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Jíloviště-Strnady, 156 04 Praha 5, Czech Republic
e-mail: admin@vulhm.cz, http://www.vulhm.cz
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Contents

SOME EXPERIENCES WITH SILVER FIR (*ABIES ALBA* MILL.) VARIABILITY WITH REGARD TO THE CONDITIONS OF THE NATURAL FOREST AREA 16 - BOHEMIAN-MORAVIAN HIGHLAND

JIŘÍ ŠINDELÁŘ – JOSEF FRÝDL
FORESTRY AND GAME MANAGEMENT RESEARCH INSTITUTE,
156 04 JÍLOVIŠTĚ-STRNADY

ABSTRACT

This contribution presents an evaluation of the silver fir experimental plot no. 67 – Pelhřimov, established in forest area 16 – in the Bohemian-Moravian Highlands. The plot is at the elevation of 680 metres above see level and the trees are 28 years old. The progeny of 56 provenances are present coming from the Czech Republic, Slovakia, Poland, Romania, Bulgaria, Croatia, Austria, Germany, France and Italy. Based on evaluations of height and diameter increment, and volume production, conclusions are based on genetically conditioned values of the investigated provenances, for the locality and similar ecological conditions. The use of silver fir reproductive material is proposed for forestry practice, due mainly to its zoning. Five partial populations (stands or sets of stands) from the Czech Republic, the progeny of which proved to be successful, are suggested for classification into the category of certified units.

INTRODUCTION

Silver fir is considered as the most productive original tree species for conditions in central and western Europe. Silver fir is a high volume producer of biomass, and has many other positive properties within forest ecosystems. At present this species is irreplaceable particularly on heavy, settled gleyed soils, at mid and higher altitudes. Firs admixed in forest stands create both by volume production and also needle fall humus types, suitable for root system penetration into the deeper soil layers. This is an important factor in stand stability.

During the last decades, the decline of fir within Europe has reached an appalling level. This long-lasting phenomenon is due to many reasons, e. g. fir decline in the Křivoklátský region documented in 1810 (SVOBODA 1943), in the northern Moravia since the latter half of the 19th century (BEDNÁŘ, HOŠEK, RAYNOCH 1963). Fir decline is caused, according to the majority of authors, by a complex set of factors. Clear-felling management, and the mass use of Norway spruce and Scots pine are usually considered as the two most significant causes of this decline, as well as the ever present threat to forest stands by harmful climatic conditions (e. g. frost, drought), changes in soil chemistry, insect pests, fungal diseases, and last but not least damage by game, which prefers natural regeneration. During the last two decades, this worsening state of health of fir has slowed down, and in some cases even stopped on many localities in the Czech Republic. One can say that fir is making a slow recovery as can be observed on some localities.

In the past silver fir was a commonly distributed tree species in the forests of central Europe, thus in the Czech Republic as well. Fir was growing mainly in highlands and mountainous areas up to the degree of subalpine spruce stands which is well documented, for example in SAMEK´S (1967) work which considers fir distribution in postglacial times, and also by results from historical investigations of forests and their management, e. g. NOŽIČKA (1957), MRÁZ (1959) etc. The original distribution of silver fir in the CR forests is estimated at cca 16 % (ŠINDELÁŘ 1994, VOKOUN 1996). As already mentioned, fir prevailed to a greater or smaller amount in mixed stands, but appeared as an exception in the unmixed stands of the oak-beech and beech-spruce vegetation forest zones.

Provenance no.	Country	Name of Provenance	Region 1	Natural Forest Zone	Altitude (m)
1-15	Czech Republic	Kamenice nad Lipou, Losy	3130	16	780 - 820
16-30	Czech Republic	Jihlava, Henčov	3130	16	600
32	Czech Republic	Nýrsko, Dešenice	3054	12	500
34	Czech Republic	VLS Horní Planá, Želnava	3054	12	820
35	Czech Republic	Petrohrad, Oráčov	3054	09	400
37	Czech Republic	Rychnov nad Kn., Skuhrov nad Běl.	3051	26	400 - 600
39	Czech Republic	Červené Poříčí, Dolce	3060	06	500
40	Czech Republic	Frýdlant v Čechách, N. Město pod Sm.	3051	21	580 - 620
49	Czech Republic	Přibyslav, Hamry	3130	16	580 - 590
50	Czech Republic	Vlašim, Smilkov	3120	16	570 - 580
51	Czech Republic	VLS Lipník nad Bečvou, Podhoří	3051	39	550 - 600
53	Czech Republic	Opočno, Bolehošť	3110	26	385
58	Czech Republic	Vimperk	3054	13	800
61	Czech Republic	Velké Karlovice, Dinotice	6070	40	600
63	Czech Republic	Český Krumlov, Chvalšiny	3054	12	740 - 940
66	Czech Republic	Nýrsko, Liščí	3054	12	600
68	Czech Republic	Vyšší Brod, Běleň	3054	13	680
70	Czech Republic	Nasavrky, Maleč	3130	16	390 - 400
71	Czech Republic	VLS Plumlov, Ruprechtov	3140	30	450 - 510
74	Czech Republic	Milevsko, Klučenice	3120	10	380
75	Czech Republic	Rájec-Jestřebí, Černá Hora	3140	30	360
81	Czech Republic	Vyšší Brod, Vitkův Kámen	3054	13	800 - 900
82	Czech Republic	Vizovice, Bratřejov	6070	38	550
83	Czech Republic	Kašp. Hory, Rejštejn	3054	13	860
86	Czech Republic	VLS Hořovice, Strašice	3070	07	650
88	Czech Republic	VLS Hořovice, Mirošov	3070	07	620
93	Austria	Wörschachwald, Steiermark	5043		1100 - 1200
94	Austria	Schneegattern, Kobernausser Wald	5013		550 - 750
95	Austria	Gröbming	5043		850
102	Czech Republic	Velké Karlovice, M. Karlovice	6070	40	600 - 700
103	France	Longemer-Gerardmer	4050		840 - 890
130	Czech Republic	Nasavrky, Podhůra	3130	16	370
131	Bulgaria	Razlog, Pirin	6260		1600
132	Bulgaria	Borovec, Rila	6260		1600
143	Austria	Laterns, Vararlberg	5013		1000
146	Germany	Schwarzwald, Schönmünzach	3320		530 - 650
147	Germany	Schwäb. Fränk. Wald, Geschwend	3210		400 - 530
151	Germany	Ostbayer, Zwiesel West	3054		900

190	Czech Republic	Frenštát pod Radh., Mořkov	6063	40	500
194	Czech Republic	Karlovice, Karlovice - sever	3051	27	720
200	Czech Republic	Zábřeh, Brníčko	3051	31	410 - 477
203	Poland	Starý Sacz	6063		300
204	Poland	Susiec	6050		260
210	Czech Republic	Nové Město na Mor., Cikháj	3130	16	690
212	Polsko	Nieskurzów	6050		480
215	Romania	Vilcea	6190		800
221	Czech Republic	Janovice u Rým., Malá Morávka	3051	27	720 -730
224	Croatia	Sokolac, Kalj. Bioštica	6220		1060
228	Italy	Vallombrosa	9120		900 - 1120
230	Italy	Arch. e Boscarel.	9140		1150
231	Poland	Baligrod, 41-49	6061		580
S - 1	Slovakia	B. Bystrica, Badín	6070		800
S - 5	Slovakia	Ružomberok, Korytnica	6064		750
S - 7	Slovakia	TANAP, Kežm. Žleby	6064		900
S - 9	Slovakia	Kriváň, Snohy	6070		630
S - 14	Slovakia	Svidník, Komárnik	6061		480

Tab. 1.
List of represented provenances

Vegetation forest zone 6 – fir-beech showed to provide optimal site conditions, especially on those sites with heavier loamy soils, gleyed and partly waterlogged soils. Forest management methods employed during the years 1950 – 1991 resulted in a heavy decrease of the fir proportion from 2.8 to 1.0 % of forest area.

Until the 1990s increment of the present (and critical) fir representation within CR forests was not included into forest management plans. According to the 1991 complex forest management plan, fir regeneration was to be realized annually only on several hundred hectares within the whole CR, approximately 0.4 % of the total regenerated land area. In the late 1990s reports commenting on the desirable perspective structure of species composition in the Czech Republic were produced by both the FGMRI Jíloviště-Strnady (Šindelář 1994) and the Institute of Forest Management (Vokoun 1996). The conclusion of these reports was that the proportion of fir should be increased to 4 or 5 %. Based on the findings of these reports, the Ministry of Agriculture regulation no. 83 (from 1996 on processing regional plans for forest development and on destination of management sets) fir is planned as the ameliorative and reinforced tree species in all the management sets, except sets 19 – management of floodplain sites and 29 – management of alder sites. Silver fir is not involved as the basic tree species in any of the target management sets. The principal area for using silver fir should be principally in the sets of the 5th fir vegetation forest and the 6th spruce-beech zones, partly in the oak-beech and beech zones, mainly in the coniferous variants of these types (fir with oak and other woody species on the heavier settled soils, e. g. in the natural forest area no. 15 – South Bohemian basins, etc.). However, these proposals which provide for a marked increase of fir in the species composition of forests stands have not yet been realized, and annual regeneration by this tree species has not yet exceeded 500 ha, which amounts to less than 2 % of the total regenerated area. To accomplish the gradual increase in silver fir to a proportion of 4 - 5 % over the next 100 years would require an annual regeneration programme of 1,000 - 1,500 ha, assuming that the existing average annual regeneration area is maintained. To achieve the required proportion during the next 50 years, an area of 2,000 - 3,000 ha would need to be regenerated annually. Due to the relatively low representation of fir in the stands suitable for natural regeneration, a substantial part of that area would need to be regenerated artificially, in our conditions mostly by planting.

There remains the danger of further fir decline, the loss of gene resources and a complete decline of this tree species in a number of areas, even in those where fir was commonly growing in the past (Krušné Mts., Jizerské Mts., etc.). In the last two or three decades, measurements for the preservation and reproduction of gene resources have been carried out. This quantification has shown that silver fir, admixed, (but mostly interspersed), is growing in 70 natural forest reserves (Maršáková et al. 1977). Until now the greater number of those stand remnants having a related natural species composition is only occurring in the beech-fir vegetation zone. Fir is also appearing, as small admixture, in 56 gene bases in various CR areas (Rambousek et al. 1999). At present a relatively large stand area of 1,651.25 ha is certified for seed crop, of which 193.78 ha is of category A. These stands are mixed, so the total area (given areas relate to fir only) of classified stands runs into several thousand hectares. Relatively small areas are registered for other categories of reproductive plantings, i. e. for seed orchards 1.60 ha and for seed stands 11.43 ha. In general, the basis for possible fir reproduction – certified stands – is quite large, and is suitable for cone collecting. Those large areas of stands certified for seed crop are mainly in the natural forest area 13 – Šumava Mts. and Novohradské Mts. (e. g. former forest management unit Prachatice 60 ha, Kašperské Hory 77 ha, Horní Planá 70 ha) and in the area 40 - Moravian-Silesian Beskydy Mts. (Frenštát 64 ha, Ostravice 42 ha, etc.).

The provenance experimental plot, evaluated in this work, was established in the natural forest area no. 16 – Bohemian-Moravian Highland. Basic data on fir representation in this area are briefly presented. The average fir proportion in the area is currently 1 % (Plíva, Žlábek 1986) and corresponds with the national average; according to the individual management units it ranges from 0.4 % (forest management unit Nové Město na Moravě) to 1.3 % (forest management unit Kácov). Fir proportion in forest stands having regeneration within this natural forest zone should be 1.4 % of the total regenerated plot according to the complex forest management plan. Research results based on the evaluation of the experimental plot established in the area of the former forest management unit Pelhřimov (at present the Forests of CR, forest enterprise Pelhřimov) should be usable especially for local conditions, but also in the broader sense of the whole natural forest zone. Specific attention is given to assessing growth properties of partial populations progeny with silver fir from the natural forest zone no. 16, represented in the experiment.

At present silver fir is poorly represented in the species composition and does not belong to the economically significant woody species. Despite this, fir as a species is permanently the subject of interest of forest research and forestry practice, which is reflected, in numerous references. Published works have mostly dealt with the problems of dieback and decline, while issues concerning the further existence of this tree species are being considered. Measures for preserving silver fir as the species and the gene sources of individual regional populations are of concern, as well as the complexities of breeding fir of suitable character that should ensure these goals and make possible the effective use of fir in forest management for the future.

RESEARCH OF VARIABILITY OF SILVER FIR AND SOME OTHER SPECIES OF *ABIES* GENUS

In 1971 the Czechoslovak Academy of Sciences and the former Ministry of Forest and Water Management began the research project studying the variability and breeding of silver fir for Czech Republic use in forest management. Research in the FGMRI Jíloviště-Strnady was based on establishing comparative plots with progeny of silver fir and other species of *Abies* genus. The research was aimed at:

- the preservation of this species for CR forest management as a result of mass selection within the species *Abies alba* Mill.
- gaining information on the genetically conditioned variability of partial populations (the economically important characters and properties of individual provenances)
- proposing partial populations (provenances) for use in forestry
- deepening of theoretical experiences about silver fir variability and information on breeding as the base for further stages of breeding work
- explore the possibilities of using another of the fir species to provide a viable alternative to silver fir in the CR

During 1970 and 1971 seed samples from 153 silver fir provenances were gathered from all parts of this species original area of distribution. The efforts to gain material from the subcontinental fir area in Switzerland were however not successful. Nearly all the individual provenances were documented in detail and stored in the archive for evaluation as part of the experiment. The Czech Republic is represented by 83 items in the assortment, Slovakia by 14, while further material was collected from 10 foreign countries. This assortment can therefore be described as representative. Material from 20 natural forest zones originates from the Czech Republic, and the entire set of 153 samples includes material from 5 regions and 32 areas, with elevations ranging from 150 to 1,600 m (Rubner, Reinhold 1951). Also crops samples from individual trees were acquired in 16 partial populations, always by 15 trees, i. e. 240 items. In addition to the above, 72 provenances of 21 species of spontaneous hybrids were collected for the experimental series from many countries including Spain, Lebanon, Syria, Turkey, Greece, Caucasian republics of the former USSR, Italy, Japan, Canada, and the U. S. A.

The seed was sown in the nursery, and was mostly successful producing a yield of some 200,000 viable seedlings. The plant breeding was completed in nurseries of forest enterprises where the experimental plots were planned to be established. A total of 19 experimental plots were established from 1973 to 1977, 13 with progeny of silver fir populations, 1 plot with progeny of individual trees and 5 plots with exotic species of *Abies* genus. The planting of a specified common provenance (standard) ensured comparability between plots. All plots were wire-fenced to eliminate damage caused by game.

Central Bohemian region with beech-oak forests	
3051	Hercynian-Sudeten area of mixed mountainous forest – Sudeten subarea
3054	Hercynian-Sudeten area of mixed mountainous forest – Hercynian subarea
3060	Plzeň basin
3070	Central Bohemian Highland
3110	Czech Elbe area
3120	Interior Bohemian Highland
3130	Czech-Moravian Highland with southern foothills
3140	Drahanská Highland with northern edge
3210	Swabia-Frankish Jura
3320	Černý Forest (Schwarzwald) with foothills and Baar
Western European region with deciduous forests	
4050	Vosges
4070	French-Swiss Jura
4092	Northern French area with mixed oak forests – Norman subarea
4120	Area of Central Massif (France)
4140	Pyrenees
Alpine region	
5013	Beech-fir-spruce area of western and northern Alps – subarea of northern edges of Alps
5030	Eastern Alpine Foothills
5043	Alpine Interior – eastern subareas
5063	Southern Alpine area with beech-fir-spruce forests with larch – Venetian subarea
Eastern European and south-eastern European region with oak-beech forests	
6050	Oak-beech-fir area of Polish Foothills of Carpathians
6061	Beech-spruce-fir area of northern Carpathians – eastern subarea
6063	Beech-spruce-fir area of northern Carpathians – western Beskydy
6064	Beech-spruce-fir area of northern Carpathians – Tatra´s area
6070	Slovakian Carpathians
6100	Eastern Austrian-Burgenland Highland
6130	Southern Foothills of Slovakia Carpathians
6190	Beech-spruce-fir area of Romanian Carpathians incl. Bihar Mts.
6220	Mixed mountainous forest of Dinaric Alps
6260	Central Bulgarian Mts.
Southern European region with hard deciduous and chestnut tree species	
9120	Mountainous forest of northern Apennines
9130	Mountainous forest of central Apennines
9140	Mountainous forest of southern Apennines

Tab. 2.
Numerical list (key) of forest regions according to Rubner, Reinhold

Experimental plots with silver fir were evaluated at the age of 9 and 15 years (Hynek 1983, 1985, 1987, 1988, 1989, 1991). Investigation results of exotic fir species planted on the plot 38 – Jíloviště were processed for the age of 9 years (Šindelář 1986).

RESEARCH GOALS

This paper presents an evaluation of one of the 19 plantings on the plot no. 67 established within the Forests of CR, forest administration Pelhřimov (former forest enterprise Kamenice nad Lipou, later forest enterprise Pelhřimov). Based on the provenance assortment of silver fir and method of establishment two principal research goals are defined:

- research of silver fir population variability related to its distribution within the wider area and especially within the Czech Republic. A base for assessment of variability was (considering the entire area with the species) the regions and areas of European forests (Rubner, Reinhold 1953). In the Czech Republic the natural forest areas (e. g. Plíva, Žlábek 1986, et al.) were taken as the fundamental phytogeographical units. Evaluation of the represented partial populations according to these criteria, will give a general assessment of fir variability, and is focused on forestry practice as far as the partial populations from the Czech Republic are concerned. Information can contribute to the targeting of activities connected with silver fir seed provision and can be used for solving regionalization problem of reproductive material for this woody species.
- Results from verification of silver fir partial populations from CR can also be incorporated into the partial material for assessment of proposals for regionalization of reproductive material that has been already processed.

Height and D.B.H., i. e. elements of biomass production, are used as an evaluation criterion in this work. However, it must be remembered that these quantifiers are not always fundamental for the evaluation of fir. Fir in its natural environment regenerates only under parent stand shelterwood, its growth is reduced due to shading often for several decades. When released, fir reacts very markedly by intensive height and D.B.H. growth, often after long periods of existence in “below” and “interlevel” position within the forest structure. For this reason fir is a basic for selection forests in the ”classical“ conditions, for instance those of Switzerland, Schwarzwald, the Vosges, etc. Evaluation results based on height and D.B.H. measured on relatively young plants – i. e. 28 years - must be considered critically bearing in mind the changing growth patterns that may often be met in the later developmental stages. In contrast, the state of health should be the most significant criterion used when evaluating partial populations of silver fir, particularly in relation to vitality and species decline. In this case however, using the state of health as a prime indicator is severely limited due to the vitality and total lack of damage to the represented provenances, regardless their origin. Therefore the suitable criterion for health state classification cannot be used at present.

MATERIAL AND METHODS

Material

Regarding the available area for planting, only a limited number of silver fir provenances are represented from the locality no. 67 Pelhřimov. A survey of 65 partial populations growing on the plot is in tab. 1. Thirty three provenances originate from the Czech Republic, of which 29 are from the Hercynian-Sudeten and Carpathian natural forest zones. Five partial provenances originate from Slovakia, 4 from Austria, 3 from Germany, 1 from France, 2 from Italy, 1 from Croatia, 1 from Romania, 2 from Bulgaria and 4 from Poland. If sorted according to European regions and areas, the material is seen to originate from 5 regions and 23 areas. The majority of trees had grown on unit no. 3051 comprising the area of Hercynian-Sudeten mixed mountainous forest and Sudeten subarea, and on unit no. 3054 in the Hercynian subarea in the marginal mountains of Bohemia and north-western Moravia. Many provenances represent area no. 3130 – Czech-Moravian Highland with its southern foothills.

It can be stated that this assortment contains the partial populations from the predominant part of the silver fir area.

The origin of those partial populations from the Czech Republic is comprised of an assortment from 15 natural forest zones, i. e. from the majority of units with fir representation where fir is the original part of forest ecosystems. Seed from some of the natural forest zones was unavailable, mainly in the Krkonoše Mts. and Krušné Mts. where fir occurs sporadically and in few localities.

Provenances represented on the research plot come from various environmental conditions. Local elevation of parent stands ranges from 260 to 1,600 m (Balkans provenances no. 131 and 132 from Rila and Pirin Mts.). Partial populations from the Czech Republic are growing in the elevation range of 358 m (provenance no. 75 – Rájec Jestřebí) to 940 m (Český Krumlov, Chvalšiny).

When assessing the variability of silver fir partial populations from the Czech Republic, the classification of origin is significant when considering the sets of Hercynian-Sudeten and Carpathian natural forest zones having different historical origins (different refugees in the glacial period – Samek 1967).

Planting material was bred in the nursery at Hořepník of the former forest enterprise Kamenice nad Lipou. Two-year-old seedlings were transplanted and prepared for planting in the same way as four-year-old transplanted plants.

Methodology

In 1976 an experimental plot was established on the locality of the former forest enterprise Kamenice nad Lipou, forest district Černovice at Tábor, on locality Hutě - Lhotka in the stand $5c_1$. At an elevation of 690 m this plot is situated on a mild southern slope of a terrain wave, the top of which overlaps the elevation level of 700 m. The underlying geological base is formed by gneiss, the soil is heavy, of sandy clay loam, acidic (exchange acidity 3.50), and with an average supply of basic nutrients (analysed in FGMRI Jíloviště-Strnady in 1982). The set of forest types is classified as 5S – medium rich, fresh fir-beech stand. According to the data of the nearest meteorological station situated at Pelhřimov, the average annual temperature for the locality ranged from 6 to 7 °C, and the annual sum of precipitation was 600 – 700 mm. Planting was completed in 3 strips having been felled in a mature spruce stand of good growth and production. Each individual strip was approximately 45 to 50 m wide and ca 200 m long.

The basic planting with 49 provenances was carried out on all three clearcuts using double grid in 4 repetitions. There are 196 lots, within double grid 28 blocks, lot sizes are 10 x 10 m. Basic spacing of planting is 2 x 1 m, i. e. 50 plants per each lot, thus each provenance on the plot is represented by 200 plants. Strips 5m wide are planned which will form the plot margins. During establishment the plots were also invaded by spontaneous seeding, which was expected and afterwards confirmed (spruce, birch).

Another small available plot, connected to the basic plot, was incorporated and planted with seven available provenances in random blocks with 4 repetitions. All techniques used within this small plot (lot size, planting spacing, number of plants per provenance) were identical to the basic plot, therefore allowing both plots to be evaluated together.

The whole plot was fenced after planting and the individual lots marked off with stakes. The transplants were treated uniformly by weed inhibitors when needed. Plot development was satisfactory, mortality losses were low and did not go over 15 %. Natural seeding, above all of birch, was removed several times until the canopy became closed. A respacing operation at the age of 15 years focused on a reduction of individuals to achieve a spacing of 2 x 2 m. The cut trees were mostly used as Christmas trees.

The first measurement on the plot was carried out at the age of 9 years, and subsequently at 15 years. In both cases total height growth and height growth in the last year were measured (Hynek 1983). The third measurement (the results of which are evaluated in this contribution) was carried out in autumn 1999, i. e. at the age of 28 years. Mortality was not recorded in this developmental stage due to the respacing operation previously mentioned.

Fig. 1.
Localities with silver fir provenances comprised in the experimental series 1973 – 1977

Basic mathematical and statistical characteristics were calculated for heights and D.B.H. (tab. 4). Variability was investigated by variance analysis for two causes of variability

$$I_{ij} = \mu + p_i + o_j + e_{ij},$$

where I_{ij} is value of i-provenance in j-repetition, μ average of experiment, p_i effect of i-provenance, o_j effect of j-repetition, e_{ij} experimental error. Average effects of provenances and repetitions as well as proportions related to uncontrolled factors were solved by normal equations based on variance analysis (Weber 1961). Repetition value – heritability – was calculated from the equation.

$$h^2 = \frac{\sigma_p}{\sigma_p + \frac{\sigma_p}{O}}$$

Differences among particular provenances were examined by the Duncan´s multiple sequence test both for height growth and D.B.H.

RESULTS

An evaluation of silver fir should not omit its significant characteristics and consideration given to the species state of health and vitality of plantings. Investigation and prescribed controls during the lifetime of the plot proved that all provenances represented on the plot are fully vital. This assessment was based on the amount of foliage and needle colour on individual trees. The differences are however minimal, and therefore could not be adequately distinguished by any suitable classification scale. For this reason the health state, or vitality, of individual provenances was not evaluated.

Height growth

The results of height growth analysis of silver fir provenances on the locality no. 67 Pelhřimov at the age of 28 years can be summarized as follows:

- Growth of silver fir provenances on the experimental plot is satisfactory. Its total average corresponds with absolute yield class value of average height 26 to 28 m at the age of 100 years and is in accordance with the growth tables introduced by the appropriate Ministry of Agriculture instruction (no. 84/1996 on forest management planning).
- Average height values of provenances on the plot range widely from ca 5 to 10 m. These differences among heights are statistically significant.
- Statistical coefficients (proportions of variance belonging to particular variability factors, repeatability) document the required reliability of the experiment.
- Height growth assessment of partial populations within regions and areas of European forests shows that provenances sets from central European region of beech-oak forest grow relatively faster (values mostly above average of the experiment), while provenances from the other regions are mostly retarded to some degree in growth. The slower growing provenances are formed mainly by the partial populations from south-eastern and southern European regions of hard deciduous tree species and chestnut forest areas.
- Average heights of silver fir partial populations from the Czech Republic, assessed according to the natural forest zones, are variable, being (with exceptions) above experimental average. Those provenances from natural forest zone no. 16 – Czech-Moravian Highland, i. e. from similar conditions where the plot had been established, are growing well. This local population is characterized by above-average growth.
- Average values of the provenance sets having a different historical origin from the CR territory, i. e. from Hercynian-Sudeten region and Carpathian region, do not differ in average height growth.
- Altitudinal influence of parent stand locality on progeny height growth represented on the plot was not statistically proven.
- The order of provenances average heights remains in the main, the same at the age of 28 years as was found at the age of 9 years. This fact is documented by the correlation of height coefficient at the age of 9 and 28 years. The value being 0.76, is positive, and as such is statistically, highly important. This result indicates that the height growth of provenances may justifiably, be considered at the age of 9 years as the standard coefficient for further growth until 28 years of age, which is important from the viewpoint of early diagnostics in the field of silver fir breeding.
- The statistical significance of differences, either within local partial population or, from an average of the experiment was not possible to use as the criterion for classification of partial populations for the categorization of certified units. If the 10% positive difference from the average of the experiment is taken as the criterion, then the following units could be proposed as the certified partial populations: 16-30 Jihlava, Henčov, 102 – Velké Karlovice, 36 – Horní Planá, Plešný, 75 – Rájec Jestřebí, 36 – Červené Poříčí, Dolce, 37 – Rychnov nad Kněžnou, Skuhrov.

D.B.H.

Results of D.B.H. analysis can be briefly summarized as follows:

- Average diameter growth of partial populations (11.46 cm) approximately corresponds with absolute yield class 28 m of height at the age of 100 years.
- Differences in diameter growth are statistically significant among provenances, as is the marked variational width (6.33 to 14.23 cm).
- Variance proportions related to provenances – being the variability factor and repeatability value - document a sufficient reliability of the experimental planting.
- Provenances from Hercynian-Sudeten natural forest zones are mostly characterized by an above-average increment in diameter. The average values of those partial populations from northern Carpathian zones and Carpathian Foothills range in general within the experimental average. Increment of partial populations from the Alps and south-western European chains is however lower, except for provenance no. 230 Spadola from the southern Apennines (Calabria).

- Provenances from the Šumava Mts., Czech-Moravian Highland and Moravian-Silesian Beskydy are excellent within the sets of provenances from the Czech Republic natural forest zones.
- Mathematical and statistical analysis proved a negative correlation relationship between diameter growth of silver fir progeny from CR (set of Hercynian-Sudeten natural forest zones) and the altitude of the parent stand site. The relationship is statistically significant.
- Based on 10% positive difference of average D.B.H. from the experimental average, partial populations no. 16-30 Jihlava, Henčov and no. 75 Rájec can be classified into category of certified units.

SYNTHETICAL EVALUATION AND INFORMATIVE OUTLOOK ON VOLUME PRODUCTION

Two quantitative coefficients, height and D.B.H., were investigated on the experimental plot. The variability of these coefficients has been evaluated in the preceding chapters, and partial conclusions were formed on the base of each of these items. In both cases they represent the basic elements of volume production. Synthetic evaluation therefore reflects itself in volume production which is represented by the average coefficients of individual provenances, and by volume production per plot that includes the mentioned basic coefficients, i. e. height and D.B.H, as well as a number of individuals growing on the plot.

