

# LESNICTVÍ FORESTRY

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# LESNICTVÍ - FORESTRY

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Negativní působení látek ze znečištěného ovzduší na lesní dřeviny a na vývoj lesních ekosystémů je v současnosti hlavním problémem lesního hospodářství v České i Slovenské republice. Působení imisních látek a projevy poškození lesních dřevin dosahovaly v severních Čechách i jinde již v padesátých letech takových rozměrů, že vyvolaly pozornost lesnického výzkumu. Postupem času vliv imisí na poškození porostů a půd přešel do zásadního faktoru ovlivňujícího existenci a prosperitu lesních porostů a plnění jejich funkcí a proto je v naší republice i problém působení imisních látek na lesní ekosystémy dlouhodobě hlavním tématem výzkumné činnosti.

V padesátých a šedesátých letech našeho století mělo poškození lesů podle intenzity a výšky komínů zdrojů emisí pouze lokální charakter v užším či širším okolí. Vyvolávalo ho přímé působení plyných sloučenin sýry, fluóru, chlóru a dusíku a spad tuhých látek (popela) na listové orgány.

Při uvádění do provozu výkonnějších energetických zdrojů s vysokými komíny se zvýšil dálkový přenos plyných sloučenin S a N, při kterém vznikají kyselé aerosoly a fotooxidanty, z nichž je nejzávažnější ozón.

S ohledem na různou intenzitu znečištění ovzduší a délku trvání tohoto zatížení se v jednotlivých oblastech naší republiky projevují rozdílné stupně poškození lesních ekosystémů. Od latentních projevů změn fyziologických procesů v listech a orgánech dřevin až po odumření porostů na stanovištích, kde je možné pěstovat porosty náhradních dřevin za použití melioračních opatření.

S ohledem na rozmístění zdrojů emisí se spalováním uhlí v republice i v sousedních státech je zatížení lesních porostů imisemi plošně velmi rozdílné. Ohrožení lesních ekosystémů imisními látkami je závislé na konfiguraci terénu, tedy na exponovanosti porostů a na nadmořské výšce. To ovlivňuje nejen přímé působení, ale i stav půdního prostředí a výživu dřevin, podmiňující jejich odolnost vůči působení toxických látek z ovzduší. Příčiny poškození lesů musíme vidět v synergickém působení řady škodlivých látek z ovzduší, v klimatických faktorech a v narušení výživy dřevin.

V širokém spektru problémů vyvolaných působením imisí na lesy patří mezi hlavní oblasti zájmu výzkumu monitoring změn v lesních ekosystémech a jejich vliv na ekologické působení lesů. Dále to jsou opatření ke snížení negativních vlivů imisí na porosty a možnosti obnovy a stabilizace ekosystémů získáváním odolnějších proveniencí a ekotypů cílových dřevin, hnojením porostů, melioracími půd a výchovnými zásahy.

## K jednotlivým příspěvkům:

Prezentované výsledky představují pouze část problému působení imisí na lesy, které řeší pracovníci Výzkumného ústavu lesního hospodářství a myslivosti v Jilovišti-Straněch. Zaměřují se na obnovu a stabilizaci lesů negativně ovlivňovaných látkami ze znečištěného ovzduší, na důsledky vlivu imisí na ekologické (vodo-hospodářské) působení lesních ekosystémů. Jde o výsledky výzkumu prováděného v nejméně zatížených oblastech Čech.

Velmi aktuální je hodnocení důsledků odumírání a mýcení původních, převážně smrkových porostů, obnovy kalamitních ploch a působení náhradních porostů na změny hydrické účinnosti lesů v Krušných horách. Retenční a retardační schopnosti půd a celých ekosystémů, spolu s průběhem ukládání a tání sněhu, mají velký vliv na povodňové průtoky.

Spad látek z ovzduší se srážkami indikuje do značné míry jeho znečištění, ale ukazuje především míru zatížení a nebezpečí změn chemismu půdního prostředí z hlediska produkčních vlastností a jejich vlivu na chemismus vody odtékající do vodních zdrojů. Příspěvek uvádí spady protonů, aniontů, kationtů a kovů zjišťované na volné ploše a v porostech hlavních dřevin. Na trvalých plochách je možné sledovat i vývoj depozice v sedmdesátých a osmdesátých letech (pro srovnání s údaji publikovanými v SRN).

Hodnocení možnosti latentního poškození lesních dřevin imisními látkami má zásadní význam pro zjištění nebezpečí jejich oslabování a zjevného poškození i v oblastech s relativně čistým ovzduším. V příspěvku autorky uvádějí některé metody užívané pro indikaci zasažených listových orgánů dřevin na základě fyziologických a biochemických testů a popisují výsledky fumigačních pokusů se sazenicemi dřevin, využitelných pro obnovu porostů cílovými i náhradními dřevinami.

Smrk je hlavní původní dřevinou horských oblastí. Proto je mimořádně významné úsilí o jeho obnovu na kalamitních plochách a o zachování dosavadních mladých porostů v období současného vysokého znečištění ovzduší. Jedinou dostupnou možností lesníků je úprava jeho výživy hnojením. Tímto zásahem lze zlepšit půdní prostředí, zásobu živin v půdě a jehličí a fyziologické procesy spojené se zvýšenou odolností vůči působení agresivních látek z ovzduší.

Předpokladem obnovy horských lesů v severní části Čech smrkem je zajištění vhodného sadebního materiálu, tolerantního ke změnám podmínek prostředí tohoto regionu. Pro hodnocení byly vybrány proveniencie smrku ztepilého z hercynsko-sudetské oblasti, vysázené na plochách původně založených pro posouzení jejich růstu v rozdílných stanovištních podmínkách. Vybrané proveniencie a jednotlivé stromy jsou zdrojem pro vegetativní množení a pro zabezpečení reprodukce některých populací, které již buď neexistují, nebo nemohou plodit.

Protože problémy působení imisních látek na lesy a lesní ekosystémy jsou aktuální v celé střední Evropě, rozhodla redakční rada o vydání tohoto čísla *Lesnictví-Forestry* v anglickém jazyce.

*A negative effect of substances from polluted air on the forest tree species and on development of forest ecosystems is now the main problem of forest management in the Czech Republic and in the Slovak Republic. The effect of immission substances and manifestations of the forest tree species damages reached in Northern Bohemia and elsewhere from the 50th such dimensions that they called for attention of the researchers from the forest research. The effect of immissions on the stand and soil damages passed with the time to fundamental factor that had an effect on the existence and prosperity of the forest stands and performance of their functions, and that is*

why also in our republic the problem of immission substances effect on the forest ecosystems is the main topic of the activity in the research.

In the 50th and the 60th years of our century the forest damages were only of the local character according to the intensity and the chimney heights that are the emission sources, in closer or larger environment. It was evoked by a direct effect of gaseous compounds of sulfur, fluorine, chlorine and nitrogen and solid compounds deposition (ashes) to the leaf organs.

At putting into operation more efficient power sources with high chimneys long-distance transmission of gaseous compounds of S and N increased, at which acid aerosols and photooxidants, out of which ozone is the most important, are formed. With respect to various intensity of the air pollution and the length of this load duration the different degrees of forest ecosystem damage are manifested in particular regions of our republic. From the latent manifestations of changes in physiological processes in the leaves and tree species organs to the stand kill on the sites, where it is possible to grow the stands of substitute tree species at use of ameliorating arrangements.

With respect to location of the emission sources, where the coal is burnt, within the republic and in the neighbour countries, the forest stand areal load by immissions is very different. Forest ecosystems endanger by the immission substances depends on terrain configuration, that means on the stand exposure and on the altitude. That influences not only a direct effect, but also a state of soil medium and tree species nutrition, conditioning their resistance to effects of toxic substances from the air. We must see the causes of forest damages in synergic effect of the whole number of toxic substances from the air, in climatic factors and in disturbance of forest species nutrition.

In the wide spectrum of problems, caused by immission effects on the forests, monitoring of the changes in the forest ecosystems and their effect on ecological forest impact belongs to the main spheres of interest in the research. Further on these are provisions to decrease negative effects of immissions on the stands and possibilities of ecosystem regeneration and stabilization by obtaining more resistant provenances and ecotypes of target tree species, by the stand fertilization, soil amelioration and tending practices.

To particular articles:

The results shown represent only a part of problems of immission effects on the forests, which are solved by researchers of the Forestry and Game Management Research Institute at Jiloviště-Strnady. They are focused on regeneration and stabilization of the forests, negatively influenced by the substances from polluted air, the impacts of immissions on the ecological (hydrological) effects of forest ecosystems. These are the results of the research, conducted in most affected regions of Bohemia.

Evaluation of the impacts of dieback and clearing of original, prevailingly spruce stands, regeneration of gale-disaster areas and the effect of substitute stands on the changes in the forest hydric efficiency in the Krušné hory Mts. is very up-to-date. Retentive and retardatory abilities of soil and the whole ecosystems together with the course of snow deposition and melting, have a big effect on the floodflows.

Fall-out of substances from the air together with precipitations indicates, to a large extent, its pollution, but shows above all a rate of immission load and a danger of changes in soil medium chemistry from the point of view of production properties and their effect on chemistry of water flowing away to the waters. The article presents proton, anion, cation and metal depositions, determined on the open area and in the stands of the main tree species. On permanent plots it is possible to observe also deposition development in the 70th and the 80th (for comparison with the data, published in Germany).

Evaluation of possibilities of the latent damages of forest tree species by immissions is of principal importance for determinations of the danger of their weakening and apparent damages in the regions with relatively clear air. The authors present in the paper some methods used for indication of the affected leaf organs of tree species on the basis of physiological and biochemical tests and they describe the results of fumigation experiments with the tree species plants, usable for the stand regeneration by target and substitute tree species.

Spruce represent the main original tree species of the mountain regions. That is why the effort to perform its regeneration on the gale-disaster areas and to maintain young stands under the present high degree of air pollution is extraordinarily important. Treatment of spruce nutrition by fertilization is the only possibility available for foresters. By this intervention it is possible to improve soil medium, nutrient reserve in the soil and needles and physiological processes connected with the increased resistance to the effects of aggressive substances from the air.

Establishment of suitable planting stock, tolerant to the changed environmental conditions in this region, is a prerequisite for mountain forests regeneration by spruce in the northern part of Bohemia. Provenances of the Norway spruce from Hercynian-Sudeten region, planted on the plots, originally established for evaluation of the spruce growth under the different conditions of the stand, were chosen. Selected provenances and particular trees are the sources for vegetative propagation and for establishment of reproduction of some populations that either do not exist any more or cannot be fertile.

As the problems of the effects of immissions on the forests and forest ecosystems are topical throughout the whole middle Europe, editorial board decided to publish this issue - *Lesnictví-Forestry* - in the English language.

Ing. Václav L o c h m a n , CSc., Forestry and Game Management Research Institute, Jiloviště-Strnady

# EFFECT OF AIR POLLUTION ON CHANGES IN HYDRICAL EFFICIENCY OF FORESTS IN THE KRUŠNÉ HORY MTS.

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Due to the effect of immissions on the forest stands and due to the changes in ecological conditions connected with it, the decline of immission-sensitive tree species occurred and their gradual replacement by tree species relatively resistant. In the Krušné hory Mountains this resulted in changes in the production function but the non-wood-producing ones were also influenced. This is the case of water management function, soil protection, recreation, aesthetic, sanitation and other functions. The study is dealing with hydric efficiency of stands of substitute tree species and ground vegetation compared with original stands, that is during vegetation and out of it, including emphasizing the specificities following from it for arboriculture. Investigations, performed by us, showed the differences between hydric efficiency of original - prevalently spruce - stands and efficiency of substitute stands mainly as quality of their action is concerned.

immissions; stand species composition; age structure; production possibilities; other functions of forests

During the last decades, the forest areas in the Krušné hory Mts. have undergone dynamical changes as a result of intensive air pollution impact. The autochthonous productive ecosystems were gradually disturbed up to their consequential degradation. This process brought about appearance of substitute stands of ground vegetation that replaced the autochthonous stands, predominantly those of spruce, on extensive areas. This „successive“ stage did not last too long because simultaneously with its existence, regeneration of the stands of substitute tree species was started, i.e. of such tree species which were relatively more tolerant of the present level of pollutant load. These situations, including reproduction methods of forest stands in the Krušné hory Mts., have been described in detail in the specialized forestry and scientific literature.

Air pollution was responsible for heavy disturbance of the functional balance of forest ecosystems. The wood-producing function was temporarily excluded due to the loss of the means of wood production - the forest stand - and this resulted in elimination of further forest effects forming the basis of the other beneficial forest functions which are also denoted as non-wood-producing functions of the forest (in the conception of wood-producing forest management). Furthermore, it resulted, of course, in changes in hydric effects of forest areas in dependence on changing stand conditions on these areas, i.e. on the process from autochthonous stands through the stands of ground vegetation to those of substitute tree species.

Within the scope of hydrological function of the forest, changes occur in individual elements of its hydric efficiency as a result of pollutant impact. With the loss in the leaf area of autochthonous stands, negative components of water balance of these stands changed, interception and transpiration of main stands decreased and the

abilities of intercepting horizontal atmospheric precipitation from the fog of low cloudiness changed, as well. On the contrary, the effects of ground vegetation and later juvenile stages of substitute tree species stands began to manifest themselves more intensively. However, this resulted in changes in hydric effects which were characteristic for the individual stages of the changes.

## ANALYSIS OF THE PROBLEMS

### BASIC HYDRICAL PROBLEMS OF THE FORESTS IN AIR POLLUTED REGIONS

As mentioned earlier, forest destruction in the Krušné hory Mts., which was evoked by industrial pollutants, was responsible for considerable changes in the quality and quantity of biomass on forest areas which were associated with essential changes in individual components of water balance. The changes began to take place in the autochthonous stands and continued in dependence on the species of substitute stands, i.e. those stands which substituted the original spruce stands.

The autochthonous, predominantly spruce, stands of fir-beech vegetation zone and, above all, spruce-beech and spruce vegetation zones, at more or less equal distribution of age classes, changed successively the level of transpiration, interception, and evaporation of the soil and ground vegetation. Thus, step by step, evapotranspiration of the main stand decreased to the benefit of evapotranspiration of ground vegetation (Běle, 1978, 1975; Šachová, 1970).

In connection with these changes, substitute tree species stands were established in the Krušné hory Mts. With regard to the fact that the principal reason for the choice of these tree species was their relative tolerance of industrial pollution impact, an essential change occurred in species composition on the forest areas of this region associated with rather significant changes in hydric effects of these areas compared to the hydric effects of autochthonous stands in the Krušné hory Mts. and other air-polluted regions (Běle, 1973, 1977, 1978, 1985, 1988; Krečmer, Fojt, 1990; Šach, Kantor, 1990, and others). The results of investigations in air polluted regions conducted by these authors should be compared to general data on hydric efficiency of forest spruce, birch, beech and/or other stands. Some of their findings may also be used for application in air polluted regions, namely in cases when no sufficient local experience is available. The results of investigations reported, for example, by Molčanov (1960, 1966), Mitscherlich (1971), Brechtel (1965), Krečmer (1971), Zelený (1972, 1980), Krešl (1969), Kantor (1982), Chroust (1991), and others, were used for these purposes.

Furthermore, disturbance and consequential degradation of the tree layer of autochthonous stands and, pre-

dominantly, of their leaf biomass brought about also removal of an active component for interception of horizontal atmospheric precipitation from the fog of low cloudiness at middle mountain altitudes of more than 700 m a.s.l. This important hydric effect of forest stands was thus eliminated and/or essentially reduced particularly in the period when ground vegetation stands prevailed. By successive reforestation of forest areas with substitute tree species stands this effect is gradually restored, more in conifers and less in introduced broadleaved stands. This fact should be particularly emphasized because horizontal precipitation at elevations of about 1000 m a.s.l. implies significant growth factor, too, as reported by Baumgartner (1956) who followed the investigations by Grunow (1955). In our country, Krečmer (1968, 1973) and Zelený (1967) were concerned with these questions.

On forest areas in air-polluted regions, especially in the phase of ground vegetation, the conditions for snow deposition, with which underground water reserves are supplied, change as compared to the snow deposition in normally growing all-aged spruce stands Běle (1980). Comparable findings were reported for normal stands for example by Molčanov (1960, 1970), Zelený (1966), Sokolov (1970), Voronkov (1976), etc.

To investigate changes in hydric effects on forest stand areas at the stages of the existence of substitute tree stands, it is necessary to consider biomass quantity and different tree species area for comparison. Biomass distribution should be studied because it is a factor which essentially influences the level of negative elements of water balance of these stands. These questions were discussed for example by Burger (1939), Molčanov (1960), Jirgle (1979), Běle (1986, 1990), Kändler (1985), and other authors.

The study of the complex of questions concerning the hydric efficiency of forest areas in the Krušné hory Mts. as a basis of hydrological function reaches the same level as the study of wood-producing function in air polluted regions. These questions and their solution do not concern only the Krušné hory Mts. but also other regions at the Jizerské hory, Krkonoše, Jeseníky, and Beskydy Mountains.

#### HYDRICAL EFFICIENCY OF THE KRUŠNÉ HORY MTS. STANDS AS EXAMPLIFIED BY SPRUCE STANDS WHICH FORMED THEIR BASIC PART

Hydric effects of forest stands, which are influenced and/or determined by the amount (area) of their biomass and its spatial distribution, act significantly on the production of available water which serves both to growth processes and supplying underground water reserves for run-off. Moreover, hydric efficiency of forest and forest stands changes in dependence on local geographical conditions of their site but it also changes in time which is in accordance with the dynamism of their development. At the same time, meteorological factors, which, however, belong to general characteristics of a given climatic region, are of essential importance. The whole complex of these characteristics constitutes hydrological conditions of forest regions.

During the winter season, the production of available water depends on the water reserves in the snow and the course of its thawing, above all how much of this reserves

is capable to soak in the soil and supply the underground water. The snow cover is influenced by forest stands in a specific way.

The water balance of autochthonous forests can be expressed by a simple equation

$$S = ETR \pm D \quad (1)$$

where:  $S$  - vertical atmospheric precipitation,  
 $ETR$  - evapotranspiration consisting of balance components  
 $I$  - interception,  $T$  - transpiration,  $V$  - evaporation from the soil and ground vegetation,  
 $D$  - water supply in the soil which can be divided into  
 $O$  - water run-off and  $\pm Z$  - soil and underground water supply.

The equation may be then transformed into the form

$$S = I + T + V + O \pm Z \quad (2)$$

In general characterization of the Krušné hory Mts. region it can be started from the average values of the water balance of the catchments of the Czech Republic (Běle, 1991) which have been found by the analysis of 357 catchments of the Czech Republic streams.

The analysis was started from a simple balance equation  $S = O + ETR \pm Z$ . Nevertheless, the water supply is considered constant with regard to a long-term character of measuring the data used. The above equation was thus simplified to the form  $ETR = S - O$  which has been used for our calculations.

The average characteristics as related to elevation conditions of the Krušné hory Mts. from 500 m a.s.l. according to forest regions (Plíva, Průša, 1969) are given in Tab. I.

It should be noted to the values of balance components presented in Tab. I that these values apply to all catchments irrespective of forest coverage of defined altitudinal vegetation zones as it was objectively confirmed in our previous investigations (Běle, Páv, 1983) that forest coverage proportion has no significant effect on evapotranspiration in catchments. Nevertheless, this fact does not exclude in principle the existence of local differences in evapotranspiration as concerned various development stages of the forest and its species composition. The values of evapotranspiration mentioned should be understood as average. These are differences which constitute hydric qualitative efficiency of forest stands (forests) associated with the ability of splitting up run-off into longer time intervals, increasing available water supply, etc.

When starting from the domestic and foreign findings in determination of general values of forest stand evapotranspiration, these values may be expressed for main regions of vegetation zones in the Krušné hory Mts. in the way mentioned in Tab. II (Běle, 1991).

Tab. II involves the general values of evapotranspiration compiled partly according to the vegetation zones, including the relation to individual degrees of spruce working circle of stands aged from 10 to 100 years and partly individual components of evapotranspiration:  $I$  - interception,  $T$  - transpiration, and  $V_p$  - evaporation from the soil and ground vegetation. The total values correspond to the model values of components and total evapotranspiration which were estimated for individual vegetation zones (Běle, 1991).

The tabular values express changes in individual components of evapotranspiration not only as related to the stand age but simultaneously to the changing altitude

I. Average annual values of water balance components of forest stands in catchments according to altitudinal zones

Altitudinal zone	VS	m	500	600	700	800	900
Vertical atmospheric precipitation	$S_v$	mm	726	800	885	981	1087
Run-off	$O$	mm	249	331	426	536	659
Evapotranspiration	ETR	mm	468	465	461	458	454
Horizontal atmospheric precipitation	$S_h$	mm	-	-	2	13	26
Vegetation zone	VS		beech, fir-beech			spruce-beech, beech-spruce	

II. Average annual values of evapotranspiration of spruce stands as related to vegetation zones *c* and *d*

ETR (at age)	10	20	30	40	50	60	70	80	90	100	Ø
	(mm)										
Vegetation zone <i>c</i> <i>I</i>	170	236	248	254	262	262	262	254	248	240	240
beech <i>T</i>	106	150	191	214	214	211	188	186	169	153	171
fir-beech $V_p$	55	32	30	43	46	47	49	51	52	56	48
Total	331	418	469	512	522	520	499	491	469	449	459
Vegetation zone <i>d</i> <i>I</i>	194	259	284	291	300	300	300	291	284	275	275
spruce-beech <i>T</i>	89	136	154	179	178	176	153	153	137	124	139
beech-spruce $V_p$	43	25	24	34	36	37	38	40	41	44	38
Total	326	420	462	504	514	513	491	484	462	443	452

characterized by the altitudinal vegetation zone. With increasing altitude there is a relative decrease in transpiration, increase in interceptive evaporation, air humidity in the crown space, etc.

The values mentioned should be completed with average annual temperatures: 6.7 to 5.9 °C in the vegetation zone (VS) *c* and 5.9 to 4.1 °C in the vegetation zone *d*. During the growing season, the average temperatures attained 12.6 to 11.7 °C in the vegetation zone *c* and 11.7 to 9.8 °C in the vegetation zone *d*. In the vegetation zone *c*, snow precipitation ranged from 240 to 350 mm and the period of snow cover lasted 73 to 110 days, in the vegetation zone *d* it was 350 to 580 mm, the period of snow cover was 110 to 140 days. The total duration of the growing season was 130 to 150 days in the vegetation zone *c* and 100 to 130 days in the vegetation zone *d*.

HYDRICAL EFFICIENCY OF SUBSTITUTE TREE STANDS IN THE KRUŠNÉ HORY MTS.

SUBSTITUTE STANDS OF GROUND VEGETATION

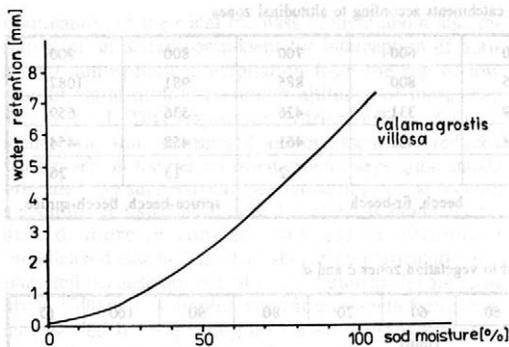
Substitute stands of ground vegetation prevailed on forest areas in the phase immediately after degradation of autochthonous stands. In this phase, wood-reed (*Calamagrostis villosa*) was the dominant species which formed extensive stands. The character of these stands gave also the character of changes in their hydrical efficiency in individual balance components.

Analysis of their individual components of water balance revealed a pronounced decrease in interception values. It was caused on the one hand by that the living biomass regenerated entirely every year, i.e. that its quantitative development could be recorded, and on the other that the arrangement of stalks and leaves was not favourable for interception of atmospheric precipitation. The growth of biomass proceeded approximately from May to the first half of August so that in the half of summer,

the area of wood-reed biomass reached maximum values, i.e. about 8.21 m<sup>2</sup> of surface area on the average which is 2.7 times less than the amount of the total surface area of e.g. a 60-year-old spruce stand on the 1st site class. Interception of wood-reed then amounts to approximately 18.0 % of the total interception of the above-mentioned 60-year-old spruce stand for the growing season. This decrease to one fifth of spruce stand interception is caused by vertical arrangement of stalks and leaves so that atmospheric precipitation intercepted on their surface mostly flow down the stalks to the sod layer. This also explains the maximum interception of 1.3 mm while in the mentioned spruce stand it amounts to 5.34 mm. On the basis of laboratory investigations of interception, the course of interception of wood-reed can be expressed by means of the first degree hyperbola of the type  $y = 1/(0.77 + 0.98/x)$ ; limit of this function is 1.298 mm = 1.30 mm.

The sod layer is formed below the wood-reed stands. It is of extraordinary importance for subsequent interception of atmospheric precipitation (Běle, 1978). The amount of water intercepted in the sod depends upon its thickness (ranging from 5 to 15 cm) and particularly upon its moisture.

An important ability of the sod layer is to retain absolutely all water at the beginning of atmospheric precipitation. This ability is conditioned above all by the moisture of the sod layer of wood-reed. The trend of water interception by sods as related to their percentage of moisture is represented in Fig. 1. The data were obtained by raining sod blocks with simulated precipitation of the same intensity of 0.45 mm per minute for 120 mins. It follows Fig. 1 that the lower the moisture, the less water retains in the sod in the initial phase of rain. According to the previous investigations (Běle, 1977, 1978), the sod rained from the initial moisture of 60 % retains water intensively up to the moisture of 75 to 80 %. At further raining (precipitation), the water uptake equals more or less the output - run-off. When following these findings



1. The amount of water retained in the sod layer at different percentage of its initial quantity

obtained, the behaviour of the sod layer of wood-reed in the field can be presumed, as well.

The estimation of evapotranspiration of wood-reed was started from the method of Molčanov (1960) based on its expression by means of saturation deficit in the growing season from May to October, taking *ETR* changes into consideration at different altitudes (Běle, 1985).

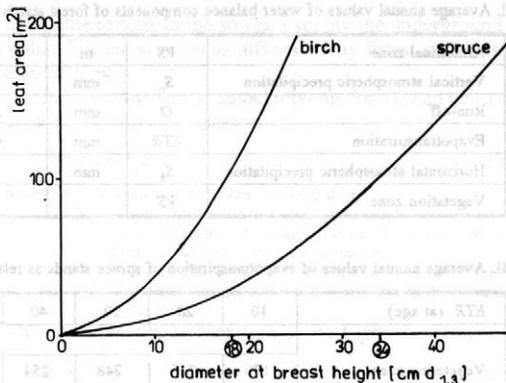
After that, the average *ETR* can be derived for the vegetation zone  $c = 254$  mm and for the vegetation zone  $d = 224$  mm. Šach, Kantor (1990) obtained a similar result. They derived the summary evaporation of 277 mm on weedy area for the growing season (May - October).

Interception of horizontal precipitation is considerably reduced in wood-reed and limited predominantly to a short period of the growing season. When starting from the findings how much horizontal precipitation is intercepted by the spruce stand (of the above-mentioned mensurational characteristics) and estimating this amount to be equal to 100 % then the stand of ground vegetation retains this precipitation only during June and October so that the amount intercepted can be estimated approximately at one fourth to one third. During the winter season when wood-reed is covered with snow, no preconditions are given for interception of this precipitation.

Snow deposition on areas with ground vegetation has a character of the formation of snow cover on free areas. It is more or less equal snow distribution on areas, the thickness of the snow layer enhancing in deponia as a result of windblowing. Snow thawing proceeds rather totally on these areas in dependence upon climatic conditions.

#### SUBSTITUTE TREE STANDS

At the end of the seventies and during the eighties, investigations were conducted into hydric efficiency in substitute tree stands in the Krušné hory Mts. (Běle, 1977, 1978, 1980, 1988; Krečmer, Fojt, 1990, and others). Thus a set of underlying data was obtained to evaluate hydric efficiency of tree species, e.g. birch, spruce exotics, etc. At the same time it was necessary to consider changes in the amount of biomass, which occurred on forest stand areas, not only from the quantitative but also qualitative point of view, for example broadleaved trees were substituted for coniferous (spruce) stands.



2. Leaf area of birch and spruce as related to diameter at breast height ( $d_{1.3}$ )

To compare interception values as exemplified by spruce and birch (substitute tree species) it is necessary to be acquainted predominantly with the surface area of their biomass. This comparison is shown in Fig. 2 on the basis of the relationship between the diameter at breast height of trees and surface area of biomass (Běle, 1988). This relation was studied by some authors as early as the thirties (e.g. Burger, 1939). Tab. III demonstrates that both the tree species under investigation do not attain identical leaf area at the same diameter at breast height. For example, spruce attains approximately 100 m<sup>2</sup> of leaf area at the diameter  $d_{1.3}$  34 cm while in birch this area is reached at the diameter at breast height of 18 cm.

To compare the leaf area of spruce and birch in individual age classes the data were used from Schwappach tables. Corresponding age classes were estimated in the IIIrd yield class and full-canopy spruce and IInd yield class and full-canopy birch in accordance with the diameter at breast height. The relevant areas were found to it according to Fig. 2.

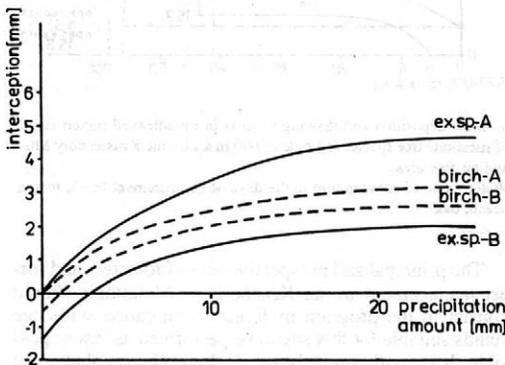
#### Interception and horizontal precipitation of substitute tree stands

If applied the size of the leaf area mechanically to the whole stands and derived e.g. the amount of retained water of vertical atmospheric precipitation, i.e. interception, from them, higher values would be attributed to birch than to spruce. The following analysis of interception of both the tree species indicates that the leaf area is only one of the factors deciding interceptive amount of individual tree species. A considerable role is played by the arrangement and size of leaves which, for example in birch are very unfavourable for interception.

Comparison of interception of substitute stands (spruce exotics - blue spruce, Omorica spruce, black spruce, and birch) at the age of 15 years is shown in Fig. 3. Interception of vertical atmospheric precipitation is mentioned here as related to precipitation amount under weather situations without horizontal precipitation from the fog of low cloudiness (situation A) and with horizontal precipitation (situation B). The measurement was conducted on experimental plots near Nové Město in the Krušné hory Mts. during 1977 to 1982. Subcrown precipitation was measured using rain gauge troughs placed in a net.

### III. Leaf area of Norway spruce and beech as related to age

Tree species	Age									
	10	20	30	40	50	60	70	80	90	100
Spruce O $d_{1,3}$	1.2	2.8	6.3	10.4	13.9	17.3	20.4	23.1	25.5	27.8
Leaf area (m <sup>2</sup> )	0.26	0.62	4.0	10.1	18.1	27.3	37.3	47.2	56.4	67.3
Birch O $d_{1,3}$	3.3	6.5	9.8	14.0	17.1	19.7	22.6	26.5		
Leaf area (m <sup>2</sup> )	4.3	15.8	33.3	63.8	92.3	120.1	155.3	209.6		



3. Comparison of interception of spruce exotics and birch at atmospheric precipitation without fog (A) and with fog (B) in the Krušné hory Mts.

Interception of atmospheric precipitation without horizontal precipitation exhibited quite normal course as concerned precipitation amount. Spruce exotics had the ability of retaining vertical atmospheric precipitation higher by 30 % on the average compared to birch. In the case of weather situations with horizontal precipitation, spruce exotics intercepted horizontal precipitation by 40 % more than birch. Likewise, it conditioned their lower interception under these situations. Fig. 3 shows that at horizontal precipitation birch exhibited negative interception values approximately to 1.2 mm of precipitation amount and spruce exotics up to 3.0 mm, on the average.

