Analysis of the health condition and the abiotic environment of forest stands in the territory of the Jizerské hory Mts, Czech Republic

Pavel Hadaš

Department of Forest Ecology, Faculty of Forestry and Wood Technology, Mendel University in Brno, Zemědělská 3, 613 00 Brno, Czech Republic,
e-mail: pavel.hadas@email.cz

Abstract

Hadaš, P. 2012. Analysis of the health condition and the abiotic environment of forest stands in the territory of the Jizerské hory Mts, Czech Republic. *Folia oecol.*, 39: 1–9.

The paper sets out to analyse the causality of the abiotic environment and health condition of forest stands for the territory of the Jizerské hory Mts natural forest region (hereinafter NFR). To reach an understanding of the potential impact of SO_2 and NO_x pollutants and climate stressors on forest ecosystems, a considerable amount of data on the abiotic environment needs to be acquired, also for territory in which such measurements of the data have not been made. This is why the data on temperature conditions, water balance, solar radiation, ozone concentrations and deposition flows of sulphur, nitrogen and hydrogen ions were derived through model applications and interpolation techniques. Geostatistical methods should be used instead based on the application of multidimensional methods. The health condition analysis of the forest stands (as manifested by defoliation) and parameters of the forest stands' abiotic environment is carried out by applying simple and multidimensional regression and correlation analyses. The cluster analysis helped determine spatial distribution of five areas of potential disposition to the damage of forest stands. The results of a multiple correlation and regression for each potential disposition area were put together to form a model explicating the forest stands defoliation status.

Key words

areas of potential disposition to forest stands damage, defoliation, climatic stress, depositions of sulphur, nitrogen and hydrogen ions, regression and cluster analyses

Introduction

The paper sets itself the task of analysing the chain of causation for the abiotic environment and health condition of forest stands in the territory of the NFR Jizerské hory Mts. The analysis rests on the hypothesis asserting that change in health condition is induced by depletion of the resistance potential of forest stands so that even the present air pollution load in the form of atmospheric sulphur and nitrogen depositions combined with climate extremes (changes in temperature and moisture regimes) and the ground (tropospheric) ozone leads to their damage (Hadaš, 2007). The resistance potential of forest stands was defined by way of the critical loads of acidic depositions and depositions of nitrogen. Atmospheric sulphur and nitrogen depositions are still among the accelerators of acidification processes in the forest soil. Acidification is slower but it has not been stopped. Critical doses of sulphur and nitrogen are exceeded on many monitored sites not only in the territory of the Czech Republic. Apart from its acidification, the forest soil is equally subject to eutrophication evoked by the entry of nitrogen.

Direct and indirect influences of the polluted atmosphere on the forest ecosystem depend on a complex of variables, including exposure intensity, conditions of abiotic and biotic environments as well as on the connatural sensitivity of the affected populations, species and societies. In order to reach an understanding of a potential impact of the SO_2 and NO_x pollutants and of climate stressors on forest ecosystems, a considerable amount of data on the abiotic environment has to be acquired also for the territory in which such data measurements do not take place. Data regarding temperature conditions, moisture balance, solar radiation, ozone concentrations, deposition flows of sulphur, nitrogen and hydrogen ions were thus derived by way of model application and interpolation techniques.

It is assumed in the undertaken analysis that the main carrier of air pollution stress inducing forest stand damage are sulphur and nitrogen deposition flows – or potentially their acidic depositions intercepted by the earth surface or by the stand. It is further assumed that extreme climatic conditions and deposition flows within the framework of their synergic effect disturb the course of physiological processes (metabolism, photosynthesis), water balance and balance of substances (Ulrich, 1987), transpiration, phenophase, nutrition uptake by roots (Mauer and Palátová, 2001) etc., which adversely reflect in the health condition of the crown. A change in the health status of trees crowns is assessed according to the loss of the assimilatory organs, i.e. defoliation.

Material and methods

The used methodology compares the derived values of the sulphur and nitrogen deposition flows and acidic depositions both above the forest stand and therein with the values of their critical doses. It also assesses the temperature conditions in terms of frost shock, moisture conditions in respect of water balance and effects of ozone immission load in relation to moisture conditions of the environment and the condition of the ozone layer in the stratosphere. The derived data represent climate and air pollution stress and figure as independent variables in the analysis of the causal relationship between the abiotic environment and forest stands health condition. The analysis simultaneously aims at defining and delimiting the areas of potential disposition to forest stand damage in NFR 21 Jizerské hory Mts.

Common analytical and statistical procedures cannot be applied on processing multidimensional data levels. Geostatistical methods need be used instead based on the application of multidimensional methods (Türk et al., 2001). While analysing relationships or processes in a heterogeneous set of data, the so-called "data levels classification" must be applied in addition to correlation and regression analyses. The classification appears to be an efficient tool for studying internal heterogeneity of data sets while searching for inherent laws of natural processes and phenomena. It makes it possible to process a considerable amount of information and allows for its presentation in a compact and comprehensible form. The classification does not merely provide generalizing information on the surveyed amount of objects and phenomena but it also helps to reveal new, previously hidden patterns.

Forest ecosystem classifications have been used fairly intensively in Germany for over 45 years (Barnes, 1984). In Canada and Australia, classification procedures suitable for extensive areas have been developed and implemented (Hills, 1960; Rowe, 1978). The ecological-climatic classification based on a combination of results from cluster and discriminant analyses was studied by Denton and Barnes (1988). Cluster analysis methods have developed from the needs for analysing and appropriately concentrating the information contained in the multidimensional data characterized by very high heterogeneity. Generally, the cluster analysis situation can be characterized as follows: We have "n" objects. "P" characteristics (properties) are measured or observed on each object so that we acquire "n" p-dimensional vectors X_1, X_2, ... X_n.

Three basic types of cluster construction types can be distinguished with the used cluster methods – parallel, sequential and hierarchic methods (Filáček et al., 1977). In this study, we applied the hierarchic method since there is some previous experience therewith (Hadaš, 1991). In the hierarchic methods of clustering, a sequence $S^{(t)}$ (t = 1, 2, ….. K) is being created of decompositions of the X set of objects with the specification that the S(t) decomposition constitutes a refining of $S^{(t')}$ decompositions for $t < t'$, $(t, t' = 1, 2, ...K)$. When the variables are selected and ordered into a matrix that describes the characteristics of the cluster objects, the first step in the implementation of the cluster algorithm is the evaluation method for the distance or similarity of objects. The calculation of the distance rate between the individual objects can be performed using Minkowski, Hemming, Euclid, Mahalanobis or Chebyshev metrics (Hebák and Hustopecký, 1987). Hemming metric was used to identify and classify larger and smaller units (areas, sub-areas) in terms of similarity rate for the surveyed area of the Jizerské hory Mts by cluster analysis. The clustering process was realized by the method of the furthest neighbour method.

The forest stands health condition (as manifested by defoliation) and the abiotic environment parameters were further analysed by applying the simple and multidimensional regression and correlation analyses to the formed clusters (areas). The aim of this stage of the analysis is to determine the impact rate of the individual factors and to define the regression model.

The potential deposition flows of sulphur and nitrogen, and the acidic depositions of hydrogen ions are calculated based on gaseous concentrations of SO_2, NO_x, (as NO and NO_2) and their dry and wet deposition flows. Calculation of the immission concentrations for SO_2 and NO_x is realized on the basis of Gaussian dispersion model (SYMOS 97, Bubník et al., 1998). The overall 2001 sums of SO_2 and NO_x emissions and the number of emission sources for the individual groups or states that were used in the model calculation of deposition flows of sulphur and nitrogen and of acid H^+ deposition are listed in Table 1. Total SO_2 emissions used in the model calculation reach 9.017 million tons and the total sum of NO_x emissions amounts to 7.016 million tons. The Czech Republic's share accounts for 0.2487 million tons of SO_2, i.e. 2.76% of the overall emission volume of SO_2, and 0.2934 million tons of NO_x, which constitutes 4.18% out of the used NO_x emission amount.

Dry depositions of sulphur and nitrogen are calculated based on the deposition rates acquired by means of the resistance model according to the procedure of BAER and NESTER (1988). The calculation of wet deposition of sulphur and nitrogen proceeds from parametrization used in the MESOPUFF II model. The model calculation uses concrete measured data (emissions, technical parameters of the emission sources, concentrations of pollutants, air temperature, atmospheric precipitation, wind direction and velocity) and mathematical approximations of indirect derivation of these parameters for the locations without measurements. Linear multiple regression and interpolation methods are applied (e.g. orographic, Lagrange interpolation). The components of solar radiation and parameters for the water balance calculation were likewise derived using a model calculation. Total precipitation amounts and immission ozone concentrations were inferred on the basis of orographic interpolation and the ozone layer thickness through interpolation grounded on inversion distances. The calculations for 2001 were made in a lattice of 1,642 grids. The location of the Jizerské hory Mts is shown in Fig. 1. For a detailed description of partial methodological procedures refer to dissertation work published by HADAŠ (2009).

Table 1. Total SO_2 and NO_x sums used in the dispersion model for the year 2001

Group / Country	SO_2		NO_x	
	Tons a year^{-1}	Number	Tons a year^{-1}	Number
REZZO 1 (CZ)	193,177.2	3,704	145,849.1	3,704
REZZO 2, 3 (CZ)	55,557.0	7,232	18,134.0	7,226
REZZO 4 (CZ)	–	–	129,434.4	4,941
Germany	1,153,519.0	540	1,593,601.9	436
Poland	1,551,132.1	307	871,705.7	308
Slovakia	112,256.1	632	110,597.9	636
Austria	40,629.9	157	190,942.0	157
Hungary	451,372.3	61	194,636.4	61
Other (the Ukraine, Denmark, Belgium, Italy, France etc.)	5,460,155.0	1,521	3,761,159.3	1,519
Total	9,017,798.7	14,154	7,016,060.4	18,988

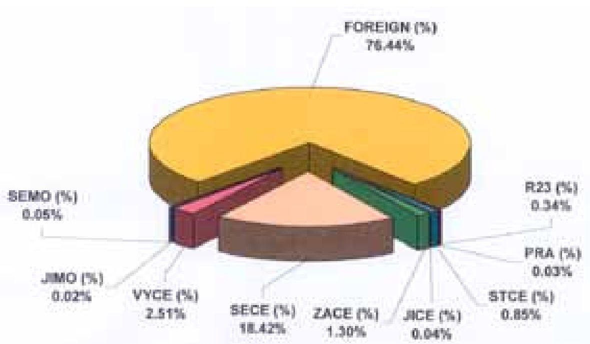
REZZO, Register of Emissions and Air Pollution Sources; 1 – very big, 2 – big; 3 – small; 4 – mobile; CZ, Czech Republic.

Fig. 1. Location of the Natural Forest Region Jizerské hory Mts.

Results and discussion

The total potential sulphur and nitrogen depositions reach values that can still considerably affect and compound the effects of natural acidification of the forest stands and soil. In 2001, the dose of throughfall acidic deposition of 2,000 mol H^+ ha^{-1} per year was exceeded on over 45% of the surveyed area. The results of the VaV /740/4/00 project (Zapletal et al., 2003) were used to assess the deposition flows of acidic depositions. The project evaluated the critical load of acidic deposition for the territory of the NFR Krušné hory Mts at 1,567 mol. H^+ ha^{-1} $year^{-1}$. In the NFR Jizerské hory Mts, the value of this critical dose is exceeded on more than 85% of the territory.

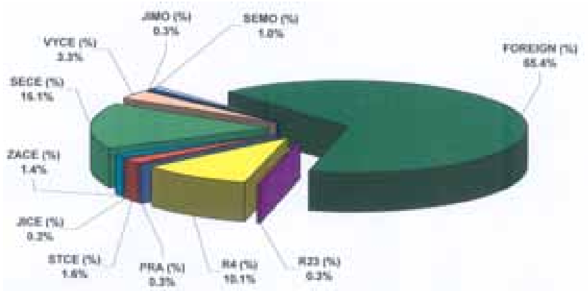
In spite of the decreased production of SO_2 emissions, the impact of both local (average share of Czech emission sources in the deposition of sulphur is 23.6%) and transboundary sulphur pollution (average share of foreign sources in the deposition of sulphur is 76.4%) is still quite noticeable in the air pollution load of the Jizerské hory Mts. The Czech NO_x emission sources contribute to potential nitrogen depositions by on average 34.6%, while the share of foreign NO_x sources is 65.4%. The partial share of the individual groups of emission sources of the Czech and foreign sources in the H^+ deposition (mol. ha^{-1} $year^{-1}$) from dry and wet sulphur depositions above the stand in the territory of the Jizerské hory Mts for 2001 is shown in Fig. 2.



FOREIGN, emissions sources from foreign countries; R23, emissions from big and small sources of Czech republic, emissions from very big sources of regions of Czech republic: PRA, Prague; STCE, central Bohemia; JICE, south Bohemia; ZACE, west Bohemia; SECE, north Bohemia; VYCE, east Bohemia; SEMO, north Moravia; JIMO, south Moravia.

Fig. 2. Average share of emission sources in the potential H^+ deposition (mol. ha^{-1} $year^{-1}$) from dry and wet sulphur depositions above the stand in the territory of the Jizerské hory Mts for 2001.

The share of these emission sources in the H^+ deposition (mol. ha^{-1} $year^{-1}$) from dry and wet nitrogen depositions above the stand in the territory of the Jizerské hory Mts for 2001 is shown in Fig. 3.



FOREIGN – Emissions sources from foreign countries, R23 – Emissions from big and small sources of Czech republic, R4 – Emissions from mobile sources of Czech republic, emissions from very big sources of regions of Czech republic: PRA – Praha, STCE – central Bohemia, JICE – south Bohemia, ZACE – west Bohemia, SECE – north Bohemia, VYCE – east Bohemia, SEMO north Moravia, JIMO – south Moravia.

Fig. 3. Average share of emission sources in the potential H+ deposition (mol. ha^{-1} $year^{-1}$) from dry and wet nitrogen depositions above the stand in the territory of the Jizerské hory Mts for 2001.

The spatial arrangement of five areas with degrees of resistance potential (DRP) to forest stand damage was defined within the scope of partial procedures of the cluster analysis – evaluation of distances between objects using Hemming metric and similarities of objects determined by the furthest neighbour method. The result of the spatial arrangement of the degrees of potential disposition to spruce stands damage is shown in Fig. 4. Table 2 lists the mean values of above-stand deposition flows of sulphur and nitrogen, defoliation, temperature minimums in March 2001 and the proportional distribution of areas in the NFR Jizerské hory Mts.

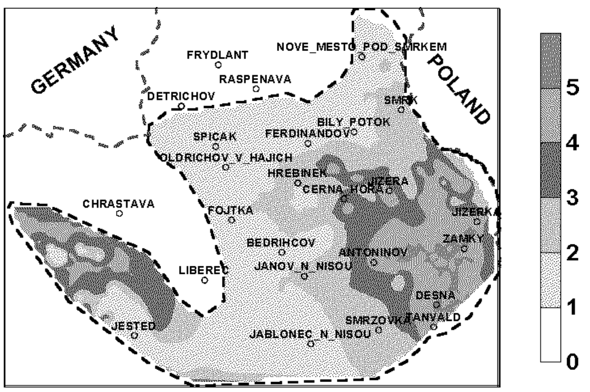


Fig. 4. Spatial distribution of the degrees of resistance potential to forest stands damage in the territory of the NFR Jizerské hory Mts (dashed line) in 2001. The natural neighbour gridding method was used for the depiction (Surfer Demo Version 9, Golden Software, 2009).

Degree 1 of the resistance potential expressing the disposition to spruce stands damage takes up more than

45% of the area of the NFR Jizerské hory Mts, Degree 2 occupies nearly 24%, Degree 3 takes up 16.5%, Degree 4 almost 13% and Degree 5 occupies over 1.5% of the area. The degree of resistance potential is derived on the basis of synergic effects of temperature fluctuations, relative air humidity, water balance condition, ozone concentration, perpendicular global radiation intensity and ozone layer thickness between March and July 2001, length of the growing season and the dose of sulphur and nitrogen deposition flow between January 1, 2001 and August 19, 2001. The date August 19, 2001 is the exposition date of the LANDSAT satellite photograph used to derive the spruce stands health condition through defoliation. The explanation of spruce stands defoliation was made by using all parameters representing the condition of atmosphere above the NFR Jizerské hory Mts. Based on the correlation analysis the parameters with the highest correlation coefficient value were selected for the purposes of setting forth the defoliation values in each degree of potential disposition.

From the results of multiple correlation and regression, a model explicating the spruce stand defoliation status was created for each area defined by the degree of resistance potential. The highest rate of air pollution and climatic stress impact on the forest stands defoliation was reached in area No. 3 (see Fig. 4 brown colour); an extremely low degree of resistance potential disposition to forest stands damage was reached where the coefficient of determination of the derived multiple regression function reaches the value of 64.2%. This means that other unused abiotic factors amount to 35.8% (e.g. soil factors, status of stands nutrition etc.). Table 3 presents parameters of regression model.

The multiple regression model has a following general form:

$$DEFOL = \text{a} \cdot ALT + \text{b} \cdot MATHN3 + \text{c} \cdot ATMI3 + \text{d} \cdot WBS58 + \text{e} \cdot RMA5 + \text{f} \cdot DUD7 + \text{g} \cdot OZOC7 + \text{h} \cdot PDRS7 + \text{i} \cdot S + \text{j} \cdot N + \text{k} \cdot GSL + \text{constant.} \qquad [1]$$

Table 2. Selected basic characteristics of principal factors applied to define the degrees of resistance potential to forest stands damage in the territory of the NFR Jizerské hory Mts in 2001

Resistance potential degree	Ø Deposition flows above the stand [mol H^+ ha^{-1} $year^{-1}$]		Ø Defoliation of spruce stands [%]	Absolute temperature minimum in March [°C]	Surface area [%]
	Sulphur	Nitrogen			
1 – high	94.9	475.1	29.6	–11.5	45.2
2 – low	134.6	539.9	31.1	–12.7	23.9
3 – extremely low	171.9	593.9	38.2	–12.7	16.5
4 – medium	69.9	418.9	28.7	–9.5	12.8
5 – very low	204.3	683.1	33.6	–13.9	1.6

Table 3. Regression diagnostics of a multiple linear function defining the dependency of the spruce stands defoliation on the abiotic environment factors for the period 1–8/2001 above the NFR Jizerské hory Mts in area of resistance potential degree No. 3

Abiotic environment factors	Factor and unit		Regression coefficient a–k	Partial correlation
Altitude	ALT	[m]	–2.9945	0.0725
Maximum thermal heating of needles in Month 3	MATHN3	[°C]	–95.2748	0.1036
Absolute temperature minimum in Month 3	ATMI3	[°C]	17.8045	0.0227
Water balance sum for Months 5–8	WBS58	[mm]	–0.1389	0.0150
Relative moisture of air Ø Month 5	RMA5	[%]	–3.8584	0.0476
Stage of stratospheric ozone layer Month 7	DUD7	[%]	–65.0530	0.0181
Ozone (tropospheric) concentration Ø Month 7	OZOC7	[μg m^{-3}]	60.9987	0.0561
Perpendicular direct radiation sum for Month 7	PDRS7	[MJ m^{-2}]	–0.3088	0.0723
Sulphur deposition above the stand	S	[mol. H^+ ha^{-1}]	0.3742	0.0057
Nitrogen deposition above the stand	N	[mol. H^+ ha^{-1}]	0.1986	0.0984
Growing season length	GSL	[days]	0.3200	0.0010
Constant	–		–1,381.2137	
R^2	0.6419			
R	0.8012			
SEE	12.2933			

DUD, Dobson unit deviation from the average; R^2, coefficient of determination; R, coefficient of correlation; SEE, Standard error of estimation.

It follows from the partial correlation coefficients that the greatest impact on defoliation have nitrogen depositions and maximum thermal heating of the needles by solar radiation. Some interesting dependences became clear from the values of regression coefficients, e.g. that defoliation of spruce stands increases with the increasing length of the growing season, with the decrease of stratospheric ozone concentrations and the increase of tropospheric ozone in July and with the anticipated growth of sulphur and nitrogen deposition flows. Defoliation is also increased by decreasing absolute temperature minimums in March.

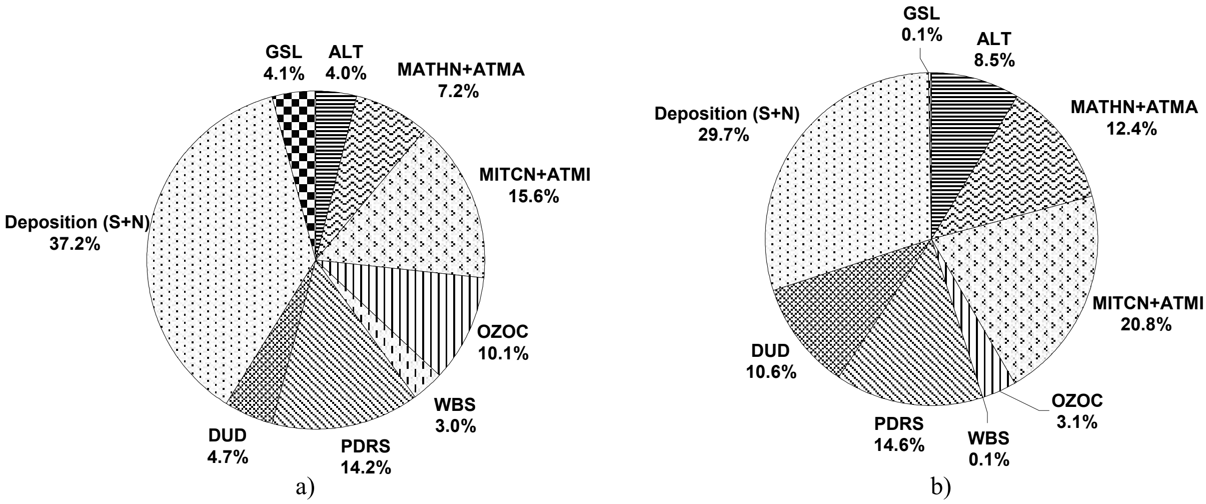
It follows from the development of SO_2 and NO_x emissions that annual SO_2 emissions produced only in the territory of Central Europe have a potential share in the mean annual sulphur deposition flow of 88.7% and that the annual NO_x emissions produced only in Central Europe have a share of 78.1% in the mean nitrogen deposition flow in the territory of the Czech Republic (Hadaš, 2009). The actual proportion is however resulting from a combined effect of many other factors. Despite the obvious decrease of SO_2 and NO_x emissions, the pollutants are still the main factor keeping the forest stands under pressure of deposition stress. A single unexpected emergence of some other abiotic factor (e.g. climate extreme) may become as a triggering factor for local or even large-scale defoliation. The derived multiple regression models clearly show that the impact of abiotic environment factors on stands defoliation is not stable but that it reflects all mutually interconnected positive and negative effects of feedbacks. Table 4 sums up partial significance levels of abiotic factors in the individual areas defined by the degree of resistance potential of the forest stands in NFR 21. The table demonstrates that the deposition flows of acid deposition formed from sulphur and nitrogen depositions show the highest significance in the interval between 13% and 60%. Within the 2–50% interval, the highest significance is shown by changes in temperature conditions (frost damage) between March and May. The influence of tropospheric ozone concentration shows a share in the defoliation change from 0.6% up to almost 29%. Possible damage by ozone is related to July moisture conditions. Conditions supporting the theory of stand damage due to ozone (Šrámek et al., 2006) occur in the areas of resistance potential degrees 1, 2, 3 and 5. In each area, a different significance level (1–21%) of ozone layer reduction was determined.