Besides health state and quality, volume production is both the principal production target in forest management and the basic criterion for evaluation of efficiency of compared units in comparable plantings. The majority of partial populations within the plot reaches Derbholz limit, i. e. D.B.H. higher than 7 cm, at the age of 28 years. However, some of provenances, mainly from the southern and south-eastern Europe did not reach Derbholz limit at the age of 28 years. For this reason biomass in Derbholz is not a base for evaluation, whereas total tree biomass, i. e. all vital material even below 7 cm in diameter can be used.

Based on the volume tables (Grundner, Schwappach 1942) the presented data giving volume of "average" – medium trees and supplies recounted per ha must be considered as tentative, and can be used only for forming preliminary conclusions. The main reason is, however, that the particular average quantities had to be rounded due to the table construction. Biomass per unit was calculated by the method of the so-called average or medium stem. The reliability of this method requires the basic coefficients, in particular D.B.H within the provenance set, to be regularly distributed. In the opposite case the distribution is asymmetric and those results gained can be negatively influenced in their reliability when this method is used.

Data on basic statistical coefficients - elements of production - can be derived from the data in tab. 3; and in particular, the number of individuals per plot unit according to the particular provenances can be assessed. Numerical data shown in the table are related to the plot of 0.04 ha because planting for each provenance was realized on 4 plots of 10 x 10 m.

Average stem volume for all provenances planted on the plot is 0.065 m^3 ranging from 0.01 to 0.097 m^3. The lowest value is a sporadic extreme and is represented by the slowest growing provenance no. 228 – Vallombrosa, Italy. The highest volume value is characteristic for provenance no. 16-30 Jihlava Henčov, then for no. 230 Spadola, Italy, followed by provenances with average volume of mean stem 0.090 m^3 (no. 102, 37, 75, etc.).

Variability tendencies in mean stem volume within region and areas of European forests follow the variability of basic production elements in as much that these differences are more distinctly due to D.B.H. used within the volume coefficient being in the square power. Therefore the provenances from central European region of beech-oak forest excel, whereas provenances sets from the western and northern Carpathians and its foothills are around the experimental average, and partial populations from the Alpine and south-European regions are distinctly below-average, except for one set.

The analogous character of variability, compared with height and diameter, occurs at provenances from the Czech Republic according to the individual natural forest zones. Existing differences

Provenance		Number of trees	Average height (m)	DBH (cm)	Volume (m^3)	Growing-stock per 1 ha (m^3)
No.	**Name of Provenance**					
1-15	Kamenice nad Lipou, Losy	87	8.6	12.1	0.077	167
16-30	Jihlava, Henčov	88	9.6	13	0.097	213
32	Nýrsko, Dešenice	75	8.9	12.2	0.077	144
34	VLS Horní Planá, Želnava	73	9	12.3	0.077	141
35	Petrohrad, Oráčov	68	7.8	12.3	0.071	121
37	Rychnov nad Kn., Skuhrov nad Běl.	85	9	12.6	0.09	191
39	Červené Poříčí, Dolce	85	9	11.5	0.077	164
40	Frýdlant v Čechách, Nové Město pod Sm.	87	7.7	11	0.06	131
49	Přibyslav, Hamry	82	8.9	12.4	0.077	158
50	Vlašim, Smilkov	90	8.2	11.7	0.071	160
51	VLS Lipník nad Bečvou, Podhoří	90	7.9	10.9	0.06	135
53	Opočno, Bolehošť	80	8.3	12.2	0.06	90
58	Vimperk	78	8.9	12.2	0.077	150
61	Velké Karlovice, Dinotice	85	8.6	12.4	0.077	164
63	Český Krumlov, Chvalšiny	82	8.5	12.4	0.077	158
66	Nýrsko, Liščí	86	7.9	11.1	0.06	129
68	Vyšší Brod, Běleň	89	7.3	10.4	0.046	102
70	Nasavrky, Maleč	93	8.4	12.2	0.071	165
71	VLS Plumlov, Ruprechtov	80	8.4	11.5	0.071	142
74	Milevsko, Klučenice	67	7.9	12.1	0.071	119
75	Rájec-Jestřebí, Černá Hora	68	9	13.2	0.09	153
81	Vyšší Brod, Vitkův Kámen	75	7.8	10.5	0.06	113
82	Vizovice, Bratřejov	81	8.5	12.8	0.09	182
83	Kašp. Hory, Rejštejn	67	7.2	10.3	0.046	77
86	VLS Hořovice, Strašice	90	8.2	13.6	0.083	187
88	VLS Hořovice, Mirošov	86	8.6	11.6	0.071	153
93	Wörschachwald, Steiermark, Austria	75	6.7	8.4	0.029	54
94	Schneegattern, Kobernausser Wald, Austria	78	8.3	11.9	0.071	138
95	Gröbming, Austria	68	8.3	10.3	0.05	85
102	Velké Karlovice, M. Karlovice	91	9.2	13	0.09	205
103	Longemer-Gerardmer, France	94	7.9	11.4	0.06	141
130	Nasavrky, Podhůra	93	8.3	12	0.071	165
131	Razlog, Pirin, Bulgaria	92	8	11.3	0.06	138
132	Boroveč, Rila, Bulgaria	105	8.4	11.4	0.06	158
143	Laterns, Vorarlberg, Austria	93	7.7	10.6	0.06	140
146	Schwarzwald, Schönmünzach, Germany	80	8.7	12.5	0.09	180
147	Schwäb. Fränk. Wald, Geschwend, Germ.	86	9.3	12.1	0.077	166
151	Ostbayer, Zwiesel West, Germany	97	8	10.3	0.05	121
190	Frenštát pod Radh., Mořkov	90	8.3	11.7	0.071	160
194	Karlovice, Karlovice - sever	72	7.8	10.4	0.05	90
200	Zábřeh, Brníčko	73	7.4	10.4	0.046	84
203	Starý Sacz, Poland	84	7.5	11.1	0.06	126
204	Susiec, Poland	86	8.3	11	0.06	129
210	Nové Město na Mor., Cikháj	46	7.1	10.2	0.046	53
212	Nieskurzów, Poland	73	8.1	10.8	0.06	110

215	Vilcea, Romania	78	7.3	10.3	0.046	90
221	Janovice u Rým., Malá Morávka	73	7.1	9.7	0.046	84
224	Sokolac, Kalj. Bioštica, Croatia	72	6.9	9.6	0.046	83
228	Vallombrosa, Italy	57	4.7	6.3	0.012	17
230	Arch. e Boscarel., Italy	48	8.3	14.2	0.096	115
231	Baligrod, 41-49, Poland	60	7.5	10.3	0.05	75
S1	B. Bystrica, Badín, Slovakia	81	8.9	12.7	0.09	182
S5	Ružomberok, Korytnica, Slovakia	85	8.1	12	0.071	151
S7	TANAP, Kežm. Žleby, Slovakia	94	8.2	11.1	0.06	141
S9	Kriváň, Snohy, Slovakia	89	7.3	10.3	0.046	102
S14	Svidník, Komárnik, Slovakia	94	8.3	12.5	0.083	195

Tab. 3.
Volume production and its elements (plot Pelhřimov at the age of 28 years)

are more distinct, with a tendency to lower production from those partial populations originating from higher elevations.

Volume production variability per plot unit (tab. 3) is, besides the values for volume of average (medium) stems, distinctly influenced by the number of trees growing on the plot unit. Their numbers keep around the experimental average (80 trees on 0.04 ha or 2,000 trees on 1 ha) with a large range from 46 or 1,150 up to 105, or 2,625 on 0.04 or 1.00 ha. It can be seen that those plots with a lower number of trees per plot unit have some individuals with above-average growth, but nevertheless these provenances still have a relatively low, below-average biomass volume per hectare (e. g. no. 230 - Spadola, Italy, no. 75 - Rájec, Jestřebí etc.). The tendency of volume production variability of tree biomass per 1 ha therefore differs from the other partial coefficients which is caused by the variable number of trees on the lots. This reality involves both variability within regions and areas of European forests, and the provenances from the Czech Republic categorized according to the natural forest areas.

Based on the evaluation of height and diameter growth, partial populations no. 16-30, 102, 37, 34, 75, 35, 82 were selected and classified as the most efficient partial populations from the Czech Republic. If the partial populations are assessed according to the further criteria, i. e. volume production of average stem and production per plot, then partial plots no. 16-30 Jihlava Henčov, no. 102 - Velké Karlovice, no. 37 - Rychnov nad Kněžnou are in accordance with these criteria. All these partial populations surpass the experimental average at least by 30 % in volume production both individually and per plot unit. Volume production of partial populations no. 82 – Vizovice Bratřejov and no. 86 – Hořovice Strašice is also excellent. Provenance no. 34 – Horní Planá shows a rather lower volume production owing to a lower number of individuals growing on the plot, as well as partial population no. 75 – Rájec, Jestřebí.

Based on the presented data and regarding all available criteria and their synthesis the following partial populations can be classified into certified units: 16-30 Jihlava Henčov, 37 - Rychnov nad Kněžnou Skuhrov, 82 - Vizovice Bratřejov, 102 - Velké Karlovice, 86 - Hořovice Strašice can also be added. This proposal must be assessed, based on additional experimental verification plots (of the same series) from the perspective of the efficiency of these partial populations.

Fig. 2.
Localities with silver fir provenances from the CR comprised in the experimental series 1973 – 1977 and localities of experimental plots

PRELIMINARY CONCLUSIONS FOR FORESTRY CONCERNING REGIONALIZATION OF SILVER FIR REPRODUCTIVE RESOURCES

The proportion of silver fir should markedly increase in species composition to a level of 4 - 5 % (Šindelář, Vokoun 1996). Owing to the present low silver fir representation natural regeneration has been very limited. A substantial part of the existing regeneration has been achieved artificially, in CR conditions mostly by planting which requires a great amount of reproductive material. If silver fir was to be planted annually on 4 to 5 % of regenerated plot, some 4 to 6 million plants would be required each year, supposing an annual regenerated area of 20 to 25 thous. ha. To breed such numbers would require 1,500 to 2,000 kg of seed, i. e. 12 to 15 tonnes of cones (Šindelář 1996).

Despite the present small proportion of fir in the composition of forest stands, there are a relatively adequate number and area of certified stands for seed cropping (1,457.47 ha) within the Czech Republic which are, however, very irregularly distributed as at December 31, 1999. The largest plots of stands certified for seed crop are recorded in the Moravian-Silesian Beskydy, Javorníky Mts. and Hostýnsko-Vsetínské Hills. Certified silver fir stands are almost entirely absent in northern Bohemia and only several tens of hectares are available in eastern Bohemia, and 100 ha in central Bohemia. Some larger areas are in the former management units Křtiny, Telč, Tišnov, Plumlov in the South-Moravian region.

Forming principles of regionalization for silver fir reproductive material is very important in this situation. According to current standards, fir does not belong to the ”selected“ species, i. e. to those which only seed originating from certified stands may be used. However, amendment of the Act on Forests and connected decrees are going to make using fir seed gained from stands certified for crop obligatory just as for the other economically important tree species. Conditions for this intention are feasible bearing in mind the considerable area of stands certified for seed crop.

Using the widely available seed from the Carpathian areas of the Czech Republic which has a relatively great supply of stands suitable for producing seed crops for the central and western areas of the Czech Republic creates an important problem for regionalization principles that must be solved. A further problem is the current shortage of reproductive material from our own resources being solved by the importation of seed or plants from Slovakia and Poland. In past years these imports have been authorized by the central office.

These problems are ameliorated when we consider results from the comparative plantings, particularly from the plot of 1973/77 series where some partial populations including those countries mentioned are growing. Evaluation from the plot no. 67 shows that partial populations from the Carpathians natural forest zones CR, from Slovakia, Carpathians, and the Polish localities close to the Carpathians type are growing satisfactory until the age of 28 years. On the plot established within the Hercynian natural forest area no. 16 – Czech-Moravian Highland, they and some of the provenances originating from Germany lag behind the set of Hercynian-Sudeten partial population in growth and production. Results from plot no. 67 to a certain degree, confirm the results from the other three plots at the age of 28 years (57 – Jíloviště, 59 – Domažlice Pivoň, 77 – Nové Hrady).

The proposal of Hynek (2000) presents an attempt to solve the problems of fir regionalization. The CR territory has been divided into 6 seed areas: 1 – Krušné Mts., 2 –Šumava Mts., 3 – Hercynian area, 4 – North Bohemian area, 5 – Sudeten area, 6 – Carpathians.

The proposed principles are as follows:

- That transfer of reproductive material is not limited within the natural forest zones
- That transfer among natural forest zones is not limited within seed areas to the extent that the permitted transfer ± one vegetation forest zone is respected
- That fir transfer into seed areas 2, 6 should not be permitted
- That reproductive material from the seed area 6 can be used for all the CR territory with exception of seed area 2“

This regionalization problem of silver fir reproductive material has also occurred in the proposals of the Ministry of Agriculture decree no. 77/1996, which in the main reiterates the proposal processed by Hynek (2000). Problem is that this proposal has not considered sufficiently the existing very limited or even unreal conditions for seed collection in some proposed seed areas.

When reviewing the state of partial population progeny on the plot no. 67, and further available information from other resources, we can regard the following recommendations as forming the basic regionalization principles of silver fir reproductive resource.

- The present poor representation of silver fir within forest stands as a percentage of species composition, and taking into consideration the associated threats to regional populations and by the tree species itself, requires systematic measures for preserving and expanding the reproduction of gene resources. In particular the preservation of existing stands vitality in order to conserve and enhance the potential resource for seed crop. In all stands considered, experiments are recommended for natural regeneration whilst recognising the expense of increased input and incurred costs. The single most critical necessity is fencing of regenerated stands against game damage to the natural seeding and advanced growth. Where natural regeneration of the existing stand or its remnants is not possible, the establishment of registered reproductive plantings (seed stands) is recommended in those areas having suitable ecological conditions, for example among other with underplantings in suitably released stands.
- If local sources of silver fir seed are available, i. e. certified or other stands, of a suitable health state, this seed is to be preferred for use. In the future seed from other stands of appropriate natural forest and adequate vegetation forest zones can also be used.
- This technique must be kept rigorously adhered to those areas with specific management regimes from the viewpoint of natural protection, e. g. in national parks, protected landscape areas, forest reserves of both categories and in gene bases.
- In case that seed complying with the criteria mentioned above is not available, sources from other natural forest zones and adequate vegetation forest zones can be used. For natural forest zones in Hercynian-Sudeten and Carpathian areas material is preferred to be used differentially from these regions if possible.

Research documents that differentiations occur in the growth and development of silver fir partial populations at higher altitudes in comparison to the material from lower elevations. For this reason it is recommended that regionalization principles are strictly observed with regard to the vegetation forest zones.

Research results also document satisfactory growth and vitality of silver fir partial populations from Slovakia and from Polish areas that are close to Carpathian areas. Therefore seed, or silver fir plants from Slovakia and the Carpathian areas of Poland can be used if required during years of seed shortage from native sources. This method should however be excluded for forest areas with specific conservation management regimes.

These stands and their sets are classified into a category of certified stands on the base of research results:

The progeny of units in the preceding table show good volume production and are growing well, being in good health. Values of basic production elements are over the experimental average by more than 10 %, and volume production outruns the experimental average by at least 30 %. The following measures are therefore recommended:

- to verify whether these populations still exist, and to assess their silvicultural condition, concentrating on state of health, fructification conditions, possible cone collection, and the conditions for natural regeneration;
- to assess the state of those forest stands with fir in their vicinity;
- to propose classification into categories of certified units, according to the new directives, if the stands, or other neighbouring stands capable of forming unified partial populations, are in good health.

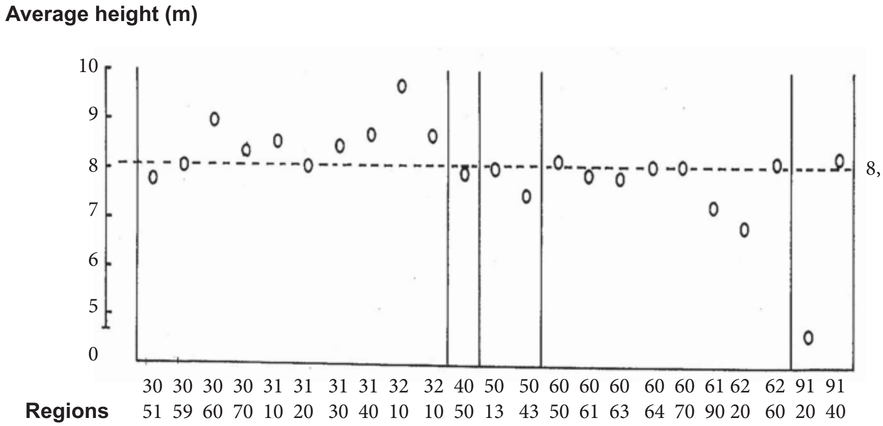

Fig. 3.
Orientation information about height growth of silver fir provenances according to European forest regions (Rubner, Reinhold, 1953). Average values of provenances sets.

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Příspěvek k poznání proměnlivosti jedle bělokoré (*Abies alba* MILL.) se zvláštním zřetelem k podmínkám přírodní lesní oblasti 16 - Českomoravská vrchovina

Souhrn

V předkládaném příspěvku jsou shrnuty výsledky pozorování na výzkumné ploše č. 67 - Pelhřimov (dříve Kamenice nad Lipou) s 56 proveniencemi jedle bělokoré, založené v r. 1976. V sortimentu je zastoupeno 33 proveniencí z České republiky, ze Slovenské republiky 5 dílčích populací, dále 4 provenience z Rakouska, 3 z Německa, 1 z Francie, 2 z Itálie, 1 z Chorvatska, 1 z Rumunska, 2 z Bulharska a 4 dílčí populace z Polské republiky. Materiál pochází ze 23 oblastí vylišených na základě regionů evropských lesů (RUBNER, REINHOLD 1953) a 22 přírodních lesních oblastí v České republice. Sazenice pro výsadbu byly vypěstovány v lesní školce Hořepník lesního závodu Kamenice nad Lipou (později Pelhřimov). Výzkumná plocha byla založena na lokalitě tehdejšího LZ Kamenice n. L. (Pelhřimov) polesí Černovice u Tábora v porostu 5 c_1 na lokalitě v nadmořské výšce 690 m. Typologicky je lokalita charakterizována jako soubor 5S, středně bohatá svěží jedlová bučina. Základní výsadba se 49 proveniencemi se uskutečnila metodou dvojité mříže ve 4 opakováních, na parcelách 10 x 10 m s výsadbou 50 sazenic na parcelu (spon 2 x 1 m). Plocha akcesorická se 7 proveniencemi byla založena formou znáhodněných bloků ve 4 opakováních. Plocha byla oplocena, ztráty po výsadbě nepřekročily 15 %. Ve věku 15 let se na ploše uskutečnil mírný výchovný zásah. V rámci prací na jaře 1999 se měřily výšky a výčetní tloušťky všech jedinců. Data byla zpracována obvyklými matematicko-statistickými postupy (základní charakteristika, analýza variance, Duncanův mnohonásobný pořadový test). Výsledky pozorování lze shrnout v tato konstatování:

- Výškový a tloušťkový růst proveniencí na ploše zastoupených je uspokojivý a v celkovém průměru odpovídá přibližně absolutní bonitě 26 až 28 m, tj. kategorii charakterizující uvedenými čísly hodnoty pro střední výšky hlavního porostu ve věku 100 let.
- Hodnoty průměrných výšek proveniencí na ploše zastoupených se pohybují v mezích 5 až téměř 10 m. Průměrné výčetní tloušťky kolísají v intervalu 6,3 až 14,2 cm. Rozdíly mezi průměrnými výškami i mezi průměrnými výčetními tloušťkami jsou statisticky vysoce významné. Statistické

ukazatele, tj. podíly variance připadající na výšku a dále i pro výčetní tloušťky, jako faktory proměnlivosti, a opakovatelnosti – heritability - naznačují dostatečnou spolehlivost pokusu.

- Pro celkovou orientaci byla na základě průměrných ukazatelů (elementů) kalkulována i objemová produkce. V přepočtu na 1 ha kolísá biomasa stromová podle proveniencí v intervalu od 17 (provenience č. 228 - Vallombrosa, Itálie) po 213 m^3/ha (č. 16-30 Jihlava Henčov).
- Posouzení růstu výškového, tloušťkového i objemové produkce na základě regionů evropských lesů a příslušných oblastí naznačuje, že relativně rychlý růst a vysokou objemovou produkci (hodnoty zřetelně nad průměrem pokusu) vykazují soubory proveniencí ze středoevropského regionu bukodubových lesů. Průměrné hodnoty sledovaných veličin jsou charakteristické pro dílčí populace z východoevropského regionu bukodubových lesů, zatímco provenience z ostatních regionů v růstu a produkci oproti předchozím většinou zaostávají. Tato skutečnost platí zejména pro populace z alpských oblastí a z regionu jihovýchodoevropských lesů a z jihoevropského regionu tvrdých listnáčů a kaštanových lesů.
- Průměrné hodnoty elementů produkce, jakož i objemová produkce jedle bělokoré z České republiky, posuzovaná podle přírodních lesních oblastí, je značně proměnlivá, pohybuje se však až na výjimky, nad průměrem celého pokusu. Osvědčují se mimo jiné provenience z přírodní lesní oblasti č. 16 - Českomoravská vrchovina, tj. z obdobných podmínek, kde je výzkumná plocha založena.
- Vliv nadmořské výšky lokalit mateřských porostů na výškový, tloušťkový růst a objemovou produkci je naznačen zápornými korelačními koeficienty pro výšky i výčetní tloušťky. Koeficient je však statisticky významný pouze pro tloušťky.
- Jako kritérium pro klasifikaci dílčích populací z České republiky k zařazení do kategorie jednotek (porostů) ověřených nebylo možno pro výšky a výčetní tloušťky použít statistické významnosti diferencí od místní dílčí populace (uvažovaná jako „standard“), ani od průměru pokusu. Proto byl jako kritérium zvolen rozdíl od průměru pokusu. Jako jednotky, které přicházejí v úvahu pro zařazení do kategorie „ověřených“, jsou uvažovány porosty nebo jejich soubory, jejichž potomstva se v pozitivním smyslu odlišují od průměru nejméně 10 % (průměrná výška, průměrná výčetní tloušťka) a v objemové produkci na jednotku plochy nejméně 30 %. Jde o tyto jednotky: 16-30 Jihlava Henčov, 37 - Rychnov nad Kněžnou Skuhrov, 82 - Vizovice Bratřejov, 86 - Hořovice Strašice, 106 - Velké Karlovice, M. Karlovice.

Source of variability	**Sum of squares**	**Degrees of freedom**	**Average square**	**Stat. F**	**Critical F for p = 1 - α**	
					α = 0.05	**α = 0.01**
Provenance	26777365.970	55	447875.563	11.95++	1.35	1.50
Repetition	2144210.024	3	714736.675	19.15++	2.60	3.70
Residual	166795295.024	4445	37524.251			
Total	193572660.990	4503	42987.489			

Tab. 4.
ANOVA, average heights, plot no. 67 (Pelhřimov) 1999 - age 28 years

Source of variability	**Sum of squares**	**Degrees of freedom**	**Average square**	**Stat. F**	**Critical F for p = 1 - α**	
					α = 0.05	**α = 0.01**
Provenance	606470.166	55	11026.730	6.88++	1.33	1.50
Repetition	86787.903	3	28929.300	18.06++	2.60	3.70
Residual	7089031.741	4425	1602.041			
Total	7782289.810	4483	1735.956			

Tab. 5.
ANOVA, average D.B.H., plot no. 67 (Pelhřimov) 1999 - age 28 years

- Na základě výsledků pozorování a hodnocení výzkumné plochy č. 67 Pelhřimov ve věku 28 let je možné formulovat některé předběžné závěry pro lesnickou praxi, zejména pro rajonizaci reprodukčního materiálu. Jde předně o využívání zdrojů místního původu a dále možnost, v případě, že krytí potřeby osiva z místních zdrojů není možné, uvažovat i materiál z jiných podmínek. S ohledem na kriticky nízké zastoupení jedle v druhové skladbě lesních porostů bude tento postup v řadě případů nutný. Nevylučuje se přenos mezi jednotlivými přírodními lesními oblastmi a to z karpatského regionu do regionu hercynsko-sudetského, i naopak. V případě kritického nedostatku reprodukčního materiálu domácího původu nevylučuje se, jako výjimka vázaná na zvláštní povolení, možnost dovozu osiva, event. sazenic z karpatských a příkarpatských oblastí Slovenské a Polské republiky.
- Přesuny reprodukčního materiálu by měly být vyloučeny nebo maximálně omezeny v lesích podléhajících specifickému režimu hospodaření (národní parky, chráněné krajinné oblasti, rezervace a genové základny).
- V souvislosti se zajišťováním reprodukčního materiálu, specificky osiva, pro rozšířenou reprodukci jedle bělokoré, jsou vysoce aktuální opatření k záchraně a reprodukci genových zdrojů jedle bělokoré nejen jako druhu, ale i všech dosud ve zbytcích existujících regionálních populací.
- Je žádoucí, aby předběžné závěry předkládaného sdělení byly ověřovány dalším pozorováním v následných etapách vývoje s využitím celého souboru disponibilních ploch.

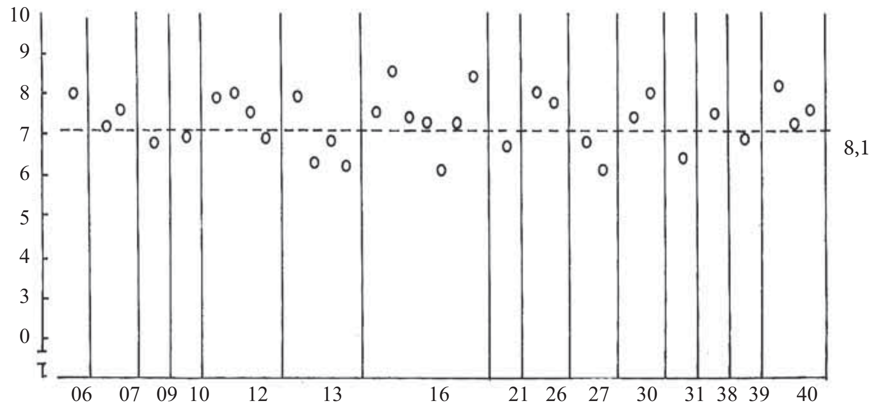
Some experiences with silver fir (*Abies alba* Mill.) variability with regard to the conditions of the natural forest area 16 - Bohemian-Moravian Highland

Summary

This contribution presents the investigation results from the experimental plot no. 67 Pelhřimov (former Kamenice nad Lipou) planted with 56 silver fir provenances established in 1976. Thirty three provenances are from the Czech Republic, of which 29 are from Hercynian-Sudeten and Carpathian natural forest zones. Five partial provenances originate from Slovakia, 4 from Austria, 3 from Germany, 1 from France, 2 from Italy, 1 from Croatia, 1 from Romania, 2 from Bulgaria and 4 provenances are from Poland. The material originating from 23 areas and from 22 natural forest zones within the Czech Republic differed according to the regions of European forests (Rubner, Reinhold 1953). Planting material was bred in the nursery Hořepník of the forest enterprise Kamenice nad Lipou (later Pelhřimov). The experimental plot was established on the locality of the former forest enterprise Kamenice nad Lipou (Pelhřimov), forest district Černovice at Tábor in stand $5c_1$ having an elevation of 690 m. The locality is situated on a mild southern slope of a terrain wave, the top of which overlaps the elevation level of 700 m. The set of forest types is classified as 5S – medium rich, fresh fir-beech stand. The basic planting with 49 provenances was carried out by the method of double grid in 4 repetitions on lots of 10 x 10 m with 50 plants per each lot (spacing 2 x 1 m). To complete the experiment another plot was populated with seven provenances and established by a method of random blocks with 4 repetitions. The plot was fenced, and losses after planting did not exceed 15 %. A mild tending operation was carried out at the age of 15 years. In spring 1999 heights and D.B.H. were measured for all individuals. The data were processed by the common mathematical and statistical methods (basic characteristic, variance analysis, Duncan´s multiple sequence test). Research results can be summarized as follows:

- Height and diameter growth of provenances within the plot are satisfactory and are in approximate accordance with absolute yield class of 26 to 28 m in average, i. e. with the category of values defined for mean heights of the main 100 years old stand.
- Provenance values of average heights represented on the plot range between 5 to nearly 10 m. Average D.B.H. are in intervals 6.3 to 14.2 cm. Differences between average heights and average D.B.H. are statistically highly significant. Statistical coefficients, i. e. variance proportions related to height and D.B.H. similarly to factors of variability and repeatability – heritability indicate sufficient experimental reliability.

