komplikované poľadové šírenie z malých glaciálnych refúgií na Apeninskom a Balkánskom poloostrove. Nižšiu genetickú variabilitu stredoeurópskej jedle potvrdzujú práce zaoberajúce sa provenienčným výskumom – ekofyziologickou (mrazuvzdornosť, tolerancia k zvýšenej koncentrácii SO_2, životnosť ihličia, intenzita asimilácie – LARSEN 1986; LARSEN et al. 1988; LARSEN, MEKIĆ 1991), fenotypovou (napr. MEKIĆ, DOHRENBUSCH 1995; SVOLBA 1995; AAS et al. 1994) a biochemickou (WOLF 1992; LANG 1994) premenlivosťou. Na kontrastnú úroveň genetickej diverzity jedle z Nemecka v porovnaní s juhoeurópskymi populáciami, ktoré sa nachádzajú v oblasti bývalých glaciálnych refúgií, poukazujú aj analýzy genofondu, založené na izoenzýmových genetických markéroch (BERGMANN, KOWNATZKI 1988 a BERGMANN et al. 1990).

Cieľom prezentovanej práce je analyzovať genofond jedle bielej v Západných Karpatoch pomocou izoenzýmových genetických markérov tak, aby sa získané výsledky mohli využiť pri obhospodarovaní jej genofondu.

Experimentálny materiál tvoria vzorky 26 prirodzene obnovených populácií zo Západných Karpát a 4 referenčných populácií zo severnej Moravy. Z hľadiska geografickej príslušnosti boli karpatské populácie rozdelené do piatich provenienčných oblastí: Západné Beskydy (Kysuce, Orava) reprezentovalo 5 populácií, Tatry (Tatry a Podtatranská oblasť) 5 populácií, Stredné Slovensko 6, východnú časť Slovenského rudohoria 3 a Východné Beskydy (vrátane poľskej časti Východných Beskýd) 10 populácií. Populačnú vzorku tvorilo v priemere 50 dospelých jedincov.

V každom jedincovi sa analyzovalo 18 izoenzýmových génov. Z genotypov jednotlivých stromov sa pre populácie a provenienčné oblasti vypočítali nasledujúce genetické charakteristiky: podiel polymorfných lokusov, celkový počet alel (M), alelické a genotypové frekvencie, očakávaná (H_e) a pozorovaná (H_o) heterozygotnosť, genetická diverzita (υ) a genetické vzdialenosti medzi populáciami.

Pri hodnotení genetických parametrov sa zistili výrazné geografické trendy v smere západ – východ. Pri alelických frekvenciách to boli štatisticky významné korelácie medzi miestom pôvodu a frekvenciou alel v 5 zo 14 polymorfných lokusov (*Idh-B, 6Pgd-A, Per-A, Lap-A, Aco*). Podobne priemerná očakávaná a pozorovaná heterozygotnosť sa plynule zvyšuje od Moravy (H_e = 0,97, H_o = = 0,99) po Východné Beskydy (H_e = 0,120, H_o = 0,110). V analyzovaných lokusoch sa okrem toho zistili 4 regionálne špecifické alely: $Aco\text{-}A_4$, $Got\text{-}A_1$, $Got\text{-}B_1$ a $Dia\text{-}A_1$. Výskyt týchto alel od seba odlišuje najmä populácie z Moravy, Západných a Východných Beskýd.

Zistené geografické trendy v genetickej variabilite sú v súlade s poznatkami o fylogenéze jedle v poľadovom období (napr. KRIPPEL 1986). Kým do Českého masívu sa rozšírila tzv. Východoalpskou migračnou cestou, do Západných Karpát sa šírila od východu. Prítomnosť, resp. absencia regionálne špecifických alel medzi severnými a južnejšie položenými provenienčnými oblasťami Západných Karpát naznačujú, že jedľa sa do tohoto horského celku šírila dvoma prúdmi – severovýchodným a juhovýchodným. Prítomnosť regionálne špecifických génov typických pre Hercýnsku oblasť na severozápadnom a strednom Slovensku zas poukazuje na širokú introgresnú zónu medzi Východoalpským a Karpatským poľadovým migračným prúdom. Introgresia prispieva k o niečo vyššiemu celkovému počtu alel a k vysokej genetickej multiplicite jedle v Západných Beskydoch.

Okrem fylogenézy ku geografickým trendom nepochybne prispieva aj adaptácia k podmienkam prostredia, najmä zvyšujúcej sa kontinentalite klímy v západo-východnom smere. Uvedený fenomén môže byť dôležitý vo vzťahu k nastupujúcim klimatickým zmenám. V prípade lokusu *Idh-B* bol totiž vplyv teplotného režimu na katalytickú aktivitu izoenzýmov alel dokázaný aj experimentálne.

Vo vzťahu k legislatíve upravujúcej získavanie a využitie reprodukčného materiálu jedle na Slovensku výsledky prezentovanej práce potvrdzujú správnosť vylíšenia semenárskych oblastí v západo-východnom smere: Podtatransko-beskydská oblasť >> Tatry (TANAP) >> Východokarpatská oblasť. Na druhej strane poukazujú na potrebu úpravy hraníc semenárskych oblastí v južnej časti areálu dreviny. S poukázaním na to navrhujeme:

1. Vytvoriť Stredoslovenskú semenársku oblasť, do ktorej by spadalo prirodzené rozšírenie jedle na juh od hlavného hrebeňa Nízkych Tatier, Slovenské stredohorie a západná časť Slovenského rudohoria.

2. Severnú časť Západokarpatskej oblasti pripojiť k Podtatransko-beskydskej semenárskej oblasti. Tým sa oddelia populácie, ktoré majú pôvod v severovýchodnom a juhovýchodnom poľadovom migračnom prúde jedle. Okrem regionálne špecifických alel ich diferenciáciu potvrdili párové testy alelických a genotypových frekvencií. Až 12 z celkovo 21 zistených rozdielov boio medzi trojicou severnejšie a dvojicou južnejšie položených západokarpatských proveniečných oblastí.

3. Vyčleniť východnú časť Slovenského rudohoria ako samostatnú semenársku oblasť. Medzi touto oblasťou a stredným Slovenskom sa zistilo viac genetických rozdielov (6) ako medzi všetkými troma severnejšími provenienčnými oblasťami navzájom. Analogický výsledok poskytuje hodnotenie fenotypového prejavu jedle v provenienčných pokusoch (LONGAUER et al. 1998).

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The Boubín virgin forest after 24 years (1972–1996) – development of tree layer

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ABSTRACT: Repeated measurements of mensurational, typological and stand characteristics were made in the National Nature Reserve of Boubín virgin forest in 1996. The works followed after the research made in 1972 and were made according to the same methodology with the subsequent assessment of changes occurring in the region under study. The fir proportion substantially decreased, and the decrease was compensated by an increase in the beech share. The spruce maintained its dominant position in the virgin forest. The number of living trees slightly decreased while the stem volume of living trees increased. 30% of the virgin forest area is covered by continuous advance growth with dominant beech. Successful regeneration of fir and spruce accompanied by other interspersed species takes place at propitious locations without beech advance growth. It is to expect that the regeneration of silver fir population and spruce regeneration will be accomplished gradually. Further management of the reserve is proposed.

Keywords: dynamics; monitoring; virgin forest

Repeated measurements of mensurational, typological and stand characteristics were made in the National Nature Reserve (NNR) of Boubín virgin forest in 1996. The measurements covered the whole area of the virgin forest and the works were performed as a part of the long-term project *Research of dynamics of the development of virgin forest reserves in the Czech Republic*, solved by the department of forest ecology at the Brno Branch of the Agency for Nature Conservation and Landscape Protection of the Czech Republic (AOPK). The works link up with the detailed study made by Ing. Eduard Průša, CSc., in 1972 and attempt at covering the developmental changes in the region under study in order to derive from them general rules and regularities of development and to provide a qualified expertise for area management.

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As to the extent of the collected and processed data, the paper published in the Journal of Forest Science contains only the results of changes recorded in the tree layer of the Reserve.

HISTORY

The main colonization wave reached the Boubín area in the 17th century with the continuing colonization of the Šumava Mts. (Bohemian Forest). One of distinct accompanying phenomena of the colonization was the development of glass industry, which had a very unfavourable influence on the then original forests (virgin forests). Glassworks used to be allocated certain forest tracks; as soon as the tracks had been cut out, glassworks owners immediately asked for other allocations. When all forests within a reachable and convenient distance were cut out, the glasswork was closed down and a new one was built usually near a watercourse with good reserves of wind-broken timber. The timber consumption began to rise towards the end of the 17th and at the beginning of the 18th century when the glass industry in the Vimperk region became famous. This was the reason why the Vimperk

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forests – both manorial and those of the subjects – were described in a rather detailed way (NOŽIČKA 1958).

The original records from Boubín mention large spruce trees with the admixture of fir and beech but also sporadic large floodplains and clearcut areas. The neighbouring Pažení forest used to consist of large spruce and fir trees with interspersed pine. Spruce-fir-beech forests used to cover the mountains Bobík, Brdo and the surroundings of Strážný (NOŽIČKA 1958).

A particularly strong colonization wave reached the Vimperk region after the family of Schwarzenberg became its owners. New settlements were founded and the pressure on the local forests increased. The Boubín forests were heavily impacted and almost destroyed by a severe gale on 27 January 1724. In the year 1750, a hunting lodge was built in Zátoň not far from the today's virgin forest the main reason being the occurrence of numerous leks (strutting places) in the surrounding forests. In the year 1799, Josef Matz produced a well-arranged mensurational elaborate with the description of individual forests in the Vimperk region, including their age and the main tree species (spruce, fir, beech, alder and maple) (NOŽIČKA 1958).

The beginning of the 19th century threatened the Boubín virgin forest with its total liquidation on the occasion of the prepared timber floating from Boubín. However, the floating was not adviced by Ing. Schimouschek who was responsible for surveying the Boubín forests since there was not enough floatable timber (NOŽIČKA 1958).

An improved management of the Vimperk forests was attempted at by the then head forester Ferdinand Mann in 1828 thanks to whom a special attention in the Vimperk region was paid to beech management since 1834. In the period 1833–1834 the Vimperk forests were once again affected by heavy storms and in 1834–1836 by a bitter period of drought which contributed to a considerable spread of bark beetle (*Ips typographus*). The disaster resulted in a great number of windthrows and windbreakages and was the reason for a new estimation of the Vimperk forests, which was elaborated by the head forester Josef John who joined the ageing head of the Vimperk forest bureau Ferdinand Mann in 1838 and later became a key personality in the virgin forest's history.

We learn from the John's description that there were virgin forests in Boubín and Bobík at those times. Josef John became the head of the forest district in Vimperk on the then Schwarzenberg estate in the year 1843. From 1847 he was getting prepared for using the observations of tree development in the virgin forest for the needs of forest science, and it is well possible that it was at that time that he started thinking of how to save them for future generations (NOŽIČKA 1958).

There is no doubt that it was Josef John's merit when the concern of Czech foresters focused on the Šumava virgin forests as early as in the year 1849. The very first excursion to the Boubín virgin forest was organized by the Czech Forest Society on 2 September 1849, which was attended by prominent experts and made it possible to many participants to see an actually natural forest. The then records indicate that there were still as many as 33,000 morgens (1 Lower-Austrian morgen = 0.5755 ha), i.e. 18,992 hectares of virgin forests on the former Schwarzenberg estates. The published report about the excursion raised the interest in the Šumava virgin forests not only in our lands but also in the neighbouring countries. No less interesting is John's report about the course of the excursion in which he a.o. reported to the estate owner as follows: "In this space there is practically an open book of nature from the lines of which one can read rules by which Mother Nature – should it be left in the forests free and undisturbed, as exactly here for hundreds of years – preserves the vegetation, accomplishing it in various forms, destroying it and restoring it again, and how this woody species here and another there show specific or exclusive habitats, at other places repeatedly separating and putting together numerous species in harmony, how an order full of life and death can be at the same time maintained inside the forest, with the wealth of material substance and individual highest power and full of conspicuous evidences against the violent devastation" (NOŽIČKA 1958).

In summer 1851, Josef John staked out eight sample plots in the Boubín virgin forest and appointed the younger forester František Jungwirth to map the plots in such a way that they would give the most illustrative and true image of the virgin forest together with the layering of all trees and their dimensions. Jungwirth made map images of seven of these plots until October 1851 and sent them to Schwarzenberg inTřeboň, from whom however John asked their return on 9 April 1852 pointing out that he needs them for scientific reasons. The requested virgin forest images were then really returned to John (NOŽIČKA 1958, 1959). It was the first research work in the world made in virgin forests!

Thanks to John's long-term efforts and support provided by the chief wood-reeve in the Breslau Province von Pannewitz, Schwarzenberg made a decision in the year 1858 that the virgin forests in compartments 31b, 34b and 35a in the Zátoň forest district should remain permanent reserves (NOŽIČKA 1958). CHADT (1883) mentions: "In the year 1858, the J. J. Duke of Schwarzenberg instituted the forest compartments 31b), 35a), 34b) the virgin forest as remainders of the former virgin forests for times eternal. No timber will be extracted here, no work performed at all and the virgin forest is to be entirely left to itself from now forever."

We learn from the plan of forest management worked out for the Zátoň forest district in 1859 that the virgin forest area was classified in more distant periods of rotation. At that time, there were still 2,429 morgens (1,398 ha) of virgin forests in the Zátoň forest district (NOŽIČKA 1958). Historical entries speak of a sufficient amount of spruce, fir and beech self-seedings fit to create new stands in the then virgin forests (PRŮŠA 1989). Fellings were made on the western and northern edges of the virgin forest, where the so called Lukenská Road was being constructed at that time (1857–1859). Later cuttings included only trees which had fallen across the road or blocked virgin forest roads.

In the plan of forest management from 1869 the virgin forest was still included in the commercial forest but there were no silvicultural or felling measures planned here any more. Total exemption of the virgin forest from management was confirmed in the forest management plan for the period 1882–1891 and included the whole compartment 31 of 47.062 ha in area and 27,400 m^3 timber reserve (PRŮŠA 1989). The Zátoň forest district suffered a heavy gale on 26 October 1870, which resulted in extensive windbreakages also in the original virgin forest stands near the Reserve. The windbreakages were gradually processed and made responsible for a further shrinkage of virgin forest stands.

The plan of forest management for 1900 introduced a regulation for the regeneration of virgin forest stands whose area – outside the Reserve – was 352 hectares. The largest stands (215 ha) were in the Zátoň forest district (PRŮŠA 1989). The distinguished virgin forest in Compartment 31 of 46.666 ha is referred to in connexion with young self-seedings and young growths suffering from browsing so that younger age categories are hardly represented. A necessity is mentioned to fence the area from red deer. The forest management plan from 1939 repeatedly mentions that the Boubín virgin forest Reserve below the Lukenská Road in the direction of the Kapelský potok (Brook) is missing undergrowths and an urgent need appears to prevent game entry. The virgin forest was thoroughly fenced in 1965–1966 under supervision of Ing. J. Ostrčil (PRŮŠA 1989).

It follows from the above historical survey that the impact on stands in the present virgin forest by logging or by other silvicultural measures was really minimal and in the comparison with the historical development of other Czech virgin forest reserves this is a unique case of the preserved original forest.

The start of modern forest research in the Boubín virgin forest dates back to the year 1954 when four permanent research plots (each of 1 ha) were aligned on different sites and in different stages of stand growth by the team of researchers led by Dr. Ing. Jaroslav Řehák (in cooperation with Ing. Věroslav Samek, CSc., and Karel Rosa, CSc.). First measurements in all permanent research plots were made in the same year, which were repeated in 1959 being extended with the alignment of positions of lying and standing stems in all plots (ŘEHÁK 1962, 1964). In addition, there were transects of 100 × 10 m demarcated at all times by two per plot, perpendicular to each other (see topical map of the virgin forest). The complete sighting of trees on the transects and their imaging was accomplished in 1960 (ŘEHÁK 1962, 1964). The precise mapping of vegetation types (in the present concept of forest types) was made in the same year their boundaries being surveyed by compass theodolite (SAMEK 1961). Callipering of all trees in the virgin forest was made in 1960–1961 simultaneously for the particular forest types. It was at that time (in 1961) when Ing. V. Samek, CSc., succeeded in disclosing one of landmarks of John's research plot No. V and there was one more found in the autumn of the same year. Aligned was one of two possible alternatives of the square area of one Lower-Austrian morgen in acreage with all trees in the area being numbered in a usual way, aligned and a location plan of their distribution in the field made. After ten years, the investigations were repeated on four permanent research plots in 1964 and the second alternative to John's plot No. V established (ŘEHÁK 1962, 1964).

Repeated measurements on the permanent research plots established by Dr. J. Řehák were made by his team in the years 1964, 1969, and on the permanent research plots I, II and IV also in the year 1972. However, the measurements of 1972 were not assessed. Repeated measurements were later carried out under the leadership of Ing. Miroslav Vaněk, CSc., on the permanent research plots I and II (1984), and III and IV (1989) (VANĚK 1990). Another repeated measurement on all permanent research plots was made in 1996.

Two cross-sectional strips (A-229.5 × 10 m; B-220.5 × 10 m) were aligned along the line perpendicular to the contour under the leadership of Prof. Dr. Ing. Miroslav Vyskot, DrSc., in 1961, on which detailed mensurational analyses were made together with studies of natural regeneration (VYSKOT 1968). Repeated measurements were made in 1969 and 1975 (VYSKOT 1976). In 1986, the sectional stripes were extended to make plots of 1 ha each and repeated investigations were made to the original methodology (STANĚK 1988).

The most extensive survey in the Reserve was made by Ing. E. Průša, CSc., and his colleagues in the year 1972 (PRŮŠA 1985, 1989), which included sighting of the whole tree layer in the virgin forest (incl. dead timber), mapping of forest types and tree species regenerations, phytocoenological relevés and soil characteristics. The presented paper is a follow up to the survey. All data mentioned in connexion with forest research relate to the so called "old virgin forest", i.e. to the preserved core of the original Schwarzenberg reserve whose area is about 47 ha.

The Boubín virgin forest reserve was officially declared on the area of 47 hectares by Act No. 143 547/33-V of the Ministry of Education and Culture from 31 December 1933. In 1958, the Reserve was extended and included a vast complex of stands which were to play a role of protection zone surrounding the original virgin forest. The extension was made effective by Decree No. 2224/58-D/1 of the Ministry of Education and Culture from 15 January 1958, and the whole area of the Boubín virgin forest State Nature Reserve amounted to 666.41 hectares. The additional registration in the Gazette was made through Decree No. 14 200/88-SÚOP of the Ministry of Culture of the Czech Republic from 29 November 1988. According to Decree No. 395/1992 Gaz. from 11 June 1992 of the Ministry of Environment of the Czech Republic the territory was classified in the category of National Nature Reserves with the officially confirmed area of 666.41 hectares.

METHODOLOGY

The repeated investigation was based on detailed maps and calculations capturing the virgin forest condition in the year 1972 (PRŮŠA 1985) and with the application of methodology modified by Ing. Průša for the collection and assessment of the logged data (VRŠKA 1997). The tree layer was revised and the maps were added all trees which reached d.b.h. 10 cm in the period under study. New dead trees were mapped. Callipered were all trees with d.b.h. over 10 cm, their characteristics recorded (dead standing tree, stub, etc.) and stage of disintegration recorded in the lying trees on the scale of three stages. The trees were classified into diameter classes by 10 cm (e.g. Diameter Class 5 = 45–54 cm) according to the achieved diameter at breast height. 490 trees were measured for height in order to construct height flow sheets as groundworks for calculation of volumes. Mensurational computations were made with the use of volume tables by Lesprojekt (1952).

To provide for stand structure study a repeated mapping was made of natural regeneration groups (undergrowths) in which the trees did not reach the d.b.h. of 10 cm. Also, the repeated measurements were made of eight transects aligned by Dr. Řehák and his team in 1960 (ŘEHÁK 1962, 1964).

Samples from the surface humus horizons were taken from 5 soil pits on the permanent typological plots (PTP) for chemical, biochemical and microbiological analyses in order to assess changes in the soil (chemical analysis). The biochemical and microbiological analyses had not been made before and were to provide comparison data for repeated measurements in the future. All soil analyses were made in accredited laboratories of the Agency for Nature Conservation and Landscape Protection of the Czech Republic (AOPK), Branch Brno. Terminology, soil horizons and soil sub-types were reworked to the soil classification system used by the Institute of Forest Management (ÚHÚL) (MACKŮ, VOKOUN 1993). Results of soil analyses from 1972 have been taken over from PRŮŠA (1985).