According to the investigations of interception evaporation in spruce exotics and birch stands aged 15 years and at full canopy, under weather situations free of fog, it attained 28.5 % in spruce and 24.7 % in birch from the sum of vertical atmospheric precipitation for the growing season. In coaction with horizontal precipitation, the interception evaporation reached in exotics and birch 14.3 and 11.3 %, respectively. The total average interception during the growing season attained in spruce exotics and birch 24.2 and 20.6 %, respectively, from the sum of vertical atmospheric precipitation. Therefore, it can be stated that at the age level of young substitute tree stands, spruce exotics retain atmospheric precipitation more by 15 % than those of birch. That all is true in the growing season. In the extra-vegetative period these differences are essentially higher.

#### Snow conditions in substitute tree stands

Snow accumulation in forest stands of spruce working circle at altitudes of 600 to 900 m a.s.l. was estimated during the winter season (Běle, 1980). It was found that snow was deposited in the way which is typical for approximately equal composition of age classes of spruce

stands. The highest amount of snow was deposited on clear felling and in stands of the youngest age classes to 20 years of age which had a lower stand height and also in old stands of 80 years and more which had an open canopy. The lowest reserves were in middle-aged canopy stands of 40 to 70 years. Increased amount of snow in these stands was caused first of all by the action of leeward effect at snow-fall which was associated with air flow resulting in enhanced snow deposition in the leeward of older stands with higher stand height, provided that they were followed by younger stands, thus of lower height, and/or by clear strip felling. These questions were discussed for example by Krečmer (1967), Fleming (1968), Zelený (1966), and others.

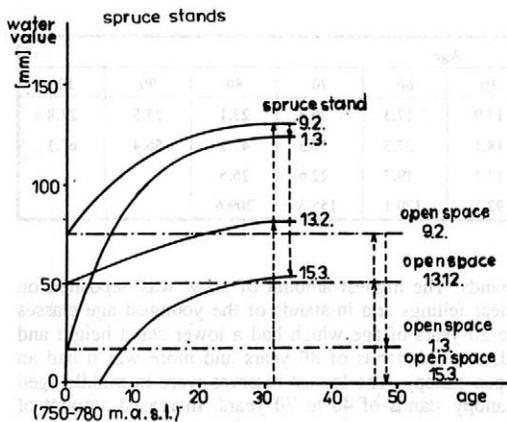
As far as substitute tree stands are concerned in the Krušné hory Mts., snow conditions are determined by other circumstances than described above. The determining factor is large-area deforestation of forest areas on which only the youngest age stages of these stands occur - up to 30 years. Under these conditions, permanently increased air flow is characteristic and thus the snow is suspended and accumulated in field deponia and in substitute tree stand which mostly are not of full canopy. The wind speed relatively decreases and snow deposits to a higher extent in the stands. The effect of leeward snow deposition, which is typical for the stands of „normal“ working circle, is mostly missing here.

Snow deposition and thawing process were analyzed on air polluted afforested areas. Fig. 4 shows water values of snow from spruce stands at elevations of 750 m a.s.l. and Fig. 5 presents those from mixed stands (birch, rowan, beech, and oak) at an altitude of 600 m a.s.l. In both cases, the least amount of snow was on free areas and in stands to 10 years of age. Conspicuously higher amount of snow was deposited in older stands. Nevertheless, thawing proceeded slowly in the spruce stands. It was the slowest in relatively older stands of 20 to 30 years, as well. The differences in the amount of snow in Figs. 4 and 5 were also given by the influence of elevation on the amount of snow deposited.

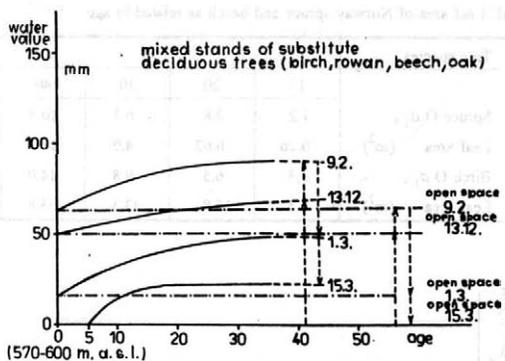
#### CONCLUSION

Dynamical changes which the forests and forest stands have undergone as a result of air pollution impact in the Krušné hory Mts. are characterized by changes in stand species composition, age structure, production possibilities, likewise in abilities to secure the effects of other all-society important forest functions.

Due to these changes, the original, predominantly wood-producing function of the forests of the Krušné hory Mts. has become different and at present, these forests and forest areas fulfil the priority role to secure the basic effects constituting the other ecological functions of the forests as follows: soil water- (wind-) erosion con-



4. Snow deposition and thawing process in spruce stands (altitude of 750 m a.s.l. - the Krušné hory Mts.) and on free area



5. Snow deposition and thawing process in broadleaved mixed stands of substitute tree species (altitude of 600 m a.s.l. - the Krušné hory Mts.) and on free area

Water value of snow in mm in the days of measurement birch, rowan, beech, oak

trol, qualitative hydric effects positively influencing retention and retardation of hydrological cycle in forest ecosystems, constitution of forest microclimate in comparison with clear cuttings, moderation of the effect of climatic extremes, and that all under the conditions of intensive pollution load. Therefore, the principal task of the forests in air polluted regions is to maintain the forest for securing its other all-society important functions that are significant not only from the point of view of the stability of natural environment in the country but they are also of importance for consequential regeneration of target tree species stands throughout the region.

Concerning the hydric efficiency of forest stand areas in the Krušné hory Mountains in the period of intensive air pollution impact, it has undergone changes which have influenced its level more or less negatively. Interception and transpiration of stands have been changed on these areas. Interception of horizontal precipitation from the fog of low cloudiness and conditions of snow deposition and snow thawing were affected negatively on extensive areas of the Krušné hory Mountains.

The most serious period in this sense was the phase when the stands of ground vegetation, which substituted these effects only in part, prevailed on the areas of forest stands in the Krušné hory Mountains. The situation slightly improved by the planting of substitute tree stands. Nevertheless, their hydric efficiency is also limited both by species composition and age structure.

The substitute tree stands were established both by natural and, predominantly, artificial regeneration. At present they are in the period when their future existence, which is also reflected in their hydric efficiency, requires specially deliberated tending, including elaboration of the stands to invigorate their other beneficial effects. The tending must be conducted in such a way to secure:

- stabilization of good health state of the existing substitute tree stands,
- formation of optimum conditions for the origin and regeneration of favourable stand microclimate which will support growth processes with respect to the stand and realization of their changes,
- realization of tending operations must be conditioned by rational time and spatial arrangement taking all arrangement aspects into account.

The principal and prospective aim of foresters and forest management in the Krušné hory Mountains should consist in the program of forest regeneration with tree stands suitable for this site to be performed as fast as possible. It is conditioned, however, by pollution abatement which will enable realization of this aim.

## References

- BAUMGARTNER, A.: Nebel und Nebelniederschlag als Standortsfaktoren am Grossen Falkenstein (Bayer. Wald). Forstwiss. Centralblatt, 77, 1958 : 230-237; 257-272.
- BĚLE, J.: Příklad k zjištění evapotranspiračních ztrát smrkových porostů. [Kandidátská disertace.] VÚLHM, 1973 : 113.
- BĚLE, J.: Prognóza změn hydrické účinnosti ploch lesů v Krušných horách. [Dílčí závěrečná zpráva.] VÚLHM, 1977 : 39.
- BĚLE, J.: Prognóza změn hydrické účinnosti ploch lesů v Krušných horách. [Závěrečná zpráva.] VÚLHM, 1978 : 36.
- BĚLE, J.: Tvorba zásob sněhu ve smrkové hospodářské skupině. Lesnictví, 26, 1980, č. 8 : 729-736.
- BĚLE, J.: Hydrická účinnost přizemní vegetace v imisních oblastech. Práce VÚLHM, 66, 1985 : 287-312.
- BĚLE, J.: Význam stromových tříd pro intercepci smrkového porostu. Práce VÚLHM, 68, 1986 : 49-71.
- BĚLE, J.: Porovnání intercepčního výparu smrkových porostů a náhradních porostů v Krušných horách. Práce VÚLHM, 73, 1988 : 149-175.
- BĚLE, J.: Význam intercepcie atmosférických srážek pro pěstování smrkových porostů. Práce VÚLHM, 75, 1990 : 157-180.
- BĚLE, J. - PÁV, B.: Příklad k vlivu lesnatosti na evapotranspiraci v povodích. Lesnictví, 29, 1983, č. 9 : 805-814.
- BRECHTEL, H. M.: Metodische Beiträge zur Erfassung der Wechselwirkung zwischen Wald und Wasser. Forstarchiv, 15, 1965, č. 11.
- BRECHTEL, H. M.: Schneeanammlung und Schneeschmelze im Wald und im Freiland. XVI. IUFRO World Congress Norway 1976 : 300-310.
- BRECHTEL, H. M. - BALÁČZ, A.: Auf- und Abbau der Schneedecke im westlichen Vogelsberg in Abhängigkeit von Höhenlage, Exposition und Vegetation. Beiträge z. Hydrologie, 3, 1976 : 35-107.
- BRECHTEL, H. M.: Möglichkeiten und Grenzen einer Steuerung der Schneeanammlung und Schneeschmelze der Forstliche Massnahmen, Mitteilungen. Schneehydrologische Forschung in Mitteleuropa, 1984 : 331-354.
- BURGER, H.: Der Kronenaufbau gleichartiger Nadelholzbestände. Mitt. d. Schweiz. d.f. Versuchswesen, 21, 1939 : 147-176.
- FLEMMING, G.: Das Klima an Waldbestandesändern. Abhandl. Met. Hydrol. Dienst. DDR, 9, 1964 : 71.

GRUNOW, J.: Der Niederschlag im Bergwald. Forstwiss. Centralblatt, 74, 1955, č. 1-2: 21-36.

CHROUST, L.: Vliv výchovných zásahů na intercepci a transpiraci v mladších smrkových porostech. [Závěrečná zpráva.] (Koloběž vody v lesních ekosystémech). VÜLHM, 1991: 35.

JIRGLE, J.: Zhodnocení náhradních porostů z hlediska biologického a ekonomického. (Zhodnocení produkce biomasy v břežových a jeřábových porostech v Krušných horách.) [Závěrečná zpráva.] VÜLHM, 1979: 50.

KANTOR, P.: Hydrická účinnost dospělých smrkových a bukových porostů. [Závěrečná zpráva.] VÜLHM, 1982: 45.

KÄNDLER, G.: Die Ermittlung von Bestandesparametern als Eingangsgrößen für Interzeptionsmodelle mit Hilfe des Luftbilds. Wald u. Wasser, Grafenau, 1985: 77-89.

KREČMER, V.: K intercepci srážek ve středohorské smrčtině. Opera Coorcortica, 1968: 83-96.

KREČMER, V.: Vodohospodářské vlivy lesů. Stud. Inform. ÚVTI, 1969, č. 405: 393.

KREČMER, V.: Vodohospodářské funkce lesů. Lesnictví, 17, 1971, č. 4: 413-430.

KREČMER, V.: Meteorologické podmínky výskytu kapalných srážek z mlhy a jejich význam pro intercepční proces ve středohorském lese. Výzkumné zprávy, 27, 1973, č. 1: 18-25.

KREČMER, V. - FOJT, V.: Záporné složky vodní bilance v porostech listnáčů. [Závěrečná zpráva.] VÜLHM, 1990: 44-47.

KRESL, J.: Příspevek k určení vodohospodářské účinnosti lesa v bezsrážkovém období. Lesnictví, 15, 1969, č. 1: 1-14.

MITSCHERLICH, G.: Wald, Wachstum und Umwelt. 2. Band. Waldklima und Wasserhaushalt. Frankfurt, 1971: 365.

MOLČANOV, A. D.: Hidrologičeskaja roľ lesa. AN SSSR, 1960: 464.

MOLČANOV, A. D.: Hidrologičeskaja roľ lesa v raznych prirodnych zonach SSSR. In: Hidrologičeskije issledovanija v lesu, 1970: 5-78.

PLÍVA, K. - PRŮŠA, E.: Typologické podklady pěstování lesů. Praha, SZN 1969: 400.

SOKOLOV, A. A.: Dynamika ionnogo tverdogo stoka s bezlesnogo i lesnogo vodosborov. In: Hidrologičeskije issledovanija v lesu, 1970: 79-93.

ŠACH, F. - KANTOR, P.: Vodní bilance mladých porostů v jedlobukovém stupni. [Závěrečná zpráva.] VÜLHM, 1990: 40-43.

ŠACHOVA, O. V.: Roľ travjano-mochovogo pokryva v vodnom balanse teritorii. In: Hidrologičeskije issledovanija v lesu, 1970: 79-93.

VORONKOV, N. A.: Hidrologičeskaja i meteorologičeskaja roľ lesnyh nasaždenij raznogo porodnogo sostava. Lesovedenije, 1976, č. 1: 3-10.

VORONKOV, N. A.: Roľ lesov v ochrane vod. Gidrometeorozdat, Leningrad, 1988: 286.

ZELENÝ, V.: Vliv porostní skladby na sněhovou pokrývku v lese. Věd. Práce Vých. Úst. melior. Zbraslav, 1966, sv. 8: 255-270.

ZELENÝ, V.: Intercepcie a horizontální srážky v Beskydech. Met. Zprávy, 20, 1967, č. 6: 154-157.

ZELENÝ, V.: Vliv hospodaření v lesích na vodní režim malých povodí. In: Nové směry v úpravách povodí. Ostrava, 1972: 31-57.

ZELENÝ, V.: Nástin výsledků 25letého lesnicko-vodohospodářského výzkumu v Beskydech. Lesnictví, 26, 1980, č. 8: 677-697.

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BĚLE, J. (Výzkumný ústav lesního hospodářství a myslivosti, Jiloviště-Strnady): *Vliv imisí na změny hydrické účinnosti lesů Krušných hor. Lesnictví-Forestry, 39, 1993 (2): 51-57.*

Dynamické změny, které prodělaly lesy a lesní porosty v Krušných horách v důsledku působení imisí, lze charakterizovat změnami porostní druhové skladby, věkové struktury, produkčních možností, ale také schop-

ností zabezpečovat účinky celospolečensky žádaných ostatních funkcí lesů.

V souvislosti s tím původní - převážně dřevoprodukční - funkce lesů ustoupila a její prioritní postavení zaujímají, i když přechodně, ostatní celospolečensky významné funkce lesů. V těchto podmínkách musí lesy plnit především funkce ochrany půdy před vodní (větrnou) erozí, zabezpečovat kvalitativní hydrické účinky pozitivně ovlivňující retenci a retardaci oběhu vody v lesních ekosystémech, zlepšování porostního mikroklimatu apod.

Základním úkolem v lesích imisních oblastí je proto zabezpečení možné a přijatelné formy lesního ekosystému, který zaručuje uplatnění společensky významných a žádaných ostatních funkcí lesů. Změnám, které prodělaly lesní ekosystémy v Krušných horách, a důsledkům, které se promítly do jejich hydrické účinnosti, jsme věnovali v posledních dvou desetiletích zvýšenou pozornost. Prováděli jsme zde dlouhodobá i ambulantní měření. Při syntézách řešeného problému jsme použili i využitelné výsledky výzkumu jiných autorů.

Procesy, které při takovéto imisní zátěži lesních ekosystémů proběhly, byly neobyčejně složité a komplikované, proběhly v omezených časových údobích, a proto je nebylo možné postihnout v plné šíři a variabilitě. Byly zjištěny především základní směry vývoje těchto procesů a zhodnoceny pro použití při dalším lesnickém hospodaření v těchto oblastech i s ohledem na zabezpečování jejich vodohospodářské funkce lesů.

Pro vyjádření hydrické účinnosti původních lesů, převážně smrkových, jsme vyšli z průměrných hodnot vodní bilance povodí, vyjádřené bilanční rovnicí  $S = O + ETR$ . Tyto hodnoty jsme získali analýzou 357 povodí v ČR. K jednotlivým výškovým stupňům zájmového území byly vypočteny průměrné roční hodnoty atmosférických srážek vertikálních a horizontálních, průměrný odtok a evapotranspirace. Z těchto údajů byly odvozeny průměrné hodnoty jednotlivých bilančních složek - intercepcie, transpirace a výparu z půdy a přizemní vegetace pro jednotlivé věkové stupně smrkových porostů. Tyto hodnoty sloužily k porovnání hydrických účinků náhradních porostů přizemní vegetace a porostů náhradních dřevin.

Došli jsme k závěrům, že se na plochách lesních porostů změnila hodnoty jednotlivých složek vodní bilance - intercepcie i transpirace včetně výparu z půdy a přizemní vegetace. Bylo negativně ovlivněno zachycování srážek z mlh nízké oblačnosti, což se projevilo na ukládání sněhu v zimním období i na jeho tání na rozsáhlých plochách.

Za nejkritičtější období je možné označit jak z lesnického, tak i vodohospodářského hlediska období, kdy v Krušných horách převládaly porosty přizemní vegetace, které pouze částečně nahradily hydrickou účinnost lesních porostů. Situace se zlepšila zalesněním oblasti porosty náhradních dřevin, i když účinnost těchto porostů je silně omezena jak druhovou skladbou, tak věkovou strukturou. Závěrem je třeba konstatovat, že základním cílem lesníků v těchto oblastech je pokud možno co nejrychlejší obnova lesů s porosty dřevin stanovištně odpovídajícími.

imise; porostní druhová skladba; věková struktura; produkční možnosti; ostatní funkce lesů

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# POLLUTANT FALL-OUT INTO FOREST ECOSYSTEMS AS RELATED TO CHANGES IN FOREST SOILS

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The paper presents the results of investigations of pollutant fall-out into forest ecosystems with precipitation water, especially as regards protons, sulphates, and nitrogen compounds which are characteristic indicators of polluted atmosphere in the Czech Republic and for damage to forest stands and their soils. The fall-out of pollutants into stands and water regime influence the motion of elements in the soil, as well. Therefore, attention was paid to their leaching from the humus horizon to the mineral profile. Furthermore, results of repeated analyses of soil samples are given from some long-term plots observed in characteristic air-polluted regions. The data set was obtained on research objects of the Forestry and Game Management Research Institute, Jiloviště-Strnady from 1973 to 1989. It can be stated that the pollutant fall-out load on forest ecosystems is rather variable under pollution conditions of the Czech Republic. The input of protons is dependent not only on the distance of plots from emission sources but also on total air pollution and exposure of plots to air flow. Conifers enrich with throughfall water more than broadleaves even when being foliated. The stem flow is contaminated essentially more. In the period of investigation of the chemistry of precipitation water, increase of its acidification was observed at the end of the seventies and at the beginning of the eighties. Felling of spruce trees in heavily loaded regions decreased the fall-out of elements. It was manifested that the dynamism of elements more pronouncedly than impacts of activation of soil biological processes. Leaching of biogenic elements increased on clear cut areas in less air-polluted regions. Nevertheless, grass ground vegetation was responsible for retention of nutrient flow particularly N compounds. Broadleaved stands acted on decrease in nitrate concentrations in soil water and lower Mg leaching from the soil. Decreases in the reserve of exchangeable cations Mg, Ca, and Mn were estimated on long-term observed plots. In oligotrophic, naturally acid soils of mountain forests, heavy acidification proceeded deeper which was associated with decrease in the supply of "accessible forms" of cations and Mn. Under strong acidification of mineral soil liberation of Al occurred and, according to soil properties, its deposition in deeper horizons or leaching was recorded. When felled spruce stands in air-polluted regions (the Krušné hory Mts.) decrease in the soil pH did not continue but the reserve of accessible forms of Mg and Ca did not increase in the mineral profile. The ground vegetation and broadleaved tree species positively influenced the cycle of elements and nutrient supply in the humus horizon. The results of investigations into deposition of pollutants and their effect on the development of soil properties of forest stands were compared with the data presented by authors from the Federal Republic of Germany. It can be said that these data are analogous to our findings. In some exposed regions of the Czech Republic, proton and sulphate load on forest ecosystems is higher. Soil properties and dynamism of elements in the soil affect the composition of water flowing to water resources.

pollutant fall-out; forest soils; spruce stands; precipitation water; acidification; protons; sulphates; nitrogen compounds

The present state of pollutant load is very disconsolate in the Czech Republic. These sub-

stances involve predominantly fall-out from polluted atmosphere. Long-term and heavy pollution impact is responsible for conspicuous damage to forest tree species and their stands in essential part of the Republic (ca. 60 % of forest area).

After acute damage to spruce stands and their dieback in the Krušné hory Mts., defoliation of spruce began to manifest itself on exposed sites of higher elevations throughout the northern part of the Czech Republic. In forests growing in less polluted atmosphere and less loaded with pollutant fall-out, symptoms of nutrient disorders are apparent in conifers. Therefore, in addition to the research on direct impact of toxic substances on leaf organs, still more attention has also been paid to the research on changes in soil environment and relation of soil chemistry to growth processes and to tree resistance to pollutants.

In the Czech Republic, atmospheric air pollution is characterized particularly by high concentrations of sulphur compounds and, closely to main emission sources with burning brown coal, also by those of fluorine and nitrogen. Precipitation exhibits high acidity throughout the territory of the country.

The aim of the present paper is to provide information about the results obtained at the Forestry and Game Management Research Institute in the research on fall-out of substances (biogens) into forest ecosystems with characteristic stand parameters under different conditions of air pollution. Furthermore, the present paper is aimed at characterization of the dynamism of elements in surface soil horizons and its relation to the state and development of soil chemistry in the forest ecosystems under study.

The results presented follow similar investigations conducted by researchers from other institutions of which it is necessary to mention the Institute of Forest Ecology of the Faculty of Forestry, University of Agriculture in Brno (K l i m o, 1992) at which analogous investigations have been realized as a part of the complex ecological research on spruce ecosystems in the surroundings of Brno, and furthermore, the research on the dynamism of elements in forest ecosystems of Western and Central Slovakia performed by co-workers from the Institute of Forest Ecology, Slovak Academy of Sciences in Zvolen (B u b l i n e c, 1985; B u b l i n e c, K u k l a, 1987).

From foreign resources, long-term research in the Federal Republic of Germany can be compared above all. It is necessary to mention the results obtained at the University of Göttingen (U l r i c h et al., 1981; U l r i c h, 1983), University of Munich (R e h f u e s s, 1983, 1990; K r e u t z e r, 1986; K r e u t z e r et al., 1991), Forest Research Institute of Baden-Württemberg in Freiburg (H i l d e b r a n d, 1986), Hessian Forest Research Centre Hann. Münden (B a l á z s, 1991; B r e c h t e l, 1990; G ä r t n e r, 1988). Limited data are available from forest research institutions in Saxony (F i e d l e r, 1989, 1990).

During the recent years, the study of deposition of substances in forest stands has been performed at numerous stations in Central Europe. The relation of precipitation chemistry to element dynamics in forest ecosystems and to the development of soil chemistry has been, however, investigated in less number of objects with regard to its more exacting character.

The research object in Solling belongs to the best known and oldest ones. Ulrich et al. (1981) reported the results of the long-term research conducted here concerning fall-out and dynamics of biogens in the stands of spruce and beech, and changes in their reserves in the soil and other components.

In the Czech Republic, Klimo, Kulhavý (1985) published the data for evaluation of the development of soil chemistry. Soil samples taken in the Beskydy Mountains in 1983 to 1984 exhibited pH decrease throughout the profile both in podzols and in brown forest soils, contrary to the samples taken on the same plots over the years 1952 to 1955.

Materna, Klimo (1990) reported the development of forest soil chemistry on experimental plots of the Lesprojekt in the Beskydy Mountains. In 1981 to 1986 percentual increase of the main nutrient content appeared in the covering humus as a result of enhanced mineralization but a decrease was manifested in Mg supply even in surface horizons of mineral soil (0 - 15). Significant decrease in the reserve of accessible cations (Mg, Ca, K) was apparent in the horizon B (zone 15 < 50 cm). Voško et al. (1990) evaluated acidic deposition as related to the health condition of the forests of the Slovak Republic.

It follows from the evaluation of the balance of pollutants that their deposition is a destabilizing factor of forest ecosystems (Ulrich, 1988; Matzner, Ulrich, 1990). The present level of proton deposition and deposition of substances with potential acidity ( $\text{NH}_4$ ) highly overreaches the possibilities of buffering by weathering of soil minerals in our country and in the substantial part of Europe (Fölster, 1985; Matzner, 1987).

In well-developed industrial regions, which our country also belongs to, this balance has been probably disturbed for decades already.

Proton exchange in the sorptive complex is responsible for impoverishment of cations Ca, Mg, K in more richly supplied soil and for mobilization of Al ions in little supplied soil. In the course of time, under long-term acidification, the buffering process of cation exchange may pass to Al mobilization process (Ulrich, 1983).

Starting from the fact that in the regions of higher pollution load (deposition of  $\text{H}^+$  and S), for example in Solling, the stands of spruce and beech are healthy and vital, and in those of lower deposition of S and N compounds, for example in the Alps and Tyrol, spruce defoliation occurs (Schmid et al., 1988; Rehfuess, 1990) concluded that other environmental conditions of the stands are also significant for spruce damage and dieback. For the symptoms of the so-called „new spruce disease“, which is manifested in yellowing and needle cast, sites of higher elevations with acid soils are characteristic. Zöttl et al. (1989) reported that site conditions and history of the stands exert the dominant effect on nutrient cycle and disease of spruce ecosystems in Schwarz-

wald. Different damage to spruce is apparent in little distant stands under the same depositions but on the soils developed from different parent rock. The highest differences between healthy and damaged trees are in the content of Mg and Ca in the leaves. The damaged trees are on poor podzolic soils with a low supply of exchangeable Mg (< 50  $\text{mg.kg}^{-1}$  of soil). As reported by Rehfuess (1990), a high content of exchangeable Al and  $\text{N/NH}_4$  may be an obstacle to the uptake of Mg and Ca by the roots because Al and  $\text{N/NH}_4$  disturb the uptake of both the cations.

Low molar Ca/Al and Mg/Al ratios in the soil solution, caused by leaching of cations and mobilization of Al, are a very important and discussed factor in the damage to tree roots.

A part of acid fall-out is buffered by ion exchange at interaction with the leaves (needles) (Ulrich, 1983). The protons received are transferred to the rhizosphere where they serve for the uptake of cations by the roots from the soil environment and for its acidification. Therefore, at the ion balance, in the root zone there is an excess of protons and soil acidification even below broadleaved species where the fall-out is lower.

The direct impact of pollutants on the leaf organs is, however, an important factor in forest damage (defoliation) under the conditions of air pollution in the Czech Republic.

## MATERIAL AND METHODS

### DESCRIPTION OF RESEARCH OBJECTS

Delimitation of the spheres of interest was conditioned by the character of air pollution and hydrological importance of the forests selected in the region. The basic data on the evaluated plots are given in Tab. I. The Krušné hory Mts., particularly their north-eastern part, are ranked among the most exposed regions with regard to spruce damage in the Czech Republic. Therefore, in 1978, an object for the research on fall-out of elements with precipitation, dynamics of elements in the soil and chemistry of the soil material was established on a newly arisen clear cut area and in heavy damaged adult spruce stand. In winter 1980/81, the stand was felled and the research continued on a reafforested clear cut area with rowan natural regeneration. Blue spruce (*Picea pungens* Engelm.) was planted in open spacing on a clear cut area arisen in 1977 so that the grass cover remained an edifier.

Plots for investigation of the effects of „substitute“ tree species, rowan and birch, were established simultaneously with a plot in a younger spruce stand near Nová Ves v Horách in 1984. In August 1988, application of relatively coarse-grained dolomitic limestone was performed throughout the region. The research plots served also for several-year study of soil biological activity and microclimatic research.

The Orlické hory Mountains are another region with increased fall-out. On the southern slope of Šerlich there are research plots on a reafforested clear cut area in spruce stands of the second and fifth age classes, in beech gap and in a young stand of spruce and rowan. The present paper shows the results obtained on the clear cut area and in adult spruce and beech stands.

In 1981 to 1984, the research on the chemistry of water flowing through the forest ecosystems was conducted on

## I. Characteristics of research plots

Number	Name of plot	Forest enterprise	Elevation above sea level	Composition of forest stand	Age in the year 1990
1	Černohorská cesta	Karlovice ve Slezsku	950	Norway spruce	85 <sup>xx</sup>
2	Červík	Ostravice			
	Catchment A		840	clear cut (Norway spruce)	1 <sup>xx</sup>
	Catchment B		980	Norway spruce	128 <sup>xx</sup>
3	Hrušková	Lesy Kladská	620	Norway spruce	100 <sup>x</sup>
4	Ješovice	Mělník	230	clear cut (Scotch pine)	7
				Scotch pine	61
				red oak	23
5	Kladská	Lesy Kladská	870	Norway spruce	80 <sup>x</sup>
6	Malá Ráztoka	Frenštát pod Radhoštěm	650	clear cut	
	Catchment		1015	beech	114 <sup>xx</sup>
7	Moldava	Litvínov	830	clear cut	
			830	Norway spruce felling 1981	95 <sup>x</sup>
8	Nová Ves	Janov	700	Norway spruce	28
			700	birch	30
			710	rowan	28
9	Pěnivý potok	Kašperské hory	1030	free plot	-
				Norway spruce	100
10	Sulice	Zbraslav	455	Norway spruce	88
				oak	88
11	Šabina	Kraslice	490	Norway spruce	80 <sup>x</sup>
12	Šerlich	Opočno pod Orlickými horami	950	clear cut (Norway spruce)	8
				Norway spruce	120
				beech	120
13	Zdíkov	Vimperk	835	Norway spruce	126
			880	beech	97
14	Želivka	Ledeč nad Sázavou	430	clear cut	-
				Norway spruce	86

<sup>x</sup> Age in the year 1979

<sup>xx</sup> Age in the year 1984

catchments in the Moravian-Silesian Beskydy Mountains: on the catchment of Malá Ráztoka on a clear cut area, in the vale of the catchment, and in adult stand of the top part, on the Červík catchment A on reforested clear cut areas in the upper part of the catchment and in the measuring weir. Likewise, on the Červík catchment B measurements were conducted in spruce stands of the top part, at the catchment boundary, and in the valley part. In summer 1983, amelioration was performed with dolomitic limestone on the Malá Ráztoka catchment.

In the Šumava Mts., the plots of Zdíkov are situated at the lower boundary of the catchment U lizu. They are located to adult stands of spruce and beech without traces of conspicuous harmful effect of pollutants on leaf organs.

In the forest of lower altitudinal zones, in immediate vicinity of the dam reservoir Želivka, the catchment of the Pekelský potok (Želivka) is situated in which several subcompartments were established in 1973. The present paper evaluates the results obtained in an older spruce stand on a clear cut area. The catchment is intended for the research on the hydrological role of the forest.

Other research plots were established in adult stands of spruce and beech in an upland region near Sulice south-easterly of Prague. The plots mentioned are situated 100 m from the margin of the forest complex in the vicinity of agricultural plots. The research on water chemistry was conducted on these plots in addition to hydro-ecological research in the years 1988 to 1990.

The plots in the stands near Ješovice are heavily polluted at a distance of 3 km from the Mělník power station. In 1986 to 1990, investigations were conducted in two stands of pine, in a younger stand of red oak, and on clear cut area. Repeated aerial fertilizations with ammonium nitrate and limestone were carried out in these forests (1980, 1984, 1987).

In the present study, partial results were also used obtained on other research plots of the Forestry and Game Management Research Institute in the Slavkovský les and the Jeseníky Mountains from a heavily damaged stand at Hrušková and from undamaged spruce stand at Kladská. From the Jeseníky Mountains, the results of soil analyses are reported from a spruce stand on the Černohorská cesta plot.

An equipment for precipitation intake was installed on research plots - troughs of artificial material (novodur). The stem flow was measured in broadleaved stands at higher elevations. To retain gravitation water, lysimeters of the type Šilová were placed below the top humus horizon and into mineral soil below genetic soil horizons. Ceramic pieces were fitted in the depth of 100 cm to suck soil capillary water. Water samples were summarized for approximately a month's period. At the same time, the chemism of water was estimated in water resources in the vicinity of the research plots under investigation. Vessels of artificial material (PVC) were used for the intake and examination of water.