Figure 5 presents an average significance level of the influence of partial abiotic factors on the health condition of forest stands of all tree species and conifers in the territory of NFR 21. The figure clearly shows that defoliation of all forest stands in the NFR 21 Jizerské hory Mts is most affected by the acidic deposition of hydrogen ions – at more than 37% (formed of sulphur and nitrogen deposition flows), by temperature fluctuations (frost shock) – at more than 22%, and by the synergic effect of moisture conditions, ground-level and stratospheric ozone concentrations at nearly 18%. The influence of ozone alone reaches 10%. It is worth noting that the impact of O_3 on the defoliation of all tree species is much higher if the water balance (representing moisture conditions of the forest stands) impact is directly proportionate. The growth of precipitation excess brings about increased defoliation (the regression coefficient is positive). This property of the derived regression models applies for DRP areas 1, 3 and 5 in which the O_3 impact reaches a proportion of more than 28%. Conversely, in the DRP area 2 the water balance shows an indirectly proportionate dependency (defoliation increase resulting from a drop in the precipitation excess) and the share of O_3 in the defoliation falls to

Table 4. Significance of the partial factors of abiotic environment in the regression model used to assess the health condition of forest stands in the NFR 21 Jizerské hory Mts

Factors	Abiotic environment significance – for woody species defoliation [%]						
	All					Conifers	
	DRP-1	DRP-2	DRP-3	DRP-4	DRP-5	DRP-2	DRP-3
Altitude	0	5.11	13.11	1.63	0.15	2.24	14.81
MATHN/ATMA	1.6	21.72	6.28	5.17	1.33	9.71	15.14
MITCN/ATMI	20.12	16.49	40.72	0.18	0.24	6.56	35.08
OZOC	12.69	3.07	5.52	0.62	28.57	0.49	5.79
WBS	2.62	4.87	4.01	0.22	3.32	0.14	0.02
PDRS	3.21	15.7	13.01	6.15	33.04	18.51	10.64
DUD	0.9	4.99	2.7	10.73	3.97	20.66	0.47
Deposition (S + N)	55.24	27.82	13.29	60.3	29.17	41.5	17.96
Growing season length	3.62	0.23	1.36	15	0.21	0.19	0.09

DRP, degrees of resistance potential to forest stands damage; MATHN, maximum thermal heating of needles; ATMA, absolute temperature maximum; MITCN, maximum thermal cooling of needles; ATMI, absolute temperature minimum; OZOC, ozone concentration; WBS, water balance sum; PDRS, perpendicular direct radiation sum; DUD, stage of ozone layer expressed as Dobson unit deviation from the average.



ALT, altitude; MATHN, maximum thermal heating of needles; ATMA, absolute temperature maximum; MITCN, maximum thermal cooling of needles; ATMI, absolute temperature minimum; OZOC, ozone concentration; WBS, water balance sum; PDRS, perpendicular direct radiation sum; DUD, stage of ozone layer expressed as Dobson unit deviation from the average; GSL, growing season length.

Fig. 5. Mean significance levels of the influence of abiotic factors on the health condition of forest stands as manifested by defoliation a) of the stands of all tree species, and b) of coniferous stands.

3%. The derived multiple regression functions thus very aptly simulate an assumption that the forest stands damage by ozone does not occur at every increase of O_3 immission concentrations. As mentioned by Šrámek et al. (2006), the stomatary uptake or ozone dose entering the organism are affected by numerous factors, such as climatic and soil factors (sufficient moisture) that apply in this case.

Defoliation of conifer stands is most impacted (in 33% of cases) by temperature fluctuations (frost shock), by acid deposition of hydrogen ions (at almost 30%) and by the synergic effect of moisture conditions and ground-level and stratospheric ozone (at almost 14%). The impact of ozone alone accounts for 3%. The ozone layer thinning also indicates possible impacts of the UV-AB radiation, which always falls during the daytime perpendicularly on a part of needles or leaves as a component of direct solar radiation with a significance level of ca. 14%. A similar inferential evidence of the possible impact of ozone layer thinning in the stratosphere on the augmentation of UV-AB direct radiation component and ground-level (tropospheric) O_3 concentrations was determined in the Silesian Beskids (Hadaš, 2007).

It appears that the potential of the models of multiple regression functions could reach even higher correlation values between the health condition of forest stands in NFR 21 and abiotic factors. The process of cluster analysis forming clusters (areas) would have to be stopped so that the enclave of Ještědský hřbet Ridge could be singled out separately. The conditions in this enclave disturbed the regression relations in the areas of resistance potential degree 1, 2, 3 and 4. Higher correlation would be probably achieved also if temperature and moisture characteristics, deposition flow and ozone concentrations from the autumn and beginning of winter of 2000 were included too.

Conclusions

The high entry of acidic deposition, the quantity of which exceeds spontaneous regeneration of the soil environment, into the forest soil continues to remain the principal cause for the dieback and damage to stands (trees and individual tree species). The high acidity of the soil environment affects nutrition of the forest stands. The weakened stands become more susceptible to damage provoked by sudden emergence of meteorological factors, namely by increasing or decreasing air temperatures. A triggering factor for large-scale defoliation may become both an extreme temperature increase or prolonged spell of drought or extreme air temperature drop between winter and spring or autumn and winter (winter 2000/2001) and a single acute or synergic damage to soil due to immissions in the form of acidic depositions.

The derived data of the abiotic environment, areas defined by degrees of the potential resistance to forest stands damage in the natural forest region of Jizerské hory Mts, can extend the database of ecological conditions (edaphic-climatic, exposure etc.) and can thus contribute to the evaluation of causes responsible for the forest stands decline, changes in the spruce stands health condition and assessment of the success of revitalization measures.

Acknowledgement

The paper was worked out within the framework of research plan MSM No. 6215648902 "Revitalization of mountain forest ecosystems damaged by air pollution".

References

Barnes, B.V. 1984. The ecological approach to ecosystem classification. In Grey, D.C., Schönau, A.P.G., Schultz, C.J. International union of forestry research organizations (eds*)*. In *Symposium on site and productivity of fast growing plantations. Pretoria and Pietermaritzburg, South Africa, 30 April – 11 May 1984. Proceedings*. Pretoria: South African Forest Research Institute, Dept. of Environment Affairs, p. 69–89.

Baer, M., Nester, K. 1988. Numerical simulation of SO_2 concentration and dry deposition fields in the TULLA experiment. In Unsworth, M.H., Fowler, D. (eds). *Acid deposition at high elevation*. Dordrecht, Boston: Kluwer Academic Publishers, p. 553–568.

Bubník, J., Keder, J., Macoun, J., Maňák, J. 1998. Systém modelování stacionárních zdrojů. Metodický pokyn odboru ochrany ovzduší MŽP výpočtu znečištění ovzduší z bodových a mobilních zdrojů „SYMOS 97" [System modeling stationary sources. Guidance to the Department of Air Protection Ministry of calculating air pollution from point and mobile sources „SYMOS 97"]. *Věst. MŽP ČR*, 3: 22–57.

Denton, S.R.. Barnes, B.V. 1988. An ecological climatic classification of Michigan: A quantitative approach. *Forest Sci.*, 34(1): 119–138.

Filáček, A., Koutník, V., Vondráček, J. 1977. Shluková analýza [Cluster Analysis]. *Čas. Pěstov. Mat.*,102: 359–411.

Hadaš, P. 1991. Ecological classification of the climate. In *IUFRO and ICP-forests workshop on monitoring air pollution impact on permanent sample plots, data processing and results interpretation.* Prachatice: Forestry and Game Management Research Institute, p. 197–201.

Hadaš, P. 2007. Stress factors of forest in the Silesian Beskids Mts. *Beskydy*, 20: 9–24.

Hadaš, P. 2009. *Vliv klimatu a atmosférických depozicí na zdravotní stav lesních porostů na území PLO Jizerské hory* [An analysis of the effect of climate and atmospheric deposition on forest health conditions in the territory of the Jizerské hory Mts natural forest region (NFR)]. PhD thesis. Brno: Mendel University, Faculty of Forestry and Wood Technology, Department of Forest Ecology. 145 p.

Hebák, P., Hustopecký, J. 1987. *Vícerozměrné statistické metody s aplikacemi* [Multivariate statistical methods with applications]. Praha: SNTL. 452 p.

Hills, G.A. 1960. Regional site research. *For. Chron*., 36: 401–423.

Mauer, O., Palátová, E. 2001. Vývin kořenového systému břízy bělokoré v imisní oblasti Krušných hor [Generation of silver birch root system of air pollution in the Ore Mountains]. In Slodičák, M. Novák, J. (eds). *Výsledky lesnického výzkumu v Krušných horách. Sborník z celostátní konference konané v rámci Grantového programu Phare CZ 9804.02.0001, Teplice 1. 3. 2001. Results of forestry research in air-polluted area of the Ore Mts. Proceedings from the workshop held in the framework of the Grant Project Phare CZ 9804.02.0001, Teplice 1. 3. 2001*. Jíloviště-Strnady: Výzkumný ústav lesního hospodářství a myslivosti, p. 73–84.

Mesopuff 1994. *A revised user's guide to MESOPUFF II Version 5.1, EPA-454/B-94-025 (EPA)*.

Rowe, J. S. 1978. The common denominator of land classification in Canada. An ecological approach to mapping. In *Proceedings: ecological classification of forest land in Canada and northwestern U.S.A., September 30-October 2, 1977, Vancouver, BC.* Vancouver, B.C.: Centre for Continuing Education, University of British Columbia, p. 195–198.

Surfer 2009. *Surfer Demo Version 9.1.352 – Apr 8 2009*. Surface Mapping System. Golden Software, Inc, 809 14th Street, Colorado 80401-1866.

Šrámek, V., Novotný, R., Bednářová, E., Hůnová, I., Buriánek,V., Maxa, M., Neuman, L., Ostatnická, J., Srněnský, R., Uhlířová, H. 2006. *Vliv zvýšených koncentrací ozonu a meteorologických faktorů na stabilitu smrkových a bukových porostů v České republice* [Influence of elevated ozone concentrations and meteorological factors on the stability of spruce and beech stands in the Czech Republic]. Report on running NAZV 1G5745 project. Jíloviště-Strnady: Výzkumný ústav lesnictví a myslivosti. 35 p.

Türk, R., Shume, H., Mayer, W., Matschinger, M. 2001. *Immissionsökologische Flechtenkartierung Zöbelboden und multivatiate Analyse der Ergebnisse. Wiederholungsinventur 1999*. Wien: Umweltbundesamt. 95 p.

Ulrich, B. 1987. Stability, elasticity and resilience of terrestrial ecosystems with respect to matter balance. *Ecol. Stud.*, 61: 11–49.

Zapletal, M., Skořepová, I., Pekárek, J. 2003. *Multikriteriální vyhodnocování vlivů látek znečišťujících ovzduší se zaměřením na acidifikaci, eutrofizaci a desikaci přírodních ekosystémů založené na principu kritických prahů dle metodologií EHK OSN* [Multicriterial assessment of negative influence of air pollution concerning to acidification, eutrofication and desication of natural ecosystems based on critical thresholds principle by UN ECE methodology]. Technical report SJ/740/4/00 project. Opava: Ekotoxa, 56 p.

Analýza zdravotního stavu a abiotického prostředí lesních porostů na území Jizerských hor, Česká republika

Souhrn

Cílem práce bylo analyzovat příčinnou souvislost abiotického prostředí a zdravotního stavu lesních porostů na území přírodní lesní oblasti Jizerské hory. Analýza je založena na hypotéze, že zdravotní stav je vyvolán vyčerpáním odolnostního potenciálu lesních ekosystémů, takže i současná imisní zátěž, ve formě atmosférických depozicí síry a dusíku, v kombinaci s výkyvy klimatu (změny teplotního a vláhového režimu) a stavu přízemního (troposférického) ozónu způsobují jejich poškození. Pro pochopení a porozumění potenciálního vlivu polutantů SO_2 a NO_x a stresorů klimatu na lesní ekosystémy potřebujeme získat značný objem dat o abiotickém prostředí i v území, kde se měření těchto dat neprovádí. Proto údaje o teplotních poměrech, vláhové bilanci, slunečním záření, koncentracích ozónu, depozičních tocích síry, dusíku a iontů vodíku byly odvozeny přes modelové aplikace a interpolační techniky. Změna zdravotního stavu koruny stromů je hodnocena na základě ztráty asimilačních orgánů – defoliací, která byla získána z družicových snímků LANDSAT. V rámci metodického přístupu jsou odvozené hodnoty depozičních toků síry, dusíku, kyselé depozice nad lesním porostem i v porostu, porovnány s hodnotami jejich kritických dávek, teplotní poměry jsou posuzovány z hlediska mrazového šoku, vlhkostní poměry z hlediska vláhové bilance, posuzování vlivu imisní zátěže ozónem z hlediska vlhkostního stavu prostředí a stavu ozónové vrstvy ve stratosféře.

Celkové potenciální depozice síry a dusíku dosahují takových hodnot, že mohou stále významně ovlivňovat a prohlubovat účinky přirozené acidifikace lesních porostů a lesní půdy. Na více jak 45 % studovaného území je překročena kritická dávka kyselé depozice 2 000 mol. H^+ ha^{-1} za rok, v PLO 21 Jizerské hory je kritická dávka překročena na cca 85 % – 90 % území. V rámci dílčích postupů shlukové analýzy – hodnocení vzdálenosti objektů Euklidovou metodou a podobnosti objektů metodou nejvzdálenějšího souseda bylo definováno prostorové rozložení pěti oblastí potenciální dispozice k poškozování lesních porostů. Oblast číslo 1 zaujímá 45,2 % území PLO 21, oblast číslo 2 téměř 24 % území, oblast číslo 3 více jak 16 % území, oblast číslo 4 téměř 19 % území a oblast číslo 5 téměř 2 % území. Z výsledků vícenásobné korelace a regrese byl pro každou oblast potenciální dispozice sestaven model vysvětlující stav defoliace lesních porostů. Nejvyšší míra vlivu imisního a klimatického stresu na defoliaci lesních porostů byla dosažena v oblasti číslo 3, kde koeficient determinace odvozené vícenásobné regresní funkce dosahuje hodnoty 64,2 %. To znamená, že na další abiotické faktory zbývá 35,8 % (např. půdní, stav výživy porostů atd.).

Za hlavní příčinou odumírání a poškozování porostů (respektive stromů, jednotlivých dřevin) stále stojí vysoký vstup kyselé depozice do lesní půdy, jejíž množství přesahuje samovolnou regeneraci půdního prostředí. Vysoká kyselost půdního prostředí ovlivňuje výživu lesních porostů. Oslabené porosty jsou tak více vystaveny poškození vyvolané nenadálým vývojem meteorologických faktorů, zejména vzestupem nebo poklesem teploty vzduchu. Například spouštěcím faktorem velkoplošné defoliace může být jak jednorázové extrémní působení zvýšené teploty nebo prodloužení periody sucha, respektive extrémní snížení teploty vzduchu na přelomu zimy a jara nebo podzimu a zimy (zima 2001/2002), tak jednorázové akutní nebo synergické poškození půdy imisemi ve formě kyselých depozicí.

Received March 24, 2010
Accepted April 5, 2011

The temporal and spatial variability of phenological phases of the Norway spruce (*Picea abies* (L.) Karsten) in the Czech Republic

Lenka Hájková[1], Věra Kožnarová[2], Soňa Sulovská[2], Dáša Richterová[1]

[1]Branch Office Ústí nad Labem, Czech Hydrometeorological Institute, Kočkovská 18, 400 11 Ústí nad Labem – Kočkov, Czech Republic; Faculty of Science, Charles University, Albertov 6, 128 43 Praha 2, Czech Republic, e-mail: hajkova@chmi.cz, dasar@chmi.cz
[2]Department of Agroecology and Biometeorology, Czech University of Life Sciences in Prague, Kamýcká 129, 165 21 Praha 6 – Suchdol, Czech Republic
e-mail: koznarova@af.czu.cz, sulovska@af.czu.cz

Abstract

Hájková, L., Kožnarová, V., Sulovská, S., Richterová D. 2012. The temporal and spatial variability of phenological phases of the Norway spruce (*Picea abies* (L.) Karsten) in the Czech Republic. *Folia oecol*., 39: 10–20.

The paper analyzes the main vegetative and generative phenological phases (the bud burst BBCH 07, the first leaves BBCH 15, the beginning of flowering BBCH 61, the end of flowering BBCH 69) of the Norway spruce (*Picea abies* (L.) Karsten) observed at Czech Hydrometeorological Institute (CHMI) phenological stations in the period from 1991–2010. There were analysed data from phenological stations located at elevations from 155 m (Doksany) to 860 m a.s.l. (Pernink). The altitude determines the mean onset dates of the phenophases: bud burst was observed from 19th April to the 10th May, the first leaves from 11th May to 26th May, male flowering from the 3rd May to 18th May, and the end of flowering on average between the 20th May and 2nd June. The duration of flowering took on average between 15 and 17 days with the standard deviation from 1.9–2.1 days. The earliest onset of the beginning of flowering was recorded on the 15th April 2009 (Lednice); the latest on the 24th May 2001 (Pernink). Vertical phenological gradients for the discissed phenological stages (BBCH 07, BBCH 15, BBCH 61 and BBCH 69) were 2 days/100 m of elevation. For the study 20-year period, all the studied phenophases show an overall tendency for the earliest onset, the results underlying this observation, however, exhibit only a low significance level.

Key words

BBCH, Czech Republic, GIS, Norway spruce, phenology

Introduction

The Norway spruce is a dominant tree species of the mountain spruce forest. The original distribution range of this species in the Czech Republic is from 700 m a.s.l. to 1,400 m a.s.l. in the climax vegetation of the upper hill country belt and the subalpine belt with the highest occurrence in the mountain belt and mainly in the upper mountain belt (Hejný et al., 1997; Coufal et al., 2004), on the peat, in floodplain habitats, frequently at the upper hilly belt and the submontane belt (min.: defiles of Labské pískovce, ca. 140 m; max.: Sněžka, 1,550 m). The Norway spruce has the highest tolerance to climate from all spruce species. It is the most frequent woody plant, covering 53% of woodland.

During the last ten years, there has been a significant increase in the interest in phenology, the study of the timing of life-cycle events of organisms. This is partly due to clearly visible shifts in the onset of flowering, leaf unfolding etc. recorded in many parts of the world and interpreted in the context of the climate change (Van Vliet et al., 2003). Phenological observations can be an important indicator (from the biological point of view) of the current environmental changes.

The vegetative and generative phenological stages of Norway spruce in Slovakia (Fig. 1, 2) showing shifted onsets to earlier dates (Škvareninová and Snopková, 2010).

Fig, 1. Norway spruce – the inflorescence.
(Photo J. Škvareninová)

Fig. 2. Norway spruce – the flowering emergence.
(Photo J. Škvareninová)

One of the first phenological maps of Europe was created in the year 1955 by Schnelle, who founded the International Phenological Gardens (IPGs) in 1957. The data collected in these IPGs for over 40 years, are now providing a homogenous set of verified data for creation of phenological map of a new type (Rötzer and Chmielewski, 2001).

The relationships between the phenological trends of plant populations and the development of the climate were studied by Balut and Sabor (2002), Bednářová and Merklová (2007), Škvareninová (2008). Střelcová and Leštianská (2009) have investigated the course of the phenological phases and diameter increment. Magová et al. (2011) investigated the response of growth processes in Norway spruce during the spring phenophase outbreak. The development and the health conditions of the root system of *Picea abies* were studied by Mauer and Palátová (2010). Hájková and Nekovář (2007) evaluated phenological phases with the aid of the Geographic Information System. Meteorological and phenological monitoring of forest woody plants on sample plots situated in the southern part of the Kremnické vrchy Mts was carried out by Domčeková et al. (2009). Hurtalová et al. (2007) pursued research on influence of snow damage on aerodynamic characteristics of spruce stands. The microclimate influence of spruce climax stands on the culmination and the dynamics of snow cover was studied by Hribík et al. (2011).

The Norway spruce belongs to the important allergenic species. The pollen grains of the Norway spruce have size from 70–90 µm, and they are equipped with air bags for easy transmitting by wind (tens of kilometres). The pollen is producted in small amounts (Rybníček et al., 1997).

Material and methods

Within the framework of phenological observations and according to the methodology of the Czech Hydrometeorological Institute, the following phenophases of the Norway spruce (*Picea abies* (L.) Karsten) are observed: the bud burst (10%), the first leaves (10, 50, and 100%), the inflorescence emergence (10%), the beginning of flowering (10, 50, and 100%), the end of flowering (100%), and the full ripeness (10%). The size of the harvest has also been recorded.

In the network of CHMI phenological stations (wild plants), the Norway spruce (*Picea abies* (L.) Karsten) is observed at stations with altitudes from 155 m (Doksany) to 860 m (Pernink). The volunteer-observed areas at stations are located on plains or on moderate slopes (slope up to 10°), in stands supplied with rich solar radiation (the direct solar radiation reaches the ground during most of the day). The typical moisture conditions are mezophytic. The volunteers make records of phenological stages following the methodology (The Czech Hydrometeorological Institute, 2009) specifying detailed phenophase description; the patterns of phenophases are illustrated in the Phenological Atlas (2004). The observers regularly send their data to the regional branches of the Czech Hydrometeorological Institute; the data are revised and digitalized into the database PHENODATA (oral communication).

We have statistically evaluated the sequence of phenological stages (the bud burst BBCH 07, the first leaves BBCH 15, the beginning of flowering BBCH 61, the end of flowering BBCH 69) providing the base for maps creation. The maps were processed with using Geographic Information Systems (Application Clidata-GIS). The mean dates of phenophase beginning (during the twenty-year period 1991–2010) were used as the input data. A horizontal resolution of altitudinal 500 meters was used for construction of maps (method of local linear regression between the measured or calculated value and the digital relief model). Regression coefficients were calculated for each station, providing with the data from the neighbouring stations and using the least squares method. The coefficients were subsequently interpolated into a space model, and the space distribution of the specific element was calculated with using tools of map algebra and linear equations. The basic statistical parameters have been also calculated for the selected altitudinal zones, with five-day air temperature for phenological stage onset. The five-day air temperature was calculated as the average value of the sequence of five daily air temperature values preceding the phenophase onset in the given year – the day of phenological stage onset is not comprised. The phenophase onset deviations from the average evaluated in percentiles and limits of the used terms are in Table 1 (Hájková et al., 2011).