Phytocoenological relevés were repeated on 23 circular PTPs of 25 m in diameter (i.e. area of about 490 m^2), which follow up the phytocoenological relevés made in 1972 (PRŮŠA 1985). Terminology of plant names was unified (DOSTÁL 1989). The stratification scale by Zlatník (RANDUŠKA et al. 1986) was used for the classification of tree species synusia in the phytocoenological relevés, and the combined scale of abundance and dominance by Braun-Blanquet, modified and refined by Zlatník (RANDUŠKA et al. 1986) was used for the classification of herb synusia. The assessment of the phytocoenological relevés was made with the use of ecological groups of plant species (EGS) used by Lesprojekt (PLÍVA, PRŮŠA 1969).

The evaluation of mensurational data by sites was made separately for zonal (water-unaffected) sites with similar growing conditions (groups of forest types – GFT – 6S, 6D, 6N) and extrazonal (water-affected) sites (GFT 7V, 6R) including inversion, water-unaffected sites (GFT 7K). The second group of sites clearly shows their greater ecological wideness; however, all of them express harsher conditions which are in general unfavourable for the development of beech and on the other hand favourable mainly for spruce.

Twenty two directional relevés were made for repeated photographing, whose place and direction were plotted in the detailed tree map.

The original maps were digitalized in the geographical information system (GIS) TOPOL by means of special software for the generation of maps of virgin forests, whose author is Mgr. Dušan Adam. All other analyses were based on the digital maps and attached databases with the common softwares FOXPRO, MS Excel, MS Word. The phytocoenological relevés were assessed by using the program TYP, developed at the Department of Forest Botany, Dendrology and Typology, Faculty of Forestry and Wood Technology, Mendel University of Agriculture and Forestry in Brno.

NATURAL CONDITIONS

Localization and broader territorial context

The Boubín virgin forest National Nature Reserve is situated about 4 km NNE of the village Zátoň in the Prachatice District, in the territory of the Šumava National Park and Šumava Mts. Protected Landscape Area, in forest stands operated by the state enterprise Lesy České republiky, s. p. (Forests of the Czech Republic), Forest Enterprise Boubín. In terms of organization it belongs in the Forest District Zátoň, Compartment 133. Total aligned area according to the digital map is 46.62 ha.

The whole area is located in the Natural Forest Region 13 – Šumava (PLÍVA, ŽLÁBEK 1986). Biogeographical regionalization is as follows: sub-province Hercynian, biogeographical region 1.62-Šumava (CULEK et al. 1995).

Geomorphological conditions

The Boubín virgin forest National Nature Reserve can be found in the Boubínská hornatina (Hilly Land) within the Boubín Mt. massif (altitude 1,362 m). The whole massif is extended from the main massif of Šumava into the inland thus enjoying milder climatic conditions than the central Šumava Mts. The altitude of the Boubín virgin forest NNR is 930–1,110 m and the area is situated in the lower part of the NE scarp of the ridge Pažení (Basumský ridge) between the Lukenská Road and the Kaplický potok (Brook) which forms a valley line. The extended slope is at some places differentiated by smaller flats and interwoven with a number of brooks which at some places form waterlogged spots on the flats or in the spring areas. A conspicuous rock knob is protruding in the central part of the scarp. The south-eastern (lowest) edge of the Reserve is formed by a lake (0.33 ha) which was established in 1833 to strengthen the stream used for floating.

Table 1. Average monthly precipitation totals (mm) in the period 1901–1950; the Horní Vltavice Station, Kubova Huť – 1,003 m (KOLEKTIV 1961)

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year	IV–IX	X–III
58	61	49	63	88	98	112	96	69	61	51	61	867	526	341

Table 2. Average monthly air temperatures (°C) in the period 1901–1950; the Horní Vltavice Station, Kubova Huť – 1,003 m (KOLEKTIV 1961)

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year	IV–IX
-5.0	-4.0	-1.0	2.0	8.0	12.0	13.0	12.0	9.0	4.0	0.0	-3.0	4.0	9.3

Geological conditions

The geological formation is of primary age. Prevailing rocks are schists – gneisses and mica schists poor in minerals with sporadically penetrating layers of coarse-grain eruptive granites. The dominating gneiss is grey, biotitic, formed mainly by quartz, spars (orthoclases in particular) and biotite. Weathering products are medium-deep to shallow stony soils (PRŮŠA 1989).

Climatic conditions

Climate is of mountain character. Precipitation data and air temperatures are presented in Tables 1 and 2, respectively. Numerous thunderstorms are typical in summer. The macroclimatic data are slightly altered on the Kaplický potok (Brook) valley bottom, i.e. within the space of the virgin forest, due to the harsh and colder inversion mesoclimate.

The region belongs in the cold zone – CH6 (QUITT 1974).

Site conditions

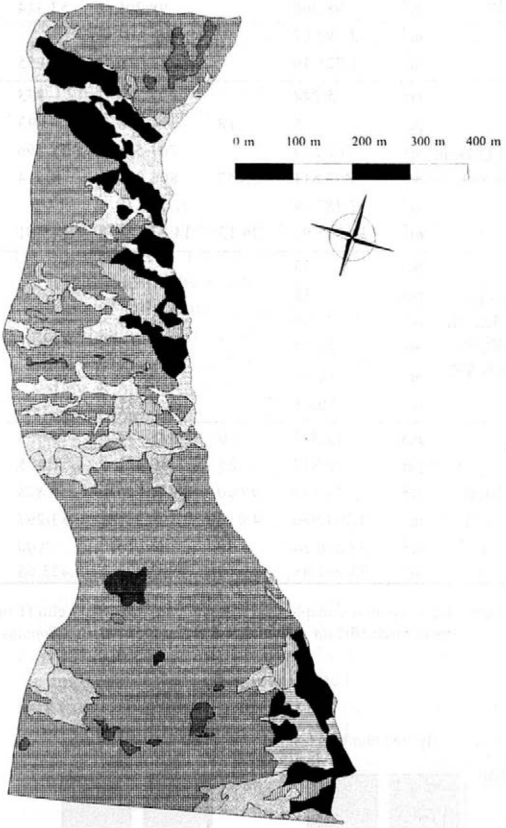
Most of the area under study is situated in the Spruce-Beech forest altitudinal vegetation zone 6 on water-unaffected sites (Fig. 1). Predominating soils are loamy-sand cryptopodzols mesotrophic, often rather stony.

Water-affected sites cut the virgin forest from the west to the east in stripes of variable breadths along streams, in the vicinity of spring areas, and in the inversion position also along the Kaplický Brook (Fig. 1). In the south-eastern part of the virgin forest in the lowest situated part there are also Peat-Spruce stands represented extrazonally. The soil mosaic consists mainly of gley-cryptopodzols which at some places melt into cambic gleys.

MENSURATIONAL CHARACTERISTICS AND THEIR CHANGES

Total

The number of live trees scored a pronounced decrease from 13,346 in 1972 to 10,842 in 1996 (Table 3, Fig. 3). The



Forest type	Area (ha)	Representation (%)
Fresh Spruce-Beech with fern – 6S2	29.39	63.0
Stony Spruce-Beech with oxalis – 6N3	0.35	0.8
Nutrient-enriched Spruce-Beech with butterbur – 6D2	2.60	5.6
Water-unaffected sites TOTAL	**32.34**	**69.4**
Moist Beech-Spruce with ferns – 7V6	6.83	14.7
Waterlogged Beech-Spruce with butterbur – 7V9	1.88	4.0
Fresh Peat-Spruce with oxalis – 6R1	0.90	1.9
Acidic Beech-Spruce with bilberry – 7K2	4.67	10.0
Water-affected sites TOTAL	**14.28**	**30.6**
TOTAL	**46.62**	**100.0**

Fig. 1. Boubín – forest types

Table 3. The summary of tree species by tree numbers, stand basal area and timber volume on the whole area

	1972 / 1996	Living trees: intact trees	Living trees: fractures	Living trees: total	Dead trees: dead standing trees	Dead trees: stubs	Dead trees: fallen	Dead trees: total	Virgin forest total	Living trees (%)	Dead trees (%)
Norway spruce	*pcs*	*7,376*		*7,376*	*877*	*1,100*	*317*	*2,294*	*9,670*	*55.3*	*49.0*
	pcs	5,981	7	5,988	1,232	169	2,580	3,981	9,969	55.2	66.0
	m^2	*1,235.758*		*1,235.758*	*41.475*	*151.102*	*41.956*	*234.533*	*1,470.291*	*56.8*	*33.7*
	m^2	1,359.142	0.856	1,359.998	101.164	46.864	406.815	554.843	1,914.841	59.9	49.6
	m^3	*16,807.59*		*16,807.59*				*4,827.17*	*21,634.76*	*52.8*	*47.3*
	m^3	19,370.57	10.36	19,380.93	1,333.12	124.69	3,853.89	5,311.70	24,692.63	53.8	48.7
silver fir	*pcs*	*693*		*693*	*203*	*286*	*40*	*529*	*1,222*	*5.2*	*11.3*
	pcs	258		258	147	199	474	820	1,078	2.4	13.6
	m^2	*236.609*		*236.609*	*64.905*	*128.93*	*11.027*	*204.862*	*441.471*	*10.9*	*29.5*
	m^2	98.206		98.206	53.344	86.888	205.459	345.691	443.897	4.3	30.9
	m^3	*3,791.07*		*3,791.07*				*3,228.83*	*7,019.90*	*11.9*	*31.6*
	m^3	1,725.19		1,725.19	940.55	370.69	2,271.24	3,582.48	5,307.67	4.8	32.9
European beech	*pcs*	*5,244*		*5,244*	*773*	*825*	*253*	*1,851*	*7,095*	*39.3*	*39.5*
	pcs	5	18	4,558	93	284	845	1,222	5,780	42.0	20.2
	m^2	*701.574*		*701.574*	*51.496*	*164.516*	*39.797*	*255.809*	*957.383*	*32.2*	*36.8*
	m^2	803.811	3.157	806.968	8.514	57.175	148.718	214.407	1,021.375	35.6	19.2
	m^3	*11,187.19*		*11,187.19*				*2,153.15*	*13,340.34*	*35.1*	*21.1*
	m^3	14,805.91	25.13	14,831.04	145.81	194.88	1,637.31	1,978.00	16,809.04	41.2	18.1
Other (KL, JL, JR, BR, OS, VR)	*pcs*	*33*		*33*				*8*	*41*	*0.2*	*0.2*
	pcs	38		38	3	3	6	12	50	0.4	0.2
	m^2	*3.599*		*3.599*				*0.000*	*3.599*	*0.2*	*0.0*
	m^2	3.777		3.777	0.275	0.298	2.631	3.204	6.981	0.2	C.0
	m^3	*54.41*		*54.41*				*4.16*	*58.57*	*0.2*	*0.0*
	m^3	59.81		59.81	4.17	0.76	24.43	29.36	89.17	0.2	0.3
Total	*pcs*	*13,346*	*0*	*13,346*	*1,853*	*2,211*	*610*	*4,682*	*18,028*	*100.0*	*100.0*
	pcs	10,817	25	10,842	1,475	655	3,905	6,035	16,877	100.0	100.0
	m^2	*2,177.540*	*0.000*	*2,177.540*	*157.876*	*444.548*	*92.780*	*695.204*	*2,872.744*	*100.0*	*100.0*
	m^2	2,264.936	4.013	2,268.949	163.297	191.225	763.623	1,118.145	3,387.094	100.0	100.0
	m^3	*31,840.26*	*0.00*	*31,840.26*	*0.00*	*0.00*	*0.00*	*10,213.31*	*42,053.57*	*100.0*	*100.0*
	m^3	35,961.48	35.49	35,996.97	2,423.65	691.02	7,786.87	10,901.54	46,898.51	100.0	100.0

Other: KL – sycamore maple (*Acer pseudoplatanus*), JL – elm (*Ulmus* sp.), JR – European mountain ash (*Sorbus aucuparia*), BR – European birch (*Betula pendula*), OS – European aspen (*Populus tremula*), VR – willow (*Salix* sp.)

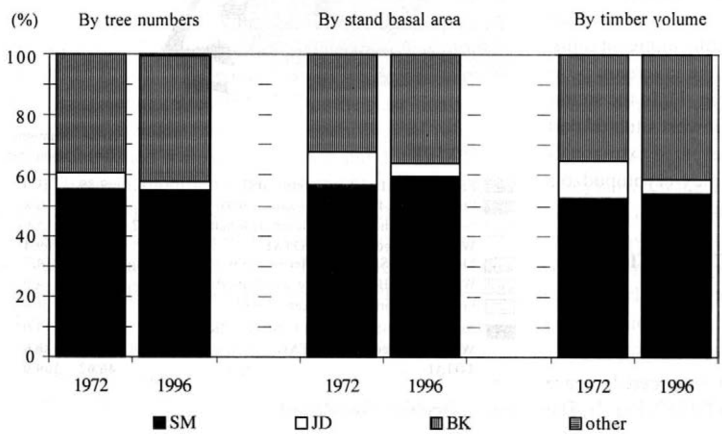


Fig. 2. The representation of living trees by species in per cent on the whole area

Legend: SM – Norway spruce (*Picea abies*), JD – silver fir (*Abies alba*), BK – European beech (*Fagus sylvatica*)

Other: KL – sycamore maple (*Acer pseudoplatanus*), JL – elm (*Ulmus* sp.), JR – European mountain ash (*Sorbus aucuparia*), BR – European birch (*Betula pendula*), OS – European aspen (*Populus tremula*), VR – willow (*Salix* sp.)

Table 4. Living trees by species and diameter classes in the whole area (intact standing trees + fractures)

Diameter class		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Living total
Norway spruce	*1972*	*980*	*1,629*	*1,215*	*842*	*910*	*633*	*484*	*327*	*177*	*98*	*43*	*25*	*10*	*2*	*1*		*7,376*
	1996	465	1,065	771	707	785	692	577	423	252	136	71	34	6	8	1		5,988
silver fir	*1972*	*25*	*50*	*56*	*79*	*92*	*76*	*88*	*93*	*53*	*44*	*21*	*8*	*4*	*4*			*693*
	1996	6	24	25	24	21	29	34	38	23	19	9	2	2	2		1	258
European beech	*1972*	*502*	*952*	*1,007*	*989*	*934*	*581*	*170*	*81*	*25*	*3*							*5,244*
	1996	247	682	701	768	830	700	434	157	36	10							4,558
Other	*1972*	*5*	*4*	*10*	*4*	*7*	*3*											*33*
	1996	7	7	9	5	8	1	1										38
Total	*1972*	*1,512*	*2,635*	*2,288*	*1,914*	*1,943*	*1,293*	*742*	*501*	*255*	*145*	*64*	*33*	*14*	*6*	*1*	*0*	*13,346*
	1996	725	1,778	1,506	1,504	1,644	1,422	1,046	618	311	165	80	36	8	10	1	1	10,842

Note: The sums by the individual diameter classes are the numbers of stems. Their sum does not correspond to the number in the column "living total" which means the number of individual trees. The difference is caused by the fact that the trees with twin or triple stems were not included.

Other: KL – sycamore maple (*Acer pseudoplatanus*), JL – elm (*Ulmus* sp.), JR – European mountain ash (*Sorbus aucuparia*), BR – European birch (*Betula pendula*), OS – European aspen (*Populus tremula*), VR – willow (*Salix* sp.)

Table 5. Hectare indices – total

		Living trees	Dead trees	Total
Trees per 1 ha (pcs)	*1972*	*286*	*100*	*386*
	1996	233	129	362
Stand basal area per 1 ha (m²)	*1972*	*46.668*	*14.899*	*61.567*
	1996	48.669	23.984	72.653
Timber volume per 1 ha (m³)	1961	718	62	780
	1972	*682.39*	*218.88*	*901.27*
	1996	772.14	233.84	1,005.98

Note: The 1972 parameteres are related to the area 46.66 ha (PRŮŠA 1985).

In 1961, only standing dead trees were considered as dead trees

virgin forest got generally "older", i.e. further individuals or groups are through the stage of expiration while the new generation is not quick enough to grow up. Resulting from the long-range blocking of natural regeneration growth the trend is explained in *Development of natural regeneration*. A survey of tree numbers in diameter classes (Table 4, Fig. 9) illustrates the disconsolate situation in smaller sizes where Diameter Class 1 is badly missing trees and Diameter Classes 3 and 4 show similar unfavourable drops. The virgin forest "ageing" is demonstrated in Figs. 3–5. While the number of live trees is falling, their basal area and stem volume are increasing (with the exception of the weakening fir population), i.e. a lower number of trees represents a larger volume of timber. Table 5 documents an exceptionally high timber reserve which is quite unique in virgin forests. As compared with the year 1972, the standing volume of live trees increased to 772 m³/ha – a value which would be more than satisfactory even in mature stands of commercial forests on the site of Spruce-Beech. It provides a good evidence that:

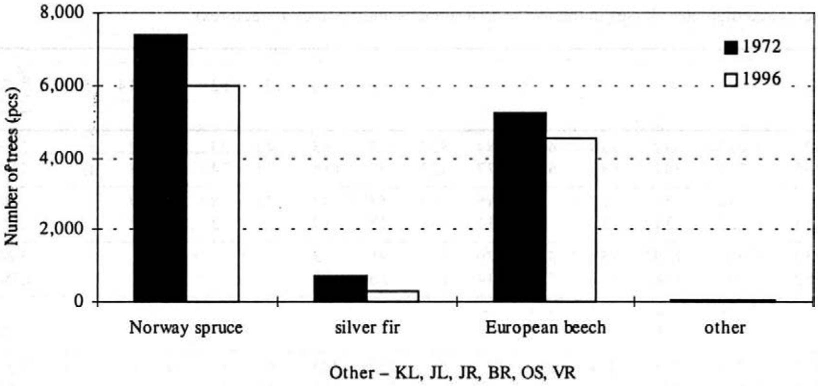
- a larger part of the stand is today at the stage of optimum and at the initial stage of disintegration,
- notwithstanding the above fact and in the comparison with other regions and their virgin forests the Boubín valley is one of the most interesting localities in the Czech Republic in terms of production.

The number of dead individuals increased from 4,682 to 6,035 with a huge increase of lying trees from 610 up to 3,905. A marked increase is also seen in basal area while stem volume shows only a vague rise (Table 3). The values indicate that it is also a considerably high number of smaller trees that die. In general, the volume of dead trees amounts to 23.2% of live trees volume.

The long-term eveness of timber supply in the virgin forest is also confirmed by Table 14. Dr. Řehák counted the complete reserve of timber to the top of 7 cm outside bark (i.e. stems from d.b.h. = 7 cm), not counting on the other hand the volume of lying dead stems. Therefore, the dead timber data can be compared only in dead standing trees while in the live trees the tree mass is negligible within the d.b.h. 7–10 cm and the aggregate data on the volume of live trees are acceptable as compared with the present situation.

Norway spruce (*Picea abies*)

Norway spruce is the main tree species in the Reserve and its representation exceeds 50% in all indicators (Table 3). The representation by tree counts remained unchanged since 1972, the representation by stand basal area and stem volume showed a slight increase. A shift of the entire population into larger dimensions is quite clear – the number of live trees fell from 7,376 to 5,988, the



For Figs. 3–5: Other
KL – sycamore maple (*Acer pseudoplatanus*)
JL – elm (*Ulmus* sp.)
JR – European mountain ash (*Sorbus aucuparia*)
BR – European birch (*Betula pendula*)
OS – European aspen (*Populus tremula*)
VR – willow (*Salix* sp.)