When all plots under study were established, soil and humus samples were taken for laboratory estimation of bioelement supplies. Repeated samplings were performed at the end of measurements or, in long-term investigations, periodically after several years.

#### SOIL AND WATER ANALYSES

Up to the year 1983, the compounds of N ( $\text{NO}_3^-$  and  $\text{NH}_4^+$ ) were determined by chemical analyses of water samples according to standardized procedures (Hofmann et al., 1965) in the laboratory of the Forest and Game Management Research Institute. From 1985, colorimetric determination methods were used on an apparatus Technicon, Autoanalyzer II (Industrial methods No. 186-75 E and No. 329/74 W B).

The total carbon content ( $C_{\text{ox}}$ ) was determined by wet combustion using chromosulphuric acid, chlorides, and fluorides by means of CRYTUR selective electrodes, phosphates were determined colorimetrically using molybdensulphuric acid. Sulphates were determined gravimetrically and, from 1985, also by means of Technicon, Autoanalyzer II (Industrial method No. 118-71 W). Dissolved cations, including metal, were identified using atomic spectrophotometers Varian Techtron AA-5 and AA-1273. Water analyses from the Beskydy Mts. catchments were carried out in the laboratory of Povodi Odry in Ostrava.

When analyzing soil samples, the total content of organic carbon ( $C_{\text{ox}}$ ) and total nitrogen ( $N_t$ ) were determined by wet combustion and by the Kjeldahl method, respectively. Accessible nutrients in 1% citric acid were estimated using analogous methods to those in water samples. The total content of elements in humus was determined after its mineralization.

### RESULTS

#### FALL-OUT OF POLLUTANTS WITH PRECIPITATION

The highest fall-out of pollutants with subcrown precipitation was found in mountain spruce stands in clearly air-polluted regions with symptoms of acute damage to the leaf organs, such as in the Krušné hory, Orlické hory, Beskydy, and Jeseníky Mts.

The maximum pollutant fall-out with throughfall precipitation was found on the margin of spruce stand in the top part of the Červík catchment B in the Beskydy Mountains over the years 1981 to 1983 (Tab. II).

The lowest pH values of precipitation water were also measured on other long-term plots in this period. In 1978 to 1980, the total annual sum of protons, cations, and ani-

ons exceeded the amount of these ions in throughfall water intercepted below the heavily damaged spruce stand at Moldava in the Krušné hory Mts., i. e. in the region generally considered to be „the dirtiest“ part of the Czech Republic.

Intensive air pollution of this region of the Krušné hory Mts. is indicated by high annual sum of  $\text{S}/\text{SO}_4^{2-}$  fall-out with precipitation and mean annual  $\text{SO}_2$  concentrations attaining the value of about  $100 \mu\text{g}\cdot\text{m}^{-3}$ . The priority in the intensity of air pollution in the east Krušné hory Mts. at the end of the eighties, as well, was confirmed by a high fall-out of  $\text{H}^+$  ions,  $\text{SO}_4^{2-}$ , and  $\text{NH}_4^+$  with precipitation in the young heavily damaged spruce stand on the plot near Nová Ves v Horách although, in accordance with the results of investigations on the clear cut area near Moldava, fall-out of protons and sulphates was slightly reduced in this period.

At the end of the eighties, a lower fall-out of H ions was found in precipitation below the adult spruce stand on the slope od Šerlich in the Orlické hory Mountains compared to the adult stand at Moldava in the period of 1978 - 1980. Nevertheless, it overreached the fall-out determined in the young spruce stand at Nová Ves for the same period. Other ions exhibited lower fall-out than in the spruce stands of the Krušné hory Mts.

In the Šumava Mts., there were different pollution conditions: it is indicated by the results of investigations of fall-out in the stands on the Zdíkov plots (U lizu catchment) where essentially lower fall-out of protons and other substances was in the spruce stand, although the fact should be considered that no fall-out with precipitation was involved in the sum during the winter months (January to March).

The ecosystems of broadleaved forests exhibited substantially lower pollution load from throughfall precipitation. The results obtained in the beech stand on Mt. Noří in the upper part of the Malá Ráztoka catchment, thus on the locality strongly exposed to air flow, indicate that precipitation brought considerably less protons, anions, and cations to the soil than the throughfall water below spruce crowns on the Červík catchment B. The stem flow exhibited higher contamination which attained up to 30% volume of the sum of subcrown precipitation at these mountain elevations.

Analogously, on Šerlich localities, the fall-out in throughfall water was lower below beech than that below spruce. The same conditions were found in the spruce and beech stands at Zdíkov (the data in Tab. II express the values of the second half of 1989).

The results obtained in younger stands of rowan and birch near Nová Ves v Horách are available from the Krušné hory Mts. Open crowns of substitute tree species intercepted less amount of pollutants than in spruce. Likewise, here, stem flow precipitation played an important role in pollutant load on soils.

The pollutant load on forest ecosystems through precipitation in an upland region with slight air pollution is indicated by the results from the plots of Želivka (Pekelský potok catchment) and Sulice.

On the Pekelský potok catchment, the evaluation of precipitation chemism on a free plot and below spruce stand was enabled by long-term observations. In the period of the years 1980 to 1983, the highest  $\text{H}^+$  ion concentrations manifested themselves on both the plots in time sequence. The level of  $\text{S}/\text{SO}_4^{2-}$  fall-out remained ap-

II. Input of ions in forest ecosystems with precipitation and into the soil from humus horizons with gravitational water (kval.ha<sup>-1</sup>.a<sup>-1</sup>)

Plots	Period of years	kval.ha <sup>-1</sup> .a <sup>-1</sup>					kg.ha <sup>-1</sup> .a <sup>-1</sup>	
		H	NO <sub>3</sub> <sup>-</sup> , F <sup>-</sup> , Cl <sup>-</sup> , SO <sub>4</sub> <sup>2-</sup>	Na <sup>+</sup> , K <sup>+</sup> , Mg <sup>2+</sup> , Ca <sup>2+</sup>	NH <sub>4</sub> <sup>+</sup>	Al	N/NO <sub>3</sub> <sup>+</sup> NH <sub>4</sub>	S/SO <sub>4</sub>
<i>Želivka</i>								
Cut area	1973 - 79	0.52	1.36	1.32	0.33		8.61	13.0
Precipitation	1980 - 83	1.46	1.46	1.77	0.27		8.4	11.7
	1984 - 89	0.36	1.90	1.65	0.50		14.5	12.7
Soil water	1973 - 79	0.21	2.15	3.34	0.48	0.33	13.7	
	1980 - 83	0.34	1.88	3.08	0.35	0.21	9.00	
	1984 - 89	0.18	1.85	2.36	0.15	0.26	4.0	
Norway spruce stand	1973 - 79	0.70	4.52	3.46	0.57		13.6	62.1
Throughfall w.	1980 - 83	1.63	5.25	3.78	0.63		15.7	69.4
	1984 - 89	0.92	5.33	3.05	1.18		28.6	65.1
Soil water	1973 - 79	0.29	3.40	3.65	0.43	0.26	13.1	
	1980 - 83	0.67	3.36	3.40	0.29	0.28	8.4	
	1984 - 89	0.50	4.19	5.01	0.40	0.45	12.3	
<i>Moldava</i>								
Cut area	1978 - 80	0.72	2.73	3.00	0.78		17.5	28.0
Precipitation	1978 - 83	1.56	3.79	3.23	0.71		16.0	40.1
	1984 - 89	0.47	3.08	2.55	0.76		19.6	27.0
Soil water	1978 - 79	2.00	2.68	2.17	0.45	0.60	9.6	
	1981 - 83	2.54	2.30	1.53	0.28	0.31	5.7	
	1984 - 89	0.86	2.00	1.13	0.26	0.35	5.2	
Norway spruce stand	1979 - 80	5.04	9.62	5.67	1.56		38.1	131.5
Throughfall w.								
Cutting in winter 1980/81								
Cut area	1981 - 83	1.58	3.54	3.76	0.60		15.9	36.1
New growth of rowan	1984 - 89	0.63	3.84	2.24	1.03		23.2	40.4
Precipitation								
Soil water	1978 - 79	2.01	8.23	3.46	1.11	1.03	25.5	
	1981 - 83	1.69	2.49	1.57	0.48	0.35	16.0	
<i>Šabina</i>								
Norway spruce								
Throughfall w.	1979	0.94	6.00	6.25	0.32		17.3	77.1
Soil water	1978 - 79	0.19	4.08	3.59	0.31	0.72		
<i>Nová Ves</i>								
Cut area	1988 - 89	0.23	3.92	2.55	1.56		29.0	41.4
Precipitation								
Norway spruce stand								
Throughfall w.	1984 - 89	1.42	9.14	4.53	2.21		44.0	116.2
Soil water	1984 - 89	0.78	5.03	2.32	0.81	1.18	30.3	
Birch stand								
Throughfall w.	1984 - 89	0.37	5.09	3.45	1.15		25.8	57.8
Stem flow	1985 - 89	0.098	0.23	0.13	0.06		1.32	13.0
Soil water	1984 - 89	0.53	2.79	1.29	0.32	0.65	8.43	
Mountain ash (rowan)								
Throughfall w.	1984 - 89	0.66	7.04	4.61	1.24		27.2	86.1
Stem flow	1985 - 89	0.122	0.65	0.41	0.09		1.96	22.0
Soil water	1984 - 89	0.70	5.18	3.19	0.42	1.00	6.83	
<i>Šerlich</i>								
Cut area precipitation	1988 - 89	0.43	2.78	1.33	0.95		21.8	18.7
Soil water	1987 - 89	0.65	3.45	2.60	0.59	0.39	18.0	
Norway spruce stand								
Throughfall w.	1988 - 89	1.90	6.27	2.18	1.48		35.4	69.1
Soil water	1988 - 89	2.54	7.40	2.49	1.86	0.73	58.3	
Beech stand								
Throughfall w.	1988 - 89	0.42	3.07	1.19	0.68		15.0	24.7
Soil water	1988 - 89	1.24	3.60	1.29	0.55	0.43	27.4	

Plots	Period of years	kval.ha <sup>-1</sup> .a <sup>-1</sup>					kg.ha <sup>-1</sup> .a <sup>-1</sup>	
		H	NO <sub>3</sub> <sup>-</sup> , F <sup>-</sup> , Cl <sup>-</sup> , SO <sub>4</sub> <sup>2-</sup>	Na <sup>+</sup> , K <sup>+</sup> , Mg <sup>2+</sup> , Ca <sup>2+</sup>	NH <sub>4</sub> <sup>+</sup>	Al	N/NO <sub>3</sub> <sup>+</sup> + NH <sub>4</sub>	S/SO <sub>4</sub>
<i>Salice</i>								
Free plot	1989	0.073	1.59	1.45	0.71		14.5	14.4
Norway spruce stand								
Throughfall w.	1989	0.32	4.24	2.16	1.41		27.2	48.1
Soil water	1989	0.17	3.66	2.61	0.53	0.25	20.2	
Oak stand								
Throughfall w.	1989	0.13	3.23	2.70	0.61		13.8	
Soil water	1989	0.032	5.75	6.41	1.04	0.14	47.9	
<i>Ješovice</i>								
Cut area	1986	0.18	4.36	2.15	1.07		28.2	37.0
Precipitation	1988 - 89	0.15	2.39	1.94	0.46		12.1	18.0
Soil water	1986	0.012	0.87	0.97	0.19	0.16	4.58	
	1988 - 89	0.0075	0.97	1.15	0.07	0.09	2.82	
Scotch pine stand								
Throughfall w.	1986	0.18	3.60	1.93	0.95		21.6	37.0
Soil water	1986	0.042	2.49	1.33	0.90	0.33	16.9	
	1988 - 89	0.136	5.38	3.88	1.50	0.61	39.6	
Red oak stand								
Throughfall w.	1986	0.12	2.63	1.74	0.66		15.7	26.4
	1988 - 89	0.094	2.14	1.64	0.49		13.0	20.4
Soil water	1986	0.10	3.17	2.31	0.93	0.67	18.8	
	1988 - 89	0.16	4.13	2.51	0.48	0.36	12.3	
<i>Maldá Ráztoka</i>								
Cut area								
Precipitation	1981 - 83	0.42	4.67	4.81	0.74		19.1	28.4
Beech stand								
Throughfall w.	1981 - 83	0.86	5.90	4.54	0.97		24.0	55.7
Stem flow	1981 - 83	1.01	2.94	2.44	0.08		17.7	33.0
<i>Cervík</i>								
Watershed A								
Cut area								
Precipitation	1981 - 83	2.20	6.45	6.03	0.44		13.5	36.7
Watershed B								
Norway spruce stand								
Throughfall w.	1981 - 83	8.79	11.05	6.92	0.96		32.1	80.45
Stem flow	1981 - 83	0.25	0.42	0.32				
<i>Hrušková</i>								
Norway spruce stand								
Soil water	1978 - 79	0.53	5.97	4.31	0.32	1.42	37.9	
<i>Kladská</i>								
Norway spruce stand								
Soil water	1978 - 79	1.04	2.13	1.44	0.28	0.27	48.1	
<i>Zátkov</i>								
Norway spruce stand								
Throughfall w.	1987 - 89	0.30	1.43	0.82	0.29		7.2	14.7
Soil water	1988	0.86	3.03	1.90	0.34	0.32		
Beech stand								
Throughfall w.	1989	0.043	0.81	0.64	0.31		7.0	7.0
Stem flow	1989	0.038	0.58	0.40	0.25		4.9	6.0
Soil water	1989	0.056	2.38	1.80	0.75	0.13	27.4	
<i>Pěvný potok</i>								
Precipitation	1988 - 89	0.066	1.07	1.39	1.05	0.77	15.6	9.7

proximately the same during the period under study but that of nitrogen compounds ( $\text{NO}_3^-$  and  $\text{NH}_4^+$ ) was enhanced during the recent years. During the comparable period of the years 1984 to 1989, the pollutant load on spruce stands was lower on this plot than that on the spruce stand plots in mountain regions of the Krušné hory and Orlické hory Mountains. Nevertheless, the fall-out of protons, ammonium ions, and sulphates into spruce stand was lower in the Šumava Mts. on the Zdíkov plot.

A lower fall-out of protons, anions, and cations manifested itself in the spruce stand at Sulice than that in the spruce stand on the Želivka. The load of N ( $\text{NO}_3^- + \text{NH}_4^+$ ) on ecosystems was approximately the same.

Precipitation contained lower amount of dissolved anions of strong acids and H ions below the oak stand as well as below other deciduous trees in comparison with subcrown precipitation in spruce. Nevertheless, the valency sum of cations was higher. The fall-out of sulphates and other substances with precipitation intercepted on free area indicates that the atmosphere and precipitation in stands near agricultural land of this region (south-eastern surroundings of Prague) was rather considerably polluted both with  $\text{SO}_4^{2-}$  and solid fall-out.

Characteristic pollution conditions were found in the forest stands at Ješovice. The impact of emissions of the Mělník power station and low precipitation sums determine the pollutant fall-out measured in precipitation on clear cut areas below the stands of pine, and those of red oak. Strong contamination of the precipitation measuring equipment with „dry fall-out“ on the clear cut area reduced the difference as compared to the values measured below the stands. Increase in the fall-out of anions, including  $\text{SO}_4^{2-}$ , was inexpressive below the pine crowns. In the red oak stand, leaves caused higher increase in cations (K, Mg, Ca) than pine needles, likewise at Sulice, oak crowns as compared to spruce crowns.

#### LEACHING OF ELEMENTS FROM THE HUMUS HORIZON WITH GRAVITATION WATER

To evaluate the total fall-out of pollutants to forest ecosystems, intensity of soil biological activity, and mineral soil profile load, the results of research on the chemism of water intercepted below the top humus horizon ( $A_0$ ) were also used.

The leaching of elements with water percolating the humus horizon and soil has been observed on the Moldava plots as early as since 1978. At that time, intensive enrichment of gravitation water with protons took place on newly originated clear cut area in humus with grass vegetation so that their transport to the mineral soil attained the values estimated in the water below the humus horizon in the heavily damaged stand although their fall-out with precipitation was essentially lower. To the contrary, this horizon separated cations and nitrogen compounds (Tab. II). In the course of experimental years, the leaching of ions to the soil profile decreased.

The humus horizon below the damaged spruce stand caused that less  $\text{H}^+$  ions and other cations and anions flowed away to the mineral soil with gravitation water than came with subcrown precipitation. Nevertheless, the values obtained on the clear cut area were exceeded. After cutting the stand in winter 1980 - 81, a decrease appeared in the fall-out of pollutants which was just manifested in reduction of their transport from the humus horizon to

the soil profile. Similar trends in retention of biogens in the humus horizon were observed in the spruce stand at Nová Ves, as well.

On the plots of Šerlich and Zdíkov, the humus horizon was responsible for conspicuous increase in the concentrations of ions in percolating water and thus their leaching. Analogous effect on element dynamism was exerted by the humus horizon on both the plots in beech stands. It should be considered, however, that the input of substances entering with stem flow was not determined on Šerlich.

In the stands of rowan and birch at Nová Ves v Horách, the humus horizon with herb layer caused, due to considerable water consumption, a decrease in element flow with gravitation water, contrary to precipitation, although concentrations of the observed substances increased in gravitation water.

The results of long-term investigations of gravitation water collected with lysimeters placed below the humus horizon on the Želivka plots indicate that after cutting the spruce stand, the bioelements released to percolating water to a higher extent on the clear cut area as a manifestation of the development of soil biological activity. Consumption of H ions took place at this process. During the existence of clear cut area with prevailing grass vegetation, enrichment of gravitation water decreased, especially for N and P compounds, the valency value of cations predominating over that of anions of strong acids.

On the contrary, in the humus horizon below the spruce stand, decrease in the motion of nearly all anions and cations occurred with gravitation water as compared to their fall-out with precipitation. With regard to the increase in anions and decrease in cations in precipitation, during the recent years, the valency value of anions has predominated over cations even in the gravitation soil water flowing away from the humus horizon.

The same humus horizon in the spruce stand at Sulice exerted its influence on the retention of protons and anions coming with precipitation and on the increase of cation concentrations in the flowing water.

Separation of protons proceeded also in the humus horizon in oak stand but the concentrations of anions and particularly cations increased essentially. It caused that in the gravitation water intercepted below this horizon, the valency value of cations (Na, K, Mg, Ca) predominated over the value of anions of strong acids. Continuous litterfall decomposition was responsible for increase in nitrogen compound concentrations, as well.

In the air polluted region of Ješovice on the reafforested clear cut area, the humus horizon retained essential portion of substances transported with contaminated precipitation. Retention of H ions and nitrogen compounds was conspicuous. The valency value of cations predominated in gravitation water.

In the pine stand, prior to fertilization with ammonium nitrate and limestone (1986), the humus horizon was responsible for retention of biogens entering with precipitation. In the period after aerial application of the nitrate (1988 - 1989), enhanced dynamism of ions was still manifested, and more N was leached from the humus horizon than its „wet fall-out“ contained with precipitation.

In the stand of red oak, enrichment of percolating water with the observed elements took place before and after fertilization and nitrogen dynamism did not increase. It can be stated that leaching of protons from the

forest floor to the mineral soil profile was relatively low in the stands under investigation, as well as on other plots at lower elevation. Likewise, the stand soils at Sulice were an example of it.

For a comparison, the results of investigations of ion motion with gravitation water obtained in the spruce stands on the Slavkovský les plots in the latter half of the seventies are shown in Tab. II. Anions and cations were leached intensively from the humus horizon by water on the strongly polluted plot of Hrušková, near the Tisová power station, in comparison with their transport on the plot Kladská in the highest, relatively pure, southern part of the Slavkovský les. Nevertheless, intensive pollution load on spruce forest at Hrušková did not cause so high soil loading with protons as long-distance pollutant transport and higher precipitation in spruce at Kladská where increased enrichment of gravitation water with nitrogen ( $\text{NO}_3^-$ ) compounds proceeded, as well.

#### DEVELOPMENT OF SOIL CHEMICAL PROPERTIES

When evaluating the fall-out of pollutants into forest ecosystems and their dynamism in the organic horizon, the state and development of its chemism can be confronted, predominantly the supply of main biogenic elements and pH. Tab. III presents their reserves determined by soil extraction by 1 % citric acid.

The development of soil chemism on the Moldava plots represents the situation in the Krušné hory Mts. During the years 1977 to 1988, it was shown that after stand cutting and reduction of proton fall-out, no decrease appeared in pH values through the supply of accessible cations continued decreasing, particularly in Mg and Mn.

At Nová Ves v Horách, the data on soil samples taken at the establishment of the plots have been available for the time being. The accessible nutrient supply in the mineral soil profiles exhibited no essential differences. In Ca and  $\text{PO}_4^{2-}$  it was found to be the highest below spruce. The lowest pH was determined in surface horizons below rowan. Mn was present in the mineral soil only in ppm units. The soils in the Krušné hory Mts. are characterized by a high presence of extractable Al in the lower part of B horizon.

Likewise, on the Šerlich plots, the soils below stands were strongly acidic in surface horizons ( $\text{pH/KCl} < 2.6 - 2.8$ ) like in the Krušné hory Mts. These soils were relatively poor in „accessible“ Mg, K, Ca, especially in B horizon, and relatively rich in  $\text{PO}_4^{2-}$  and Mn. To evaluate the process of degradation in the past years, analyses of soil samples were available carried out in 1959. They show that as early as thirty years ago the soil horizons were acidic here but in the course of years, acidification proceeded more deeply to the profile and K and Ca supplies were reduced. Decrease in nutrient supply was more remarkable in deeper horizons. There was no essential difference between the soil chemism below spruce and beech.

On the contrary, at Zdikov, the soil analyses indicate that the surface part of the soil profile was less acidic below beech and there were more K, Mg, Ca, and Mn cations in the humus horizon and mineral soil than below spruce where only traces of accessible Mn were found in surface horizons.

The development of chemism on the Želivka plots can be evaluated on the basis of the analyses of samples taken over the years 1972 to 1988. Up to the year 1983, both

the plots compared showed a trend of pH decrease ( $\text{H}_2\text{O}$  and KCl) while in the next years, pH decrease was observed only in water extract. In surface horizons, however, the supply of accessible Mg, Ca, Mn still decreased with indication of their shift into deeper parts of the soil profile. The decreasing trend of  $\text{PO}_4^{2-}$  supply was alternated with an increase in 1983 and on.

From the Sulice plots the data from the period of their establishment were available. Lower soil load of protons manifested itself in higher pH ( $\text{pH/KCl} > 3.1$ ) and in high bioelement supply in the humus horizon. Distribution of accessible nutrient supply in the mineral soil was equal and, with regard to the present conditions in the Czech Republic, good. In the oak stand, Ca, Mg, and K content was even higher in the humus material than in the humus below spruce. The mineral soil of oak stand exhibited higher pH in addition to higher supply of cations and Mn.

The climatic and pollution conditions on the Ješovice plots were responsible for lower leaching of H ions in the soil. Under repeated ammonium nitrate and limestone fertilizations, the content of Ca, Mg, and K was relatively high in the humus horizon but this material remained acidic. The soil samplings of the years 1985 to 1991 indicated pH increase for the period under investigation, predominantly in surface horizons. Ca supply in the mineral soil remained on the same level, in Mg and K a decrease was recorded throughout the profile, likewise a shift of Mn from humus-rich horizons to the soil underground.

The maxima of Ca and Mg were, consequently, in the forest floor, as well as in horizons enriched with clayey particles and  $\text{CaCO}_3$  concretions.

#### DISCUSSION

To compare the results of our investigations of the fall-out of elements into forest ecosystems with the possibility of evaluating their impact on the development of forest soil chemism, objects have been established with long-term data collection. The results obtained on some research objects in the Czech Republic and predominantly extensive materials presented by the authors and institutions of the Federal Republic of Germany are of good use for these purposes.

A well-arranged elaboration of pollutant depositions is presented in DVWK Mitteilungen Nr. 14 (F ü h r e r et al., 1988). The sources from various authors of the seventies up to the year 1986 were concentrated and evaluated in it. In view of variable climatic and pollution conditions in the countries of the former FRG, the pollutant depositions were very variable, too.

The annual fall-out of H ions (protons) on free area varied from 0.06  $\text{kval.ha}^{-1}$  (Niedersachsen) to 1.4  $\text{kval.ha}^{-1}$  in the industrial region of Nordrhein-Westfalen. The lower limit of the value range is very close to the data from the catchment of the Pěnivý potok in the Šumava Mts. and the station at Sulice. However, the maximum value of proton fall-out reported in the FRG was exceeded on pollution-affected clear cut areas of exposed mountain regions (Červík catchment, Moldava).

A high  $\text{S/SO}_4$  fall-out was estimated on the former east frontier of the FRG and the highest annual  $\text{S/SO}_4$  fall-out in general ( $39.4 \text{ kg.ha}^{-1}$ ) was determined in the federal country Nordrhein-Westfalen. In the neighbouring Bavaria, the sulphur fall-out with precipitation water

## III. Soil acidity and reserve of elements extracted with 1 % citric acid

Plot and depth of profile (cm)	Sampling year	pH		ppm					
		H <sub>2</sub> O	KCl	Na	K	Mg	Ca	PO <sub>4</sub> <sup>3-</sup>	Mn
<i>Moldava</i>									
Spruce stand cutting 1981									
Ao <sub>3</sub> (H)	1977	3.2	2.5		121	70	561	241	10
	1988	3.2	3.1	34	112	28	185	129	1
0 - 8	1977	3.2	2.3		34	22	126	214	10
0 - 10	1988	3.4	2.6	8	26	6	298	285	1
8 - 15	1977	3.3	2.5		51	23	113	124	20
10 - 20	1988	3.4	2.7	12	22	8	123	245	1
15 - 35	1977	3.9	3.5		21	13	62	338	20
20 - 30	1988	4.0	3.5	15	20	8	66	248	1
35 - 70	1977	4.2	4.1		22	9	45	338	10
30 - 60	1988	4.5	4.2	12	12	2	27	181	15
<i>Šerlich</i>									
Spruce stand									
Ao <sub>3</sub> (H)	1959	3.6	2.4		136	18	442	245	
	1986	3.1	2.5	22	121	66	511	282	17
0 - 10	1959	3.8	2.7		90	6	85	676	
	1986	3.3	2.6	6	37	24	58	872	42
20 - 30	1959	4.3	3.8		49	6	139	311	
	1986	4.1	3.7	5	29	20	55	209	263
30 - 45	1959	4.7	4.2		40	19	348	686	
	1986	4.3	4.0	5	20	16	94	322	104
80 - 90	1959	4.8	4.2		43	45	65	1247	
	1986	4.5	4.1	3	20	11	576	1811	108
<i>Černohorská cesta</i>									
Spruce stand									
0 - 10	1982	4.0	3.6	19	53	50	175	218	406
	1987	3.7	3.1	29	50	37	88	138	8
10 - 30	1982	4.4	3.8	16	34	19	115	134	506
	1987	4.2	3.7	23	14	17	64	135	9
30 - 65	1982	4.5	4.1	18	33	13	95	120	263
	1987	4.6	4.2	29	19	7	84	120	16
<i>Želivka</i>									
Spruce stand									
Ao <sub>3</sub> (H)	1980	3.9	3.1	22	315	98	1001	187	1575
	1988	3.8	3.0	15	154	110	1008	202	81
0 - 5	1974	3.9	3.8		68	76	170		
0 - 10	1983	3.8	3.1	20	31	30	88	17	40
0 - 4	1988	3.7	3.2	11	32	35	83	20	10
5 - 20	1972	4.6	4.5		50	96	222	4	
10 - 20	1983	4.2	3.5	18	32	21	73	13	158
4 - 20	1988	4.0	3.5	14	27	39	35	28	50
20 - 40	1972	5.1	4.4		74	91	320		
	1983	4.5	3.5	19	34	71	199	13	173
	1988	4.4	3.7	8	35	45	117	17	234
40 - 70	1972	5.4	4.4		49	136	383		
	1983	4.9	3.7	25	24	102	418	6	61
	1988	4.7	3.8	18	29	142	511	16	42

Plot and depth of profile (cm)	Sampling year	pH		ppm					
		H <sub>2</sub> O	KCl	Na	K	Mg	Ca	PO <sub>4</sub> <sup>3-</sup>	Mn
<i>Kladská</i>									
Spruce stand									
Ao <sub>3</sub> (H)	1974	3.5	3.1	24	156	105	380		56
	1981	3.2	2.5	22	174	116	426	490	60
	1989	3.8	3.2	49	105	71	256	457	28
0 - 7	1974	3.7	3.6		80	13	74	382	
0 - 8	1981	3.5	2.8	11	86	16	115	358	69
	1989	3.7	3.2	18	42		96	576	14
7 - 30	1974	4.5	4.4		63	19	149	1381	
8 - 20	1981	4.2	3.6	11	44	31	170	557	181
	1989	4.1	3.6	8	59	57	75	331	64
20 - 30	1981	4.4	4.0	10	26	14	230	691	63
	1989	4.4	4.4	17	26	15	164	491	44
30 - 50	1974	4.8	4.7		27	13	182	936	
30 - 40	1981	4.5	4.1	13	19	10	345	646	40
	1989	4.7	4.4	9	31	11	218	521	32
<i>Pěňvívý potok</i>									
Spruce stand									
Ao <sub>3</sub> (H)	1986	3.2	2.7	17	127	101	400	203	11
0 - 5	1986	3.5	3.0	11	43	67	110	95	3
5 - 20	1986	3.9	3.8	8	9	10	24	40	3
20 - 30	1986	4.4	4.2	9	8	2	40	37	7
30 - 40	1986	4.5	4.2	7	6	1	22	21	3
40 - 50	1986	4.5	4.2	7	13	3	40	21	3
<i>Sulice</i>									
Spruce stand									
Ao <sub>3</sub> (H)	1988	3.8	3.1	19	255	95	1009	282	288
0 - 8	1988	3.7	3.1	12	57	57	166	200	
8 - 20	1988	4.1	3.4	8	49	37	162	80	30
20 - 30	1988	4.2	3.5	9	38	14	149	150	52
30 - 40	1988	4.3	3.5	7	49	26	220	181	64
40 - 50	1988	4.6	3.5	14	46	33	388	190	87
Oak stand									
0 - 10	1988	4.6	3.6	19	89	53	464	101	189
10 - 20	1988	4.6	3.5	28	41	46	303	52	137
20 - 30	1988	4.9	3.4	30	24	85	570	37	110
30 - 40	1988	5.1	3.5	25	27	106	756	34	99
40 - 50	1988	5.4	3.7	11	31	112	875	101	15
<i>Zdíkov</i>									
Spruce stand									
0 - 5	1986	3.4	2.7	8	33	25	59	61	2.5
5 - 10	1986	3.6	2.9	9	26	23	43	40	2.5
10 - 25	1986	4.1	3.6	5	20	13	36	18	2.5
25 - 45	1986	4.4	4.2	5	17	8	36	31	2.5
Beech stand									
0 - 2	1989	4.3	3.7	16	127	75	329	123	230
2 - 10	1989	4.3	3.8	12	64	44	136	101	87
10 - 20	1989	4.5	4.3	17	23	15	55	74	54
20 - 40	1989	4.6	4.0	9	15	16	54	43	42
40 - 55	1989	4.7	4.3	21	29	19	66	49	111

ranged from 11.6 to 26.9  $\text{kval}\cdot\text{ha}^{-1}$ . In our country, a lower sulphur deposition was found only in the Šumava Mts. on the Pěňivý potok. In more intensively polluted regions, the  $\text{S}/\text{SO}_4$  fall-out values exceeded the data from Bavaria, and at Moldava they attained the maximum reported in the FRG.

The highest ammonium nitrogen fall-out was at the stations in mid-mountains exposed to winds from the Ruhrgebiet, in regions of intensive breeding of cattle, and in Berlin. The maximum annual deposition of inorganic N ( $\text{N}/\text{NO}_3 + \text{NH}_4$ ) was reported 25.7  $\text{kg}\cdot\text{ha}^{-1}$  in the FRG. In the Czech Republic, these values were exceeded in the vicinity of emission sources. At Nová Ves and Ješovice, the total fall-out of both the inorganic forms of N amounted to 29.0  $\text{kg}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$  and 28.2  $\text{kg}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$ , respectively.