Average height



Natural forest zones

Fig. 4.
Average heights of silver fir provenances from the Czech Republic according to natural forest zones

No.	Forest administration, forest district	Stand, certified unit	Natural forest zone	Vegetation forest zone
16-30	Jihlava, Popice	38 b_2, c	16 – Czech-Moravian Highland/ Českomoravská vrchovina	5
37	Rychnov n. K. Sk.	IIB-JD-83-II-RK	26 – Orlické Mts. Foothills/ Předhůří Orlických hor	5
82	Vizovice, Bratřejov	IIB-JD-28-IV-G	38 – White Carpathians/ Bílé Karpaty	4
86	Hořovice, Strašice	30g	07 – Brdy Upland/ Brdská vrchovina	5
102	Velké Karlovice, M. Karlovice	IIB-JD-13-VIb-VS	41 – Hostýnské Hills Javorníky Mts./ Hostýnskovsetínské vrchy a Javorníky	5

- Based on average coefficients (elements) volume production was also calculated. Recounted tree biomass per 1 ha has intervals from 17 (provenance no. 228 – Vallombrosa, Italy) to 213 m^3/ha (no. 16-30 Jihlava Henčov) according to provenances.
- Height and D.B.H. growths and volume production based on regions of European forests and appropriate areas show that relatively fast growth and high volume production (having values distinctly above-average) occurred in those sets of provenances from the central European regions of beech-oak forests. Average investigated coefficients are characteristic for partial populations from the eastern European region of beech-oak forests whereas provenances from the other regions mostly lag behind in growth and production, compared to the previous provenances. This fact is seen mainly in populations from the Alpine regions and regions of southern European forests, as well as in deciduous tree species and chestnut forests in the southern Europe.
- Average values of production elements, and volume production of silver fir from the Czech Republic are also variable if originating from natural forest areas, nevertheless they are keeping mostly above the experimental average. Also, other provenances from natural forest area no. 16 – Czech-Moravian Highland, having the similar conditions as the established experimental plot, proved to be suitable,
- Altitudinal influence of parent stands localities on height, diameter and volume production is indicated by the correlation coefficients for heights and D.B.H. This coefficient is statistically significant only for diameters.

- For heights and D.B.H., statistical significance of differences from local partial populations (taken as "standard") or from experimental average was not possible to use as a criterion for categorization of partial populations from the Czech Republic into certified units (stands). For this reason the difference from the experimental average was taken as a criterion. For units that can be classified as "certified units" such stands or their sets are considered as the progeny that differ in the positive sense from the average by at least 10 % (average height, average D.B.H.) and in volume production per unit at least by 30 %. These units are considered: 16-30 Jihlava Henčov, 37 - Rychnov nad Kněžnou Skuhrov, 82 - Vizovice Bratřejov, 86 - Hořovice Strašice 106 - Velké Karlovice, M. Karlovice.
- Based on investigation results and the evaluation of experimental plot no. 67 Pelhřimov at the age of 28 years the preliminary conclusions for practice, particularly for regionalization of reproductive material, can be presented. Resources of local origin are to be used preferably. In cases that seed is unavailable from local sources, material from other localities could be taken. This technique will often be necessary when considering the critically low fir representation in forest stands composition. Transfer among individual natural forest zones, from the Carpathians into Hercynian-Sudeten and vice versa, is not excluded. The critical shortage of native reproductive material may give rise for the importation of seed or plants from the Carpathians and close-to Carpathian areas of the Slovakian and Polish Republics as on a special case basis, requiring special permission.
- Transfers of reproductive material should be excluded or severely limited to forests under specific management regime (national parks, protected landscape areas, reserves and gene bases).
- Ensuring reproductive material, principally seed, for enhanced silver fir reproduction, requires a significant updating of measures for gene resource preservation and reproduction of silver fir, not only as a species but also for all remaining remnants existing in regional populations.
- The preliminary conclusions presented in this paper must be verified and investigated in the next developmental stages using the entire set of available plots.

ACKNOWLEDGEMENT

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Photo 1, 2.
Provenance plot with silver fir on the plot no. 67 – Pelhřimov (Photo J. Frýdl)

PROVENANCE PLOT WITH EUROPEAN BEECH (*FAGUS SYLVATICA* L.) No. 50 – PELHŘIMOV, KŘEMEŠNÍK 25 YEARS AFTER PLANTING

Jiří Šindelář
Forestry and Game Management Research Institute,
156 04 Jíloviště-Strnady

ABSTRACT

This paper presents an evaluation of the experimental plot "European beech no. 50" Pelhřimov, Křemešník established in the natural forest area no. 16 – Czech-Moravian Highland at an elevation of 700 m. Progeny of partial populations from the Hercynian-Sudeten, Carpathian, Slovakian and Romanian natural forest areas are assessed at the age of 28 years. Height and diameter increment are evaluated and used in the classification of stem quality; conclusions in the form of an economic appraisal of suitability for each investigated provenance are stated, (for the given locality and similar ecological conditions), and the regional use of reproductive material in forestry is proposed.

INTRODUCTION, RESEARCH GOALS

In recent decades forestry research in genetics, tree breeding and forest seed management has been focused on coniferous tree species. Since the 1930s, many experimental provenance plots with Norway spruce, Scots pine and European larch have been established in many countries including the Czech Republic and Slovakia. Some projects have been organized on an international level, mainly within the framework of IUFRO activities. Since the 1950s however, the importance of deciduous tree species for forest stand species composition has been appreciated, culminating in the development of experimental plots, established principally for the conditions of central and western Europe. In Germany, Krahl-Urban was an initiator of research concerning oaks and European beech (e. g. Krahl-Urban 1972). These early investigations were focused on gathering basic information on tree species variability, diagnostic signs, and properties of the particular oak species – English and sessile oaks – were also verified.

The first provenance plot with European beech was established in the Czech Republic in 1972. Observations presented basic information on properties of the population progeny and were aimed in particular at assessing the suitability of seed or plants imported from Slovakia into the Czech lands. In autumn 1971 the former Forestry Faculty of the University of Forestry and Wood-Processing Technology at Zvolen offered the FGMRI Jíloviště-Strnady several European beech provenances from different areas of Slovakia for research plantings. This material was complemented by plants from other locations in Bohemia and Moravia. Suitable material was obtained from the state enterprises of that time. In total, 16 provenances from different areas of Bohemia and one beech provenance from Romania (plants were bred in the forest nursery of the Moravian former forest enterprise Žatec from seed imported from Romania) were used. These plants were mostly three years old, whilst a small number of two-year old, and one-year old material was also used. This age difference was not in accordance with establishment principles for comparable experimental plots and would negatively influence later evaluation (this experimental plot with 23 provenances was established in 1972). The already mentioned age difference was observed at the first evaluation in 1981, when average annual height growth was added to the heights of younger provenances and the total value reached approximately the comparable age of 13 years.

At the same time, more experimental plots were established by Balkovič in Slovakia using a wider assortment of Slovakian provenances, their remnants were imported into the Czech Republic. Since then, vitality height growth, diameter increment and seasonal dynamics of diameter increment have been

Photo 1.
Provenance experimental plot with European beech no. 50 – Pelhřimov, Křemešník

evaluated several times on the experimental plots in Slovakia (Balkovič 1974, 1978, Červenka, Paule 1978, 1980, Paule 1983), by Balkovič (1974, 1978) growth rhythm of provenances from flushing to colour changes and defoliation in autumn have been analysed. The results acquired from Slovakia and the Czech Republic are not comparable due to the varying number of provenances and evaluation at different ages.

Investigation at the age of 28 years has been aimed at comparing height and diameter increment in addition to preliminary assessment of stem and crown properties. Mortality was not observed or recorded as only one relatively mild thinning has been carried out to date. This involved removing self-seeded natural tree species, and only in small part, some beech plants. Consideration is given to the variability among investigated partial populations and within populations aimed at assessing the possibilities of collective and individual selection. Growth and further properties of a set from the Hercynian-Sudeten natural forest areas of the Czech Republic, and from the Carpathian areas are characterized and evaluated. Assessing the possibilities of using seed and beech plants from the Carpathian area of eastern Moravia and Slovakia, in the western parts of the Czech Republic is important for forestry.

MATERIAL AND METHODOLOGY

The survey of experimental provenances is shown in table 1. In this survey there are 10 mentioned provenances from the Hercynian-Sudeten part of the Czech Republic, 13 from the Carpathian region, of which 7 are from Slovakia, 1 from Romania, the rest originating from the Moravian-Carpathian areas. Material from the Czech Republic originated from 8 units, collected from different localities within the Czech Republic e. g. 4 from the natural forest area no. 10 – Central Bohemian Highland, 2 from the Šumava Mts., etc. The mountain natural forest area no. of northern and western Slovakia are represented by 2 provenances, central Slovakia is characterized by 4 partial populations, while eastern Slovakia with its majority of deciduous forests is represented only by one provenance.

The experimental plot was established in two parts of the former forestry nursery within the former forest enterprise Kamenice nad Lipou (later Pelhřimov), forest district Horní Cerekev in the stand 38b. The site is at an elevation of 660 m within the Křemešník Foothills (765 m), is level and at time of establishment was characterized as a spruce-beech stand with *Carex pilulifera*. Based on the currently used method the site is classified as 6 K (acid spruce-beech stand), and 6 L (loamy acid spruce-beech stand). Long-term average annual temperatures of 5.8 °C and annual precipitation sum of 760 mm are derived from the climatic map of the former CSSR. Both parts of the experimental plot are in close proximity to each other (at a distance of less than 50 m).

The plot was established by the complete randomized block method, in three repetitions comprising 72 lots. Lot size was 7.5 m x 7.5 m, while plant spacing was 1.5 m x 1.5 m. Each lot was planted with 25 plants, 75 individuals of each particular provenance. Strips around the plot margins were occupied by birch, spruce and pine self-seeding. The entire area of the experimental plot excluding the marginal strips stands at 0.42 ha. Most planting was carried out in the spring of 1972. Growth and development of the culture were satisfactory. In 1976 the plot was fertilized by combined NPK fertilizer. Natural regeneration, mainly of birch and spruce, but also of pine and larch to a lesser degree, was reduced in the first years after planting. Cutting and extracting of this natural regeneration was carried out several times until the canopy had formed. Grasses, in particular *Calamagrostis epigeios* was controlled by mowing.

First measurement and further investigation were carried out in late 1981, and the results were subsequently processed and published (Šindelář 1985). The second measurement and classification occurred during the autumn of 1997, i. e. 25 years after planting. The majority of provenances planted on the plot was 28 years old at that time. All represented provenances on the plot were measured with the presupposition that a one-year age difference involving a small number of individuals could, to a certain degree be accepted during the period of more than two decades, and that the possible differences would fall within a satisfactory experimental error. Height and diameter increment were therefore measured, and stem quality classified. Growth, averaging heights of more than 10 m for the majority of provenances, did not allow detailed classification of stem and crown qualitative features as in 1981. For this reason only stem quality was evaluated according to the scale: 1 – continuous stem up to the top (direct); 2 – fork within crown; 3 – fork under crown; 4 – fork in the lower stem part. Stem form is satisfactory within a wide average. Individuals with direct or mildly curved stems prevail, individuals with markedly curved stem occurred very rarely.

Photo 2.
Provenance plot with European beech no. 50 – plot interior

Basic mathematical and statistical characteristics for quantitative features, height and D.B.H. were calculated, stem quality is represented by spectrum (representation) of the particular categories. Variability of quantitative features was investigated by variance analysis with two causes of variability

$$I_{ij} = \mu + P_i + O_j + e_{ij},$$

where I_{ij} is value of j-repetition, μ experimental average, P_i effect of i-provenance, O_j effect of j-repetition, e_{ij} experimental error. Average effects of provenances and repetitions as well as variance proportion related to uncontrolled factors were solved by standard equations based on variance analysis (e. g. Weber 1961). Repeatability – heritability - value was calculated according to the formula

$$h^2 = \frac{\sigma^2_p}{\sigma^2_p + \frac{\sigma^2_{op}}{o}}$$

The interpretation of results considered certain methodical specifics of the experimental plot arising from the planting of reproductive material bred in non-homogeneous conditions. For these reasons investigation results must only be considered as basic orientation, requiring completion, employing data from other, later established plots, principally the extensive series from 1984.

RESULTS

Height growth

Average height of the provenance within the plot is 10.87 m. The data of growth tables (Schober 1995) present an average height of 8.70 m for the first yield class and mild thinning only for 30 years old. The average height of the entire plot already exceeds the table value at the age of 28 years by more than 2 m, i. e. over one yield class. If the medium height for the fastest growing provenance S_3 is 12.45 m, this surpassing of table data is very important. This fact is surprising because a visual estimation of neighbouring stands suggests a small above-average growth rate. While the significantly increased height growth could be a result of plot fertilizing in 1976, it should also be remembered that the growth tables, used for comparison, are based on data investigated in Germany and may not therefore correspond with local conditions.

Average height variation of compared provenances ranges from 8.19 m (provenance 19 – Prachatice, Boubín) to 12.45 m (S3 – Zvolen). Table 2 shows average heights and characteristics of height variability for the particular provenances. The most suitable coefficient – (variation coefficient) ranges from 12.82 to 23.72 %. These coefficients approximately correspond with values of height growth variability for other tree species of a comparable age within the experimental plots. The values of variation coefficients indicate that possible individual selection can be made from within the population for use in further breeding for example on the basis of individual selection and autovegetative reproduction.

Variance analysis (tab. 3) demonstrates that differences among average heights of the investigated provenances are statistically highly important, whereas differences among repetitions are not statistically signife. From the viewpoint of height growth this result indicates the required site plot homogeneity and thus also the relative reliability of evaluation. Provenances with the variability factor contribute to variance by 54 %, in repetition by 7 %, the rest, i. e. 39 %, falls to uncontrolled factors or residual variance. Repeatability (heritability) value is $h^2 = 0.81$. This coefficient confirms, compared with usual minimal value 0.70 % for comparative plantings, the sufficient methodological reliability of the experiment.

The regional origin of beech provenances in the experimental growth of units from the Hercynian-Sudeten natural forest areas, from the Moravian Carpathians, Slovakia and Romania is assessed and presented in fig. 1. The set of four provenances from the Moravian Carpathians shows the fastest growth, followed by the Romanian provenance, then by the set of provenances from Slovakia, and in average the most slowly grows material originated from the Hercynian-Sudeten area. These results may be influenced, among others, by the actual site of origin (site of parent stand), especially by altitude. Of the Slovakian set provenances S_1 – Kláštor pod Znievom, S_2 – Vigláš and S_5 – Žarnovica originate from higher elevations. Only these partial populations from higher elevations are growing slower than the Slovakian provenances from lower elevation localities.

This is clearly evident for the provenances set from the Hercynian-Sudeten areas where elevation of parent stands is quite variable. Greater number of provenances represented in this set could enable statistical analysis by calculating height growth correlation coefficient to elevation of the basic parent stands origin site. Provenance adaptation from higher altitudes to shorter vegetation period supposes a negative correlation coefficient. Within the set of Hercynian-Sudeten areas the lowest average heights show four provenances: 19 – Prachatice, Boubín; 20 – Rožmitál, Hutě; 21 – Horní Planá, Nová Pec and 23 – Kamenice nad Lipou, Nový Rychnov, from elevations ranging from 700 to 1,000 m, whereas the other provenances with the faster height growth originate from altitudes of 400 to 500 m. Dependence was verified by calculating the correlation coefficient between average progeny heights from

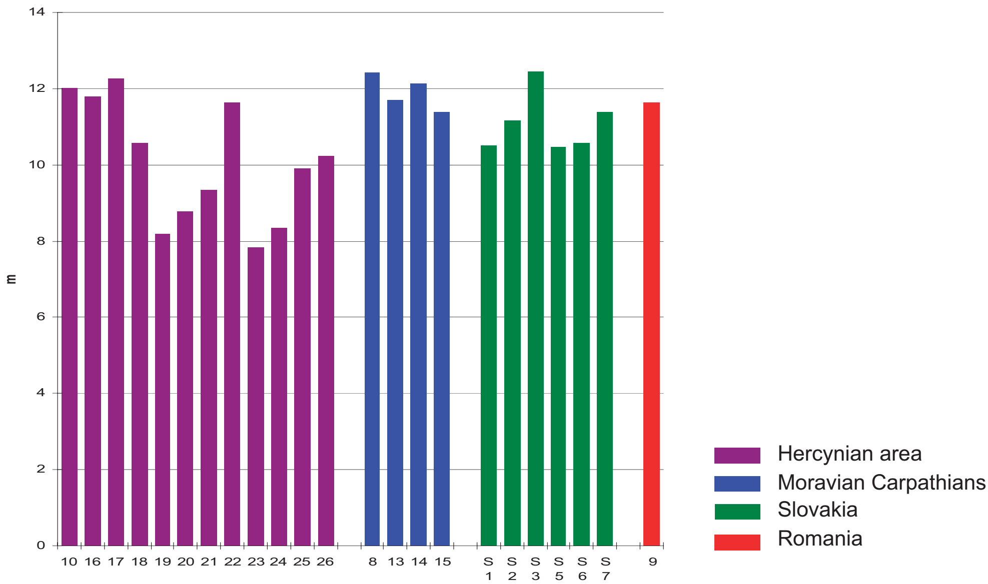

Fig. 1.
Results of height growth evaluation

the Hercynian-Sudeten areas and site elevations of parent stands. Value of calculated correlation coefficient r = - 0.60. The negative value affirms that height progeny growth theoretically increases with increasing elevation of parent stands localities. Partial beech populations from higher altitudes are therefore thought to be adapted to the shorter vegetation period and demonstrate slower growth rates. This phenomenon is known from many experiments and experiences also for other tree species, for example for Norway spruce in the Alpine areas (Holzer 1986).

Diameter at breast height (D.B.H.)

The variability within the D.B.H. range was investigated in a similar manner to height growth. The variability within this coefficient showed average values of particular provenances, ranging from 5.48 cm (provenance no. 23 – Hořovice, Strašice) to 9.96 cm (S_3 – Zvolen). The average d.b.h. of the entire set in the experimental plot is 8.11 cm that corresponds with the 2nd yield class in the growth tables (Schober 1995). D.B.H. of the most intensively growing provenance achieved the 1st yield class of the “Schober” growth tables, which is appropriate for crops under a mild thinning regime. The variability of diameter increment is markedly higher than for the heights, as is usual for many species; intervals from 31 to 49 % according to the provenances are recorded, and can be to a certain degree, dependent on density and spacing of individuals growing on the lot. The dependence of the variation coefficient value of diameter increment upon the number of individuals growing on the lots is not evident. Variation coefficient for provenances with a relatively high population can be below-average; occasionally however, the coefficient is high for the same number of individuals (e. g. provenance no. 23 Kamenice nad Lipou).

Results of variance analysis for diameter increment are shown in tab. 3. Differences among the investigated provenances are statistically significant, i. e. at a level lower than probability of error 0.01. Differences among repetitions are not statistically significant. Variance proportion for specific causes of variability was also analyzed, the provenances being represented by 37 %, repetitions by 2 %, and uncontrolled factors by 61 %. The certain proportion of variability included into the coefficient for uncontrolled factors may be influenced by a higher or lower imbalance of individuals on the lots caused by mortality after planting and during further development. So far, no prescribed removal of planted

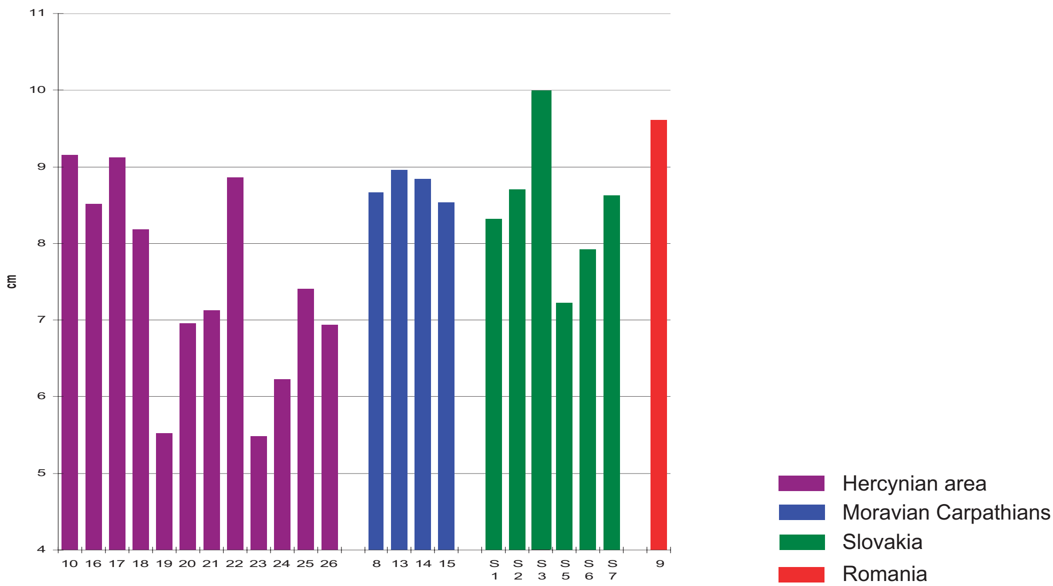

Fig. 2
Results of D.B.H. evaluation

individuals within the plots has been carried out. During removal of natural seeding only dead beech individuals were removed. The repeatability (heritability) figure of 0.65 for diameter increment is somewhat lower than for heights, being caused by the higher variance proportion of uncontrolled factors – 61 % - whereas for heights it is 39 %.

Based on Duncan´s test results of variance analysis for particular provenances, the diameters classify provenances S_3 – Zvolen, 9 – Romania, S_4 – Pruské into the category of provenances with distinctly above-average D.B.H, whereas progeny 23 – Kamenice nad Lipou, 19 – Prachatice, Boubín, 26 – Kostelec nad Černými lesy diameter increment is the slowest.

If the diameter increment is assessed according to classified sets from geographical areas, a set of partial populations from the Moravian Carpathians shows the highest average D.B.H. – 9.75 cm, followed by the provenance from the Romanian Carpathians – 9.61 cm and a set of Slovakian provenances – 8.16 cm. Diameter increment – 7.57 cm – of partial populations from the Hercynian-Sudeten natural forest zones is relatively the lowest. This sequence analogous to height growth is explainable by the known common and non-linear positive correlation between D.B.H. and heights, universal for all tree species.

As with heights, the relationship of diameter increment vigour to elevations of the parent stand sites can be most clearly demonstrated by the provenances from the Hercynian-Sudeten areas. Here also the correlation is negative. Value of correlation coefficient is –0.71; this value is statistically significant on the level of probability of error $0.05 > p > 0.01$. Coefficient of determination $r^2 = 0.51$ indicates that diameter increment is conditioned by altitudinal change of the parent stand site in ca 50 %. The similar tendency in diameter increment variability related to elevations of the original localities can be observed for the provenances from Slovakia.

Stem and crown quality

In addition to volume production and D.B.H. the most significant feature - stem form - (straightness) defines the value of produced wood, in particular the proportion and assortment of timber within the total biomass. The genetic influence upon stem quality (form) variability has not been clearly defined. Krahl-Urban (1972) observed a relationship between stem quality and crowns of parent trees from

Provenance no. - Forest Enterprise	Forest District	Elevation (m)	Natural Forest Area
1 - Kláštor p. Z.	Slovanov	1000	Mala Fatra Mts.
2 - Vigláš	Kalinka	850	Javorie Mts.
3 - Zvolen	Kováčová	500	Kremnické Mts.
4 - Pruské	Ilava	420	Strážovská Highland/Strážovská pahorkatina
5 - Žarnovica	Hrabičov	800	Vtáčník
6 - Banská Štiavnica	Skl. Teplice	700	Štiavnické Mts./Štiavnické pohoří
7 - Sobrance	R. Hámre	450	Vihorlat Mts.
8 - Vsetín	Kychová	680	41 - Hostýnskovset. Hills and Javorníky Mts.
9 - Romania			Romania Carpathian
10 - V. Karlovice	Halenkov	700	41 - Hostýnskovset. Hills and Javorníky Mts.
13 - Bučovice	Haluzice	400	36. Mediterran. Carpathians/Středomor. Karpaty
14 - Vizovice	Bratřejov	450	38 - White Carp. and Viz. Hills/Bílé Karpaty a Vizovivké vrchy
15 - Brumov		400	38 - White Carp. and Viz. Hills/Bílé Karpaty a Vizovivké vrchy
16 - Protivín	Rábinka	460	10 - Středočeská pahorkatina/Central Bohemian Highland
17 - Hluboká . Vlt.	Nová obora	400	10 - Středočeská pahorkatina/Central Bohemian Highland
18 - Nižbor	Dřevíč	420	8a - Křivoklátsko region
19 - Prachatice	Zátoň - Boubín	1000	13 - Šumava Mts.
20 - Rožmitál	Hutě	720	7 - Brdská Highland/Brdská vrchovina
21 - Horní Planá	Nová Pec	900	13 - Šumava Mts.
22 - VLS Hořovice	Strašice	650	7 - Brdská Higland/Brdská vrchovina
23 - Kamenice n. L.	Nový Rychnov	700	16 - Czech-Moravian Highland/Českomor. vrhovina
25 - Mor. Třebová	Hartinkov	500	31 - Czech-Moravian Highland/Českomor. mezihoří
26 - Kostelec n. Č. l.	Jevany - Voděradské beech stands	480	10 - Central Bohemian Higland/Středočeská pahorkatina

Tab. 1.
Characteristics of provenances

natural seedings and advanced regeneration that could be mostly considered as the progeny of these trees. His investigations showed that stem form (straightness) conjoined in particular with axial forkedness may be properties that are genetically conditioned.

Beech stem form is often characterized by forking, frequently resulting in multi-stemmed trees. Double-stemmed trees occur in various forms within beech and many other deciduous species. Forking often appears in unmanaged or neglected stands affecting even mature trees within the height of a few metres but mostly appearing within or just under the crowns. Repeated stem forking is also present, but is most commonly restricted to the crown. Stem forking is the greatest single technical defect, considerably lowering timber value; usually, the lower down the stem the fork appears, the greater decrease in timber value.

The evaluation of stem form together with forking at the age of 30 years, i. e. in a relatively early stage of evaluation, reveals further qualitative development. As no operations reducing the number of individuals (except for removal of dry individuals) have been carried out on the experimental plot, those results gained characterize the genetically conditioned variability of the investigated provenances.

Evaluation of stem quality was related mainly to axial continuality, and to occurrence and position of forks on the axis. Those individuals with continuous stems and those with forking restricted to the higher parts of the crown have a mostly straight axis. Trees susceptible to fork forming mainly on stem and under crown are often of poor axial shaping.

Investigation results are following. On average only 12 % of individuals show continuous stem without forks, whereas nearly one half (42 %) is forked within the crown. A significant number of individuals have forks under crown (27 %) and one fifth of the total amount is characterized by forking within the medium to lower stem section. From the economic point of view, trees having continuous stems can be classified as an optimal category, and individuals with forks in crown can also be included in this category. The remaining two categories can be described as less suitable or unsuitable. In accordance with these criteria, provenances S_5 – Žarovnica, S_1 – Kláštor pod Znievom, 8 – Vsetín can be optimal. Of those provenances originating from the Hercynian areas, provenance no. 22 – Hořovice from natural forest zone 7 – Brdská Highland shows optimal stem and crown quality. When the sets of provenances are categorized from a geographical viewpoint, the provenances from Slovakia (59 %) and Moravian Carpathians (58 %) comprise approximately the same proportion of individuals with straight stem and forks in crown. Suboptimal values were recorded for Romanian provenances (54 %) and for the set of populations from the Hercynian-Sudeten area (51 %).

Variability of stem form does not appear to depend on the elevation of the parent stand. Similarly, as for heights and D.B.H. this relationship was arithmetically verified for a set of populations from the Hercynian-Sudeten natural forest areas. Resulted correlation coefficient 0.57 is positive, and not statistically significant, but its value approaches the limiting coefficient for probability of error $0.05 > p > 0.01$. Coefficient of determination $r^2 = 0.32$ documents that stem quality of beech is improving with increasing elevation of parent stand locality and this trend is conditioned in one third just by altitudinal changes.