Fig. 3. Changes in numbers of living trees in main tree species

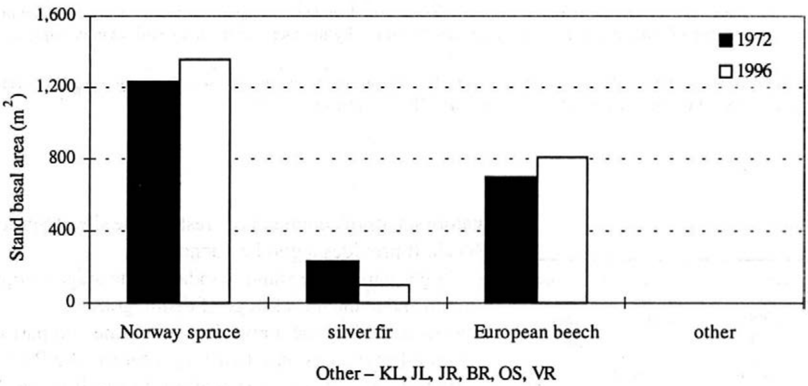


Fig. 4. Changes in stand basal area of living trees in main tree species

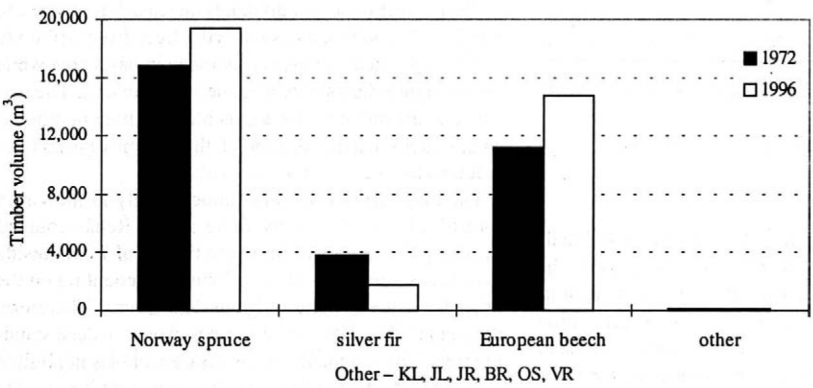


Fig. 5. Changes in timber volume of living trees in main tree species

stand basal area and the stem volume slightly increased (Table 3). The curve of tree numbers in diameter classes corroborates the trend, illustrating the loss of trees particularly in Diameter Classes 1, 2 and 3, i.e. the loss of important trees of the new generation.

A slightly increased volume of dead timber (from 4,827 to 5,311 m³) is primarily contributed to by a plot in the south-eastern part of the virgin forest, in which a whole-area disintegration occurred in 1993 (see tree map 1:1,000).

Beech (*Fagus sylvatica*)

Similarly as in Norway spruce the entire beech population was displaced toward the larger diameter classes. The number of live trees decreased from 5,244 to 4,558, and the volume of live stems increased from 11,187 to 14,831 m³ (Table 3). A slight decrease of numerousness in the diameter classes was recorded in Diameter Classes 1, 2, 3 and 4 while in Diameter Classes 6, 7 and 8 the whole popula-

Table 6. The summary of tree species by tree numbers, stand basal area and timber volume at the water-unaffected sites

	1972 1996	Living trees: intact trees	Living trees: fractures	Living trees: total	Dead trees: dead standing trees	Dead trees: stubs	Dead trees: fallen	Dead trees: total	Virgin forest total	Living trees (%)	Dead trees (%)
	pcs	*3,898*		*3,898*	*144*	*510*	*81*	*735*	*4,633*	*42.8*	*25.8*
	pcs	3,172	6	3,178	625	84	1,308	2,017	5,195	42.5	54.2
Norway	*m²*	*708.772*		*708.772*	*9.458*	*86.162*	*10.540*	*106.160*	*814.932*	*46.2*	*20.6*
spruce	m²	770.720	0.786	771.506	63.254	30.906	249.266	343.426	1,114.932	48.4	41.4
	m³	*9,758.86*		*9,758.86*				*3,178.13*	*12,936.99*	*42.4*	*41.0*
	m³	11,003.57	10.21	11,013.78	856.34	89.90	2,360.67	3,306.91	14,320.69	42.1	40.8
	pcs	*507*		*507*	*149*	*242*	*36*	*427*	*934*	*5.6*	*15.0*
	pcs	191		191	100	166	367	633	824	2.6	17.0
silver	*m²*	*187.381*		*187.381*	*54.428*	*113.348*	*10.202*	*177.978*	*365.359*	*12.2*	*34.5*
fir	m²	78.783		78.783	39.977	78.720	175.072	293.769	372.552	4.9	35.4
	m³	*3,044.15*		*3,044.15*				*2,822.25*	*5,866.40*	*13.2*	*36.4*
	m³	1,391.33		1,391.33	710.34	344.78	1,954.37	3,009.49	4,400.82	5.3	37.1
	pcs	*4,693*		*4,693*	*745*	*701*	*238*	*1,684*	*6,377*	*51.5*	*59.1*
	pcs	4,069	17	4,086	85	260	719	1,064	5,150	54.7	28.6
European	*m²*	*636.662*		*636.662*	*49.626*	*143.563*	*37.952*	*231.141*	*867.803*	*41.5*	*44.9*
beech	m²	740.005	3.031	743.036	7.572	52.942	130.049	190.563	933.599	46.6	23.0
	m³	*10,189.23*		*10,189.23*				*1,753.74*	*11,942.97*	*44.3*	*22.6*
	m³	13,691.67	24.74	13,716.41	128.82	185.16	1,459.40	1,773.38	15,489.79	52.4	21.9
	pcs	*16*		*16*				*2*	*18*	*0.2*	*0.1*
Other	pcs	18		18	2	2	3	7	25	0.2	0.2
(KL, JL,	*m²*	*2.050*		*2.050*				*0.000*	*2.050*	*0.1*	*0.0*
JR, BR)	m²	2.010		2.010	0.267	0.227	1.995	2.489	4.499	0.1	0.3
	m³	*31.43*		*31.43*				*2.08*	*33.51*	*0.1*	*0.0*
	m³	32.83		32.83	4.14	0.69	16.47	21.30	54.13	0.1	0.3
	pcs	*9,114*	*0*	*9,114*	*1,038*	*1,453*	*355*	*2,848*	*11,962*	*100.0*	*100.0*
	pcs	7,450	23	7,473	812	512	2,397	3,721	11,194	100.0	100.0
	m²	*1,534.865*	*0.000*	*1,534.865*	*113.512*	*343.073*	*58.694*	*515.279*	*2,050.144*	*100.0*	*100.0*
Total	m²	1,591.518	3.817	1,595.335	111.070	162.795	556.382	830.247	2,425.582	100.0	100.0
	m³	*23,023.67*	*0.00*	*23,023.67*	*0.00*	*0.00*	*0.00*	*7,756.20*	*30,779.87*	*100.0*	*100.0*
	m³	26,119.40	34.95	26,154.35	1,699.64	620.53	5,790.91	8,111.08	34,265.43	100.0	100.0

Other: KL – sycamore maple (*Acer pseudoplatanus*), JL – elm (*Ulmus* sp.), JR – European mountain ash (*Sorbus aucuparia*), BR – European birch (*Betula pendula*)

tion continually proceeded into the higher diameter class with hardly any loss in the count of individuals (Fig. 9).

The trend is also confirmed by a slight decrease in both number and volume of dead timber. Older trees of larger diameters got gradually disintegrated, there were only a few newly dead trees, and the lower diameters are subjected to a much faster disintegration.

Silver fir (*Abies alba*)

Fir exhibits a long-range decrease in all parameters under study. Expiration of the population grown up prior to the long-term disturbance of developmental relations due to overpopulated red deer is quite evident. The curve of live tree numbers in the respective diameter classes scored a deep fall (Fig. 8) similarly as both relative and absolute values of studied parameters which show an unstoppable decay of the present population. The representation of fir in all indicators is below 5%. The total number of live trees dropped from 693 in 1972 to 258 in 1996, which is an entirely unsatisfactory situation with respect to the studied stand area (46.62 ha) (Table 3).

A logical consequence to the above situation is the increase of dead timber – both in numbers and in terms of volume, which also showed in an increased representation of dead timber as related to other species in the Reserve.

Other

Apart from the three above mentioned "main" tree species in the virgin forest, there are some interspersed species whose importance is also high not only from the viewpoint of the biodiversity of natural communities. Spe-

Table 7. Living trees by species and diameter classes at the water-unaffected sites (intact standing trees + fractures)

Diameter class		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Living total
Norway spruce	1972	631	885	525	395	384	324	274	209	135	70	33	24	7	2			3,898
	1996	300	658	393	290	309	299	302	257	180	98	54	28	5	7	1		3,178
silver fir	1972	10	35	40	46	60	57	69	73	46	39	18	8	4	2			507
	1996	1	18	17	19	12	19	24	28	22	16	9	2	2	1		1	191
European beech	1972	446	852	888	864	846	535	156	78	25	3							4,693
	1996	188	597	634	663	754	649	413	149	35	9							4,086
Other	1972		3	5	2	4	2											16
	1996	2	3	5	3	4		1										18
Total	1972	1,087	1,775	1,458	1,307	1,294	918	499	360	206	112	51	32	11	4	0	0	9,114
	1996	491	1,276	1,049	975	1,079	967	740	434	237	123	63	30	7	8	1	1	7,473

Note: The sums by the individual diameter classes are the numbers of stems. Their sum does not correspond to the number in the column "living total" which means the number of individual trees. The difference is caused by the fact that the trees with twin or triple stems were not included.

Other: KL – sycamore maple (*Acer pseudoplatanus*), JL – elm (*Ulmus* sp.), JR – European mountain ash (*Sorbus aucuparia*), BR – European birch (*Betula pendula*)

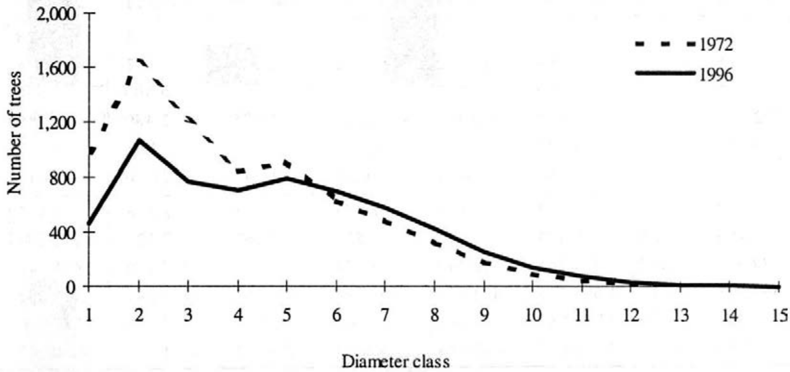


Fig. 6. The number of living trees in diameter classes – Norway spruce

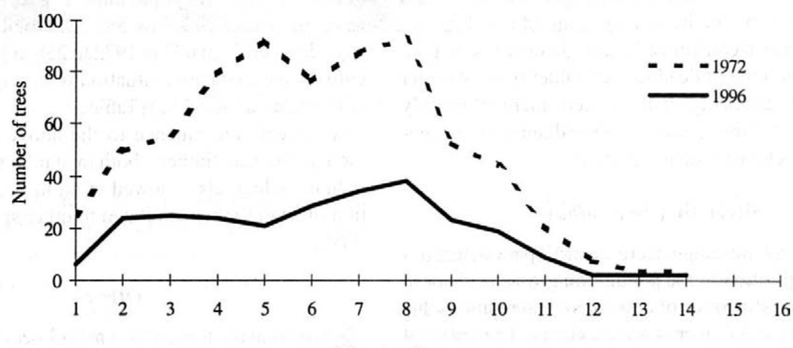


Fig. 7. The number of living trees in diameter classes – silver fir

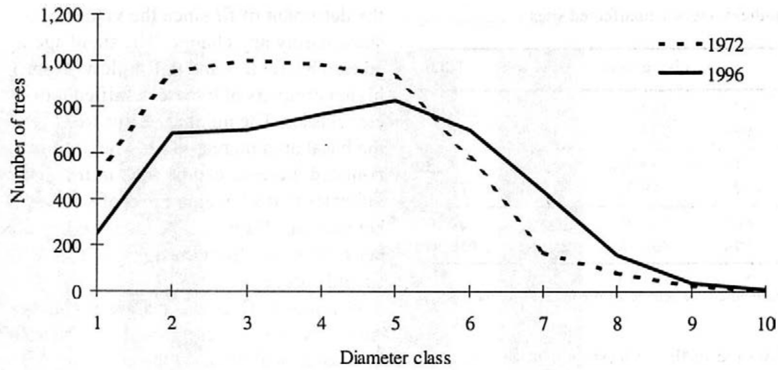


Fig. 8. The number of living trees in diameter classes – European beech

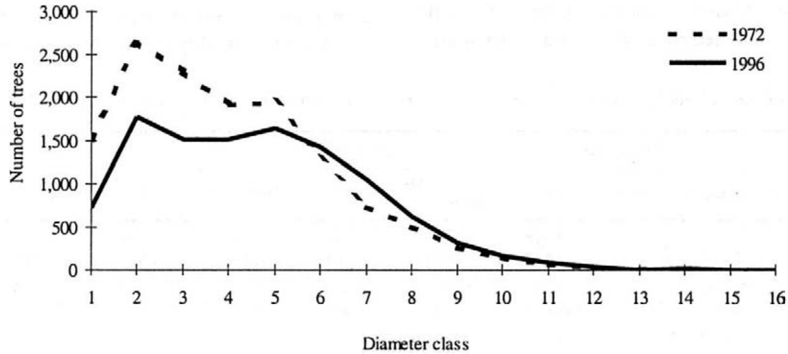


Fig. 9. The number of living trees in diameter classes – total

Table 8. The representation of living trees by species in per cent at the water-unaffected sites

Area 32.34 ha		Norway spruce	Silver fir	European beech	Other	Total
The representation by tree numbers	*1972*	*42.8*	*5.6*	*51.4*	*0.2*	*100*
	1996	42.5	2.6	54.7	0.2	100
The representation by stand basal area	*1972*	*46.2*	*12.2*	*41.5*	*0.1*	*100*
	1996	48.4	4.9	46.6	0.1	100
The representation by timber volume	*1972*	*42.4*	*13.2*	*44.3*	*0.1*	*100*
	1996	42.1	5.3	52.5	0.1	100

Other: KL – sycamore maple (*Acer pseudoplatanus*), JL – elm (*Ulmus* sp.), JR – European mountain ash (*Sorbus aucuparia*), BR – European birch (*Betula pendula*)

cies recorded in the year 1996 were sycamore maple (*Acer pseudoplatanus*), Scotch elm (*Ulmus glabra*), rowan (*Sorbus aucuparia*), common birch (*Betula pendula*), European aspen (*Populus tremula*), and willow (*Salix* sp.) (Table 3). Their total representation in all studied parameters ranges from 0.2–0.4%.

Changes by sites

Changes in the tree layer as related to site conditions were assessed for water-affected sites including sites in thermal inversion (forest types 7V6, 7V9, 6R1, 7K2) and for water-unaffected sites (forest types 6S2, 6N3, 6D2).

Table 9. Hectare indices – water-unaffected sites

		Living trees	Dead trees	Total
Trees per 1 ha (pcs)	*1972*	*281*	*88*	*369*
	1996	231	115	346
Stand basal area per 1 ha (m^2)	*1972*	*47.358*	*15.899*	*63.257*
	1996	49.33	25.672	75.002
Timber volume per 1 ha (m^3)	*1961*	*710.39*	*239.32*	*949.71*
	1996	808.73	250.81	1,059.54

Note: The 1972 parameteres are related to the area 32.41 ha (PRŮŠA 1985)

The long-term balance in the representation of tree species between the water-affected and -unaffected sites is illustrated in Fig. 10. The only apparent change is the whole-area shrinkage of fir (with no respect of site).

Dominant species on the water-unaffected sites is beech, closelly followed by spruce (Tables 6, 8). In the case of beech, all studied parameters always increased to the detriment of fir since the values of spruce indicators show hardly any change. The stand ageing is documented also by Table 7 and 9. It follows from Table 7 that the higher numbers of live trees shifted into the higher diameter classes. The number of live trees generally dropped, the basal area increased only negligibly but a more pronounced increase can be seen in the tree volume, which indicates that a lower number of trees bears a higher timber volume (Table 6). The increased volume of dead timber follows out from the dying of the older generation of fir and spruce.

The water-affected sites are typically dominated by spruce whose representation in all studied parameters increased, at all times at the cost of fir (Table 10). Representation of beech shows hardly any change and can be considered maximum on these sites (provided that the existing water regime is maintained). Beech makes use of mildly elevated plots and exhibits an abundant representation on transitions towards the fresh and nutrient-enriched types. Stability of stands on these sites is very

Table 10. The summary of tree species by tree numbers, stand basal area and timber volume at the water-affected sites

		Living trees			Dead trees				Virgin forest total	Living trees (%)	Dead trees (%)
	1972 / 1996	intact trees	fractures	total	dead standing trees	stubs	fallen	total			
Norway spruce	*pcs*	*3,478*		3,478	*733*	*590*	*236*	*1,559*	*5,037*	*82.2*	*85.0*
	pcs	2,809	1	2,810	607	85	1,272	1,964	4,774	83.4	84.9
	m^2	*526.986*		*526.986*	*32.017*	*64.940*	*31.416*	*128.373*	*655.359*	*82.0*	*71.3*
	m^2	588.422	0.071	588.493	37.910	15.959	157.548	211.417	799.910	87.4	73.4
	m^3	*7,048.83*		*7,048.83*				*1,649.00*	*8,697.83*	*79.9*	*67.1*
	m^3	8,367.00	0.16	8,367.16	476.78	34.81	1,493.22	2,004.81	10,371.97	85.0	71.8
silver fir	*pcs*	*186*		*186*	*54*	*44*	*4*	*102*	*288*	*4.4*	*5.6*
	pcs	67		67	47	33	107	187	254	2.0	8.1
	m^2	*49.228*		*49.228*	*10.477*	*15.582*	*0.825*	*26.884*	*76.112*	*7.7*	*14.9*
	m^2	19.423		19.423	13.367	8.168	30.387	51.922	71.345	2.9	18.0
	m^3	*746.92*		*746.92*				*406.58*	*1,153.5*	*8.5*	*16.5*
	m^3	333.86		333.86	230.21	25.91	316.9	573.02	906.88	3.4	20.5
European beech	*pcs*	*551*		*551*	*28*	*124*	*15*	*167*	*718*	*13.0*	*9.1*
	pcs	471	1	472	8	24	126	158	630	14.0	6.8
	m^2	*64.912*		*64.912*	*1.869*	*20.953*	*1.846*	*24.668*	*89.580*	*10.1*	*13.7*
	m^2	63.805	0.126	63.931	0.943	4.233	18.668	23.844	87.775	9.5	8.3
	m^3	*997.96*		*997.96*				*400.41*	*1,398.37*	*11.3*	*16.3*
	m^3	1,114.24	0.39	1,114.63	16.99	9.72	177.9	204.61	1,319.24	11.3	7.3
Other (KL, JL, JR, BR, OS, VR)	*pcs*	*17*		*17*				*6*	*23*	*0.4*	*0.3*
	pcs	20		20	1	1	3	5	25	0.6	0.2
	m^2	*1.549*		*1.549*				*0.000*	*1.549*	*0.2*	*0.0*
	m^2	1.767		1.767	0.008	0.071	0.636	0.715	2.482	0.3	0.2
	m^3	*22.98*		*22.98*				*2.08*	*25.06*	*0.3*	*0.1*
	m^3	26.98		26.98	0.03	0.07	7.97	8.07	35.05	0.3	0.3
Total	*pcs*	*4,232*	*0*	*4,232*	*815*	*758*	*255*	*1,834*	*6,066*	*100.0*	*100.0*
	pcs	3,367	2	3,369	663	143	1,508	2,314	5,683	100.0	100.0
	m^2	*642.675*	*0.000*	*642.675*	*44.363*	*101.475*	*34.087*	*179.925*	*822.600*	*100.0*	*100.0*
	m^2	673.417	0.197	673.614	52.228	28.431	207.239	287.898	961.512	100.0	100.0
	m^3	*8,816.69*	*0.00*	*8,816.69*	*0.00*	*0.00*	*0*	*2,458.07*	*11,274.76*	*100.0*	*100.0*
	m^3	9,842.08	0.55	9,842.63	724.01	70.51	1,995.99	2,790.51	12,633.14	100.0	100.0

Other: KL – sycamore maple (*Acer pseudoplatanus*), JL – elm (*Ulmus* sp.), JR – European mountain ash (*Sorbus aucuparia*), BR – European birch (*Betula pendula*), OS – European aspen (*Populus tremula*), VR – willow (*Salix* sp.)