The time of flowering, including inflorescence emergence, was studied within the period 1991–2010; we evaluated deviations of phenological phase onsets from the long term average 1991–2010 and linear regression equations of selected phenological stages too. These results are presented in graphs.

Results and discussion

The results of average onset of selected phenological phases (the bud burst, the first leaves 100%, the beginning of flowering and the end of flowering) are illustrated in the maps.

Phenophase the bud burst (BBCH 07)

The map of the bud burst (BBCH 07) shows six areas with five-day intervals (Fig. 3). In some localities (very small area), the first day of this phenophase has already been dated before the 22nd April, in the lowlands, it started between 23rd April and 27th April. Across the major part of the territory was the average phenophase onset dated between 28th April and 7th May and in several locations in the highest situated mountain after 13th May. Škvareninová and Snopková (2010) examining

Table 1. Limits of used terms

Term of limit	Percentile	Term of limit	Percentile	Term of limit	Percentile
Extraordinary long	<2.0			Short	75.1–90.0
Very long	2.0– 9.9	Normal	25.0–75.0	Very short	90.1–98.0
Long	10.0–24.9			Extraordinary short	>98.0

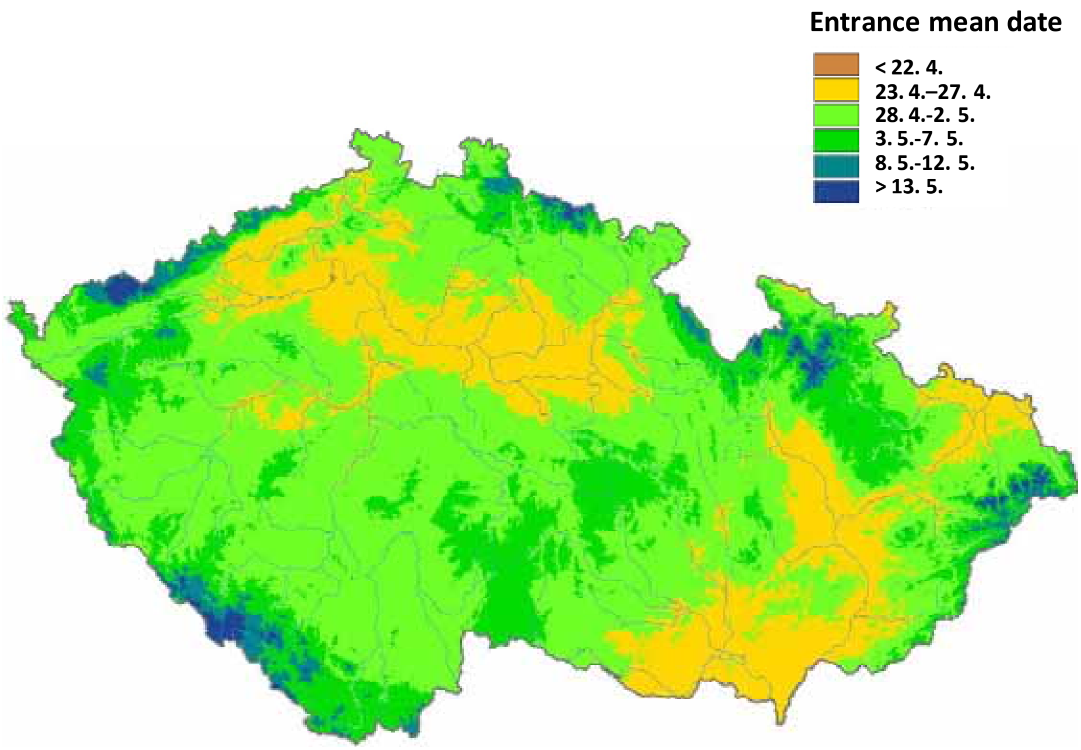


Fig. 3. The bud burst – the mean date of phenophase onset (1991–2010).

the bud burst of the Norway spruce in Slovakia within the period 1996–2008 have observed the mean starting date of the stage from 21st April till 6th May.

Phenophase the first leaves 100% (BBCH 15)

The map of the first leaves 100% (BBCH 15) shows six areas with five-day intervals (Fig. 4). In some localities (very small area), the first day of this phenophase is already dated before the 7th May, in the lowlands between 8th May and 12th May, across the major part of the territory between 13th May and 22nd May and in some of the highest situated mountain stations after 28th May.

Phenophase the beginning of flowering (BBCH 61)

The map of the beginning of flowering (BBCH 61) shows five areas with three-day intervals (Fig. 5). Before 4th May, the start of the phenophase was recorded in lowlands, across the major part of the territory was the average phenophase onset between 5th May and 7th May, and in the highest situated mountain after 14th May. Škvareninová and Snopková (2010) found out the average phenophase onset in Slovakia (male flowers of Norway spruce) from 12th till 19th May (the period 1996–2008).

Phenophase the end of flowering (BBCH 69)

Figure 6 shows the map of the beginning of flowering (BBCH 69) with five areas with three-day intervals. In the lowlands, the first flowers appeared before 21st May. The average phenophase onset was between 22nd May and 24th May in the major part of the territory. The region with the phenophase onset after 31st May was found in the highest situated mountain locations.

The graph on Fig. 7 expresses the deviations of the onset of phenological phases from the long term average 1991–2010. In the years 1991, 1996 and 2010 the phenophase onset was delayed, on the contrary in the years 2000 and 2009 they started earlier. The biggest negative deviations (i.e. earlier phenophase onset) were the following: the bud burst 8 days (2009), the first leaves (100%) 8 days (2000, 2009), the inflorescence emergence 11 days (2009), the beginning of flowering 13 days (2009) and the end of flowering 14 days (2009); the biggest positive deviations (i.e. later phenophase onset): the bud burst 11 days (1991), the first leaves (100%) 8 days (1991), the inflorescence emergence 13 days (1991), the beginning of flowering 9 days (1996) and the end of flowering 14 days (1991).

Figure 8 illustrates the duration of flowering of the Norway spruce, including the inflorescence emergence, in years over the studied 20-year period in details, both the number of days of its duration, and the earliest and the latest date of the phenophase onset. The earliest beginning of the flowering was recorded in the year 2009 (the average obtained for the whole network phenological stations for wild plants was 26th April); the latest onset of flowering was in the year 1991, with average of 22nd May.

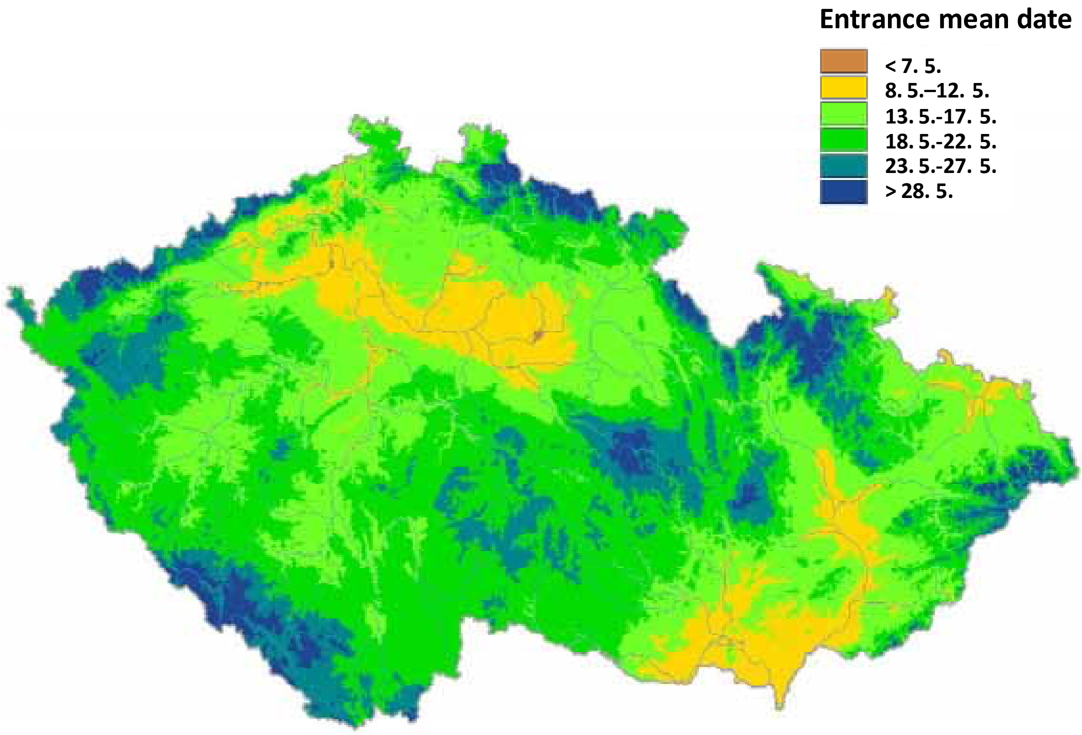


Fig. 4. The first leaves (100%) – the mean date of phenophase onset (1991–2010).

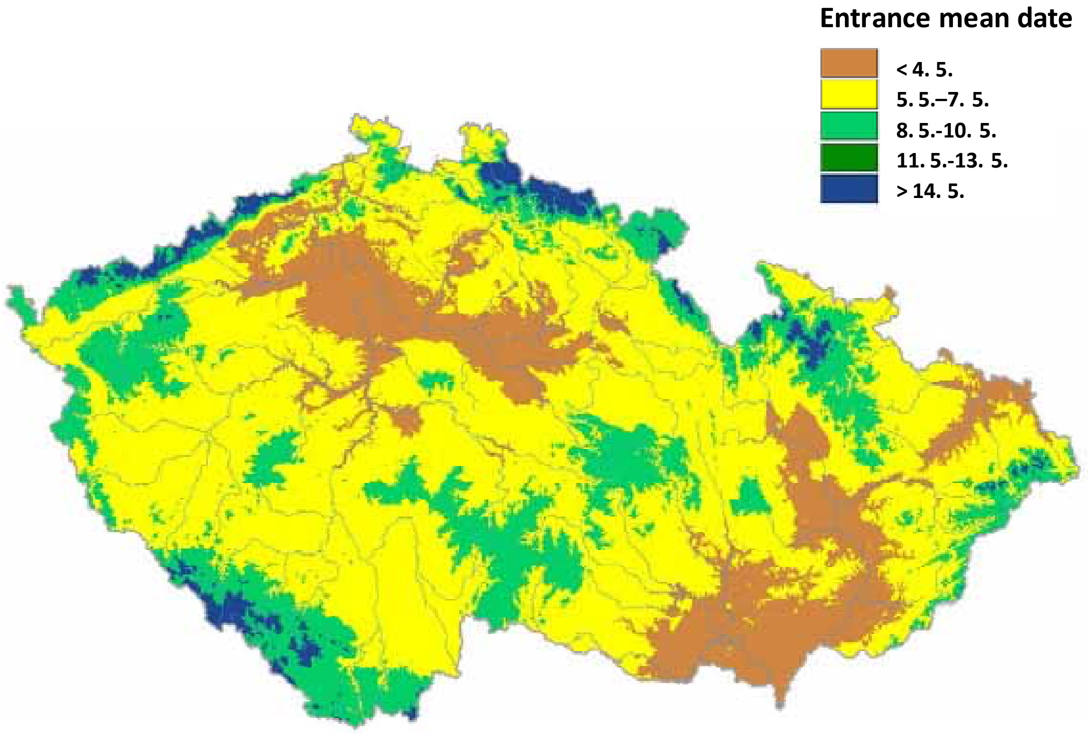


Fig. 5. The beginning of flowering – the mean date of phenophase onset (1991–2010).

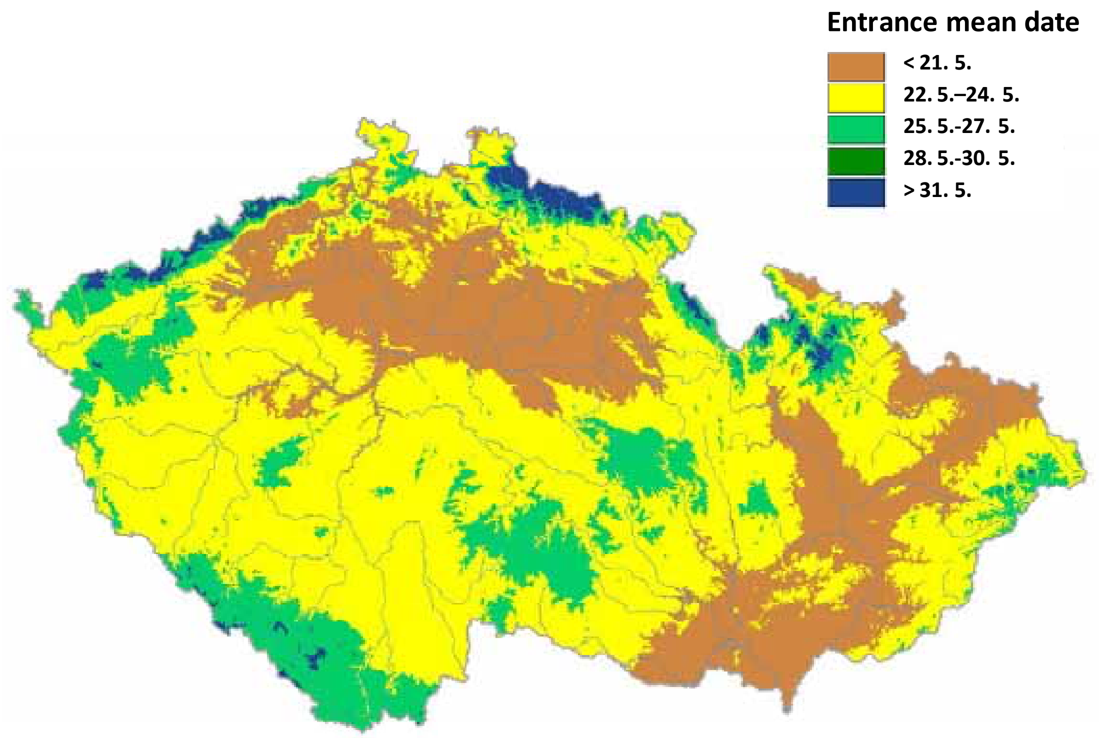


Fig. 6. The end of flowering – the mean date of phenophase onset (1991–2010).

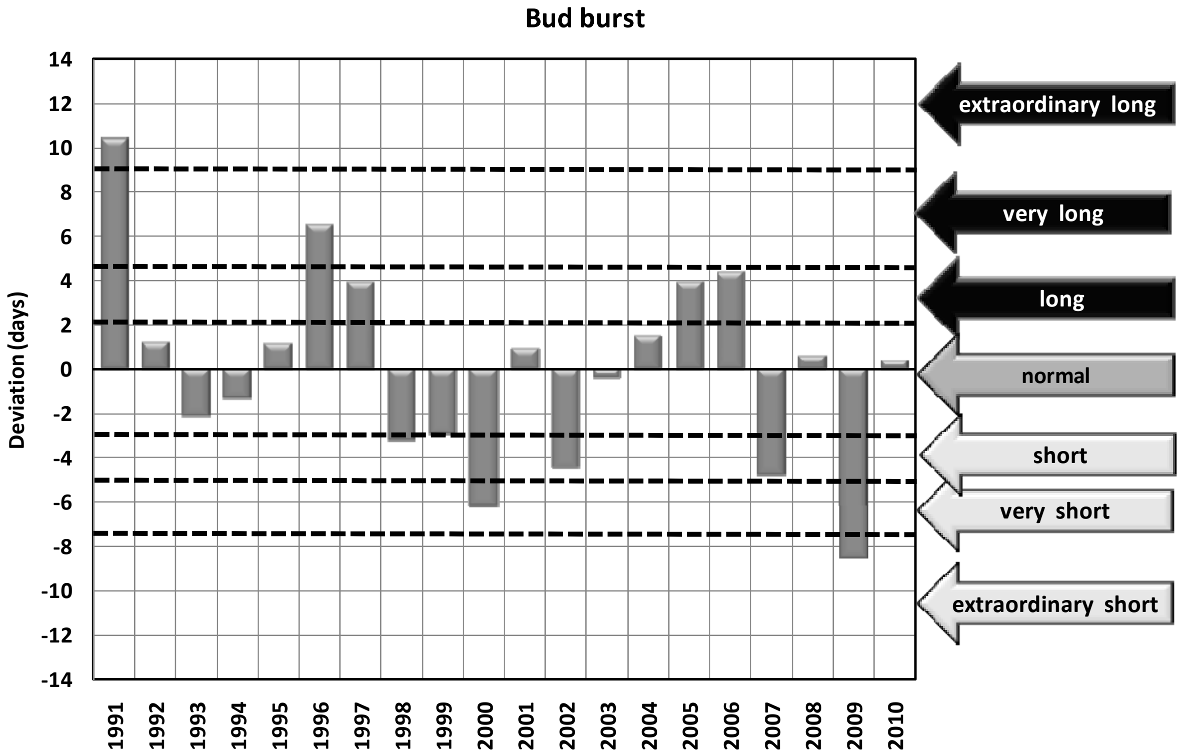


Fig.7a. Deviation of bud burst onsets from the long-term average 1991–2010.

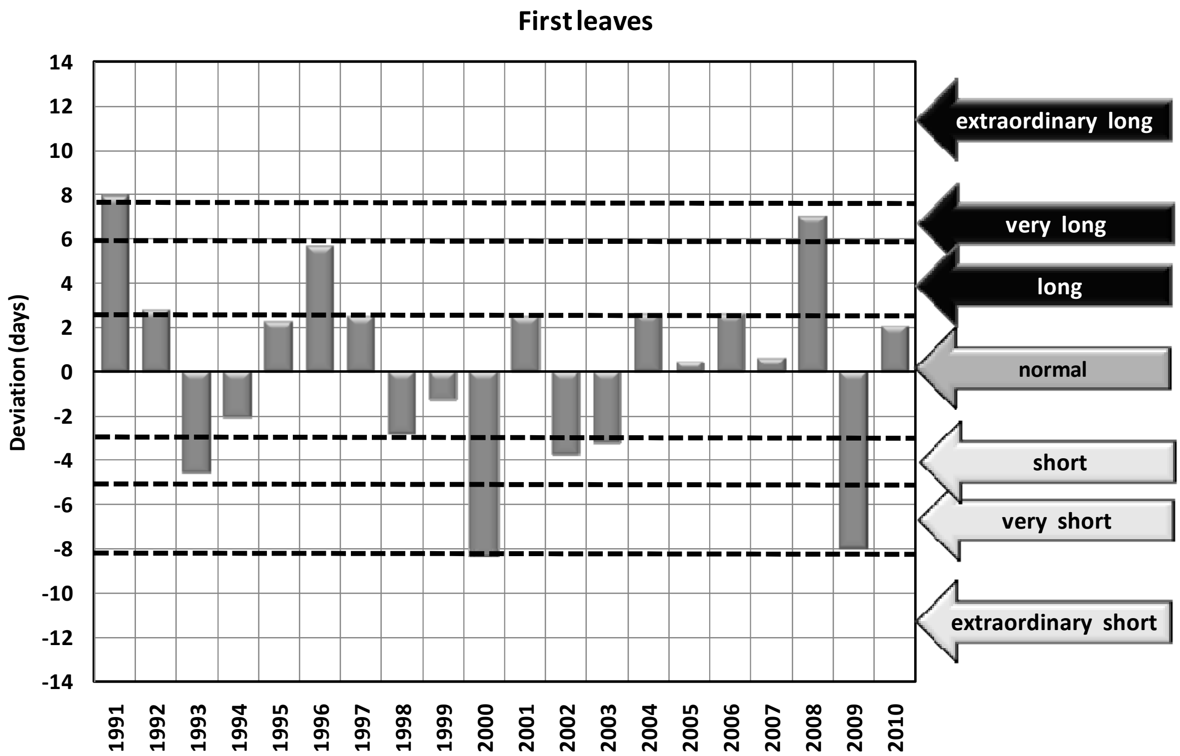


Fig.7b. Deviation of first leaves onsets from the long-term average 1991–2010.

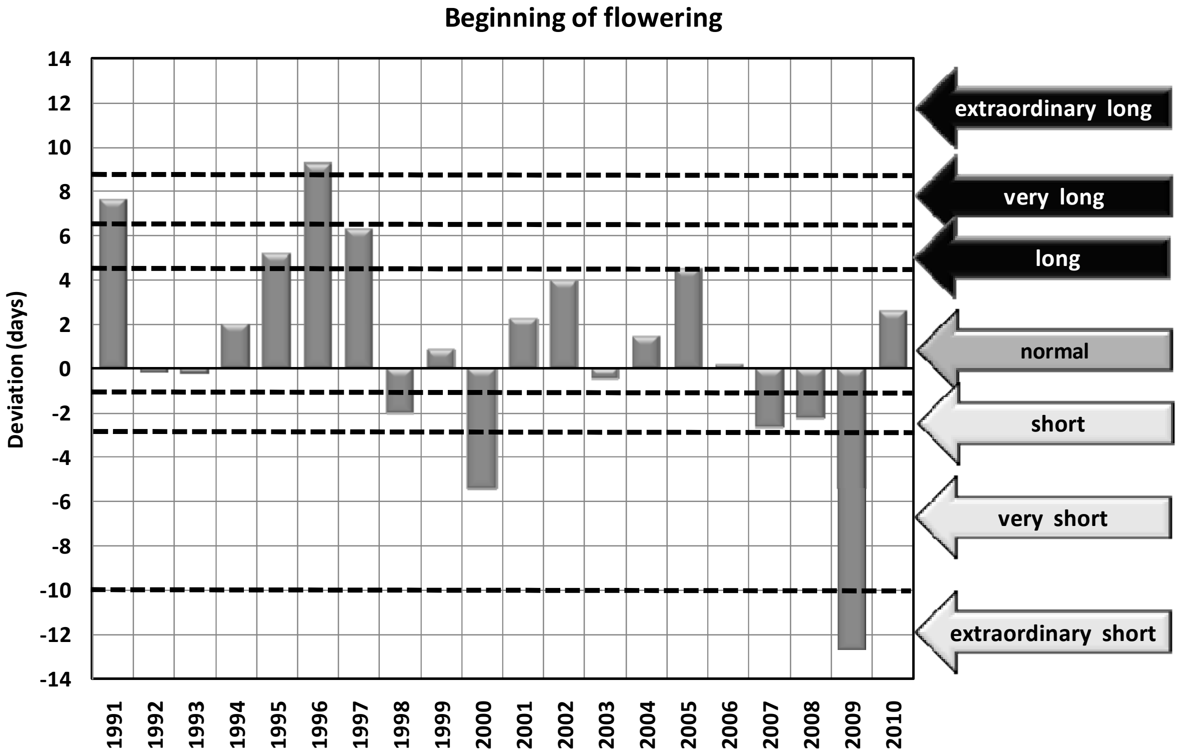


Fig.7c. Deviation of beginning of flowering onsets from the long-term average 1991–2010.