Planting development during the last 15 years

The first assessment was carried out at the age of 13 years, looking in particular at the overall height growth of all planting, and of individual provenances within the experimental plot. Total height increment is 9.93 m for the whole plot in the fifteen-year period, average annual periodical increment is 0.60 m. The highest average values of average periodical height increment show the fastest growing provenances: S_3 – Zvolen (0.62 m) and 8 – Vsetín (0.64 m). The lowest increment values are observed for provenances 23 – Kamenice nad Lipou and 19 – Prachatice, Boubín, 0.47 and 0.49 m resp.

The sequence of individual provenances based on height growth is important for assessing height growth and production of partial populations from the viewpoint of breeding. This coefficient is known to be in correlation with diameter increment and to a certain degree with incremental D.B.H. and volume within circular plots. To maximise the value of the forest tree species breeding programme, the total production of individual provenances needs to be assessed as early as possible allowing selection of the most productive populations, appropriate to their use in forestry.

The sequence of changes in height increment during the last 15 years has been defined by the calculation of correlation coefficient according to sequence (e. g. Myslivec 1952). The value of this correlation coefficient is 0.82. Height dependence at the mentioned age intervals is statistically highly significant. Mainly fast growing provenances at the age of 13 years have maintained growth rates at the age of 28 years. The same or similar tendencies are obvious within the slowest growing provenances. Partial transitional populations differ a little in sequence but differences in absolute values are very low.

Investigation results based on height increment indicate that provenances have held the same sequence during the last 15 years. The conclusion can therefore be derived that on this experimental plot the total trend of height growth of investigated provenances as well as other economically important coefficients can be assessed as early as 13 years. Further verification on other experimental plots, in particular, on those established later in the Czech Republic, is needed to confirm if this trend for European beech can be generalized. Diameter increment was not recorded at the age of 13 years, and this coefficient was not evaluated.

Because of the different classification methodologies employed, qualitative features were characterized only by the proportion of individuals with stem forking. Stem was characterized at the age of 28 years

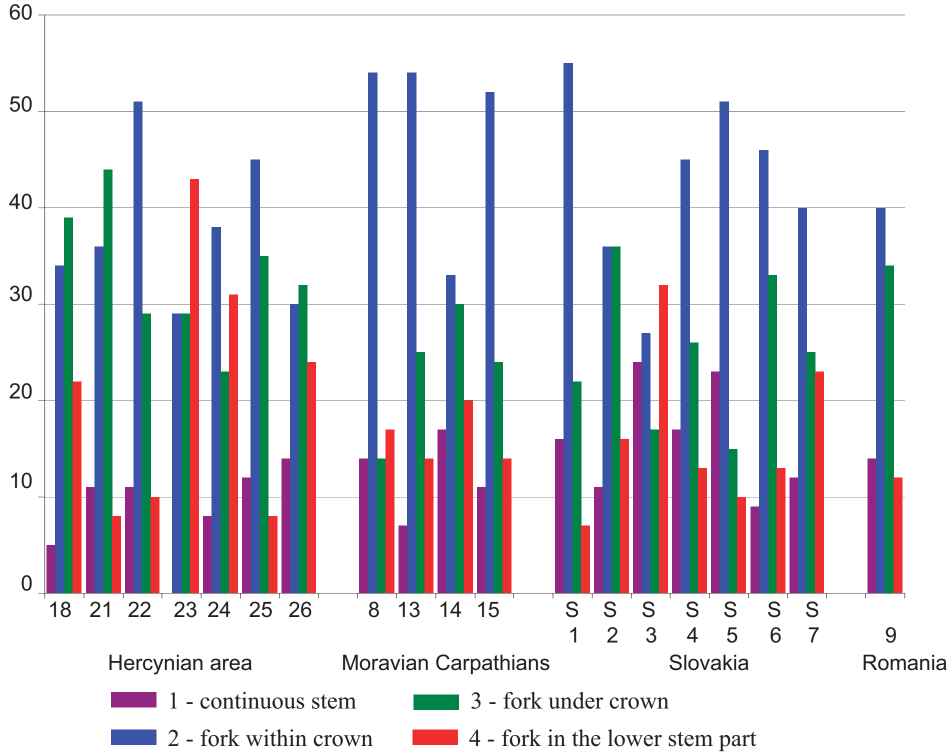

Fig. 3.
Category of stem forming

according to four categories: 1 – those having a continuous stem to the top; 2 – those having a fork (or forks) in crown; 3 – those having a fork (or forks) below the crown; 4 – those having a fork (or forks) in the lower part of the stem. A similar classification was used at the age of 13 years. The proportion of individuals within the first and second categories was used as an assessment criterion of these characteristics. Individuals of this type are suitable from an economic viewpoint when compared with those from the other two categories. Correlation coefficient for this criterions r = 0.18 is positive. This coefficient is at a level of 5 % and 1 %, and is statistically insignificant when commonly chosen errors of probability are taken as criterion. These results document that morphological properties of stem – branching – have markedly changed during the last 15 years. For this reason the condition found at the age of 13 years cannot be taken as the decisive criterion for stem quality development, especially for forkedness of partial populations within the plot.

Synthetic evaluation

For the estimation of total economical value of those investigated provenances, all quantitative characteristics, i. e. heights and D.B.H., must be considered in a similar way, to those used for the investigations at the age of 28 years. Objectivity is ensured by the chosen sequence of investigated provenances based on measured or classified coefficients. The survey of provenances with sequence definition for heights, D.B.H. and stem quality would seem to be practical for this evaluation. Conclusions based on these results assume that all the mentioned characteristics are of the same importance.

The category of the most valuable provenances comprises no. 8 – Vsetín, 17 – Hluboká, S_3 – Zvolen, S_4 – Pruské, 13 – Bučovice. The group of the least valuable is represented by provenances no. 23 – Kamenice nad Lipou, 19 – Prachatice, Boubín, 26 – Kostelec nad Černými lesy, 20 – Horní Planá, 19 – Rožmitál.

Classified according to the geographical areas (Slovakia, Romania, Carpathians part of CR, Hercynian-Sudeten areas of CR) the species from Slovakia can be estimated to be like a valuable set of provenances, followed by the provenance from the Moravian Carpathians; the least valuable group in this developmental stage is a group of provenances from the Hercynian-Sudeten natural forest areas. Also the Romanian provenance is growing relatively fast being of good quality.

The resulting investigation can be considered with evaluation results at the age of 13 years. In this developmental stage the most valuable provenances in growth, stem and crown quality were no. 17 – Hluboká, 8 – Vsetín, the least valuable ones no. 23 – Kamenice nad Lipou, 19 – Prachatice, Boubín. Investigation results at the age of 28 years are similar to those at the age of 13 years.

Good production and quality are documented for the set of provenances from the Moravian Carpathian areas within those provenance sets from the Czech Republic. But, as already mentioned, fast-growing provenances of good quality are also occurring among partial populations from the Hercynian-Sudeten areas. These partial populations should be investigated particularly from the viewpoint of crop and seed use, or should become a subject for further breeding research in their own right.

Stem quality characterized by the proportion of trees with continuous stem and fork in crown is quite variable within particular provenances. In individual provenances, proportions of these categories range from 29, up to 64 % of the total number of individuals growing on a lot. Having an average number of individuals higher than 2,000 per ha is proportionally sufficient, when suitable tending operations are employed, to produce productive stands of good quality for all the represented stands.

DISCUSSION

Experimental plot no. 50 from 1972 was established in parallel with plantings on several localities in Slovakia. Slovakian provenances growing in the Czech Republic are also bred on the Slovakian plots. The results from these plantings can therefore be considered. Slovakian plots were evaluated by Balkovič (1974, 1978) a few years after planting. Observations were focused on mortality, flushing phenology, leaf-colouring and foliage loss. Results from evaluations of the Slovakian plots at the age of 12 years (Paule 1982) document an extraordinary fast growth of provenance S_3 – Zvolen which was in accordance with observation on the CR plot.

Specific attention must be given to the local provenances no. 23 – Kamenice nad Lipou and to two partial populations from the state natural reserves, namely no. 19 – Prachatice, Boubín and no. 26 – Kostelec nad Černými lesy – Voděradské beech stands. Here, height growth, and other coefficients of the local provenance are below-average. Progeny from the previously mentioned state natural reserves can also be classified as slower-growing, and similar trends are observed for diameter increment. Based on the proportion of individuals with continuous stem and fork in crown the three mentioned populations are classified as below-average.

Investigations, particularly the characteristics of the local population (parent stands of provenance no. 23 is a few kilometres from the planting site), promote the known fact that local original provenances are not always excellent in growth and biomass production in comparison with populations from other areas.

CONCLUSIONS FOR REGIONALIZATION OF EUROPEAN BEECH REPRODUCTIVE MATERIAL

European beech has not yet belonged to the listed tree species, the seed of which is allowed only from certified stands. Promotion to this list however, is expected. The conditions for implementing this intention are due to the mentioned area of stands certified for seed crop and the possibility of certifying mature stands (stands over 60 years of age).

In some natural forest areas beech is almost absent, (and therefore any viable seed source is also absent) and so beech material from other areas must be used for regeneration. A problem exists in obtaining regional beech reproductive material, from the Carpathian areas of CR whilst a relatively sufficient supply of suitable seed crop exists in central and western parts of the Czech Republic, i. e. in Bohemia and western parts of Moravia. The problem of a native reproductive material shortage is exacerbated by seed imported from Slovakia. In the past a great volume of beech seed and plants was imported from Slovakia into the Czech lands, including plantings from natural seeding.

Just as for the results from the experimental comparative plantings, data from experimental plot no. 50 from 1972, also add to our understanding. As mentioned in previous chapters, partial populations from the Carpathian natural forest areas of Moravia and Silesia and from Slovakia are satisfactorily growing on the plots established in the natural forest area 16 – Czech-Moravian Highland, where they are largely outperforming those provenances from the Hercynian-Sudeten areas in diameter increment, and show no significant reduction in stem quality.

Research results gathered from the experimental plots with beech partial populations and from other sources (mainly from the 1984 evaluation), are the base for proposals and recommendations for forestry. The following principles can be argued for the regionalization of European beech reproductive material:

- Local resources of beech seed, from certified or other suitable stands, should be preferred, i. e. seed from an appropriate natural forest area and corresponding vegetation zone. In any case where local seed is not available, the seed from the nearest suitable neighbouring forest area can be used.
- This method must be strictly observed in the areas under a specific regime of natural preservation (national parks, protected landscape areas, forest reserves of both categories) and in gene bases.
- Resources from other forest areas can be used where seed mentioned in the two preceding recommendations is unavailable. However material from the Hercynian-Sudeten and Carpathian natural forest areas, should be treated (and used) separately.
- If there is no material from natural forest areas of the Hercynian-Sudeten areas, seed and plants from the Carpathian areas of the Czech Republic can be used, however, due to the relatively large amount of reproductive resource available in the Carpathian area of the CR, using reproductive material from the Hercynian-Sudeten region is not recommended within the Carpathian area.
- Research results document good growth and vitality of beech partial populations from Slovakia on the CR sites, particularly in the western parts of the territory. For these reasons reproductive material from Slovakia can be used where there is a shortage of seed or plant material from native resources, with exception of those forest areas with specific regime.
- Research shows some differences in growth of European beech partial populations on the higher elevations in comparison with material from lower sites. Populations from higher vegetation zones are adapted to the specific ecological conditions of these sites, especially to a shorter vegetation period, and to other specific characteristics, e. g. lower temperatures in the early vegetation period, etc. These features can cause a little slower height and diameter increment in youth. Due to some results indicating (Šindelář 1985, 1989) an enhanced resistance to late frosts it is recommended to follow the directive about strict use of reproductive material in the given range of forest vegetation zones (± 1 forest vegetation zone).
- Exclusion of beech reproductive material use from natural forest areas of the Carpathians region of Moravia and Silesia, or of Slovakia in some Hercynian-Sudeten natural forest areas of CR seems to be unrealistic. This would markedly restrict, in some areas, and even exclude the possibilities of applying beech in forest stands of a corresponding site type. This tree species in the required proportion is central to ensuring the stability of future forest ecosystems.

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Source of variability	Sum of squares	Degrees of freedom	Average square	Stat. F	Critical F for p = 1 - α	
					α = 0.05	α = 0.01
Provenance	137.97	23	6.00	5.17++	1.77	2.24
Repetition	11.73	2	5.87	5.06+	3.20	5.10
Residual	53.34	46	1.16			
Total	203.04	71				

Tab. 2.
ANOVA, average heights, plot no. 50 (Pelhřimov, Křemešník) 1997 - age 28 years

Provenienční plocha s bukem lesním (*Fagus sylvatica* L.) č. 50 – Pelhřimov, Křemešník 25 let po výsadbě

Souhrn

V České republice bylo až do současnosti založeno několik sérií výzkumných ploch s bukem lesním, mimo jiné i výsadby realizované v rámci mezinárodní spolupráce (IUFRO). V rámci tohoto příspěvku jsou shrnuty výsledky pozorování, které se uskutečnilo na ploše č. 50 – Pelhřimov-Křemešník z r. 1972. Plocha byla založena v přírodní lesní oblasti 16 – Českomoravská vrchovina na stanovišti v nadmořské výšce 700 m. Jde o lokalitu typologicky klasifikovanou jako kyselá smrková bučina. Na ploše bylo vysazeno celkem 23 proveniencí z hercynsko--sudetských i karpatských přírodních lesních oblastí České republiky, dále pak sedm proveniencí ze Slovenska. Sortiment je doplněn jednou proveniencí z Rumunské republiky. Lokality původu jsou v práci charakterizovány, mimo jiné podle nadmořské výšky stanovišť mateřských porostů, která se pohybuje v intervalu 400 až 1 000 m. Plocha byla založena standardním způsobem kompletním blokovým uspořádáním ve třech opakováních, na parcelách 7,5 x 7,5 m. První měření a hodnocení plochy se uskutečnilo ve věku 13 let, předmětem tohoto příspěvku jsou výsledky zjištěné na ploše ve věku 28 let. V rámci šetření byly registrovány a hodnoceny výšky jedinců, dále výčetní tloušťky a hodnocena jakost kmene, zejména se zřetelem na vidličnatost a polohu vidlic na ose.

Hodnocení se uskutečnilo s využitím standardních metod matematické statistiky. Výsledky pozorování lze stručně shrnout v tato konstatování:

- Výškový a tloušťkový růst proveniencí na ploše zastoupených je uspokojivý a v celkovém průměru dosahuje první bonity růstových tabulek pro příslušný věk (Schober 1995).
- Do kategorie nejrychleji rostoucích proveniencí se zařadily, pokud jde o jednotlivé dílčí populace, především provenience z moravských karpatských přírodních lesních oblastí a ze Slovenska. Do této skupiny se však řadí i některé provenience ze západní části republiky, např. č. 17 – Hluboká.
- Analýza výškového růstu, stejně tak i výčetních tlouštěk, naznačuje, že existuje negativní, statisticky vysoce významný korelační vztah mezi naměřenými veličinami zkoumaných proveniencí a nadmořskou výškou stanoviště mateřského porostu. Tato skutečnost naznačuje pravděpodobnou adaptaci jednotlivých dílčích populací buku zejména na délku vegetační doby na lokalitě původu.
- Pokud jde o jakost kmene, považuje se, z hlediska praxe lesního hospodářství, za vyhovující soubor typů s průběžným kmenem a typů s vidlicí v koruně. Podíl jedinců těchto typů souborně kolísá značně v rámci pokusu, pokud jde o jednotlivé provenience, v mezích 29 – 74 %, v průměru jde o hodnotu 55 %. Tento podíl by měl umožňovat vhodnou porostní výchovou dopěstovat do věku zralosti lesní porosty žádoucí hospodářské hodnoty. Do kategorie nejhodnotnějších dílčích populací podle jakosti kmene se řadí některé populace z karpatských oblastí Moravy a Slezska, ze Slovenské republiky, i z přírodních lesních oblastí hercynsko-sudetských. Jde zejména o provenience S_1 – Kláštor nad Znievom, S_5 – Žarnovica, 15 – Brumov nad Vlárou aj.
- Vzhledem k tomu, že jsou k dispozici některé výsledky měření a hodnocení ve věku 13 let, bylo možno tyto údaje konfrontovat s poznatky získanými ve věku 28 let. Pokud jde o pořadí výškového růstu, jsou výsledky z obou časových řad analogické, což dokumentuje příslušná hodnota korelačního koeficientu podle pořadí r = 0,88. Poznatek lze interpretovat tak, že hodnocení již ve věku 13 let naznačuje směrodatně růstový vývoj proveniencí. Tato informace přispívá k objasnění problému časné diagnostiky u proveniencí buku. Bude třeba však poznatek ověřit i v dalších sériích srovnávacích ploch.
- Syntetické hodnocení dílčích populací zkoumaných na ploše s využitím výškového a tloušťkového růstu a jakosti kmene naznačuje, že do kategorie nejhodnotnějších proveniencí se řadí některé dílčí populace z moravských karpatských oblastí (8 – Vsetín, 15 – Brumov nad Vlárou), ze Slovenska (např. S_3 – Zvolen), i jednotlivé provenience z hercynsko-sudetských oblastí České republiky (např. 15 – Hluboká, 16 – Protivín). Výsledky nelze ovšem interpretovat tak, že by z další reprodukce v lesnické praxi měly být vylučovány dílčí populace dosud pomaleji rostoucí. Růstový průběh je patrně do určité míry podmíněn nadmořskou výškou původního mateřského porostu, adaptací na kratší vegetační dobu. Vedle toho lze u těchto proveniencí z klimaticky drsnějších lokalit předpokládat některé velmi pozitivní vlastnosti, např. větší odolnost k pozdním mrazům (Šindelář 1989).
- Na základě výsledků pozorování a hodnocení výzkumné plochy ve věku 28 let je možno formulovat některé závěry pro lesnickou praxi, zejména pokud jde o rajonizaci reprodukčního materiálu. Jde především o využívání zdrojů místního původu a dále možnost v oblastech, kde krytí z těchto zdrojů není možné, využívat vhodně i materiál z jiných podmínek. Jde zejména o možné přesuny ze souboru přírodních lesních karpatských oblastí Moravy a Slezska, případně ze Slovenska do lesních oblastí hercynsko-sudetských. Zdůrazňuje se v této souvislosti obecně zachování intervalu přenosu podle výškové polohy lokality použití (± 1 vegetační lesní stupeň). Přenosy reprodukčního materiálu by měly být vyloučeny nebo v maximální míře omezeny v lesích podléhajících specifickému režimu hospodaření (genové základny, objekty, na nichž mají specifický zájem instituce ochrany přírody a krajiny). Je žádoucí, aby formulované závěry byly ověřovány na základě dalších poznatků hodnocením výzkumné plochy v dalších etapách vývoje, jakož i sledováním dalších disponibilních ploch.

Provenance plot with European beech (*Fagus sylvatica* L.) no. 50 – Pelhřimov, Křemešník 25 years after planting

Summary

In the Czech Republic several series of experimental plots with European beech have been established, along with plantings undertaken within the international collaboration (IUFRO). This paper summarizes the evaluation results from the 1972 plot no. 50 – Pelhřimov, Křemešník. The plot was established in the natural forest area 16 – Czech-Moravian Highland at a local elevation of 700 m, and classified as an acid spruce-beech stand. The plot was planted by 23 provenances from the Hercynian-Sudeten and Carpathian natural forest areas of the Czech Republic, and by 7 provenances from Slovakia. This assortment was completed by one Romanian provenance. The localities of origin are characterized according to the parent stands' altitude that range between 400 to 1,000 m. The plot was established as a standard complete block arrangement in three repetitions on the lots 7.5 x 7.5 m. The first measurement and plot evaluation were provided at the age of 13 years. This paper presents results from those measurements taken at the age of 28 years, and include heights of individuals, D.B.H., stem quality related to forkedness, and fork position on axis. Standard methods of mathematical statistics were used, and the results can be briefly summarized as follows:

- Height and diameter increment of provenances on the plot are satisfactory, and on average, of first yield class according to the growth tables for the appropriate age (Schober 1995).
- Individual partial populations of the provenance from the Moravian Carpathian natural forest areas and from Slovakia are classified into the fastest-growing category. In addition, some provenances from the western part of the Czech Republic, e. g. no. 17 – Hluboká, also belong to this category.
- Analysis of height growth and D.B.H. indicates "negative" statistically, and therefore a highly significant correlation relationship between the measured coefficients of tested provenances and the altitudes of parent standsites. This indicates a probable adaptation of particular beech populations in particular to vegetation period at the locality of origin.
- Evaluating stem quality of the set of types with continuous stem and fork in crown is expedient. The proportion of individuals within particular provenances has a wide range of 29 – 74 %, the average being 55 %. This proportion should enable the breeding of mature forest stands to the required economical value by suitable stand tending. The most valuable partial populations when described by stem quality comprises a number of those populations from the Carpathian areas of Moravia and Silesia, from Slovakia and from the Hercynian-Sudeten natural forest areas: S_1 – Kláštor nad Znievom, S_5 – Žarnovica, 15 – Brumov nad Vlárou.
- Acquired results from measurement and evaluation at the age of 13 years could be compared with the results taken at the age of 28 years. The results of height growth sequence from both time series are analogous, which is documented by the sequence coefficient of r = 0.88. This experience proves that evaluation at the age of 13 years indicates the growth development of provenances, and explains the problem of early diagnostics for beech provenances. This conclusion must be verified in further series of comparative plots.
- Synthetic evaluation of partial populations based on research of height, diameter increment and stem quality, classifies some partial populations from the Moravian Carpathians areas (8 – Vsetín, 15 – Brumov nad Vlárou), from Slovakia (e. g. S_3 – Zvolen), and particular provenances from the Hercynian-Sudeten area of the Czech Republic (e. g. 15 – Hluboká, 16 – Protivín) into the category of the most valuable. These results do not exclude slower growing partial populations from the further reproduction. Growth may be influenced, by the original altitude of the parent stand, and its adaptation to a shorter vegetation period. Provenances from the climatically harsher localities are understood to have very positive properties, for instance higher resistance to late frosts (Šindelář 1989).
- Based on results from this investigation and the evaluation of the experimental plot at the age of 28 years, some conclusions for forestry can be presented, particularly for the regionalization

Source of variability	Suma of squares	Degrees of freedom	Average square	Stat. F	Critical F for p = 1 - α	
					α = 0.05	α = 0,01
Provenance	**103.92**	**23**	**4.52**	**3.72++**	**1.77**	**2.24**
Repetition	4.17	2	2.09	1.72-	3.20	5.10
Residual	55.8	46	1.21			
Total	163.89	71				

Tab. 3.
ANOVA, DBH, plot no. 50 (Pelhřimov, Křemešník) 1997 - age 28 years

of reproductive material. Above all, resources of local origin are required for planting, while material from other conditions should only be used where no suitable resource exists in the area. Transfer is however possible from the natural forest areas of Carpathian Moravia and Silesia or Slovakia into the Hercynian-Sudeten forest areas. A transfer interval in altitude (± l vegetation forest degree) must be observed. The transfer of reproductive material should be excluded or to a large extent restricted in forests under specific management regimes (gene resources, and those objects in which the institutions of environmental protection are interested). The presented conclusions must also be verified by further investigation of development on the experimental plot and other available plots.

ACKNOWLEDGEMENT

Author also wishes to thank Dr. Nick Evans (Forestry Commission, U.K.) for language control.

GROWTH OF SPRUCE YOUNG PLANTATIONS ESTABLISHED AT MOUNTAIN LOCATIONS BY VARIOUS PLANTING STOCK AFTER THE APPLICATION OF FINE-GROUND AMPHIBOLITE

Horst Kriegel
Research Institute of Forestry and Game Management – Research Station,
Na Olivě 550, 517 73 Opočno, Czech Republic

ABSTRACT

In the permanent research plot Pláň established at an altitude of 980 – 1,080 m, development and health conditions were monitored of spruce young plantations planted by bare-rooted 1.5/1.5 and 2/2 transplanted plants raised in forest nurseries situated at various altitudes (260, 350 and 700 m) and 2/1.5/0.5 container-grown plants raised in peat pots. Growth parameters were compared with values obtained in plantations ameliorated by fine-ground amphibolite. Some meteorological and air-pollution characteristics were also recorded in the plot. Results of the study did not prove significant differences between particular types of bare-rooted plants, however, as compared with container-grown plants and plants ameliorated by amphibolite flour they did not achieve comparable parameters.

INTRODUCTION

Forest regeneration on extensive clear-felled areas in mountain air-polluted locations is considerably difficult (Lokvenc et al. 1992). Growth processes of young plantations are limited to a great extent by the quality of planting stock, methods of its raising, carefulness of workers carrying out particular partial operations, climatic and ecological factors occurring on forested localities (Kriegel 1991, Vacek, Lokvenc 1992) etc. One of the well-tried technologies supporting survival and growth of established plantations in mountain locations is the use of container-grown plants (Kriegel 1974, Lokvenc, Skoupý 1967, Lokvenc 1990, Lipták 1970 etc.). The development of plantations is also favourably affected by the application of soil-improving materials, viz. through the acid environment modification by liming (Balcar 1998, Podrázský 1994, 1997, Podrázský, Balcar 1996) or through the enrichment of soil by nutrients (Balcar, Podrázský 1995, Nárovec, Šach 1994, Podrázský 1999).

The objective of the paper is to study the survival and growth of spruce young plantations established by various planting stock and to verify possibilities of improving the quality of plantations by the application of soil-improving materials at exposed mountain locations of the Krkonoše Mts. (Giant Mts.) under conditions of simultaneous recording some meteorological and air-pollution parameters at the locality.

METHODS

The problem was studied in the Vrchlabí Forest Enterprise, Forest District Špindlerův Mlýn, forest type $8K_9$ – acid spruce forest situated on a slope, management group of stands 73 – natural spruce management of acid sites, altitude 980 – 1,080 m, slightly cold climatic district C1 and pollution damage zone B. The long-term research plot Pláň (LTRP Pláň) is situated on an extensive steep (15 – 30%) 30 ha clear-felled area of northern aspect where the forest stand occurs only in the uppermost part. Humus podzol is a predominating soil type. The experiment is part of an extensive study of acclimation and specific growth of mountain spruce established by Dr. A. Jurásek in 1994.

The following planting stock of Norway spruce coming from seed of the 8th forest vegetation zone of the Krkonoše Mts. was used for planting:

- three-year-old 1.5/1.5 bare-rooted plants – seedlings raised for 1.5 year under a polythene cover in the Research Station (RS) Opočno (altitude 260 m) and then transplanted into mineral soil;
- four-year-old 2/2 bare-rooted plants – seedlings raised for two years in open beds in the Veliny forest nursery (altitude 270 m) sorted out to a height of 8 – 14 cm and transported for transplanting to forest nurseries at Hostinné (altitude 350 m) and Vysoké (altitude 700 m);
- four-year-old 2/1.5/0.5 container-grown plants – seedlings raised for two years in the Veliny forest nursery (altitude 270 m) sorted out to a height of 8 – 14 cm and transported for transplanting to a forest nursery at Vysoké (altitude 700 m). After 1.5-year raising on beds the plants were transplanted into peat pots.

More detailed information on methods of raising the planting stock is given in a paper of Jurásek, Martincová (1996).

In the course of manual planting in 1994, fine-ground amphibolite flour was added to some plants into pits at an amount of 0.5 litre/plant. The amphibolite flour dispatched by Krosil Co. contained on average 11% CaO, 8% MgO, 1% K_2O and 0.3% P_2O_5.

After finishing the growth, in particular types of plants and comparative groups (untreated plants, control and plants treated by fine-ground amphibolite) growth parameters were determined such as height of above-ground parts, stem diameter and losses due to death and differences were evaluated by means of mathematical-statistical methods (t-test) and in percentages. The health condition of plantations was evaluated by damage to plants and assimilatory organs, percentage of foliage, number of needle year-classes, content of nutrients (N, P, K, Ca, Mg) and sulphur in one-year assimilatory organs. Since in particular trees multiple damage can occur, the sum of particular types of damage with the proportion of undamaged trees needs not give a value of 100% but can exceed it substantially. Foliage gives the proportion of an actual amount of needles per plant to a theoretical amount in percentage.

For soil analyses, mixed soil samples were taken from pits from the immediate vicinity of plants at a depth of 0 – 20 cm to determine the following characteristics: active and exchangeable acidity, the content of total nitrogen by Springer Klee method, the content of available nutrients of nitrogen, phosphorus, potassium, calcium and magnesium in an extract of 1% citric acid (Šmídová 1990).

In the plot under study, some climatic characteristics were determined such as minimum and maximum air temperature, snow depth, depth of soil freezing and further air pollution load (the content of sulphur in the atmosphere) by a contact summation method. Data obtained were compared with values measured in the Krkonoše Mts. in the permanent research plot Lesní bouda (altitude 1.080 m) at a distance of 7 km.