Below older closed spruce stands, the proton fall-out entering with subcrown precipitation was the highest and ranged from 0.25 to 3.8  $\text{kval}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$  in the FRG. Excess of the maximum value mentioned from the stand of Nordrhein-Westfalen was reported on our plots of Moldava in the years 1978 to 1980 and in precipitation intercepted below marginal spruces in the top part of the Červík B catchment in the years 1981 to 1983. In this period, culmination of subcrown precipitation acidity was found in the spruce stand in Solling (Meiwes, König, 1986).

The highest inputs of sulphates ( $\text{S}/\text{SO}_4$ ) were reported also in the spruce stand in Solling - 85.3  $\text{kg}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$ , in mountain regions in Nordrhein-Westfalen - 155.1  $\text{kg}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$ , and in Hessen in the year 1982 - 150  $\text{kg}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$ . The forests of Southern Germany are loaded with the lowest values. Our observations indicate that over 100  $\text{kg}\ \text{S}/\text{SO}_4$  per hectare have fallen in spruce stands in the Krušné hory Mts. yearly. 50 - 100  $\text{kg}\ \text{S}/\text{SO}_4\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$  have entered the soil of mountain spruce stands with throughfall water in the Beskydy Mountains (Červík), Orlické hory Mountains (Šerlich), likewise in the Želivka and at Slavkovský les (Šabina). The sulphate fall-out at Zdíkov was on the level of the lowest values determined in spruce stands in Southern Germany.

According to Schoen (1986), the annual load of nitrogen ( $\text{N}/\text{NO}_3 + \text{NH}_4$ ) fall-out on spruce stand soils attained 6 to 60  $\text{kg}\cdot\text{ha}^{-1}$ , in extreme cases 100  $\text{kg}\cdot\text{ha}^{-1}$  in the FRG. The share of ammonium N reached 32 to 70 %. The greatest portions of this nitrogen form were reported in Northern Germany. It is necessary to add organic N in the amount of Ca. 1 to 10  $\text{kg}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$  to the fall-out of inorganic forms.

The highest fall-out of inorganic N was found below spruce stands at Moldava (38.1  $\text{kg}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$ ) and at Nová Ves v Horách (44.0  $\text{kg}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$ ). In less exposed spruce stand at Zdíkov,  $\text{N}/\text{NO}_3 + \text{NH}_4$  fall-out with subcrown precipitation corresponds to lower values recorded in South Germany.

In pine stands at Ješovice, the annual fall-out of  $\text{S}/\text{SO}_4$  was found 32.4 and 37.0  $\text{kg}\cdot\text{ha}^{-1}$  and that of  $\text{N}/\text{NO}_3 + \text{NH}_4$  attained 12.6 and 19.3  $\text{kg}\cdot\text{ha}^{-1}$ . It is roughly within the fall-out of these elements in throughfall water below pine stands in Hamburg and in the northern federal countries, including Hessen (35.0 - 52.9  $\text{kg}\ \text{S}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$ , 5.1 - 29.1  $\text{kg}\ \text{N}/\text{NH}_4$ , and 7.3 - 9.3  $\text{kg}\ \text{N}/\text{NO}_3\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$ ).

With regard to a short distance of our plots from the main emission source and thus to increased fall-out of

ash and dust capable to buffer acid substances, the load of protons on their soils was lower than that in the FRG (0.17 and 0.18  $\text{kval}$ , contrary to 0.24 - 1.8  $\text{kval}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$ ).

The proton depositions in beech stands in the countries Niedersachsen and Nordrhein-Westfalen varied considerably according to the amount of precipitation and pollution load on the environment of the plots under observation (0.04 - 1.9  $\text{kval}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$ ). In Baden-Württemberg, the proton fall-out was lower and better balanced (0.11 - 0.18  $\text{kval}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$ ). The sums of protons in precipitation intercepted below crowns of beech on Nofiči on the Malá Ráztoka catchment (0.96  $\text{kval}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$ ) and on Šerlich (0.43  $\text{kval}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$ ) are comparable with the values in beech stands of Northern Germany.

The proton depositions at Zdíkov correspond to the conditions in beech stands in Baden-Württemberg. The amount of protons found in beech stem flow (1.00  $\text{kval}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$ ) highly exceeds the data obtained in the stands on the FRG territory (0.04 - 0.37  $\text{kval}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$ ).

$\text{S}/\text{SO}_4$  fall-out in the top part of the Malá Ráztoka catchment exceeded the values determined in the FRG. It attained the upper limit of value range on the plot of Šerlich and was very low at Zdíkov. There are analogous relations in the wet deposition of N compounds, as well.

To evaluate pollution load on the soils of oak stands, the data from three plots in the FRG and those from our plot at Sulice can be used. The values of H ions attained 0.48  $\text{kval}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$  in the FRG and 0.128  $\text{kval}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$  in the CR, and those of  $\text{S}/\text{SO}_4$  attained 28.0 - 47.7 and 35.4  $\text{kg}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$ , respectively. In the oak stands of the FRG, the annual fall-out of  $\text{N}/\text{NH}_4$  attained 3.9 and 8.8  $\text{kg}$  and that of  $\text{N}/\text{NO}_3$  4.5 - 5.0  $\text{kg}$  per hectare. On the plot at Sulice, the total annual fall-out of  $\text{N}/\text{NO}_3 + \text{NH}_4$  attained 13.8  $\text{kg}\cdot\text{ha}^{-1}$ .

Similar limited possibilities of confronting the results were in the stand of red oak. In the stands growing in the federal country Nordrhein-Westfalen, the annual fall-out of protons attained 0.82  $\text{kval}$  and at Ješovice 0.12 and 0.094  $\text{kval}$  per hectare. The values of  $\text{S}/\text{SO}_4$  fall-out attained 33.7 to 36.4  $\text{kg}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$  in these stands on the territory of Germany and 20.4 and 26.4  $\text{kg}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$  at Ješovice. The annual  $\text{N}/\text{NH}_4$  fall-out amounted to 16.0  $\text{kg}\cdot\text{ha}^{-1}$  and that of  $\text{N}/\text{NO}_3$  5.9 to 7.2  $\text{kg}\cdot\text{ha}^{-1}$  in the FRG. The annual fall-out of  $\text{N}/\text{NO}_3 + \text{NH}_4$  with subcrown precipitation attained 13.0 and 15.7  $\text{kg}\cdot\text{ha}^{-1}$  at Ješovice. Samplings of stem-flow water have not been taken on our plots. We have no foreign data for rowan and birch stands.

In addition to the above mentioned publication of DVWK Nr. 14, there are many papers in Germany dealing with evaluation of pollutant depositions in forest stands. It is necessary to point out the reports by Brechtel (Brechtel, 1990; Brechtel et al., 1985, 1986).

For evaluation of pollution load on our forests it is suitable to compare the data from the network of stations in Hessen. Balazs (1991) gave a survey of measurements lasting several years. His data were obtained on eight objects with parallel measurement of free area and below spruce stands. These data indicate different values of annual fall-out of the pollutants under study in stands situated at a short distance.

It follows from the results that the input of protons was two to three times higher in stands with subcrown precipitation than that on a parallel free area. At the main

measuring stations, the range of annual fall-out values of protons was 0.44 to 0.71  $\text{kval}\cdot\text{ha}^{-1}$  for the period of several years. The proton fall-out values estimated on the same research objects below spruce crowns ranged from 0.94 to 2.15  $\text{kval}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$ .

The amount of fall-out did not depend only on the precipitation sum (the level of precipitation) but also on fog frequency, fall-out of basic cations, and buffering action of crowns. The highest input of protons with throughfall water in spruce stand was determined 2.15  $\text{kval}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$  at the station of Witzenhausen which is situated by the northern frontier of the federal country and is exposed to air flow from the west. The highest fall-out of protons was found on a free area of this station, as well.

The fall-out of protons with throughfall water was essentially lower in beech stands than in spruce stands (0.20 to 0.29  $\text{kval}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$ ). Nevertheless, it was only a part of the total input of  $\text{H}^+$  ions with precipitation water. In stem-flow water, up to 50 % of the total deposition of these ions entered the soil (F ü h r e r et al., 1988). Moreover, the input of protons through the leaf organs under their buffering influence can be added to it.

The annual fall-out of  $\text{S}/\text{SO}_4$  on research objects in Hessen reached 13.1 to 21.0  $\text{kg}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$  on free area, 36.8 to 62.3 in spruce stands and 17.6 to 21.5  $\text{kg}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$  below beech crowns.

The average annual deposition of  $\text{N}/\text{NO}_4$  on the free areas under investigation ranged between 2.75 and 7.24  $\text{kg}\cdot\text{ha}^{-1}$ , in spruce stands between 6.5 and 14.0  $\text{kg}\cdot\text{ha}^{-1}$ , and in beech it attained 5.09 to 8.23  $\text{kg}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$  only with throughfall water.  $\text{N}/\text{NO}_3$  deposition was higher attaining 5.31 to 9.66  $\text{kg}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$  on free area and 9.08 to 19.3  $\text{kg}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$  in spruce stands.

When comparing the results from research plots in Hessen reported by B a l a z s (1991) with the data from our plots (Tab. II), an analogy can be found in proton fall-out on clear cut areas and in spruce stands on the plots of the Želivka, Šerlich, Moldava, and even Nová Ves if considered the same time period of the second half of the eighties.

In  $\text{S}/\text{SO}_4$  fall-out on free area, the values from the objects of the Želivka, Sulice, and Šerlich were comparable. Higher values were measured on the plots in the Krušné hory Mountains. The fall-out of  $\text{S}/\text{SO}_4$  on the Želivka and Šerlich was slightly higher than on the most loaded plot in Hessen, namely the plot of Witzenhausen. The fall-out was lower at Sulice and essentially higher at Nová Ves.

On our plots, approximately the same amount of sulphates was determined in throughfall water below beech crowns as in throughfall water below beech stands in Hessen. Likewise, the fall-out of inorganic forms of N on clear cut areas and in spruce stands on the plots of the Želivka, Šerlich, and Sulice was similar to the data from Hessen. In the Krušné hory Mts.,  $\text{N}/\text{NO}_3 + \text{NH}_4$  deposition was higher. On the contrary, in the region of the Šumava Mts., the fall-out of H,  $\text{S}/\text{SO}_4$ , and  $\text{N}/\text{NO}_3 + \text{NH}_4$  was lower on free areas and below stands than that at stations in Hessen, through our data did not represent the fall-out sum throughout the year (in the absence of measurement during the winter season).

H ü s e r, R e h f u e s s (1988) reported evaluation of pollutant deposition on forest-free area and in forest stands of the neighbouring Bavaria. Furthermore, they presented the basic data on fall-out in other original

countries of the FRG from the period of the first half of the eighties.

The results obtained at six stations in the region of the Bavarian Forest (elevation of 490 to 1150 m a.s.l.) and at five stations in a borderland on the CR in the vicinity of Tachov and Cheb regions (elevation of 550 to 840 m a.s.l.) are of special interest for us.

The mean annual fall-out of protons ranged from 0.27 to 0.59  $\text{kval}\cdot\text{ha}^{-1}$  on free area and from 0.83 to 1.50  $\text{kval}\cdot\text{ha}^{-1}$  below adult spruce stand crowns in the region of the Bavarian Forest. In spruce, the input of  $\text{S}/\text{SO}_4$  with subcrown precipitation attained 37.1 to 51.2  $\text{kg}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$  and the fall-out of  $\text{N}/\text{NO}_3$  amounted to 7.2 to 13.3  $\text{kg}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$ .  $\text{N}/\text{NH}_4$  deposition was reported only for the station Bodenmais and reached 11.6  $\text{kg}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$ .

In the borderland neighbouring upon our Cheb region, the fall-out of protons with precipitation attained the values of 0.38 to 0.58  $\text{kval}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$  on free area and 1.59 to 2.22  $\text{kval}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$  below spruce stands. Below the same stands, the average annual amount of  $\text{S}/\text{SO}_4$  with subcrown precipitation attained 56.6 to 61.4 kg per hectare and that of  $\text{N}/\text{NO}_3$  was 8.7 to 13.4 kg per hectare.

According to our results obtained in the region of the Šumava Mts. (the plots of Zdíkov and the Pěňvív potok catchment), the load of the depositions of H,  $\text{S}/\text{SO}_4$ , and  $\text{N}/\text{NO}_3 + \text{NH}_4$  on forests was lower at the end of the eighties than the load on forests on the Bavarian side in the first half of the eighties.

The deposition of protons with precipitation on forest-free area and below spruce stands in north-eastern Bavaria corresponded to the load on forest ecosystems on the plots of the Želivka, Šerlich, Moldava and Nová Ves at the end of the eighties. The fall-out of  $\text{S}/\text{SO}_4$  in spruce stands was on the level of the Želivka and Sulice plots. On the plots in the Krušné hory Mts. (Moldava and Nová Ves) and on Šerlich, the fall-out of sulphates was higher while it was lower at Zdíkov.

Moreover, H ü s e r, R e h f u e s s (1988) presented an outline of the load of the main pollutants on forest ecosystems in Baden-Württemberg. The results of the recent research were evaluated by H o c h s t e i n, H i l d e b r a n d t (1992). It follows from these data that the load of direct fall-out of protons and  $\text{SO}_4^{2-}$ ,  $\text{NO}_3^-$ , and  $\text{NH}_4^+$  was also high on some plots. Spruce stands on the plots of the north-western part of the country are particularly concerned. In the hydrological year 1988/89, the fall-out of H ions amounted to 1.74 and 2.02  $\text{kval}\cdot\text{ha}^{-1}$  here in spruce stands on the plot of Heidelberg. In the same period, deposition of H ions attained 1.71 and 2.04  $\text{kval}\cdot\text{ha}^{-1}$  on the plot of Rotenfels. Furthermore, a relatively high fall-out of  $\text{S}/\text{SO}_4$  and  $\text{N}/\text{NO}_3 + \text{NH}_4$  was found at the above stations in that year. Essentially lower values estimated in the subsequent year 1989/1990 indicate considerable fluctuation in annual values. The pollution load on forest soils in Baden-Württemberg decreased towards the south and east.

The data on the influence of acid precipitation on ion motion and ion supply in the soil have been reported by German authors, as well. U l r i c h et al. (1981) experienced the effect of spruce stand on enhanced load of substances from polluted air on the ecosystem in comparison with beech stand. The balance of element flow in the overlying humus indicates that separation of the majority of elements under investigation proceeded in

beech stand (losses being found in Ca, Mg, and Mn) while in spruce stand the elements were leached from the overlying humus, with an exception of  $H^+$ , P, and N. The authors also reported the changes in accessible nutrient supply in the soil profile of 0 - 50 cm in the period of 1966/1973. In beech stand, an increase in H, Na, Mg, and Mn supply was found. On the contrary, Ca and Fe were leached throughout the profile, Al from the upper part, in Mn a vertical shift being apparent, too. An increase in H, Mn, and Fe supply was found in spruce. Nevertheless, in cations (Na, K, Mg, Ca) and Al, impoverishment of the mineral profile appeared to the depth of 50 cm.

Kreutzer et al. (1986) reported the results of the investigations of the chemism of precipitation and soil water in spruce and beech stands at the object Högelwald. Differences in element concentrations in soil water were in accordance with their higher input to spruce stands with throughfall water. The differences in average concentrations of the observed elements in the soil water below spruce and beech stands balanced with the depth of the soil profile. In the depth of 40 cm, the water with higher  $H$ ,  $NO_3^-$ ,  $SO_4^{2-}$ , Ca, and Mg concentrations and lower K and  $NH_4^+$  concentrations was removed by suction in spruce.

The above mentioned papers confirm enhanced pollution load on the spruce stand in comparison with beech. This fact is responsible for higher leaching of biogenic elements in the covering humus and in surface horizons of mineral soil. It is in accordance with more intensive impoverishment of surface soil horizons from cations and Al in spruce stand than below beech stand.

Kreutzer et al. (1991) also reported observation of the influence of artificial acid rain on the development of element supply in the spruce stand soil as a part of complex research. Artificial acid rain (pH of  $H_2SO_4$ -acidified water 2.7 - 2.8) was responsible for pH reduction in the humusc horizon, increase in  $H^+$  supply, and decrease in Ca, Mg, and Mn reserves. In the surface layers of mineral soil (0 - 10 cm), decrease in exchangeable cations was not recorded and pH differences were minimal as compared to the soil rained with normal precipitation water (pH 5 - 5.5).

On the plot with artificial acid rain, leaching of elements from the humus horizon with flowing water is manifested in increase of  $NO_3^-$ ,  $Cl^-$ , and  $SO_4^{2-}$  concentrations and attains approximately the value of increased input with artificial acid rain. The output of  $H^+$  ions reached 25 % of their input. Exchange of Ca, Mg, K, Mn,  $NH_4^+$  and mobilization of Al participate predominantly in consumption of these protons which is in agreement with their leaching and decrease in their supply.

The differences in element dynamism between the plots with acid and normal artificial rain are in mineral soil, too.

In the soil rained with normal precipitation, a lower leaching of anions, Al and Mg, was observed in the surface zone, in comparison with the soil artificially acidified. In the depth of 20 - 40 cm, a lower leaching of Ca, Mg, and Mn, and lower Al retention were apparent. Retention of all mobile Al, proton residues, and Mn was observed in the profile from 40 to 175 cm. Nevertheless, leaching of Mg, Na, and particularly Ca was manifested.

In the soil enriched with acidified precipitation water, a higher motion of anions, Ca, Mg, Mn, and predominantly Al takes place. No influencing of water flowing away to underground resources occurs on these deep

soils. It is of interest that from 24.5 kmol  $H$ .ha<sup>-1</sup> introduced to the soil with acid rain in the years 1984 - 1989, 24 kmol.ha<sup>-1</sup> were consumed in the soil profile up to the depth of 40 cm and their deeper transport was higher only by 0.5 kmol.ha<sup>-1</sup> than on the plot rained with non-acidified precipitation water.

The results presented indicate that increased fall-out of protons and their neutralization in the soil profile participate predominantly in conspicuous decrease in the supply of „accessible“ cations and Mn in the soils of forest stands on our plots in air-polluted regions. It should be noted that even before the beginning of a pronounced effect of pollutant fall-out, considerable portion of forest soils of the CR exhibited essentially lower buffer ability than the soil on the object Högelwald under evaluation.

In the past, only little information was published on the state of air contamination and pollutant fall-out on the territory of the former GDR and nowadays, this situation has been improved. The research on the impact of pollutant fall-out on the chemism of precipitation and soil water is conducted by the researchers of the Technical University of Dresden, the station of Oberbärenburg near Zinnwald. According to the information of Dr. Lux, in the latter half of the eighties, the annual fall-out of protons was estimated on free area and below spruce stand 0.37 kval.ha<sup>-1</sup> and 1.24 kg.ha<sup>-1</sup>, respectively. The values of S/SO<sub>4</sub> were 40.1 kg.ha<sup>-1</sup>.year<sup>-1</sup> and 65.3 kg.ha<sup>-1</sup>.year<sup>-1</sup>, respectively. It indicates a slightly lower pollution load on forest ecosystems on northern slopes of the Krušné hory Mts. than on the forest on the Czech side. The soil waters are strongly contaminated.

## CONCLUSION

The presented results of the research on pollutant fall-out into forest ecosystems with precipitation water show that on clear-cut or forest-free areas, the precipitation water intercepted to open rain gauges is affected by dry fall-out of dust and ash and, therefore, the pH of precipitation is higher in the vicinity to emission sources with burning coal and other sources of solid fall-out than on more distant and cleaner plots.

The crowns of spruce stands enrich the penetrating precipitation water with protons and other elements more than pine stands. Broadleaves are responsible for lower enrichment of subcrown precipitation also in the growing season than conifers, cation exchange on leaf surface participates in neutralization of precipitation water. In broadleaves, the stem flow is contaminated essentially more than throughfall water.

Long-term observation of the chemism of precipitation water indicates its highest acidification at the end of the seventies and at the beginning of the eighties. During the recent years, S/SO<sub>4</sub> contamination of precipitation has decreased but contamination with N compounds has increased, particularly with N/NH<sub>4</sub>.

Less favourable forms of the covering humus with the presence of spruce roots cause retention of elements, the humus horizon in broadleaved stands enhances the dynamism of elements with percolating water. Leaching of substances from surface horizons increases on new clear cut areas but ground vegetation, particularly grasses, are responsible for retention of nutrient flow, predominantly N compounds.

The ecosystems of deciduous forests have a more favourable effect not only on the chemism of subcrown precipitation but they also reduce concentrations of nitrates in soil water and cause lower leaching of Mg. Increased concentrations of sulphates and nitrates in soil water are in accordance with increased Ca, Mg, and Na concentrations. The above mentioned anions have their origin in the atmosphere and unless fall-out of cations takes place simultaneously, they must be added from the soil; under their deficiency the protons are consumed for Al mobilization. Decreases in the supply of exchangeable cations Mg, Ca, and Mn are determined on the long-term plots under investigation which corresponds to their leaching in the soil with water.

In oligotrophic naturally acidic soils of mountain forests, strong acidification proceeds to deeper horizons and decrease in the supply of accessible forms of cations and Mn takes place with acidification in surface horizons. In deeper loamy soils they are shifted to lower horizons. Under strong acidification of the profile, Al release and shift occur in the mineral soil to the soil underground (with  $\text{pH}/\text{H}_2\text{O} > 4.2$ ) where also other ions are bound (sulphates, fluorides, phosphates, and heavy metals).

After cutting of spruce stands in strong pollution load regions, the soil pH does not decrease on clear cut areas but accessible Mg and Ca supply does not enhance in the mineral soil. The ground vegetation and substitute stands of broadleaved species influence improvement of biological element cycle and nutrient supply in the humus horizon. Nevertheless, in these stands, with regard to a low buffering soil capacity, increased motion of Al with soil water ( $\text{mg.l}^{-1}$  units) continues even under decrease of proton load on the ecosystem.

In surface water resources of forest catchments in the Krušné hory Mountains with terrestrial soils, water has not contained elevated concentrations of Al and heavy metals for the time being.

The presented results of research on depositions of pollutants and their influence on the development of soil properties in forest tree stands in the FRG show considerable similarity to pollution and natural conditions in our Republic and thus the possibilities of utilization of the results of special sophisticated research and conclusion for our investigations and measures in forest management. However, specific pollution conditions in the region of Northern Bohemia and their impacts on forests have no analogy to those in the countries of the original FRG.

## References

- BALAZS, A.: Niederschlagsdeposition in Waldgebieten des Landes Hessen - Ergebnisse von den Mess-Stationen der „Waldökosystemstudie Hessen“. Forschungsberichte Hessische Forstliche Versuchsanstalt, Hann. Münden, B. 11, 1991 : 168.
- BRECHTEL, H. M.: Quantifizierung der räumlichen und zeitlichen Variabilität der Niederschlagsdeposition im Freiland und in Waldbeständen. Vortrag bei der 1. Fachtagung BIOMET vom 8. - 11. 10. 1989 in München. Bayerischen Landwirtschaftliches Jahrbuch, München, 1990 : 627-634.
- BRECHTEL, H. M. - FÜHRER, H. W.: Bericht über Wasserqualitätsuntersuchungen 1975-1986. Arbeitsgruppe Forsthydrologie für weisungsbundene forstliche Forschung in Bund und Ländern, Eigenverlag der Hessischen Forstlichen Versuchsanstalt-Institut für Forsthydrologie, Hann. Münden, 1986 : 69.
- BRECHTEL, H. M. - SONNEBORN, M. - LENHARDT, F.: Konzentration und Frachten gelöster anorganischer Inhaltsstoffe im Freilandniederschlag sowie im Bestandesniederschlag von Waldbeständen verschiedener Baumarten. Reihe Tagungsberichte, Nationalpark Bayerischer Wald, Grafenau, 5, 1985 : 153-168.
- BUBLINEC, E.: Effect of air pollution on some components of nutrient cycling in the forest. In: Proc. of Symp. Air Pollution and Stability of Coniferous Forest Ecosystems, Ostravice, October 1-5, 1984. Univ. of Agric. Brno, 1985 : 131-135.
- BUBLINEC, E. - KUKLA, J.: The effect of spruce ecosystems stocking on the transformation of precipitation acidity and concentration of metallic elements. Problems of forest ecosystems treated by emissions in the SSR, in Slov. Dom techniky ČSVTS Žilina, 1987 : 54-63.
- FIEDLER, H. J.: „Die Hochlagenerkrankung“ der Fichte in bodenkundlich - standortkundlicher Sicht. Arch. f. Naturschutz und Landschaftsforschung Berlin, 1989 : 99-103.
- FIEDLER, H. J.: Untersuchungen zu Azidität, Ionenbelegung und Mineralbestand im SO<sub>2</sub> Immissionsgebiet des Osterzgebirges. In: Projektgruppe Bayern zur Erforschung der Wirkung von Umweltschadstoffen, Juli 1991.
- FÖLSTER, H.: In: MATZNER, B. - ULRICH, B.: Acid precipitation and forest decline in Germany: Summary of the present state of knowledge. Proc. of the Workshop Verification of Hypotheses on the Mechanisms of Damage and Possibilities of Recovery of Forest Ecosystems, Beskydy Mountains, September 4-8, 1989. Univ. of Agric. Brno, 1990 : 77-87.
- FÜHRER, H. W. - BRECHTEL, H. M. - ERNSTBERGER, H. - ERPENBECK, CH.: Ergebnisse von neuen Depositionsmessungen in der Bundesrepublik Deutschland und im benachbarten Ausland. DVWK Mitteilungen 14, Bonn, 1988 : 122.
- GÄRTNER, E. J.: Forest Decline in the Federal Republic of Germany - appearance, extent, potential causes. Geo Journal, 17. 2. 1988 : 165-171.
- HILDEBRAND, E. E.: Zustand und Entwicklung der Austauschereigenschaften von Mineralböden aus Standorten mit erkrankten Waldbeständen. Forstl. Cbl., 105, 1986 : 60-76.
- HOHSTEIN, E. - HILDEBRAND, E. E.: Stand und Entwicklung der Stoffeinträge in Waldbestände von Baden-Württemberg. Allgemeine Forst u. Jagdzeitung, 1992 (in Druck).
- HOFMANN, P. - HAVRÁNEK, M. - ČŮTA, J. - CHALUPA, J. - MADERA, V. - HAMÁČKOVÁ, J. - KOHOUT, M.: Jednotné metody chemického rozboru vod. Praha, SNTL 1965.
- HÜSER, R. - REHFUESS, K. E.: Stoffdeposition durch Niederschläge in ost und südbayerischen Waldbeständen. Schriftenreihe der Forstwirtschaftlichen Fakultät der Universität München und Bayerischen Forstlichen Versuchs- und Forschungsanstalt, 1988, Nr. 86 : 153.
- KLIMO, E.: Cycling of elements in the ecosystem on spruce monoculture. Manmade Spruce Ecosystem, Report from Project Rájec, Univ. Agric., Institut Forest Ecology Brno, 1992 : 95-142.
- KLIMO, E. - KULHAVÝ, J.: Acidification of forest soils in region of the Moravskoslezské Beskydy Mts. In: Proc. of Symp. Air Pollution and Stability of Coniferous Forest Ecosystems, Ostravice, October 1 - 5, 1984. Univ. of Agric. Brno, 1985 : 93-98.
- KREUTZER, K.: Zusammenfassende Diskussion der Ergebnisse aus experimentellen Freiland-Untersuchungen über den Einfluss von sauren Niederschlägen und Kalkung in Fichtenbeständen [*Picea abies* (L.) Karst.] Forstw. Cbl., 105, 1986 : 371-379.
- KREUTZER, K. - DESCHU, E. - HÖSL, G.: Vergleichende Untersuchungen über den Einfluss von Fichte [*Picea abies* (L.) Karst.] und Buche (*Fagus sylvatica* L.) auf die Sickerwasserqualität. Forstw. Cbl., 105, 1986 : 364-371.
- KREUTZER, K. - GÖTTLEIN, A. - PRÖBSTLE, P.: Auswirkungen von saurer Beregnung auf den Bodenschemismus in einem Fichtenbestand [*Picea abies* (L.) Karst.]. Ökosystemforschung Högelwald, Verlag Parey, Hamburg u. Berlin, 1991 : 174-186.
- LOCHMAN, V.: The influence of enriching the spruce ecosystems from atmosphere on the element dynamics in the soil. Communicationes Instituti Forestalis Cechosloveniae, Vol. 13, 1983 : 171-191.
- LOCHMAN, V.: The effect of element dynamics in precipitation and gravitational water on the development of principal production characteristics of forest soils. Communicationes Instituti Forestalis Cechosloveniae, Vol. 14, 1985 : 147-172.
- MATERNA, J. - KLIMO, E.: State and causes of forest decline in the Czech Republic. Proceedings of the Workshop Verification of

Hypotheses on the Mechanisms of Damage and Possibilities of Recovery of Forest Ecosystems, Beskydy Mountains, September 4-8, 1989. Univ. of Agricult. Brno, 1990 : 5-31.

MATZNER, E.: Rates of Na, K, Ca and Mg release by weathering derived from long term flux monitoring in two forest ecosystems of Germany. GEOMON Workshop, Extended Abstracts, Geological Survey Praha, 1987 : 10-12.

MATZNER, E. - ULRICH, B.: Acid precipitation and forest decline in Germany. Summary of the present state of knowledge. Proc. of the Workshop Verification of Hypotheses on the Mechanisms of Damage and Possibilities of Recovery of Forest Ecosystems, Beskydy Mountains, September 4-8, 1989. Univ. of Agricult. Brno, 1990 : 77-90.

MEIWES, K. J. - KÖNIG, N.: H-Ionen-Deposition in Waldökosystemen in Norddeutschland. In: HÖFKEN, K. O. - BAUER, H. (Hrsg.): IMA-Querschnittsseminar „Deposition“, Neuherberg, 25. 2. 1986, Gesellschaft für Strahlen und Umweltforschung, München (GSF), BTP-Bericht 8/86 : 7-18.

REHFUESS, K. E.: Walderkrankung und Immissionen - eine Zwischenbilanz. Allgem. Forstzeitschrift, 38, 1983 : 601-610.

REHFUESS, K. E.: Review of forest decline research activities and results in the Federal Republic of Germany. Proc. of the Workshop Verification of Hypotheses on the Mechanisms of Damage and Possibilities of Recovery of Forest Ecosystems, Beskydy Mountains, Sept. 4-8, 1989. Univ. of Agricult. Brno, 1990 : 53-76.

SCHMIDT, S. - GLATTES, F. - LEITNER, J.: Höhenprofil Zillertal. Messbericht 1987. FBVA Berichte 26, Wien, 1988.

SCHOEN, R.: Zur Rolle von Ammonium bei der Versauerung von Böden und Gewässern. Papier f. das Umweltbundesamt, Univ. Hohenheim, Inst. f. Landeskultur, 11, 1986.

ULRICH, B.: Gefahren für Waldökosystem durch saure Niederschläge. Immissionsbelastungen von Waldökosystemen. Sonderheft der Mitteilungen - Erweiterte Neuaufgabe 1983, Landesanstalt Ökologie, Landschaftsentwicklung u. Forstplanung Nordrhein-Westfalen, 1983 : 9-25.

ULRICH, B. - MAYER, R. - KHANNA, P. K.: Deposition von Luftverunreinigungen und ihre Auswirkungen in Waldökosystemen im Solling. Forstl. Fak. Univ. Göttingen, 58, Sauerländer's Ver. Frankfurt am Main, 2. Aufgabe, 1981.

ULRICH, B.: Ökochemische Kennwerte des Bodens. Z. Pflanzenernähr. Bodenk., 151, 1988 : 171-176.

VOŠKO, M. - BUBLINEC, E. - KONÓPKA, J.: Emissions situation, acid deposits, and health of forests in the Slovak Republic. Proc. of the Workshop Verification of Hypotheses on the Mechanisms of Damage and Possibilities of Recovery of Forest Ecosystems, Beskydy Mountains, September 4-8, 1989. Univ. of Agricult. Brno, 1990 : 33-51.