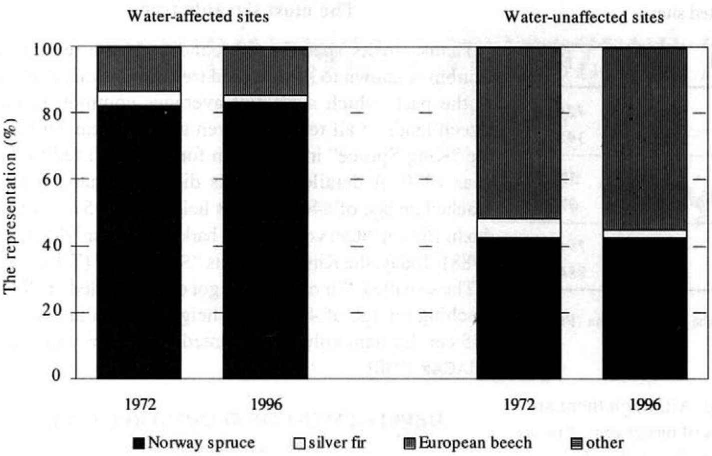


Fig. 10. The representation of living trees by tree numbers at individual sites

Other: KL – sycamore maple (*Acer pseudoplatanus*), JL – elm (*Ulmus* sp.), JR – European mountain ash (*Sorbus aucuparia*), BR – European birch (*Betula pendula*), OS – European aspen (*Populus tremula*), VR – willow (*Salix* sp.)

Table 11. Living trees by species and diameter classes at the water-affected sites (intact standing trees + fractures)

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Living total
Norway spruce	*1972*	*349*	*744*	*690*	*447*	*526*	*309*	*210*	*118*	*42*	*28*	*10*	*1*	*3*		*1*		*3,478*
	1996	165	407	378	417	476	393	275	166	72	38	17	6	1	1			2,810
silver fir	*1972*	*15*	*15*	*16*	*33*	*32*	*19*	*19*	*20*	*7*	*5*	*3*			*2*			*186*
	1996	5	6	8	5	9	10	10	10	1	3				1			67
European beech	*1972*	*56*	*100*	*119*	*125*	*88*	*46*	*14*	*3*									*551*
	1996	59	85	67	105	76	51	21	8	1	1							472
Other	*1972*	*5*	*1*	*5*	*2*	*3*	*1*											*17*
	1996	5	4	4	2	4	1											20
Total	*1972*	*425*	*860*	*830*	*607*	*649*	*375*	*243*	*141*	*49*	*33*	*13*	*1*	*3*	*2*	*1*		*4,232*
	1996	234	502	457	529	565	455	306	184	74	42	17	6	1	2	0		3,369

Note: The sums by the individual diameter classes are the numbers of stems. Their sum does not correspond to the number in the column "living total" which means the number of individual trees. The difference is caused by the fact that the trees with twin or triple stems were not included.

Other: KL – sycamore maple (*Acer pseudoplatanus*), JL – elm (*Ulmus* sp.), JR – European mountain ash (*Sorbus aucuparia*), BR – European birch (*Betula pendula*), OS – European aspen (*Populus tremula*), VR – willow (*Salix* sp.)

Table 12. The representation of living trees by species in per cent at the water-affected sites

Area	14.28 ha	Norway spruce	Silver fir	European beech	Other	Total
The representation by tree numbers	*1972*	*82.2*	*4.4*	*13.0*	*0.4*	*100*
	1996	83.4	2.0	14.0	0.6	100
The representation by stand basal area	*1972*	*82.0*	*7.7*	*10.1*	*0.2*	*100*
	1996	87.3	2.9	9.5	0.3	100
The representation by timber volume	*1972*	*79.9*	*8.5*	*11.3*	*0.3*	*100*
	1996	85.0	3.4	11.3	0.3	100

Other: KL – sycamore maple (*Acer pseudoplatanus*), JL – elm (*Ulmus* sp.), JR – European mountain ash (*Sorbus aucuparia*), BR – European birch (*Betula pendula*), OS – European aspen (*Populus tremula*), VR – willow (*Salix* sp.)

Table 13. Hectare indices – water-affected sites

		Living trees	Dead trees	Total
Trees per 1 ha (pcs)	*1972*	*297*	*129*	*426*
	1996	236	162	398
Stand basal area per 1 ha (m²)	*1972*	*45.1*	*12.626*	*57.726*
	1996	47.172	20.161	67.333
Timber volume per 1 ha (m³)	*1961*	*618.72*	*172.5*	*791.22*
	1996	689.26	195.41	884.67

Note: The 1972 parameteres are related to the area 14.25 ha (PRŮŠA 1985)

poor due to permanent waterlogging. Although there are some fluctuations due to windthrows of larger extent (see tree map 1:1,000 – south-eastern part of the virgin forest), the sites as a whole maintain the stable values of studied parameters or the parameters exhibit a slightly increasing tendency (Tables 10, 13) in accordance with the above described developmental trend of the so called "ageing".

The most sizeable trees

Thanks to its specific site conditions the region of Boubín is known to have scored tree dimensions already in the past, which surmount averages common in the Czech lands in all respects. Even today we can still see the "King Spruce" in the virgin forest, which fell in the year 1970. A detailed analysis disclosed that the tree reached an age of 440 years, its height being 57.6 m and d.b.h. 162 cm. Stem volume with bark was 29.2 m³ (MACAR 1988). Today, the King has got its "Successor" (Table 15).

The so called "Fir of Boubín" got dry and felled in 1984, reaching an age of 450 years, height 51.8 m and d.b.h. 145 cm. Its stem volume amounted to 33.6 m³ with bark (MACAR 1988).

DEVELOPMENT OF STAND STRUCTURE AND TEXTURE

Development of natural regeneration

The area and structural development of natural regeneration is illustrated in enclosed maps. The situation of

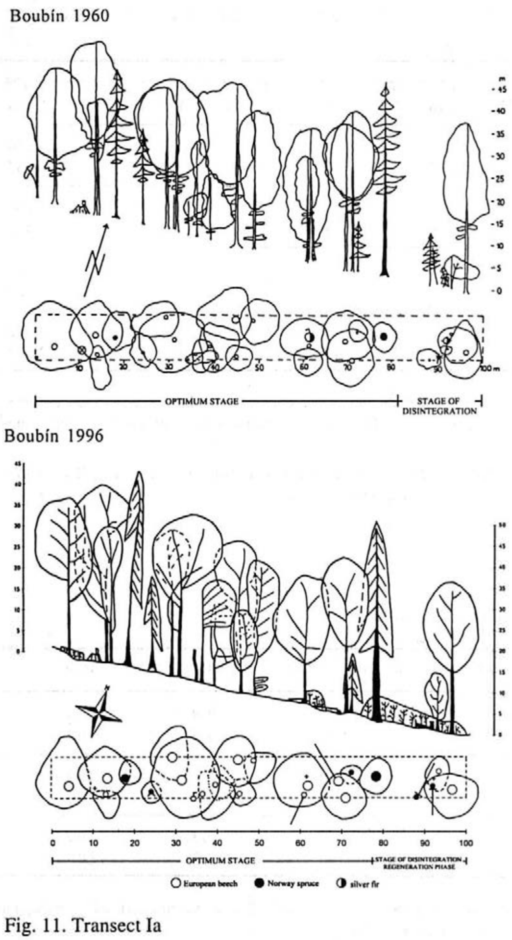


Fig. 11. Transect Ia

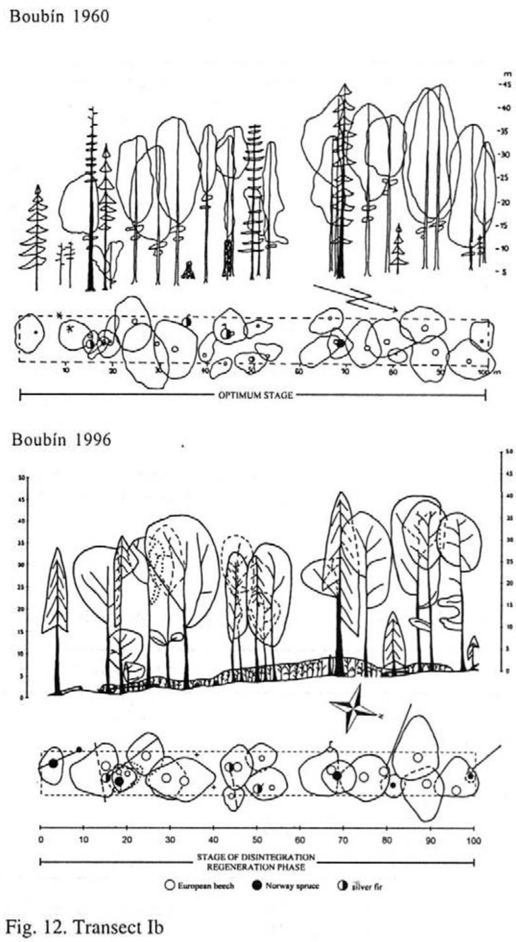


Fig. 12. Transect Ib

BOUBÍN 1972 – PŘIROZENÉ ZMLAZENÍ

Vysvětlivky:

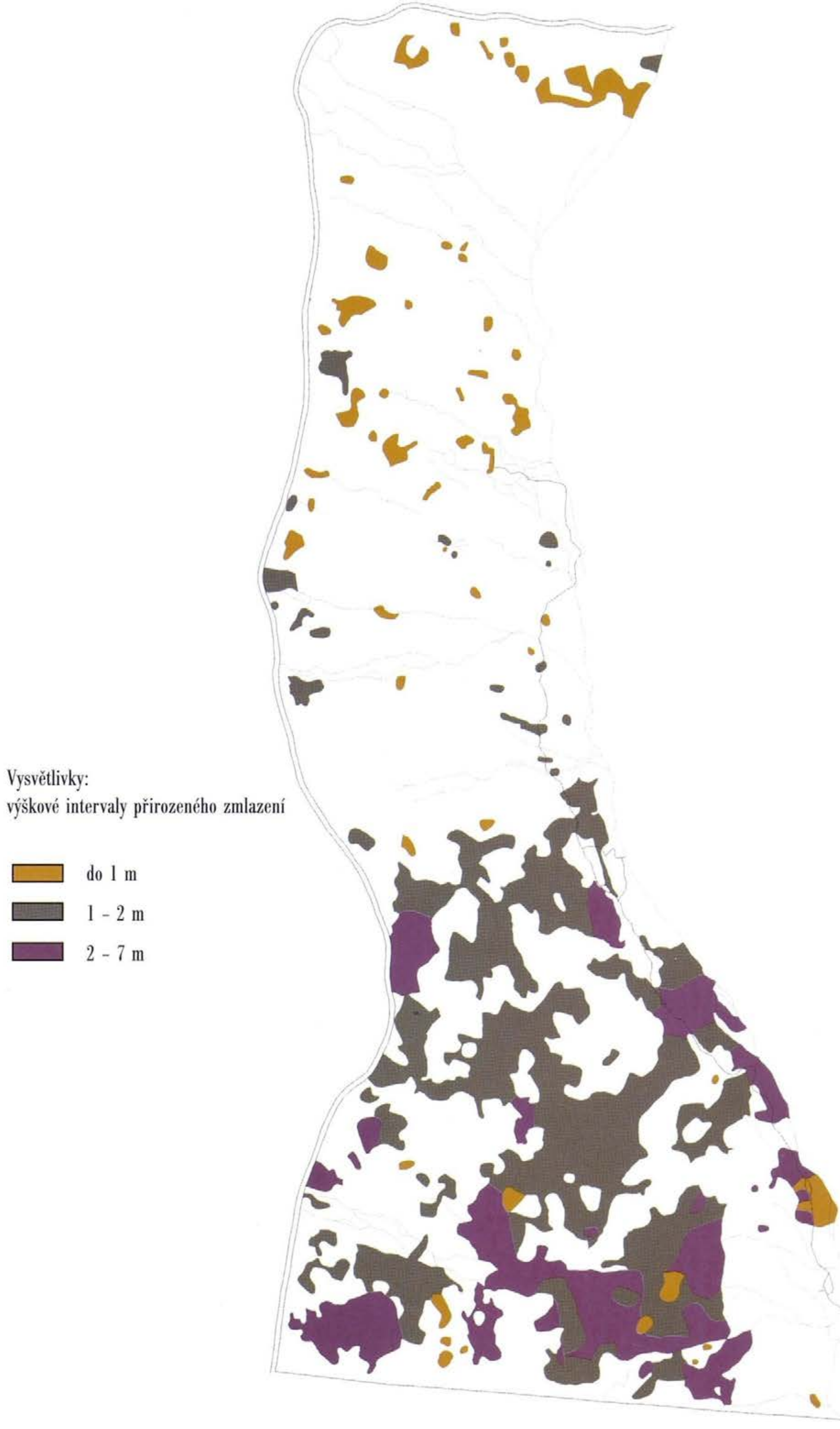
BK – většina o výšce 1 až 2 m

TopoL 22. 9. 1999

1 : 6000

AOPK ČR, det. prac. Brno, Dr. T. VRŠKA a kol. 1999

BOUBÍN 1988 – PŘIROZENÉ ZMLAZENÍ



TopoL 5. 4. 2000

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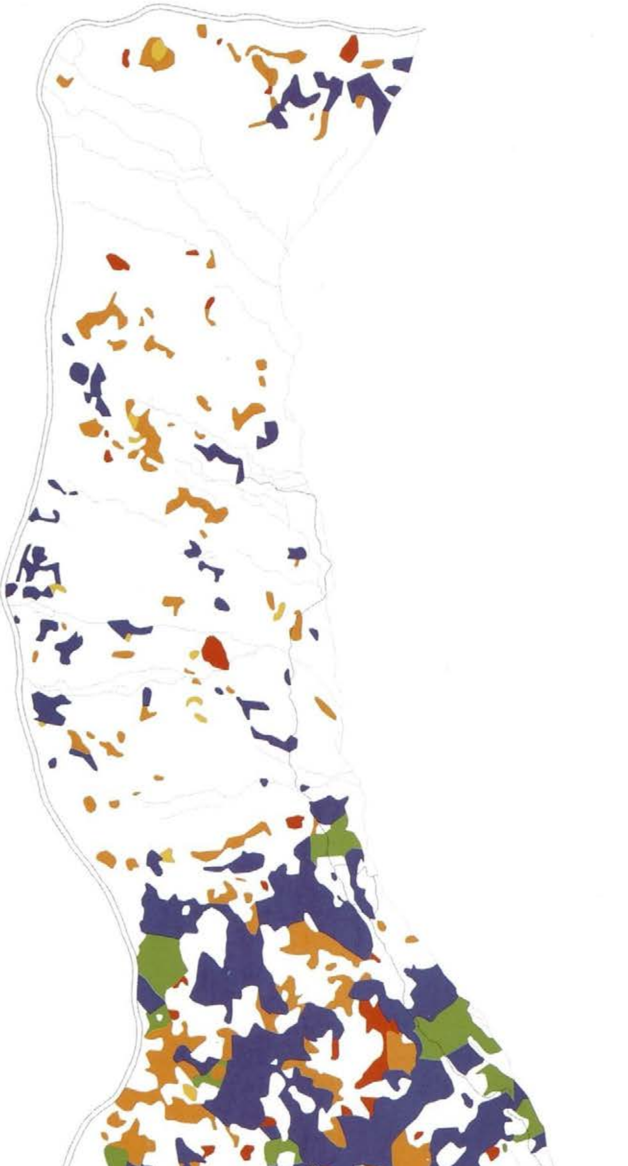
AOPK ČR, det. prac. Brno, Dr. T. VRŠKA a kol. 2000

BOUBÍN 1996 – PŘIROZENÉ ZMLAZENÍ



Vysvětlivky:
výškové intervaly přirozeného zmlazení

- do 0,5 m
- 0,5 - 1 m
- 1 - 2 m
- 2 - 4 m
- 4+ m

Topol. 5. 4. 2000

1 : 6000

AOPK ČR, det. prac. Brno, Dr. T. VRŠKA a kol. 2000

Ležící Král smrků (padl v roce 1970). Mohutný smrk v pozadí za kořenovým vývratem Krále smrků je tzv. Nástupce (v roce 1996 výčetní tloušťka 125 cm, výška 55 m) – The King Norway spruce fell in 1970. The sizeable spruce tree at the background behind the windthrow of the King Norway spruce is a so called Successor (1996: d.b.h. 125 cm; height 55 m)

Husté bukové zmlazení přesně indikuje plochy vodou neovlivněných stanovišť (6S4 – svěží smrková bučina bukovincová). Na vodou ovlivněných stanovištích (7V – vlhká buková smrčina s bikou lesní) se zmlazuje smrk pouze jednotlivě na ležících kmenech – The dense beech regeneration precisely indicates the surface area of sites not affected by water (6S4 – the fresh Norway spruce-beech stand with *Gymnocarpium dryopteris*). The regeneration of Norway spruce on water-affected sites (7V – the moist beech-Norway spruce stand with grove woodrush) occurs only on individual fallen stems

Rozsáhlé vývratiště na stanovišti svěží rašelinné smrčiny šťavelové (6R1) je typickým příkladem náhlého (katastrofického) rozpadu smrčin na podmáčených stanovištích a v této podobě je přirozenou součástí vývojového cyklu přírodního lesa na obdobných stanovištích – The extensive windthrow area on the site of the fresh peat Norway spruce stand with Oxalis (6R1) is a typical example of a sudden (disastrous) disintegration of the Norway spruce stands on the water-logged sites, being in this form a natural component of the natural forest evolution cycle on the sites of a similar character

Table 14. Sums of tree species according to the timber to the top of 7 cm o.b. (1961) or the stems respectively at the whole area

		Living trees			Dead trees				Virgin forest total	Living trees (%)	Dead trees (%)
		intact trees	fractures	total	dead standing trees	stubs	fallen	total			
Norway spruce	1961	17,750.00		17,750.00	1,612.00		?	1,612.00	19,362.00	53.0	
	1972	*16,807.59*		*16,807.59*				*4,827.17*	*21,634.76*	*52.8*	*47.3*
	1996	19,370.57	10.36	19,380.93	1,333.12	124.69	3,853.89	5,311.7	24,692.63	53.8	48.7
silver fir	1961	4,533.00		4,533.00	713.00		?	713.00	5,246.00	13.5	
	1972	*3,791.07*		*3,791.07*				*3,228.83*	*7,019.90*	*11.9*	*31.6*
	1996	1,725.19		1,725.19	940.55	370.69	2,271.24	3,582.48	5,307.67	4.8	32.9
European beech	1961	11,232.00		11,232.00	581.00		?	581.00	11,813.00	33.5	
	1972	*11,187.19*		*11,187.19*				*2,153.15*	*13,340.34*	*35.1*	*21.1*
	1996	14,805.91	25.13	14,831.04	145.81	194.88	1,637.31	1,978.00	16,809.04	41.2	18.1
Total	1961	33,515.00		33,515.00	2,906.00		?	2,906.00	36,421.00	100.0	
	1972	*31,840.26*	*0.00*	*31,840.26*	*0.00*	*0.00*	*0.00*	*10,213.31*	*42,053.57*	*100.0*	*100.0*
	1996	35,961.48	35.49	35,996.97	2,423.65	691.02	7,786.87	10,901.54	46,898.51	100.0	100.0

Note: In 1961 data (ŘEHÁK 1964), deadwood values are not stated

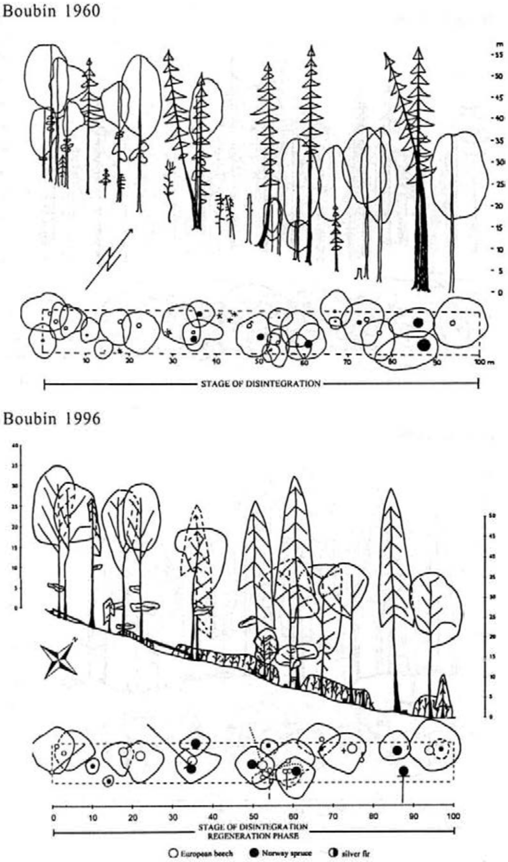


Fig. 13. Transect IIa

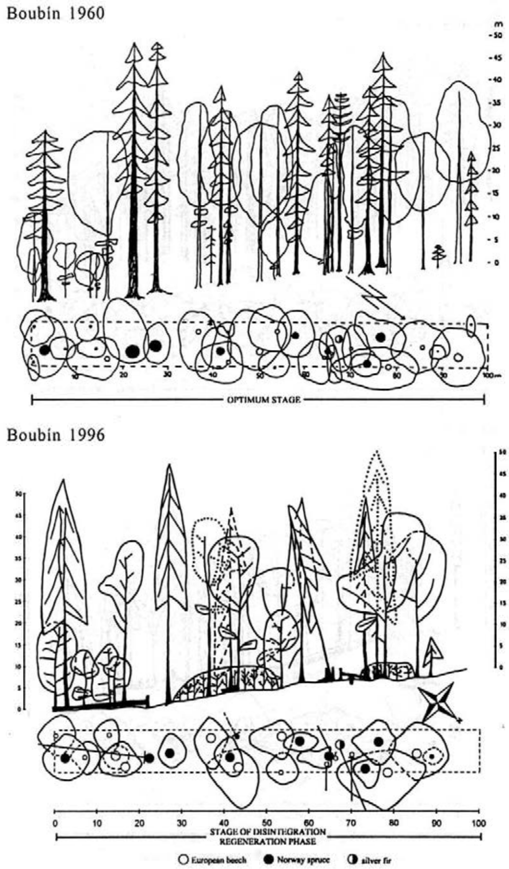


Fig. 14. Transect IIb

1972 can be considered a clear response of the virgin forest to fencing erected in the years 1965–1966 when the impact of red deer before the fencing was so severe that it did not make possible the growth of any natural regeneration (with the exception of dispersed isolated individuals). More continuous stretches of beech regeneration from 1972 came to existence particularly in the southern half of the area with a greater representation of water-unaffected sites (Fig. 1) on which the only regenerating tree species is beech and where the forest stand largely shows the stage of disintegration. On these sites, light conditions facilitated the regeneration of fir and beech already earlier, in the initial phase of the stage of disintegration but seedlings were eaten by the game with no exception. Later on, with the gradual opening of the stand (developing stage of disintegration) spruce could have regenerated too but was blocked by browsing as well. The fencing brought a sudden change of conditions for the natural regeneration, and the species which got specialized in regeneration at different light intensities (fir-beech-spruce in the gradient severe shade-mild shade-semishade) due to the long-term competitive pressure were all of a sudden put on the "starting line" under nearly uniform light conditions comparable with those of semishade. Furthermore, beech in particular formed for years browsed "brushes" which were about 10–20 cm high and with root systems of good quality. The winner was naturally decided on in advance. In 1972, the beech regeneration took up 11.17 ha (24% virgin forest area) and was almost undifferentiated (height 1–2 m).