RESULTS

Growth of young plantations

The height development of spruce plantations showed certain differences caused particularly by using container-grown plants; plants set out in peat pots reached significantly higher values as compared with other tested bare-rooted plants. On the other hand, insignificant differences in the height growth were noticed between 7-year-old plantations established by bare-rooted plants of different age (three- or four-year-old), way of raising (polythene cover, open bed) and plants raised at various altitudes of forest nurseries (Opočno 260 m, Hostinné 350 m and Vysoké 700 m). After the application of fine-ground amphibolite into pits, all plantations showed significantly higher growth as compared with untreated control the highest parameters being reached by plantations established using container-grown planting stock (Fig. 1, Tab. 1).

Similar situation was recorded in evaluating the diameter growth when significant differences were not found between plantations established by bare-rooted plants of different age, method and place of raising in the 7th year after planting. Plantations established by container-grown plants reached substantially higher values. Application of even relatively small amounts of amphibolite flour to plants (0.5 litre/pit) positively affected the diameter development of tested plantations (Tab. 1).

Planting stock	Place of cultivation Elevation	Treatment	Height	Stem diameter	Foliage	Number of needle years	Mortality
			cm	mm	%		%
1,5/1,5 P	Opočno 260 m	control – untreated amphibolite meal	63 85 ++	12.0 17.8 ++	64 83 ++	2.9 3.7 ++	11 7
2/2 P	Hostinné 350 m	control – untreated amphibolite meal	70 88 ++	12.9 16.0 +	69 81 ++	2.9 3.4 ++	11 8
2/2 P	Vysoké 700 m	control – untreated amphibolite meal	69 88 ++	12.8 16.8 ++	78 89 ++	3.0 3.5 ++	10 8
Average	Bare-rooted plants	control – untreated amphibolite meal	67 87 ++	12.6 16.9 ++	70 84 ++	2.9 3.5 ++	11 7
2/1,5/0,5 RCK	Vysoké 700 m	control – untreated amphibolite meal	81 104 ++	16.2 19.9 ++	80 88 ++	3.6 3.6 -	7 7

Tab.1.
Characteristics of spruce plantations 7 years after planting to experimental plot Pláň
Note: ++ -values statistically high significant; + - values statistically significant

After the planting to an extreme locality (see below), relatively low losses due to dying off were found in all tested types of planting stock and methods of treatment. Although differences in the survival rate are not too significant (4 – 11%), it is possible to notice lower losses in container-grown plants and in plants ameliorated by amphibolite flour (Tab. 1) as compared with bare-rooted plants.

Health conditions of young plantations

When analysing the damage to spruce plantations established by particular types of bare-rooted plants – 1.5/1.5 from Opočno, 2/2 from Hostinné and Vysoké – significant differences were not found. Therefore, all tested bare-rooted plants were evaluated together and results obtained were then compared with plantations established by container-grown plants. Results of the study showed impaired health conditions of those spruce plantations which were planted without adding a soil-improving material (Tab. 2). Unfavourable health conditions were manifested by the lower proportion of trees showing any type of damage, increased occurrence of trees with terminal shoots lacking assimilatory organs (it has not been positively proved if the cause consists in a physiological damage or a fungus *Ascocalyx abietina*) but particularly by the higher occurrence of chlorotic and necrotic damage to assimilatory organs. Plantations established using a soil-improving material demonstrated significantly improved health conditions irrespective if they were established by bare-rooted or container-grown plants.

The amount of assimilatory organs is an important factor participating in the health condition of young plantations. Although the percentage of foliage and the number of needle year-classes slightly changed in particular years in relation to climatic, ecological, soil and other site conditions, it is possible to notice lower values in plantations established by bare-rooted plants (Fig. 2, Tab. 1). Total increase in the assimilatory organs occurred in plantations where fine-ground amphibolite was applied into pits or after planting the container-grown seedlings.

Nutrient content

Health conditions and the development of plantations are best characterized by the amount of nutrients in assimilatory organs. A carried out analysis proved findings mentioned above that control untreated bare-rooted plants showed usually the lower content of nutrients than plants ameliorated by amphibolite flour (Tab. 3). Particularly the deficit of nitrogen and magnesium - according to criteria of Bergmann (1998) - was then the cause of high chlorotic and necrotic damage to assimilatory organs and slow development of plantations.

Improved growth conditions of plants ameliorated by fine-ground amphibolite are also demonstrated by soil analyses of mixed samples taken from the place of former pits (Tab. 4). Although the soil did not always contain the ideal amount of nutrients for the growth of young plantations (Lesprojekt

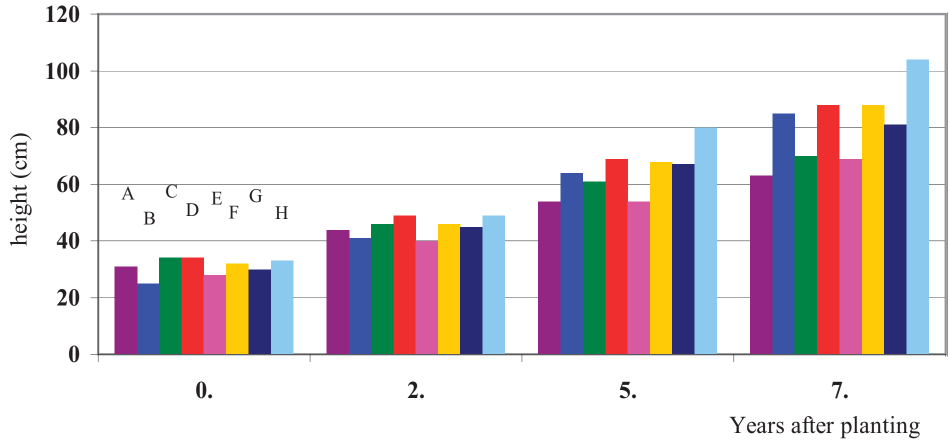

Fig. 1.
Height growth of various stock types of Norway spruce planted in spring 1994
A – control, bare-rooted, 1,5/1,5, Opočno, B – amphibolite, bare-rooted 1,5/1,5 Opočno, C – control, bare-rooted 2/2, Hostinné, D – amphibolite, bare-rooted, 2/2, Hostinné, E – control, bare-rooted, 2/2, Vysoké, F – amphibolite, bare-rooted, 2/2 Vysoké, G – control, containerized, 2/1,5/0,5, Vysoké, H – amphibolite, containerized, 2/1,5/0,5, Vysoké

1983), the content of nutrients is higher in the absolute majority of cases as compared with places without the application. Positive effects of the soil-improving material are significant and demonstrable even after seven years.

Meteorological and air pollution investigations

In the course of measuring the air temperature in the LTRP Pláň in the winter/spring period 1999 - 2000, more or less standard course of weather was recorded. A minimum temperature (-18 °C) was recorded at the beginning of February (Fig. 3) while maximum temperatures were found at the beginning (8.3 °C) and at the end of measurement (9 °C). This course of temperatures quite corresponded with values measured in the parallel LTRP Lesní bouda (Fig. 4) at a distance of 7 km.

Placing the permanent research plot on the part of an extensive clear-cut area (30 ha) results in the marked disturbance of air circulation and deposition of solid precipitation. Considerably steep ground (15 – 30%) of a northern aspect without the lateral protection of forest stands did not reduce the speed of prevailing west winds so that the transported snow was deposited on more leeward sites (stands, terrain depressions etc.) and moreover, it was partly blown away from the plot. The snow cover depth measured in the winter period 1999 – 2000 ranged only from 17 to 30 cm (Fig. 3) while on the flat area of the Lesní bouda LTRP protected by a stand the values ranged from 73 to 220 cm.

The snow cover atypical depth in the Pláň LTRP fundamentally affected a temperature in the surface soil layer where the main mass of tree roots was concentrated. The low snow cover layer does not show sufficient insulating capability and, therefore, at high mountain locations upper soil layers are frozen through down to a depth of 23 cm. The dynamics of soil freezing in the Pláň LTRP and insulating effects of a thicker snow cover in the Lesní bouda LTRP are evident from Figs. 3 and 4. (In the period from 1 March to 1 April 2000, it was not possible to determine the frozen soil depth in the Lesní bouda LTRP due to the permanent overlaying the measuring device by snow cover).

In studying the air pollution load (sulphur content) by the contact summation method extraordinary situations were not noticed in the course of last two years. The condition of air pollution by sulphur is relatively low and stabilized and does not significantly differ from long-term monitoring carried out in the other part of the Krkonoše Mts., viz. the Lesní bouda LTRP (Fig. 5).

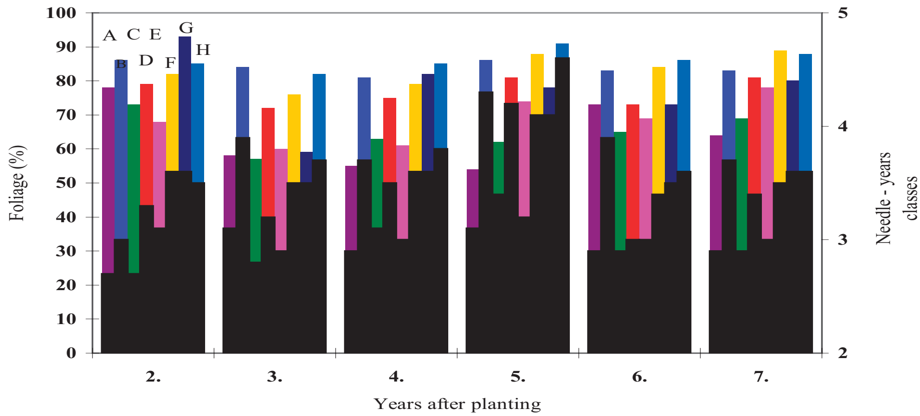

Fig. 2.
Percentage of foliage (crosshatched) and number of needle year-classes (black) in spruce plantations on experimental plot Pláň
A – control, bare-rooted, 1,5/1,5, Opočno, B – amphibolite, bare-rooted 1,5/1,5 Opočno, C – control, bare-rooted 2/2, Hostinné, D – amphibolite, bare-rooted, 2/2, Hostinné, E – control, bare-rooted, 2/2, Vysoké, F – amphibolite, bare-rooted, 2/2 Vysoké, G – control, containerized, 2/1,5/0,5, Vysoké, H – amphibolite, containerized, 2/1,5/0,5, Vysoké

CONCLUSION

Based on the study carried out in the permanent research plot Pláň it is possible to give the following findings:

- climatic conditions, particularly strong air circulation on an extensive (circa 30 ha) steep unprotected area, small depth of snow cover and frozen soil surface are not typical of mountain sites planned for reforestation;
- height and diameter increment of spruce young plantations as well as losses caused by dying off were partly affected by the planting stock used. Favourable growth parameters were achieved after 7-year monitoring in young plantations established by 4-year-old container-grown plant. Significant differences were not noticed between bare-rooted transplanted plants of different age (3- or 4-year-old), method of raising (polythene cover, open bed) and altitude (260, 350 and 700 m); measured values were, however, significantly lower as compared with container-grown plants;
- to increase parameters of young spruce plantations established by bare-rooted and container-grown plants it is recommended to add soil-improving amphibolite flour into particular planting pits at an amount of at least 0.5 litre/pit;
- application of the ameliorating material resulted in the significant improvement of health conditions of spruce young plantations established both by bare-rooted and container-grown plants. The higher content of nitrogen and magnesium showed favourably in the reduction of chlorotic and necrotic damage to assimilatory organs.

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Treatment	Coefficient	Years after planting													
		2		3		4		5		6		7		Average	
		P	O	P	O	P	O	P	O	P	O	P	O	P	O
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
untreated - control	undamaged	23	30	14	16	25	64	31	41	64	69	44	49	34	45
	dry top	3	3	5		4	4	9	1	9	4	7	5	6	3
	damaged terminal	11	8	5	9	9	4	7	9	3	4	3	1	6	6
	stem deformace	2	1	8	13	4	5	17	11	5	4	15	12	9	8
	stem rupture									1		4	2	1	
	pine weevil		1												
	Lammas shoot														
	chloroses	67	65	84	53	60	23	39	37	32	26	41	36	54	40
	necroses	2		11	55	59									
amphibolite flour	undamaged	54	45	59	65	55	61	71	62	79	88	71	76	65	66
	dry top l								1	2		2		1	0
	damaged terminal	5	4	4	4	7	14	6	7	4	7	3	7	5	7
	stem deformace	2	1	8	1	5	1	6	8	2	1	11	5	6	3
	stem rupture									1		4	2	1	
	pine weevil	2													
	Lammas shoot							1	1						
	chloroses	41	54	35	30	25	20	16	16	15	4	11	11	24	23
	necroses		1	1		29	7	5	5					6	2

Tab. 2.

Mean state of health of spruce plantations established on experimental plot Pláň by bare-rooted (P) and containerized (O) plants with and without finely ground amphibolite application

Note: Used planting stock comprised bare-rooted plants 1.5 /1.5 bred at Opočno, 2/2 grown at Hostinné and Vysoké and containerized plants in RCK 2/1, 5/0.5 bred at Vysoké.

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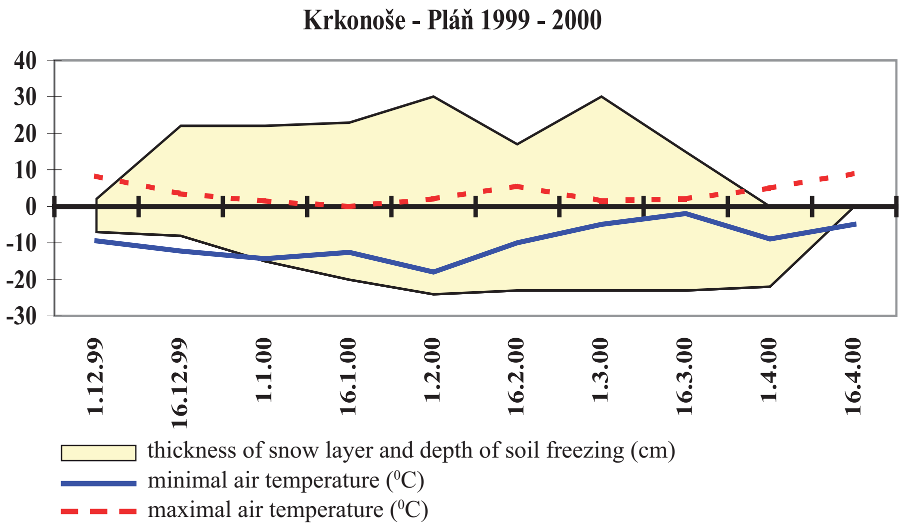

Fig. 3.
Maximal and minimal air temperature, thickness of snow layer and depth of soil freezing on experimental plot Pláň during years 1999 to 2000

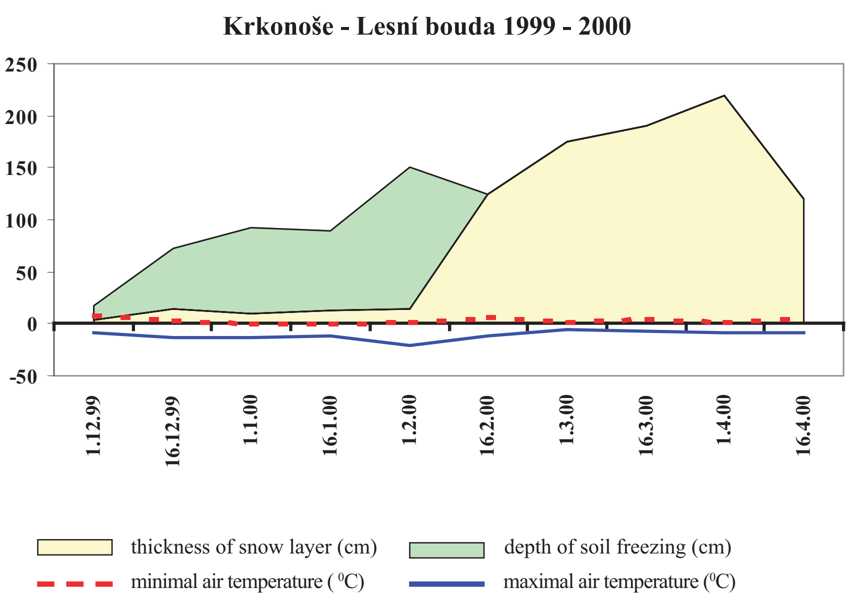

Fig. 4.
Maximal and minimal air temperature, thickness of snow layer and depth of soil freezing on experimental plot Lesní bouda during years 1999 to 2000

Year of sampling	Treatment	Nutrient (%)					S
		N	P	K	Ca	Mg	%
1995	untreated – control - amphibolite	0.83 0.79	0.14 0.17	0.31 0.42	0.22 0.33	0.083 0.103	0.077 0.100
1996	untreated – control - amphibolite	0.89 1.06	0.19 0.25	0.46 0.30	0.14 0.28	0.093 0.100	0.201 0.141
1997	untreated – control - amphibolite	1.28 1.73	0.19 0.25	0.29 0.37	0.33 0.43	0.089 0.106	0.104 0.119
1998	untreated – control - amphibolite	1.14 1.47	0.15 0.20	0.26 0.30	0.26 0.29	0.064 0.076	0.110 0.134
1999	untreated – control - amphibolite	1.26 1.55	0.22 0.31	0.31 0.36	0.18 0.18	0.061 0.069	0.098 0.084
2000	untreated – control - amphibolite	1.33 1.44	0.19 0.21	0.29 0.33	0.13 0.13	0.036 0.071	0.131 0.144

Tab. 3.
Nutrient and sulphur content in one year old spruce needles on experimental plot Pláň

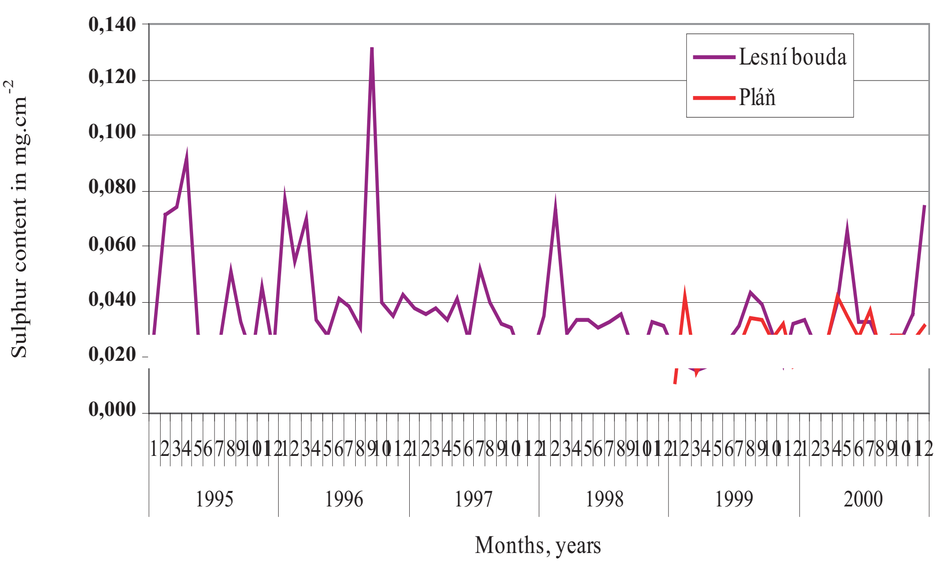

Fig. 5.
Sulphur content in air during several months on experimental plots Pláň and Lesní bouda

Year of sampling	Treatment	Mixed soil sample into depth of 20 cm							
		pH H_2O	pH KCl	P_2O_5	K_2O	CaO	MgO	Hu-mus	Nt
				mg.kg^{-1}				%	%
1994	untreated - control	4.4	2.8	130	41	104	17	8,2	0,32
1997	untreated - control		3.3	57	101		76	35.3	0.73
	amphibolite		3.6	48	149		73	35.2	0.79
1998	untreated - control	3.8	2.4	117	58	273	47	15.1	0.54
	amphibolite	4.5	2.4	161	166	373	93	41.1	1.37
1999	untreated - control	5.0	2.6	34	37	133	21	7.8	0.25
	amphibolite	5.4	3.2	278	127	153	61	19.7	0.62
2000	untreated - control	4.2	2.3	210	147	213	57	11.8	0.42
	amphibolite	4.9	3.1	379	200	213	68	22.4	0.92

Tab. 4.
Soil acidity (pH) and nutrient content in soil on experimental plot Pláň

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Růst smrkových kultur založených v horských polohách rozdílným sadebním materiálem po aplikaci amfibolitové moučky

Souhrn

V horské oblasti Krkonoš byla na rozlehlé nechráněné odtěžené ploše (cca 30 ha) založena výzkumná plocha, kde se sledoval růst a zdravotní stav smrkových kultur vysázených různým sadebním materiálem z 8. lvs meliorovaným amfibolitovou moučkou.

K výsadbě byly použity:

- tříleté prostokořenné sazenice pěstované 1,5 roku pod polyetylenovým krytem v nadmořské výšce 260 m a přeškolkované do minerální zeminy,
- čtyřleté prostokořenné sazenice pěstované dva roky v nadmořské výšce 270 m, na volných záhonech školky, vytříděné na výšku 8 – 14 cm a převezené k dopěstování ve školkách v nadmořských výškách 350 m a 700 m,

- čtyřleté obalené sazenice v rašelinocelulózových kelímcích (RCK) pěstované dva roky v nadmořské výšce 270 m, na volných záhonech školky, vytříděné na výšku 8 – 14 cm, převezené k 1,5roční-mu pěstování na volných záhonech školky v nadmořské výšce 700 m a potom přesázeny do RCK.

Při ruční výsadbě v roce 1994 byla k některým sazenicím zapracována do jamek drcená amfibolitová moučka v množství 0,5 l. Látka obsahovala v průměru 11 % CaO, 8 % MgO, 1 % K_2O a 0,3 % P_2O_5. Po ukončení růstu byly u testovaných druhů sazenic zjišťovány růstové parametry a zdravotní stav, obsah živin v asimilačních orgánech a v půdních vzorcích. Současně byly na ploše evidovány některé klimatické charakteristiky jako minimální a maximální teplota vzduchu, výška sněhové pokrývky, hloubka promrzání půdy a dále i imisní zátěž (obsah síry v ovzduší).

Na základě provedeného šetření je možné uvést následující:

1. klimatické podmínky – zejména silné proudění vzduchu na rozlehlé (cca 30 ha), svažité, nechráněné ploše, dále malá výška sněhové pokrývky a promrznutí půdního povrchu – nejsou typické pro horská stanoviště určená k zalesnění;
2. výškový a tloušťkový vývoj smrkových kultur, stejně jako i ztráty uhynutím byly částečně ovlivněny použitým sadebním materiálem. Příznivých růstových parametrů bylo po 7letém sledování dosaženo u kultur založených 4letými obalenými sazenicemi. Mezi použitými prostokořennými školkovanými sazenicemi rozdílného věku (3 nebo 4leté), způsobu pěstování (polyetylenový kryt, volný záhon) i nadmořské výšky pěstování (260 m, 350 m a 700 m) nebyly zaznamenány podstatnější rozdíly; naměřené hodnoty však byly v porovnání s obalenými sazenicemi prokazatelně nižší;
3. ke zvýšení parametrů smrkových kultur zakládaných prostokořennými a obalenými sazenicemi je výhodné při výsadbě zapravit do jamek meliorační amfibolitovou moučku v množství alespoň 0,5 l;
4. aplikací meliorační látky došlo k podstatnému zlepšení zdravotního stavu smrkových kultur zakládaných jak prostokořennými, tak i obalenými sazenicemi. Vyšší obsah dusíku a hořčíku se příznivě projevil na omezení chlorotického a nekrotického poškození asimilačních orgánů.

Growth of spruce young plantations established at mountain locations by various planting stock after the application of fine-ground amphibolite

Summary

Experimental plot was set up on large clear cut (about 30 ha) in the Krkonoše Mts. Growth and health state of plantations established by various kind of planting stock originated from high altitudes and ameliorated by finely ground amphibolite were investigated on the plot.

Used stock types:

- Three years old transplants 1.5+1.5 P grown under plastic cover in altitude 260 m a. s. l. during 1,5 years and then transplanted into mineral soil;
- Four years old bare rooted transplants 2+2 P grown during first two years in open beds in altitude 270 m a. s. l. and sorted to height 8 to 14 cm before transplanting. Seedlings were transplanted in several nurseries in altitudes from 350 to 700 m a. s. l.
- Four years old transplants in peat pots (Jiffy pots) grown during first two years in open beds in altitude 270 m a. s. l. and after sorting to height 8 to 14 cm transplanted in altitude 700 m a. s. l. After next 1.5 year they were transplanted into peat pots.

Finely ground rock – amphibolite – (0.5 l) was added into holes to some plants during hand planting. This material contained on average 11 % CaO, 8 % MgO, 1 % K_2O and 0,3 % P_2O_5. At the end of growth season some growth characteristics, state of health and mineral nutrients content in plants and in soil were evaluated. Some climatic characteristics as minimal and maximal air temperature, depth of snow cover, depth of frozen soil layer and moreover sulphur content in the airflow were monitored on the same plot.

Results suggest:

1. Climatic conditions – namely strong air flow on large (30 ha) unprotected slope, low snow cover and freezing of soil surface – are not typical conditions in mountain localities destined for reforestation.
2. Growth in height and diameter and mortality were partly influenced by stock types. Favourable growth after 7 years occurred in plantations founded by four-year old plants in peat pots. No considerable differences occurred among bare-rooted plants of various age (3 or 4 years), different way of cultivation (with or without plastic cover) or various altitude of nursery (260, 360, 700 m a. s. l.). Bare-rooted plants however, grew worse than containerized ones.
3. Application of amelioration finely ground amphibolite (minimal 0,5 l) is recommended for growth enhancement both containerized and bare rooted plants.
4. Application of amelioration material caused considerable improvement of health state of spruce plantations established by bare rooted or containerized planting stock. Higher nitrogen and magnesium content favourably influenced depression of needle chlorosis or necrosis.

Note:

The experiment is funded as a part of MZe CR research project no. 00 207 0201: “Stabilization of the forest functions in biotopes disturbed by anthropogenic activity under changing ecological conditions”.

WATER CHEMISTRY DEVELOPMENT OF SURFACE SOURCES IN THE ŽELIVKA AREA WITH REGARD TO POLLUTION LOAD AND MANAGEMENT IN THE CATCHMENT

Václav Lochman, Věra Fadrhonsová, Milan Bíba
Forestry and Game Management research Institute,
Jíloviště-Strnady

ABSTRACT

Since 1973 the amount of dissolved substances in bulk water, in throughfall and stream water at the weir and at spring has been investigated in the forest catchment Pekelský stream, right-handed tributary of the Želivka river at Kožlí, and spring water analysed in the fields at village Brzotice. Sampling and analyses of stream water in meadows at village Kožlí were finished in 1984. Despite high annual fallout of H ions, N (30 – 40 kg . ha^{-1}) and S/SO_4^{2-} (60 – 70 kg) compounds in mature stands stream water contained low concentrations of these elements. In the 1990s deposition of H ions and S/SO_4^{2-} markedly decreased, as well as mildly N/NO_3^- + NH_4^+ deposition. For years pH values in the stream remained approximately on the same level. Average concentrations of nitrates increased from 1 mg . l^{-1} to more than 2 mg . l^{-1} and concentrations of sulphates were still increasing to 15 and 20 mg . l^{-1}. Contents of nitrates and sulphates were substantially higher in spring water of the catchment formed by richer forest types and agricultural soil. The most nitrates and sulphates were found in spring water of fields, and their values did not drop in the 1990s (NO_3 > 80 mg . l^{-1}, SO_4^{2-} 20 – 35 mg . l^{-1}). Great retention ability for mentioned ions occurs on the catchments with prevailing spruce stands on oligotrophic soils.

INTRODUCTION

Since 1973 bulk chemistry, deposition of elements, chemistry of soil water and surface source water in the stream and a spring have been investigated on the experimental catchment Pekelský stream (Želivka area). Until 1990 this investigation, aimed at recognizing interconnection of hydrological and production functions of forest, had been involved into complex research of influence of spruce stands and regeneration methods on hydrological and ecological effects of forests. Increment of air pollution and deposition of pollutants in the catchment of the Želivka river dam for drinking water increased also importance of results assessing the level of forest ecosystems load by pollutants and their impact on changes in forest soils and in water compounds running off into drinking water resources. Until the early 1980s (1983) samples taken from the stream draining water from the catchment with agricultural forest stands at Kožlí and from the spring in the catchment completely agriculturally managed were analysed and compared. Investigation of spring water has been continuing till now. After 1990 hydrological research gradually focused on operating the hydrometeorological station and measuring run-off at the weir. This paper presents results from investigation of forest stands (mostly spruce ones) influence on running-off water chemistry during development of pollution load since 1973 until the end of the 1990s and comparison of water chemistry of agriculturally managed catchment.