ZÖTTL, H. W. - BRAHMER, G. - FEGER, K. H.: Project Arinus III. Stoffbilanzen und Düngung der Einzugsgebiete. KfK-PEE-Bericht 50, Bd. 1, 1989 : 23-34.

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LOCHMAN, V. (Výzkumný ústav lesního hospodářství a myslivosti, Jiloviště-Strnady): Spady imisních látek do lesních ekosystémů ve vztahu ke změnám v lesních půdách. Lesnictví-Forestry, 39, 1993 (2) : 58-72.

V práci jsou prezentovány výsledky sledování spadu látek do lesních ekosystémů se srážkovou vodou především se zaměřením na protony, sulfáty a sloučeniny dusíku, které jsou charakteristickými indikátory znečištěného ovzduší ČR a poškozování lesních porostů a jejich půd. Spady látek do porostů a vodní režim půd ovlivňují i pohyb prvků v půdě, proto je v příspěvku věnována pozornost jejich vymývání z humusového horizontu do minerálního profilu. Z některých dlouhodoběji sledovaných ploch v imisně charakteristických oblastech jsou uvedeny i výsledky analýz opakovaných odběrů půdy. Soubor dat je z výzkumných objektů VÚLHM Jiloviště-Strnady z let 1973 až 1989.

Je možné říci, že zatížení lesních ekosystémů spady látek je v imisních poměrech ČR velmi proměnlivé. Vstup protonů je závislý nejen na vzdálenosti ploch od zdrojů emisí, ale i na celkovém znečištění ovzduší a exponovanosti ploch vůči proudění vzduchu. Jehličnany obohacují okapovou vodou více než listnáče, a to i při jejich olistění. Stok po kmenech je podstatně více kontaminován. V období sledování chemismu srážkových vod se ukazuje vzestup jejich acidifikace koncem sedmdesátých let a počátkem osmdesátých let. Smýcení porostů smrku v silně zatížených oblastech snižuje spad prvků; to se v dynamice prvků projevuje výrazněji než dopady aktivizace půdní biologické činnosti. V oblastech méně zasažených imisemi se na sečích zvyšuje vymývání biogenních prvků, ale přízemní travní vegetace působí retenci toku živin, hlavně sloučenin N. Listnaté porosty působí i na snižování koncentrací nitrátů v půdní vodě a nižší vymývání Mg z půdy. Na dlouhodoběji sledovaných plochách se zjišťují poklesy zásoby výměnných kationtů Mg, Ca a Mn. U oligotrofních, přirozeně kyselých půd horských lesů postoupilo silné okyselení hlouběji a s ním i snížení zásoby „přístupných forem“ kationtů a Mn. Při okyselení minerální půdy na pH < 4,2 v ní dochází k uvolňování Al a podle půdních vlastností k jeho ukládání v hlubších horizontech nebo vymývání. Při smýcení smrkových porostů v imisních oblastech (Krušných hor) již nepokračuje snižování půdního pH, ale zásoba přístupných forem Mg a Ca v minerálním profilu nestoupá. Přízemní vegetace a listnaté dřeviny pozitivně ovlivňují koloběh prvků a zásobu živin v humusovém horizontu. Výsledky výzkumu depozice imisních látek a jejich vlivu na vývoj půdních vlastností lesních porostů jsou porovnávány s údaji prezentovanými autory ze SRN. Je možné říci, že tyto údaje jsou podobné s naším zjištěním. V některých exponovaných oblastech ČR je zatížení lesních ekosystémů protony a sulfáty vyšší. Půdní vlastnosti a dynamika prvků v půdě ovlivňují složení vody odtékající do vodních zdrojů.

imisní spady; lesní půdy; smrkové porosty; srážková voda; acidifikace; protony; sulfáty; sloučeniny dusíku

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# DIAGNOSTICS OF LATENT AIR POLLUTION DAMAGE TO TREE SPECIES

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In fumigation experiments with HF, SO<sub>2</sub>, and O<sub>3</sub>, separately, the methods suitable for differential diagnosis of air pollution damage were experienced in *Fagus sylvatica*, *Picea pungens*, *Larix decidua*, *Betula verrucosa*, *Salix sp.*, *Pinus sylvestris*, *Picea abies*, and *Quercus robur* seedlings at the latent stage. The responses of the tree species under study to individual gases evaluated by the methods of: buffer capacity, potential acidification or potential acidity, S, F, and MDA accumulation in the assimilatory organs, uptake rate of <sup>14</sup>CO<sub>2</sub> and transpiration rate, simultaneously determined the sensitivity of individual tree species. Some methods were used to evaluate pollution load in young-growth mountain spruce stands.

air pollution; tree species; latent damage; diagnosis

## THE PRESENT STATE OF THE PROBLEMS UNDER STUDY

While visual methods evaluate the state of forest in the Czech Republic from qualitative points of view (per cent of defoliation, colour changes in the needles), inner quantitative changes can be perceived thus early at the „invisible stage“ before the appearance of clear symptoms of damage. Defoliation does not indicate the causes of damage. A more precise view on the problem may be provided by detailed physiological and biochemical analysis of the needles and/or leaves. Finding the influence of air pollution on the assimilatory organs enables us to determine the degree of damage in as early as the latent phase. Orientation of the diagnosis to assimilatory organs is logical because the assimilatory organs are sites of immediate contact with air pollution. The uptake of air pollutants is analogous to the uptake of CO<sub>2</sub>. It is affected by the same factors (climatic factors, cuticle permeability, stomatal opening).

The theory on the function of saccharides for the uptake of air pollutants, i.e. affecting the osmotic potential of stomata, was reported, for example, by Mejnartowicz, Luksiak (1985) in the needles of pine tolerant and sensitive to HF and SO<sub>2</sub>. The tolerant types exhibited mechanism of a more effective change of glucose to polysaccharides which resulted in stomatal closure and limitation of the entry of air pollution. The entry of air pollution is followed by specific and unspecific reactions (formation of radicals, mechanism of detoxification) which allow a timely diagnosis (Jäger et al., 1986). Chloroplasts of mesophyll cells, which respond very sensitively, are a site of the early contact with air pollution. Coulson, Heath (1974) found that even one-minute exposure of isolated chloroplasts to 100 ppb ozone inactivated the electron transport entirely. Wild (1987), observing spruce on different localities, found that air pollution damage manifested itself even in green needles by an injury to cell membranes. The loss in chlorophyll and activity of electron transport associated with a damage to thylakoids results in disturbance of assimilatory activity.

Although a protective mechanism is present in cells, combined action of anthropogenic and natural stressors disturbs the balance between processes of degradation and reparation, and causes damage to the cells. The category of protective mechanisms involves the buffering system of tissues which is particularly effective at the action of acidic agents in air pollutants. Czuchajowska, Niemtur (1978) found in larch that air pollution was responsible only for modifications in pH values, the effect being manifested more remarkably in the buffering capacity.

When investigating the effect of air pollutants, particularly their individual components, valuable information is provided by air pollution simulation in fumigation experiments. L'Hirondelle et al. (1986) found, for example, that after eight-week fumigation of aspen and *Pinus banksiana* seedlings with relatively low SO<sub>2</sub> (0.3 ppm) concentrations, the net assimilation transiently decreased in both the species but convalescence after fumigation was rapid and there was no evidence of increased sensitivity to fumigation and its duration.

Retardation of stomatal response, partial closure of stomata and decrease in transpiration were found by Keller, Häslér (1986) under continuous fumigation with low SO<sub>2</sub> concentrations. The evidence that air pollution gases acted more toxically in combination than separately was reported by Guderian et al. (1985) in a long-term experiment with spruce and poplar seedlings under the exposure to real concentrations of individual pollutants. In combined variants of the experiment, significant growth depression, chlorosis, necrosis, and premature leaf shedding appeared.

In the experiment with *Pinus taeda* seedlings, Simmons, Kelly (1989) found that ozone fumigation had no significant effect on nutrient concentration in tissues. Early effect of ozone influence was observed by Castillo et al. (1987) in the experiment with spruce seedlings. Ozone was responsible for an increase in peroxidase and superoxidismutase (detoxification enzymes) activities and reduction of ascorbic acid (detoxification agent) content. Fumigation of the seedlings of principal forest tree species with ozone and SO<sub>2</sub> was responsible for accumulation of malondialdehyde (MDA) in the leaves and needles (Uhlířová, 1991). Formation of MDA as a product of lipid peroxidation was described by Teige et al. (1974) in the study of membrane lipid reaction with ozone.

It follows from the fumigation experiment of Barnes, Davison (1988) that ozone predisposes tree species to frost and drought damage and these interactions are important factors contributing to a damage to spruce at higher elevations. For example, since 1981, in the Bavarian Alps, forests have evidently died back due to pollution of different origin: photooxidation, pollutants from local sources or their transport from more distant sources (Mössner, 1986). Badot et al. (1988) studied the physiology of dieback in spruce needles. They

found a lower water content in the needles of diseased trees than in those of healthy individuals, and perspicuous changes in waxes around the needle stomata of diseased trees.

B e n n e r , W i l d (1987) observed differences between the physiological activity of damaged and undamaged 22-year-old spruce trees. Photosynthesis was reduced in the damaged trees but only small differences were found in transpiration between the two groups. K r z a k e t al. (1988) compared assimilation processes of healthy looking and diseased spruces growing in a region with elevated incidence of atmospheric ammonium and relatively high ozone concentration (100 ppb). In the diseased trees, there were faster photosynthesis and transpiration and significantly decreased total chlorophyll content. B e r m a d i n g e r e t al. (1989) analyzed changes in the needles of diseased spruces as related to altitude. At lower altitudes (700 m a.s.l.) the damage corresponded to the effect of acid pollutants (lower ascorbic acid content, elevated content of thiols, clear damage of epicuticular waxes) while at higher altitudes (1000 m a.s.l.) the diseased spruce trees rather exhibited symptoms of the effect of photooxidants (high ascorbic acid content, low level of pigments) in spring months. At altitudes of above 1500 m a.s.l., physiological changes in the needles were attributed by the authors only to the effect of natural stress factors.

A warning dieback of mountain spruce stands in the Czech Republic led us to focus on diagnostics of the first symptoms of endangering young-growth spruce stands using such methods which were easy and rapid. The possibility of prevention of irreversible changes characterizing forest dieback by means of a suitable ecological and forest management policy can be seen only in rapid and widespread monitoring of changes which have been, perhaps, reversible for the present.

## MATERIAL AND METHODS

In 1983 a fumigation experiment was conducted to determine the effect of relatively high concentrations of HF and combination of HF + SO<sub>2</sub> on the seedlings of several tree species. It was a short-term experiment of 14-day fumigation for ca. 3 h per day with pause over the period of 26 July to 19 September, 1983. The daily HF concentration in the variant HF ranged from 12 to 324 ppm F, and in the variant HF + SO<sub>2</sub> from 6 to 27 ppm F and 0.3 mg.m<sup>-3</sup> SO<sub>2</sub>. The source of SO<sub>2</sub> was a pressure bottle and the source of gaseous HF was a solution of hydrofluoric acid whose vapours were carried along from a fan to a foil tunnel by air flow. SO<sub>2</sub> concentration was measured continuously with a coulograph, HF concentration was measured with an ion selective electrode after absorption in NaOH solution. The effect on *Picea pungens*, *Larix decidua*, *Fagus sylvatica*, *Betula verrucosa*, and *Salix sp.* seedlings was evaluated according to sulphur and fluorine accumulation in the assimilatory organs and determination of buffering capacity. At the end of the experiment, mean samples of assimilatory organs were taken to estimate S and F, and fresh undamaged needles and leaves to determine buffering capacity (P a s u t h o v á 1985).

In the fumigation experiment 1989, 4-5-year-old *Picea abies*, *Picea pungens*, *Pinus sylvestris*, *Quercus robur*, and *Fagus sylvatica* seedlings, grown in containers, were used. The fumigation experiment was conducted in 3 variants: control, SO<sub>2</sub>, and O<sub>3</sub>. The SO<sub>2</sub> variant was

supplied with sulphur dioxide from a pressure gas bottle, ozone was evolved in a generator Labo 76 by the firm Trailgaz. Air samples for the monitoring of ozone were taken with a teflon hose and led to an ozone analyzer CSI (model 3100). To determine the amount of SO<sub>2</sub> in the compartment of the tunnel, the gas was drawn off with a hose to an absorber with sodium chloromercurate solution with an addition of EDTA. The samples of gases were taken daily and the amount of SO<sub>2</sub> trapped in the absorbent was estimated colorimetrically and compared with the calibration curve for standard sodium sulphite solution at different concentrations corresponding to the incidence presumed.

In 1989 the fumigation experiment was carried out from 31 July to 24 August. SO<sub>2</sub> fumigation was performed with a delay from 9 August and took place for 3-4 h/day. The average concentration was 229 ± 40 µg.m<sup>-3</sup>. Ozone fumigation was realized for 2-3 h/day from 11 a. m. to 2 p. m. which was in accordance with increasing ozone concentration under natural conditions during the day. Prior to the start of fumigation and after its finishing, ozone concentrations were monitored in ambient air. They ranged from 0 to 25 µg.m<sup>-3</sup> at the beginning and from 30 to 80 µg.m<sup>-3</sup> at the end. Excepting the time of fumigation, the seedlings were grown under free atmosphere.

In the experiment conducted in 1990, containerized seedlings were used as well, but younger (3-year old) and without *Picea pungens*. The experiment was arranged analogously to that in the previous year, only fumigation was started earlier, 12 June, and finished 22 August being interrupted in the period of 30 July to 9 August. Sulphur dioxide was applied at an average concentration of 838 ± 87 µg.m<sup>-3</sup> for 3-4 h per day, ozone was applied at an average concentration of 284 ± 55 µg.m<sup>-3</sup> for 2-3 h per day.

The field research was focused on localities affected by air pollution in a different way. In 1990 young-growth spruce stands were chosen in the Jizerské hory Mts., Krkonoše Mts., and Krušné hory Mts., according to endangered zones: in the Jizerské hory Mts. at an altitude of 820 - 915 m a.s.l., Jizera 1060 m a.s.l., in the Krkonoše Mts. there were Jánské lázně, Janovy boudy, Pomezí boudy, Jelenka, and Černá hora at 825, 950, 1040, 1110, and 1260 m a.s.l., respectively; in the Krušné hory Mts. at 680 - 840 m a.s.l. The data on the air pollution endangered zones were obtained from Lesprojekt.

## METHODS

- Total sulphur in pulverized assimilatory organs was determined spectrophotometrically after combustion of the weighed amount of the sample in oxygen flow on a platinum spiral and absorption of liberated SO<sub>2</sub> in hydrogen peroxide.
- The amount of malondialdehyde MDA was determined in fresh leaves and needles by a modified method of H e a t h , P a c k e r (1968), and in a dry sample using the method as described earlier (U h l í ř o v á , 1991). In the experiment in 1989, MDA was determined in fresh needles and leaves, and then converted into dry matter. In 1990 the amount of MDA was estimated already in dry matter of the sample pulverized in a Janke-Kunkel cooled mill.
- Determination of the photosynthetic rate measured by the amount of incorporated <sup>14</sup>C<sup>14</sup>CO<sub>2</sub> to the needles of spruce and pine seedlings was carried out in 1989 but, contrarily to the previously reported experiment, fumi-

gation by the both gases was prolonged to 4 October (average SO<sub>2</sub> concentration 200 µg.m<sup>-3</sup>, O<sub>3</sub> 276 µg.m<sup>-3</sup>). Immediately prior to <sup>14</sup>C-<sup>14</sup>CO<sub>2</sub> application, the seedlings were fumigated by O<sub>3</sub> and SO<sub>2</sub> separately under the above-mentioned conditions for 2 hours and then transferred to a perspex assimilation chamber with air circulation and <sup>14</sup>C-potassium carbonate placed in the upper third of the chamber. After a thorough shutting of the chamber, CO<sub>2</sub> enriched with <sup>14</sup>CO<sub>2</sub> (550 · 10<sup>4</sup> Bq · mol<sup>-1</sup>) began to liberate by injection of a sufficient amount of 1 : 1 diluted H<sub>2</sub>SO<sub>4</sub> to a vessel with K<sub>2</sub> <sup>14</sup>CO<sub>3</sub>. After 15 mins of action, the aboveground parts of seedlings were excised and killed in formaldehyde vapours. After drying, the needles were burned in Tri-carb Sample Oxidizer, Packard, and radioactivity was measured in INSTA-GEL (Packard) environment in Liquid Scintillation Spectrometer-Model 2003, Packard.

- The leaf potential acidification was determined in an extract of dried needles (and/or leaves) by the consumption of a titrant (0.05 N HCl) in ml at titration up to the change by 1 pH.
- The leaf potential acidity expressed the consumption of a titrant (0.05 N NaOH) necessary for titration of acids to the equivalence point related to 1 ml of sample. It was also determined in an extract from dried assimilatory organs.
- The transpiration rate was measured by means of a portable porometer LICOR 1600 on intact shoots and/or leaves of the seedlings of tree species.

Some methods were reported previously (e.g. Uhlířová, Pasuthová, 1992).

## RESULTS

### EXPERIMENT 1983 (Tab. I).

A short-term fumigation experiment with seedlings of some tree species by relatively high HF and SO<sub>2</sub> concentrations was conducted to verify the response of these tree species to fumigation up to the incidence of damage symptoms. In larch, the needles were damaged and already shed several days from the beginning of fumigation and then they bursted again. The values in the variants HF and HF + SO<sub>2</sub> concern the bursted needles. After SO<sub>2</sub> fumigation, sulphur slightly accumulated in the assimilatory organs: in beech and birch approximately to the double of the control. Newly bursted needles of larch did not accumulate sulphur (the variants HF and HF + SO<sub>2</sub>

did not differ). Fluorine accumulation in the tree species under study was considerable the lowest being in blue spruce, absolutely and relatively as compared with the control. The buffering capacity of assimilatory organs increased by fumigation in beech and goat willow and decreased in blue spruce and birch. Likewise, apparently higher buffering capacity in larch after fumigation was concerned newly bursted needles and was incomparable with the control.

### EXPERIMENT 1989

The fumigation experiment 1989 was orientated towards the response to ozone and sulphur dioxide in seedlings of several tree species. Potential acidification of the extract of assimilatory organs was used as a diagnostic character among others. From the point of view of this character, the tree species responded to fumigation in a different way. After SO<sub>2</sub> action, the value of potential acidification increased in oak and blue spruce, decreased in Norway spruce and beech. After ozone action, the value increased in Scotch pine and blue spruce, decreased in Norway spruce and beech (Fig. 1). The transpiration rate was investigated 14 days after ozone fumigation. The fumigation influenced transpiration in such a way that the transpiration rate decreased in the species under study excepting blue spruce where it increased: Norway spruce, Scotch pine, oak, beech, and blue spruce exhibited, 47, 54, 83, 64, and 133 % of the control, respectively.

MDA accumulation in the needles and leaves was a result of peroxidation processes in all tested tree species fumigated with SO<sub>2</sub> and O<sub>3</sub> (Fig. 2). With an exception of beech, the increase in MDA concentration was much more conspicuous after ozone fumigation. The most sensitive response was exhibited in Scotch pine: 2.5-fold increase in MDA concentration in O<sub>3</sub>-tested seedlings, but significant increase was also observed in both spruces and oak. The content of total sulphur in assimilatory organs increased quite logically in all SO<sub>2</sub>-fumigated seedlings with an exception of blue spruce (Fig. 3). In ozone-fumigated seedlings (except oak), the total sulphur content decreased in comparison with unaffected control. In Fig. 3, where the average sulphur content in the control is expressed as 100 %, the sulphur content in ozone-affected Scotch pine represents only 62 %.

After the next 21-day fumigation with both the gases, the photosynthetic rate was measured by the amount of <sup>14</sup>CO<sub>2</sub> assimilated to the needles of Norway spruce and

I. Effects of HF and combination HF, SO<sub>2</sub> on some forest species - experiment 1983

Spec.	Control			HF			HF + SO <sub>2</sub>		
	BC	S	F	BC	S	F	BC	S	F
Beech	0.568	0.093	36.5	0.614	0.107	1180	0.623	0.166	610
C. b. s.	1.667	0.056	20.0	1.302	0.079	118	1.510	0.087	89
Larch	2.408	0.183	9.5	x3.011	0.170	300	x3.048	0.168	95
Birch	0.846	0.071	0.7	0.749	0.098	280	0.707	0.175	220
G. w.	0.695	0.205	6.1	0.822	0.122	1050	0.753	0.288	240

C. b. s. - Colorado blue spruce

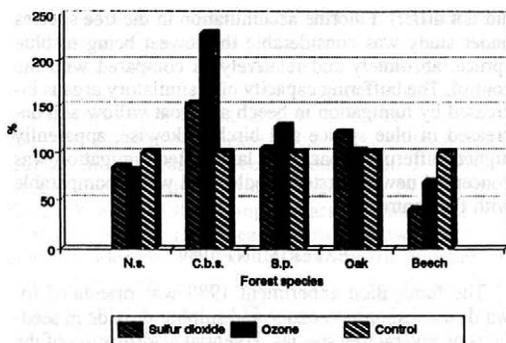
G. w. - Goat willow

BC - buffer capacity

S - sulphur content (%)

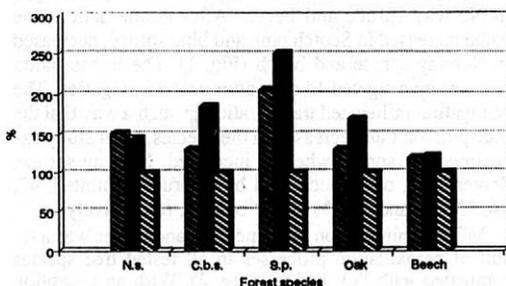
F - fluor content (ppm)

x - Lammas shoot needles

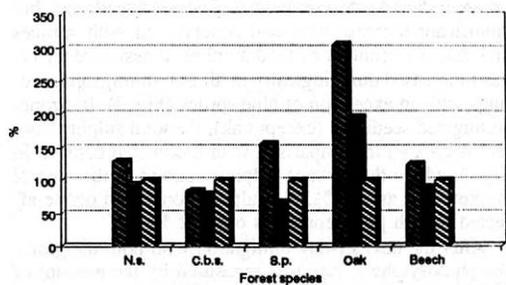


Applies to Figs. 1 - 3

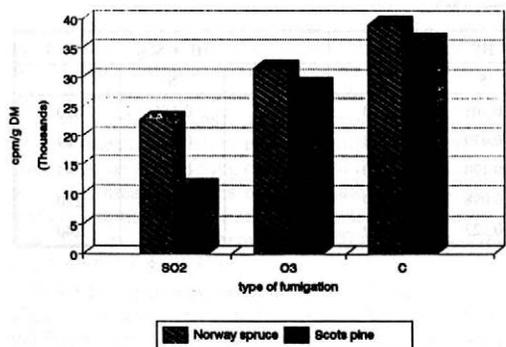
1. Sulphur dioxide and ozone effects on leaf potential acidification



2. Sulphur dioxide and ozone effects on the MDA content



3. Sulphur dioxide and ozone effects on needle sulfur content



4. Sulphur dioxide and ozone effects on 14-C incorporation into needles

Scotch pine for 15 mins. In Fig. 4, the radioactivity of  $^{14}\text{C}$  absorbed to the current year needles in unaffected controls is compared with both the fumigated variants. It is obvious that photosynthesis was suppressed more considerably by  $\text{SO}_2$ , particularly in Scotch pine.

EXPERIMENT 1990

This experiment differed from the previous experiment in generally shorter fumigation with earlier start after bursting the leaves and new needles and, simultaneously, in much more higher  $\text{SO}_2$  concentration.  $\text{O}_3$  concentration was approximately identical. Under these conditions, MDA concentration increased more markedly in the current year needles than in 1-year-old needles. Pine responded to ozone more sensitively than to  $\text{SO}_2$ , contrarily to spruce. Both the broadleaved species, beech and oak, responded to ozone more sensitively by increased MDA concentration. Over a relatively short time, high  $\text{SO}_2$  concentration manifested itself in increased total sulphur content in the leaves and in the both needle year-classes tested. Ozone fumigation exerted no unambiguous influence on sulphur content in the assimilatory organs of the tree species under study. The sulphur content decreased in spruce and beech, on the contrary, it increased in pine and oak (Tab. II).

The next character investigated in this experiment was the potential acidity (PA). In  $\text{SO}_2$ -fumigated spruce, PA increase appeared in 1- and 2-year-old needles (107 and 106 % of the control, respectively),  $\text{O}_3$  fumigation resulted in PA decrease to 93 % in 1-year-old needles. In pine, both  $\text{SO}_2$  and  $\text{O}_3$  fumigation were responsible for PA decrease in 1- and 2-year-old needles. 2-year-old needles of pine clearly differed from 1-year-old needles. The value of 1-year-old needles was practically 6 times higher than that of 2-year-old needles. In spruce, this value represented 1.6-multiple. In beech,  $\text{SO}_2$  fumigation was responsible for PA increase to 113 % but in oak it resulted in decrease to 78 % of the control. Similar effect was found in oak after ozone fumigation - decrease to 90 % of the control.

At the end of the experiment, the transpiration rate ( $\mu\text{g}\cdot\text{cm}^{-2}\cdot\text{s}^{-1}$ ) was determined on intact shoots of 10 seedlings each:

	control	ozone
<i>Picea abies</i>	2.343	1.882
<i>Fagus sylvatica</i>	2.440	1.448
<i>Quercus robur</i>	1.771	0.979

Under the influence of ozone, the transpiration rate decreased in 3 species investigated as follows: in spruce, beech, and oak to 80, 59, and 55 % of the control, respectively.

OBSERVATIONS ON AIR POLLUTED LOCALITIES 1991

A survey of the situation on some localities in air polluted regions from the point of view of the content of sulphur, MDA, and PA in the needles is given in Tab. III. It presents the values of 1- and 2-year-old spruce needles. In general, five localities under study in the Jizerské hory Mts. seem to be balanced in PA as well as in the content of sulphur in the needles. The PA values of 2-year-old

II. Effects of SO<sub>2</sub> and O<sub>3</sub> fumigation on leaf changes of main forest species - experiment 1990

Spec.	§ yr	Control			SO <sub>2</sub>			O <sub>3</sub>		
		MDA	PA	S	MDA	PA	S	MDA	PA	S
Norway spruce	89	4.364	1.523	0.164	4.367	1.629	0.118	4.535	1.535	0.151
	90	1.670	2.585	0.162	3.063	2.780	0.242	2.569	2.419	0.151
Scots pine	89	2.166	0.527	0.101	2.154	0.299	0.174	2.944	0.502	0.148
	90	1.115	3.119	0.106	1.778	2.241	0.192	1.960	2.167	0.128
Beech		2.451	0.248	0.184	2.934	0.280	0.285	3.122	0.253	0.121
Oak		1.496	0.367	0.088	1.782	0.285	0.270	2.214	0.330	0.172

§ 89 - one-year needles and 90, current-year needles

MDA - malondialdehyde content ( $\mu\text{mol.g}^{-1}$ ) of dry leaves (needles)

PA - potential acidity

S - sulphur content (%)

## III. Affecting of some air-polluted mountain young spruce stands, spring 1991

	1-yr needles			2-yr needles			Zone
	MDA	PA	S	MDA	PA	S	
<i>Jizerské hory Mts.</i>							
Polubný	9.786	1.868	0.161	9.903	1.307	0.182	C
Kobyła	8.947	1.538	0.139	9.747	0.975	0.196	B
Tetřeví	10.836	1.893	0.155	11.578	1.542	0.219	A
Smrčí	9.630	1.874	0.146	9.337	1.147	0.169	B
Jizera	10.530	1.628	0.148	-	-	-	A
<i>Krušné hory Mts.</i>							
Klíný	5.905	2.679	0.290	6.513	1.768	0.354	A
Načetín	4.953	2.140	0.322	6.341	1.649	0.296	B
Kálek	6.418	2.611	0.311	6.821	1.735	0.304	A
Nová Ves	5.157	2.474	0.297	5.698	1.418	0.286	A
Svatý Šebestián	8.348	2.404	0.300	8.428	1.518	0.378	A
Abertamy-1	6.896	1.814	0.107	8.728	1.155	0.135	B
Abertamy-2	7.018	1.420	0.136	8.942	1.173	0.166	B
Kovářská	6.292	1.517	0.155	7.906	1.060	0.206	B
<i>Krkonoše Mts.</i>							
Černá hora	7.893	1.860	0.113	-	-	-	B
Jánské lázně	7.403	2.027	0.104	-	-	-	C
Janovy boudy	8.988	2.500	0.132	-	-	-	B
Pomezní boudy	7.364	1.720	0.105	-	-	-	B
Jelenka	9.554	1.829	0.118	-	-	-	B

MDA - malondialdehyde content ( $\mu\text{mol.g}^{-1}$ ) of dry needles

PA - potential acidity

S - sulphur content (%)

Zone A, B, C - pollution zones

needles were lower among the localities with similar relations to those in 1-year-old needles (the lowest and highest PAs). The Krušné hory Mts. localities differed in PA values according to air pollution exposure. The needles with higher sulphur content exhibited higher potential acidity, as well. It is also true when comparing the localities separately for 1- and 2-year-old needles. In 5 localities of the Krkonoše Mts., only 1-year-old needles were analyzed. As far as PA values is concerned, the locality of Janovy boudy corresponded to some localities of the Krušné hory Mts. Likewise, the needles contained relatively highest amount of sulphur within the scope of the Krkonoše Mts. localities but in absolute comparison,

the sulphur content in the needles was lower than on nearly all localities of the Krušné hory Mts. under investigation. The content of malondialdehyde in 2-year-old needles was always higher than that in 1-year-old needles regardless to the locality. The highest MDA concentrations in spruce needles were determined in the Jizerské hory Mts., slightly lower in the Krkonoše Mts., and the lowest in the Krušné hory Mts.

## DISCUSSION

Latent damage to forest tree species involves air pollution-induced changes early before the appearance of

visible symptoms. In 1983 the situation was recorded by the experiment with HF and SO<sub>2</sub> closely before the development of the symptoms. Under this short-term effect by relatively high concentrations, larch was damaged already. The other tree species responded by accumulation of S and F in the assimilatory organs and changes in the buffer capacity (BC) in the sense of an increase or decrease in the values according to the tree species but similarly to HF and its combination with SO<sub>2</sub> because an acid air-pollution type was in question. Czuchajowska (1979) reported BC increase with air pollution increase in Scotch pine. In spruce, Wolfenden et al. (1988) found reduction of alkaline BC in an air polluted region. In this experiment, BC was reduced in *Picea pungens* after the action of both the pollutants.

The toxic effect of HF and SO<sub>2</sub> has been sufficiently recognized and verified. Now, attention has also been paid to ozone in Europe. It follows from the experiments, for example with *Populus tremuloides*, that even the ozone concentrations of 100 and 200 µg.m<sup>-3</sup> influenced the persistence of leaves and production of this ozone bioindicator (Keller, Bühlmann, 1987). These concentrations are also real air pollutants because, for example, Einig et al. (1987) found the highest month's average ozone concentrations of 100 µg.m<sup>-3</sup> in the South Schwarzwald. The changes following sulphur dioxide and ozone fumigation were tested by other diagnostic characters of potential acidification and potential acidity in the experiments in 1989 and 1990. Both the determination methods differ from each other and both the characters represent different possibilities of pollution compensations (see Methods) which was also observed in a different way of the effect of fumigation on individual tree species. For example, fumigation of *Picea abies* was manifested in the increase in potential acidity of 1- and 2-year-old needles. This trend was verified under field conditions, as well, where SO<sub>2</sub> pollution was in action. The experiment revealed higher total PA values in conifers when compared to deciduous trees. Higher PA values in conifers were associated with lower natural pH of the needles and lower optimum soil pH for conifer growth (4.5 - 5.0 pH). The buffering capacity, potential acidification, and potential acidity are characters which express the possibilities of detoxification or pollution compensation while the transpiration rate indicates the possibilities of limiting pollution uptake by the stomata. Vogels et al. (1986) found reduction of transpiration in spruce following the exposure to 194 µg.m<sup>-3</sup> ozone. In our experiment, 300 µg.m<sup>-3</sup> O<sub>3</sub> fumigation was responsible for reduction of transpiration rate in spruce, beech, and oak.