In the period 1972–1988, the growing-up regeneration responded to light conditions of its microlocalities with diverse growth intensities and a greater (and desirable) differentiation occurred both in terms of height and area. Apart from this there were some additional regeneration

Table 15. The most sizeable live trees in the core part of the Boubín virgin forest National Nature Reserve in 1996

	d.b.h. (cm)	Height (m)
Spruce Successor	129	**57**
Spruce	**142**	52.5
Fir	137	**55**
Beech	77	**45.5**
Beech	**91**	36

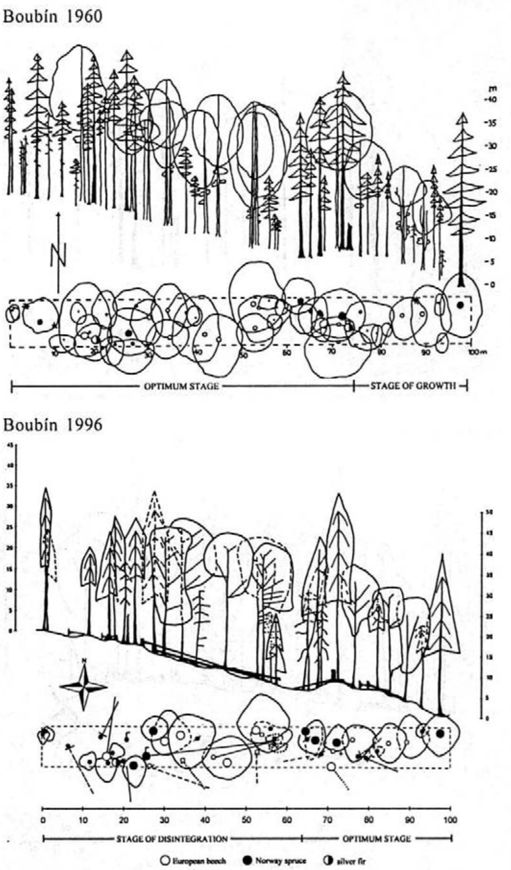


Fig. 15. Transect IIIa

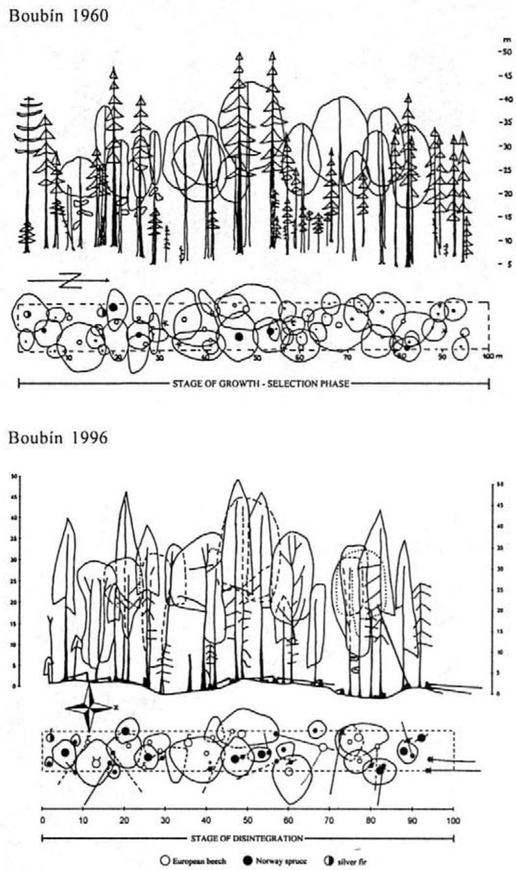


Fig. 16. Transect IIIb

plots coming into existence and the total area became as large as 12.50 ha (27% virgin forest area) in 1988. Beech was still the dominant species as its dense advance growths did not provide enough light to fir. Spruce and fir were regenerating individually outside the beech groups.

And there were more changes in the differentiation of natural regeneration before 1996. The size of individual plots within a certain height interval decreased and the total area of natural regeneration slightly increased up to 13.93 ha (30% virgin forest area). The lower height classes (0.5–1.0 m and 1–2 m) include representations of spruce and rowan because there are more than just a few isolated individuals. Outside these areas there are both individuals and small groups (several individuals at a distance of about 0.5–2 m) of regenerating spruce and fir, which successfully grow up (seedlings have several whorls at the increasing distance). Sycamore shows a sporadic occurrence at some places.

In the year 2000, the dispersed regenerations of fir and spruce exhibit a clear stabilization particularly in the south-eastern part of the virgin forest. An important representation is that of the generation old about 4 to 5 years. The area of the disastrous disintegration in 1993 (red colour in the tree map) is beginning to be grown through. However, a portion of the seedlings shows signs of browsing and the virgin forest exhibits signs of roe deer presence.

Stand structure and texture

The development of virgin forest structure in the period 1960–1996 is illustrated in Figs. 11–18. There is no doubt that the stand structure in the whole virgin forest was simplified due to the long-term impact of red deer in the 20[th] century. Parts with a more complicated structure in the selection phase of the stage of growth were gradually shifted into the stage of optimum with only one main storey which rather exceptionally exhibited a greater height differentiation because the new generation was missing colts (transects Ia – Fig. 11; IIIb – Fig. 16; IVa – Fig. 17). Stands which proceeded into the stage of disin-

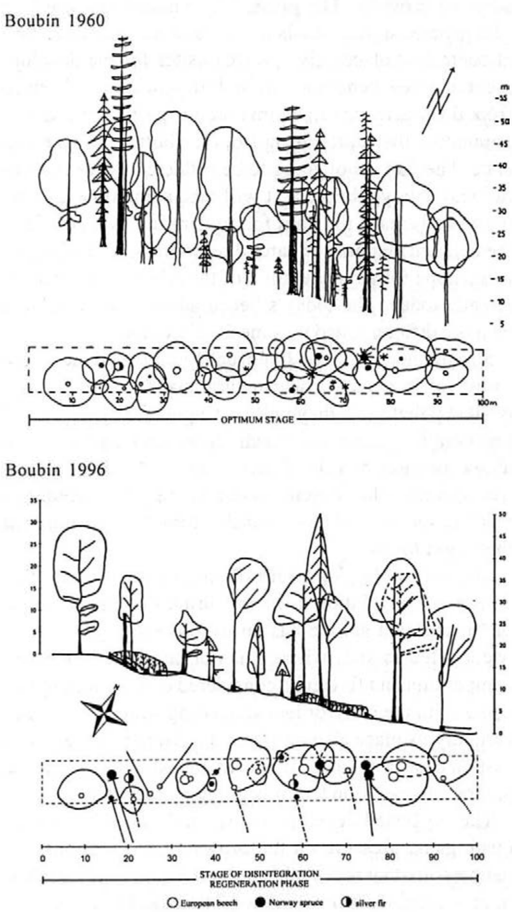


Fig. 17. Transect IVa

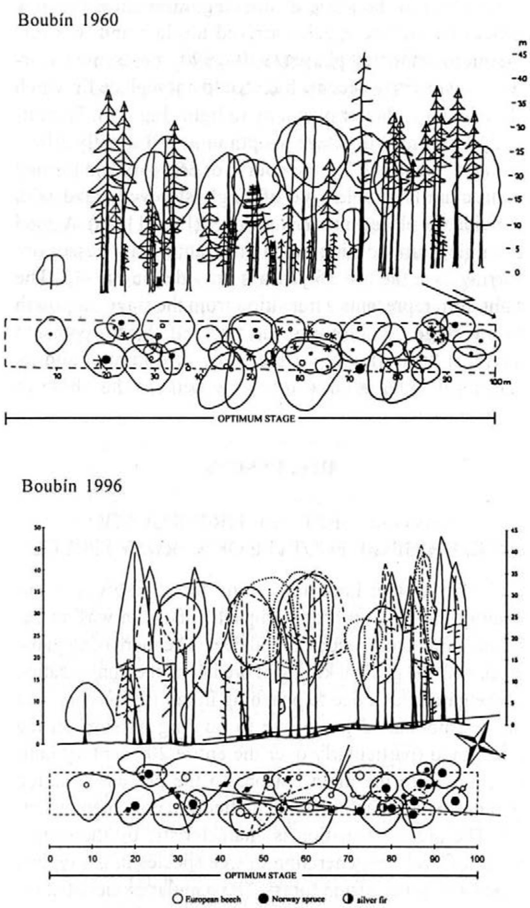


Fig. 18. Transect IVb

tegration were not followed by a new generation of tree species (regeneration phase) which made the stage of disintegration unnaturally lengthy (transect IIa – Fig. 13). The main storey canopy closure was gradually shrinking with the disintegration of groups with originally interconnected crowns. Transects from the year 1960 show the two above mentioned models of development and the fully enclosed, structurally simpler stages of optimum (transects Ib – Fig. 12; IIb – Fig. 14; IIa – Fig. 13) or the transition from the stage of growth to the stage of optimum (transect IVb – Fig. 18).

It was only the fencing of the virgin forest in 1965–1966 that enabled a spontaneous development of the new generation of tree species thus triggering a new structural differentiation of the virgin forest. The stage of disintegration was added the phase of regeneration (Fig. 13, right quarter of Fig. 11), a majority of plots in the stage of optimum moved over to the stage of disintegration, the phase of regeneration, and began to form a more complex two- up to three-storeyed structure (Figs. 12, 14, 17). The surviving plots of the selection phase of the stage of growth, filling nearly the entire growing space, gradually appeared themselves in the stage of disintegration since the new generation of tree species arrived too late and was furthermore in the first phase (1970–1990) represented nearly exclusively by beech which could not replace fir which shows a much better plasticity to light (Fig. 16). The initially newly arriving stage of optimum, still slightly differentiated, "matured" in the course of 36 years and formed a structurally simple type of single-storeyed stand with individually placed intermediate trees (Figs. 11, 18). A good example, summarizing the main structural processes occurring over the last 35 years is provided in Fig. 15. The right third represents a transition from the stage of growth to the stage of optimum, the two left thirds represent a typical "maturation" of the stage of optimum and its starting disintegration (up to now without the phase of regeneration).

DISCUSSION

SURVIVAL OF SILVER FIR POPULATION AND ORIGINAL ECOTYPE OF NORWAY SPRUCE

Unlike in other important virgin forest reserves of our country the only anthropic impact in Boubín was an extremely fluctuating stock of red deer. The increasing game stock with the gradual killing of predators, the minimization of the game stock due to poaching in the 19th century, and the overpopulated game due to hunting passion on the other hand (particularly over the entire 20th century until fencing) were the main reasons to the present situation (a range of side factors being difficult to document exactly). The present situation is characteristic by the disturbance of cyclic regeneration of tree species in the typical beech-fir-spruce virgin forest. The popular model of alternating beech generations with generations of fir and spruce was presented in a simplified form as early as in 1883:

"A view of experienced foresters is that the leafy trees: beech alternating with coniferous: spruce and fir formed overgrowths at the time of 500 years return. In the first period the fast growing conifers took over the young and long developing beech trees which formed the undergrowth in the second period; later in the third period when the conifers developed into the overgrowth, repeatedly sowing the soil with seeds, by this way preparing the coniferous undergrowth." (CHADT 1883).

The existing condition of the populations of three main species might be somewhat pesimistic at the first sight, especially so with regard to the maintenance of fir in this Reserve as a species and to the conservation of autochthonous ecotype of mountain spruce as an extraordinarily valuable genetic material also for the surrounding commercial forests and naturally also for the remaining – non virgin forest – part of the existing Reserve (666 ha). Both developmental curves and mensurational tabular data indicate that the decrease of measured quantities has not stopped – with one exception. There are natural regenerations of fir and spruce which grow mainly at places where beech did not succeed in forming continuous advance growths. The present increments and position of regenerated individuals in the stand (situation in 2000) at controlled places give pre-requisites for the development of a new generation of both fir and spruce. Viewed from this angle we can claim that it is particularly the fir population that starts rising from the bottom of its existence. The fact is not going to be reflected by the mensurational data yet because it will take some time that the individuals reach the limit for registration. Nevertheless, the detailed mapping of natural regeneration gives us justified hope for a regeneration of the silver fir population already today. The today's beech advance growths will be more differentiated in some 50–70 years.

Should there be some live fructifying firs in the virgin forest (or in adjacent near-natural stands in the today's NNR) by that time, they will find a possibility of gradual regeneration under the beech storey and will start the above mentioned cycle of alternating main stand-forming tree species. The present randomly dispersed seedlings that will survive will most probably form the mid-storey of the virgin forest.

The same holds for spruce. Perhaps with a remark that its present population does not shrink that much as that of fir, and that spruce has an irreplaceable position on water-affected sites where it is not threatened by beech competition and fir can be considered competitor only on edges with the more or less stagnating water. Spruce has certainly its place also on water-unaffected sites and it is assumed on the basis of recent investigations into its natural regeneration that it is going to keep it as well.

The suggested development is conditioned by an adequate game pressure on the browsing of seedlings, i.e. the pressure that will enable at least a quarter up to a half of individuals to grow. This condition can be met only by permanent fencing at the present time. Although there might be individual heads of game making their way into the virgin forest, they cannot do too much damage as in the unfenced virgin forest which would become a unique chamber for both red and roe deer game thanks to good shelter, abundant natural food and quiet.

DISASTROUS DISINTEGRATION ON WATERLOGGED SITES

Spruce stands on waterlogged sites, often with peat soils, demonstrated even in the Boubín virgin forest their capacity of rather fast regeneration after a sudden (disastrous) whole-area disintegration. The originally 2 to 4 m high layer of fallen trees set down at some places to a half after seven years from the disintegration (red coloured surface in the tree map), i.e. in the period 1993–2000, and the tangle starts to be grown through by a colourful mixture of tree species – rowan, willow, beech, fir, spruce, sycamore – each species on a microlocality fitting its requirements. The spontaneity (which is by the way made possible by the fact that the tangle is inaccessible to game) is a good evidence that the large-scale disintegration does not necessarily always mean an entire extinction of the ecosystem and its degradation (or the degradation of developed soils) into pre-climax stages. However, a condition to this is the existence of climax communities in the immediate surroundings. Also, this will limit the size of disintegrated areas – there will never be hundreds of hectares where for example climatic regulation of the surrounding stand would be impossible, which enables among other to maintain the existing soil environment.

Main problem to understand these processes in the management of forest territories under special protection becomes time. All of us have fixed in our minds the magic 2 legal years for reforestation of clear-cut areas and the subsequent five years for establishment of the plantations and we somehow ignore the fact that this technical element (however beneficial to maintain at least the minimum criteria of the existence of the commercial forest) is an absurdity in the natural forest. Although the virgin forest grows still at the same pace, the human impatience to see results of work grows with the acceleration of human activities.

GENERAL EVALUATION

Based on detailed historical surveys, the Boubín virgin forest can be considered a singular example of the preserved stand of virgin-forest character. The sole significant influence controlling the development of the virgin forest was hoofed game whose stock was regulated by man.

There were practically no larger fluctuations of main mensurational indicators in the period under study 1960–1972–1996, expressing the values for the whole area of the virgin forest under study although sudden disintegrations of the existing stand occurred at a number of places, the population of silver fir exhibits clear signs of ageing and decay, etc. The fact confirms the unique character of the Boubín virgin forest and demonstrates the viability and stability of virgin forest formations that have been left to the spontaneous development on a sufficiently large continuous area.

The representation of fir showed a pronounced shrinkage the loss being compensated for by the increased participation of beech. Norway spruce has kept its dominant position in the virgin forest. The number of live trees slightly decreased but the stem volume of live trees increased which gives evidence of general virgin forest ageing. Nevertheless, 30% of the surface is covered by the continuous advance growth with dominant beech. The advance growths are so far below the registration limit of mensurational measurements; however, a greater structural differentiation of the virgin forest and hence a new balance of some parameters (number of trees versus their volume, etc.) is expected to occur in the future. Spruce and fir successfully regenerate at fitted places outside the beech advance growths and are accompanied by other interspersed tree species. It can be assumed that the population of silver fir will be gradually regenerated similarly as the spruce of local mountain ecotype.

CONCLUSIONS FOR THE FURTHER DEVELOPMENT OF THE TERRITORY

The results of repeated investigations led to the following recommendations:

- Notwithstanding all disputable consequences of complete fencing of the virgin forest, this is considered to be the only solution that can ensure a relatively spontaneous development of the forest. This is why the fencing must be kept in good condition and the game which accidentally gets into the forest must be hunted or forced out.
- The virgin forest should not be subject to any intentional measures.
- The measure-less zone can include stands above the Lukenská road (within the existing National Nature Reserve), whose structure and species composition meet the criteria for their classification with the stands of virgin forest character (stands 134 A, 134 C) and in which a pre-requisite exists of long-term stability.
- On the other hand, the measure-less zone should not include other stands in the existing NNR of Boubín virgin forest, which do not meet the criteria of structural (age) differentiation, species representation and genetic origin. These stands should be preferrably subjected to active measures aimed at a greater structural differentiation of the stands, active introduction of missing target species, possibly existing species of suitable origin. The stands in question are those between the Horní Basumská road and the Basumský ridge (stands 135 A-C, 134 B, D), in the vicinity of Boubín Mt. peak (compartment 127) and in the surroundings of hunting lodge (compartment 129).