RESEARCH SURVEY

Establishment of the FGMRI experimental plot Želivka was motivated by the enhanced interest in production of larger volume of qualitative water running off from forest catchments into water resources. This intention became still more actual at the turn of 1960s and 1970s; during this period concentrations of unhygienic substances increased in water resources from agriculturally managed catchments due to chemization of agricultural production. Research was focused on determination of water balance in forest stands, microclimatic and hydropedologic conditions of forest growth, volume, way and distribution of water run-off and influence of running-off precipitation water chemistry by forest stands and management methods.

Research results were presented in the final report of Lochman et al. (1990), partly in other final reports from 1994 and 1998 (Lochman et al. 1994, 1998). Regarding content of investigated substances during their run-off into water resource Lochman et al. (1983) and (Lochman 1989, 1997) evaluate influence of forest ecosystems and husbandry in them in chronical order like positive from the viewpoint of water management demands for drinking water. Compared with water resources from agriculturally managed catchments water from forest ecosystems contains less nitrates. Different influence of forest stands and of agricultural soil management on element concentration was observed by Balek et al. (1978) and Pačes, Moldan (1981) in surface water of the Trnávka catchment.

Hydrological effectiveness of ecosystems in forest catchments and elements circulation were investigated in the other objects built within the Želivka catchment. Since 1990 substances deposition, chemical composition of surface water and element cycling in the catchment of Anenský and Lesní streams at Košetice village are investigated as a part of the international programme GEMS (Global Environment Monitoring System). Results of measurement are presented in Váňa et al. (1995).

Since 1994 deposition of substances in the wooded part of catchment (Lesní stream) and their losses with running-off water have been investigated as a part of GEOMON programme of the Czech Geological Institute (Fottová, Skořepová 1998). The authors present also results from small wooded catchments in the Bohemian-Moravian Highland, from Salačova Lhota and Loukov.

Also some authors abroad deal with influence of soil management on nutrient content in running-off water of surface sources, for instance Lenhart et al. (1983) in the Hesse catchment (FGR). Regarding the U. S. A. conditions Swanson et al. (2000) completely evaluated influence of substances deposition, forest stands characteristics and management in forests on water cycling and substances transport as well as influence of substances on forests growth and water resources quality.

Based on interest in water supply of the dam - drinking water resource for Prague - Czech Hydrological and Meteorological Institute issued complete information on evaluation of long-term measurement in the Želivka catchment (Böhm et al. 1993).

Importance of forests for producing “pure“ water for hydrologically important streams continued in the Czech Republic in the late 1990s when unfavourable state was found out for concentrations of nitrate and nitrite nitrogen and in coefficients of microbial pollution (Report of the Ministry of Agriculture and Ministry of Environment CR 1999). High water pollution with nitrogen compounds in streams managed by the State Ameliorative Administration is also documented in the Report of the Ministry of Agriculture CR (1998).

METHODOLOGY

Description of catchment and partial plots

Experimental catchment plot Pekelský stream (Želivka) has an area of 119 ha, of which 117 ha are forests in possession of forest cooperative Zaháj at Ledeč nad Sázavou, and 2 ha are arable land. Catchment elevation ranges between 360 and 471 m. The 1970s inventory documents that spruce prevails (85 %) in stands species composition, the rest involves pine, fir, larch and beech. This species composition had not substantially changed during research. Until the 1980s only accidental logging was realized, in recent years annual principal felling has not overstepped the area of 1 ha. The majority of stands is now over 60 years of age.

Soil conditions incl. forest floors were evaluated by Mráz (1973) based on “Evaluation of hydrogeological works“ (1972). Soils of the experimental catchment are of variable texture composition. Parent rock is created by deeply weathered biotitic paragneiss with might overlapping of older (tertiary) clay layer in the northern part. Eastern part lies on loamy pit-run gravel, central part is formed by loess loam.

Only in the southern part of catchment overlayers eroded and soil substrate was formed by weathered parent rock. Fluvisol occurs on alluvia in the close vicinity of the stream. Cambisol developed on nearly the whole catchment, stagnic and dystric cambisols in the northern part. Terrain depressions are fulfilled with gleyic cambisols and luvisols on loess loam overlayers. Haplic and dystric cambisols formed on the weathered parent rock in the southern part of catchment (WRB Soil Taxonomy 1998).

Mor moder is prevailing forest floor in spruce stands, on the poorest soils also mor with *Leucobryum glaucum* HAMPE. Typical moder covers cambisols in the lower part of the catchment in fresh fir stands with *Oxalis acetosella*. According to MRÁZ (1973) most of the catchment´s forest types belongs to typical fir stands with *Luzula luzuloides* sp. (*Luzulo-Abietum typicum*) and blueberry fir stands (*Myrtillo abietum*), acid types of hornbeam-fir beech stands are growing in the lower part of the catchment.

Groundwater level appears in tertiary sediments and weathered parent rock of moldanubic rock (Evaluation of hydrogeological works 1972) mainly of biotitic paragneiss. According to hydrogeological investigation seeping precipitation water fluently flows into the stream. Accumulated groundwater flows away in springs – in the spring in the valley part and the spring (spring area) of the Pekelský stream in the upper part of the catchment. Investigation of water composition at the weir was completed by water analysis of mentioned spring rising in the lower part of the catchment (ca 150 m upwards from the weir), whose catchment comprises about 2 ha of arable soil.

In the period 1973 – 1983 water samples were taken from meadow stream flowing from Kožlí. Except for meadows and arable soil this catchment comprises also forest stands and is crossed by a road. Housing estate of the village Kožlí may influence the water, too.

Water chemistry in the field spring at Brzotice has been investigated since 1973. In the late 1980s the well was covered during technical improvement of plots, and water has been drained by cement pipe into dig along the road. This catchment is completely formed by agricultural arable soil.

Chemistry of precipitation and soil water, and deposition of substances have been observed on the partial plots (I - IV) since 1973, as well as in nature spruce stand and the clearcut (plot I and III). Trees at shelterwood felling (plot II) were felled in 1989, and measurement at newly established clearcut and young spruce stand (plot IV) was finished in 1998. In 1989 sampling of precipitation and soil water began in a young beech stand (plot V). Detailed data are in table 3.

Description of work and laboratory methods

Precipitations on the plots were caught into troughs and snowmeters, running-off soil water was measured by lysimeters placed under forest floor into the depth of 30 and 100 cm. Water samples were taken in the months´ intervals, and since 1995 in two weeks´ intervals and processed in the FGMRI laboratory, Jíloviště-Strnady. Since October 1997 deposition has been observed also in mature spruce stand (99 years) at the monitoring plot of Level II (plot I 140) within the international ICP Forests programme. Sampling methodology is the same, but samples are collected in 10-day intervals into the intercepting cups rather different (larger intercepting plot) than on the other plots.

Following description of laboratory methodology is aimed at ions assessed in this contribution. Concentration of H ions (pH) was determined by glass electrode. Ions NH_4^+ and NO_3^- were initially found out colorimetrically, since 1985 Technicon Auto-Analyzer II has been used. Since 1994 NO_3^- is defined on the ion liquid chromatograph Thermoseparation Products and NH_4^+ on the colorimeter SAN Plus Analyzer of the firm Skalar. Sulphates were determined gravimetrically until 1984, since 1985 on the device Technicon and since 1994 on the liquid chromatograph. Concentration of fluorines (F-) was detected by ion selective electrodes until 1993, since 1994 on liquid chromatograph.

RESULTS

Chemistry of precipitation water and total fallout of substances into forest ecosystems are the decisive factors affecting both production of hygienic water running off into water resources and soil properties. Also for the Želivka area direct fallout of protons (H^+), nitrogen compounds and fallout

Sampling place	Gauss-Krieger coordinates		Elevation (m)
	x	y	
Pekelský stream - weir	35 17 10	55 04 05	360
forest spring	35 17 00	55 04 15	370
spring in fields at Brzotice	35 10 45	55 04 70	410
stream in meadow at Kožlí	35 18 40	55 05 10	435

Tab. 1.
Data on observed source

Year	mm	Year	mm	Year	mm
1973	509	**1983**	671	**1992**	482
1974	765	**1984**	576	**1993**	651
1975	670	**1985**	580	**1994**	605
1976	549	**1986**	679	**1995**	718
1977	869	**1987**	827	**1996**	559
1978	615	**1988**	663	**1997**	669
1979	644	**1989**	696	**1998**	735
1980	619	**1990**	469	**1999**	584
1981	805	**1991**	514	**2000**	619
1982	611				

Tab. 2.
Annual precipitation sums at the meteorological station of FGMRI Myslivna, Pekelsko (for annual period 1 - 12)

Plot	Species composition	Age to Jan. 1, 1997	Yield class	Forest type	Soil type	Elevation
I	spruce 100	93	4	4P1	Epidystric Luvisols	440
II*)	spruce 10, beech 10	8	4	4P1	Epidystric Luvisols	440
III	non-forested	-	-	4P1	Epidystric Luvisols	440
IV	spruce 100	55	1	4P1	Epidystric Cambisols	440
V	beech 100	31	2	3K1	Haplic Cambisols	420

* in 1972 shelterwood felling in spruce stand by removing 50% of stands mass, remained trees were cut down in 1989, and beech planting

Tab. 3.
Characteristics of partial plots until 1989

of sulphates (SO_4^{2}), i. e. potentially acid substances, are of principal importance.

Tab. 4 to 8 present concentrations of theses substances in precipitation for felling (plot III), for adult spruce stand (plot I), shelterwood felling (plot II), for younger spruce stand (plot IV), for young beech stand (plot V), and for the plot I 140 in time intervals. Concentrations of H ions in bulk (water) on the clearcut (plot III) were dropping since the late 1980s and in the early 1990s. Content of sulphates has been decreasing since 1970s. The highest concentrations of $N(NO_3^- + NH_4^{+)}$ occurred at the turn of the 1980/1990s. At the end of 1990s (1998 – 1999) pH rather decreased and contents of nitrates and ammonium ions increased in bulk caught on open space (tab. 4).

Time course similar to precipitation from open space was found for oscillation of concentrations of mentioned ions in throughfall of mature (I) and young spruce stands (IV) – tab. 5, 7. For the shelterwood felling (II) concentrations of SO_4^{2}, H^+, NO_3^- and NH_4^+ were increasing in throughfall until the remained trees were felled at the end of 1989 (tab. 6). Measurement on this plot (already on the clearcut) and on the plot IV was finished in 1998. Investigation of throughfall chemistry in beech stand (plot V) began in 1989, and until 1999 average SO_4^{2-} concentrations had been decreasing here. For protons (H^+) and nitrogen compounds the changes were not unambiguous (tab. 8).

The greatest growth of average concentrations of pollutants in throughfall, compared with bulk precipitation on the open space, occurred in mature spruce stand. Also throughfall in thinned spruce stand on shelterwood felling was heavy contaminated, and in the late 1980s values were even equal on both plots. Distinctly lower enrichment of throughfall with SO_4^{2}, H^+, NO_3^- and NH_4^+ was observed under crowns of young spruce stand (IV), and the lowest average concentrations of these substances, especially of sulphates, were in throughfall of beech stands.

pH development of soil water caught under humus horizon O on the clearcut (plot III) is the same like for precipitation water, since the 1980s concentrations of H ions (tab. 4) have decreased. Amount of nitrogen compounds decreased after decomposition of forest floor and did not increase either in the 1990s. Decrease of SO_4^{2} has been observed since 1994. Concentrations of ammonium nitrate and sulphate ions in water caught in the depth of 30 cm develop differently - the highest values were found

Sampling place	**Period**	**H^+**	**NH_4^+**	**NO_3^-**	**N**	**SO_4^{2-}**	**S**
bulk	1973-79	0.088	1.01	3.05	2.23	6.39	2.13
	1980-83	0.226	0.81	3.48	1.93	5.78	1.93
	1984-89	0.054	1.36	5.04	2.35	5.71	1.91
	1990-93	0.029	1.55	4.72	2.36	5.11	1.71
	1994-97	0.010	0.62	2.97	1.41	4.11	1.37
	1998-99	0.016	0.95	4.01	1.53	3.50	1.17
	2000	0.017	1.04	4.04	1.42	2.73	0.91
gravitation water beneath O horizon	1973-79	0.044	1.99	7.10	4.30	12.20	4.07
	1980-83	0.070	1.57	4.36	3.84	11.60	3.87
	1984-89	0.042	0.66	1.99	3.65	13.90	4.64
	1990-93	0.017	0.93	0.96	3.43	12.00	4.01
	1994-97	0.010	0.51	1.29	1.77	6.07	2.03
	1998-99	0.030	0.26	1.53	1.25	4.66	1.56
	2000	0.028	1.66	3,00	2.30	4.49	1.50
gravitation water in depth of 30 cm	1973-79	0.015	0.21	8.51	6.47	27.90	9.31
	1980-83	0.028	0.19	0.60	4.37	18.70	6.24
	1984-89	0.008	0.70	1.64	3.91	14.90	4.97
	1990-93	0.006	1.10	2.05	4.99	18.30	6.11
	1994-97	0.010	0.69	2.93	5.14	20.40	6.81
	1998-99	0.005	0.43	14.35	6.95	29.27	9.77
gravitation water in depth of 100 cm	1973-79	0.009	0.05	4.70	5.08	22.30	7.44
	1980-83	0.018	0.05	0.37	4.04	17.70	5.91
	1984-89	0.035	1.05	1.72	5.44	20.47	6.83
	1990-93	0.004	0.82	0.74	6.46	25.80	8.61
	1994-97	0.003	1.08	0.68	5.47	20.52	6.85
	1998-99	0.010	0.23	10.25	5.98	25.68	8.57

Tab. 4.
Želivka - plot III - clear cutting - average concentrations (mg . l^{-1})

out on the newly arisen clearcut in the 1970s and then again in the late 1990s. Also in water collected in the depth of 100 cm nitrates reached the highest concentration first at the end of 1990s.

The highest annual concentrations of protons were measured in water running off from forest floor in spruce stand (I) in 1984 to 1989, sulphates reached their maximum in 1990 to 1993, nitrates in 1998 and 1999 (tab. 5). In the same time maxima of mentioned ions appeared also in water taken in the depth of 30 cm. The last sampling from the depth of 100 cm was provided in 1989; until that time concentrations of observed ions developed similarly like in water of surface soil horizons. Water pH increased and nitrogen compounds decreased with profile depth. The highest concentrations of sulphates gradually transferred from surface humus horizon into lower layer. Similar transfer of maximal SO_4^{2} occurrence into water caught in the depth of 100 cm was also in the clearcut soil but average values were rather lower than in water from soil profile under spruce stand. Also water enrichment with ions H^+, NO_3^- and NH_4^+ was here lower. In decade 1990 – 1999 concentrations of sulphates under the beech stand (plot V) decreased in precipitation and soil water, concentrations of H^+, NO_3^- and NH_4^+ did not show any certain trend of development in soil water (under horizon O and in the depth of 20 cm) decreased (tab. 8).

Sampling place	Period	H^+	NH_4^+	NO_3^-	N	SO_4^{2-}	S
throughfall	1973-79	0.212	3.16	7.78	4.21	53.90	17.99
	1980-83	0.460	3.18	8.89	4.48	58.80	19.63
	1984-89	0.260	5.99	15.46	8.14	55.00	18.36
	1990-93	0.177	7.46	18.42	9.95	54.50	18.19
	1994-97	0.048	4.07	11.64	5.79	30.50	10.18
	1998-99	0.038	4.18	23.94	8.65	24.40	8.14
	2000	0.041	4.97	26.76	9.90	19.20	6.41
gravitation water beneath O horizon	1973-79	0.131	3.24	10.83	4.96	53.40	17.82
	1980-83	0.230	2.01	7.84	3.33	58.60	19.56
	1984-89	0.274	2.85	13.39	5.24	73.40	24.50
	1990-93	0.140	7.10	18.16	9.62	78.10	26.07
	1994-97	0.151	2.41	11.92	4.56	48.70	16.26
	1998-99	0.125	4.93	20.23	8.40	30.20	10.08
	2000	0.068	6.67	34.65	13.01	18.90	6.31
gravitation water in depth of 30 cm	1973-79	0.042	0.94	2.06	1.20	36.90	12.32
	1980-83	0.244	0.80	3.57	1.43	46.50	15.52
	1984-89	0.076	4.79	10.11	6.00	67.40	22.50
	1990-93	0.065	4.32	17.47	7.30	87.30	29.14
	1994-97	0.039	1.25	5.70	2.26	113.30	37.82
	1998-99	0.022	3.25	17.91	6.57	50.19	16.75
	2000	0.030	1.44	7.92	2.91	28.30	9.45
gravitation water in depth of 100 cm	1973-79	0.017	0.05	0.23	0.09	9.20	3.07
	1980-83	0.058	0.33	0.56	0.38	12.80	4.27
	1984-89	0.024	0.92	5.27	1.90	52.30	17.46
	1990-93	0.009	1.23	1.97	1.40	74.40	24.83

Tab. 5.
Želivka plot I - spruce stand - average concentrations (mg . l^{-1})

Sampling place	Period	H^+	NH_4^+	NO_3^-	N	SO_4^{2-}	S
throughfall	1973-79	0.009	2.28	6.81	3.31	30.98	10.34
	1980-83	0.213	2.73	8.93	4.14	35.21	11.75
	1984-89	0.243	5.93	15.19	8.04	47.05	15.71
	1990-93	0.024	1.49	3.70	1.99	7.54	2.52
	1994-97	0.011	0.93	4.69	1.78	5.40	1.80
gravitation water beneath O horizon	1973-79	0.215	1.89	3.18	2.19	25.44	8.49
	1980-83	0.320	1.66	3.58	2.10	27.80	9.28
	1984-89	0.306	1.25	2.85	1.61	51.44	17.17
	1990-93	0.062	1.94	2.29	2.02	18.96	6.33
	1994-97	0.023	0.05	1.24	0.32	7.10	2.37
gravitation water in depth of 30 cm	1973-79	0.030	0.21	0.60	0.30	57.60	19.23
	1980-83	0.055	0.24	0.72	0.35	69.30	23.13
	1984-89	0.197	0.92	3.23	1.44	62.20	20.76
	1990-93	0.013	1.38	0.61	1.21	83.40	27.84
	1994-97	0.004	1.01	1.76	1.18	22.20	7.41
gravitation water in depth of 100 cm	1973-79	0.040	0.01	2.06	0.47	46.12	15.39
	1980-83	0.067	0.00	0.56	0.13	42.23	14.10
	1984-89	0.006	1.57	3.27	1.96	44.07	14.71
	1990-93	0.005	1.54	1.40	1.51	44.11	14.72
	1994-97	0.003	2.23	4.29	2.70	35.57	11.87

Tab. 6.
Želivka - plot II - shelterwood felling until 1989, since 1990 on clearcut - average concentrations (mg . l^{-1})

TOTAL DEPOSITION OF SUBSTANCES

Total deposition of SO_4^{2-}, H^+, N(NO_3^- + NH_4^+) and F^- with bulk and throughfall water is presented in graphs 1 to 4. Its development roughly corresponds with concentration of these ions. In the 1970s total fallout of H ions increased up to 1 kmol . ha . $year^{-1}$ on the clearcut (plot III), since the half of 1980s H ions fallout had gradually decreased and after 1995 reached neither 0.1 kmol . ha . $year^{-1}$. Deposition of protons in the spruce stand on the plot I developed similarly dropping from high annual values (up to 2 kmol . ha) in the early 1980s to 0.1 kmol . ha at the end of 1990s.

High fallout of protons was observed also in precipitation of shelterwood felling (plot II) before cutting down spruce with low stand density. The lowest amount of H ions was caught with throughfall in young beech stand (plot V), less than on the clearcut.

Bulk deposition of sulphates on clearcut shows rather balanced annual values with minimum of 13.0 kg in 2000 and maximum of 80.00 kg in 1988. High SO_4^{2-} deposition occurred in mature spruce stand (I) overstepping 200 kg . ha^{-1} . $year^{-1}$ in 1978 to 1988. Its significant decrease is obvious until 1995 (< 100 kg . ha^{-1}). Fallout of sulphates was high on the shelterwood felling as well, and in the late 1980s deposition was higher than in closed spruce stand. Deposition values of SO_4^{2-} in young closed spruce stand reached half of fallout found in mature stand. Fallout of sulphates with throughfall was lowest in young beech stand in comparison with the other investigated stands and after 1995 dropped to values about 20 kg . ha^{-1} . $year^{-1}$.

Annual deposition of nitrogen compounds (N/NO_3^- + NH_4^+) was mostly lower than 10 kg . ha^{-1} on the clearcut (III). Their growth was found out first in the half of 1980s and continued until the beginning of 1990s. Since 1993 deposition has been balancing round 10 kg . ha^{-1}. Within the same time intervals

Sampling place	Period	H^+	NH_4^+	NO_3^-	N	SO_4^{2-}	S
throughfall	1973-79	0.191	1.95	4.47	2.52	28.20	9.41
	1980-83	0.209	1.62	5.81	2.57	23.40	7.81
	1984-89	0.205	3.17	9.24	4.55	29.78	9.94
	1990-93	0.088	3.78	8.24	4.80	25.72	8.59
	1994-97	0.034	2.07	6.93	3.17	18.15	6.06

Tab. 7.
Želivka - plot IV - young spruce stand - average concentrations (mg . l^{-1})

Period	pH	H^+	NH_4^+	NO_3^-	SO_4^{2-}	N	S
1997*)	5.03	0.009	2.75	9.28	24.38	4.23	8.14
1998	5.04	0.009	2.06	7.82	27.04	3.36	9.03
1999	4.82	0.015	3.04	7.59	10.76	4.07	3.59
2000	4.91	0.012	2.42	9.18	9.00	3.95	3.01

** October - December 1997*

Tab. 7a.
Average concentrations of substances on the plot I 140 (ICP Level II) (mg . l^{-1})

annual N deposition with precipitation caught under spruce stand (I) had changed from values lower than 20 kg to more than 30 kg . ha^{-1} and since 1993 to the value a little higher than 20 kg . ha^{-1}. In the shelterwood felling (II) total N deposition overstepped values from closed stand (I). Substantially lower fallout of N was in young closed spruce stand (IV), and the lowest fallout was observed under young beech stand (round 10 kg). During the investigation period development of total annual fallout of fluoride (F^-) was roughly the same like sulphur fallout overstepping 1 and 2 kg . ha^{-1} on plots with mature spruces (I and II) until 1994; at the same time the annual depositions were pretty balancing on these plots.

Deposition of mineral nitrogen ($N/NO_3^- + NH_4^+$) presented in table 9 (in years 1998 to 2000) and losses in running-off water (1998 - 1999) document that nitrogen consumption in forest ecosystems overreached 10 kg^{-1} . $year^{-1}$ in the late 1990s.

WATER CHEMISTRY IN SOURCES

Forest ecosystems and agricultural management in catchments influence different concentrations of investigated substances in water of assessed surface sources. Graphs 5 - 7 illustrate course of average annual pH values. This graph shows that the highest pH was found out in water of the Pekelský stream at the weir, close values were in water of meadow stream at Kožlí (observed until 1983), followed by values of pH water from forest spring, and the lowest pH values were measured for water of field spring at Brzotice. This order had not changed both during the whole investigation and at a drop of pH values occurring in the forest stream between years 1979 and 1984, in forest spring during 1978 and 1985 and for a short period 1982 to 1985 in spring water in fields. Also in meadow brook water acidity increased in years 1982 and 1983. The highest annual values of pH water were measured in the observed sources in the 1990s.

Nitrate concentration is increasing. Annual NO_3^- values balancing round 1 mg . l^{-1} have increased since 1985 and overstepped 2 mg . l^{-1} in the Pekelský brook. Substantially higher average concentrations of nitrates were in water from forest spring, 3.0 to 5.8 mg . l^{-1} until 1984. In the next period their values distinctly enhanced and overstepped 15 mg . l^{-1} in some years. In meadow stream annual NO_3^- averages

Sampling place	Period	H^+	NH_4^+	NO_3^-	N	SO_4^{2-}	S
throughfall	1990-93	0.021	1.84	5.77	2.73	11.74	3.92
	1994-97	0.017	1.38	5.20	2.25	9.16	3.06
	1998-99	0.017	1.33	5.77	2.34	4.99	1.67
	2000	0.039	0.93	6.60	2,21	3.49	1.16
gravitation water beneath O horizon	1990-93	0.040	2.22	27.71	7.98	20.71	6.91
	1994-97	0.014	1.13	22.26	5.91	9.94	3.32
	1998-99	0.016	1.67	28.85	7.81	8.79	2.93
	2000	0.028	1.87	21.40	6.29	6.00	2.00
gravitation water in depth of 20 cm	1990-93	0.021	1.84	16.59	5.18	23.18	7.74
	1994-97	0.010	1.73	12.02	4.06	13.70	4.57
	1998-99	0.044	0.61	12.95	3.40	8.78	2.93
	2000	0.041	0.63	9.40	2.61	7.37	2.46

Tab. 8.
Želivka - plot V - young beech stand - average concentrations (mg . l^{-1})

ranged between 19.7 to 30.8 mg . l^{-1} in 1973 to 1983. In the spring arisen in fields at Brzotice annual average concentrations of nitrates were between 30.4 to 60.1 mg . l^{-1} until 1984, since 1985 they had increased and had not dropped under 70 mg . l^{-1}even at the end of 1990s (in 2000 annual average reached 100.8 mg . l^{-1}). During investigation concentrations higher than 6 mg . l^{-1} (1985, 1994) were found out twice in individual water samples from forest stream, in a sample from 1992 it was 8.5 mg . l^{1}.

Since the beginning of research in 1973 water in forest stream has the lowest SO_4^{2-}concentration. During the 1990s annual SO_4^{2-} concentrations increase in water of the three investigated surface sources; they did not yet overstep 20 mg . l^{-1} in forest stream, but annual average in forest spring was over 77 mg . l^{-1} in 2000. At the same time concentrations of sulphates in water of forest well in the upper part of the Pekelský stream catchment do not reach either 10 mg . l^{-1} for individual sampling.

The highest annual concentrations of fluorides were observed in water of forest stream (0.04 to 0.19 mg . l^{-1}) and the lowest in the spring in fields (0.03 to 0.15 mg . l^{-1}). It may be caused by water runoff through the mantle rock in the Kožlí surroundings that contains higher amount of fluorine.

DISCUSSION AND SUMMARY

Until 1990 the level of forest ecosystems load by compounds of sulphur, nitrogen and other pollutants in the Želivka was lower than on experimental plots in the northern Bohemia and Moravia (Lochman 1993). Also in the 1990s deposition of pollutants was here lower than in the Krušné Mts. or Orlické Mts. Nevertheless, it is higher than forest ecosystems load in the southern Bohemia, incl. the Šumava Mts. (Lochman, Šebková 1998, Lochman et al. 1998, 2000, 2001).

Immission conditions of the Želivka catchment are relatively balanced affected by many local sources in the district Pelhřimov and in the neighbouring districts as well as by remote transfer of pollutants. The observatory of the Czech Hydrometeorological Institute, distant 15 km south-east of the experimental catchment, measures climatological characteristics, air chemistry, deposition of substances, substances composition of surface water and observes other parts of environment (Váňa et al. 1995). Results presented by these authors document that in years 1990 to 1993 the average annual pH values of bulk precipitation on forest-free area (4.34 – 4.41) was very close to average values found on the clearcut (plot III) within the Želivka area (4.30 – 4.85). In the same period average annual sulphur deposition (S/SO_4^{2-}) was 8.81 kg . ha^{-1} at Košetice and 9.18 kg . ha^{-1} on Želivka, nitrogen deposition ($N/NO_3^- + NH_4^+$) was 10.38 kg . ha^{-1} at Košetice and 11.93 kg . ha^{-1} on the Želivka clearcut. Also in the next years (1994 – 1998) annual fallout 7.44 kg SO_4^{2-}. ha^{-1} at Košetice (FOTTOVÁ 1999) was lower than 9.69 kg . ha^{-1} on Želivka.