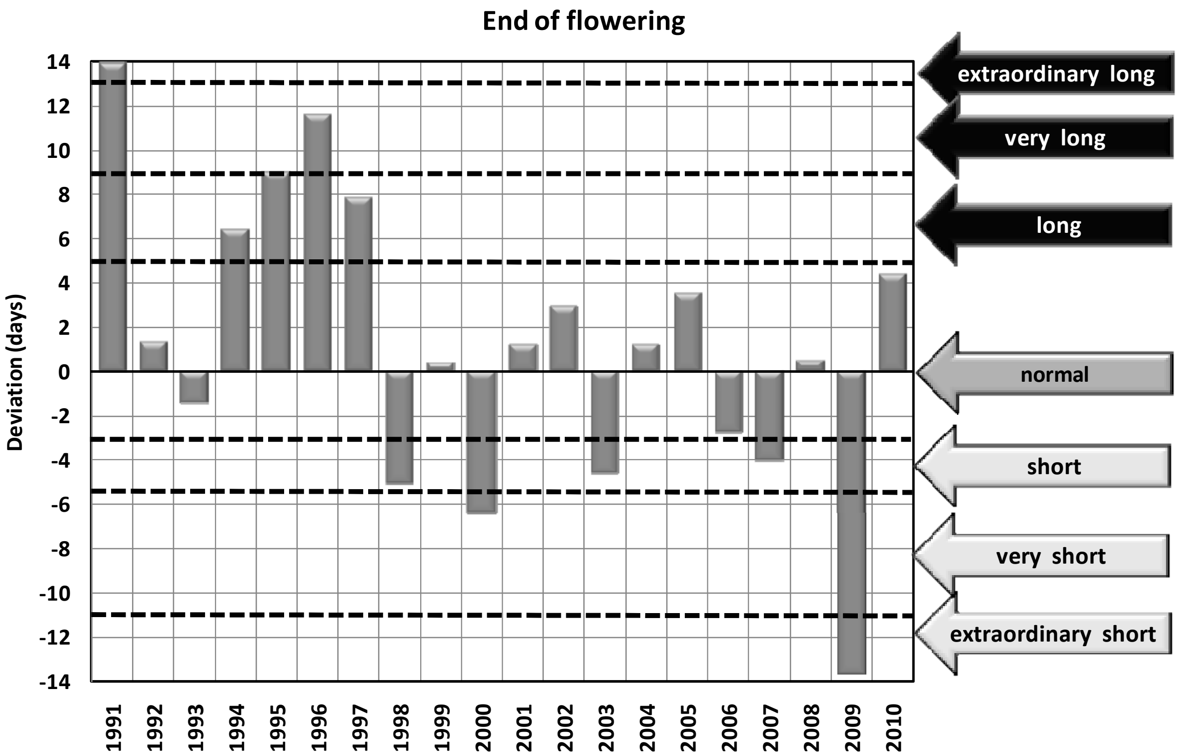


Fig.7d. Deviation of end of flowering onsets from the long-term average 1991–2010.

The Norway spruce begins to flower on average between 3rd and 18th May, the average time of flowering in the selected elevation zones was 15–17 days with the standard deviation 1.9 to 2.1 days. The most often recurring the beginning of flowering was recorded between 5th and 14th May (42%) and between 15th April and 4th May (32%). The earliest onset of the beginning of flowering was recorded on 15th April 2009 (Lednice); the latest onset was on 24th May 2001 (Pernink).

The statistical characteristics of vegetative and generative phenological stages are presented in Tables 2 and 3. The Table 2 shows the average phenophase onset with the standard deviation and five-day air temperature preceding phenological phase onset. The five-day temperature of phenophase onset is decreasing with increasing altitude in all four phenological stages. The onsets of these stages come usually in May.

The Table 3 describes the earliest and latest onsets within the period 1991–2010, with coefficients of variation (s_x %). The coefficient oscillates between values 3.15 and 8.88. Some of the results were compared with Škvareninová and Snopková (2010) giving the values of these coefficients (s_x %) for the bud burst varying from 6.26 till 8.42 and for the phenopase of beginning of flowering (male flowers) between 6.89 and 9.55.

The average onset days calculated by using regression equations are evaluated in Figures 9 and 10.

Table 2. The statistical characteristics of selected phenological phases at elevation zones

	Bud burst (BBCH 07)			First leaves (BBCH 15)			Beginning of flowering (BBCH 61)			End of flowering (BBCH 69)		
m a.s.l.	avr.	σ	t_{pent}	avr.	σ	t_{pent}	avr.	σ	t_{pent}	avr.	σ	t_{pent}
<200	19. IV.	9.1	12.0	11. V.	8.1	13.7	3. V.	7.2	13.2	20. V.	7.7	15.4
201–400	28. IV.	5.7	11.7	20. V.	7.6	13.5	6. V.	7.7	12.8	22. V.	8.1	15.0
401–600	1. V.	5.4	11.0	23. V.	6.7	13.0	10. V.	6.4	12.5	26. V.	7.2	14.3
601–800	5. V.	6.4	9.7	24. V.	7.2	12.7	13. V.	6.5	12.1	29. V.	8.0	13.9
>801	10. V.	6.4	9.0	26. V.	8.4	12.3	18. V.	5.5	11.9	2. V.	5.7	13.5

avr., average phenophase onset [date]; σ, standard deviation [day]; t_{pent}, pentad air temperature [°C].

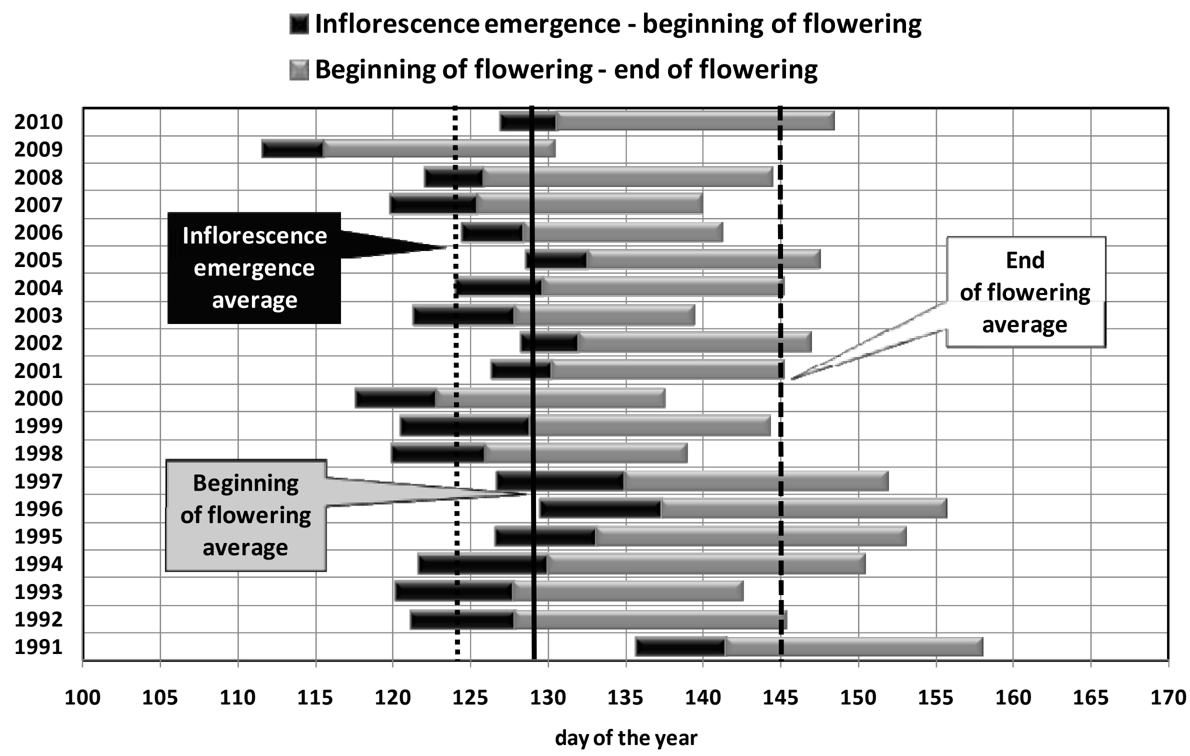


Fig. 8. The duration of flowering including the inflorescence emergence (1991–2010).

Table 3. The statistical characteristics of selected phenological phases at elevation zones

	Bud burst (BBCH 07)			First leaves (BBCH 15)			Beginning of flowering (BBCH 61)			End of flowering (BBCH 69)		
m a.s.l.	earl.	lat.	s_x %	earl.	lat.	s_x %	earl.	lat.	s_x%	earl.	lat.	s_x %
<200	12. IV.	15. V.	8.88	25. IV.	2. VI.	7.06	15. IV.	2. VI.	6.82	23. IV.	19. VI.	6.81
201–400	15. IV.	18. V.	5.38	26. IV.	18. VI.	6.54	16. IV.	3. VI.	7.27	1. V.	17. VI.	6.35
401–600	16. IV.	17. V.	5.09	30. IV.	25. VI.	5.60	17. IV.	5. VI.	5.96	2. V.	20. VI.	5.92
601–800	19. IV.	23. V.	5.84	2. V.	29. VI.	5.94	22. IV.	5. VI.	5.81	5. V.	12. VI.	6.40
>801	30. IV.	1. VI.	5.35	12. V.	30. VI.	6.40	22. IV.	5. VI.	3.15	8. V.	25. VI.	3.70

earl., earliest phenophase onset [date]; lat., latest phenophase onset [date]; s_x %, coefficient of variation [%].

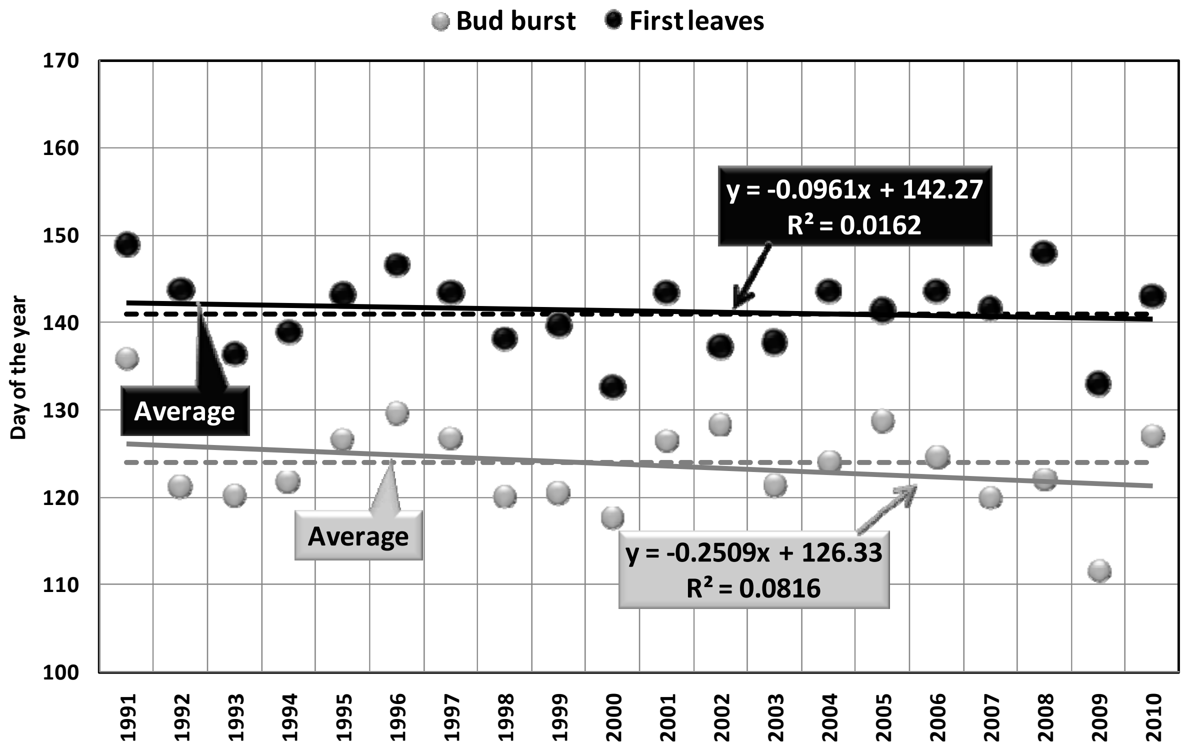


Fig. 9. The average starts of vegetative phenological phases and trends of development (1991–2010).

Conclusions

This paper represents investigation results for selected vegetative (the bud burst BBCH 07; the first leaves BBCH 15) and generative (the beginning of flowering BBCH 61; the end of flowering BBCH 69) phenological phases of the Norway spruce (*Picea abies* (L.) Karsten*)*, provided with using data from the CHMI phenological stations (wild plants) situated at altitudes from 155 m (Doksany) to 860 m (Pernink). The research ran in years 1991–2010.

The mean starting date of the bud burst (BBCH 07) was timed from 22nd April till 13th May, the variation coefficients (s_x %) reached the values within 5.35–8.88. The average air temperature over five days preceding this phenophase onset varied with the altitude: from 9.0 to 12.0 °C. The average date of the phenophase first leaves 100% (BBCH 15) occured between 7th May and 28th May, with the preceding five-day air temperature 12.3–13.7 °C and variation coefficients (s_x %) 5.60–7.06.

The preceding five-day air temperature for the beginning of flowering onset was from 11.9 to 13.2 °C with variation coefficients (s_x %) 3.15–7.27; and for the end of flowering onset from 13.5 to 15.4 °C, with variation coefficients (s_x %) 3.70–6.81. The pollen release onset was started on average on 4th May–14th May, and the end of flowering from 21st May to 31st May.

In the selected elevation zones, the average time of flowering is 15–17 days, with the standard deviation from 1.9 to 2.1 days. The earliest beginning of the flowering was recorded in the year 2009 (the average for the entire phenological station network for wild plants was 26th April); the latest onset of the flowering was re-

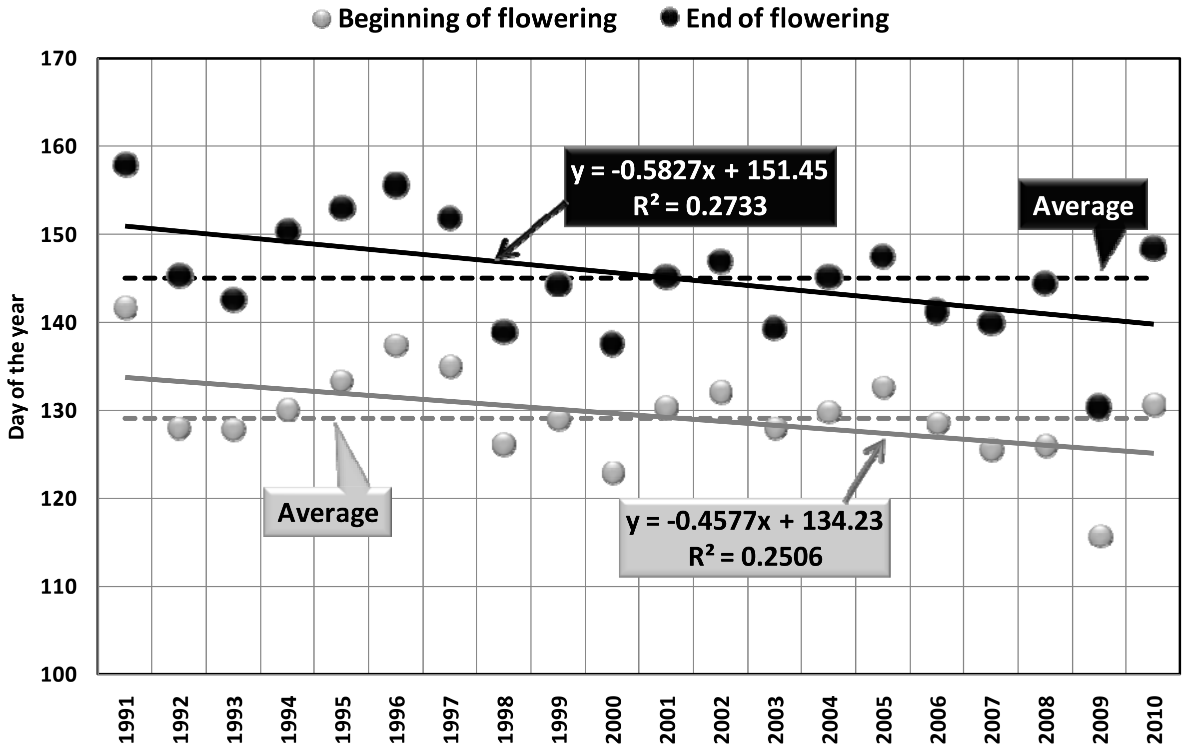


Fig. 10. The average starts of generative phenological phases and trends of development (1991–2010).

corded in the year 1991 (the average for all phenological stations was 22nd May).

The phenological phases were shifted earlier in the years 2000 and 2009; on the contrary, the onsets were delayed in the years 1991 and 1996. All the observed phenophases show an overall tendency to the earliest onsets, however at only a low level of statistics significance over the 20-year study period.

Acknowledgement

The authors gratefully thank to the Czech Ministry of Education, Youth and Sports, research project OC 09029 (*Phenology atlas of Czechia*), research projects 6046070901 (*Sustainable agriculture, quality of agricultural products, sustainable use of natural and landscape resource*) and SVV-2011-263202 for funding this research.

References

Balut, S., Sabor, J. 2002. *Inventory provenance test of Norway spruce (Picea abies (L.) Karts.) IPTNS-IUFRO 1964/68 in Krynica*. Krakow: Akademia Rolnicza im. H. Kollataja w Krakowie. 200 p.

Bednářová, E., Merklová, L. 2007. Vyhodnocení fenologie mladého smrkového porostu v oblasti Drahanská vrchovina [Phenological evaluation of a young spruce stand in the Drahanská vrchovina Hills]. In Rožnovský, J., Litschmann, T., Vyskot, I. (eds). *Klima lesa. (Mezinárodní vědecká konference, Křtiny, 11.–12. 4. 2007). Sborník abstraktů a CD*. Praha: Česká bioklimatologická společnost, p. 5.

Coufal, L., Houška, V., Reitschläger, J., D., Valter, J., Vráblík, T. 2004. *Fenologický atlas* [Phenological atlas]. Praha: Český hydrometeologický ústav 264 p.

Český hydrometeorologický ústav 2009. *Návod pro činnost fenologických stanic – lesní rostliny* [Methodical instructions for phenological stations – forest plants]. Metodický předpis č. 10. Praha: Český hydrometeorologický ústav. 74 p.

Domčeková, D. 2008. Porovnanie priebehu zalistenia spoločenstiev drevín na dvoch monitorovacích plochách v južnej časti Kremnických vrchov v rokoch 2007–2008 [Comparing of foliage development between woody plant associations on two monitoring plots in the southern part of the Kremnické vrchy Mts in years 2007–2008]. In Rožnovský, J., Litschmann, T. (eds). *Bioklimatologické aspekty hodnocení procesů v krajině. Sborník abstraktů a CD-ROM: sborník příspěvků z mezinárodní konference: Mikulov 9. – 11. 9. 2008*. Praha: Český hydrometeorologický ústav, p. 17.

Hájková, L., Nekovář, J. 2007. *Zpracování fenologie smrku a břízy pomocí GIS map* [Spruce and Birch phenology represented by means of GIS maps].

Sborník prací ČHMÚ. Svazek 50. Praha: Český hydrometeorologický ústav, p. 67–83.

Hájková, L., Kožnarová, V., Sulovská, S. 2011. Phenology season onset in relation to synoptic situations in the Czech Republic within 1991–2010. In *International conference on current knowledge of climate change impacts on agriculture and forestry in Europe. Book of abstracts. Topolčianky, Slovakia 3rd – 6th May.* [Geneve]: World Meteorological Organization, 2011, p. 129–130.

Hejný, S., Slavík, B. (eds) 1988. *Květena ČSR* [Flora of the CSR]. Praha: Academia. 543 p.

Hribík, M., Škvarenina, J., Bartík, M. 2011. Vplyv porastovej mikroklimy klimaxovej smrečiny na ukladanie a dynamiku snehovej pokrývky na výskumnej ploche Červenec – TANAP v sezónach [The stand microclimate influence of a climax spruce stand on accumulation and dynamics of of snow cover on the research plot Červenec – the Západné Tatry Mts]. In Středová, H., Rožnovský, J., Litschmann, T. (eds). *Mikroklima a mezoklima krajinných struktur a antropogenních prostředí. Sborník abstraktů a CD. Mezinárodní vědecká konference, Skalní mlýn, 2.–4. 2. 2011*. Praha: ČBkS v nakl. ČHMÚ, p. 19.

Hurtalová, T., Matejka, F., Janouš, D., Pokorný, R., Rožnovský, J. 2007. Influence of snow damage on aerodynamic characteristics of spruce stand. *Folia oecol.*, 34: 97–104.

Magová, D., Střelcová K., Škvareninová, J. 2011. Odozva rastových procesov proveniencií smreka obyčejného (Picea abies (L.) Karst.) na nástup jarných fenologických fáz v arboréte Borová Hora [Response of growth processes of Norway spruce provenances (Picea abies (L.) Karts.) to the spring phenophases outbreak in the Arboretum Borová Hora]. In Středová, H., Rožnovský, J., Litschmann, T. (eds). *Mikroklima a mezoklima krajinných struktur a antropogenních prostředí. Sborník abstraktů a CD. Mezinárodní vědecká konference, Skalní mlýn, 2.–4. 2. 2011.* Praha: ČBkS v nakl. ČHMÚ, p. 32.

Mauer, O., Palátová, E. 2010. Decline of Norway spruce in the Krkonoše Mts. *J. Forest Sci.*, 56: 361–372.

Rötzer, T., Chmielewski, F.M. 2001. Phenological maps of Europe. *Climate Res.*, 18: 249–257.

Rybníček, O., Rybníček, K., Rybníčková, E. 1997. *Miniatlas pylových alergenů* [Miniatlas of the plants producing allergic pollen]. Brno: Městská hygienická stanice. 46 p.