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Boubínský prales po 24 letech (1972–1996) – vývoj stromového patra

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ABSTRAKT: V roce 1996 byla provedena opakovaná měření taxačních, typologických a porostních charakteristik v národní přírodní rezervaci Boubínský prales. Tyto úkony následovaly po výzkumu provedeném v roce 1972 s použitím stejné metodiky a následným vyhodnocením změn, k nimž ve sledované oblasti došlo. Došlo k výraznému poklesu zastoupení jedle a tento úbytek byl nahrazen zvýšenou účastí buku. Dominantní postavení si v pralese udržel smrk. Počet živých stromů mírně klesl, naopak stoupl objem kmenů živých stromů. Celkem 30 % plochy pralesa je pokryto souvislým nárostem s dominancí buku. Na vhodných místech mimo bukové nárosty se úspěšně zmlazuje jedle i smrk s doprovodem dalších vtroušených dřevin. Lze předpokládat, že postupně dojde k obnově populace jedle bělokoré i k obnově smrku. Je navržen další management rezervace.

Klíčová slova: dynamika; sledování; prales

Boubínský prales lze na základě podrobných historických průzkumů považovat za ojedinělý příklad dochovanosti pralesovitého porostu. Jediným významným vlivem, působícím na vývoj pralesa, byly člověkem ovlivňované stavy spárkaté zvěře.

V roce 1996 bylo na území původní pralesovité rezervace provedeno opakované šetření dendrometrických, typologických a porostních charakteristik. Práce navazují na původní šetření z roku 1972, byly provedeny stejnou metodikou a následně byly vyhodnoceny změny, ke kterým na sledovaném území došlo.

Ve sledovaném období 1960–1972–1996 prakticky nedošlo k výraznějšímu výkyvu hlavních dendrometrických ukazatelů, vyjadřujících hodnoty za celou sledovanou plochu pralesa, a to přesto, že na řadě míst došlo k náhlým rozpadům stávajícího porostu, dochází k výraznému stárnutí a odumírání populace jedle bělokoré apod. Tato skutečnost potvrzuje jedinečnost Boubínského pralesa a dokazuje životaschopnost a stabilitu pralesovitých útvarů, ponechaných samovolnému vývoji na dostatečně velké souvislé ploše.

Došlo k výraznému poklesu zastoupení jedle a tento úbytek byl nahrazen zvýšenou účastí buku. Dominantní postavení si v pralese udržel smrk. Počet živých stromů mírně klesl. Naopak stoupl objem kmenů živých stromů, což svědčí o celkovém stárnutí pralesa. Celkem 30 % plochy je však pokryto souvislým nárostem s dominancí buku. Tyto nárosty jsou zatím pod registrační hranicí dendrometrických šetření, v budoucnu však dojde k větší strukturální diferenciaci pralesa a k vyrovnání některých ukazatelů (počet stromů versus jejich objem apod.). Na vhodných místech mimo bukové nárosty se úspěšně zmlazuje jedle i smrk s doprovodem dalších vtroušených dřevin. Lze předpokládat, že postupně dojde k obnově populace jedle bělokoré i k obnově smrku zdejšího horského ekotypu.

Na základě výsledků opakovaných šetření je doporučeno:

- I přes všechny diskutabilní důsledky, které přináší úplné oplocení pralesa, je to v současné době jediné řešení, zajišťující jeho relativně přirozený samovolný vývoj. Proto je třeba trvale udržovat oplocení v provozuschopném stavu a podle možností lovit či vytlačovat ven zvěř, která se do pralesa dostane.
- V pralese by neměly být prováděny žádné úmyslné zásahy.
- Do bezzásahového režimu je možné zařadit porosty nad Lukenskou cestou (v rámci stávající národní přírodní rezervace), které svou strukturou i dřevinnou skladbou splňují kritéria pro zařazení mezi porosty pralesovitého charakteru (porosty 134 A, 134 C) a je u nich předpoklad dlouhodobé stability.
- Naopak do bezzásahového režimu nezařazovat ostatní porosty ve stávající NPR Boubínský prales, které nesplňují kritéria strukturální (a tedy i věkové) diferenciace, druhového zastoupení a ani genetického původu. V těchto porostech je žádoucí aktivně provádět zásahy vedoucí k větší strukturální diferenciaci porostů – aktivní vnášení chybějících cílových dřevin, příp. přítomných dřevin, ovšem vhodného původu. Jedná se zejména o porosty mezi Horní Basumskou cestou a Basumským hřebenem (oddělení 135 A-C, 134 B, D), v okolí vrcholu Boubína (oddělení 127) a loveckého zámečku (oddělení 129).

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Qualitative analyses of the Norway spruce seeds *Picea abies* (L.) KARST.

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ABSTRACT: This article contains the specific knowledge of detailed qualitative analyses of Norway spruce seeds from the Krkonoše Mts. Anatomical analyses, biochemical analyses and tests of germination were realized in 8 different samples. Unusual results were obtained – polyembryony, incompletely developed embryos and abnormally germinating seeds.

Keywords: Norway spruce seeds; detailed analyses; incompletely developed seeds; polyembryony; abnormally germinating seeds

Seeds with low germination or nongerminating seeds have accounted for a large portion of Norway spruce seed production (SIMANČÍK 1965). Different chemical and physical methods were used to stimulate seed germination (TIMONIN 1966; WEINBERGER et al. 1978). Their practical use has not been verified yet. There is not much information about biochemical and cytogenetic seed analyses (BUCCI et al. 1997).

The seed quality is investigated by the biochemical tetrazolium test and germination test (ČSN 48 1211 Zkoušky jakosti plodů a semen lesních dřevin [Fruit and Seed Quality Tests in Forest Tree Species]; BASRA 1995; REHAP 1983). It is only known according to the cytogenetic analyses that a standard karyotype of the Norway spruce contains 24 chromosomes (PAZOURKOVÁ, PAZOUREK 1960), and the first genetic linkage map of a single tree was solved (BUCCI et al. 1997).

It is clear according to the mentioned information that no complex qualitative information of the Norway spruce seeds has been available till now. That is why the aim of this experiment was to study the vitality and quality of seeds, germination and different anomalies during the germination processes.

MATERIAL AND METHODS

Seeds of the Norway spruce (8 samples) from the Krkonoše Mts. (altitude 950–1,050 m a.s.l.) were examined. Water content was 7.8–8.8% in different samples of seeds. The total quantity of each seed sample (100 g) was divided into 4 parts (4 × 100 seeds from each sample) for different analyses. Other seeds were stored.

These seed analyses were carried out:

a) content of full seeds (4 × 100 from each sample), according to the Standard ČSN 48 2111 Jakost plodů a semen lesních dřevin (Fruit and Seed Quality Tests in Forest Tree Species),

b) anatomical structure – content of vital and nonvital seeds (4 × 100 from each sample) analysed by the longitudinal section under the stereomicroscope Olympus (magnified 5 times), as nonvital seeds were considered those seeds in which embryos were smaller than 2/3 of the longitudinal length of the axial duct and seeds with 2 and more embryos – polyembryony,

c) biochemical analysis – study of the seed vitality by a modified tetrazolium test – the development and colour were examined in a longitudinal section (4 × 100 seeds of each sample) under the stereomicroscope Olympus (magnified 5 times), nonvital seeds had another colour than red,

d) the tests of germination were carried out after anatomical and biochemical analyses of each sample (according to the Standard ČSN 48 1211 Jakost plodů a semen lesních dřevin [Fruit and Seed Quality Tests in Forest Tree Species]). Some anomalies were registered during the processes of germination. Data on germinative energy, germination, data from analyses of seed qualities were statistically processed by calculating the arithmetic means and using one-factor analysis of variance.

RESULTS

Results of the detailed qualitative analyses (based on anatomical and biochemical tests and germination tests) are given in Table 1.

Data in Table 1 show that the content of full seeds was between 78.8 and 95.5% in different samples. The content of nonvital seeds according to the anatomical analyses ranged from 1.2% to 67% and according to the biochemical analyses from 1.9% to 11.2%. The polyembryony was

Table 1. Results of qualitative analyses and germination tests of the Norway spruce seeds

Sample	Content of full seeds (%)	Anatomical analyses (%)		Biochemical analyses (%)			Germination tests (%)		
		vital	nonvital	vital	nonvital	polyembryony	germinative energy	germination	anomalies
SM 1	88.8	97.8	2.2	95.3	3.4	1.3	13.8	67.5	0.0
SM 2	91.5	93.8	5.2	91.0	5.5	3.5	11.3	61.5	2.5
SM 3	83.5	98.8	1.2	95.8	1.9	2.3	14.5	62.3	2.0
SM 4	94.0	93.3	6.7	88.5	10.5	1.0	0.8	45.3	7.3
SM 5	87.0	96.0	4.0	94.3	5.2	0.5	14.0	64.5	3.3
SM 6	95.5	94.5	5.5	91.8	6.9	1.3	12.5	59.5	2.3
SM 7	87.0	95.8	4.2	93.0	6.7	0.3	12.3	63.5	0.8
SM 8	78.8	94.0	6.0	88.0	11.2	0.0	6.0	43.3	8.0

Fig. 1. The atypically germinating Norway spruce seed

evident in 7 samples and accounted for maximally 3.5%. The results of germination tests show that germinative energy was 0.8–14.5% and germination amounted to 43.3–67.5%. Anomalies during the germination tests were found in seeds of 7 samples and they accounted for 8%. They germinated abnormally – by green parts of epicotyls (see Fig. 1).

Fig. 1 illustrates the atypically germinating Norway spruce seed.

Fig. 2 shows a completely developed embryo of the Norway spruce seed as seen under an electron microscope REM-JSM-35-Jeol.

Statistical analyses document a significant relation between altitude and content of full seeds. Similar results were obtained between altitude and anatomical analyses,

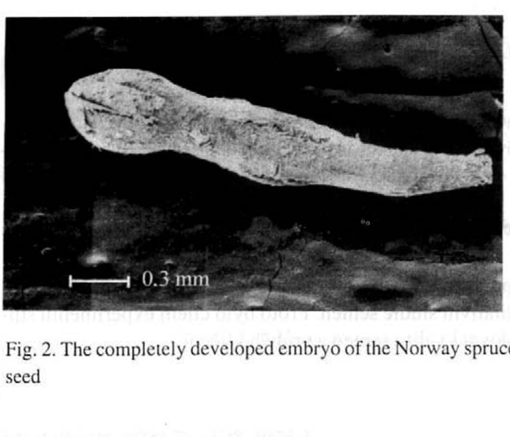

Fig. 2. The completely developed embryo of the Norway spruce seed

between altitude and biochemical analyses. A significant relation was registered between altitude and other qualitative characteristics of the germination tests.

Results of these investigations are very important for a more complex study to be carried out in future.

DISCUSSION

Referring to the knowledge of some authors (LEADEM 1988; REHAP 1972), this study was concerned with some important aspects, qualitative analyses, germination tests and anomalies of the Norway spruce seeds from the Krkonoše Mts.

Analogously to the study of LOKVENC and ŠTURSA (1985), who studied the germination of Swiss Mountain Pine seeds from different regions of the Krkonoše Mts. and according to my own research (HRABÍ 1993), the seed vitality and morphological development of Norway spruce seeds showed similar abnormalities. Some atypical changes in the seed structure probably influenced the process of germination. A complex of extreme factors could cause the polyembryony and incompletely developed embryos. It is possible that the most frequent negative factors were air pollution and UV radiation at these high altitudes. Incompletely developed embryos as well as polyembryony were documented in all samples. These phenomena have not been established yet. Contrary to other authors (BEWLEY, BLACK 1986; KHAN 1977), another atypical aspect of germinating seeds was observed during this experiment – some seeds germinated by green parts of epicotyls. These results cannot be compared with results of other researchers (BUCCI et al. 1997) because the aim of their studies was not analogous. Beside some external factors, there could be some internal ones contributing to obtained results – incompletely developed pollen grains, failure of pollination and fertilization and probably some mutations. Many other precise analyses have to be conducted in future (BUCCI et al. 1997).

CONCLUSION

A lot of atypical changes in the Norway spruce seeds were observed during this experiment. These structural and germination changes have not been established in the studied areas yet. Some polyembryonal seeds were detected by a modified tetrazolium test. Their number was different in different samples (maximally 4%). Data of the germinative energy were very low in all samples, but the results of germination ranged from 43% to 68%. Atypically germinating seeds were evident during this study and amounted to 8% maximally. This study is the basis for subsequent recommended investigations:

- To study the Norway spruce seeds and their embryos by precise biochemical methods based on the content of growth regulators.
- To study surrounding conditions – air and soil pollution.
- To carry out karyologic studies.

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Kvalitativní analýzy semen smrku ztepilého *Picea abies* (L.) KARST.

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ABSTRAKT: V článku jsou zahrnuty údaje o detailních kvalitativních analýzách osiva smrku ztepilého z různých lokalit Krkonoš. Anatomické analýzy, biochemické analýzy a zkoušky klíčivosti byly aplikovány u osmi oddílů semen. Byly registrovány také neobvyklé údaje – polyembryonie, nekompletně vyvinutá embrya i atypicky klíčící semena.

Klíčová slova: semena smrku ztepilého; detailní analýzy; nekompletně vyvinutá semena; polyembryonie; atypicky klíčící semena

V poslední době je velká část produkce osiva smrku z horských oblastí tvořena semeny s nízkou klíčivostí. Bývají používány různé fyzikální a chemické metody stimulace klíčení, jejichž účinek v praxi nebyl dostatečně prokázán. Také nebyly dosud uskutečněny komplexní kvalitativní studie semen. Proto bylo cílem experimentu studovat kvalitu semen a průběh klíčení.

Výzkum byl realizován na semenech osmi oddílů z Krkonoš (z nadmořských výšek 950–1 050 m). Modifikované detailní analýzy byly prováděny za účelem zjištění podílu plných semen a anomálií v jejich anatomii, také se hodnotil průběh klíčení a získané údaje byly statisticky zpracovány.

V tab. 1 jsou shrnuty výsledky experimentu. Obr. 1 dokumentuje atypicky klíčící semeno smrku a obr. 2 znázorňuje kompletně vyvinuté embryo.

Z výsledků je zřejmé, že podíl plných semen se u jednotlivých oddílů lišil. Polyembryonie byla registrována jen pomocí modifikovaného tetrazoliového testu a dosáhla až 4 %. Průběh klíčení byl pozvolný. U sedmi oddílů byla zjištěna i atypicky klíčící semena (až 8 %), která klíčila zelenými děložními lístky. Byl zjištěn statisticky průkazný vztah mezi nadmořskou výškou a jednotlivými kvalitativními charakteristikami.

Z uskutečněné studie vyplývá, že kvalitativní rozbory semen řezem pod stereomikroskopem informují o jejich vývinu, ale modifikovaný tetrazoliový test je lepším ukazatelem jejich anatomické a biochemické kvality, neboť je možné spolehlivě registrovat i polyembryonii. Polyembryonie a semena klíčící zelenými děložními lístky jsou neobvyklé úkazy, které dosud nebyly detekovány a je velmi obtížné vysvětlit, čím byly způsobeny. V závěrečné části článku je doporučeno několik perspektivních metod dalšího výzkumu.

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The evaluation of height growth of wild pear (*Pyrus pyraster* [L.] Burgsd.) progenies from different regions of Slovak Republic

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ABSTRACT: Wild pear is considered to be an exceptional wild fruit tree. It is distinctive by its longevity, good growth abilities and by quite a large ecological amplitude in relation to soil moisture. It is a light-demanding tree, which produces fine timber with an interesting colour. Therefore the wild pear should be widely plant not only in the countryside but also in the mixed oak forests. Within the research project of the wild pear variability in Slovak Republic, 21 experimental plots with wild pear were established and 364 pear individuals were evaluated. In the paper the growth of the open pollinated wild pear progenies was evaluated and the purpose was to find differences in the growth abilities of the wild pear progenies from different environmental conditions. During two years height growth of 18 pear provenances was evaluated. Already in the first year statistically significant differences in seedling heights were found between the progenies of different origin. It was possible to identify provenances with significantly different height growth. It was found that sowing in the open seedbeds and transplanting of seedlings at the end of the vegetative period are convenient planting methods for the successful growing of wild pear seedlings.

Keywords: seedlings; height growth; progeny testing; wild pear; provenances

Wild pear together with other fruit woody plants has become interesting for the wood-processing industry in last few years. Pear timber has a decorative colour and it is used to make unique furniture, sliced veneers, sport and health utensils and also in artistic woodcarving.

In Slovak Republic little attention has been paid until now to utilisation of this woody plant in timber production, probably because of its rare occurrence in forest stands.

Wild pear mostly occurs in the agricultural landscape. It grows as a solitary tree on balks, or in larger groups of trees on grazing lands. It is a light-demanding tree, which is tolerant to slight shading just at young age. The occurrence of wild pear in forest crops is rather sporadic, it often grows on stand margins or in open woodlands where it has a sufficient amount of light.

Besides its light requirements, the wild pear is considerably tolerant to soil conditions, it is resistant to lower soil moisture, but it can also grow in inundated territories of floodplain forests and it is resistant to extreme temperatures. Therefore it is considered as xerophytic; it is a pioneer species that can also grow at extremely hot sites with low soil moisture content.

In Slovak Republic the wild pear grows mainly in southern parts of the country – Ipeľsko-rimavská brázda, lowlands of the Danube river (Podunajská nížina), part of the Slovenský kras and south-western part of Východoslovenská nížina (PENIAŠTEKOVÁ 1992). It was also found at localities in a northern direction from the above-mentioned territories, in the area of Bukovské vrchy (Zboj), Javorníky (Kolárovice) and Kysucká vrchovina (Horný Vadičov, Nová Bystrica, Kysucký Lieskovec) (PAGANOVÁ 1996). In the Slovak territory the wild pear grows to an altitude 800 m above sea level, the highest location is in Párnica at the altitude 1,063 m (BLATTNÝ, ŠŤASTNÝ 1959).

Except the nonforest landscape, the wild pear could enforce itself in competition with other woody plants only at such sites where it was in advantage. More frequent occurrence of wild pear was found in sparse forest steppe communities with *Quercus pubescens* and in broken topography of carbonates. The wild pear seldom grows in the 3rd (oak-beech) or in the 4th (beech) altitudinal zone. It also grows in the drier types of floodplain forests where it has larger dimensions.

Since 1994 more detailed research focused on the variability of wild pear populations has been conducted in Slovak Republic. In 1994–1996 a classification was elaborated for evaluation of trunk and crown qualitative traits of wild pear for forestry purposes. This classification was tested on several experimental plots. Variability of the evaluated qualitative traits of pear individuals was demonstrated. Very good qualitative characteristics (thin branches, straightness of trunk and its good cleaning, individuals without twisted growth) were found on several trees. Little damage was observed in the evaluated set of 201 wild pear individuals. The most frequent was mechanical injury of trunk (23%) which appeared mainly on individuals growing on grazing lands, the rate of trees with rotten knots and swells was very low (3%) (PAGANOVÁ 1996). According to the obtained results, it is possible to suppose the wild pear resistance to some biotic and abiotic pathogens.

Considering the growth characteristics and resistance of wild pear, this plant could be widely established in forest crops and substitute some of the more sensitive woody plants in connection with expected global climatic change. The establishment of wild pear in forestry practice requires profound knowledge of its biological characteristics, ecology and also selection of suitable ecotypes and individuals with good phenotypic characteristics.

MATERIAL AND METHODS

In 1997–1999 21 experimental plots were established in the Slovak territory and 364 individuals of wild pear were analysed. Majority of them were solitary trees, or they formed small groups of plants on former grazing lands, sites near fruit orchards, bulks, or at the edge of forest stands. The environmental characteristics of 18 analysed plots are given in Table 1.

The height and trunk diameter at breast height (d.b.h.) were measured and qualitative traits of crown and trunk were evaluated according to the elaborated classification of all wild pear individuals (PAGANOVÁ 1996).

Fruits were collected from each evaluated tree on the experimental plot and after seed extraction the seed samples representing each experimental plot were obtained that were used in progeny tests. The seeds were placed in a refrigerated store for 8 weeks and stratified in damp sandy medium at a temperature 3–4°C. After the stratification they were sown on the biological base Stráže of the Forest Research Institute in Zvolen (altitude 330 m a.s.l.).

A part of the seeds (90) from each experimental plot was sown to plastic pots with substrate, the rest of the seed samples were sown onto open seedbeds. The heights of one and two years old seedlings were measured to the nearest 1 mm, the seedlings from seedbeds and potted plants were measured separately.

18 provenances (localities) of the wild pear were evaluated (Fig. 1), the first measurements of one-year old seedlings were done at the end of vegetative period in autumn 1998 and the second measurements in 1999.