Keller, Jäger (1980) reported a faster S uptake by the leaf area than by roots through the soil in SO<sub>2</sub>-fumigated Norway spruce and beech seedlings over the period of 3 months. In our experiments in 1989 and 1990, analogous response of both the tree species was observed even after substantially shorter fumigation. A slight decrease in S content in the assimilatory organs of the tested tree species in comparison with non-fumigated control can be explained by a quite different mechanism of ozone action. While SO<sub>2</sub> induces stomatal closure (Gross, 1987), disturbs epicuticular waxes in the vicinity of stomata and simultaneously increases the content of cell thioles (Bermadinger et al., 1989), ozone influences directly the photosynthetic apparatus and thus the uptake of CO<sub>2</sub> (Gross, 1987) and probably S, too. The result, decrease in photosynthetic capacity, is the same

at the beginning but it is reversible in SO<sub>2</sub>, contrarily to that in O<sub>3</sub> (Selinger et al., 1986).

In our experiment, suppression of <sup>14</sup>CO<sub>2</sub> assimilation by spruce and pine needles was more conspicuous in SO<sub>2</sub> variant than in that of O<sub>3</sub> (Fig. 4) because the experiment was performed immediately after fumigation. At that time, the stomata were probably still closed in parts after SO<sub>2</sub> fumigation. A higher sensitivity of pine than that of spruce to both the gases was also confirmed by higher concentrations of accumulated MDA in the youngest needles. The trend of higher MDA accumulation after ozone fumigation was also exhibited in the other fumigation tree species during the experiments in 1989 and 1990. MDA concentration characterized the damage to membranes which occurred due to peroxidation processes induced by O<sub>2</sub><sup>2-</sup> superoxid radical (Sakaki et al., 1984). This radical originates by a direct reaction of ozone and other photooxidants with unsaturated bonds of fatty acids of membrane lipids, furthermore at radical SO<sub>2</sub> oxidation to a sulphate, likewise at enhanced transfer of electrons to molecular oxygen under a photosynthetic disturbance. This disturbance can be induced by suppression of CO<sub>2</sub> fixation which is usually caused by depression of enzymatic RuBPC activity (Elstner, Oswald, 1984).

Differential diagnosis of the damage to young mountain spruce stands is based on PA and MDA values besides the necessary determination of total leaf S and simultaneously on actual pollution data on SO<sub>2</sub> concentrations. For completeness' sake, fluorine wants to be estimated in the needles which can be presumed to a great extent on some localities of the Jizerské hory Mts. Increased fluorine concentrations were estimated on the locality Smědava in 1989 (Lomský, Uhlířová, 1993). High MDA concentration on individual localities of the Jizerské hory Mts. at a relatively low S content in the needles indicates rather O<sub>3</sub>-induced damage and possible co-action of HF. The affection of young spruce trees corresponds to higher SO<sub>2</sub> concentration in the atmosphere on the majority of localities in the Krušné hory Mts. (the data of Czech Hydrometeorologic Institute). On some localities in the Krkonoše Mts., high concentration of MDA and simultaneously low PA and S concentrations, contrarily to higher PA and S concentrations besides relatively low MDA concentration indicate combined air pollution conditions in these mountains.

When comparing our results with the observations of Bermadinger et al. (1989), a conclusion can be drawn that at higher elevations (about 1000 m a.s.l.), spruce trees are damaged by photooxidants (higher MDA values) rather than by SO<sub>2</sub> while SO<sub>2</sub>-induced damage (higher PA and S content in the needles) prevails at lower altitudes (700 - 800 m a.s.l.). The diagnostic methods experienced serve as indirect evidence of the action of photooxidants which have not been monitored continuously in our country up to the present.

## References

- BADOT, P. M. - GARREC, J. P. - MILLET, B. - BADOT, M. J. - MERCIER, J.: Dieback and water status of needles of *Picea abies*. Can. J. Bot., 66, 1988, No. 9: 1693-1701.  
BARNES, J. D. - DAVISON, A. W.: The influence of ozone on the winter hardiness of Norway spruce [*Picea abies* (L.) Karst.]. New Phytologist, 108, 1988, No. 2: 159-166.

- BENNER, P. - WILD, A.: Measurement of photosynthesis and transpiration in spruce trees with various degrees of damage. *J. Plant Physiol.*, 129, 1987, No. 1-2 : 59-72.
- BERMADINGER, E. - GRILL, D. - GUTTENBERGER, H.: Thiole, Ascorbinsäure, Pigmente und Epikutikularwache in Fichtennadeln aus dem Höhenprofil „Zillertal“. *Phyton (Horn)*, 29, 1989, No. 3 : 163-185.
- CASTILLO, F. L. - MILLER, P. R. - GREPPIN, H.: Extracellular biochemical markers of photochemical oxidant air pollution damage to Norway spruce. *Experientia*, 43, 1987, No. 1 : 111-115.
- COULSON, C. - HEATH, R. L.: Inhibition of the photosynthetic capacity of isolated chloroplasts by ozone. *Plant Physiol.*, 53, 1974 : 32-38.
- CZUCHAJOWSKA, Z.: Seasonal changes of pH and buffer capacity of aqueous homogenates of *Vaccinium vitis-idaea* and *Vaccinium myrtillus* leaves. *Acta Soc. Bot. Pol.*, 48, 1979, No. 1 : 35-46.
- CZUCHAJOWSKA, Z. - NIEMTUR, S.: Seasonal variability of chlorophyll content and the changes of the acidity and buffer capacity in the needles of *Larix decidua* and *Larix leptolepis* in different air pollution conditions. *Acta Soc. Bot. Pol.*, 47, 1978, No. 1-2 : 41-49.
- EINIG, W. - KEIL, R. - BENT, T. - HAMPP, R.: Stoffwechselfeldzustände gesunder und geschädigter Fichtennadeln. *Allg. Forstz.*, 27/28/29, 1987 : 744-745.
- ELSTNER, E. F. - OSWALD, W.: Fichtensterben in „Reinluftgebieten“: Strukturresistenzverlust. *Naturwissenschaftliche Rundschau*, 37, 1984 : 52-61.
- GROSS, K.: Gaswechselformen an jungen Fichten und Tannen während Begasung mit Ozon und Schwefeldioxid (allein und in Kombination) im Kleinphyton. *Allgemeine Forst- und Jagdzeitung*, 158, 1987, No. 2-3 : 31-36.
- GUDERIAN, R. - KÜPPERS, K. - SIX, R.: Wirkungen von Ozon, Schwefeldioxid und Stickstoffdioxid auf Fichte und Pappel bei unterschiedlicher Versorgung mit Magnesium und Kalzium sowie auf die Blatflechte *Hypogymnia physodes*. In: *Forest Dieback: Influencing Factors and their Evaluation. Proceedings of a symposium held at Goslar, W. Germany, 18-20 June, 1985, VDI-Berichte*, No. 560, 1985 : 657-701.
- HEATH, R. L. - PACKER, L.: Photoperoxidation in isolated chloroplasts. I. Kinetics and stoichiometry of fatty acid peroxidation. *Arch. Biochem. Biophys.*, 125, 1968 : 189-198.
- L'HIRONDELLE, S. J. - ADDISON, P. A. - HUEBERT, D. B.: Growth and physiological responses of aspen and jack pine to intermittent SO<sub>2</sub> fumigation episodes. *Can. J. Bot.*, 64, 1986, No. 11 : 2421-2427.
- JÄGER, H. J. - WEIGEL, H. J. - GRÜNHAGE, L.: Physiologische und biochemische Aspekte der Wirkung von Immissionen auf Waldbäume. *Eur. J. For. Path.*, 16, 1986 : 98-109.
- KELLER, T. - BÜHMANN, U.: Zur Verwendung der amerikanischen Aspe als Bioindikator für Ozon. *Schweiz. Zeitschr. Forstwes.*, 138, 1987, No. 11 : 993-998.
- KELLER, T. - JÄGER, H. J.: Der Einfluss bodenbürtiger Sulfationen auf den Schwefelgehalt SO<sub>2</sub>-begaster Assimilationsorgane von Waldbaumarten. *Angewandte Botanik*, 54, 1980 : 77-89.
- KELLER, T. - HÄSLER, R.: The influence of a prolonged SO<sub>2</sub> fumigation on the stomatal reaction of spruce. *Eur. J. For. Path.*, 16, 1986 : 110-115.
- KRZAK, J. - DONG, P. H. - BÜTTNER, G. - HÜTTERMANN, A. - KRAMER, H. - ULRICH, H.: Photosynthesis, nutrient, growth and soil investigations of declining Norway spruce (*Picea abies*) stand. *Forest Ecology and Management*, 24, 1988, No. 4 : 263-281.
- LOMSKÝ, B. - UHLÍŘOVÁ, H.: Evaluation of an experiment with fertilization and liming of young-growth spruce stands in the Jizerské hory Mts. *Lesnictví-Forestry*, 39, 1993, č. 2 : 80-86.
- MEJNARTOWICZ, L. E. - LUKSIK, H.: Level of sugars in Scots pine trees of different sensitivity to fluoride and sulphur dioxide. *Eur. J. For. Path.*, 15, 1985, No. 4 : 193-198.
- MÖSSNER, R.: Verteilung der neuartigen Waldschäden an der Fichte nach Bestandes- und Standortmerkmalen in den Bayerischen Alpen. *Forstliche Forschungsberichte München*, 1986, No. 73 : 146.
- PASUTHOVÁ, J.: Vliv vysokých koncentrací SO<sub>2</sub> a HF na vybraný sortiment dřevin. *Práce VULHM*, 66, 1985 : 313-338.
- SAKAKI, I. - KONDO, N. - SUGAHARA, K.: Breakdown of photosynthetic pigments and lipids in spinach leaves with ozone fumigation: Role of active oxygens. *Res. Rep. Natl. Inst. Environ. Stud.*, Jpn., 65, 1984 : 219-230.
- SELINGER, H. - KNOPPIK, D. - ZIEGLER-JÖNS, A.: Einfluss von Mineralstoffernährung, Ozon und stomatare Leitfähigkeit von *Picea abies* (L.) Karst. *Forstwissenschaftliches Centralblatt*, 105, 1986, No. 4 : 239-242.
- SIMMONS, G. L. - KELLY, J. M.: Effects of acidic precipitation, O<sub>3</sub>, and soil Mg status on throughfall, soil, and seedling loblolly pine nutrient concentrations. *Water, Air, and Soil Pollution*, 43, 1989, No. 1-2 : 199-210.
- TEIGE, B. - Mc MANUS, T. T. - MUDD, J. B.: Reaction of ozone with phosphatidylcholine liposomes and the lytic effect of products on RBC. *Chem. Phys. Lipids*, 12, 1974 : 153-171.
- UHLÍŘOVÁ, H.: Is it possible to use malondialdehyde content to damage assessment? IUFRO and ICP-Forests Workshop on Monitoring, Prachatic 2. - 6. 9., ČSFR 1991 : 233-235.
- UHLÍŘOVÁ, H. - PASUTHOVÁ, J. - BREJCHA, J.: Charakteristika diagnostických metod vhodných pro testování odolnosti dřevin k různým typům stresu. *Zpr. lesn. Výzk.*, 2, 1992 : 13-15.
- VOGELS, K. - GUDERIAN, R. - MASUCH, G.: Studies on Norway spruce (*Picea abies* Karst.) in damaged forest stands and in climatic chambers experiments. In: *Acidification and Its Policy Implications. Proceedings of an international conference held in Amsterdam, 5-9 May, 1986*.
- WILD, A.: Physiologische und cytologische Charakterisierung von Immissionsbelasteten Fichten. *Allg. Forstz.*, 27/28/29, 1987 : 734-737.
- WOLFENDEN, J. - ROBINSON, D. C. - CAPE, J. N. - PATERSON, I. S. - FRANCIS, B. J. - MEHLHORN, H. - WELLBURN, A. R.: Use of carotenoid ratios, ethylene emissions and buffer capacities for the early diagnosis of forest decline. *New Phytologist*, 109, 1988, No. 1 : 85-95.

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UHLÍŘOVÁ, H. - PASUTHOVÁ, J. (Výzkumný ústav lesního hospodářství a myslivosti, Jiloviště-Strnady): Diagnostika latentního poškození dřevin imisemi. *Lesnictví-Forestry*, 39, 1993 (2) : 73-79.

Ve fumigačních pokusech s HF, SO<sub>2</sub> a O<sub>3</sub> odděleně byly na sazenicích *Fagus sylvatica*, *Picea pungens*, *Larix decidua*, *Betula verrucosa*, *Salix sp.*, *Pinus sylvestris*, *Picea abies*, *Quercus robur* prověřeny metody vhodné k diferenciální diagnóze imisního poškození v latentním stadiu. Reakce testovaných dřevin na jednotlivé plyny hodnocené metodami: pufrční kapacita, potenciální acidifikace nebo potenciální acidita, akumulace S, F a MDA v asimilačních orgánech, rychlost příjmu <sup>14</sup>CO<sub>2</sub> a rychlost transpirace, rozlišují zároveň citlivost jednotlivých dřevin. Některé metody byly použity při hodnocení imisního zatížení horských smrkových mlazin.

imis; dřeviny; latentní poškození; diagnóza

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# EVALUATION OF AN EXPERIMENT WITH FERTILIZATION AND LIMING OF YOUNG-GROWTH SPRUCE STANDS IN THE JIZERSKÉ HORY MTS.

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In 1986 an experimental plot was established in 18-year-old young-growth spruce stand of Frýdlant (Smědava) Forest Enterprise at an altitude of 880 m a.s.l. The following variants of fertilization were applied to 10 x 10 m compartments: micronized dolomitic limestone (Ca), ammonium nitrate with limestone (SP), urea with an addition of other nutrients (U+), ammonium nitrate with limestone with an addition of other nutrients - P, K, Mg, and Ca (U+, SP+). Besides estimation of biometric values, analyses of soil and needles, biochemical and physiological determinations were performed: content of total free sugars, RuBPC activity, estimation of needle dry matter, accumulation of S, F, and malondialdehyde in the needles, chlorophyll content, stomatal conductivity, transpiration rate, and visual evaluation of health condition according to the defoliation degree. After the application of complete fertilization (SP+ and U+), the soil poor in Mg, Ca, and K was enriched with these elements particularly in the organic soil horizon. After three years of the experiment, the pH values increased by 0.3 - 0.6 units in comparison with the control (pH 3.4). Prior to fertilization, the nitrogen content in the needles ranged closely above the deficiency limit (1.3 - 1.5 % dry matter of the needles), after the treatment with fertilizers, N content attained up to 2.0 % during the first two years, the fastest response being exhibited in U+ variant, the longest action was observed in SP+ variant. Magnesium deficiency in the needles was fully saturated only after three years following the application of fertilizers. The height increment, as well as the results of the above-mentioned biochemical and physiological characteristics indicate the optimum action of SP+ variant of fertilization. Likewise, from the point of view of visual evaluation of the health condition of young-growth stands, the fertilization variant SP+ manifested itself to be the best.

young-growth spruce stands; fertilization; liming; biochemical and physiological determinations; soil analyses; nutrients

According to the forest area (more than 4.5 mill. ha) and 35.5 % forest land (of which more than 2.6 mill. ha and 33.2 %, respectively, are in the Czech Republic), Czechoslovakia was one of the woodiest states in Europe. It is only exceeded by Austria and some Northern countries. Likewise, as far as deposition of pollutants is concerned, the Czech Republic ranks among the most loaded regions. For example, the average annual sulphur deposition amounts to 53 kg.ha<sup>-1</sup> of which foreign sources form nearly a half. The average annual nitrogen deposition attains 10 kg.ha<sup>-1</sup>, more than 2/3 originating in foreign sources.

The area of the Jizerské hory Mts. is numbered among the most loaded regions of the Czech Republic. The average annual sulphur and nitrogen depositions here attain 98 and 29 kg.ha<sup>-1</sup>, respectively. Considerable portion of

these pollutants comes from Poland and eastern region of Germany. In this part of the country, all forests are damaged by pollutants and the damage represents more than 50 % of forest area throughout the Czech Republic (Moldan et al., 1990).

At higher altitudes of the Jizerské hory Mts., young-growth spruce stands have survived for the time being. Therefore, our interest was focused on them. Our aim was to evaluate the effect of liming with dolomitic limestone, fertilization with urea and ammonium nitrate with limestone and an addition of Mg, K, and P on nutrition and health state as compared to unfertilized variant. Furthermore, we intended to characterize subsequent changes in soil conditions and growth manifestations of young spruce trees including physiological and biochemical processes.

## MATERIAL AND METHODS

In May 1986 an experimental plot was established in the Jizerské hory Mts. (Frýdlant Forest Enterprise, Forest District Zadní Studánka, stand 235 A2) near Smědava (Smrčí cesta) in an 18-year-old young-growth stand. The area is situated at an altitude of 880 m a.s.l. on NE slope leaning towards the Polish Republic, endangered zone B in air polluted region (Tab. I).

On the area, compartments were laid out (by 100 m<sup>2</sup>) in such a way to repeat each variant five times. Besides control unfertilized areas (Var. C), the following variants of fertilization were chosen:

SP+ - 27.5 % ammonium nitrate with limestone was applied at the dose of 150 kg N.ha<sup>-1</sup>, potassium sulphate (K<sub>2</sub>SO<sub>4</sub>) at the dose 240 kg K.ha<sup>-1</sup>, superphosphate (SPG) at the dose of 150 kg P.ha<sup>-1</sup>, Kieserit at the dose of 10 kg Mg.ha<sup>-1</sup>, and micronized limestone at the dose of 1100 kg.ha<sup>-1</sup>.

U+ - Instead of ammonium nitrate with limestone, 46 % urea was used at the dose of 150 kg N.ha<sup>-1</sup>. The other fertilizers were applied at the above-mentioned doses.

SP - Only ammonium nitrate with limestone was applied at the dose of 150 kg N.ha<sup>-1</sup>.

Ca - Micronized dolomitic limestone was applied at the dose of 1100 kg Ca.ha<sup>-1</sup>, i.e. 5 t of limestone per hectare.

The dosage of fertilizers was started from the results of soil analyses conducted prior to the experiment. Our choice of using these kinds of fertilizers was supported by the fact that at this time forestry practices began to use aerial liming (dolomitic limestone) and fertilization (urea or ammonium nitrate with limestone) to a wide extent. The application of fertilizers was carried out manually in May 1986.

I. Annual mean SO<sub>2</sub> concentrations (µg.cm<sup>-3</sup>), annual mean temperature (°C) and annual total precipitation (mm) at chosen stations HMI in the Jizerské hory Mts. during 1986 - 1989 (values according to measuring HMI)

Station	Height above sea level	SO <sub>2</sub> concentration in µg.m <sup>-3</sup>			
		1986	1987	1988	1989
Nové Město pod Smrkem	525 m	81	70	53	54
Hejnice	410 m	58	59	52	51
Bílý potok	505 m	50	50	47	39
Bedřichov	780 m	48	62	35	34
Annual mean temperature (°C)					
Nové Město pod Smrkem	525 m	7.13	6.03	7.70	8.80
Hejnice	410 m	7.66	6.90	8.50	9.10
Bedřichov	780 m	4.67	3.85	6.30	6.00
Annual total precipitation (mm)					
Nové Město pod Smrkem	525 m	1169	1128	1078	806
Hejnice	410 m	1064	999	1163	807
Bedřichov	780 m	1225	1281	1368	1042

Samples for leaf analysis were always taken from the 4th whorl in October. Mean samples were taken from each compartment. Analyses of needles were performed in HCl solution and analyses of soil samples in citric acid solution. Total nitrogen was evaluated by Kjehdahl method, phosphorus was measured spectrophotometrically in molybdosulphuric solution. The other cations were measured by AAS (L o m s k ý, 1985). The total sulphur content in the needles was determined spectrophotometrically after combustion of the sample on a platinum spiral in a test tube with 3 % H<sub>2</sub>O<sub>2</sub> under oxygen atmosphere. To estimate fluorine, an ion-selective electrode was used.

The measurement of stomatal conductivity (CD; cm.s<sup>-1</sup>) and transpiration rate (E; µg.cm<sup>-2</sup>.s<sup>-1</sup>) was carried out according to the methods recommended by the firm LICOR (Davenport 1978) using a portable porometer LICOR 1600 with the chamber for conifers.

During the last year of evaluation (1989), the activity of ribuloso-1,5-bisphosphate carboxylase (RuBPC) was determined twice, at the end of June and in October. Spruce shoots were excised under water and transported to the laboratory in vessels with water. The youngest needle year-class was homogenized and enzymes were extracted and measured using an adapted method after B e a d l e et al. (1983). Enzymatic activity in chloroplasts was related to the amount of chloroplast protein and thus expressed as specific activity. The amount of protein in chloroplasts was determined according to P o t t y (1969). Concentration of chlorophylls a, b was estimated spectrophotometrically in 80 % acetone extract after A r n o n (1949). The needles were dried at 60 °C and their dry matter was calculated. The content of total 80 % ethanol-soluble sugars was determined in dry matter according to S o m o g y i (1952). The content of malondialdehyde was estimated in the extract from dry needles (U h l í ř o v á, 1991). The annual height increment was always measured at the end of the growing season. The health condition of young-growth spruce stands was evaluated unpeatedly in 1989 by means of the method used by ICP Forests.

The results were statistically evaluated by Tukey-Scheffe test at  $P = 0.95$ .

## RESULTS AND DISCUSSION

### EFFECT OF PERFORMED FERTILIZATION ON SOIL

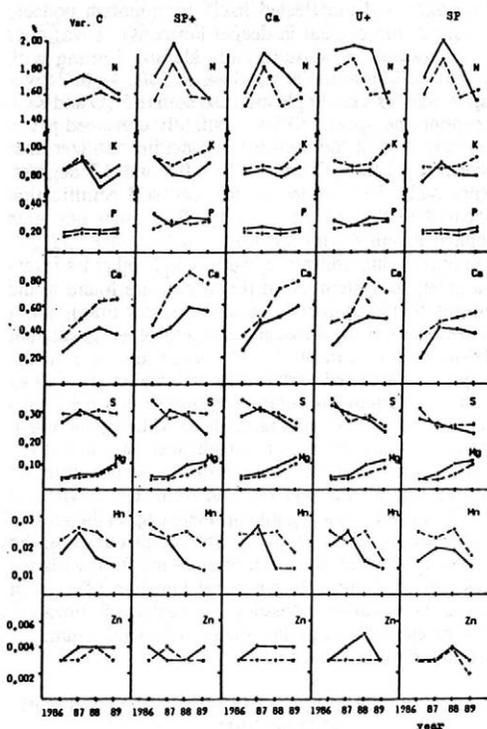
In the compartments, the forest soil had a low content of nitrogen and manifested itself as mountain podsole (enhanced iron content in deeper horizons). It was poor in magnesium, potassium, and calcium. Liming with micronized limestone (at the dose of 5000 kg.ha<sup>-1</sup>) was responsible for a slight pH increase both in H<sub>2</sub>O and KCl. Excepting the upper soil layer (slightly enhanced pH in comparison with the control), the acidic fertilizer urea decreased pH in H<sub>2</sub>O and KCl by 0.5 and 0.3 degrees, respectively. Even more pronounced soil acidification appeared in SP variant (Tab. II). The other nutrients supplied together with nitrogen (variants SP+ and U+) were mostly immobilized by humus and sod grass layers in a given ecosystem. No differences were found in the content of phosphorus, potassium and magnesium between the fertilized variants and control. Only calcium content increased in the limed variant and in both the completely fertilized variants. In this region, as well as in some German mountain regions (K a u p e n j o h a n et al., 1989), acid rain, photooxidants, and nitrogen deposits are the reason for changes in nutrient balance. These substances are probably responsible for leaching Mg, K, Ca, and Zn both from the crowns and soil. They can exert a negative influence upon the growth and health condition of spruce stands. In our case, the question is whether liberation of nutrients from withered grass can markedly affect mineral nutrition of a given site. So far it will be necessary to repeat the fertilization for research purposes giving attention to magnesium, potassium, and lime fertilizers.

### EFFECT OF FERTILIZATION ON STAND NUTRITION AND INCREMENT

When starting from the limiting values for nutrient deficiency determined by M a t e r n a (1964), the results of leaf analysis (Fig. 1) indicate that in the needles of all variants there was a sufficient nitrogen content. Due to this fact, statistically insignificant changes occurred after the application of nitrogenous fertilizers. Nitrogenous fertilizers increased the content of nitrogen in the first

II. Soil analyses (citric acid solution) of samples taken from sample plot

Variant	Depth (cm)	pH		C <sub>org</sub>	H	N <sub>t</sub>	P	Ca	Mg	K	Zn	Fe
		H <sub>2</sub> O	KCl									
C	humus	3.60	3.15	22.56	38.89	1.070	63	164	73	90	4.77	1005
	0-15	3.40	3.30	2.62	4.52	0.138	47	30	24	20	11.1	1054
	15-25	4.90	3.50	2.86	4.93	0.116	74	46	21	12	5.5	3217
	25-+	5.05	4.15	1.29	2.23	0.058	63	48	7	8	7.53	1016
SP+	humus	3.85	3.00	22.8	39.23	1.040	232	788	79	208	12.8	711
	0-15	3.85	3.00	3.13	5.39	0.143	56	122	17	42	3.8	1074
	15-25	4.15	3.35	2.8	4.82	0.143	42	134	17	67	2.8	3452
	25-+	4.45	3.95	1.43	2.48	0.057	41	45	6	62	5.7	879
Ca	humus	3.95	3.30	25.67	44.24	1.361	71	297	79	128	10.4	1793
	0-15	4.05	3.35	2.92	5.03	0.143	73	47	30	20	21.1	2051
	15-25	4.15	3.55	3.12	5.38	0.150	63	100	20	21	4.25	3310
	25-+	5.45	4.15	1.56	2.69	0.054	63	78	5	14	4.2	1081
U+	humus	3.95	3.20	17.22	26.69	0.930	89	433	95	128	9.88	856
	0-15	3.70	3.15	2.7	4.65	0.122	49	83	28	27	4.1	961
	15-25	4.00	3.30	2.78	4.79	0.123	47	93	33	30	4.4	2760
	25-+	4.60	3.90	1.12	1.94	0.055	51	24	10	26	5.61	1207
SP	humus	3.75	2.75	19.3	33.25	1.050	79	252	96	79	5.15	1357
	0-15	3.85	3.10	4.94	8.49	0.096	41	34	24	18	2.28	687
	15-25	4.05	3.45	2.33	4.00	0.216	70	60	40	30	2.5	1546
	25-+	3.70	3.00	1.63	3.53	0.098	67	46	26	18	3.05	2237



1. Element contents in needles. Affecting by fertilization  
 — current n.  
 - - - - one-year-old needle

needle-year class as early as 1986. Maximum values in the first needle-year class were attained in 1987 (SP - 2.00 %, SP+ - 1.98 %, U+ - 1.97 %). Likewise in 1988,

the variant U+ kept also equal nitrogen content while in the other variants the nitrogen content decreased. In 1989, N in all variants reached values near to those in the control variant (the values of about 1.60 %). Good and/or increasing nitrogen content in the soil and needles of the control variant might be influenced by deposition of nitrogenous compounds which ranged from 24 to 49 kg N.ha<sup>-1</sup>.year<sup>-1</sup> in this region (Š k o d a et al., 1985, 1988). After fertilization, the contents of Ca, K, P, and Zn in the needles increased and reached food levels and suitable interproportions. During the first two years following the application of fertilizers, magnesium was the only deficient element. It was true for both the fertilized and unfertilized variants. The limit of Mg deficiency as determined by foresters is 0.06 % (M a t e r n a, 1964). Nevertheless, it has been proved that it is approximately double the values of physiological minimum (P f a n z, B e y s c h l a g, 1990). The first needle-year class exhibited an improvement in nutrition by magnesium as late as 1988 (in completely fertilized and limed variants), in the second needle-year class, improvement appeared as late as 1989, i. e. three years after performed fertilization.

When evaluating the increment, three-year period is, however, a very short time to arise distinct statistically significant differences. Tab. III and Fig. 2 show annual increments both in absolute values and percentages of the control. The Figure indicates that over the period of 1987-1989 the increment increased in all variants (least in SP - 101 %, most in U+ and Ca - 105 and 106 %, respectively, as compared with the control). A positive action of urea is in accordance with the results of the experiments by L e d i n s k ý (1977) conducted in spruce seedlings. During the experiment, each variant responded to the fertilization at time in a different way. The variants U+ and Ca reached maximum in 1988 (111 and 110 %, respectively). The variants with ammonium nitrate (SP+ and SP) reached maximum as late as 1989 (107 and 104 %, respectively, when compared with the control). Urea is very well acceptable for tree species and exhibits

III. Annual height increment (cm) on sample plot during 1987 - 1989

Variants	C	SP+	Ca	U+	SP
Year / Increment (cm)					
1987	47.9	48.7	49.5	49.6	46.9
1988	42.1	41.9	46.0	46.8	41.6
1989	49.8	53.3	52.3	50.3	51.8
Σ	139.8	143.9	147.8	146.7	140.3

a rapid effect but shortly after application there is a danger of slow ripening of shoots associated with lower frost resistance in autumn (R y š k o v á, U h l í o v á, 1984).

EFFECT OF FERTILIZATION ON PHYSIOLOGICAL PROCESSES

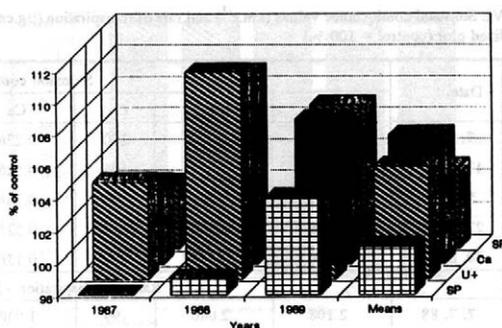
Since 1987, samplings of needles have been carried out each November to determine chlorophyll content (Tab. IV). As early as 1987, fertilization with nitrogen manifested itself by increased content of chlorophyll a and b in the variants SP+ and U+. In the subsequent year, only the variant U+ reached higher contents of the both chlorophylls than the control which corresponded to the course of N-content curve in a given variant. At evaluation in 1989, the variant U+ was found below the level of the control and was overtopped only by the variant SP+. These results are comparable with the published data (K o c h, 1986; L e w a n d o w s k a et al., 1976). The application of urea decreased the chlorophyll a/b ratio and influenced the synthesis of chlorophyll b, acted positively on the production of aerial chlorophyll system which could result in better utilization of incident radiation in the young-growth spruce stand.

IV. Chlorophyll a, b contents (mg.g<sup>-1</sup> fresh matter) in samples taken from unfertilized and fertilized plots in November

Year		Variants				
		C	SP+	Ca	U+	SP
1987	Chl a	1.065	1.128	1.092	1.194	1.080
	Chl b	0.252	0.281	0.269	0.306	0.246
	Ratio a/b	4.230	4.010	4.060	3.900	4.390
1988	Chl a	0.792	0.760	0.745	0.806	0.707
	Chl b	0.296	0.283	0.275	0.303	0.261
	Ratio a/b	2.680	2.690	2.710	2.660	2.710
1989	Chl a	0.748	0.800	0.742	0.719	0.748
	Chl b	0.288	0.313	0.269	0.281	0.275
	Ratio a/b	2.600	2.560	2.760	2.560	2.700

V. Values of relative air humidity (RH:%), air temperature (LT:°C) and light conditions (QU: μE.m<sup>-2</sup>.s<sup>-1</sup>) during measuring period

Plot	Smrčí cesta		
	RH	LT	QU
7. 9. 1988	46.8	19.4	635
17. 5. 1989	27.2	23.2	866
5. 6. 1989	36.4	19.3	750
27. 6. 1989	26.8	29.4	915
30. 8. 1989	51.6	12.5	548



2. Annual height increment on sample plot during 1986 - 1989

Other physiological measurements were conducted using a porometer LICOR 1600 direct in the field. Climatic conditions for individual measurements are given in Tab. V. Tab. VI presents the values of stomatal conductivity and transpiration rate. It follows from Tab. VI that maximum values of stomatal conductivity were attained in all variants under optimum temperature, humidity, and light conditions at the beginning of June 1989. The transpiration rate, as also reported by L a r c h e r (1988), decreased and increased with increasing temperature. The maximum values of transpiration rate were attained in the measurement at the end of June (from 9.6 to 12.4 μg H<sub>2</sub>O.cm<sup>-2</sup>.s<sup>-1</sup>). The lowest values were obtained at the end of August when the transpiration rate did not exceeded 1 μg H<sub>2</sub>O.cm<sup>-2</sup>.s<sup>-1</sup>.