In 1990 – 1993 greater differences occurred in fallout of substances caught with throughfall in spruce stands. Deposition of S and N (61.40 and 38.37 kg . ha^{-1}, resp.) was higher in the older spruce stand (5th age class) on the plot I than under spruce stand of the 4th age class (27.39 and 14.42 kg . ha^{-1}, resp.) at Košetice. In contradiction, fallout of S and N was lower (23.34 and 12.92 kg . ha^{-1}, resp.) in the younger spruce stand on the plot IV (3rd age class). Average pH values for throughfall were not significant for older stands – 3.68 to 3.97 at Košetice, 3.65 and 3.90 on the Želivka plot I. Average annual pH 3.95 to 4.20 throughfall was higher on the plot Želivka IV (VÁŇA et al. 1995, LOCHMAN 1997). For next years (1994 – 1998) annual fallout of 37.69 kg . ha^{-1} S and 11.23 kg . ha^{-1} N/NO_3^- was higher in the spruce stand on Želivka than that of 19.40 and 5.92 kg . ha^{-1}, resp., at Košetice (FOTTOVÁ, SKOŘEPOVÁ 1998, FOTTOVÁ 1999). These authors evaluate the Želivka area (Bohemian-Moravian Highland) like mildly polluted, yet deposition of S and N oversteps critical loads for oscillation of these elements in the Anenský stream catchment (Košetice) and can endanger forest ecosystems by acidification. Based on evaluation of environment in the Košetice area VÁŇA et al. (1995) determine that S/SO_4^{2-} deposition is here lower than on other stations of the Czech Geological Survey.

Concentrations of SO_4^{2-}, NO_3^- and NH_4^+ reached lower values in soil water caught on the clearcut (plot III) than in soil water under spruce stand due to lower load of ecosystems by S and N compounds. More intensive decomposition of forest floor enhanced concentration of nitrogen compound on the clearcut in the first years after cutting of spruce stand. Until 1998 N compounds were separated from soil water in deeper horizons by vegetation roots (rhizosphere) and their concentrations in depth of 100 cm approached to concentrations found in the Pekelský stream (1 - 3 mg. l^{-1})

During research NO_3^- content increased in water of this source sampled at the weir in average of 1 to 2 mg . l^{-1} which is negligible growth in absolute values but relatively great growth in relation to low average value until 1985 (1 mg . $l^{-1)}$. In water of spring arisen in the lower part of the catchment nitrates concentrations enhanced twice or three times in the 1990s compared to the 1970s. In 2000 the highest average values were calculated for the spring in forest (16.95 mg . l^{-1}) and for the spring in the fields at Brzotice (100.8 mg . l^{-1}).

Water chemistry in the investigated sources is influenced by complex of factors. In forest ecosystems it is mainly deposition of substances with precipitation (wet deposition) enriched with substances caught by above-ground biomass. Another factor is elements oscillation between phytocenose and soil which is influenced both by amount, composition and velocity of litterfall decomposition (incl. underground biomass) and consumption of elements (and their compounds) by vegetation roots. Sorption properties of soil are presented above all by cations content as well as chemism and texture of mantle rock.

Pollutants highly concentrated in mature spruce stands are washed down the crowns. Their volume is enhanced by nearly 50% interception of precipitation water (evaporation from crown surface) (FOJT 1987, KREČMER, FOJT 1988), which results in enhanced proportion of observed substances in throughfall. Clay and loamy soils of the experimental catchment Želivka (Pekelský stream) and mild washing regime cause only slow water run-off with nutrients from rhizosphere in the vegetation period (MRÁZ 1987, MRÁZ et al. 1990) enabling effective draining of nitrogen compounds from soil solution by roots. Nitrogen uptake is positively influenced by oligotrophic character of sites and good health state of spruce stands.

During selective uptake of ions by roots from solution SO_4^{2-} ions are discriminated (ULRICH et al. 1981) and therefore their concentrations are increasing with profile depth in soil water. Unlike the nitrates ions sulphate ions can be transformed with oxides of Al and Fe into insoluble colloid compounds, so that water running off into underground water and water resources have significantly lower concentrations of these ions. During pH changes of soil environment reversible compounds decompose and release into soil environment which reflects in growth of sulphates in water resources even during reduction of their deposition (MANDERSCHEID et al. 1995).

Sampling place	Období	NO_3^-	N/ NO_3^-	NO_3^-	NH_4^+	N/ NH_4^+	NH_4^+
		kg	kg	k mol	kg	kg	k mol
plot I - spruce stand	1998-2000	60.59	13.33	0.952	10.79	8.42	0.601
clear cutting plot III	1998-2000	26.77	5.89	0.421	5.69	4.44	0.317
plot V - beech stand	1999	32.33	7.11	0.521	6.3	4.91	0.346
run-off at the weir for Ho = 107 mm	1998-1999	2.59	0.57	0.042	0.105	0.082	0.006

^{x} Ho = annual run-off

Tab. 9.
Balance of nitrogen compounds in the Pekelský stream catchment - annual fallout with precipitation and annual output at the weir

Deep soils with large aquifer layers of weathered parent rock enable also neutralization of acid precipitation water. Fluorides concentrations in run-off water are also influenced by their bond to oxides Al and Fe like SO_4^{2-} (Herrnstadt 1995) and by probable F occurrence in biotite of parent rock or in other minerals mined in the catchment´s neighbourhood like the F source. Since the very beginning of research (since 1973) water from the spring arisen above the weir has been mildly more acid than the stream water and contained more nitrates, sulphates and fluorides. Differences in concentrations enhanced above all in the late 1990s, and could not be explained by the different deposition of these substances but by soil and geological conditions and agricultural management of the catchment´s part (2 ha). Soils in the catchment are more granular, more permeable, do not lie on the large layers of weathered rock and sediments (Evaluation of hydrogeological investigation 1972) and form richer forest types (Mráz 1973). Conditions for draining nitrates from soil water are not here so favourable neither for greater bond of sulphates in soil. Water chemistry is affected by fertilizing of agricultural land and maybe by reduced felling in recent years.

On the contrary, concentrations of NO_3^- and SO_4^{2-} are still lower in water samples of the spring (Pekelský stream spring) in the upper part of the catchment with oligotrophic soils lying on the large layers of clay sediments than in the stream water at the weir.

High concentrations of nitrates, sulphates and other herein non-evaluated substances (Cl^- and cations) in spring water in fields at Brzotice are caused by agricultural soil management based on fertilizing. Similarly influenced was water composition in the brook in meadows at Kožlí agriculturally managed in its substantial part of catchment.

Still continuing high NO_3^- concentrations in spring water at Brzotice in the last years are not explainable because nearly for 10 years lower doses of mineral fertilizers are used in the fields. In 2000 nitrates content even increased in forest well in the Želivka catchment as well as in the spring in fields at Brzotice. This may be caused by enhanced mineralization of organic soil mass, incl. humus substances, and by nitrification of ammonium ions during extremely warm weather (according to Šrámek average annual temperature at the FGMRI station – Myslivna Pekelsko was 9.14 °C). In 2000 nitrates concentrations grew also on the clearcut (plot III) in the Pekelský stream catchment in water running through surface soil horizons (in depth 0 – 30 cm).

As mentioned above, nitrogen deposition reached comparable values both in forest-free area and in forest ecosystems within the forest contributory catchment of the Anenský stream at Košetice and Pekelský stream which documents similar level of air pollution by N compounds in the whole area. Higher fallout of S/SO_4^{2-} was observed in the Pekelský stream catchment.

In 1987 to 1993 average NO_3^- concentration was 8.72 mg . l^{-1} in forest stream at Košetice (Váňa et al. 1995), 2.20 mg . l^{-1} in the Pekelský stream at the weir and 8.26 mg . l^{-1} in the forest spring in the same catchment. At the same time average SO_4^{2-}content was 48.93 mg . l^{-1} in forest stream water at Košetice, 13.91 mg . l^{-1} in the Pekelský stream water and 21.51 mg . l^{-1} in forest spring water. This proves that forest ecosystems influence on retention of nitrogen and sulphur compounds from fallout in the forest spring catchment in the Želivka area is closer to influence of ecosystems in forest stream at Košetice than total influence of the Pekelský stream catchment ecosystems that have higher retention ability for N and S compounds.

Annual losses of N(NO_3^- + NH_4^+) with running-off water from the Želivka (Pekelský stream) catchment do not overstep 1 kg . ha^{-1} (0.65 kg N . ha^{-1}in 1998 - 2000) and most of N deposition remains bound in biomass and in soil or disappears in the air (tab. 9, graph 2). When consumption of deposited N is calculated, then consumption of NO_3^- prevails and more protons (H^+) are accepted with nitrate ions than released during uptake of ammonium ions. Consumption and changes of N forms in forest ecosystems of the Pekelský stream catchment as a whole would not contribute to acidification of soil environment (Khanna, Ulrich 1984) unlike the conditions in mountainous spruce forests loaded by high fallout of nitrogen and intensive leaching of NO_3^- from ecosystems by running off water.

Significant management influence in the catchment on water chemistry in surface sources was investigated in the Želivka river catchment in the 1970s. Higher concentrations of cations S, N and Cl in streams water with agricultural production in the Trnávka catchment (contributory of the Želivka) than those in a source in forested catchment are described by Pačes, Moldan (1981). Balek et al. (1978) found that nitrogen from fallout is at most bound in forest ecosystems mass of investigated catchments. Also Lenhardt et al. (1983) describes positive influence of forest ecosystems on running-off water quality, especially on decrease of N compounds concentrations in the Hesse (FRG) catchments.

Results of long-term research of forests in the Pekelský stream catchment comparing water chemistry in their sources with agriculturally managed areas can be generalized even when nitrate concentrations are higher in source water than on the assessed catchment in the areas with higher nitrogen deposition and with draining water regime.

CONCLUSION

Mild pollution of bulk precipitation occurs on the open space of the Pekelský stream catchment. However, deposition of pollutants is significantly higher under older spruce stands enhanced of substances caught in tree crowns. During the long-term evaluation in the 1990s protons deposition of (H^+) and sulphur (S/SO_4^{2-}) markedly decreased, as well as fallout of nitrogen compounds (N/NO_3^- + NH_4^+) in recent years (in the late 1990s).

Since the 1980s concentrations of NO_3^- and SO_4^{2-} have been mildly growing in the stream water. Concentrations of these ions and of other investigated substances correspond with standard requirements for drinking water. Decrease of protons concentration of (H^+) and S and N compounds in running-off water is caused by their effective retention and consumption in ecosystems. This is due to oligotrophic, but deep clay soils on the might mantle rock, low washing regime and relatively healthy growing stands and soil vegetation that enable N consumption and S binding in soil and in mantle rock; mantle rock causes also pH increase of running-off water. Fertilization of agricultural soils very markedly influences concentrations of NO_3^- as well as of other substances.

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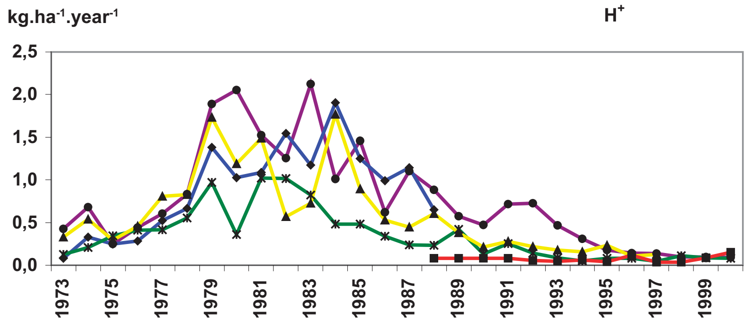
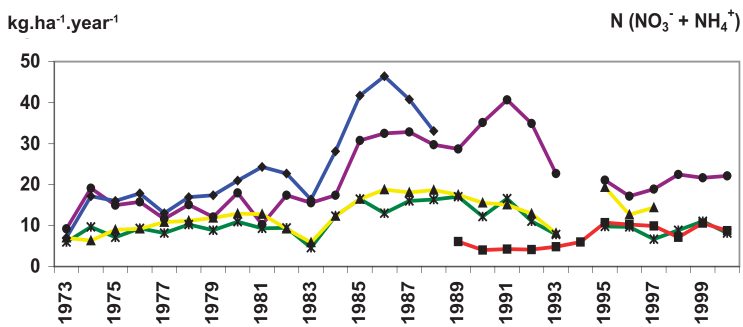
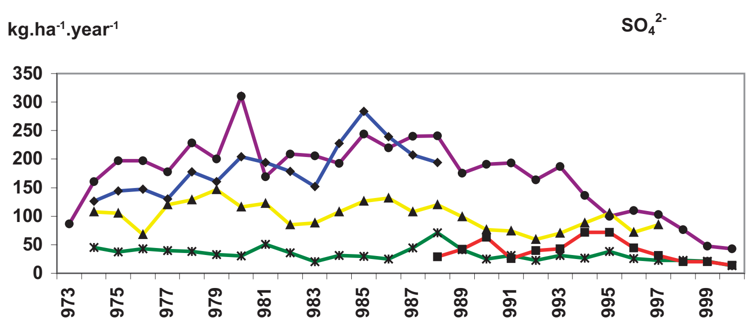


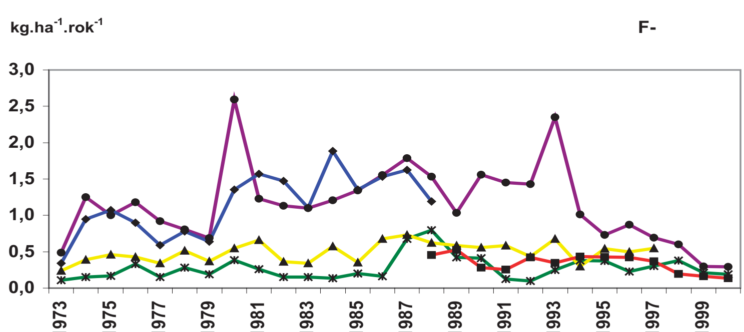
Graph 1.



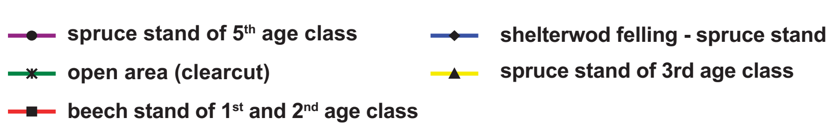
Graph 2.



Graph 3.



Graph 4.



Graphs 1 – 4.
Annual fall of substances with throughfall on Želivka plots

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Vývoj chemismu vody v povrchových zdrojích v oblasti Želivky s ohledem na imisní zatížení a hospodaření v povodí

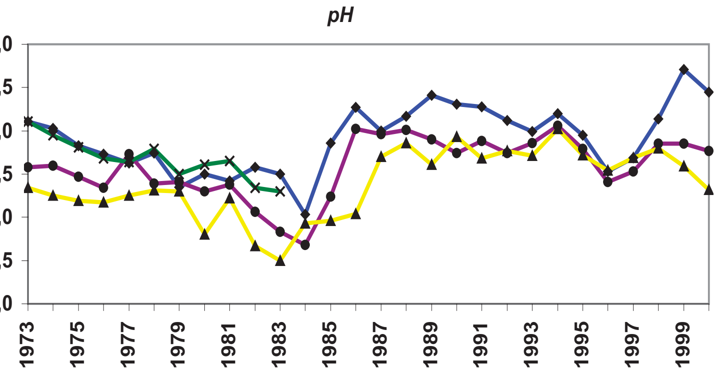
Souhrn

Na lesním povodí Pekelského potoka (objektu Želivka), pravostranném přítoku přehradní nádrže na pitnou vodu, probíhá od roku 1973 na výzkumných plochách nepřerušené sledování chemismu srážkové vody, depozice látek, chemismu půdní vody a chemismu vody v potoce na přepadu a v prameni. Povodí vytváří 117 ha lesní půdy (s převahou smrku) a 2 ha zemědělsky obhospodařovaných pozemků. Od roku 1973 je také odebírána a analyzována voda z pramene v zemědělsky obhospodařovaném povodí u Brzotic. Do roku 1983 byl sledován i chemismus vody potůčku tekoucího loukami u obce Kožlí.

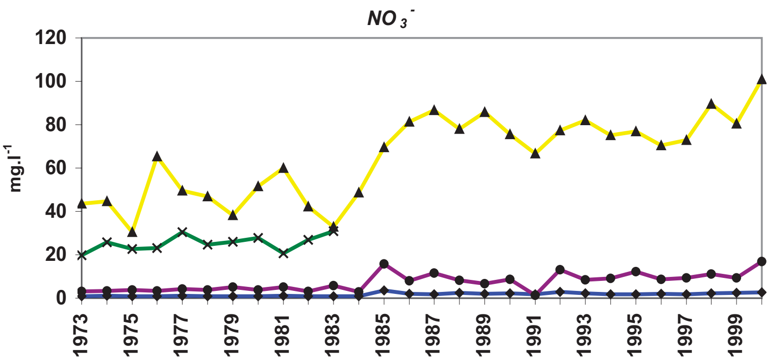
V roce 1973 započalo systematické měření depozice látek se srážkovou vodou a sledování chemismu půdní vody v dospělém porostu smrku (plocha I), na clonné seči (se snížením zásoby hmoty na 50 %) (plocha II), na holé seči (plocha III) a v mladším porostu smrku (plocha IV). V roce 1989 započaly odběry a rozbory srážkové a půdní vody v mladém porostu buku (plocha V). V roce 1989 byly domýceny stromy na clonné seči. Na této ploše a v mladém porostu smrku (plocha IV) bylo ukončeno měření v roce 1998.

V tomto příspěvku je věnována pozornost hlavním složkám imisního zatížení v ČR, tj. spadu a dynamice vodíkových iontů (H^+), síranům (SO_4^{2-}), minerálnímu dusíku ($N/NO_3^- + NH_4^+$) a fluoridům (F^-). Je zde hodnocen dlouhodobější vývoj depozice a chemismu vody v odlišných lesních ekosystémech.

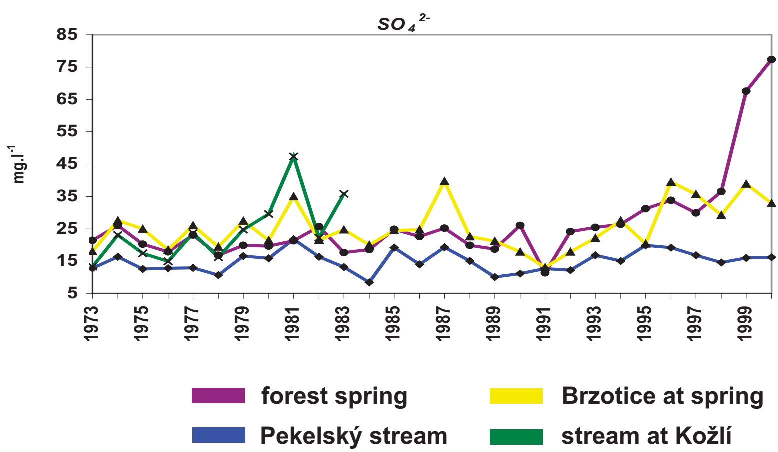
Na holé seči jsou zachycovány srážky do otevřených nádob (bulk). Nejvyšší koncentrace a depozice vodíkových iontů ve srážkách na holé seči (plocha III) se projevily od konce 70. let do po-



Graph 5.



Graph 6.



Graph 7.

Graphs 5 – 7:
Annual average concentrations of substances and pH water in observed streams on Želivka plots ($mg.l^{-1}$)

loviny 80. let (až 1 kmol . ha^{-1}. rok^{-1}), v dalších letech se postupně spad snižoval na méně než 0,1 kmol . ha^{-1}. rok^{-1} na konci 90. let. Obdobný vývoj měla depozice protonů (H^+) ve smrkovém porostu na ploše I, která z vysokých ročních hodnot v první polovině 80. let (až 2 kmol . ha^{-1} . rok^{-1}) poklesla na hodnoty blízké depozici na holé seči (0,1 kmol . ha^{-1}. rok^{-1}). Vysoký spad protonů (H^+) byl zjišťován i na clonné seči (plocha II), který se v období před domýcením porostu vyrovnával spadu v zapojeném porostu (I). Nejnižší depozice protonů byla stanovena v mladém porostu buku.

Celková depozice síranů se srážkami na seči (bulk) mírně kolísala a od poloviny 90. let klesala na hodnoty mezi 10 a 20 kg . ha^{-1}. rok^{-1}. V dospělém porostu smrku (I) probíhala nejvyšší depozice SO_4^{2-} v letech 1979 až 1988; tehdy překračovala i 200 kg . ha^{-1}. rok^{-1}. Její podstatné snižování je patrné od poloviny 90. let, na < 50 kg . ha^{-1}. rok^{-1} na konci 90. let minulého století. Na clonné seči (plocha II) byl spad síranů také vysoký a na konci 80. let dokonce překračoval depozici v zapojeném smrkovém porostu (I). V mladém porostu smrku (IV) dosahovala roční depozice SO_4^{2-} přibližně poloviny spadu zjišťovaného v dospělém porostu. V mladém porostu buku (V) byl spad síranů s podkorunovými srážkami nejnižší, ve srovnání s porosty smrku a po roce 1995 se snížil na hodnoty okolo 20 kg . ha^{-1}. rok^{-1}.

Roční depozice minerálního dusíku ($N/NO_3^- + NH_4^+$) na holé seči (III) nedosahovala od počátku měření až do poloviny 80. let 10 kg . ha^{-1}. V dalším období až do počátku 90. let se projevilo zvýšení depozice minerálního dusíku, ale od roku 1993 se roční hodnoty snížily pod 10 kg . ha^{-1}.

Ve stejných časových obdobích probíhaly změny roční depozice N s podkorunovými srážkami v porostu dospělého smrku, z hodnot nižších než 20 kg na vyšší než 30 kg . ha^{-1} a od roku 1993 na množství o málo vyšší než 20 kg . ha^{-1}. rok^{-1}. Na clonné seči (II) celková depozice $N/NO_3^- + NH_4^+$ překračovala hodnoty zjištěné v zapojeném dospělém porostu (I). Podstatně nižší spad minerálního dusíku byl v mladém porostu smrku (IV) a jeho nejnižší depozice byla stanovena pod mladým porostem buku (okolo 10 kg . ha^{-1}).

Vývoj celkového ročního spadu fluoridů (F^-) měl na plochách objektu Želivka zhruba stejný průběh jako spad síry (SO_4^{2-}). V dospělých porostech smrku (plochy I a II) překračoval 1 (i 2) kg . ha^{-1} až do roku 1994.

Při hodnocení půdní vody na seči (III) je zřejmé, že ve vodě zachycované pod horizontem pokryvného humusu (O) v hloubce 30 a 100 cm se pH vyvíjelo v časové řadě obdobně jako ve srážkové vodě. Obecně lze říci, že s hloubkou půdního profilu její pH stoupá. Množství nitrátových a amonných iontů ($N/NO_3^- + NH_4^+$) v ní pokleslo po ukončení zvýšeného rozkladu materiálu pokryvného humusu na nově vzniklé holé seči. Pokles SO_4^{2-} lze pozorovat až od roku 1994. Jiný vývoj koncentrace nitrátových a síranových iontů probíhal ve vodě zachycované v hloubce 30 cm, kde byly nejvyšší hodnoty zjištěny nejen v 70. letech, ale opět na konci 90. let. Také ve vodě jímané v hloubce 100 cm dosáhly nitráty největších koncentrací až na konci 90. let.

V porostu smrku (I) byly v půdní vodě odtékající z pokryvného humusu stanoveny nejvyšší průměrné koncentrace protonů v letech 1984 až 1989. Maximální množství sulfátů (SO_4^{2-}) se projevilo v období 1990 až 1993 a nitrátů (NO_3^-) v letech 1998 a 1999. Ve vodě zachycované v hloubce 30 cm byly ve srovnávaných obdobích zjištěny nižší koncentrace nitrátů než ve vodě odtékající z pokryvného humusu, stejně tak i koncentrace síranů až do konce 80. let, a v 90. letech byly naopak vyšší koncentrace těchto iontů ve vodě odebírané v hloubce 30 cm. Ve vodě získané v hloubce 100 cm probíhal vývoj koncentrací hodnocených iontů obdobně jako ve vodě z povrchových horizontů.

Obecně lze říci, že v odtékající vodě se s hloubkou půdního profilu zvyšovalo pH (klesající koncentrace H^+) a snižovaly se obsahy $NO_3^- + NH_4^+$. Nejvyšší koncentrace SO_4^{2-} se postupně přesouvaly z povrchového humusového horizontu do vody v půdní spodině. Podobný posun největších koncentrací SO_4^{2-} do vody zachycované v hloubce 100 cm probíhal během sledovaného období i v půdě na seči, ale průměrné hodnoty byly podstatně nižší než ve vodě z půdního profilu pod smrkovým porostem. Rovněž obohacování vody ionty H^+, NH_4^+ a NO_3^- zde bylo nižší.

V porostu buku (V) byl v období 1990 až 2000 zjištěn pokles koncentrací síranů (SO_4^{2-}) ve srážkové a půdní vodě.

Při hodnocení chemismu vody sledovaných zdrojů je zřejmé, že nejvyšší průměrné hodnoty pH měla voda odebíraná z Pekelského potoka na přepadu. Podobné hodnoty byly zjišťovány ve vodě z lučního potůčku u Kožlí. Nižší pH bylo stanoveno ve vodě z lesního pramene a nejnižší hodnoty vykazovala voda z pramene v polích u Brzotic.V období od konce 70. let do poloviny 80. let se v různé míře ve vodě všech sledovaných zdrojů projevil pokles pH. Půdy a zvětralinový plášť v povodí Pekelského potoka působí ve vodě ze srážek při odtoku do zdrojů snížení koncentrací vodíkových iontů více než o dva řády (zvýšení pH o dva stupně).

Nejnižší koncentrace SO_4^{2-} měla již od roku 1973 voda v lesním potoce. V 90. letech se koncentrace těchto iontů ve vodě sledovaných tří zdrojů zvyšovaly, zejména v lesním prameni, kde v roce 2000 překročil roční průměr 77 mg . l^{-1}. Ve vodě lesního potoka nedosahovaly průměrné koncentrace SO_4^{2-} 20 mg . l^{-1}, i když v půdní vodě ve stejném období byly tyto koncentrace překračovány. Na převážné části povodí tedy stále probíhala retence S/SO_4^{2-} v půdní spodině a ve zvětralinovém plášti vazbou na oxidy Fe a Al. Prudké zvýšení koncentrací SO_4^{2-} ve vodě lesního pramene naznačuje vyčerpání této kapacity v půdách jeho povodí nebo uvolňování síranových iontů z reversibilních (nestálých) sloučenin do odtékající vody.

V lesním potoce měla voda také nejnižší koncentrace NO_3^-. Do roku 1984 kolísaly roční průměry okolo 1 mg . l^{-1}, od roku 1985 se zvýšily na více než 2 mg . l^{-1}. Voda v lesní studánce měla do roku 1984 průměrné roční koncentrace nitrátů 3,0 až 5,8 mg . l^{-1}, v dalších letech se projevilo jejich zvýšení a některé roční průměry překračují 15 mg . l^{-1}. V lučním potůčku se do roku 1983 pohybovaly roční průměrné koncentrace NO_3^- mezi 19,7 až 30,8 mg . l^{-1}. Ve vodě pramene v polích u Brzotic do roku 1984 kolísaly roční průměry nitrátů mezi 30,4 až 60,1 mg . l^{-1} a po tomto roce se ještě zvýšily a ani na konci 90. let neklesly pod 70 mg . l^{-1}.

Nízké koncentrace nitrátových iontů ve vodě lesního potoka zapříčiňuje spotřeba cca 10 kg N přicházejícího se srážkami v lesních ekosystémech povodí. Tento proces usnadňuje malá promyvnost půd ve vegetačním období. Na povodí lesního pramene jsou půdy zrnitější a méně hluboké a na části (2 ha) jsou i zemědělsky obhospodařované. Zvyšování koncentrací NO_3^- i NH_4^+ v půdní vodě sledovaných ploch koncem 90. let (včetně roku 2000), při poklesu depozice dusíku, lze vysvětlit jejich uvolňováním z půdní organické hmoty při zvýšených letních teplotách vzduchu posledních let. To by vysvětlovalo nejen nárůsty obsahu nitrátů ($NO_3^{-)}$ ve vodě lesní studánky, ale i ve vodě pramene v polích u Brzotic.

Na odčerpávání sloučenin dusíku z půdní vody a na tvorbu a vymývání nitrátů má vliv i trofnost půd (stanovišť). Zatímco většinu území povodí vytvářejí borůvkové jedliny (*Myrtillo-Abietum*) a bikové jedliny (*Luzulo-Abietum*), povodí pramene zaujímají bohatší typy (jedlobučiny).

Porovnání průměrných hodnot pH průměrné roční depozice S/SO_4^{2-} a N/ NO_3^- + NH_4^+ v 90. letech ve srážkové vodě na seči v objektu Želivka (plocha III) a na bezlesí v objektu observatoře ČHMÚ v Košeticích ukazuje velmi podobné hodnoty, což svědčí o poměrně vyrovnané intenzitě (míře) znečištění ovzduší v povodí Želivky. Rozdílná velikost depozice hodnocených iontů s podkorunovými srážkami v porostech smrku je způsobena především rozdílnými taxačními parametry porostů.