Střelcová, K., Leštianská, A. 2009. Prírastok a zmeny obvodu kmeňa klonov smreka obyčajného počas nástupu jarných fenofáz [Diameter increment and stem circumference changes in spruce clones at onset of spring phenophases]. In *Fenológia rastlin v meniacich sa podmienkach prostredia*. Zvolen: Technická univerzita, p. 69–72.

Škvareninová, J., Snopková, Z. 2010. The temporal variability of phonological stages of Norway spruce (Picea abies (L.) Karst.) in Slovakia. *Folia oecol.*, 37: 212–221.

Van Vliet, A. J. H., De Groot, R. S., Bellens, Y., Braun, P., Bruegger, R., Bruns, E., Clevers, J., Estreguil, Ch., Flechsig, M., Jeanneret, F., Maggi, M., Martens, P., Menne, B., Menzel, A., Sparks, T. 2002. The European Phenology Network. *Int. J. Biometeorol.*, 47: 202–212.

Časová a prostorová variabilita nástupu fenologických fází smrku ztepilého (*Picea abies* (L.) Karsten) v České republice

Souhrn

V příspěvku jsou vyhodnoceny časové nástupy vybraných vegetativních fenologických fází (rašení BBCH 07 a první listy BBCH 11) a generativních fenologických fází (počátek kvetení BBCH 61 a konec kvetení BBCH 69) smrku ztepilého (*Picea abies* (L.) Karsten), který je součástí pozorovacího programu fenologické sítě ČHMÚ. K tomuto účelu byla zpracována data za období 1991–2010 z fenologických stanic s nadmořskou výškou od 155 m (Doksany) do 860 m (Pernink).

Průměrné datum nástupu rašení je v závislosti na nadmořské výšce od 19. dubna do 10. května, první listy se objevují v průměru mezi 11. až 26. květnem, počátek kvetení nastává v průměru mezi 3. až 18. květnem a konec kvetení přichází mezi 20. květnem a 2. červnem. Doba kvetení je v průměru mezi 15 až 17 dny se standardní odchylkou od 1,9 do 2,1. Nejčasnější nástup počátku kvetení byl zaznamenán 15. dubna 2009 (Lednice); nejpozdnější nástup byl 24. května 2001 (Pernink). Vertikální fenologický gradient je pro vybrané fenofáze rašení, první listy (100 %), počátek kvetení a konec kvetení 2 dny / 100 m nadmořské výšky. Všechny sledované fenofáze vykazují za 20-leté období celkovou tendenci k dřívějšímu nástupu, avšak předložené výsledky jsou na nízké hladině statistické významnosti.

Received June 6, 2011
Accepted October 25, 2011

Shot-hole disease on *Prunus persica* – the morphology and biology of *Stigmina carpophila*

Helena Ivanová[1], Monika Kaločaiová[2], Milan Bolvanský[1]

[1]Branch for Woody Plants Biology, Institute of Forest Ecology of the Slovak Academy of Sciences, Akademická 2, 949 01 Nitra, Slovak Republic,
e-mail: helena.ivanova@ savzv.sk, e-mail: milan.bolvansky@savzv.sk
[2]Department of Ecology, Faculty of Natural Sciences, Constantine the Philosopher University, A. Hlinku 1, 949 74 Nitra, Slovak Republic,
e-mail: mkalocaiova@ukf.sk

Abstract

Ivanová, H., Kaločaiová, M., Bolvanský, M. 2012. Shot-hole disease on *Prunus persica* – the morphology and biology of *Stigmina carpophila*. *Folia oecol*., 39: 21–27.

Shot-hole disease caused by *Stigmina carpophila* (Deuteromycetes) is a major limiting factor in peach production, causing foliage shot hole in spring and early summer; fruit-spotting and cankers on limbs and twigs during autumn rains. The fungus overwinters, for at least two seasons, in cankers and killed buds. During spring and summer of 2009–2010, there occurred optimal conditions for manifestation of these symptoms on peach leaves and for the fungus activation. In such humid conditions is activated germination of brown, smooth walled, fusiform conidia with truncate base and rounded apex 16 to 20 µm by 8–10 µm in size, which accounts for the winter infection of buds. The fungus *Stigmina carpophila* isolated from damaged leaves of *Prunus persica* formed in culture sub-hyaline, septate and smooth walled mycelium, and dark brown stromata, partly superficial and partly immersed. The evaluation of mycelium growth suggested a significant effect of cultivation media on the assessed mycelium size on each of the eight days of the experiment. Since the third cultivation day, the size of mycelium on CzD was significantly smaller than the mycelium size on PDA and V-8. The variability of mycelium size on all media decreased with the time of cultivation. There was observed formation of terminal, intercalary, often chained chlamydospores on PDA in the dark. The most serious aspect of shot hole disease on peach is leaf infection leading to defoliation, as severe defoliation during the early fruit development can cause falling young fruits, and repeated defoliation weakens the trees and reduces their yield.

Key words

shot hole blight, *Stigmina carpophila*, stone fruit trees

Introduction

Shot hole blight or shot hole disease is a fungal disease of stone fruit trees including peach, nectarine, apricot, plum, cherry and almond. The most commonly affected are apricot, peach and nectarine, and to lesser degree cherries.

Stone fruit trees are economically important landscape plants. The most limiting factor to their production is shot-hole disease. On leaves, the symptoms of shot-hole disease range from small reddish or purplish, with yellow halo bordered spots, the centre of which drops out as the spot ages, to larger, irregular, reddish-brown spots occurring usually along the leaf margin – where the affected area also drops out (Woodward, 1999). On twigs, the symptoms are small black spots which later enlarge and become sunken. The disease is the most harmful in intensified cool and wet conditions of spring, although it can occur and cause damage at any time during prolonged wet weather (Evans et al., 2008). Overhead sprinkler irrigation and closely spaced plants favour the disease development.

The primary causal pathogen of shot-hole disease was described as *Xanthomonas pruni*. This bacterium, in association with another bacterium *Xanthomonas campestris*, has been blamed for all the damage. Preliminary evidence suggests that shot-hole disease is not caused solely by bacteria but also by one or several fungal pathogens (Woodward, 1999). Identical symptoms can be caused by a minor fungal pathogen known as *Stigmina carpophila* (Lév.) M.B. Ellis, [syn. *Thyrostroma carpophilum* B. Sutton, *Coryneum beyerinckii* Qud., *Wilsonomyces carpophilus* (Lév.) Adask., *Ascospora beijerinckii* Qud., *Clasterosporium carpophylum* (Lév.) Aderh.], (*Dothideomycetes*, *Capnodiales*, *Mycosphaerellaceae*). The fungus was first observed in France in 1846, later in Africa, Asia, Europe, North, Central and South America, Australia and Oceania (Văcăroiu et al., 2008).

On some *Prunus* species (*P. amygdalus, P. armeniaca, P. avium, P. cerasus, P. communis, P. domestica, P. dulcis, P. italica, P. laurocerasus, P. persica*) particularly laurel, shot-holing may occur following any factor damaging leaf tissue. In addition to *Pseudomonas* and *Stigmina,* such factors include powdery mildew, other leaf-spotting fungi, pests, nutritional problems and damage from adverse soil or weather conditions. Morphological and physiological characters of affected leaves may be necessary for identifying the precise cause.

Material and methods

During spring and summer 2009–2010, leaves of *Prunus persica* (L.) Batsch, syn. *Persica vulgaris* Mill. showing symptoms of discoloration, piercing, brown spots or necroses were sampled from affected plants in private gardens of the town Nitra. Visual characteristics of necrotic and chlorotic leaves were examined with a stereomicroscope SZ51 (Olympus). Investigation of fungal structures immersed in water was performed with a clinical microscope BX41 (Olympus), under 400× and 1000× magnification.

The leaf pieces cut from the diseased plants were surface-sterilized with a 3% sodium hypochlorite solution for 20 min., rinsed in sterile distilled water (2–3 times) and dried carefully with filter paper. After the surface sterilization, the tissue samples were cut to small pieces, placed on potato-dextrose agar (3% PDA) and subsequently incubated in Petri dishes. There followed cultivation in a versatile environmental test chamber MLR-351H (Sanyo) at 24 ± 1 °C temperature, 45% humidity and photoperiod 12/12 hours, and finally isolation on potato-dextrose agar (3% PDA). Pure fungal cultures were obtained after multiple purifications. The growth rate of mycelium was balanced on three growth media: PDA, V-8 and CzD, each in 30 Petri dishes, for eight days. The mycelium size was assessed daily, based on two diameter values measured perpendicular each to other. The obtained data were evaluated for each day separately, by analysis of variance – to assess the influence of the three media on growth of *S. carpophila*. Subsequently, multiple range test of growth means for media was performed. The package Statgrafic was used for statistical analysis.

The colonies of fungi were identified using various keys for identification**:** Adaskaveg et al. (1990), Ellis and Ellis (1997) and Kirk (1999), working with micro- and macroscopic symptoms. Based on morphological and physiological characters and optimal temperatures for growth in the culture, all the isolates were identified as *S. carpophila*. Samples of material have been deposed at the Institute of Forest Ecology of the Slovak Academy of Sciences, Branch for Woody Plants Biology in Nitra.

Results and discussion

In our experiments, during the spring and summer, red dots were scattered all over the leaves; then they expanded into larger circular lesions. These lesions had a necrotic brownish centre and purple margins. The central necrotic area gradually gave way and droppped out, resulting in a hole (Fig. 1a, b). At the beginning, the lesions were small, round purplish-black spots on the surface of the affected leaf parts (Fig. 1c). On young leaves, the diseased areas sometimes expanded rapidly (Fig. 1d) and killed large areas of the blade (Fig. 1e). We have confirmed the results of Smith et al. (1988) that shot hole disease of stone fruit trees, caused by the fungus *S. carpophila,* produces lesions on leaves, fruits, flowers and succulent shoots. Across all the growing areas of stone fruits, this serious pathogen causes large circular purple-brown spots with chlorotic haloes on leaves. Buds and twigs are affected, too.

Leaf infection leading to defoliation in the most serious aspect of shot hole diseases, because severe defoliation during early fruit development can cause the young fruits to fall, and repeated defoliation weakens the trees and reduces their yield (Teviotdale et al., 1999). With lesions on the petiole, the leaf is killed outright (Kotte, 1941; Kirk, 2005). Frequently, large numbers of young leaf clusters are killed by lesions that develop on the base of the petioles. In our observations, the affected areas of the blades of mature leaves separated quickly from the non-affected tissue by abscission zones and immediately fell away. Newly formed leaves with only a few lesions dropped (Fig. 1f), but older leaves commonly remained on the tree, despite a number of lesions. The association between defoliation and shot-hole infections was reported earlier by Wilson (1953). According to his study, if a leaf infection causes an early defoliation and if the early defoliation adversely affects the tree growth or vigour, then defoliation over several years may cause stress to the trees or reduce the amount of their fruiting wood.

During spring and summer 2009 and 2010, there were very suitable conditions for the fungus growth. According to the climatic data of Shmi (2011), the average sums of rainfall in Slovakia in the of spring-summer periods 2009 and 2010 were above normal. The year 2009 in Slovakia had an 871 mm atmospheric precipitation total, the year 2010 an about 164% precipitation total compared to the normal. These conditions resulted in an extensive damage to *Prunus* trees by the fungus *S. carpophila*, as the spores of this fungus infect susceptible plant tissues during periods of persistent moisture. According to Evans et al. (2008), the disease is most harmful in extended cool and moist periods in spring, while it can occur and cause damage at anytime during long lasting wet weather.

The infection is spread by conidia, in dry conditions viable for several months but not possible to detach and spread by the wind. Rain is necessary for their dispersal. In humid conditions, they can germinate at highly varying temperatures above 2 °C, which accounts for the winter infection of buds. Temperature and duration of wet periods during the inoculation influenced the development of shot-hole disease on leaves of the *Prunus* species caused by *S. carpophila*. (Văcăroiu et al., 2009).

Grove (2002) detected the influence of temperature and high humidity on the infection of cherry and peach foliage by this fungus. The effects of temperature and wetness duration on infection of *P. avium* and *P. persica* were examined under controlled conditions. In cherry, the disease severity increased with wetness duration. After 24 h of wetness presence, the maximum disease severity of 10.5 lesions cm^{-2} was obtained at 20 °C. Although severity values were different, the general responses to temperature and wetness period were similar on peach. Shaw et al. (1990) observed in controlled environment studies that a 14-hr wetness period resulted in 0.1 and 45.0 lesions per leaf after 10 days at 8 °C and 22 °C, respectively. Extended wetness periods during the infection period increased the number of lesions per a leaf regardless of the temperature. According to Larsen (1999), temperature from 70 °F to 80 °F (21–27 °C) is optimum for *Coryneum* infection. Lesions can develop at 45 °F (7 °C), however, at a much slower rate. It takes from two to five days for a spore to initiate infection and cause a visible lesion. According to Hickman (2001) and Evans et al. (2008), in spring under sustained moisture, the pathogen can actively colonize host tissues at temperature as low as 36 °F (2 °C) in as few as 24 hours, while at 77 °F (24.5 °C) the fungus can infect a suitable host's tissues in as few as 6 hours. Infection periods are determined by duration of moisture conditions and the temperature. At cooler temperatures, longer periods of moisture are required (Shaw et al., 1990).

In our experiments, the fungus *S. carpophila* isolated from the damaged leaves of *Prunus persica* formed sub-hyaline, septate and smooth walled mycelium (Fig. 1g, h, i) with septate, thin-walled, branched hyphae growing in a culture on 3% PDA (at 24 ± 1 °C temperature, 45% humidity and 12/12 hours of photoperiod), and dark brown stromata which were partly superficial and partly immersed. No growth was observed in the culture above 30 °C.

The evaluation of mycelium growth by anova has suggested a significant effect of cultivation media on assessed mycelium size on each of the eight days of the experiment. Beginning with the third day of cultivation, the size of mycelium on CzD was significantly smaller than the mycelium size on PDA and V-8 (Table1). In addition, the mycelium on CzD showed a lower growth rate: its size on the seventh day was 6 to 7-times smaller than the mycelium size on the other two media. The differences in mycelium size between PDA and V-8 substrates were smaller, significant, however, in most of the cultivation days. On the first and the seventh day, the mycelium on PDA was smaller than on V-8; contrarily, on the second, fifth and sixth day it was larger than on V-8 (Fig. 1j-k). Statistically insignificant differences in mycelium size between PDA and V-8 were observed on the second, third and eighth day. Different growth rates of mycelia on individual media are demonstrated in Fig. 2. Fluctuation in mycelium size on a single medium was the highest on the CzD substrate where the mycelium was of the smallest size on average. This medium stopped the fungus vegetative development and fructifications were reduced. The second biggest size fluctuation in mycelia cultivated on 30 Petri dishes was obtained on medium PDA. The lowest mycelium size fluctuation was on medium V-8. Generally, on all media, the fluctuation of mycelium growth decreased with cultivation time (see the coefficient of variation in Table 1).

The conidia were brown, fusiform, with a truncate base and rounded apex, smooth walled with 3, occasionally 4 dark transverse and 1–2 oblique septa with dimensions from 16 to 20 µm by 8–10 µm (Fig. 1l-n). These pigmented spores are extremely durable and can survive dormant on leaf or bud surface for months, waiting just for the right temperature and moisture conditions to germinate and infect its host (Evans et al., 2008). Formation of chlamydospores on PDA was obtained in the dark. Chlamydospores were single, terminal and intercalary, often chained (Fig. 1o).

The mycelium of this fungus obtained by Kafi and Rizvi (1971) in culture from apricot fruits was septate, sub-hyaline and smooth walled. The conidiophores, outgrowing from the upper cells of the dark brown stromata, were straight, sub-hyaline to pale brown. The conidia produced acrogenously were clavate elipsoid or fusiform, with truncate base and rounded or acute apex, sub-hyaline to brown. The basal cells of conidia were

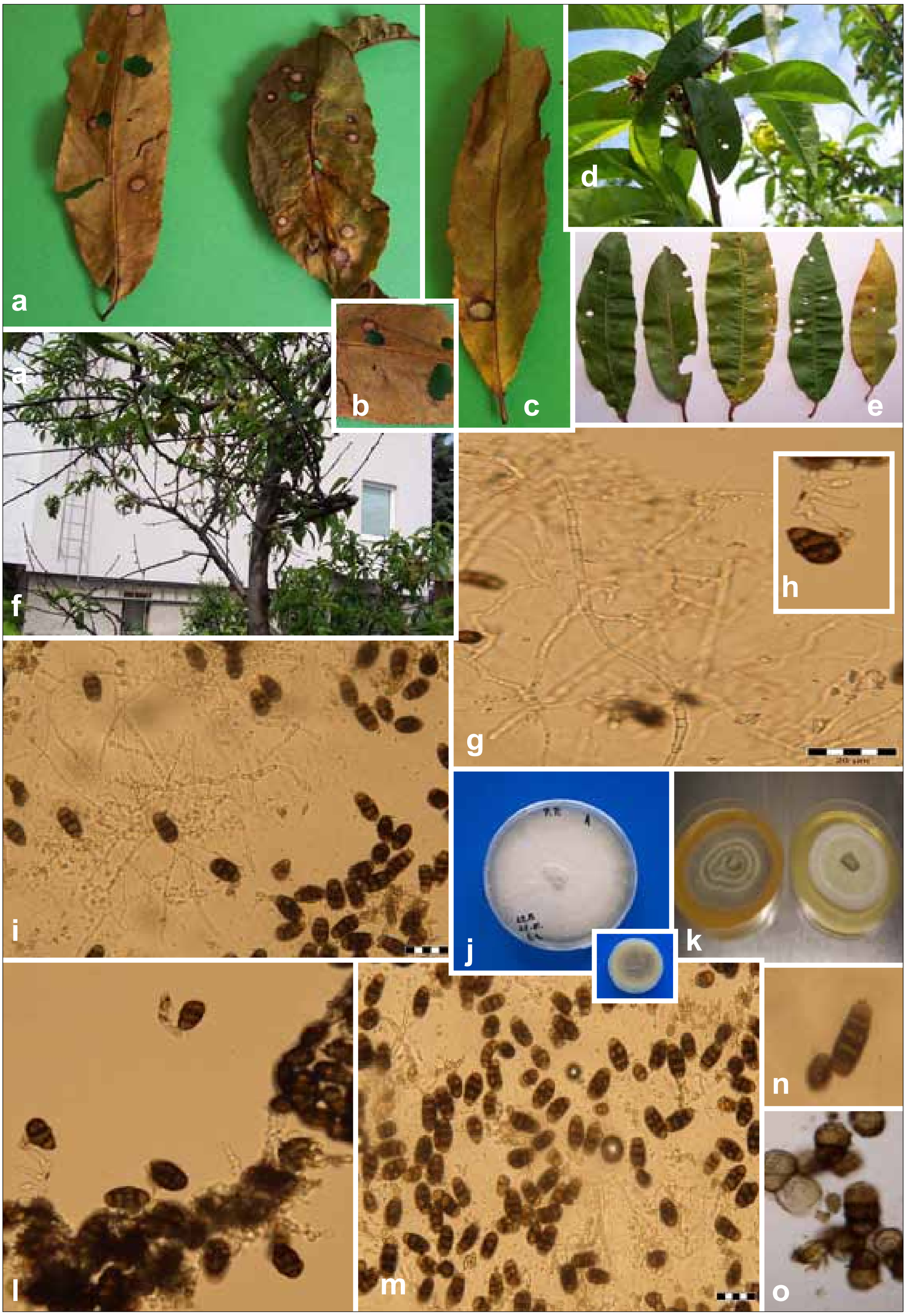


Fig. 1. Fungus *Stigmina carpophila* isolated from affected leaves of *Prunus persica*: a, b, Central necrotic area gradually gives way and drop out resembling in a hole; c, The lesions at first were small, round purplish-black spots on the surface of the affected part; d, e, On the young leaves, the diseased areas may expand rapidly and kill large areas of the blade; f, Newly formed leaves with only a few lesions will drop; g, h, i, Sub-hyaline, septate and smooth walled mycelium in culture; j-k, Culture of *Stigmina carpophila* after 36 days cultivation on PDA (reverse side-detail) and V-8 media; 1-n, Brown, fusiform, smooth-walled conidia with 3–4 dark transverse and 1–2 oblique septa; o, Formation of chlamydospores on PDA in the dark conditions.

hyaline, sometimes forming a beak. The conidia were smooth walled with 2 to 7 dark transverse and occasionally 1 to 2 oblique or longitudinal septa, measuring from 21.6 µm to 65.6 µm by 9.6 µm to 14.4 µm. Ellis and Ellis (1997) obtained similar results. The conidia produced in culture were brownish, fusiform with a truncate base, 3–7-septate, with dimensions of 30–60 × 9–18 µm.

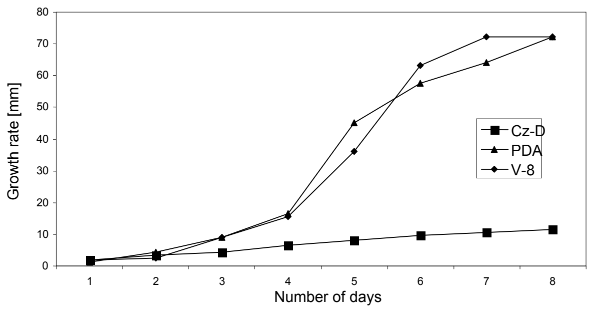


Fig. 2. Comparison of growth rate of the mycelium of the fungus *Stigmina carpophila* isolated from *Prunus persica* on three different media.