The obtained data were evaluated separately for each provenance (locality) and summary statistics were computed. The influence of origin on the height growth of wild pear seedlings was evaluated by one-way analysis of variance. The significance of height differences between the mean values of particular provenances was evaluated by Tukey's test on 95% confidence level.

RESULTS AND DISCUSSION

EVALUATION OF THE HEIGHT GROWTH OF THE WILD PEAR PROGENIES IN THE FIRST YEAR (1998)

A total of 851 container-grown seedlings was evaluated in 1998 which represented 18 provenances of the wild pear. The average height of the whole population was 59.96 mm, heights of the plants were very variable (s_x = 23.78 mm, $s_{x\%}$ = 40%) and they ranged from 14 mm to 208 mm. 2,060 seedlings growing on the open seedbeds were evaluated which represented 14 provenances of the wild pear. The average height of the seedlings from this population was 95.33 mm, with standard deviation (s_x) 46.37 mm, coefficient of variance ($s_{x\%}$) 49% and range 10–398 mm.

A large variability of the seedling height was found in the population of containerised seedlings and population of seedbed plants. These differences in the values of height growth between the progenies (coming from different localities) were statistically significant in both populations mentioned above (Tables 2 and 3).

The results of analysis of variance show a significant influence of the seed origin on the height growth of seedlings. It means that there are possibly some more or less strong ecotypes within wild pear intraspecific variability, similarly like in other woody plant species.

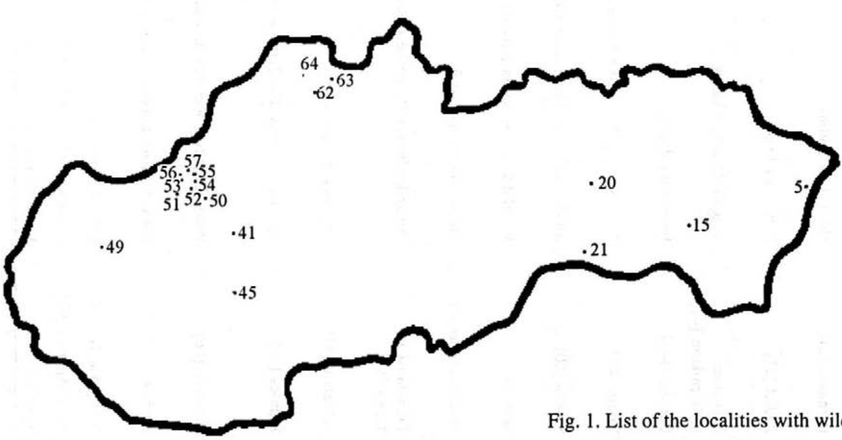

Fig. 1. List of the localities with wild pear in Slovak Republic

Table 1. Environmental characteristics of the wild pear localities

Locality	Geomorphological unit	Forest enterprise	Exposure	Altitude (m)	Description of stand conditions and species structure
Ubľa [5]	Vihorlat Ublianska pahorkatina	Sobrance	SW-S	250–300	meadows with holding covers, *Carpinus betulus*, *Malus sylvestris*, *Crataegus* sp., *Prunus spinosa*, *Rosa* sp.
Dargov [15]	Slánske vrchy Mošník	Košice	SE	290–340	grazing land, *Fagus sylvatica*,, *Quercus robur*, *Acer platanoides*, *Acer campestre*, *Crataegus* sp., *Prunus spinosa*, *Viburnum opulus*
Richnava [20]	Hornádska kotlina	Margecany	E-NE	480–530	grazing land, *Acer campestre*, *Populus tremula*, *Crataegus* sp., *Prunus spinosa*, *Viburnum opulus*, *Ligustrum vulgare*
Zádiel [21]	Slovenský kras	Košice	S	250–300	slope basis, low density forest, *Fagus sylvatica*, *Alnus glutinosa*, *Carpinus betulus*, *Pinus sylvestris*, *Padus racemosa*, *Cornus mas*, *Prunus spinosa*
Kamenec p.Vtáčnikom [41]	Vtáčnik Vysoký Vtáčnik	Partizánske	N-NW	420–470	stand margin, *Fagus sylvatica*, *Carpinus betulus*, *Acer campestre*, *Malus sylvatica*, *Crataegus* sp., *Rosa* sp.
Čaradice [45]	Pohronský Inovec	Topoľčianky	S-SE	280–300	grazing land, *Fagus sylvatica*, *Carpinus betulus*, *Acer campestre*, *Malus sylvatica*, *Crataegus* sp., *Rosa* sp., *Prunus spinosa*
Trstín [49]	Malé Karpaty Brezovské Karpaty	Smolenice	SE	350	grazing land, *Quercus robur*, *Quercus cerris*, *Fraxinus excelsior*, *Cerasus avium*, *Robinia pseudoacacia*, *Crataegus* sp., *Prunus spinosa*, *Corylus avellana*
Svinná [50]	Strážovské vrchy Hornianske predhorie	Trenčín	SE	280–300	bulks and holding covers, *Quercus cerris*, *Acer campestre*, *Crataegus* sp., *Prunus spinosa*, *Rosa* sp.
Selec [51]	Považský Inovec Vysoký Inovec	Trenčín	S	400–500	grazing land, *Carpinus betulus*, *Acer platanoides*, *Sorbus torminalis*, *Tilia cordata*, *Crataegus* sp., *Prunus spinosa*, *Corylus avellana*
Mníchova Lehota [52]	Strážovské vrchy Ostrý	Trenčín	S	320–400	grazing land, *Fagus sylvatica*, *Acer campestre*, *Sorbus torminalis*, *Cornus mas*, *Crataegus* sp., *Rosa* sp.
Trenčianska Turná [53]	Považský Inovec Považské podolie	Trenčín	plain	300–350	grazing land, *Quercus robur*, *Fagus sylvatica*, *Acer campestre*, *Cerasus avium*, *Tilia cordata*, *Robinia pseudoacacia*, *Betula pendula*, *Crataegus* sp., *Rosa* sp., *Frangula alnus*
Soblahov [54]	Strážovské vrchy Ostrý	Trenčín	SW	350	grazing land, *Crataegus* sp., *Acer campestre*, *Cerasus avium*, *Crataegus* sp., *Cornus mas*, *Swida sanguinea*, *Corylus avellana*
Kubrica [55]	Strážovské vrchy Trenčianska vrchovina	Trenčín	NE-SW	330–360	former grazing land, *Quercus*, *Fagus sylvatica*, *Fraxinus excelsior*, *Acer pseudoplatanus*, *Sorbus torminalis*, *Cornus mas*, *Crataegus* sp., *Prunus spinosa*, *Corylus avellana*
Zlatovce [56]	Biele Karpaty Lopenická hornatina	Trenčín	SW-SE	350	former orchards, *Quercus*, *Sorbus torminalis*, *Sorbus domestica*, *Malus sylvatica*, *Crataegus* sp., *Ligustrum vulgare*
Zamarovce [57]	Biele Karpaty Lopenická hornatina	Trenčín	plain	300	valley of the river Váh, *Quercus robur*, *Fagus sylvatica*, *Sorbus torminalis*, *Salix* sp., *Populus* sp., *Corylus avellana*
Horný Vadičov [62]	Kysucká vrchovina Kysucké bradlá	Čadca	S	500–600	grazing land, *Picea abies*, *Fagus sylvatica*, *Crataegus* sp., *Corylus avellana*
Nová Bystrica [63]	Kysucká vrchovina Vojenné	Čadca	SW-SE	750–800	protective zone of the water reservoir, *Picea abies*, *Abies alba*
Kysucký Lieskovec [64]	Kysucká vrchovina Vojenné	Čadca	SW-SE	580–620	grazing land, *Carpinus betulus*, *Corylus avellana*, *Crataegus* sp.

Table 2. One-way analysis of variance for the height of one-year old containerised wild pear seedlings

Source of variation	Sum of squares	d.f.	Mean square	*F*-value	Sig. level
Locality	989,515.51	17	5,818.5596	12.693	0.0000
Residual	381,865.28	833	458.4217		
Total (corrected)	480,780.80	850			

Table 3. One-way analysis of variance for the height of one-year old wild pear seedlings – seedbeds

Source of variation	Sum of squares	d.f.	Mean square	*F*-value	Sig. level
Locality	761,156.5	13	58,550.496	32.673	0.0000
Residual	3,666,436.4	2,046	1,792.002		
Total (corrected)	4,427,592.9	2,059			

Differences in the average height values between the particular provenances were verified by Tukey's test on 95% confidence level (Tables 4 and 5). The provenances that were not significantly different in the values of average heights are listed in a homogeneous group (with the same letter).

It is clear from the results of Tukey's test within the population of one-year old containerised seedlings (Table 4) that statistically significant differences in average heights were between the provenance Horný Vadičov with the lowest value of average height (41.98 mm) and the provenances Zádiel (83.46 mm), Ubl'a (79.81 mm), Nová Bystrica (67.63 mm), Trstín (64.19 mm), Trenčianska Turná (62.84 mm), Dargov (62.78 mm), Soblahov (61.97 mm), Zlatovce (61.80 mm), Zamarovce (61.62 mm), Čaradice (60.13 mm) and Kamenec p. Vtáčnikom (58.07 mm). The significant height differences were also between two provenances with the highest values of average height (Zádiel, Ubl'a) and the provenances Trstín, T. Turná, Dargov, Soblahov, Zlatovce, Zamarovce, Čaradice, Kamenec p. Vtáčnikom, Selec (52.55 mm), Kubrica (51.29 mm), Svinná (48.48 mm), Mníchova Lehota (48.25 mm), Richnava (44.94 mm) and Kysucký Lieskovec (43.55 mm).

The values of average height for the wild pear seedlings grown on the seedbeds are given in Table 5. Statistically significant differences in the values of average

Table 4. Average values of the height growth of one-year old containerised wild pear seedlings

Code	Locality	*N*	Average (mm)	95% Tukey's HSD intervals	Homogeneous groups
62	Horný Vadičov	47	41.98	34.25–49.71	A
64	Kysucký Lieskovec	33	43.55	34.32–52.77	A B
20	Richnava	16	44.94	31.69–58.18	A B C
52	Mníchova Lehota	55	48.25	41.11–55.40	A B C D
50	Svinná	56	48.36	41.28–55.44	A B C D
55	Kubrica	23	51.61	40.56–62.66	A B C D E
51	Selec	42	52.55	44.37–60.72	A B C D E F
41	Kamenec p. Vtáčnikom	60	58.07	51.23–64.91	B C D E F G
45	Čaradice	45	60.13	52.24–68.03	B C D E F G
57	Zamarovce	34	61.62	52.53–70.71	B C D E F G
56	Zlatovce	49	61.80	54.22–69.37	C D E F G
54	Soblahov	62	61.97	55.24–68.70	C D E F G
15	Dargov	46	62.78	54.97–70.60	C D E F G
53	Trenčianska Turná	43	62.84	54.76–70.92	C D E F G
49	Trstín	69	64.19	57.81–70.57	C F G
63	Nová Bystrica	70	68.79	62.45–75.12	E G H
5	Ubl'a	60	78.87	72.03–85.71	H
21	Zádiel	41	83.46	75.18–91.74	H
Total		851	59.96	58.15–61.78	

Table 5. Average values of the height growth of one-year old wild pear seedlings – seedbeds

Code	Locality	N	Average (mm)	95% Tukey's HSD intervals	Homogeneous groups
15	Dargov	842	80.00	76.54–83.47	A
51	Selec	7	85.71	47.73–123.70	AB
52	Mníchova Lehota	93	85.75	75.33–96.17	ABC
63	Nová Bystrica	100	89.76	89.76–99.81	ABCD
62	Horný Vadičov	86	91.87	81.03–102.71	ABCD
45	Čaradice	70	93.44	81.43–105.46	BCDE
49	Trstín	149	101.97	93.74–110.21	BCDE
5	Ubľa	479	103.50	98.91–108.09	B DE
21	Zádiel	17	115.00	90.62–139.38	B DEF
56	Zlatovce	70	126.10	114.09–138.11	B F
54	Soblahov	58	127.66	114.46–140.85	B F
57	Zamarovce	37	140.57	124.04–157.09	B F
41	Kamenec p. Vtáčnikom	10	147.60	115.82–179.38	B EFG
53	Trenčianska Turná	42	176.21	160.71–191.72	G
Total		2,060	95.33	93.12–97.54	

height were found between the provenance Trenčianska Turná (176.21 mm) and the other evaluated provenances except the provenance Kamenec p. Vtáčnikom (147.60 mm). Similarly, between the provenance Dargov (80.00 mm) and the provenances: Čaradice, Trstín, Ubľa, Zádiel, Zlatovce, Soblahov Zamarovce, Kamenec p. Vtáčnikom, Trenčianska Turná.

A comparison of the results for one-year old seedlings confirmed that the values of average height of seedlings on the seedbeds were significantly higher than those within the population of the container-grown seedlings. For example seedlings of the provenance Soblahov which were grown on the seedbed had the average value of height 127.66 mm while the seedlings of this provenance which were grown in the containers had the average value of height only 61.97 mm.

EVALUATION OF THE HEIGHT GROWTH OF THE WILD PEAR PROGENIES IN THE SECOND YEAR (1999)

During 1999 the progenies were kept at the same place and their height was measured at the end of vegetative period.

848 wild pear plants grown in containers were evaluated and the average value of the height within the whole population was 238.12 mm. The heights of particular plants were very variable (s_x = 100.17 mm, $s_{x\%}$ = 42%), they ranged from 65 mm to 675 mm. 1,723 wild pear seedlings were evaluated on the seedbeds. The average value of their height within the whole population (268.51 mm) was higher than within the population of the container grown plants. The values of height of the two-years old seedlings

Table 6. One-way analysis of variance for the height of two-year old containerised wild pear plants

Source of variation	Sum of squares	d.f.	Mean square	F-value	Sig. level
Locality	2,568,135.1	17	151,066.77	21.143	0.0000
Residual	5,930,226.1	830	7,144.85		
Total (corrected)	8,498,361.2	847			

Table 7. One-way analysis of variance for the height of two-year old wild pear plants – seedbeds

Source of variation	Sum of squares	d.f.	Mean square	F-value	Sig. level
Locality	1,914,446	13	147,265.06	9.731	0.0000
Residual	25,712,290	1,699	15,133.78		
Total (corrected)	27,626,736	1,712			

on the seedbeds were also very variable (s_x = 127.03 mm, $s_{x\%}$ = 47%) and they ranged from 20 mm to 814 mm.

In both these populations quite a high variability of the values of progeny height was found and a statistically significant influence of the seed origin on the height growth of two-years old container grown plants and plants on the seedbeds was confirmed (Tables 6 and 7).

Average values of the height were calculated for each provenance in both evaluated populations and statistical significance of their height differences was also tested.

A comparison of the average values of height within the population of two-years old containerised wild pear seedlings (Table 8) showed that the best growing provenances were Ubľa (339.64 mm), Dargov (328.30 mm) and Zamarovce (325.47 mm). The worst growing provenances (with the lowest value of average height) were provenances Kysucký Lieskovec (148.90 mm), Richnava (156.86 mm) and Horný Vadičov (161.91 mm).

Among the progenies grown on seedbeds (Table 9), the best growing provenances in the second year were Kamenec (494.20 mm), Trenčianska Turná (380.46 mm) and Zamarovce (360.96 mm). The weak growing provenances were Horný Vadičov (232.44 mm), Mníchova Lehota (243.66 mm), Nová Bystrica (252.61 mm) and Ubľa (254.16 mm).

A comparison of the average values of height (Tables 8 and 9) shows some reduction of the height differences between containerised plants and seedlings on the seedbeds. The average values of height of the containerised and free growing plants were very similar within some provenances, for example within the provenance Mníchova Lehota, Nová Bystrica, Zádiel. This similarity of the height growth in 1999 was probably a result of the seedling growth on the seedbeds with a plastic covering on the ground. The seedlings were grown without transplanting there and they could not develop their root system into deeper layers.

Several provenances had well-balanced growth rates in both evaluated years 1998 and 1999. For example, within the population of the containerised plants the provenances Horný Vadičov, Kysucký Lieskovec, Richnava and Kubrica were weak-growing progenies. On the contrary, the provenances Nová Bystrica, Ubľa, Zádiel were strong-growing progenies with a high growth rate. A fixed growth rate was also observed in the provenances Selec, Kamenec p. Vtáčnikom and Soblahov (Tables 6 and 8).

Some division of the provenances according to their growth rate has also appeared in the seedlings growing on the open seedbeds. Within this population (Tables 7 and 9) in both evaluated years the weak-growing provenances were Mníchova Lehota, Nová Bystrica, Horný Vadičov and the strong-growing provenances were Trenčianska Turná, Kamenec p. Vtáčnikom and Zamarovce.

It is difficult to compare the growth abilities of those progenies that were grown as containerised and free-growing plants (on the seedbeds) because they could be influenced by different growth conditions, for example there were different conditions for growth and development of the root system and also different sowing density on the seedbeds. With respect to future evaluation of the wild pear, it is very important to find the provenances

Table 8. Average values of the height growth of two-year old containerised wild pear plants

Code	Locality	N	Average (mm)	95% Tukey's HSD intervals	Homogeneous groups
64	Kysucký Lieskovec	31	148.90	111.33–186.47	A
20	Richnava	14	156.86	100.95–212.76	AB
62	Horný Vadičov	44	161.91	130.37–193.45	ABC
56	Zlatovce	49	170.20	140.32–200.09	ABC
55	Kubrica	20	192.50	145.72–239.28	ABCD
51	Selec	37	197.11	162.72–231.50	ABCD
50	Svinná	60	201.08	174.08–228.09	ABCD
41	Kamenec p. Vtáčnikom	62	215.74	189.18–242.31	BCD
49	Trstín	70	218.41	193.41–243.42	BCD
53	Trenčianska Turná	42	220.71	188.44–252.99	BCDE
45	Čaradice	49	230.25	200.36–260.13	B DEF
52	Mníchova Lehota	59	247.41	220.17–274.64	DEF
54	Soblahov	57	247.72	220.01–275.43	DEF
63	Nová Bystrica	69	271.71	246.53–296.89	EFG
21	Zádiel	42	290.00	257.72–322.28	FGH
57	Zamarovce	32	325.47	288.49–362.45	GH
15	Dargov	47	328.30	297.78–358.81	H
5	Ubľa	64	339.64	313.49–365.79	H
Total		848	238.12	230.94–245.31	

Table 9. Average values of the height growth of two-year old wild pear plants – seedbeds

Code	Locality	N	Average (mm)	95% Tukey's HSD intervals	Homogeneous groups
15	Dargov	842	80.00	76.54–83.47	A
62	Horný Vadičov	57	232.44	193.74–271.13	A
52	Mníchova Lehota	88	243.66	212.52–274.80	A
63	Nová Bystrica	98	252.61	223.10–282.12	A
5	Ubľa	438	254.16	240.20–268.12	A
49	Trstín	127	260.63	234.71–286.55	A B
45	Čaradice	60	264.62	226.90–302.33	A B
15	Dargov	608	264.91	253.06–276.76	A B C
21	Zádiel	19	275.26	208.24–342.29	A B C D
56	Zlatovce	67	280.76	245.07–316.45	A B C D E
54	Soblahov	47	328.94	286.32–371.55	B D E F
51	Selec	6	356.83	237.56–476.10	A B C D E F G
57	Zamarovce	47	360.96	318.34–403.57	D F G
53	Trenčianska Turná	41	380.46	334.84–426.09	D F G
41	Kamenec p. Vtáčnikom	10	494.20	401.81–586.58	G
Total		1,713	268.51	261.45–275.57	

with different growth abilities, for example for tests of their adaptability to extreme environmental conditions.

In spite of the variability of the evaluated populations (containerised and seedbed-grown plants), it was possible to identify the provenances with well-balanced growth rate for the whole evaluated period. Within the containerised plants the provenances Ubľa, Zádiel, Horný Vadičov, Kysucký Lieskovec and Richnava had the well-balanced growth rate.

The provenance Ubľa as well as the provenance Zádiel (Slovenský kras) are from Eastern Slovakia (Vihorlat). They had a very high growth rate. In 1998 they reached the average heights 79.81 mm (Ubľa) and 83.46 mm (Zádiel) and in 1999 their average heights were 339.64 mm and 290.00 mm. In both evaluated years the average heights of these provenances were significantly different from the average heights of provenances Horný Vadičov (41.98 mm, 188.91 mm) and Kysucký Lieskovec (43.55 mm, 148.90 mm), both originating from Kysucká vrchovina, and also of the provenance Richnava, which is from Hornádska kotlina (44.94 mm, 156.86 mm). The provenances Horný Vadičov, Kysucký Lieskovec and Richnava were weak-growing progenies for the whole of the evaluated period.