Water chemistry development of surface sources in the Želivka area with regard to pollution load and management in the catchment

Summary

Since 1973 chemistry of bulk water, deposition of substances, chemistry of soil water and of water at the weir and in the spring have been investigated in the forest catchment Pekelský stream (Želivka object), the right-handed dam tributary for drinking water. The catchment involves 117 ha of forest soil (with spruce prevalence) and 2 ha of agricultural land. Since 1973 water from the spring in agriculturally managed catchment at Brzotice is collected and analyzed. Until 1983 water chemistry in the brook flowing through meadows at Kožlí village were also investigated.

In 1973 systematic measurement of substances deposition began as well as investigation of soil water chemistry in mature spruce stand (plot I), on shelterwood felling (with decrease of supply mass to 50 %) (plot II), on clear cutting (plot III) and in the young spruce stand (plot IV). In 1989 bulk and soil water was sampled and analyzed in the young beech stand (plot V). In 1989 the trees on shelterwood cutting were removed. Measurement on this plot and in young spruce stand (plot IV) was finished in 1998.

This contribution is focused on the main components of pollution load in the Czech Republic, i. e. on fallout and dynamics of hydrogen ions (H^+), sulphates (SO_4^{2-}), mineral nitrogen ($N/NO_3^- + NH_4^+$) and fluorides (F^-). The long-term development of deposition and water chemistry in different forest ecosystems is assessed, too.

On the clear cut bulk water is captured in the open containers. The highest concentrations and depositions of hydrogen ions in bulk precipitation on the clear cutting (plot III) had occurred from the late 1970s until the mid-1998s (up to 1 kmol . ha^{-1}. $year^{-1}$), in the next years the fallout was gradually dropping to less than 0.1 kmol . ha^{-1}. $year^{-1}$ at the end of the 1990s. Similarly was developing proton (H^+) deposition in spruce stand of the plot I dropping from the high annual values in the early 1980s (up to 2 kmol . ha^{-1}. $year^{-1}$) to values close to deposition on the clear cutting (0.1 kmol . ha^{-1}. $year^{-1}$). High fallout of protons (H^+), equal to fallout in closed stand (I) during period before stand felling, was found also on the shelterwood felling (plot II). The lowest deposition of protons was determined in the young beech stand.

The total sulphates deposition with bulk precipitation on the clearcut slightly balanced and since the mid-1990s has been dropping to values between 10 to 20 kg . ha^{-1}. $year^{-1}$. In the mature spruce stand (I) the highest SO_4^{2-} deposition was in years 1979 to 1988; then it was even over 200 kg . ha^{-1}. $year^{-1}$. Since the mid-1990s important reduction can be observed, being < 50 kg . ha^{-1}. $year^{-1}$ at the end of the 1990s. Sulphates fallout was also high on the shelterwood felling (plot II) overstepping even deposition in closed spruce stand (I) in the late 1980s. Annual SO_4^{2-} deposition in the young spruce stand (IV) reached nearly half of the fallout found in the mature stand. Sulphates fallout with throughfall was the lowest in the young beech stand (V) when compared with spruce stands and decreases to values about 20 kg . ha^{-1}. $year^{-1}$ after 1995.

Annual deposition of mineral nitrogen ($N/NO_3^- + NH_4^+$) on the clear cutting (III) did not reach 10 kg . ha^{-1}. $year^{-1}$ from the beginning of measurement until the mid-1980s. Deposition of mineral nitrogen was increasing in the next period until the early 1990s, but since 1993 annual values have dropped below 10 kg . ha^{-1}.

Annual N deposition with throughfall in mature spruce stand changed during the same time intervals, from values a little lower than 20 kg to higher than 30 kg . ha^{-1}. $year^{-1}$ and since 1993 the N deposition was a little higher than 20 kg . $N/NO_3^- + NH_4^+$. $year^{-1}$. On the shelterwood felling (II) deposition of $N/NO_3^- + NH_4^+$ overstepped values found in closed mature stand (I). Substantially lower fallout of mineral nitrogen was in the young spruce stand (IV) and its lowest deposition was detected under the young beech stand (around 10 kg . ha^{-1}).

Within the Želivka plots total annual fallout of fluorides (F^-) was developing roughly in the same way like sulphur fallout (SO_4^{2-}). Until 1994 this fallout was over 1 (or 2) kg . ha^{-1} in mature spruce stand (plot I and II).

Evaluation of soil water on the cutting (III) reveals that in time series pH developed similarly in water caught beneath forest floor horizon (O) in depth of 30 and 100 cm like in bulk water. Generally speaking, water pH increases with the depth of soil profile. Amount of nitrate and ammonium ions ($N/NO_3^- + NH_4^+$) decreased after enhanced decomposition of forest floor on newly arisen clear cutting. Decrease of SO_4^{2-} was observed until 1994. In water caught in the depth of 30 cm concentrations of nitrate and sulphate ions developed differently; the highest values were observed not only in the 1970s but also in the late 1990s. As well, in water caught in the depth of 100 cm concentrations of nitrates were the highest at the end of the 1990s.

The highest average concentrations of protons were determined in soil water of spruce stand (I) running-off the forest floor in 1984 to 1989. Maximal amount of sulphates (SO_4^{2-}) occurred in the period

1990 to 1993 and of nitrates (NO_3^-) in years 1998 to 1999. Until the late 1980 lower concentrations of nitrates and sulphates were observed in water caught in the depth of 30 cm than in water running-off the forest floor during the reference periods; on the contrary, in the 1990s concentrations of these ions were higher in water sampled in the depth of 30 cm. In water from the depth of 100 cm concentrations of assessed ions were of similar development like in water from surface horizons.

It can be generalized that pH increased (decreasing H^+ concentrations) in running-off water and contents of NO_3^- + NH_4^+ decreased in dependence on soil profile depth. The highest SO_4^{2-} concentrations gradually shifted from surface humus horizon into underground water. During the investigation similarly highest SO_4^{2-} concentrations appeared in water caught in the depth of 100 cm also in the cutting soil but average values were principally lower than in water from soil profile under the spruce stand. Also water enrichment by H^+ ions, NH_4^+ and NO_3^- was here lower.

In 1990 to 2000 sulphate concentrations (SO_4^{2-}) dropped in bulk and soil water of the beech stand (V).

Evaluation of water chemistry of investigated sources showed, that the highest average pH values were in water taken from the Pekelský stream at the weir. The similar values were found in water from the meadow brook at Kožlí. Lower pH was determined in water from the forest spring and the lowest values were in water from the field spring at Brzotice. In the period late 1970 to mid-1980s pH decrease of different volume appeared in water of all the investigated sources. Due to soils and mantle rock in the catchment Pekelský stream hydrogen ions concentrations in bulk precipitation are reduced of more than two orders (pH increment of two degrees) during run-off into water sources.

The lowest SO_4^{2-} concentrations were in forest brook water already in 1973. In the 1990s concentrations of these ions had increased in water of the investigated three sources, mainly in forest spring, where in 2000 annual average was over 77 mg . l^{-1}. Average SO_4^{2-}concentrations did not reach 20 mg . l^{-1} in forest brook water though in the same period these concentrations were overstepped in soil water. So within the prevailing part of the catchment retention was still going on in soil underground and mantle rock by fixing to oxides Fe and Al. Steep increment of SO_4^{2-}concentrations in forest spring water indicates exhaustion of this capacity in soils of spring catchment or release of sulphate ions from reversible (unsteady) compounds into running-off water.

Water in forest brook had also the lowest NO_3^- concentrations. Until 1984 annual averages balanced around 1 mg . l^{-1}, since 1985 they have increased onto more than 2 mg . l^{-1}. Until 1984 average annual concentrations of nitrates in forest well water were 3.0 to 5.8 mg . l^{-1}, increasing in next years, some annual averages being over 15 mg . l^{-1}. Until 1983 annual average NO_3^- concentration in meadow brook ranged between 19.7 mg . l^{-1} to 30.8 mg . l^{-1}. Until 1984 nitrates averages were between 30.4 to 60.1 mg . l^{-1} in spring water at Brzotice, and either in the late 1990s they did not drop below 70 mg . l^{-1}.

Concentrations of nitrate ions in forest stream water are low due to consumption of ca 10 kg N falling with precipitation in forest ecosystems of the catchment. This process is enabled by low soil leaching during vegetation period. Soils in the catchment of forest spring are more textural and not so deep and a part (2 ha) is managed agriculturally. Enhancement of NO_3^- and NH_4^+ concentrations in soil water together with nitrogen deposition in the late 1990s (including the year 2000) can be explained by their release from soil organic mass during increased summer air temperatures in recent years. This could be explanation not only for growth of nitrates contents (NO_3^-) in forest well water but also in spring water in fields at Brzotice.

Draining of nitrogen compounds from soil water and nitrates creation and their leaching are influenced by soil (site) trophy. Whereas majority of the catchment area is formed by *Myrtillo-Abietum* and *Luzulo-Abietum* species, spring catchment is covered by richer types (fir-beech stands). Comparison of the 1990s average pH values of average annual S/ SO_4^{2-} and N/NO_3^- + NH_4^+ depositions in the bulk water of the cutting in the Želivka object (plot III) and in the forest-free area of the Czech Hydrometeorological Institute observatory at Košetice shows very similar values which documents relatively balanced intensity (measure) of air pollution within the Želivka catchment. Different deposition volume of assessed ions with throughfall in spruce stands is caused mainly by different mensurational stands parameters.

Note: This contribution was elaborated in the frame of research intention MZE no. 0002070201 "Stabilization of forest functions in biotopes disturbed by human activities under changing environmental conditions".

STUDY OF GENETIC VARIABILITY OF ELMS USING ISOENZYME ANALYSIS

Ondřej Ivanek, Jana Malá, Jarmila Cikánková
Forestry and Game Management Research Institute,
156 04 Jíloviště-Strnady

ABSTRACT

Autochthonous stands of wych elms, European white elm and smooth-leaved elm from 10 localities in CR were sampled, and polymorphism of malate dehydrogenase (MDH), phosphoglucomutase (PGM), leucine aminopeptidase (LAP) and phosphogluconate dehydrogenase (6-PGDH) enzymes were investigated with isoenzyme analysis. Genetic stability of selected samples during in vitro cultivation was also studied with this method. The results of isozyme analysis enable distinguishing among individual elm species. No genetic changes during the in vitro cultivation were observed.

INTRODUCTION

Evaluation of natural populations depends on existence of genetic variability and its distribution within a population. Studies dealing with plant isoenzymes and their diversity proved that endemic and scarcely distributed species are of lower genetic diversity than those generally spread (Hamrick, Gott 1989). Analogically, species geographically isolated form less polymorphic loci and lower number of allels in locus (Karron 1987). Subsequent works (Hamrick 1992) have confirmed the assumption that isolated populations have lower genetic diversity within the species when compared with the other populations of the same species.

The method of isoenzyme analysis is successfully used for clone identification. This method is based on assumption that isoenzyme patterns on zymogram of any enzymatic system can be used for unambiguous characterization of a clone even without identification of corresponding genotype (Cheliak 1993).

The oldest works dealing with elm isoenzymes (Feret, Stairs 1971) describe analyses of isoperoxidase of *Ulmus pumila* species introduced into the North America. The first analyses of elms in Europe were done by Pearce and Richens (1977, 1984) with investigated elms naturally occurring on the British Islands. These works affirmed polymorphism of particular enzymatic systems of some European elms species.

Machon et al. (1995) used isoenzyme analysis for determination (estimation) of genetic variability of three elms - *Ulmus laevis* Pall., *U. minor* Mill. and *U. glabra* Huds. The author presented three main findings:

a) Elms are partly (in certain segments of chromosomes) tetraploid.
b) Some enzymatic systems of *U. laevis* form zymograms that unambiguously differ this species from the others within the *Ulmus* sp. genus.
c) Isoenzymes of elms are highly polymorphic.

Another study of Machon et al. (1997) investigated geographical structure of the *Ulmus* sp. genus. Repeated sample analyses proved high genetic diversity, high degree of polymorphism with high number of allels per locus. Interesting was low number of heterozygotes for all the enzymatic systems. The study proved that genetic variability is determined by the variability inside regions. In contradiction, trees from different regions are genetically very alike. Assumption that Dutch elm disease significantly decreased their genetic diversity was not proved.

Cogolludo-Augustin et al. (2000) used isoenzyme analysis for identification of natural and hybrid elm species on the Iberian Island. Based on results of analyses the authors supported the hypothesis that the investigated elm species (*U. minor* and *U. pumila*) were diploid and isoenzymes were of codominant heredity. The study also supports the hypothesis that each species has its own specific allels and their characteristic distribution.

Reproducibility of the isoenzyme analysis was tested for three elms species (*Ulmus glabra* Huds., *Ulmus minor* Gled. and *Ulmus laevis* Pall.) in this work and species identification and possible differences between isoenzymes of plant individuals and rejuvenated material in explant cultures were investigated. To further research, representative populations with characteristic morphological features were sampled. Concerning the explant cultures, a spectrum of isoenzymes for explants and donor individuals was compared. Isoenzyme analysis was also used for studying sets of in vitro, for longer period cultivated elms from viewpoint of representation of isoenzyme systems.

SELECTION AND PREPARATION OF MATERIAL

During years 1999, 2000 and 2001 plant material (dormant buds) was sampled for studying inter-species variability by means of isoenzyme analysis. In 1999 *U. laevis* was sampled in the Průhonický park, in village Měchenice and in the Botanical garden Na Slupi. In 2000 isoenzyme analyses were done on the sets of *U. laevis* taken from other localities - Křivoklát and Břežanské valley, of *U. glabra* from the same localities and from the seed orchard Telč in the Ore Mts., and of *U. minor* sets from the Drahanská ravine. In 2001 *U. glabra* from locality Zlín-Lukov (tab. 1) completed the study.

Clonal homogeneity or genetic stability of explant cultures was studied using clone samples of explants *U. laevis* and *U. minor* gained by induction of organogenesis on full-grown winter bud tops of donor individuals after long-term cultivation. Isoenzyme analysis of these cultures was carried out in 1999 and 2001. In 1999, preliminary analysis of several clones of *U. laevis* and *U. minor* was performed. In 2001, two clones of *U. glabra* from the Ore Mts. and one from the Břežanské valley, and two clones of *U. minor* from the locality Litoměřice-Terezín were analysed.

Sampling 1999			
Species	**Locality**	**Number of samples**	**Sampling**
Ulmus laevis	Průhonický park	28	IX 1999
	Měchenice	6	
	Botanical garden	2	
Sampling 2000			
Species	**Locality**	**Number of samples**	**Sampling**
Ulmus laevis	**Břežanské valley**	**6**	
Ulmus glabra	*Ore Mts:*		
	Janov	6	X/2000
	Litvínov	4	X/2000
	Klášterec	16	X/2000
	Křivoklát	16	X/2000
	Břežanské valley	16	X/2000
Ulmus minor	Drahanská ravine	20	X/2000
Sampling 2001			
Species	**Locality**	**Number of samples**	**Sampling**
Ulmus glabra	Zlín - Lukov	13	III/2001

Tab. 1.
Sampling of elm dormant buds

METHODOLOGY OF ISOENZYMES ANALYSIS

Samples were homogenized with extract buffer according to Wendel and Weeden (1989): tris-HCl, saccharose, mercaptoethanol, sodium ascorbate, diethyldithiocarbamate, beef albumin BSA and PVP-40. The isoenzymes were separated by horizontal one-dimensional electrophoresis on starch gel using histidin-citrate buffer, pH 5,7. Malate dehydrogenase (MDH), phosphate glucose mutase (PGM), leucine amino peptidase (LAP) and glucose phosphate dehydrogenase (6-PGDH) enzyme systems were stained according to Pasteur et al. (1988). According to increasing mobility in electrical field during electrophoresis the isoenzyme allels were marked as A, B, … reflecting mobility of isoenzyme patterns, i. e. allels and their combination, i. e. genotypes. Within chosen sets of elm samples, genotype and allelic frequencies were evaluated for MDH, PGM and 6-PGDH enzymes. These enzymes were chosen according to Machon et al. (1995, 1997). Zymograms were evaluated both by visual interpretation and in digital manner using Pharmacia Biotech software ImageMaster.

Significance of differences among molecular-genetic characteristics of elms was tested by means of χ^2-test for absolute allelic frequency on significance level $\alpha = 5$ %. Calculation was done by methods of contingency tables using statistical software STATGRAPHICS.

RESULTS

In the year 1999, first orientation analyses of *Ulmus laevis* Pall. from Průhonický park, Měchenice and from Botanical garden were carried out, and uniformism of zymograms was found for these localities. On the contrary zymograms of *Ulmus minor* Gled. from Botanical garden showed differences within individual clones, especially for enzymatic system PGM.

Further measurement of *Ulmus* sp. sets was carried out in the 2000 and 2001 years. Due to relative low number of samples, individual localities were not compared during evaluation of results, only individual elm species were. At interpreting results tetrasomy was supposed for enzymes PGM and MDH that is presented by Machon et al. (1995) for *Ulmus* sp. Results for enzymes 6-PGDH, MDH and PGM are in tables 2 to 7 like absolute genotype and allelic frequencies. These characteristics are related to enzymatic systems 6-PGDH of *Ulmus* sp. samples from localities Břežanské valley (*U. glabra*, *U. laevis*), Drahanská ravine (*U. minor*) and Křivoklát (*U. laevis*) and from the Ore Mts. localities Janov, Litvínov and Klášterec and locality Zlín-Lukov (*U. glabra*) (tab. 2). Genotype and allelic frequencies of MDH from the same localities and also from Záblatská basin (*U. glabra*) and Průhonice are described in tab. 3. Tab. 4 shows genotype and allelic frequencies of PGM system from localities Drahanská ravine (*U. minor*), Záblatská basin (*U. glabra*) and Průhonice, Poděbrady and Křivoklát (*U. laevis*).

Results presented in table 2 and 3 show that the low allel is always more distributed in enzymes 6-PGDH and MDH: in system 6-PGDH it is allel A, in MDH allel B. For system PGM (tab. 4) similar conclusion cannot be unambiguously presented, but it can be stated that allels B and C are always represented more than allels A and D.

Calculation of absolute allelic frequencies onto relative from table 2 shows that allelic frequencies of minority allel of enzyme 6-PGDH is 0 % for *U. glabra* for investigated sets, approximately 4 % for *U. laevis* (from Břežanské valley) and 25 % for *U. minor* (from locality Drahanská ravine). Allelic frequencies of minority allel MDH is 17 % for *U. glabra*, 17 % for *U. laevis* and 25 % for *U. minor* (tab. 3.). Tab. 4 shows that frequencies of minority allels are approximately 4 % for *U. glabra*, 23 % for *U. laevis* and about 25 % for *U. minor*.

Results of isoenzyme analysis of chosen explant clones comprised in tables 5 to 7 show genotype difference of individual clones for enzymatic systems 6-PGDH, MDH and PGM. Similar conclusion can be formed for enzyme MDH of investigated *U. glabra* sets. On the other side there is documented allelic uniformity of each of clones, i. e. their mutual genetic identity for observed enzymes. In this context genetic identity of all donor trees and their explants within investigated explants can be confirmed. Genetic identity of donor individuals and explants has proved also orientation observation of isoenzymes of LAP system.

DISCUSSION

Calculations of relative allelic frequencies for enzymes 6-PGDH, MDH and PGM, based on data from tables 2, 3 and 4 show that representation of minority allel (B) for 6-PGDH increases in order *U. glabra* – *U. laevis* – *U. minor*, and for *U. glabra* allel B is not represented at all. Investigated enzymatic system is quite monomorphic for *U. glabra*, and this result can be considered as representative regarding relatively high number of the samples. Representation of minority allel (A) increases in order *U. laevis* – *U. glabra* – *U. minor* for system MDH, the less frequent allels A, D in order *U. glabra* – *U. laevis* – *U. minor* are represented for PGM.

χ^2-test for absolute frequencies corresponding with representation of particular allels showed statistically significant differences (on level $\alpha = 5$ %) between *U. glabra* and *U. minor* for enzyme 6-PGDH ($\alpha = 10^{-5}$), between *U. laevis* and other two species *Ulmus* sp. for MDH ($\alpha = 0.008$ and 0.0035) and between *U. glabra* and *U. laevis* for PGM ($\alpha = 0.005$).

These results confirm that all quantitatively studied enzymes are suitable genetic markers for investigation of interspecies elm variability at using isoenzyme analysis.

Investigating genetic stability of explant elm clones, tables 5 – 7 show that no molecular-genetic changes were found for selected *Ulmus* sp. clones within investigated enzymatic systems 6-PGDH, MDH and PGM that would be caused by induction of organogenesis on full-grown winter buds of donor individuals (and their subsequent, long-term in vitro cultivation).

Species	**Locality (number of samples)**	**Genotype**	**Frequency**	**Allele**	**Frequency**
Ulmus glabra	Břežanské valley (16)	AA	16	A	32
		A*B*	0	*B*	0
	Ore Mts. – Janov (6)	AA	6	A	12
		A*B*	0	*B*	0
	Ore Mts. - Litvínov (4)	AA	4	A	8
		A*B*	0	*B*	0
	Ore Mts. – Klášterec (16)	AA	16	A	32
		A*B*	0	*B*	0
	Zlín - Lukov (13)	AA	13	A	26
		A*B*	0	*B*	0
Ulmus laevis	Křivoklát (6)	AA	6	A	12
		A*B*	0	*B*	0
	Břežanské valley (6)	AA	5	A	11
		A*B*	1	*B*	1
Ulmus minor	Drahanská ravine (20)	AA	12	A	32
		A*B*	8	*B*	8

Tab. 2.
Genotype and allelic frequencies of 6-PGDH enzymatic system of *Ulmus* sp. sets and populations (rare alleles are in italics)

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Species	**Locality (number of samples)**	**Genotype**	**Frequency**	**Allele**	**Frequency**
Ulmus glabra	Břežanské valley (16)	(*AA*BB)	1	*A*	13
		(*A*BBB)	11	B	49
		(BBBB)	4	-	-
	Ore Mts. – Janov (6)	*A*BBB	6	*A*	6
		-	-	B	18
	Ore Mts. - Litvínov (4)	*A*BBB	4	*A*	4
		-	-	B	12
	Ore Mts. - Klášterec (16)	BBBB	16	*A*	0
		-	-	B	64
		-	-	-	-
	Zlín - Lukov (13)	*AA*BB	1	*A*	14
		*A*BBB	12	B	38
Ulmus laevis	Křivoklát (6)	BBBB	6	*A*	0
				B	24
	Břežanské valley (6)	*AA*BB	2	*A*	4
		*A*BBB	4	B	12
	Průhonice (19)	*A*BBB	3	*A*	3
		BBBB	16	B	73
Ulmus minor	Drahanská ravine (20)	*A*BBB	20	*A*	20
		-	-	B	60

Tab. 3.
Genotype and allelic frequencies of MDH enzymatic system of *Ulmus* sp. sets and populations (rare alleles are in italics)

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Studium genetické variability jilmů pomocí izoenzymových analýz

Souhrn

Byla studována genetická variabilita autochtonních porostů jilmu horského, jilmu vazu a jilmu habrolistého. Byly odebrány vzorky z 10 lokalit ČR a měřeny 4 enzymatické systémy malátdehydrogenáza (MDH), fosfoglukomutáza (PGM), leucinaminopeptidáza (LAP) a fosfoglukonátdehydrogenáza (6-PGDH) s využitím horizontální elektroforézy na škrobovém gelu. Pro enzymatické systémy MDH, PGM a 6-PGDH, u kterých byl zjištěn vysoký stupeň polymorfismu, byly vypočteny genotypové a alelické frekvence. Tyto výsledky umožňují rozlišení jednotlivých druhů jilmu. U vybraných vzorků byla sledována genetická stabilita během kultivace in vitro, přičemž nebyly zjištěny žádné genetické změny.

Study of genetic variability of elms using isoenzyme analysis

Summary

Genetic variability of autochthonous stands of wych elm, European white elm and smooth-leaved elm was studied. Samples were taken from 10 localities in CR and 4 enzymatic systems malate dehydrogenase (MDH), phosphoglucomutase (PGM), leucine aminopeptidase (LAP) and phosphogluconate dehydrogenase (6-PGDH) were measured using horizontal electrophoresis on starch gel. Genotype and allelic frequencies were calculated for MDH, PGM and 6-PGDH systems for which high degree of polymorphism was found. These results enable distinguishing among individual elm species.

Genetic stability during in vitro cultivation of selected samples from 4 localities was studied and no genetic changes were observed.

Species	Locality (number of samples)	Genotype	Frequency	Allele	Frequency
Ulmus glabra	Záblatská hole (14)	*AA*BB	1	*A*	2
		BBCC	5	B	19
		BCCC	7	C	35
		CCCC	1	*D*	0
Ulmus laevis	Průhonice (19)	BBCC	11	*A*	0
		BB*DD*	4	B	34
		B*DDD*	4	C	22
		-	-	*D*	20
	Poděbrady - Huslík (15)	*AA*CC	2	*A*	4
		BBCC	3	B	16
		BB*DD*	1	C	35
		BCCC	7	*D*	5
		B*DDD*	1	-	-
		CCCC	1	-	-
	Křivoklát (6)	*A*BCC	4	*A*	5
		*A*B*DD*	1	*B*	5
		CCCC	1	C	12
		-	-	*D*	2
Ulmus minor	Drahanská ravine - b (8)	BBCC	7	*A*	0
		BB*DD*	1	B	16
				C	14
				D	2

Tab. 4.
Genotype and allelic frequencies of PGM enzymatic system of *Ulmus* sp. sets and populations (rare alleles are in italics)

Species	Locality - clone number	Genotype	Frequency	Allele	Frequency
Ulmus glabra	Břežanské valley – 1	AA	10	A	20
	Ore Mts. – 3	AA	10	A	20
	Ore Mts. – 5	AA	10	A	20
Ulmus minor	Litoměřice, Terezín - 33	A*B*	10	A*B*	10,10
	Litoměřice, Terezín - 34	(U)	10	-	-
	Litoměřice, Terezín – 35	A*B*	10	A*B*	10, 10
	Litoměřice, Terezín – 36	A*B*	10	A*B*	10, 10
	Litoměřice, Terezín – 37	A*B*	10	A*B*	10, 10
	Litoměřice, Kersko - 38	A*B*	10	A*B*	10, 10

Tab. 5.
Genotype and allelic frequencies of 6-PGDH enzymatic system of various clones of *Ulmus* sp., for 10 individuals (rare alleles are in italics) (U) - uniform zymogram

Species	Locality - clone number	Genotype	Frequency	Allele	Frequency
Ulmus glabra	Břežanské valley – 1	*AAAA*	10	*A*	40
	Ore Mts. – 3	*AAAA*	10	*A*	40
	Ore Mts. – 5	*A*BBB	10	*A*B	10, 30
Ulmus minor	Litoměřice, Terezín - 33	*AAA*B	10	*A*B	30, 10
	Litoměřice, Terezín - 34	BBBB	10	B	40
	Litoměřice, Terezín – 35	-	10	B	--
	Litoměřice, Terezín – 36	BBBB	10	B	40
	Litoměřice, Terezín – 37	BBBB	10	B	40
	Litoměřice, Kersko – 38	BBBB	10	B	40

Tab. 6.
Genotype and allelic frequencies of MDH enzymatic system of various clones of *Ulmus* sp., for 10 individuals (rare alleles are in italics)

Species	Locality - clone number	Genotype	Frequency	Allele	Frequency
Ulmus glabra	Břežanské valley – 1	*AA*BB	10	*A*B	20, 20
	Ore Mts. – 3	*AA*BB	10	*A*B	20, 20
	Ore Mts. – 5	*AA*BB	10	*A*B	20, 20
Ulmus minor	Litoměřice, Terezín - 33	*AA*BB	10	*A*B	20, 20
	Litoměřice, Terezín - 34	*AA*BB	10	*A*B	20, 20
	Litoměřice, Terezín – 35	*AA*BB	10	*A*B	20, 20
	Litoměřice, Terezín – 36	*A*BBB	10	*A*B	10, 30
	Litoměřice, Terezín – 37	*A*BBB	10	*A*B	10, 30
	Litoměřice, Kersko - 38	*A*BBB	10	*A*B	10, 30

Tab. 7.
Genotype and allelic frequencies of PGM enzymatic system of various clones of *Ulmus* sp., for 10 individuals (rare alleles are in italics)