The fungus *S. carpophila* develops very well in laboratory conditions, on different crop substrates. The fungus acted best on PGA (potato-glucose-agar), followed by PDA (potato-dectrose-agar), where colonies (from morphological aspect, specific to the fungus and with a very good fructification) were formed. The MA environment produced bigger conidia, the progress, however, was rather slow. The Czapek-Dox environment stopped the fungus vegetative development, and fructifications were cut (Văcăroiu et al., 2009). Ahmadpour et al. (2009) isolated from infected leaves, fruits and twigs of different *Prunus* species (apricot, almond, peach, nectarine, plum, sweet cherry and sour cherry) hyphae of the fungus *Wilsonomyces carpophilus* (syn. *S. carpophila*). The hyphae were septate, thin-walled, branched, 2.5–7.5 µm in diameter, sub-hyaline to light brown. Conidiophores in the sporodochia were sympodial, scars on conidiophores inconspicuous to conspicuous, conidia fusoid with apical cells ovate and basal cells truncate, 2.5–5 µm at the base, with 2–4 transverse septa (occasionally 0–8 septa), holoblastic, rhexolytic, 20–67.5 × 7.5–15 µm in size, sub-hyaline

Table 1. Descriptive statistics for the mycelium growth of *Stigmina carpophila* on three different media and multiple range test of means

Day	*Medium	No. of dishes	Mean size	Standard error	Minimum	Maximum	Coeff. of variation
1	PDA	30	1.235a	0.068	0.700	2.210	30.428
	V-8	30	1.994b	0.062	1.440	2.720	17.022
	CzD	30	1.794b	0.164	0.800	5.060	50.083
2	PDA	30	4.539b	0.189	2.080	6.720	22.816
	V-8	30	2.612a	0.065	1.960	3.420	13.745
	CzD	30	3.376a	0.389	0.990	9.000	63.194
3	PDA	30	9.352b	0.300	5.750	13.200	17.579
	V-8	30	8.622b	0.219	6.500	11.700	13.939
	CzD	28 (*2)	4.304a	0.488	1.200	9.920	60.037
4	PDA	30	16.878b	0.548	9.000	25.650	17.793
	V-8	30	15.523b	0.162	13.200	17.480	5.700
	CzD	27(*3)	6.450a	0.455	1.800	10.540	36.668
5	PDA	30	45.234c	0.658	36.000	53.290	7.973
	V-8	30	36.014b	0.355	32.940	40.800	5.413
	CzD	27(*3)	8.108a	0.543	2.560	13.200	34.793
6	PDA	30	57.697c	0.773	49.000	64.000	7.332
	V-8	30	48.648b	0.443	42.600	56.000	4.989
	CzD	27(*3)	9.649a	0.608	4.560	15.910	32.760
7	PDA	30	64.000b	0.000	64.000	64.000	0.000
	V-8	30	72.250c	0.000	72.250	72.250	0.000
	CzD	27(*3)	10.683a	0.602	5.630	16.900	29.276
8	PDA	30	72.250b	0.000	72.250	72.250	0.000
	V-8	30	72.250b	0.000	72.250	72.250	0.000
	CzD	27(*3)	11.577a	0.603	6.200	18.000	27.051

PDA – Potato-dextrose-agar, V-8 agar (V-8 juice, $CaCO_3$, agar); CzD – Czapek-Dox agar; (*2) or (*3), the number of contamined PM.

to golden brown, dark olivaceous to black in mass. No growth was observed in culture below 5 °C or above 30 °C. Văcăroiu et al. (2008) observed conidium germination starting at a temperature of 2 °C (1–3%), the optimal temperature was recorded between 16 and 24 °C (25–80%) and it decreased to 5% at 30 °C. Progressive spore growth was recorded starting from 2 °C, the highest colony growth rate was reached at 20 °C, decreasing until 30 °C.

Only one type of propagative structure is regularly produced. It is three- to six-celled, ovoid, yellowish conidium, borne on a short stalk (conidiophore) emerging from a simple cushion of fungal cells. The conidia generated by inoculum source are transported by rain and infect flowers and young leaves. On the leaves, the infection hypha penetrates directly through the cuticle, and it is seldom if ever found entering stomata. After the entry of the infection hypha, the fungus produces mycelium between the walls of the host tissue. From this mycelium, loosely packed cushions of hyphal cells emerge to the surface, and give rise to conidia (Văcăroiu et al., 2008).

Adaskaveg (1995) studied the morphology and ultrastructure of shot hole disease of almond infected by conidia *Wilsonomyces carpophilus* using light, scanning and transmission electron microscopy. The multicelled conidia of this fungus were thick-walled and darkly pigmented. The conidial wall was multilayered and mainly consisted of an electron-dense cuter-wall layer, and an electron-translucent inner-wall layer. Septa of conidia were also multilayered. The conidia lacked true septa and germinated by rupturing their outer-wall layers. The germination hyphae penetrated, indirectly through stomata or directly through the cuticle, into leaf tissue from appressoria that were produced terminally or on lateral branches of germ tubes. In cankers, the fungus may persist for several years. The pathogen overwinters on infected dormant leaves and blossom buds on twigs. According to Highberg (1986), *S. carpophila* conidia can survive the dormant season in association with healthy dormant buds, thereby contributing to the overwintering population of the fungus on the almond tree.

More serious and widespread diseases of *Prunus* leaves caused by other fungi may appear similar. Three species cause a shot-hole symptom, in which the necrotic tissue in limited spots dries and falls out of the leaf. All these fungi cause repeated defoliation which makes the tree more susceptible to winter injury and may eventually kill it.

Acknowledgement

This study was carried out with financial support from the scientific project grant agency VEGA of the Slovak Academy of Sciences No. 2/0149/10 and with the grant of the Science and Technology Assistance Agency APVV No. 0421-07.

References

Adaskaveg, J.E. 1995. Conidial morphology, host colonization, and development of shot hole of almond caused by Wilsonomyces carpophilus. *Can. J. Bot.*, 73: 432–444.

Adaskaveg, J.E., Ogawa, J.M., Butler, E.E. 1990. Morphology and ontogeny of conidia in Wilsonomyces carpophilus, gen. nov., and comb. nov., causal pathogen of shot hole disease of Prunus species. *Mycotaxon*, 37: 275–290.

Ahmadpour, A., Ghosta, Y., Javan-Nikkhah, M., Fatahi, R., Ghazanfari, K. 2009. Isolation and pathogenicity tests of Iranian cultures of the shot hole pathogen of Prunus species, Wilsonomyces carpophilus. *Austral. Pl. Disease Not.*, 4: 133–134.

Ellis, M.B., Ellis, J.P. 1997. *Microfungi on land plants: an identification handbook*. Slough: Richmond Publishing Co. 868 p.

Evans, K., Frank, E., Gunnell, J.D., Shao, M. 2008. *Coryneum or shothole blight*. Utah pests fact sheet. Utah State University Extension. [Utah]: Utah State University Extension, Utah Plant Pest Diagnostic Laboratory. 3 p.

Grove, G.G. 2002. Influence of temperature and wetness period on infection of cherry and peach foliage by Wilsonomyces carpophilus. *Can. J. Pl. Path.*, 24: 40–45.

Hickman, G.W. 2001. *Preventing shot hole disease backyard horticulture*. News Release. Backyard Horticulture [cit. 2010-11-24]. http://cemariposa.ucdavis.edu/newsletters/Preventing_Shot_Hole_Disease37040.pdf

Highberg, L.M. 1986. Survival of shot-hole inoculum in association with dormant almond buds. *Pl. Dis.*, 70: 828–831.

Kafi, A., Rizvi, M.K. 1971. Fungi intercepted from abroad. *Mycopath. et Mycol. appl.*, 45: 317–325.

Kirk, P.M. 1999. Stigmina carpophila. (Descriptions of fungi and bacteria). *IMI descriptions of fungi and bacteria*, 140: Sheet 1393 [cit. 2010-04-28]. http://www.cabi.org/dfb

Kotte, W. 1941. *Krankenheit und Schädlinge im Obstbau und ihre Bekämpfung*. Berlin: Verlag Parey. 329 p.

Larsen, H. 1999. *Coryneum Blight*. Fact sheet, No. 2.914. Crop series, Diseases. Colorado: Colorado State University Extension. 2 p.

Shaw, D.A., Adaskaveg, J.E., Ogawa, J.M. 1990. Influence of wetness period and temperature on infection and development of shot-hole disease of almond caused by Wilsonomyces carpophilus. *Phytopathology*, 80: 749–756.

SHMI 2011. *Dlhodobý režim teploty vzduchu v Hurbanove a úhrnov atmosférických zrážok na Slovensku* [Long-term regime of air temperature at Hurbanovo and areal precipitation totals in Slovakia] [cit. 2011-04-15]. http://www.dmc.fmph.uniba.sk/public.../Hurbanovo.htm

SMITH, I.M., DUNEZ, J., PHILLIPS, D.H., LELLIOTT, R.A., ARCHER, S.A. 1988. *European handbook of plant diseases*. Oxford: Blackwell Scientific Publications. 583 p.

TEVIOTDALE, B.L., GOODELL, N., HARPER, D. 1999. Shot hole encourages almond drop, doesn´t harm kernels. *California Agriculture*, 53: 16–18.

VĂCĂROIU, C., ZALĂ, C.R., CRISTEA, S. 2008. Research on the morphology and biology of the Stigmina carpophila fungus. In *Scientific conferences with international participation Durable agriculture – Agriculture of future, 4th edition. Book of Abstracts, 28th–29th November 2008*. Craiova (Romania): Faculty of Agriculture, University of Craiova. 110 p.

VĂCĂROIU, C., ZALĂ, C.R., CRISTEA, S., OPREA, M. 2009. Research regarding the influence of temperature, atmospheric humidity and light upon the biology of the Stigmina carpophila fungus. *Sci. Pap., Series A, Agronomy, Bucharest*, 52: 398–403.

WILSON, E.E. 1953. Coryneum blight of stone fruits. In *USDA Yearbook of Agricultural Plant Diseases*. Washington, DC: Government Printing Office, p. 705–710.

WOODWARD, J.L.W. 1999. *Effect of fungicide treatment to control shot-hole disease of cherry laurel* [cit. 2011-10-12]. http://www.canr.org/98013.pdf

Dierkovitosť listov *Prunus persica* – morfológia a biológia huby *Stigmina carpophila*

Súhrn

Dierkovitosť alebo suchá škvrnitosť listov je všeobecne známe ochorenie kôstkovín, ktoré postihuje zástupcov rodu *Prunus* rastúcich v sadoch a záhradách, v ovocných a okrasných škôlkach. Ochorenie vyvoláva huba *Stigmina carpophila* (Lév.) M. B. Ellis. Jej výskyt podporuje daždivé počasie na jar a skoro v lete, ako aj vlhké počasie na jeseň a v zime. Pôvodca ochorenia prezimuje tzv. pučiacim mycéliom v škvrnách, v nádoroch na konárikoch, v púčikoch, v mumifikovaných plodoch, ale aj konídiami v opadaných listoch a na kôre stromov. Na jar 2009–2010 boli na sledovanom území mesta Nitra zaznamenané priaznivé teplotné podmienky na aktiváciu huby. Príznaky na listoch sa prejavili skoro na jar po vypučaní listov vo forme okrúhlych, niekoľko milimetrov veľkých, oranžových, neskôr ostro ohraničených hnedých škvŕn rozsiatych po celej listovej čepeli. Huba tvorila sub-hyalinné, delené, hrubostenné mycélium a valcovité, 3–4 priehradkové konídie veľké 16 – 20 × 8–10 µm, ktoré vďaka vlhkému počasiu infekciu ďalej rozširovali na pučiace listy. Vyhodnotenie rastu hýf mycélia huby *in vitro* analýzou variancie poukázalo na štatisticky významný vplyv kultivačného média na veľkosť mycélia počas 8-dňovej kultivácie. Od tretieho dňa kultivácie bola veľkosť mycélia na médiu CzD preukazne nižšia v porovnaní s dosiahnutou veľkosťou mycélia na médiách PDA a V-8. Predlžovaním kultivácie sa variabilita veľkosti mycélia huby na všetkých testovaných médiách znižovala. Na PDA agare pri kultivácii v tme sa pozorovala tvorba jednotlivých, terminálnych a interkalárnych chlamydospór často tvoriacich retiazky. Ochorením vznikajú na ovocných drevinách hospodársky významné škody. Silne poškodené listy predčasne opadávajú, čím sa znižuje asimilačná plocha, klesá intenzita fotosyntézy ako aj tvorba zásobných látok. Viacročné napadnutie predovšetkým mladých stromov spôsobuje ich oslabenie, výnimočne aj ich odumretie.

Received November 7, 2011
Accepted December 12, 2011

The concentration of SO_4^{2-} and amount of S-SO_4^{2-} in soil water and throughfall in beech forest of Štiavnické vrchy Mts, Slovakia

Rastislav Janík[1], Eduard Bublinec[1, 2], Margita Dubová[1]

[1]Institute of Forest Ecology of the Slovak Academy of Sciences, Štúrova 2, Zvolen, Slovak Republic, e-mail: janik@savzv.sk
[1, 2]Institute of Biology and Ecology, Faculty of Education, Catholic University in Ružomberok, Ružomberok, Slovak Republic

Abstract
Janík, R., Bublinec, E., Dubová, M. 2012. The concentration of SO_4^{2-} and amount of S-SO_4^{2-} in soil water and throughfall in beech forest of Štiavnické vrchy Mts, Slovakia *Folia oecol*., 39: 28–35.

The paper deals with the results of concentration SO_4^{2-} and amount of S-SO_4^{2-} in soil water from the beech forest situated in the the Štiavnické vrchy Mts. The mean concentration of SO_4^{2-} increased from 19.06 mg l^{-1} in the depth of surface humus (F_{00}) to 29.32 mg l^{-1} in the depth 0.25 m (F_{25}). To the soil during the study period input 415 kg S-SO_4^{2-} ha^{-1} – F_{00} and 587 kg S-SO_4^{2-} ha^{-1} in the layer F_{25}. The highest SO_4^{2-} concentration were observed during the year 1988 in the all depths, but the lowest values were found in the year 2010 in the F_{00} layer with 8.02 mg l^{-1}. The SO_4^{2-} concentration in soil water with the depth increased. The regression analysis found out a statistically significant influence of the sulphur content in the atmospheric deposition on the sulphur content in soil water. A significant correlation between the precipitation amount and the content of sulphur in precipitation and in soil water was observed. Student's t-test for dependent variables confirmed statistically strong significant differences of the sulphur content in soil water in the 0.1 m and 0.25 m depth between the study areas. No significance of differences between the years at the same plot was found.

Key words
SO_4^{2-} concentration, sulphate, soil water, Štiavnické vrchy Mts, throughfall

Introduction

Sulphur dioxide inputs to soil via atmospheric precipitation (Quilchano et al., 2002; Stachurski and Zimka, 2000). In soil it causes displacement of base ions and consequent acidification. Acidification is a long-term cumulative and dynamic process (Hruška et al., 2001; Cosby et al., 1986). Its effect is expressed after long period and has mainly a negative sense.

The alarmed situation of environmental and forest soil degradation led to the introducing of the deposition limits for forest ecosystems (Minďáš et al., 2001). The determination of deposition limits has become an important tool in the development of the national strategies for decreasing emissions of sulphur and nitrogen in Europe and North America (Matzner and Meiwes, 1994). These efforts, industrial slowdown (predominant the mining in Poland, Northern Bohemia and the formed GDR) and conversion of economy in the whole of Eastern Europe had a considerable impact on decreasing of the emission amount of sulphur and nitrogen (Dubová and Bublinec, 2006; Lindroos et al., 2006; Zapletal, 2006; Prechtel et al., 2001). The region of Slovakia is moderately environmentally sensitive according to the assessment of the selected sustainable development indicators. The critical values of sulphur deposition for Slovakia is 10–30 kg ha^{-1} yr^{-1} but it has been exceeded approximately at 25% of forest soil.

In Slovakia during 1989–1999 period was observed the diminution of the emitted primary pollutants by 57.9%, it presented average annual decreasing by about 6%. In 1998 to Slovakia were imported approximately 75,000 tons of sulphur (151,400 tons of SO_2) and exported 74,600 tons of sulphur (149,200 tons of SO_2), it means less by 2,200 tons.

In 2000 the emissions of particle matter released to the atmosphere were by 83% (58,408 t yr^{-1}) lower than in the 1985–1987 period. The decreasing of emission amount was observed also in the SO_2 emissions (by 77% to the value 134,376 t yr^{-1}) and the NO_x emissions (by 42% to the value 113,877 t yr^{-1}) (Kalúz, 2004). According to The Slovak Forest Health Monitoring Report 2003 (www.forestportal.sk) was the atmospheric deposition of sulphur at all monitored sites lower than the atmospheric deposition of nitrogen. In 2006 was observed decrease of the sulphur atmospheric deposition by 50% (3.8–16.4 kg $ha^{-1}yr^{-1}$) compared to 2001 levels.

In 2000 in the Czech Republic the SO_2 emissions decreased by 86% and the total ammonia emissions by 53% compared to 1990 levels. The dry deposition of SO_x (SO_2 + SO_4^{2-} in aerosol) declined by 81% and the wet deposition of SO_4^{2-} by 32% (Zapletal and Chroust, 2005). Fiala et al. (2001) showed the data about the decreasing of SO_4^{2-}concentration from 7.5 mg l^{-1} in 1987 to average 2.5 mg l^{-1} in 1997.

Sulphur dioxide emissions in the west Europe (Netherlands, Germany, and Sweden) have decreased since the beginning of the 1980 (Prechtel et al., 2001).

In spite of these optimistic results the danger of acidification is still actual problem. It follows from two facts: acidification is a long-term process and the cumulative ability of sulphur in the bottom soil layers. The aim of this paper was to show the trends of SO_4^{2-} concentration and in deposition of sulphate sulphur in the area of the Štiavnické vrchy Mts which was strong affected by pollutants.

Sites description

The research plots (RP) is situated in the south part of the Štiavnické vrchy Mts (48°35´ N, 18°51´ E), middle Slovakia. The stands plots are formed by beech stands (*Fagus sylvatica* L.) of the age 110 years with the stocking 0.9. The elevation 470 m a.s.l. and climatologically belongs to the warm district. The mean annual precipitation is in the range 700–750 mm. The average air temperature ranges from 8.0 to 8.5 °C and in the growing period and during the year is 14.5–5.5 °C (Kellerová, 2005).

The Štiavnické vrchy Mts was strong affected by pollutants from the regional sources (production of aluminium, power industry, transport, waste dump). The main contaminants were oxides of fluorine, sulphur and nitrogen, heavy metals as arsenic and cadmium, ozone and particulate matter. The long-time increased input of these pollutants from air to the ecosystems of the Štiavnické vrchy Mts caused the changes in the ecological conditions. This situation led to the negative quality of the beech stands in the study region. The worst effect for the beech forests had sulphur dioxide (SO_2) and fluorine (Mihálik and Bublinec, 1995). Many years the region of the Štiavnické vrchy Mts around the aluminium plant was regarded as an area with the most polluted environment in Slovakia. For this reason in the 1990's this area was classified to the II.–III. degree of exhalation. Since the end of the 1990's the amount of the pollutants has been decreasing rapidly because of the modernization production processes and more strictly legislation. The concentration of fluorine was cutting down on the tolerable level 1 μg m^{-3} (Urminská et al., 2000).

Material and methods

Soil solution was sampled by plate plastic lysimeters (1,000 cm^2 each). The first set of the lysimeters were instaled in the organic layer in the depth 0.0 m. The second and third set were located at 0.10 m (upper mineral layer) and 0.25 m dephts (lower mineral layer) at both study areas (Kukla, 2002). The samples had been collected monthly since 1988. After sampling the samples were chemical treated and evaluated (Janík et al., 2011).

The samplers for throughfall consisted of a bottle equipped with a funnel (660 cm^2 each) inserted into the cap of the bottle. Ten sampling devices were installed on each site (both open field and stand). The samples were collected monthly, eventually after a strong precipitation events. Samples of the open field and stand were individually pooled after each sampling period. These representative samples were analyzed.

Sulphate ions were determined by direct titration with lead nitrate with dithizone as indicator. The results were converted to the sulphate sulphur content.

The data were processed using the statistical program Statistica 7. Student's t-test for dependent variables was used to assess the statistical significance of differences between the study areas. Two-sample test by using the program Statgraphics was used for confirming these results. The impact of precipitation amount to the sulphate sulphur amount in precipitation and in soil water was estimated by simple regression analysis.

Results

The average SO_4^{2-} concentration in soil water with the depth increased from 17.13 mg l^{-1} (surface humus), 23.72 mg l^{-1} in depth 0.10 m to 29.32 mg l^{-1} in the 0.25 m depth (Fig. 1a). This same phenomenon was observed at the plots in the Kremnické vrchy Mts. The mean SO_4^{2-} concentration at the open field was lower 14.92 mg l^{-1} than in beech throughfall (17.13 mg l^{-1}). It can be explained by the washing-off effect. The forest canopy enriched the passing precipitation by captured sulphur compounds. The maximum values of

SO_4^{2-} concentration in soil water was measured in 1988 in each soil depth and ranged from 30.184 mg l^{-1} (surface humus) to 42.031 mg l^{-1} (0.25 m soil layer). The lowest values of SO_4^{2-} concentration in soil water were monitored in 2010 and varied from 8.02 mg l^{-1} – humus layer, 13.43 mg l^{-1} year 1989 in 0.10 m soil depth and 15.16 mg l^{-1} SO_4 0.25 m soil depth, respectively in the year 2005.

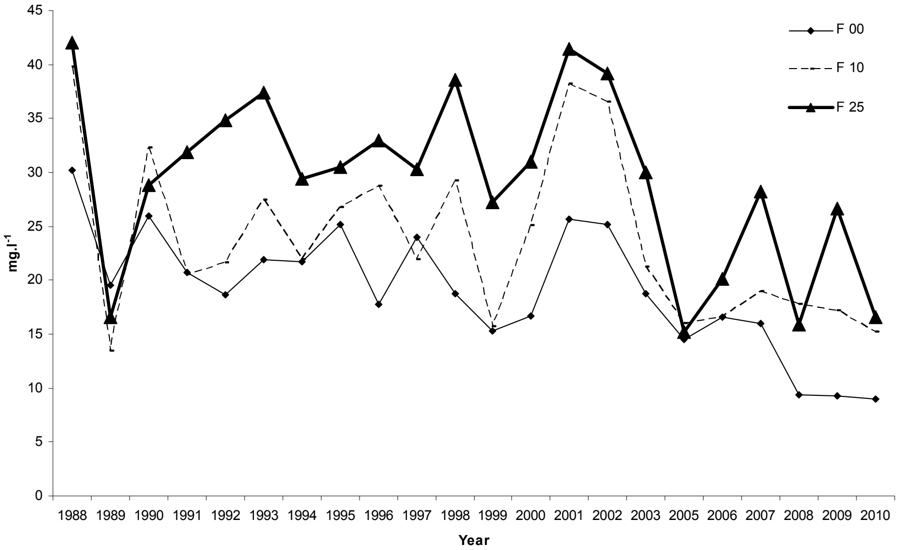


Fig. 1a. The concentration of SO_4^{2-}in soil water in the Štiavnické vrchy Mts in years 1988– 2010.

Table 1. Descriptive statistics of SO_4^{2-} concentrations and S-SO_4 in the Štiavnické vrchy Mts in years 1988–2010

Plot	F00	F10	F25	Open plot	Forest plot
			mg l^{-1}		
Valid	22	22	22	16	16
Mean	19.10	23.72	29.32	14.92	17.13
Minimum	8.01	13.43	14.16	3.25	9.64
Maximum	30.18	39.73	42.03	25.33	24.68
Standard deviation	5.77	7.76	8.22	5.48	4.07
Standard Error	1.23	1.65	1.75	1.37	1.01
Coefficient of variation	30.40	32.60	27.90	36.70	23.80
			kg ha^{-1}		
Valid	22	22	22	16	16
Mean	18.9	20.5	26.7	24.3	19.1
Minimum	8.9	9.1	11.8	12.4	7.2
Maximum	35.1	37.9	52.6	45.2	33.3
Standard deviation	7.2	9.0	11.7	9.6	6.2
Standard Error	1.5	1.9	2.5	2.4	1.5
Coefficient of variation	38.3	43.9	43.8	39.5	32.5

F_{00} – Lysimeter in the soil depth 0.0 m. F_{10} – Lysimeter in the soil depth 0.1 m. F_{25} – Lysimeter in the soil depth 0.25 m.