The variant with liming, as the only at all measurements of stomatal conductivity, did not reach the level

of the control (81 - 96 %). The transpiration rate was the same and/or slightly exceeded the control at lower temperatures. Analogous course was exhibited in the urea-fertilized variant. Maximum conductivity was attained at the beginning of the growing season (112 % of the control), the subsequent values were lower than in the control variant. In this variant, the transpiration rate had never exceeded the control variant and ranged from 80 to 95 % of the control. Likewise, the variant SP did not reach the control values of the transpiration rate but the transpiration decrease was not so conspicuous as in the urea-ferti-

Date	Stomatal conductance - $\text{cm}^2 \cdot \text{s}^{-1}$ : (C = 100 %)								
	Var. C	SP+	(%)	Ca	(%)	U+	(%)	SP	(%)
7. 7. 88	0.238	0.239	100	0.226	95	0.219	92	0.238	100
17. 5. 89	0.546	0.573	105	0.526	96	0.614	112	0.616	113
5. 6. 89	0.841	0.809	96	0.764	91	0.776	92	0.749	89
27. 6. 89	0.649	0.676	104	0.523	81	0.592	91	0.680	105
30. 8. 89	0.146	0.178	122	0.138	95	0.111	76	0.093	64

Date	Rate of transpiration - $\mu\text{g} \cdot \text{cm}^{-2} \cdot \text{s}^{-1}$ : (C = 100 %)								
	Var. C	SP+	(%)	Ca	(%)	U+	(%)	SP	(%)
7. 7. 88	2.108	2.086	99	1.930	92	1.925	91	2.008	95
17. 5. 89	8.944	7.856	88	6.771	76	8.532	95	8.746	98
5. 6. 89	5.670	5.906	104	5.584	99	5.462	96	4.979	88
27. 6. 89	12.410	11.240	91	9.681	78	10.720	86	12.260	99
30. 8. 89	0.720	0.992	138	0.741	103	0.575	80	0.494	69

lized variant. The stomatal conductivity was by 13 and 5 % higher than in the control. During the first four measurements, the values of stomatal conductivity of the variant SP+ varied about these obtained in the control (96, 105 %). The maximum increase to 122 % was measured at the last measurement in August.

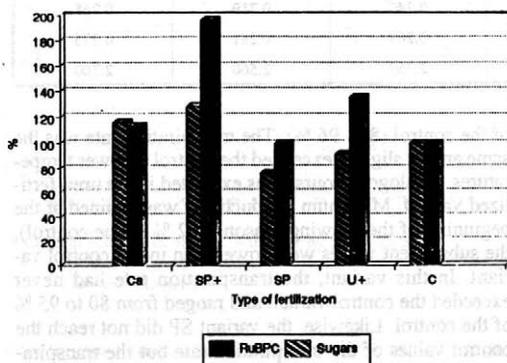
Similar course was exhibited in the values of transpiration rate. The differences attained were not statistically significant in this variant. Nevertheless, it can be stated that, equally to the previous paper (Marek, Lomský, 1988), ammonium nitrate free of an addition of fertilizers and urea with an addition of the other nutrients decreased transpiration in the young-growth spruce stand. During the growing season 1989, the authors of the present paper twice attempted to evaluate the growth processes from the biochemical point of view, namely at the end of June and at the end of October. The activity of ribuloso-1,5-bisphosphate carboxylase (RuBPC) and, simultaneously, the level of free saccharides in needles of the current year were measured.

Fig. 3 shows percentual expression of these values in fertilized spruce trees during the culmination of growing season as related to values estimated in the unfertilized variant (100 %). RuBPC activities, as well as levels of free saccharides were optimum during this period in ferti-

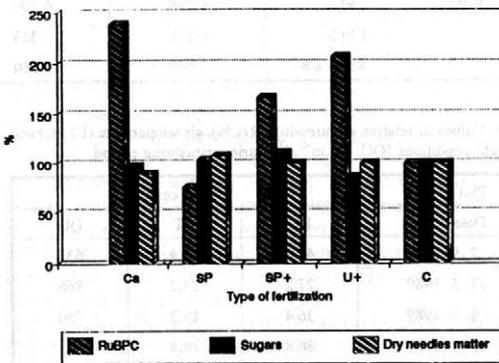
lization variants SP+ and Ca. In the variant U+, the RuBPC value increased in comparison with the control but the level of free saccharides in needles decreased. At the end of the growing season, the situation was evaluated from the point of view of the preparation of the assimilatory apparatus for the coming winter.

In addition to both the growth parameters, the third important parameter, dry matter of needles, was evaluated (Fig. 4). Higher RuBPC activity was not essential to such an extent, the level of free sugars and dry matter of needles as high as possible were of importance. These parameters were best fulfilled in the variants SP+ and SP. A relatively high RuBPC activity and simultaneously decreased content of free sugars in the variants Ca and U+ as compared with unfertilized control did not constitute a good precondition for the resistance to early autumn frosts. Sufficient supply of free sugars in assimilatory apparatuses is a necessary precondition of good resistance of tree species to HF effect (Garrec et al., 1981) and to the impact of acid fog and ozone (Elsner, Oswald, 1984; Dugger et al., 1962).

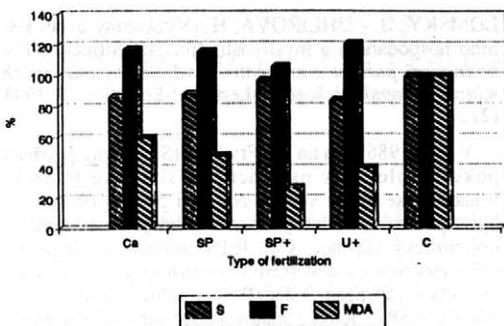
Comparison of accumulation of sulphur, fluorine, and malondialdehyde in the needles carried out at the same time (Fig. 5) confirmed a good resistance of spruces fertilized in the variant SP+. The uptake of sulphur decreased



3. Growth period



4. The end of growth period



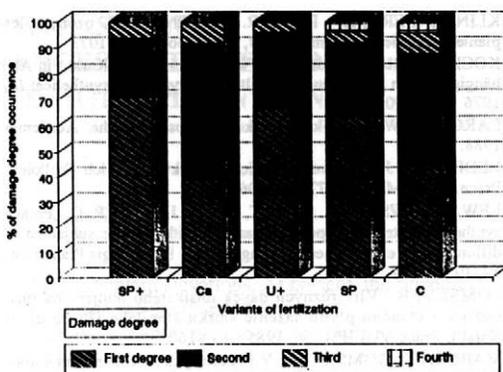
5. S, F, MDA accumulation in needles. Affecting by fertilization

in all fertilized variants while the uptake of fluorine was enhanced. Calcium and phosphate regimes of tree species exerted an influence on HF uptake. Phosphate was accepted by NaF-loaded tissues to a high extent. This uptake increased even more when the tree species was sufficiently supplied with calcium. According to it, a different resistance of plant species to fluorine pollutants could be derived on the basis of the interrelationship among F, Ca, and P (Penot, Diouris, 1984).

Fertilization has a favourable effect on suppression of peroxidation products in the needles, e.g. malondialdehyde. Production of MDA and probably other substances is closely associated with damage to the photosynthetic apparatus. According to Elstner, Oswald (1984), spruce trees responded to air pollutants by retarding the activity of the key enzyme RuBPC which fixed CO<sub>2</sub>. It resulted in depression of the photosynthetic uptake of light energy and increased electron transfer to molecular oxygen under the formation of superoxide radical. This radical can also arise by direct reaction of gaseous photooxidants with unsaturated bonds of membrane lipids and cuticular waxes as well as at radical oxidation of SO<sub>2</sub> to sulphate. These reactions resulted in consequent reactive compounds as hydrogen peroxide and products of peroxidation of lipids, for example MDA. Damage to the photosynthetic apparatus reduced the supply of carbohydrates, including free sugars, and thus limited the ability of plants to overcome undesirable influences as leaching of cations by acid fog, premature frost, etc. (Klinkenberg et al., 1988).

#### VISUAL EVALUATION OF HEALTH CONDITION

At the conclusion of the experiment in 1989, evaluation of the health state of young-growth spruce stands was performed, three years after the application of fertilizers according to the Methods of monitoring the forest state (VULHM-ICP). The results of evaluation of the health condition are presented in Fig. 6. Practically, none quite healthy tree was found in the given air polluted region. The health condition of nitrogen-fertilized variants was better (the degree 1 prevailed: SP+ - 71 %, U+ - 67 %) than in the control (45 %) and limed variant (39 %). Likewise, the 4th degree of damage appeared in the control and only nitrate-fertilized variants (4 % in both the cases).



6. The health state assessment

#### CONCLUSION

The results indicate that fertilization on the area Smrčica showed a positive but, from the point of view of short-term evaluation, statistically insignificant effect on growth processes in young-growth spruce stands for the time being. Only after four years following the application of fertilizers, an improvement appeared in mineral nutrition which exhibited an obvious deficiency in magnesium. From the point of view of long-term effect on spruce stands, fertilization with ammonium nitrate with limestone and addition of the other nutrient (SP+) seems to be the optimum. This variant of fertilization constitutes good preconditions for assimilation processes which are characterized by a high annual increment, relatively best health condition and low uptake of sulphur and aggressive fluorine from the atmosphere, and lowest formation of peroxidative products. This kind of fertilization may be recommended as a path to the improvement of health condition in young-growth spruce stands on the locality under investigation.

#### References

- ARNON, D. I.: Copper enzymes in isolated chloroplasts Polyphenol oxidase in *Betula vulgaris*. *Plant Physiology*, 24, 1949 : 1-15.
- BEADLE, C. L. - HART, J. W. - JARVIS, P. G.: The extraction and activity of carboxylases in Sitka spruce and some other conifers. *Photosynthetica*, 17, 1983 : 322-333.
- DAVENPORT, D. C.: Stomatal resistance from cuvette transpiration measurement. *Washington State University Bulletin*, 809, 1975 : 1-12.
- DUGGER, W. M. Jr. - TAYLOR, O. C. - CARDIFF, E. - THOMPSON, C. R.: Relationship between carbohydrate content and susceptibility of pinto plants of ozone damage. *Proc. Amer. Soc. Hort. Sci.*, 81, 1962 : 304-315.
- ELSTNER, E. F. - OSWALD, W.: Fichtensterben in „Reinluftgebieten“: Strukturresistenzverlust. *Naturwissenschaftliche Rundschau*, 37, 1984 : 52-61.
- GARREC, J. P. - PLEBIN, R. - AUDIN, M.: Effect of fluorine on the levels of free sugars and amino acids in the needles of fir (*Abies alba* Mill.). *Environmental Pollution*, 26, 1981, No. 4 : 281-295.
- KAUPENJOHANN, M. - ZECH, W. - HANTSCHHEL, R. - HORN, R. - SCHNEIDER, B. U.: Mineral nutrition of forest trees: A regional survey. In: SCHULZE, E. D. - LANGE, O. L. - OREN, R.: *Forest Decline and Air Pollution*. *Ecological Studies*, 77, Springer Verlag Berlin, 1989 : 282-296.

KLINKENBERG, H. - PAUL, R. - IMPENS, R.: L'ozone et les plantes. *Annales de Gembloux*, 94, 1988, No. 2 : 89-107.

KOCH, W.: Blattfarbstoffe von Fichte (*Picea abies* Karst.) in Abhängigkeit von Jahrgang, Blattalter und -typ. *Photosynthetica*, 10, 1976 : 280-290.

LARCHER, W.: Fyziologická ekologie rostlin. Praha, Academia 1988.

LEDINSKÝ, J.: Hnojení borovice a smrku v lesních školkách. *Práce VÚLHM*, 51, 1977 : 81-106.

LEWANDOWSKA, M. - HART, J. W. - JARVIS, P. G.: Photosynthetic electron transport in plants of Sitka spruce subjected to different light environments during growth. *Physiologia Plantarum*, 37, 1976 : 269-274.

LOMSKÝ, B.: Vliv různých dávek dusíkatého hnojení na růst, výživu a výměnu plynů sazenic smrku ztepilého (*Picea abies* Karst.). *Práce VÚLHM*, 66, 1985 : 137-160.

MAREK, M. - LOMSKÝ, B.: Vliv odlišných forem hnojení amonným dusíkem na fotosyntetickou produktivitu různých proveniencí smrku ztepilého. *Lesnictví*, 33, 1987, č. 2 : 109-120.

MATERNA, J.: Hnojení smrkových porostů. *Met. Zavád. Výsl. Výzk. Praxe, ÚVTI*, 19, 1964 : 1-21.

MOLDAN, B. et al.: Životní prostředí ČR. Praha, Academia 1990.

PENOT- DIOURIS in ARNDT, U.: Über die Wirkungen von Fluorimmissionen auf die Vegetation. *Haustechnik-Bauphysik-Umwelttechnik-Gesundheits-Ingenieur*, 105, 1984, No. 6 : 32-39.

PFANZ, H. - BEYSCHLAG, W.: Photosynthetic performance of Norway spruce in relation to the nutrient status of the needles. A study in the forest of the Ore mountains. Symposium: Research on Forest Decline in Eastern Central Europe and Bavaria, Passau, 13. - 15. 10. 1990.

POTTY, V. H.: Determination of protein in the presence of phenols and pectin. *Anal. Biochem.*, 29, 1969 : 535-539.

RYŠKOVÁ, L. - UHLÍŘOVÁ, H.: Mrazuvzdornost a hnojení smrku ztepilého. *Práce VÚLHM*, 65, 1984 : 147-172.

SOMOGYI, M.: Notes sugar determination. *Journal Biol. Chemistry*, 195, 1952 : 19-23.

ŠKODA, J. - NOVOTNÁ, H. - WEISS, A.: Výzkum kvality srážek na stanicích VÚV. [Závěrečná zpráva.] Praha, 1985.

ŠKODA, J. - NOVOTNÁ, H. - WEISS, A.: Výzkum kvality srážek na stanicích VÚV. [Závěrečná zpráva.] Praha, 1988.

UHLÍŘOVÁ, H.: Is it possible to use malondialdehyde content to damage assessment? IUFRO and ICP-Forests Workshop on Monitoring, Prachatice 2. - 6. 9., ČSFR 1991 : 233-235.

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LOMSKÝ, B. - UHLÍŘOVÁ, H. (Výzkumný ústav lesního hospodářství a myslivosti, Jiloviště-Strnady): *Vyhodnocení pokusu s hnojením a vápněním smrkových mlazin v Jizerských horách*. *Lesnictví-Forestry*, 39, 1993 (2) : 80-86.

V roce 1986 byla na LZ Frýdlant (Smědava) založena pokusná plocha v osmnáctileté smrkové mlazině v nadmořské výšce 880 m. Na dílčí plochy 10 x 10 m byly aplikovány následující varianty hnojení: mikromletý dolomitický vápenc (Ca), ledek amonný s vápencem (SP), močovina s dodatkem ostatních živin (U+), ledek amonný s vápencem s dodatkem ostatních živin - P, K, Mg a Ca (SP+). Kromě stanovení biometrických hodnot, rozborů půdy a jehličí se prováděla biochemická a fyziologická stanovení - obsah celkových volných cukrů, aktivity RuBPC, stanovení sušiny jehličí, akumulace S, F a malondialdehydu v jehličí, obsah chlorofylu, stomatární vodivost, rychlost transpirace a vizuální hodnocení zdravotního stavu podle stupně defoliace.

Půda chudá na Mg, Ca a K byla po aplikaci kompletního hnojení (SP+ a U+) obohacena o tyto prvky hlavně v organickém půdním horizontu. Po třech letech pokusu se hodnoty pH zvýšily o 0,3 - 0,6 jednotky ve srovnání s kontrolou (pH 3,4). Obsah dusíku v jehličí se před hnojením pohyboval těsně nad hranicí nedostatku (1,3 - 1,5 % sušiny jehličí), po aplikaci hnojiv dosahoval v prvních dvou letech obsah N až 2,00 %, nejrychleji reagovala varianta U+, nejdéle působila varianta SP+. Nedostatek hořčíku v jehličí byl plně saturován až po třech letech po aplikaci hnojiv. Výškový přírůst, stejně jako výsledky biochemických a fyziologických charakteristik, ukazují na optimální působení varianty hnojení SP+. Rovněž z hlediska vizuálního hodnocení zdravotního stavu mlazin se varianta hnojení SP+ projevila jako nejlepší.

smrkové mlaziny; hnojení; vápnění; biochemická a fyziologická stanovení; rozborů půdy; živiny

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# THE GROWTH OF DIFFERENT NORWAY SPRUCE [*PICEA ABIES* (L.) KARST.] PROVENANCES IN THE EXPOSED AIR POLLUTED REGION OF THE KRUŠNÉ HORY MOUNTAINS

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In 1976, an experimental provenance plot with Norway spruce was established, as a part of international experimental series, in ridge location of the Krušné hory Mountains near the Klíny settlement. The experiment was generally aimed at verification of the progeny of selected parent stands from the Hercyn-Sudeten region and followed the international inventory experiment IPTNS/IUFRO 1964/68 (Vinš, Vančura, 1983). The previous experiments with this most significant commercial species in our country have pointed out the importance of choosing suitable provenance not only with regard to the quality and quantity of wood production under different site conditions but also as related to the resistance to unfavorable environmental factors, including ecological changes induced by man-made activity. For these reasons, the aim of the research became not merely to estimate suitability of the provenances for different altitudinal forest zones and to verify the effect of genetically conditioned variability and environmental factors but also to experience convenient populations for air polluted regions. These problems were observed first of all on the Klíny locality which is highly exposed also from the climatic point of view.

spruce; provenances; air pollution

## MATERIAL AND METHODS

### THE PROVENANCES USED

The seed samples were collected over the years 1968 to 1972. They originated predominantly from the Hercyn-Sudeten region of spruce distribution. After completion of comparative origins from other regions, the experimental set was represented by 35, 12, 6, 5, 4, and 2 provenances from the CSFR, the former GDR, Poland, Byelorussia, Austria, and Bulgaria, respectively (the basic data on the provenances tested are given in Tab. I).

### BRIEF DESCRIPTION OF THE PLOT AND ARRANGEMENT OF THE EXPERIMENT

The experimental plot is situated on the transition between mountain acidophilous beechwoods and climax spruce stands near the mountain settlement Klíny in an extreme locality with high degree of pollution. The rough climate of the ridge location of the Krušné hory Mts. at an altitude of 820 m a.s.l. (mean annual temperature 5.6 °C, mean annual precipitation 860 mm) is marked still more by large-area deforestation. At the time of establishment of the plot, only dying spruce stands remained in the surroundings. At the end of the eighties, the forecast was fulfilled that the vitality of spruce stands was presumed for 30 to 40 years from the end of the 2nd World War when a more intensive anthropogenic pollution began. At the time of the preparation of the experiment, the average SO<sub>2</sub> concentrations were 0.059 mg.m<sup>-3</sup>

at these mountain elevations. At present, the surrounding older stands are degraded at all.

The experimental plot originated on the site of a former forest nursery. The soil was long-termly cultivated by ploughing and fertilization, including the application of herbicides. In spite of these measures, which might be applied at different intensity in individual parts of the plot, the cover was uncommonly homogenous and indicated no considerable soil differences at the time of forestation. The soil type was podzol, sandy loam soil with a low content of humus. The pH value varied between 4.2 to 4.5.

The arrangement of the plot was regular with square-shaped blocks of individual replications excepting the block 4 which had a shape of an elongated rectangle. 64 provenances of Norway spruce were planted on the plot according to the principle of 8 x 8 double grid in four replications. Each of 256 experimental subcompartments was sized 10 x 10 m, the total area of the plot was, consequently, 2.56 ha. The side-hole line planting was performed at 2 x 1 m spacing, i.e. that 50 trees were planted on one experimental subcompartment. In total, 12,800 seedlings were planted, the number of seedlings was 200 per one provenance.

### EVALUATION METHODS

The experimental plot at Klíny is a part of the international experimental series prepared in cooperation with IF Eberswalde. Likewise at present, coordination of research approaches and joint evaluation is secured with the Saxon Forestry Research Institute at Graupa (Weiss, 1988). The existing evaluation was based first of all on:

- estimation of survival rate and mortality and/or survival of tree seedlings on the experimental plot (inventory was made at 1- to 2-year intervals after planting),
- height measurements at 5, 10, and 15 years of age after planting and biometrical evaluation of data estimated and/or measurement of seedling heights in the nursery,
- evaluation of vitality estimated as a combination of the shape and colour of individual trees at the time of the first height measurement and/or estimation of the number of survived needle year-classes.

The survival rate was estimated by tree inventory in the autumn of the planting year, mortality was observed at one- to two-year intervals and/or in height measurements at later age.

The tree heights were measured by means of a lath with an accuracy of 1 cm up to ten years after planting, later with an accuracy of 5 cm.

When evaluating the differences in survival, height growth, etc., the method of variance analysis was used with estimations of significant differences by Scheffé's test. Furthermore, relative values of individual variables were

## I. Tested provenances and a survey of some results of their evaluation

Region	No.	Provenance No./Name	Evaluation 1981 - order			Height measurements H <sub>91</sub>		
			Survival S	Vitality V	Height H	Average height $\bar{x}$ (cm)	Standard deviation s	Order
Krušné hory Mts.	10	01 Nové Hamry	13	25	18	135.5	70.9	17
		02 Strádov	25	15	23	138.3	71.6	12
Šumava Mts.	21	03 Horní les	10	27	38	118.6	66.8	39
		04 Kvilda	32	40	33	95.6	56.8	60
		05 Ježová	14	21	55	135.9	65.2	14
		06 Černý KHŽ	54	36	54	126.1	63.7	30
Český les	37	07 Babylon	64	48	56	124.7	60.1	32
		08 Nová Huť	57	42	39	107.0	44.9	55
Brdy Mts.	37	09 Kokšín	39	22	34	128.9	66.9	24
Jizerské hory Mts.	39	10 Smédava	49	53	11	146.7	79.8	7
		11 Kateřinky	15	10	15	114.7	61.8	47
Krkonoše Mts.	39	12 Černá hora	23	16	9	123.2	68.2	34
		13 Černý důl	24	26	13	139.2	68.8	10
		14 Labská	34	8	5	154.9	69.6	3
		15 Rezek	9	9	1	126.6	68.1	28
Central Bohemian Uplands	41	16 Vodčeraď	26	37	50	118.6	65.1	40
		17 Jedlá	5	6	6	135.2	62.5	18
		18 Želivka	28	19	29	138.8	70.1	11
		19 Zbraslavice	45	31	37	120.6	67.2	37
Bohemian-Moravian Uplands	42	20 Svinošice	55	45	42	122.8	61.0	35
		21 Lísek	12	20	17	113.1	53.5	49
		22 Herálec	50	30	35	122.7	54.2	36
		23 Městec	62	55	2	158.7	69.8	2
Jeseniky Mts.	43	24 Devět Skal	16	2	21	119.1	52.8	38
		25 Vrbno	48	47	16	146.9	72.2	6
		26 Hubertov	2	5	26	126.2	63.2	29
Beskydy Mts.	45	27 Vidly	43	49	44	139.3	69.0	9
		28 Řečice	35	52	53	108.1	52.5	54
Low Tatras	47	29 Červená Skála	38	57	49	102.4	50.0	58
		30 Lipt. Mikuláš	30	41	32	109.9	48.6	53
High Tatras	48	31 T. Lomnica I	17	33	30	134.9	58.0	19
		32 T. Lomnica II	47	56	40	127.5	64.7	26
		33 T. Lomnica III	29	34	12	135.8	68.7	15
Orlické hory Mts.	64	34 Mladkov	56	60	25	132.2	73.2	21
		35 Říčky	27	18	7	139.5	66.3	8
Lausitz	09	36 Krauschwitz	31	46	31	111.4	64.7	52
Elbsandsteingebirge	09	37 Reinhardtsdorf	44	35	14	116.6	58.6	43
Erzgebirge	10	38 Schindelbach	21	32	24	132.0	68.4	22
		39 Brückenberg	51	50	36	86.2	48.4	63
		40 Gr. Mittweida	8	12	3	151.5	75.2	4
		41 Heinzebank	53	44	52	115.7	59.9	45
		42 Tellerhauser	6	14	10	117.3	57.7	42
		43 Rehefeld	20	24	22	128.3	56.2	25
Thuringian Forest	11	44 Alortal	36	54	41	113.0	62.6	50
		45 Katzhütte	42	51	47	116.1	69.4	44
		46 Gehlberg	33	29	19	113.7	59.8	48

Region	No.	Provenance No./Name	Evaluation 1981 - order			Height measurements H <sub>91</sub>		
			Survival S	Vitality V	Height H	Average height $\bar{x}$ (cm)	Standard deviation s	Order
Harz	11	47 Scharfenstein	1	1	4	169.4	72.5	1
	Alps	28	48 Matrei	41	59	58	87.0	46.1
30		49 Granitz	37	43	43	91.5	44.9	61
30		50 Fastenberg	18	39	48	125.7	67.8	31
32		51 Schneegatterm	61	64	61	105.8	51.0	56
Rodopi		56	52 Čepelare	19	4	62	103.9	51.9
Rila	56	53 Bistrica	4	7	8	137.3	64.8	13
Beskids	63	54 Istebna 345	40	38	27	127.2	58.7	27
		55 Istebna 667	63	62	64	84.7	33.9	64
Oder/Neisse	65	56 Brody	59	61	28	115.5	50.9	46
Maziria, the Baltic	67	57 Konstancjowo	46	58	59	129.3	57.9	23
		58 Ilawa	58	63	46	98.1	49.4	59
Byelorussian Uplands	68	59 Borki	7	17	20	124.2	71.3	33
	70	60 Krugoviči	3	3	45	132.6	66.3	20
		61 Bělověžeskaja	52	23	60	118.4	54.0	41
	75	62 Riskovskoje	11	13	57	151.0	71.6	5
		63 Červen	22	11	51	111.6	53.9	51
		64 VENDOROCH	60	28	63	135.7	69.7	16

used for the evaluation, usually related to the average value of the plot as 100 % (V a n ě u r a , 1985).

## RESULTS

### EVALUATION OF SURVIVAL RATE AND SURVIVAL

The survival rate and later the natural loss in the trees of the culture planted are important criteria for the evaluation of provenance suitability for a given site. This evaluation is very difficult and not quite reliable because the development of losses after planting is affected by a number of uncontrollable factors which can be eliminated from the evaluation only with difficulties. Nevertheless, the percentage of survived individuals may express a certain degree of adaptability and resistance of single provenances or trees to unfavourable conditions of a given environment (V i n š , 1990).

On the plot No. 15 - Klíny, the survival rate was influenced by the fact that planting had been performed on a plot of the former nursery. In the previous period, the treated soil and non-existence of heavy forest weed favourably influenced the development of losses so that after the first growing season they amounted to only 2.76 % of the trees planted while the losses averaged 7.75 % throughout the series of plots. This ratio was kept even the second year after planting when the losses increased to 4.83 % on the Klíny and they were still the lowest within the series of 9 experimental plots (Ø 17.44 %). Nevertheless, the pollution impact was gradually apparent and in 1981, at the first height measurements, the losses slightly exceeded the average of the experiment (29.60 % / 26.28 %) but the rest is considered to be „still surviving“, with regard to the total state. At that time,

only 56 % of surviving trees exhibited more than one needle year-class and at the end of 1981, 34 % of individuals had a character of vital healthy coloured trees unless their shrubby and umbrella-shaped growth was considered. During the following years, losses increased so that at the last height measurement (H<sub>91</sub>) only 5933 individuals were evaluated, i.e. 46.35 % of the originally planted.

In 1981, approximately a half of the provenances (33) exhibited higher survival than the average of the experiment. When considering this average as the base (100 %) for the expression of survival in relative values, the best results were shown in the provenances of both sides of the Krušné hory Mountains, the Krkonoše Mountains, the Harz, the Central Bohemian Uplands, the Ash Mountains but, above all, of the Baltic and, surprisingly, of the Bulgarian Rila and Pirin hills. The lowest losses were exhibited in the provenances 47 - Scharfenstein (9 %), 26 - Hubertov (14 %), 60 - Krugoviči (15 %), 53 - Bistrica (16 %), and 17 - Jedlá (17 %). The worst provenances, with high losses, were 23 - Městec (47 %), 55 - Istebna (51 %), and 07 - Babylon (52 %).

Tab. I presents the order of individual provenances according to survival (analogously for vitality and height) throughout the tested set during this youngest period, from which the losses did not usually increase essentially under normal development.

After ten years, the order of provenances virtually unchanged with regard to losses and/or survival, only in the permanently best provenances (47, 26, 60, 53, 17, 42, 59, 40, 15) the losses increased up to 11 to 16 %.

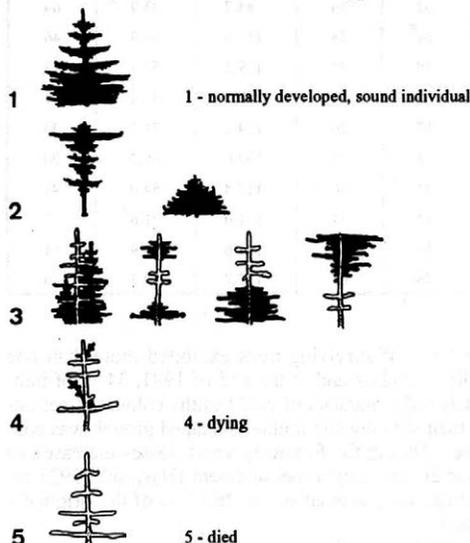
In comparison with the other plots of the total experimental series, a coincident classification among the best and worst provenances was exhibited only in the prov. 26 - Hubertov (+), and/or 56 - Brody and 64 - VENDOROCH (-).

When evaluating the survival using the variance analysis, it is true that statistically significant influence of the provenance on total variability in tree survival was determined throughout the experiment but, in accordance with the estimation of assumed effects of individual reasons for this variability, the highest portion came to uncontrolled factors and experimental errors.

During the last years, losses caused by red deer, which got into a fenced area, were observed in some cases.

### VITALITY

At the age of 5 years after planting, the vitality of trees was evaluated on the basis of their total appearance (9 subcategories). The colour of needles and number of needle year-classes of individual trees were additional indicators. Fig. 1 and 5 show the basic types of the shapes



1. The most frequent tree types on the experimental plot Klíny (vitality evaluation scale)

which occurred most frequently and, together with other above mentioned characteristics, served for estimation of the coefficients  $K_1$  and  $K_2$ .

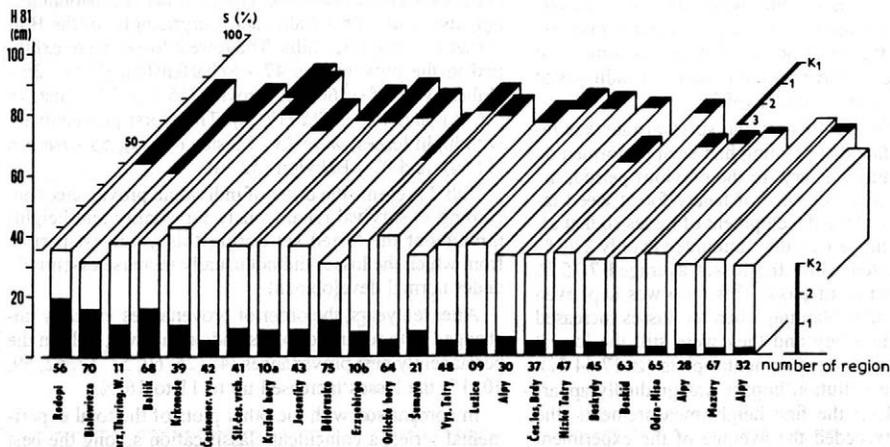
The vitality coefficients expressed the ratio of the frequencies of quite healthy („normal“ - 1) individuals to those died ( $K_1 = 1 : 5$ ); and/or of surviving individuals to dying and died ones ( $K_2 = 1$  to  $3 : 4$  and  $5$ ). The coefficients together with survival and height growth served then for the total evaluation of provenances from the point of view of their general growth abilities under given, very unfavourable, conditions.