Within the seedbed-grown provenances of the wild pear, the statistically significant differences of the average heights were found between the weak-growing provenances (Mníchova Lehota, Nová Bystrica, Horný Vadičov) and the provenances Trenčianska Turná, Kamenec p. Vtáčnikom a Zamarovce which were the best-growing in the evaluated period.

The provenance Mníchova Lehota from Strážovské vrchy had lower average heights (85.75 mm and 243.66 mm) than were the values of the average height of all evaluated progenies, similarly like the provenances Nová Bystrica (89.76 mm, 252.61 mm) and Horný Vadičov (91.87 mm, 232.44 mm), both from Kysucká vrchovina. On the contrary, the provenances Trenčianska Turná (origin from Považský Inovec), Kamenec (origin from Vtáčnik) and Zamarovce (from the Biele Karpaty) had significantly high growth rates and their values of average height exceeded the average height of all the evaluated provenances.

Within the comparison of both planting techniques (in plastic containers and on the seedbeds) for the whole evaluated period (in both years), the weakest growth was determined in the provenance Horný Vadičov originating from Kysucká vrchovina (altitude 500–600 m) and the best growth characteristics were observed in the provenance Zamarovce originating from Biele Karpaty (altitude 300 m).

The influence of the progeny origin on the growth abilities of the wild pear provenances was confirmed not only within this evaluation but also within the investigation of the wild pear adaptability to water stress in 1999 (PAGANOVÁ 2000). Four progenies (Zádiel – Slovenský kras, Mníchova Lehota – Strážovské vrchy, Dargov – Slánske vrchy and Trstín – Malé Karpaty) were included in testing and their height growth was estimated. The impact of water stress on plant growth was statistically highly significant and its influence on height growth was negative in comparison with the control plants. Statistically significant differences in the values of average heights were confirmed between the particular two-years old progenies which were growing in conditions of water stress. Differences were statistically significant between the provenances Zádiel (226.60 mm) and Mníchova Lehota (423.20 mm) as well as between provenances Zádiel (226.60 mm) and Trstín (349.40 mm).

If the above-mentioned results are compared with the growth evaluation of two-years old containerised plants of the same origin, some differences in their growth abilities are found. In the conditions of regular irrigation no statistically significant differences in average height values between the provenances Zádiel (290.00 mm) and Mníchova Lehota (247.41 mm) were confirmed. Significant differences were found only between the provenances Zádiel (290.00 mm) and Trstín (218.41 mm).

In connection with the obtained results, it is important to mention the growth rate of the provenance Trstín. During the testing in conditions of water stress this provenance did not show any statistically significant differences in the average height values between stressed plants (349.40 mm) and control plants (394.40 mm) (PAGANOVÁ 2000). Unlike the other provenances, Trstín reduced its growth rate insignificantly in response to water stress. However, in the conditions of full irrigation this provenance was even a weaker-growing progeny (the value of average height was 218.41 mm).

It is necessary to verify the obtained results of progeny characteristics and their growth abilities within a larger investigation. Already these findings show possible occurrence of ecotypes among the wild pear populations in Slovak Republic. These ecotypes can have different growth rates and their responses to water stress can also be different.

CONCLUSIONS

The evaluation of height growth of the wild pear progenies from several regions of Slovak Republic showed significant differences in the growth rate of progenies coming from different environmental conditions. A significant influence of the progeny origin on seedling growth was confirmed, and significance of the growth differences between the provenances increased with their age.

During the two years it was possible to identify weaker- and stronger-growing progenies while differences in their growth rates were statistically highly significant.

It was found that planting onto the seedbeds is a more suitable planting technology for the wild pear than sowing its seeds directly in the containers. One-year old wild pear seedlings planted on the seedbeds were nearly twice higher than containerised plants. These differences were quite balanced in the second year of wild pear planting and in several provenances seedlings growing on the seedbeds and containerised plants reached similar values of average height.

With respect to a reduction in height growth of the wild pear plants that were growing the second year without transplanting, it will be necessary to transplant them at the end of the first vegetation period.

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Hodnotenie výškového rastu potomstiev hrušky planej (*Pyrus pyraster* [L.] Burgsd.) z rôznych oblastí Slovenskej republiky

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ABSTRAKT: Hruška je považovaná za výnimočnú planú ovocnú drevinu. Vyznačuje sa dlhovekosťou, dobrým rastom a pomerne širokou ekologickou amplitúdou vo vzťahu k pôdnej vlhkosti. Je to svetlomilná drevina, ktorá produkuje kvalitné, farebne zaujímavé drevo. Preto by v budúcnosti mohla nájsť širšie uplatnenie nielen v krajine, ale tiež v zmiešaných spoločenstvách teplých dubín. V rámci výskumu premenlivosti populácií hrušky planej bolo na Slovensku v rokoch 1997–1999 založených 21 pokusných plôch a celkovo sa analyzovalo 364 jedincov tejto dreviny. V práci sa venovala pozornosť rastu semenáčikov hrušky planej z voľného opelenia s cieľom zistiť prípadné odlišnosti v rastových reakciách potomstiev, ktoré pochádzali z rozličných podmienok prostredia. Hodnotil sa výškový rast 18 proveniencií hrušky v dvojročnom období 1998 a 1999. Už v prvom roku sa zistili štatisticky významné rozdiely vo výškovom raste medzi provenienciami rozličného pôvodu. Podarilo sa identifikovať proveniencie s preukázateľne odlišnou intenzitou výškového rastu. Zistilo sa, že pri pestovaní hrušky planej je výhodnejší výsev na voľné záhony a preškôlkovanie rastlín na konci vegetačného obdobia.

Kľúčové slová: semenáčiky; výškový rast; testy potomstiev; hruška planá; proveniencie

Hruška sa v poslednom období spolu s ďalšími planými ovocnými drevinami dostáva do popredia záujmu spracovateľov dreva. Dôvodom je farebne zaujímavé drevo, ktoré sa využíva na výrobu nábytku, športových a zdravotníckych potrieb ako aj v umeleckom rezbárstve.

Hruška planá sa okrem kvalitného dreva vyznačuje aj toleranciou voči vlastnostiam pôdy a pomerne širokou ekologickou amplitúdou vo vzťahu k pôdnej vlhkosti. Ako výrazne svetlomilná drevina by v budúcnosti mohla nájsť širšie uplatnenie v zmiešaných spoločenstvách teplých dubín.

Na Slovensku sa táto drevina vyskytuje prevažne v nelesnej krajine, na pasienkoch a v bývalých ovocných sadoch. Jej hojnejší výskyt bol zaznamenaný v riedkych lesostepných spoločenstvách, na karbonátových podložiach a suchších stanovištiach tvrdého lužného lesa. V rámci výskumu premenlivosti populácií hrušky planej sa v rokoch 1997–1999 na Slovensku založilo 21 pokusných plôch a celkove sa analyzovalo 364 jedincov. Zisťovali sa ich taxačné veličiny (výška a hrúbka) a zhodnotili kvalitatívne znaky kmeňa a koruny. Z každého jedinca sa zozbierali plody a získali súborné vzorky semien pre testy potomstiev.

Venovala sa pozornosť rastu semenáčikov hrušky planej z voľného opelenia s cieľom zistiť prípadné odlišnosti v rastových reakciách potomstiev pochádzajúcich z rozličných podmienok prostredia. Celkove bolo hodnotených 18 proveniencií (lokalít) a prvé vyhodnotenie výškového rastu semenáčikov sa vykonalo na jeseň 1998 a následne v roku 1999.

Už v prvom roku sa zaznamenali rozdiely vo výškovom raste medzi provenienciami rozličného pôvodu. Rozdiely sa prejavili aj medzi semenáčikmi rovnakého pôvodu, ktoré boli pestované na voľných záhonoch a v plastových poloobaloch. Rastliny v poloobaloch dosahovali preukazne nižšie hodnoty výšky, pričom priemerná hodnota výšky za celý súbor 851 rastlín bola 59,96 mm. V súbore semenáčikov pestovaných na voľných záhonoch (celkom 2 060 rastlín) bola priemerná hodnota výšky preukazne vyššia – 95,33 mm.

V druhom roku sa rozdiely v hodnotách výšky medzi hodnotenými súbormi rastlín zmiernili pravdepodobne aj preto, že semenáčiky na záhonoch neboli preškôlkované. Priemerná hodnota výšky rastlín pestovaných v poloobaloch bola 238,12 mm, pri semenáčikoch pestovaných na záhonoch predstavovala 268,51 mm.

Čo sa týka výškového rastu jednotlivých proveniencií, v sledovanom období sa prejavil preukazný vplyv pôvodu na ich rast. V súbore rastlín pestovaných v poloobaloch na základe priemerných hodnôt výšky v rokoch 1998 a 1999 ku najlepšie rastúcim provenienciám patrili Ubľa (79,81 mm, 339,64 mm) a Zádiel (83,46 mm, 290,00 mm). Ku najslabšie rastúcim patrili Horný Vadičov (41,98 mm, 188,91 mm) a Kysucký Lieskovec (43,55 mm a 148,90 mm), ktoré pochádzajú z najsevernejšie situovaných lokalít s hruškou v Kysuckej vrchovine. V súbore semenáčikov pestovaných na záhonoch patrili ku najlepšie rastúcim proveniencie Trenčianska Turná (176,21 mm, 380,64 mm), Kamenec (147,60 mm, 494,20 mm) a Zamarovce (140,57 mm, 360,96 mm). Ku najslabšie rastúcim patrili proveniencie Mníchova Lehota (85,75 mm, 243,66 mm), Nová Bystrica (89,76 mm, 252,61 mm), Horný Vadičov (91,87 mm, 232,44 mm).

V sledovanom období sa potvrdil vplyv pôvodu na rast potomstiev hrušky planej a podarilo sa identifikovať proveniencie s preukazne odlišnou intenzitou výškového rastu. Zároveň sa zistilo, že pri pestovaní hrušky planej je výhodnejší výsev na voľné záhony a preškôlkovanie rastlín na konci vegetačného obdobia.

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Notes to the synonymy of some forest species of the families *Otitidae* and *Lauxaniidae* (*Diptera*-Acalyptrata) in Central Europe

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ABSTRACT: The author gives evidence for the legitimacy of an independent position of the species *Otites ruficeps* (Fabricius, 1805) (family *Otitidae*). The present valid name, *Otites bacescui* Gheorghiu, 1987, is interpreted as a younger synonym (syn. nov.). Results of a comparison of the male genitalia of two species occurring in Central Europe, *Sapromyza setiventris* (Zetterstedt, 1847) and *S. obsoletoides* Schnabl, 1876 (family *Lauxaniidae*) are presented. It is confirmed that both these taxa represent in fact an identical species, i.e. *Sapromyza setiventris* (Zett., 1847) and thus the name *S. obsoletoides* Schnabl, 1876 is only a younger synonym of this species. According to the author's conclusions *S. obsoletoides* Schnabl is barely a younger synonym of *Sapromyza apicalis* Loew (PAPP 1984b).

Keywords: *Diptera*; *Otites ruficeps*; *Sapromyza setiventris*; synonymy

In 1996–2000 the author identified his own materials of *Diptera* from the above mentioned families on the one hand and collections of some other entomologists on the other hand, mainly of RNDr. B. MOCEK (Department of Natural History of the East Bohemian Museum at Hradec Králové), Prof. RNDr. M. BARTÁK, CSc. (Department of Zoology and Fishery, Faculty of Agronomy of the Czech University of Agriculture, Prague) and others. In addition, the author received a reprint of an important taxonomic paper about representatives of the family *Otitidae* in Italy (RIVOSECCHI 1995) which is based, among other things, on huge collections of Prof. Dr. C. RONDANI from the half of the 19th century. Dr. Rivosecchi could thus contribute to an explanation of the legitimacy of *Otites ruficeps* (Fabr.). After mutual agreement the author also sent some species of the family *Lauxaniidae* for a revision (comparison) to Dr. M. CARLES-TOLRÁ in Barcelona. Results of these studies and discussions are published below.

Problem of the independent position of *Otites ruficeps* (Fabricius, 1805) (family *Otitidae*)

Already in 1978 (MARTINEK 1980) the author suggested that Fabricius' species cannot be only a mere variety of *Otites formosa* (Panzer) in the Hennig's sense (1939) and in the sense of some other authors before and after him (cf. e.g. PANDELLÉ 1902; SOÓS 1957, and others). These authors did not provide the evidence of legitimacy of their standpoints by an analysis of genitalia. But on the other hand, others, partly also older authors, obviously separated *O. ruficeps* (Fabricius) from *O. formosa* Panzer (SCHINER 1864; BECKER 1905 or SÉGUY 1934, etc.) although they did not study the male genitalia of both species either. HENNIG (1939) says in his excellent monograph of this family (p. 29): "In addition to the species "*formosa* Panzer" many authors who studied this group of the species, give as the second species "*Otites ruficeps* Fabricius" which here and there is to come together with *O. formosa* and is to be different from it mainly by the red rear part of the head". SCHINER (1864) and after him also SÉGUY (1934) give a set of other differences. But because these differences are not significant, I cannot consider the "forma *ruficeps*" as a distinct species, but I must see it as a red-headed individual variety of the typical form of *O. formosa* occurring at many sites. Altogether, HENNIG (1939) had only 3 comparable specimens of this species to his disposal from Hendel's collection and it is not clear from his text if he had both sexes or only females and therefore the study of the male genitalia was not virtually possible at that time.

In 1978 the author (MARTINEK 1980) carried out the analysis of the genitalia of a typical male of *Otites formosa* (Panz.) and of *O. ruficeps* (Fabr.) for the first time. The male genitalia of both species are different in the form of surstyle at a glance. In the above-mentioned paper the author thus evidently distinguished *Otites ruficeps* (Fabr., 1805) from *O. formosa* (Panz., 1798). In MARTINEK (1980, Fig. 1B) the male genitalia of *Otites ruficeps* (Fabr., 1805) are figured for the first time.

Later on GHEORGHIU (1987) used Fabricius' original name "*ruficeps*" for the "variety" of *O. formosa* (Panzer) again (according to HENNIG's view 1939) though his illustration of the male genitalia is fully identical with the figure of the male genitalia of *O. ruficeps* (Fabr.) in my contribution (MARTINEK 1980, Fig. 1B) and absolutely differing from the genitalia of *O. formosa* (Panz.) (MARTINEK 1980, Fig. 1A). He has not taken into account this morphological difference of both species at all. But simultaneously he described a new species *Otites bacescui* Gheorghiu, 1987 (MARTINEK 1994).

The author of the present contribution analyzed many tens of specimens of *O. formosa* and *O. ruficeps* during his 50 years' entomological practice. But he has found no individual of *O. formosa* in Central Europe until now that simultaneously has the red lower and rear parts of the head. If the lower part was red, then it was always *O. ruficeps* Fabr., a species of smaller size compared with usually larger *O. formosa*. The latter species occurs on warmer forest-steppe-like slopes, and *O. ruficeps* is usually found there together with this larger species. The variety "*Otites formosa ruficeps*" (with the genitalia of *O. formosa* type) has not been recorded in Central Europe by the author.

Recently, RIVOSECCHI (1995) published a monograph about Italian species of the family *Otitidae* and examined an ample material from Rondani's collection. In his detailed contribution based on analyses of the genitalia of individual species, Rivosecchi documents that *Otites formosa* Panz. and *O. ruficeps* (Fabr.) (sensu RONDANI 1869) are quite distinct and well distinguished species because of their widely different form of surstyli!

Recently I sent to Dr. Rivosecchi (Rome) a copy of my contribution from 1980 and a copy of Gheorghiu's paper (1987) and asked him for his opinion on the new description published by the Romanian author. The answer (May 22, 1997) was as follows: "Thank you for your offprints and those of Gheorghiu. At last I have resolved the question of *Otites ruficeps* sensu Rondani = your *ruficeps* (Fabr.) = *bacescui* Gheorghiu."

The valid name of the species under discussion is *Otites ruficeps* (Fabricius, 1805) and the younger name *O. bacescui* Gheorghiu, 1987 is its new synonym (syn. n.). The valid name of this species, *Otites ruficeps* (Fabr., 1805), should be included in the Check-list of the *Diptera* Species of the Czech and Slovak Republics (CHVÁLA 1997) and the name *O. bacescui* Gheorg. as a synonym below it.

Problem of the synonymy of *Sapromyza setiventris* (Zetterstedt, 1847) (family *Lauxaniidae*)

In the last years the author identified the species *S. setiventris* (Zett., 1847) from various forest areas of the Czech Republic, Romania and other countries. According to the key by CZERNY (1932) it may be confused with *S. obsoletoides* Schnabl, 1876 as PAPP (1984a) also noted because the reportedly stable "colour of palpi" is actually very variable. In typically coloured specimens of *S. setiventris* the palpi (according to Czerny's key) should be yellow in the distal half and only sometimes is the extreme tip blackish and the forehead fully shining. The third antennal segment is obviously concave with widely rounded tip. *S. obsoletoides* should have the distal end of palpi black and on the contrary, the thin low stem yellow and the forehead should be dull except for lateral borders, and the area of the ocellar triangle reaches to the middle of the frons. The third segment of antennae should be straighter on the upper side. In both these forms the 3rd antennal segment is black apically. A larger number of males of both "species" from various areas of the Czech Republic and Romania were sent to a revision to Dr. M. CARLES-TOLRÁ (Barcelona). He found that the male genitalia of all specimens of both these morphologically fairly different groups are fully identical. All examined specimens belong to the same species showing a large variability in the colour of palpi and frons. This conclusion was made without studying the type specimens which were not at disposal. Both forms display a characteristic form of the third antennal segment being more or less concave along the dorsal margin and black and widely rounded apically. The frons is more or less dull (except the stripes between orbital bristles and ocellar triangle). Absolute identity of the genitalia of compared males proves that the species is identical with that described already in 1847 by Zetterstedt as *S. setiventris*.

However, PAPP (1984b) considered the name "*obsoletoides* Schnabl" on the basis of CZERNY's concept (1932) as a synonym to *Sapromyza apicalis* Loew. Nevertheless, CZERNY (1932) stated that there are two notes by Schnabl "against this interpretation: 1) the frons in "*obsoletoides*" is mostly dull whereas the whole frons is shining in *S. apicalis* Loew and 2) the cross veins in "*obsoletoides*" are considerably near each other so that their distance is equal to a half of the distance of t_p from the wing end and does not occur in the species in *S. apicalis* Loew (the distance of veins $t_a - t_p$ equals approximately to the whole distance t_p from the wing end)."

For all above-mentioned reasons and mainly because of the identity of the male genitalia the younger species "*S. obsoletoides* Schnabl, 1876" is considered to be a younger synonym (syn. n.) of *S. setiventris* (Zetterstedt, 1847).

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Poznámky k synonymice některých lesních druhů čeledí *Otitidae* a *Lauxaniidae* (*Diptera*-Acalyptrata) ve střední Evropě

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ABSTRAKT: Autor předkládá argumenty a důkazy o oprávněnosti samostatného postavení druhu *Otites ruficeps* (Fabricius, 1805) (čeleď *Otitidae*), přičemž se dosavadní platný název druhu, *Otites bacescui* (Gheorghiu, 1987), stává mladším synonymem (syn. n.). Autor dále uvádí výsledky porovnání utváření genitálií samců dvou dosavadních, ve střední Evropě se vyskytujících, druhů *Sapromyza setiventris* (Zetterstedt, 1847) a *S. obsoletoides* Schnabl, 1876 (čeleď *Lauxaniidae*). Potvrzuje se, že oba tyto taxony ve skutečnosti představují jeden zcela totožný druh, a to *Sapromyza setiventris* (Zett., 1847), takže název *S. obsoletoides* Schnabl, 1876 je mladším synonymem tohoto staršího druhu. Autor mj. také zdůvodňuje, že zařazování druhu *S. obsoletoides* Schnabl jako mladšího synonyma ke druhu *Sapromyza apicalis* Loew (PAPP 1984b) není oprávněné.

Klíčová slova: dvoukřídlý hmyz (*Diptera*); druhy *Otites ruficeps*, *Sapromyza setiventris*; synonymika

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