Table 2. Amount of sulphate [kg ha^{-1}] in the Štiavnické vrchy Mts in years 1988–2010

Lysimeter	F_{00}	F_{10}	F_{25}	Forest through fall	Open plot wet deposition
1988	22.2	29.52	52.61		
1989	10.89	13.5	20.1		
1990	22.2	31.7	33.3		
1991	11.1	17.5	27.3		
1992	11.1	17.1	33.1		
1993	11.7	14.1	15.6		
1994	21.9	32.2	47.4	7.2	12.4
1995	21.4	24.4	33.8	23.9	24.9
1996	26.8	34.5	37.2	19.8	32.3
1997	21.8	15.1	21.9	19.5	28.4
1998	17.3	26.6	29.4	15.8	23.6
1999	21.8	15.9	26.1	18.4	26.6
2000	16.1	16.8	18.2	12.9	20.8
2001	35.1	37.9	37.6	27.9	45.2
2002	33.8	32.2	41.1	19.5	27.8
2003	18.8	17.5	22.8	22.3	38.9
2005	20.4	14.2	11.8	16.2	18.1
2006	22.8	10.8	12.2	14.9	30.4
2007	16.5	9.7	17.2	13.7	13.6
2008	8.9	9.1	14.1	18.1	20.7
2009	9.5	9.9	12.5	22.3	12.5
2010	13.3	22.2	21.9	33.3	12.8
Mean	18.9	20.5	26.7	19.1	24.3
Total	414.8	451.9	587.1	305.8	389.1

F_{00} – Lysimeter in the soil depth 0.0 m.; F_{10} – Lysimeter in the soil depth 0.1 m.; F_{25} – Lysimeter in the soil depth 0.25 m.

The yearly mean S-SO_4^{2-} deposition to the surface humus was 18.9 kg ha^{-1} yr^{-1}. The highest values of S-SO_4^{2-} were measured in 2001 with the yearly deposition 35.1 kg ha^{-1} yr^{-1} (Table 2). In this year the maximum sulphur contents were observed also in precipitation (45.2 kg ha^{-1} yr^{-1}), it corresponded to the SO_4^{2-} concentration 21.84 mg l^{-1}. The lowest annual flux of S-SO_4^{2-} to the soil (8.9 kg ha^{-1}yr^{-1}) was obtained in 2008. The variability of results is cca 30% (Table 1).

In the stand in the 0.10 m soil depth was observed yearly 20.5 kg ha^{-1} yr^{-1} S-SO_4^{2-}. It was caused by the accumulation ability of sulphur in the bottom soil horizons. This phenomenon was actual during the 1988–1999 and 2008–2010 period.

The variability of the results is approximately 43.9%. The highest concentration SO_4^{2-} and sulphur content was measured in the 0.25 m soil depth. The mean concentration SO_4^{2-} is 29.32 mg l^{-1} and content in this soil horizon was 26.7 kg ha^{-1} yr^{-1}, it was higher in about 29.3% than in the surface humus layer. The highest values of S-SO_4^{2-} were observed at the beginning of the research in 1988 with average values 52.6 kg ha^{-1} yr^{-1} resp. 42.03 mg l^{-1} SO_4^{2-} concentration. The lowest values of sulphate sulphur content 11.8 kg ha^{-1} yr^{-1} in this soil depth were measured in 2005 (15.16 mg l^{-1} SO_4^{2-}). During the research period the content of sulphate sulphur in each soil depth declined, though the highest contents were observed in 2001 and 2002. The cause can be still in active lignite incineration plant in Nováky (Slovakia).

During the research the highest fluxes of sulphur in the soil were measured in the autumn months. The values of throughfall deposition and open field deposition during the study period decreased, the exception was year 2001. In this year were found the highest SO_4^{2-} contents and concentrations in both depositions. At the open field the S-SO_4^{2-} flux to the humus layer was 45.3 kg ha^{-1} yr^{-1} – 21.84 mg l^{-1} SO_4^{2-}. In year 2003 were found total highest SO_4^{2-} concentration in the throughfall also at the open plot (25.33 mg l^{-1} SO_4^{2-}), also in the forest stand (24.68 mg l^{-1} SO_4^{2-}). The lowest concentration of SO_4^{2-} were found in the year 2010 with 3.3 mg l^{-1} SO_4^{2-} at the open plot and 9.6 mg l^{-1} SO_4^{2-} in the forest stand (Fig. 1b).

The results of testing of differences did not confirm the differences among the soil horizons. Evidently was observed the effect of the sulphur content in precipitation on the sulphur content in soil water. However were proved very significant differences ($p < 0.001$) in the sulphur content in the 0.10 m and 0.25 m soil depth.

It implies that the present emissions in atmospheric deposition do not have effect on the sulphur content in the soil. On the contrary, the accumulation ability of sulphur in the bottom soil horizons was occurred and there sulphur persistently impacts on pedochemical processes.

Discussion

The most important factors are the composition of parent material (Cosby et al., 1986) and the soil depth (Manderscheid et al., 2000). Katutis et al. (2008) pointed at the composition of humus layer. Important factor is also the forest stand composition. To these important factors can we integrate physical and chemical soil properties. A negative strong correlation between the sulphur content in soil water and the precipitation amount was found (Lindroos et al., 2006). Furthermore, the sulphur concentration in soil water is influenced by sulphur content in atmospheric deposition (Novotný et al., 2008). To these „natural“ determining factors belongs also the influence of the altitude (Kopeć and Gondek, 2002).

On the present the anthropogenic factors are predominant. These factors influenced the variability of the results from sulphur and its compounds research mainly in the form of deposition to all parts of forest and aquatic ecosystems.

Dubová and Bublinec (2006) measured at the same stands in the Kremnické vrchy Mts 25 kg S ha^{-1} yr^{-1} in bulk atmospheric deposition and 24.9 kg S ha^{-1} yr^{-1} in throughfall deposition. They confirmed the highest sulphur content in precipitation during the 1994–1995 period. They presented that the maximum sulphur concentrations in this period were observed in atmospheric deposition and soil water in the whole Europe. According to the results from the emission monitoring in Europe in this period was observed the increasing of the emissions amount (>20.0 kg S ha^{-1} yr^{-1}) in the southeast of the Great Britain and in the industry areas of Central Europe.

In the low polluted area the Kremnické vrchy Mts the highest values of sulphate sulphur were measured in the H_{00} horizon. Similar data presented Káňa and Kopáček (2005) whose research was done in forest soils of the Czech Republic. Interesting fact is the highly sulphur content in soil water than in throughfall after some years (4, 5, 6 years) after the cutting intervention aimed at the reduction of stocking. It can be explained by high sulphur concentrations and sulphur content in horizontal precipitation (mist, dew) (Škvarenina,

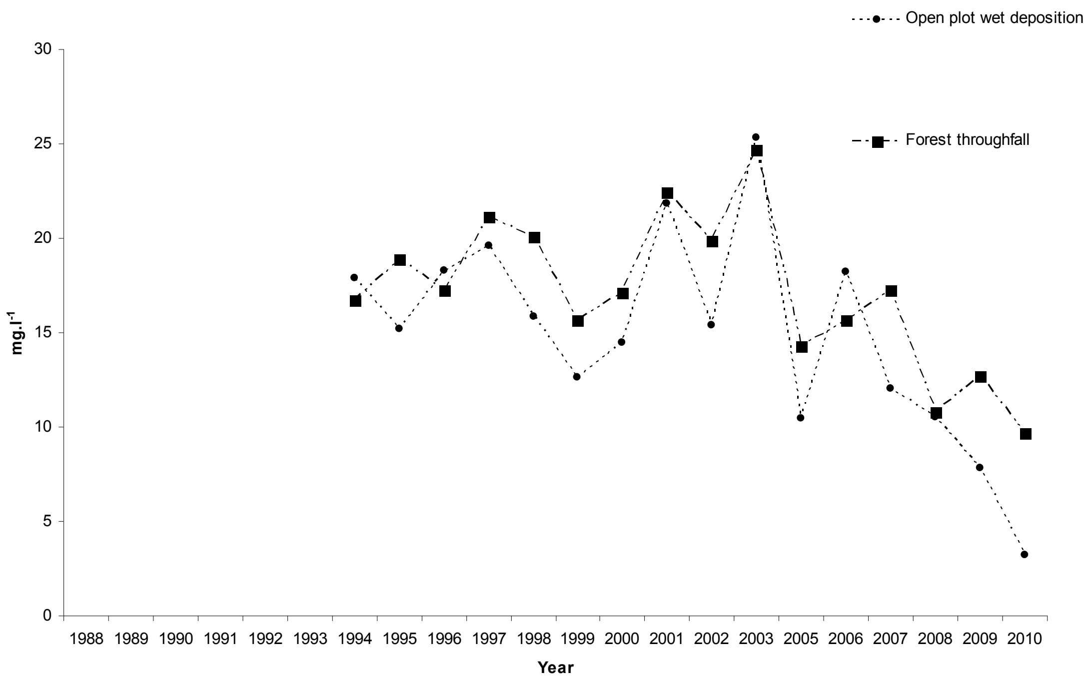


Fig. 1b. The concentration of SO_4^{2-} in the precipitation and throughfall in the Štiavnické vrchy Mts in years 1988–2010.

1998). Yamada et al. (2001) found out the sulphur concentration in throughfall and in stemflow in the southwest Japan is higher than in open bulk precipitation.

At the research plots in the Štiavnické vrchy Mts (Slovakia) in a 180–190 years old oak stand (altitude 680 m a.s.l.) the soil received via throughfall 23 kg S ha^{-1} (Kunca, 2007).

Similar occurrences of the highest sulphate sulfur contents in precipitation and soil water in the autumn and the winter months found out Bublinec and Dubová (1995).

The significance of differences between the years in the sulphur content in soil water and in precipitation was statistically insignificant.

Conclusions

The situation in the polluted area the Štiavnické vrchy Mts is principally different in two facts: the sulphur content and its accumulation in the soil horizons. The lowest mean content of $S\text{-}SO_4^{2-}$ (18.9 kg ha^{-1} yr^{-1}) was observed in the surface humus and the highest mean content (26.7 kg ha^{-1} yr^{-1}) in the 0.25 m depth. During the research the total $S\text{-}SO_4^{2-}$ flux to this soil depth was 587.1 kg ha^{-1}. Interesting data were observed in throughfall deposition, the sulphur content in it was lower than in soil water. It can be caused by the filtration effect of the forest canopy or the accumulated sulphur content in soil.

The testing of differences showed no significant difference between the sulphur content in precipitation between the experimental sites. In contrast, the differences between the sulphur content in 0.10 m and 0.25 m soil depth between the study areas were statistically significant. It can be explained by accumulation of sulphur in soil in these areas till 1990. We proved that the precipitation amount and the sulphur content in atmospheric deposition significantly influenced the sulphur content and concentration in each soil horizon.

Temporal variability in sulphur content pointed out the occurrence of the maximum $S\text{-}SO_4^{2-}$ values in the autumn months. The lowest $S\text{-}SO_4^{2-}$ values were observed in the summer and in the spring. To this fact are also linked the SO_4^{2-} concentrations.

On the basis of the mean sulphur fluxes to each soil horizon and the sulphur content in precipitation during the research the forests of the Štiavnické vrchy Mts are presented as an area with lower sulphur load not only on the national level, but on the European level. The exception is the sulphur content in precipitation at the open field during years 1996, 2001, 2003 and 2006. In these years was the sulphur critical limit exceeded.

Acknowledgement

This research was supported by the Scientific Grants Agency of the Slovak Academy of Science No. 2/0068/10.

References

Bublinec, E., Dubová, M. 1995. Mokrá depozícia v hrebeňovej časti Nízkych Tatier [Wet deposition in the crest part of the Low Tatras]. *Acta Fac. for. Zvolen,* 37: 85–95.

Cosby, B.J., Hornberger, G.M., Wright, R.F., Galloway, J.N. 1986. Modelling the effect of acid deposition: control of long-term sulphate dynamics by soil sulphate adsorption. *Wat., Resour. Res.,* 22 (8): 1283–1291.

Dubová, M., Bublinec, E. 2006. Evaluation of sulphur and nitrate-nitrogen deposition to forest ecosystems. *Ekológia (Bratislava),* 25: 366–376.

Fiala, J., Rieder, M., Dvořáková, M., Livorová, H. 2001. Trends in the atmospheric and hydrological cycle of sulphur at catchments in the Czech Republic. *Atmosph. Envir.,* 35, Suppl. 1: 55–62.

Hruška, J., Cienciala, E., Moravčík, P., Navrátil, T., Hoffmeister, J. 2001. Dloudohodbá acidikace a nutričná degradace lesních půd – limitující faktor současného lesnictví [The long-term acidification and nutric degradation of forest soils – an limiting factor in contemporary forestry]. *Lesn. Práce*, 80 (12): 24–32.

Janík, R., Bublinec, E., Dubová, M. 2011. Impact of regeneration cutting on sulphate concentration and amount in throughfall water in conditions of submontane beech forests in the Western Carpathians Mts. *Folia oecol.*, 38: 156–161.

Kalúz, K. 2004. *Imisná situácia na Slovensku a poškodzovanie ekosystémov* [Imission situation in Slovakia and ecosystems deterrioration]. Nitra: Slovenská poľnohospodárska univerzita v Nitre. 8 p. [cit. 2012-01-04]. http://fzki.uniag.sk/web/bpd2004/content/08Sekcia_geofaktorov_a_zivotneho_prostredia/Kaluz.pdf

Káňa, J., Kopáček, J. 2005. Sulphate sorption characteristics of the Bohemian forest soils. *Silva Gabreta,* 11: 3–12.

Katutis, K., Repsiene, R., Baltramaityte, D. 2008. The effects of different soil genesis on the concentration of biogenic elements in lysimetric water. *Agronomijas Vēstis* (*Latvian J. Agron.* 10: 37–41.

Kellerová, D. 2005. The air pollution in the surroundings of an aluminium plant. *Ekológia (Bratislava),*24: 122–128.

Kopeć, M., Gondek, K. 2002. The effect of long-term fertilization on the sulphur content in soil and the mountain meadow sward (Czarny Potok). *Rostl. Výr.*, 48, 12: 525–530.

Kukla, J. 2002. Variability of solutions percolated through cambisol in a beech ecosystem. *Ekológia (Bratislava)*, 21, Suppl. 2: 13–25.

Kunca, V. 2007. Air deposition and critical load of climax oak in the Štiavnické vrchy Mts. In Střelcová, K., Škvarenina, J., Blaženec, M. (eds). *Bioclimatology and natural hazards. Imternational scientific conference. Proceedings. [17-20 september 2007, Zvolen – Poľana nad Detvou, Slovakia].* Zvolen: Technical University, p. 1–4. electronic optical disc (CD-ROM).

Lindroos, A.J., Derome, J., Derome, K., Lindgren M. 2006. Trends in sulphate deposition on the forest and forest floor and defoliation degree in 16 intensively studies forest stands in Finland during 1996–2003. *Boreal Envir. Res.*, 11: 451–460.

Manderscheid, B., Schweisser, T., Lischeid G., Alewell, C., Matzner, E. 2000. Sulphate pools weathered substrata of a forested catchment. *Soil Sci. Soc. Amer. J.*, 64: 1078–1082.

Matzner, E., Meiwes, K.J. 1994. Long-term development of element fluxes with bulk precipitation and throughfall in two German forests. *J. Environ. Qual.*, 23 (1): 162–166.

Mihálik, A., Bublinec, E. 1995. The clayish-mineralogical characteristics and properties of the soil in the environment of maximal immission load of aluminium works. *Lesnícky Čas. – For. J.*, 41: 39–49.

Minďáš, S., Škvarenina, J., Závodský, J., Kremler, M., Molnárová, H., Pavlenda, P., Kunca, V. 2001. Doterajšie výsledky hodnotenia kritických úrovní a záťaží na Slovensku [Present results of critical levels/loads estimation in Slovakia]. In *Bioklimatológia a životné prostredie: XIII. bioklimatologická konferencia SBkS a ČBkS*. [Bratislava]: Slovenská bioklimatologická spoločnosť SAV. 11 p. 1 electronic optical disc (CD-ROM).

Novotný, R., Lachmanová, Z., Šrámek, V., Vortelová, L. 2008. Air pollution load and stand nutrition in the Forest District Jablunkov, part Nýdek. *J. Forest Sci.,* 54: 49–54.

Prechtel, A., Alewell, C., Armbruster, M., Bittersohl, J., Cullen, J.M., Evans, C.D., Helliwell, R., Kopáček, J., Marchetto, A., Matzner, E., Meesenburg, H., Moldan, Mority̌ż, K., Veselý, J., Wright, R.F. 2001. Response of sulphur dynamics in European catchments to decreasing sulphate deposition. *Hydrol. Earth Syst. Sci.*, 5: 311–326.

Quilchano, C., Haneklaus, S., Gallardo, J.C., Schnug, E., Moreno, G. 2002. Sulphur balance in a broadleaf, non polluted, forest ecosystem (central western Spain) *Forest Ecol. Mgmt,* 161 (1–3): 205–214.

Stachurski, A., Zimka, J.R. 2000. Atmospheric input of elements to forest ecosystems: a method of estimation using artificial foliage placed above rain collectors. *Envir. Pollut.*, 10: 345–356.

Škvarenina, J. 1998. *Kyslé horizontálne zrážky v jedľo-bukovom ekosystéme v rokoch 1989–1997* [Acid horizontal precipitation (fog and cloud water) in the fir-beech ecosystem in 1989–1997]. Štúdia SBkS SAV, roč. 12, č. 15. Nitra: Slovenská poľnohospodárska univerzita. 49 p.

Urminská, J., Khun, M., Jurkovič, Ľ. 2000. Riziko vplyvu niektorých nežiadúcich prvkov v životnom prostredí Žiarskej kotliny a ich vzťah k zdravotnému stavu obyvateľstva [Risk of influence of certain non-desired elements in the environment of the Žiarska kotlina Basin and their relation to the health state of the local population. In Kontrišová, O., Bublinec, E. (eds). *Monitorovanie a hodnotenie stavu životného prostredia III. Zborník referátov*. Zvolen: Technická univerzita vo Zvolene, p. 165–173.

Yamada, T., Yoshinaga, S., Morisada, K., Hirai, K. 2001. Sulphate and nitrate loads on a forest ecosystem in Kochi in Southwest of Japan. *Wat. Air. Soil. Pollut.*,130 (1): 1115–1120.

Zapletal, M. 2006. Atmospheric deposition of nitrogen and sulphur in relation to critical loads of nitrogen and acidity in the Czech Republic. *J. Forest Sci.*, 52: 92–100.

Zapletal, M., Chroust, P. 2005. The nonlinear relationship between SO_2 and wet and air deposition of sulphur in the selected localities of Czech Republic. In Holoubková, I. *Ovzduší 2005. Program a sborník konference, Brno, 9.–11. května 2005* Brno: Masarykova univerzita, p. 100–108.

Koncentrácia SO_4^{2-} a množstvo S-SO_4^{2-} v pôdnych vodách a zrážkach v bučinách Štiavnických vrchov, Slovensko

Súhrn

V práci vyhodnocujeme výsledky koncentrácie síranových iónov a množstva síranovej síry v pôdnej vode a zrážkach v podmienkach bukového porastu Štiavnických vrchov. Priemerná koncentrácia SO_4^{2-} kolíše v rozmedzí 19,06 mg l^{-1} vo vrstve povrchového horizontu v lese do 29,32 mg l^{-1} vo vrstve 0,25 m pod povrchom zeme. Do pôdy sa počas doby výskumu deponovalo 415 kg S-SO_4^{2-} ha^{-1} – do vrstvy povrchového humusu a 587 kg S-SO_4^{2-} ha^{-1} – do hĺbky 0,25 m. Najvyššia koncentrácia SO_4^{2-} bola zaznamenaná v roku 1988 vo všetkých pôdnych hĺbkach, naopak najnižšia v roku 2010 vo vrstve povrchového humusu s 8,02 mg l^{-1}. Koncentrácia SO_4^{2-} smerom do hĺbky stúpala.

Regresnou analýzou bol potvrdený vplyv úhrnu zrážok a množstva síry v zrážkach na obsah a koncentráciu síry v pôdnej vode. Studentovým t-testom bola potvrdená rozdielnosť množstva síry a koncentrácie SO_4^{2-} v pôdnych hĺbkach 0,1 m a 0,25 m. Významnosť medzi jednotlivými rokmi sa nepreukázala.

Received January 10, 2012
Accepted March 3, 2012

Measurement of European beech transpiration rate under drought stress

Dana Kovalčíková[1], Katarína Střelcová[1], Ľubica Ditmarová[2]

[1]Faculty of Forestry, Technical University in Zvolen, Masarykova 24, 960 53 Zvolen, Slovak Republic,
e-mail: kovalcikova@vsld.tuzvo.sk
[2]Institute of Forest Ecology of the Slovak Academy of Sciences, Štúrova 2, 960 53 Zvolen, Slovak Republic

Abstract

Kovalčíková, D., Střelcová, K., Ditmarová, Ľ. 2012. Measurement of European beech transpiration rate under drought stress. *Folia oecol.*, 39: 36–44.

The paper presents results of a pilot measurement of transpiration rate in European beech plants under drought stress. The measurement was carried out with "Baby EMS 62 modular sap flow systems for small stems or branches". The plants used for measuring the transpiration rate were 4-year-old, the measurements was carried out in the summer 2010. The trees were divided into two groups: a drought-stressed group and a regularly irrigated (control) group. The simulation of drought started on July 9 2010, the measurement of sap flow on August 20 2010. In order to find out the possibility for the transpiration recovery, irrigation was applied after a severe drought exposure on the drought-stressed plants on August 24 2010. Despite expectations, the irrigation did not influence transpiration of the drought-stressed plants, although the absolute value of the soil water potential dropped to a minimum. The drought-stressed individuals achieved substantially lower values of transpiration rate, both before and after irrigation, in comparison with the control group. Further, dependence between transpiration and meteorological factors was investigated. The meteorological factors in concern are continually recorded at the mesoclimatic station situated in the "Borová hora" Arboretum. The values of transpiration rate for the drought-stressed individuals were less dependent on meteorological factors (relation fitted with a polynomial regression function of the second order) than for the control plants.