The highest vitality was exhibited in the provenances No. 47 - Scharfenstein (up to 670 % of mean evaluation), 24 - Devět skal (391 %), 60 - Krugoviči (363 %), 52 - Čepelare (316 %), and 26 - Hubertov (247 %). The opposite end of the spectrum was represented by the provenances 55 - Istebna (14 %), 58 - Ilawa (14 %), and 51 - Schneeggatter from the Alps (16 %).

From the point of view of vitality of individual regions, the first places were occupied by the Bulgarian hills (56), Byelorussia (70), the Harz and the Thuringian Forest (11), the Bohemian-Moravian Uplands (42). The Alpine provenances (32), those of the Poland region Oder/Neisse (65), and the Baltic (67) were ranked among the worst. Fig. 2 provides graphical representation of evaluation of the regions where the data on survival and height growth are compared, as well.

### HEIGHT GROWTH

The first data on the growth in individual provenances were estimated as early as plant lifting at the Johanka nursery of the Kamenice n. L. Forest Enterprise where the planting stock was grown for the first part of the experimental series. The average height of 4-year-old seedlings (2/2) was  $34.3 \pm 0.5$  cm. Statistically significant differences were calculated in height growth among individual provenances (AnVa) already in the nursery. The greatest height was attained in the provenances 32 - Tatranská Lomnica, 54 and 55 - Istebna. The pronouncedly smallest height was showed in the provenances 26 - Hubertov, 16 - Voděrady, 42 - Tellerhauser, 45 - Katzhütte, and those of Byelorussia.



2. Average height of provenances, survival and vitality coefficients according to regions of origin

In 1981 height evaluation ( $H_{81}$ ), the tree heights ranged nearly at the similar level on the plot Klíny. The average height was 36.51 cm with the maximum of 50.69 cm (15 - Rezek) and minimum of 28.38 cm (55 - Istebna //).

The difference of individual replications compared to the average was -3.60 cm as a maximum, namely in the 3rd replication with the lowest average height. The height growth was very variable even within the scope of single experimental plots. The variation coefficients averaged 40.43 % within a range from 28.45 % (05 - Ježová) to 44.46 % (34 - Mladkov). When evaluating by the variance analysis, the result of  $F$ -test highly exceeded even 99 % probable accuracy ( $F = 17.35$ ) for the provenances. With regard to the fact that the  $F$  values for replications were equally significant, the effect of external conditions cannot be eliminated. Although in origin, the plot seemed homogenous, some spots free of vegetation appeared in its western part after forestation just in the 3rd replication. This probable result of using herbicides might have an effect upon the soil difference and consequential influencing the growth.

As on the majority of plots of the series, neither here the negative dependence of the height growth on the altitude above sea level of the original location of the provenance was conspicuous (correlative coefficient  $r = -0.189$ ). The decrease in the average height of progeny per each 100 metres of altitude was only 0.67 cm. Analogous negative relation was estimated between the height  $H_{81}$  and eastern geographical longitude. The average height of progeny decreased with its increasing value ( $r = -0.227$ ). A more pronounced regression relation was observed between the height of individual provenances and number of survived trees. The provenances in which lower losses were recorded were unambiguously higher ( $r = 0.422$ ).

In that period, the fastest growth was clearly exhibited in the provenance 15 - Rezek. Only the Krkonoše Mts. and/or the Jizerské hory Mts. provenances were evaluated as very fast-growing ones, all the others were classified to the category „average“ ( $\pm 5$  % of the average of the whole experiment) and slow-growing. The height growth of the provenances from single regions can be compared in Fig. 2; the order of provenances according to the height  $H_{81}$  is given in Tab. I. The slowest growth was exhibited in the provenance 55 - Istebna which was ranked among the best growing in evaluation in nursery as well as in height measurement  $H_{81}$  on the other plots of the series.

On the locality Klíny, the average height increased only by 88.51 cm over 10 years and it amounted to 125.09 cm in 1991. The following 7 provenances were evaluated as above-average very fast growing ones: 47 - Scharfenstein, 14 - Labská, 40 - Grosse Mittweida, 25 - Vrbno, 10 - Schindelbach, 23 - Městec, which was the only belonging to this category as early as its nursery

stage, and Byelorussian 62 - Riskovskoje. The worst growing were repeatedly 48 - Matrei, 51 - Schneegattern, 52 - Čepelare, and 55 - Istebna. This category involved no Byelorussian provenances which after initial slow growth began to get forward among those with better growth also on the other plots of the series.

The following Tab. II provides a survey of classification of provenances according to the height growth at the age of 20 years after sowing which was the basis for working out the cartogram in Fig. 3. The bold-faced numbers are related to those provenances which attained above-average values in all three height growth evaluations. The provenances which exhibited still increasing trend of the height growth are underlined. In the experiment there were 17 (26.5 %) such provenances altogether. In the same number of cases, an opposite decreasing trend was estimated and 30 (46.9 %) provenances altogether may be denoted variable from this point of view. The trend of development in the periods under study can be evaluated in Fig. 4 which represents the shift of average relative heights  $H_{76-91}$  of individual regions.

In 1991, the results of the two-factor variance analysis were analogous to those obtained in the first evaluation. The effect of replication on the variability of the height growth was rather less conspicuous but still statistically significant. Likewise, the effect of the provenance was evident even on 1 % significance limit.

#### Variance analysis - height $H_{91}$

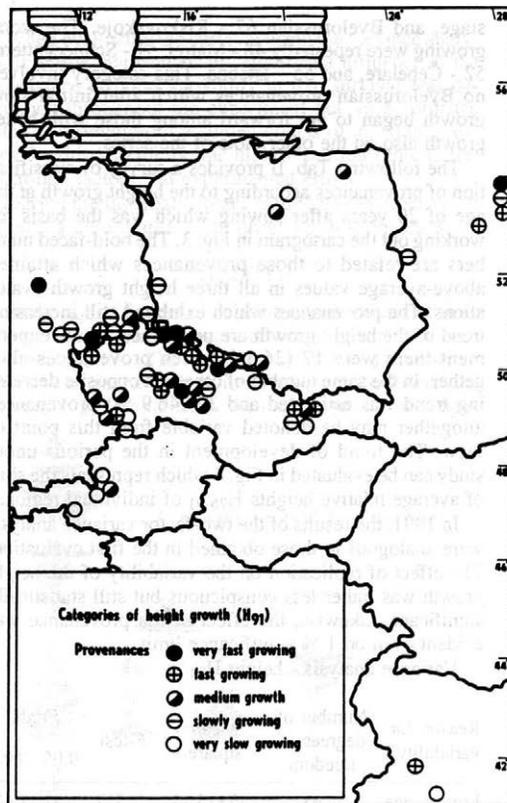
Reason for variability	Number of degrees of freedom	Mean square	$F$ -test	$F$ -tab.	
				0.05	0.01
Provenance	63	27325.12	7.537	1.31	1.45
Replication	3	103557.57	28.563	2.59	3.77
Interaction	189	12287.73	3.389	1.17	1.25
Residual	5677	3625.54			

## SUMMARY AND CONCLUSION

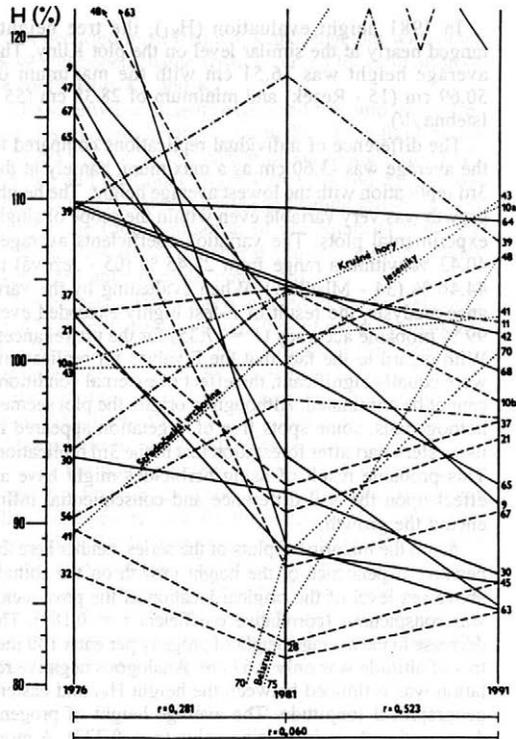
The experimental plot with different spruce provenances was established on a climatologically unfavourable and air polluted locality at the time when the stage of damage culmination was virtually finished and followed by the period of critical damage to forest stands in the region of the Krušné hory Mountains (S a m e k, 1990). At that time, it was already well-known that chronic spruce damage can be induced by as few as about 0.03 mg of mean annual  $SO_2$  concentration per  $m^3$  of air and therefore, spruce should be eliminated from regeneration of these ridge mountain localities. Nevertheless, the aim of the experiment briefly described here was,

## II. Provenance categories according to height growth ( $H_{91}$ )

Category	$H_{91}$	N	Nos. of provenances	
			Fast-growing	Slow-growing
Very fast-growing	115+	7	47 (23) (14) (40) (62) (25) (10)	
Fast-growing	105-	15	35 27 13 18 (02) 53 05 (33) 64 01 (17) 31 60 (34) (38)	
Average	95-	16	57 09 43 32 54 (15) 26 06 50 07 59 12 20 22 12 24	
Slow-growing	85-	17	03 16 61 42 37 45 41 56 11 46 21 44 63 36 30 28 08	
Very slow-growing	-84.9	9	51 52 29 58 04 49 48 39 55	



3. A cartogram of height growth categories (H<sub>91</sub>)



4. Height growth trend according to individual regions of origin

among others, to verify the applicability of some tested provenances in continuously air polluted region.

On the basis of the results of survival rate, development of losses, height growth and individual evaluation of single trees, different degree of variability in their resistance can be attributed to the provenances under investigation. It is a guarantee of the possibility of application of breeding principles to develop this property (Hynek, Frýdl, 1988).

During 16 years, on the experimental plot, the tested set of provenances was subjected to air pollution impact which multiplied the natural selection. Under these conditions, quite other provenances appeared to be better in some cases than on the other („unpolluted“) plots of the experimental series in the Czech Republic and Germany. It can be exemplified by the Polish provenance No. 55 - Istebna, evaluated also in other international experiments as highly productive, which ranked among the worst provenances on the above mentioned locality Klíny both from the point of view of the losses and height growth. Likewise, other usually fast-growing provenance 20 - Svinošice belonged only to the average here. The previous finding seems to be confirmed that the pollution resistance is related to the growth rate - slow-growing tree species or populations are more resistant.

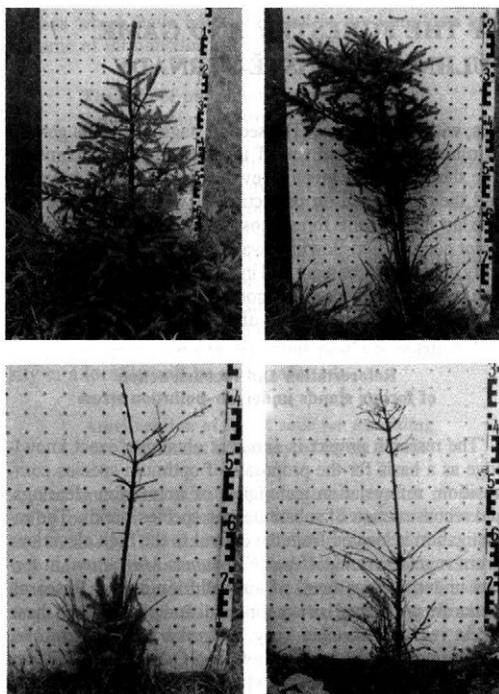
At present, on the basis of the results, the following provenances are considered relatively resistant and convenient for possible future use in breeding programs:

Provenance No.:	the Harz	reg. 11
47		
11 12 14 15	Jizerské hory Mts. Krkonoše Mts.	39
02 40 42	Krušné hory Mts.	10
52 53	Bulgarian hills	56
60 62 63	Byelorussia	70 75

Considering the results throughout the experimental series and evaluation from this air polluted locality, which indicate a wide ecovalency of the provenances from the Bohemian-Moravian Uplands (Nos. 21, 23, 24) and the Central Bohemian Uplands (Nos. 17, 18, 19), these can be designated quite universal.

Since in the present activities aimed at preservation of surviving tolerant genotypes, their rational utilization is of importance, it is necessary to focus our effort not only on possible reproduction and further verification of selected provenances but also on that of single vital trees for the sake of which, in a concrete case of the plot Klíny, the first silvicultural treatments should be conducted. Then the selected trees may be vegetatively propagated for further use either in the proper operational reforestation or for future breeding activity.

Simultaneously, the experimental plots of this series can be considered a possible source ensuring reproduction of some populations which do not reproduce or even



5. Different degrees of damage to ten-year-old spruce trees (Photo B. V i n š , 1981) - degree 1 to 4

do not exist due to unfavourable conditions (the Krušné hory Mts., Jizerské hory Mts., Krkonoše Mts.), and, at the same time, on the basis of the results obtained, they could have been of great use just in air polluted regions.

#### References

HYNEK, V. - FRÝDL, J.: Šlechtitelská opatření k záchraně a reprodukci genofondu smrku ztepilého z Krušných hor. Lesn. Práce, 67, 1988, č. 8 : 350-356.

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SAMEK, V. et al.: Příprava zalesňovacího materiálu pro imisní oblasti. Lesnický průvodce 4/1990, VÚLHM : 1-56.

ŠINDELÁŘ, J. et al.: Přehled výsledků výzkumu z oboru genetiky, šlechtění, introdukce lesních dřevin a lesního semenářství za období 1986-1990. Lesnický průvodce 2/1991, VÚLHM : 1-84.

VANČURA, K.: Přspěvek k výzkumu proměnlivosti smrku ztepilého. KDP, VÚLHM, 1985 : 112.

VINŠ, B. - VANČURA, K.: Čs. série srovnávacích výsadeb MPP se smrkem ztepilým ČSR-NDR 1972/76-77. [Závěrečná zpráva.] VÚLHM, 1983 : 65.

VINŠ, B.: Zhodnocení provenienčních ploch se smrkem ztepilým. [Závěrečná zpráva.] VÚLHM, 1990 : 33.

WEISS, M. et al.: Fichtenprovenienzversuche - Ergebnisse der gemeinsamen Versuchsauswertung. IFE 1988 : 8.

WENTZEL, K. F.: Gibt es immissionsfeste oder rauchharte Bäume? Forstarchiv, 35, 1964, č. 3 : 3.

Received 7. 7. 1992

VANČURA, K. (Výzkumný ústav lesního hospodářství a myslivosti, Jiloviště-Strnady): *Růst různých proveniencí smrku ztepilého [Picea abies (L.) Karst.] v exponované imisní oblasti Krušných hor.* Lesnictví-Forestry, 39, 1993 (2) : 87-93.

V roce 1976 byla jako součást mezinárodní pokusné série založena pokusná provenienční plocha se smrkem ztepilým v hřebenové poloze Krušných hor nedaleko osady Klíny. Pokus byl všeobecně zaměřen na ověření potomstev vybraných mateřských porostů z hercynsko-sudetské oblasti a navazoval na mezinárodní inventarizační pokus IPTNS/IUFRO 1964/68 (V i n š , V a n ě u r a , 1983). Předcházející pokusy s touto naší hospodářsky nejvýznamnější dřevinou poukázaly na význam volby vhodných proveniencí nejen s ohledem na kvalitu a kvantitu produkce dřeva v různých stanovištních podmínkách, ale i s ohledem na odolnost vůči nepříznivým faktorům prostředí včetně ekologických změn vyvolaných antropickou činností. Z těchto důvodů se cílem výzkumu stalo nejen zjištění vhodnosti proveniencí pro různé vegetační lesní stupně a ověření vlivu geneticky podmíněné proměnlivosti a faktorů prostředí, ale i vhodnosti dílčích populací pro imisní oblasti. Tato problematika je sledována především na lokalitě Klíny, která je i z hlediska klimatického velmi silně exponovaná.

smrk; provenience; imise

# SURVEY OF RESEARCH TASKS SOLVED BY THE FORESTRY AND GAME MANAGEMENT RESEARCH INSTITUTE (VÚLHM), JÍLOVIŠTĚ-STRNADY

## Alternative use of farm land for intensive silviculture

The intensive silviculture is considered as one of the alternative use of farm land released from food production. The principal objective of the proposed project is to select species and apply within species, namely clonal, selection with the main criteria of dendromass production and wood quality. Intensively cultivated plantations (short-term rotation stands), i.e. plantations for wood industry, energy purposes and paper and chemical industry. Following species will be used: poplars, willows, ash, alder, hybrid larch, walnut, black locust. Agroforestry system for the Czech Republic will be introduced.

## Growing of plant material for regions damaged with air-pollution

The aim of research is to improve the ways of raising high quality planting stock suitable for air-polluted regions. This task includes the whole process of cultivation, beginning from stimulation of germination, through growing practices to handling and assessment of plant physiological quality. The important problem included in solution is the detection of anatomical and genetical changes in seeds originated from air-polluted regions. Due to permanent insufficient quantity of seeds in polluted areas, technology of spruce and beech vegetative propagation become more important. Repeated evaluation of physiological condition during nursery cultivation, handling and after outplanting will enable to select the best practices and to raise plants the most suitable for specific sites in air-polluted regions.

## Increase of stability and production of forest stands by thinning

The subproject deals with the thinning in spruce and pine stands and in the stands of substitute tree species in air-polluted areas. Research is based on individual selection of more resistant trees and on improving of growing conditions for the individuals left after thinning. Results (mainly the data on dbh and height growth and defoliation variously tended forest stands) are collected on the network of 55 experimental series founded in all regions of the Czech Republic in last decades. Research is divided into three parts:

1. Thinning of spruce stands
2. Thinning of pine stands
3. Thinning of stands of substitute forest trees

The subproject is an integral part of the main project Stabilization and development of wood-producing and other functions of forests under the stress of industrial air-pollution.

## Management of positive effects of forest resources in landscape environment

The main aim of the research task is to evaluate water management functions of forest stand loaded by air pollutants with different intensity. The influence of damaged stands on water components and the impact of forest management especially on stand regeneration and tending processes are evaluated. The task is divided into four periods. The first one deals with water balance of different tree spe-

cies, with water regime. The second stage solves the genesis of runoff process and runoff in experimental catchments. The third period is given to evaluation of torrent trainings and their influence on protection of water and landscape. The last one presents forest ecosystem influence on chemical water composition flowing away to water sources in differently loaded environment and in different natural conditions. The results obtained will become the basis for conception of measures for arrangement of forest ecological functions.

## Reforestation and reconstruction of forests stands under air-pollution stress

The research project is aimed at obtaining exact knowledge as a basis for the proposals of optimum species composition, reforestation techniques of immission clearings, and reconstruction of substitute tree species stands. The investigation is located from the central to the high elevations (from vegetation zone *Abieto-Fagetum* to *Mughetum*) in forests under various level of air-pollution stress. Research works are performed on experimental and pilot plots in these forest regions: Krušné hory, Jizerské hory, Krkonoše, Podkrkonoší, Sudetské Mezihofí, and Orlické hory. The research project is divided into 6 parts.: „Development of local and introduced tree species under immission stress as a basic information for reforestation of air-polluted areas“, „Immission tolerance testing of tree species“, „Applicability of autochthonous tree species and their varieties in the mountains“, „Reforestation techniques of calamity clearings“, „Reconstruction of substitute tree species stands“, and „Regeneration felling ecology“. From a view-point of cooperation, the research project is a part of the complex research project „Stabilization and development wood-producing and other functions of forests under industrial air-pollution stress“.

## Introduction of forest tree species (Biology and breeding of introduced tree species)

Research project is divided into four independent stages. These stages follow directly from the accepted branch research project of 1992. As for the goal of this project, there is an effort to preserve and reproduce our forest stands of the first - quality and individuals by means of establishing seedling - seed orchards, saying in other words, to eliminate the influence of incompatibility by means of rooted cuttings. The IUFRO international provenance test assessment should contribute in the case of Douglas fir as well as in the case of other species of genus *Abies* to more precise information, concerning the growth and progress of tested forest tree species in our conditions. There is the goal to obtain a necessary information for the choice of suitable provenances and for seed zoning. Testing of species of the genus *Pine* (*P. contorta*, *P. peuce*, *P. strobus*, *P. nigra*, *P. strobiformis*, etc.) has a similar goal. As for the main reason of testing, there is in this case founding of varieties which would be suitable for reforestation of some extreme areas, e.g. the coal-mine spoils, extent clearings of air-polluted regions, or the extreme arid sites. The goal of testing of cedars, hemlocks and giant sequoia is concerning the extension of the experience (which is quite insufficient for a while) with some forest tree

species which have been proposed in the long-time programme of introduction for our conditions.

#### **The role of pheromone traps in reducing the population density of *Ips typographus***

This project includes solving some basic problems which refer to the system of control measurements against *Ips typographus*, based on using pheromone traps. Although the application of pheromone traps is a common part of used control measurements, from some points of view their role in the whole system is not clear up to now. In this project the effectiveness of their application and their role in the regulation of pest's population will be evaluated. Possibility of using pheromone traps to determine pest's population density in a locality will be also evaluated.

#### **Amelioration of forest soils for amending the functional efficiency of forest stands**

The immission disaster has negative impacts on forest soil productivity. Immissions affects forest lands directly and indirectly. The direct impacts are represented by changing the soil chemistry, the indirect impacts are represented by using the extended salvage clearcuts with lots of bad effects on forest plots. Solving the partial project Amelioration of forest soils for amending the functional efficiency of forest stands includes:

- study of soil-forming processes on forest soils conditioned by man's activity,
- study of immission effects on nutrition deterioration and healthy stage of tree species,
- study of biomass removing during harvesting on soil productivity and possibilities of using the slash for amending the forest soils,
- solving problems pertaining to ameliorative liming on forests and on cutover, s,
- improving the healthy stage and growth of forest stands by mineral fertilization,
- treatment of soil water regime,
- hindering from logging, preparation and water erosion with preventive and amending treatments,
- sustaining the soil productivity in forest nurseries.

#### **Stabilization and development of wood-producing and other functions of forests under the stress of industrial air-pollution**

The project deals with the most important silvicultural problems connected with the air-pollution stress with respect to forest ecology. The research is based on interdisciplinary collaboration between silviculture and forest ecology and is divided into five thematic groups: afforestation and reconstruction of forest stands, rising of forest plants for air-polluted areas, amelioration of forest soils with injured chemistry, increasing of stability and production by thinning and providing the positive hydric influence of forests.

#### **Phytopathological and mycological aspects of the monitoring of forest health state under air-pollution impact**

Phytopathological and mycological approaches are considered as inevitable constituents of any monitoring activity in air-polluted forest areas. They enable to diagnose latent stages of disturbance of forest stability and to prepare prognoses for recent processes of forest extermination. Data ob-

tained from the phytopathological and mycological monitoring give a possibility to analyze local correlations between biotic and abiotic components of forest ecosystems influenced by air pollution, inclusive of a capability of bioindicators sensitive or tolerant to the air pollution.

#### **The control of diseases of seeds and seedlings in forest nurseries**

In the Czech Republic there is a considerable lack of manual for nursery managers helping them in identifying reliably most of the important damaging agents and to use in this way appropriate control methods and reduce pesticides impact on the environment.

Objectives of this proposal are as follows:

- to introduce Integrated Pest Management approach and by this way to reduce the use of chemicals in forest nurseries,
- to improve disease control of reproductive materials and subsequently the quality of forest nursery production,
- to increase forest nursery production by using appropriate storage and presowing pretreatment,
- monitoring of pests and diseases in Czech forest nurseries,
- to collect informations and materials for production of a practical handbook enabling the nursery managers to identify more exactly the important damaging agents of forest reproductive materials,
- prepare a basis for a future Expert System having the same goal as the handbook for the nursery growers.

#### **Breeding of domestic coniferous tree species**

The coniferous tree species are the most economically important species in the conditions of the Czech Republic. For this reason the great attention had been devoted to it also in the past. These coniferous tree species are very endangered by the industrial immissions nowadays. So the breeding of domestic forest tree species follows up the works carried out in the frame of permanent research sites assessment. The goal of this research is concerning the extension of current knowledge of variability of populations of domestic coniferous tree species and the use of this knowledge in solving the task concerning keeping up of all current forest functions (wood-producing functions and mainly non-wood-producing functions) in the frame of the ecological conditions which have been changing. The breeding programmes present practical result of this research, which can be used by all forest owners.

#### **Broadleaved tree breeding**

The presented project includes phenotypic variability studies, evaluation of already established provenance trials, establishment of new plots and selection of clonal varieties for some broadleaved forest trees. The following species are included: beech (*Fagus sylvatica*), oak (*Quercus robur* and *Q. petraea*), ash (*Fraxinus excelsior* and *F. angustifolia*), poplars (*Populus* sp.) and birch (*Betula verrucosa*). The main objective is natural reproductive resources and the production of new varieties both clonal and seed orchard ones. Besides wood production, gene conservation approach is applied.

#### **New methods of control of spruce stands against *Cephalcia abietis* and monitoring of its populations**

This research includes new possibilities of ecological control of the spruce web-spinning larch sawfly's popula-

tions and also the monitoring of its natural enemies (parasites). It means entomopathogenic organisms and their possible using against this pest also in reservations and water sources regions. The monitoring of natural enemies (parasites) would be aimed at using new acquaintances in practice mainly the percentage of larval parasitism and the prognosis of female's fertility of this pest.

#### Research of biotechnological methods in forest protection

The development and operational implementation of biological forest protection practices as an alternative to the use of chemicals has been identified as a priority by the Ministry of Agriculture as well as the Ministry of Environment in the Czech Republic.

Insect viruses are highly effective biological agents for insect control. Forestry Canada in conjunction with academic and industry scientists has developed several forest pest viruses to the production and application stage. High education levels, couples with the traditionally labour intensive methods of forest management in Czech Republic represent a good milieu for the establishment of virus production facilities and control programmes.

The technical programme involve three phases! Training in Canada of three personnel establishment in Czech Republic a pilot production facility for one or more selected insect viruses and demonstration and testing of virus. Duration - 1993 - 1994. Canadian specialist will be available for advice and consultation and consultation as required.

In the Czech Republic the problem of the calamity occurrence of *Ips typographus* is more important with respect to the occurrence of two to three generations per year. We were concentrated on testing various methods of the adjustment of pheromone mixtures into pheromone dispensers.

#### Forest valuation

The methodology of valuation of forest land, forest stands, damages to forests and their indemnification and compensation both for productive and non-productive forest functions has been worked out. Results will be used for:

1. amendment of current inconvenient valid legislation,
2. practical expert activity (study m, coursed),
3. use in economic branches related (system of taxes and subsidies, economic regionalization of forests, economic management, etc.).

Current materials for amendment of legislation of forests stands valuation according to age value factors and for differentiation of forest land prices are prepared.

#### The prognosis and the conception of forest management and forest policy

The prognoses are an integral part of the forestry management. It is not possible to manage an intricate phenomenon in dynamic conditions without knowing the consequences of the decisions made. It is obligated to know what measures are needed to get things on the right way. Prognosis should be alternative so there are scenarios for different circumstances. Models of different level and type are used for this purposes. An intention of the prognosis is not to be exact but to help to reach the aim-sustainable forest management. The target is now very difficult to reach because of getting worse and worse ecological conditions.

#### The oak and other trees decline in forests with symptoms of the tracheomycosis

Problems of oak and other trees decline with symptoms of the tracheomycosis is solved in view of its phytopathological and ecological aspects. This multi-year complex project is to recover the significance of particular biotic and abiotic factors and their interactions for the forest health deterioration. Only on this basis, both preventive and protective measures can be proposed with the aim to stop negative trends.

#### Influence monitoring of ecological changes on game and preservation of gene resources and valuable population

The object of the solution is more deep knowledge of current ecological situation and its development. Methodologically all works are aimed at obtained information usable in creation and protection of environment, preservation of different game species and rational use of natural sources.

We have a lot of information at disposal, classification, their final experimental approval and synthesis according the methodology will be realized in 1993.

#### Application of biotechnology in breeding of forest trees

##### Aims of the project:

The elaboration of suitable methods for the rapid clonal multiplication of important forest trees by means of the organogenesis and somatic embryogenesis with the purpose to preserve genetic resources of the valuable tree populations.

To create a strategy of the long-lasting preservation of threatened genotypes.

The introduction of genetic engineering technology for transgenic forest trees with increased resistance to pollution.

#### Experimental methods in breeding of forest trees especially for polluted areas

The main result of this project is the technology of clonal breeding for selected forest trees. Methodological steps are as follows: Induction of axillary or adventitious buds on primary explant in aseptic conditions *in vitro*. The roots formation of growing shoots in a nonsterile substrate. Acclimatization of full plantlets.

#### Monitoring the influence of liming and liquid fertilization on mycorrhizal conditions in spruce forests in Krkonoše Mts.

The influence of liming and Nitromag application on mycorrhizal conditions and ectotrophic forest stability are observed and evaluated in permanent plots in spruce forests in the Krkonoše Mts. Some preliminary results demonstrated that while the nitrogen application caused a strong loss of the species diversity of ectomycorrhizal fungi, corresponding to the lethal stage of disturbance of ectotrophic forest stability, the limestone application surprisingly caused a slight increase in the percentage of ectomycorrhizal species, indicating a trend to the reinforcement of the ectotrophic stability.

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**P o d r á z s k ý V.:** Krátkodobé účinky vápnění v extrémních imisně ekologických podmínkách Orlických hor – Short-term effects of liming in extreme immission and site conditions of the Orlické hory Mts.

**Š i n d e l á ř J.:** Nové poznatky o variabilitě růstových a morfologických vlastností borovice lesní (*Pinus sylvestris* L.) – Recent information on the variability of growth and morphological characteristics of Scots pine (*Pinus sylvestris* L.)

**P e t r á š R., N o c i a r V., P a j t í k J.:** Changes in increment of spruce damaged by air pollution – Prírastkové zmeny smreka poškozeného imisiami

**V r e š t i a k P.:** Vývoj listovej fytohmoty bresta horského (*Ulmus montana* Stok.) – Leaf phytomass development of wych elm (*Ulmus montana* Stok.)

**U r b a n J.:** Výskyt a vývoj pilatky *Nematus (Pteronidea) melanaspis* Htg. (*Tenthredinidae*, *Hymenoptera*) na vrbách pěstovaných na plantážích na Moravě – The occurrence and development of the sawfly *Nematus (Pteronidea) melanaspis* Htg. (*Tenthredinidae*, *Hymenoptera*) in willows grown in plantations in Moravia

**M a d ě r a P., K u l a E.:** Poznámky ke kontrole píďalky podzimní (*Operophtera brumata* L.) – Comments on the control of winter moth (*Operophtera brumata* L.)

**K o n o p k a J.:** Effect of felling intensity on static stability of spruce stand under the impact of remote transport pollutants – Vplyv intenzity ťažbového zásahu na statickú stabilitu smrekového porastu pod vplyvom imisií z diaľkového prenosu

**Š i š á k L.:** Ochota potenciálně platit jako metoda oceňování významu sociálních stránek funkcí lesa – Willingness to pay potentially as a method of evaluation of the importance of social benefits of the forest

**Č e r n ý Z., N e r u d a J., U l r i c h R.:** Evaluation of functional parameters of working organs of brush cutters – Posouzení řezných vlastností pilových kotoučů křovinořezů