Key words

drought, *Fagus sylvatica* L., heat balance method, transpiration

Introduction

In relation to the discussion about the climatic changes, attention is paid to drought problems and their impact on forest ecosystems. Shortage of available water in growing season and presence of harmful meteorological events – including long drought periods, are only some of supposed impacts of climatic changes (Hanson and Weltzin, 2000; Liesebach, 2002; Šútor et al., 2004; Houghton, 2005; Lapin and Szemesová, 2009).

In general, drought is defined as condition or time period with water deficit (Novák, 2009) in soil, in plants or in atmosphere (Sobíšek et al., 1993). If this condition or time period exceeds limits of the plant's tolerance, the plant is exposed to stress. The stress inhibits normal functions of plants, which results in reduction of growth and reproduction (Slováková and Mistrík, 2007). The occurrence of drought is possible to consider not only from the meteorological and hydrological point of view, but also in relation to tree physiology – which means the direct detection of the water status in plant. That approach is the most reliable way how to define the presence of stress influencing the plant.

Transpiration is one of the physiological processes suitable for serving as tools in detecting drought stress. It serves an important role in the plant cooling, removal of excessive turgor and increase in uptake and transport of mineral nutrients (Kmeť, 1998). There have been developed numerous methods for measuring sap flow in tree trunks. Much attention is paid to the "trunk heat balance method" (ČERMÁK et al., 1973). A modification of this method is baby sensors (ČERMÁK et al., 2004), suitable for measuring sap-flow in branches and trunks with small diameters (6–20 mm), produced by EMS Brno (Fig. 1), described by ČERMÁK et al. (1984), and lately by LINDROTH et al. (1995).

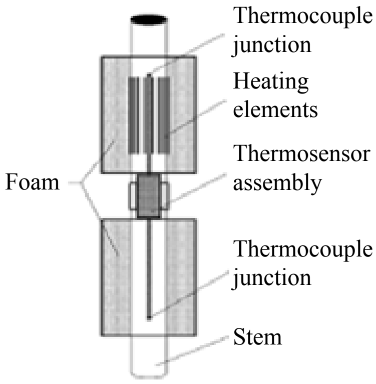


Fig. 1. Scheme of an EMS „baby sensor" designed for branches or trunks with a small diameter (ČERMÁK et al., 2004).

It is also possible to determine transpiration of plants grown in containers – by means of the gravimetric method. In this way, transpiration has been considered to be the only source of water output, because of the elimination of soil evaporation (KOVALČÍKOVÁ et al., 2010). The gravimetrical method is precise, but demanding on time and work. These drawbacks can be eliminated by using scales providing a continual record of weight changes.

The above mentioned baby sensors show many advantages, such as easy application, low time consumption and continual record. Another positive feature is no need for plastic bags used for elimination of soil evaporation (unlike in gravimetric method where only packing the lower parts of plants into plastic bags could exert stress on them).

ROSE et al. (2009) studied the physiological response of beech plants of different provenances to drought stress from the viewpoint of their adaptation to drought. DITMAROVÁ et al. (2010) studied influence of the advance drought on the physiological characteristics of spruce plants. ROSE et al. (2009), similarly as DITMAROVÁ et al. (2010), carried out experiment in conditions of containers. SCHRAML and RENNENBERG (2002) concerned with response of different beech ecotypes to drought stress, by observation of their physiological characteristics. Many authors observed drought effects on transpiration rate and on physiological parameters (SALA and TENHUNEN, 1996; CIENCIALA et al., 1997; COCHARD et al., 2002; ASLAM and TAHIR, 2003).

The attempts for quantitative estimations of the water use in adult trees, with using data achieved from plants in containers, were not successful (WULLSCHLEGER et al., 1998). In thickets and in small trees, the water flow across the main trunk is equivalent to the crown transpiration. In larger trees, it is possible to observe a significant delay between the variation in transpiration and the variation in the water flow measured near the trunk base (SCHULZE et al., 1985). The delay can take from a few minutes to several hours and, according to available information, it is caused by the water exchange between the sap flow and the store volume of the trunk above the point in which the water flow is measured (WULLSCHLEGER et al., 1998). The trees with higher store capacity keep their maximal transpiration rate for a substantially longer part of day than the trees with lower store capacity (GOLDSTEIN et al., 1998).

Our research aims have been set as follows:

- Quantification of transpiration rate reduction [g; g m^{-2}] in drought-stressed beech plants in comparison with potential transpiration in regularly irrigated plants
- Confirmation of dependence of transpiration on meteorological variables represented by vapour pressure deficit
- Evaluation of the results of the pilot measurement with sap flow carried out on beech plants with using the "baby EMS 62 standard system for measuring branch transpiration or transpiration of trunks with small diameters".

Material and methods

The object of our research was a group of ten four-year-old European beech (*Fagus sylvatica* L.) plants, from the forest enterprise Beňuš, provenance of the seed area Podtatranská (6. vegetation zone). The plants were transferred into the Arboretum "Borová hora" and covered with a roof for eliminating precipitation. The sap flow in trunks was measured using a "baby" EMS 62 standard system (Fig. 2, Fig. 3). The transpiration rate (kg h^{-1} cm^{-1}) was recorded at intervals of 10 minutes. The transpiration rate was calculated based on the tree circumference [cm], so the values of transpiration rate were expressed in kg h^{-1}.

Fig. 2. "Baby EMS 62 modular sap flow system for small stems or branches".

Fig. 3. Container experiment with beech plants.

The measurements were carried out during the summer of 2010. The plants were divided in 2 groups: drought-stressed plants and regularly irrigated (control) plants. The simulation of drought started on July 9 2010, the measurement of sap flow on August 20 2010. To test the ability to recovery, the drought-stressed plants were exposed to irrigation on August 24 2010.

Meteorological data, continually recorded by a mesoclimatic station situated in area of the Arboretum, were used for evaluation of the effects of environmental variables on transpiration rate. The concerned meteorological data are available on the Website of the Technical University in Zvolen (www.tuzvo.sk). The soil water potential was recorded simultaneously, with the aid of gypsum blocks Datalogger MicroLog SP3 (EMS Brno). The measured meteorological characteristics were visualised and processed, with using a MINI 32 software (EMS Brno). The vapour pressure deficit was calculated according to the Magnusson's formula, providing with the recorded meteorological data (Sobíšek et al., 1993). For fitting the relation between transpiration rate and vapour pressure deficit, we used the polynomial regression analysis of the second order in the MINI 32 software.

For each examined beech plant, we calculated the area of its assimilatory apparatus, with using the Cernota (Kalina and Slovák, 2004) computer programme. Then the obtained data were used for calculation of the transpiration rate per a unit assimilatory area (g m^{-2}). Statistical analysis was carried out in the program package Statistica 7 (Duncan test).

Results and discussion

Water usage in plants is defined also as the amount of water used for transpiration, because the most of the water in plants is used in this process (Penka, 1985). At presence of sufficient soil moisture, the transpiration is generally controlled by atmospheric conditions: primarily air temperature and air humidity. Global radiation also influences the transpiration rate in a positive way (Kincl and Krpeš, 2000).

The values of the total mean daily transpiration rate in drought-stressed plants over a 26-day period (20.8.–14. 9. 2010) reached only 84.58 g of water – representing but 10.87% of 778.38 g transpirated by regularly irrigated plants. If we declare values of irrigated plants as potential values, then the transpiration loss makes 89.13%.

After estimation of the assimilatory area in plants done with the program Cernota, we found out that the assimilatory apparatus of the regularly irrigated plants was 1.5-times larger (on average) in comparison to the drought-stressed plants. According to the Duncan test, the differences in assimilatory apparatus between the drought-stressed and control plants were statistically significant (Fig. 4). Another statistically significant difference between variants was also revealed in the trunk circumference (Fig. 5). The trunk circumference in regularly irrigated plants was 1.2-times, on average, the circumference in the drought-stressed plants.

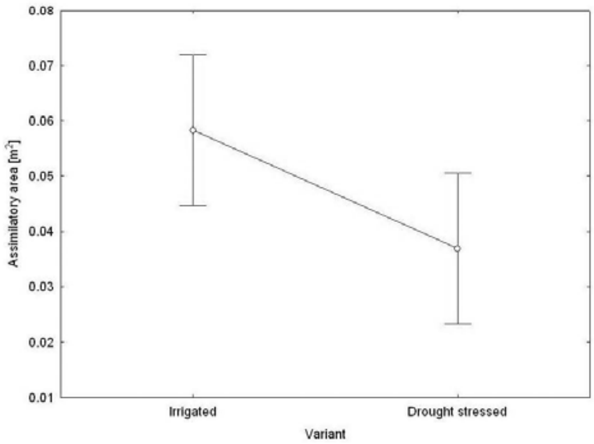


Fig. 4. Difference in assimilatory area between irrigated and drought-stressed beech seedlings. Assimilatory area was determined with a program Cernota (Kalina and Slovák 2004); variant; LS; means current effect: F (1, 8) = 6.5059, p = 0.03414; effective hypothesis decomposition; vertical bars denote 0.95 confidence intervals.

We assume that the drought stress, influencing plants for more than 2 months, could have been the reason for the significant reduction of the assimilatory apparatus and, similarly, the reduction of trunk circumferences in the drought-stressed plants. The lack of water in their tissues probably caused the trunks to shrink and to reduce their overall size.

In case of transpiration rate per unit of area [g m^{-2}], the calculated difference between the drought-stressed and regularly irrigated plants was somewhat lower. The value of transpiration rate of the drought-stressed plants achieved 2,524.63 g m^{-2}, making 17.74% of the potential value of transpiration rate represented by the regularly irrigated plants: 14,233.64 g m^{-2} in course of the experiment. The transpiration [g m^{-2}] values in the period 20. 8.–14. 9. 2010 are summarised in Fig. 6. On August 23 2010, the device broke down – causing that the transpiration of the regularly irrigated plants dropped to zero.

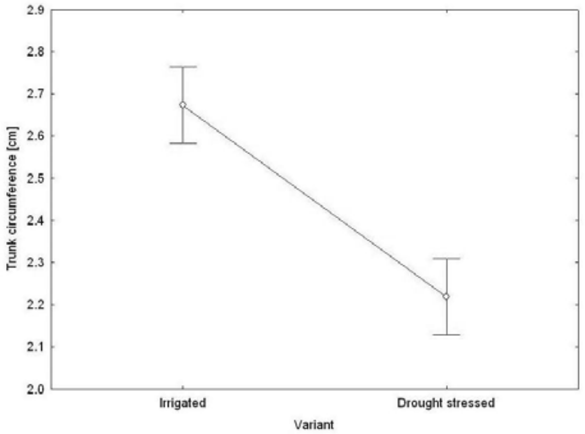


Fig. 5. Difference in trunk circumference between irrigated and drought-stressed beech seedlings; variant; LS; means current effect: $F(1, 8) = 67.030$, $p = 0.00004$; effective hypothesis decomposition; vertical bars denote 0.95 confidence intervals.

In trees sufficiently supplied with soil water, transpiration is influenced primarily by evaporative demands of the atmosphere (Masarovičová et al., 1989; Matejka et al., 2009). Masarovičová (1989) discovered a linear dependence of water uptake on mean daily temperature, and water uptake on vapour pressure deficit. Masarovičová et al. (1989) found out that in trees sufficiently supplied with water, their internal water deficit was not influenced by soil water deficit, but primarily by evaporative demands of the atmosphere. This fact has also been confirmed by Matejka et al. (2009), who observed transpiration accelerated due to high vapour pressure deficit – mostly in the seasons, when forest was sufficiently supplied with soil water. During seasons with dry soil, the differences between the transpiration influenced by mean vapour pressure deficit and high vapour pressure deficit are negligible.

The mean daily transpiration rate correlated with the daily mean vapour pressure deficit better in the regularly irrigated plants than in the drought-stressed plants – as it is shown in Table 1 and Table 2 summarising the results of our correlation analysis. According to the mean coefficients of determination, the influence of vapour pressure deficit explains about 36.19% (R^2) in irrigated plants and only 10.39% (R^2) in drought-stressed plants. The values of daily transpiration total [g m^{-2}] and daily average of vapour pressure deficit are illustrated in Fig. 7.

During the measurement period, there were registered 6 rainy days (a rainy day was defined by a daily precipitation total exceeding 1 mm) and 6 days with the daily precipitation total lower than 1 mm. The lower transpiration rate in rainy days is caused not only by the rain itself, but mainly by the lower daily global radiation at presence of cloudiness and higher air humi-dity. The transpiration values observed on the cloudy days are shown in Fig. 8. The transpiration rate in plants manifested lower values during the rainy days in comparison with the days without precipitation and days with precipitation less than 1 mm. Fabrika et al. (2009) suggests the 1 mm daily precipitation total as the threshold for statistically significant differences in rate of tree transpiration. Herzog et al. (1998) declared that precipitation retained by tree canopies provides moisture to the layer adjacent to the leaves. This moisture is depleted earlier than the water

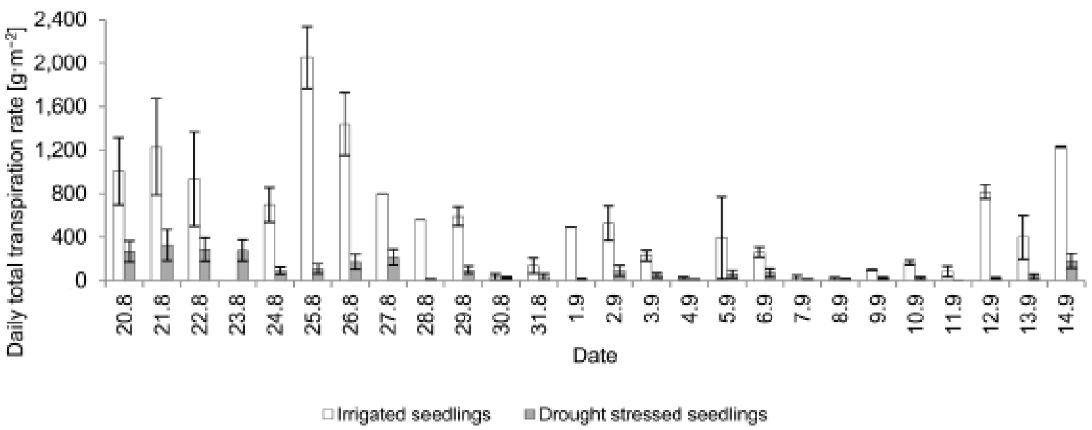


Fig. 6. Dynamics of daily transpiration total in course of 26 days, measured in the "Borová hora" Arboretum, measured by using "baby sensors" – heat balance method. Error bars express the average mean error.

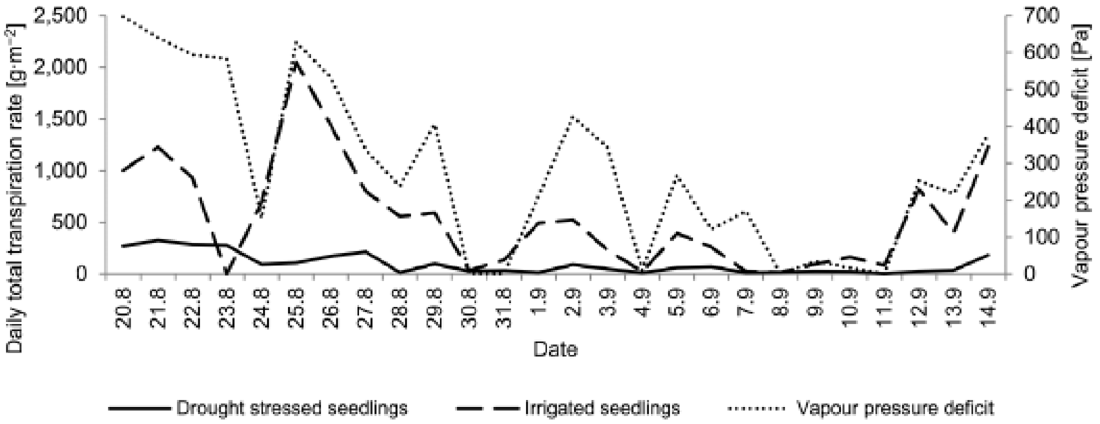


Fig. 7. Course of the mean daily totals of transpiration rate during the 26 days, measured in the "Borová hora" Arboretum, by using "baby sensors" – heat balance method. The graph is supplemented by a curve for vapour pressure deficit, calculated according to the Magnuson´s formula from meteorological characteristics (air temperature and humidity) recorded continually by the mesoclimatic station in the Arboretum.

Table 1. Results of regression analysis with the MINI 32 program, showing dependence of transpiration rate [kg h^{-1}] in regularly irrigated beech plants on vapour pressure deficit

Plant No.	CP	DV	n	Regression coefficients for $y = ax^2 + bx + c$			R^2
				a	b	c	
1	VPD	ITR	3,744	9.04204E-9	–3.78421E-6	0.000500118	0.534665
2	VPD	ITR	3,744	1.30384E-9	1.18287E-6	0.000714083	0.148871
3	VPD	ITR	3,744	2.33054E-9	1.81571E-6	0.000203131	0.506251
4	VPD	ITR	3,744	1.18158E-9	5.84139E-6	0.000310635	0.480084
5	VPD	ITR	3,744	–519.10900E-12	3.027700E-6	14.06116E-6	0.139747

CP, categorical predictor; DV, dependent value; VPD, vapour pressure deficit; ITR, transpiration intensity [kg h^{-1}]; n, number of measurements.

Table 2. Results of regression analysis with the MINI 32 program, showing dependence of transpiration intensity [kg h^{-1}] in drought-stressed beech plants on vapour pressure deficit

Plant No.	CP	DV	n	Regression coefficients for $y = ax^2 + bx + c$			R^2
				A	b	c	
1	VPD	ITR	3,744	18.337E-12	–13.3796E-9	5.01318E-6	0.003177
2	VPD	ITR	3,744	1.05035E-9	–121.921E-9	0.000115561	0.247219
3	VPD	ITR	3,744	1.44459E-9	–924.882E-9	96.4591E-6	0.249679
4	VPD	ITR	3,744	–3.0182E-12	–59.023E-9	94.4895E-6	0.012474
5	VPD	ITR	3,744	51.9111E-12	–11.2442E-9	32.1239E-6	0.006867

CP, categorical predictor; DV, dependent value; VPD, vapour pressure deficit; ITR, transpiration intensity [kg h^{-1}]; n, number of measurements.

contained in plants, so the transpiration is limited, and the demand on evaporation is reduced. However, in our case, this interception was eliminated by sheltering the plants with a roof.

To test the potential for recovery of the transpiration in the studied plants, the drought-stressed plants were irrigated on August 24. Despite the expectations, the irrigation was not responded by transpiration, although the absolute value of soil water potential dropped in some cases as much as 11 bars to a minimum close to zero. In contrast to the drought-stressed plants, decreasing transpiration values were observed in

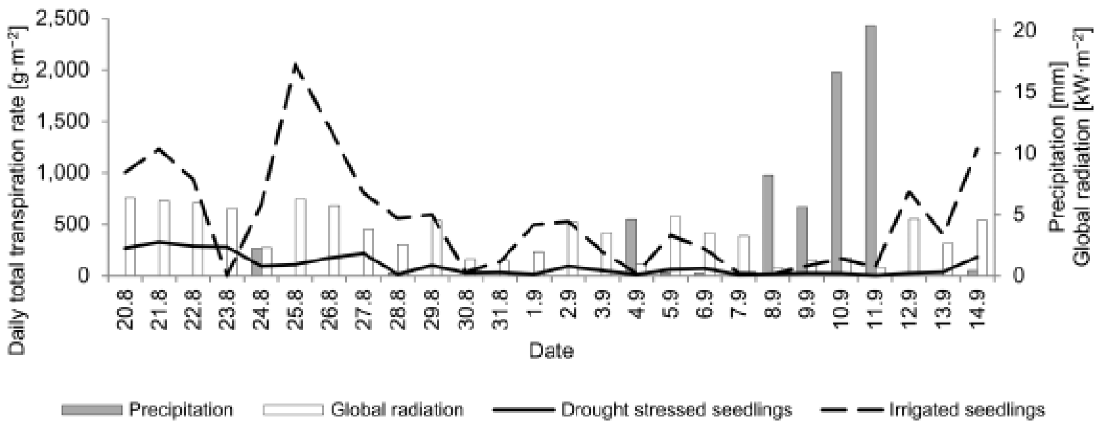


Fig. 8. Course of mean daily totals of transpiration [g m^{-2}] during 26 days, measured in the "Borová hora" Arboretum by using "baby sensors" – heat balance method. The graph is supplemented by the daily totals of precipitation and global radiation intensity, recorded continually by the mesoclimatic station in the Arboretum.

regularly irrigated plants on the day following the irrigation (August 25 2010) (Fig. 7, Fig. 8).

It is useful to compare the transpiration rate in plants between our two most frequent tree species – beech and spruce. The maximum value of mean daily transpiration in irrigated 4-year-old beech plants represented 2,052 g m^{-2} – compared to 544 g m^{-2} measured in 4-year-old regularly irrigated spruce plants. Comparing between these two species requires also comparing between their assimilatory areas: 0.0583 m^2 in beech plants and 0.4055 m^2 in spruce plants (Kovalčíková et al., 2011). Petráš et al. (1985) found that the leaf biomass in spruce is more abundant than in beech or pine. The authors also observed that the difference was more pronounced with increasing tree diameter. It could be one of the reasons why spruce is seriously endangered by drought. The larger area of assimilatory organs, together with a lower surface resistance (Roberts, 1983) in relation to evaporation, would be the cause underlying the lower resistance of spruce to drought stress.

Hanson and Weltzin (2000) observed that the younger growth stages were more sensitive to the water deficit caused by strong or long-lasting drought then the adult trees. Adult trees show lower sensibility for water deficit due to their deep root system and significant reserves of carbohydrates and nutrients. However, drought can make trees more prone to attacks by insects and diseases. The significance of influence of the interaction between the genotype and environment is also decreasing with increasing age (Krajmerová, 2007).

Conclusions

The low transpiration rate observed in the drought-stressed plants is no surprise. The timing of irrigation of the drought-stressed plants was too late, so the irrigation was not responded by an increase in transpiration rate in the drought-stressed plants.

There were observed significant differences in values of biometrical characteristics (assimilatory area, trunk circumference) between the drought-stressed plants and the regularly irrigated plants. We may conclude that it was caused by the negative effect of long-lasting drought stress.

Comparing the results of the pilot measurement of sap flow in beech plants with using "baby EMS standard systems for small stems or branches" with the results obtained by applying the gravimetric method, we found the two in a good accordance. However, it is necessary to notice that the first show many profits compared to the gravimetric method, such as low demands on time and continuity. Moreover, the installation of baby sensors is simple. However, the recording failure on August 23 2010, in the case of regularly irrigated plants, shows that certain risk is not possible to exclude with using technical equipments.

Acknowledgement

This publication is the result of the project implementation: Extension of the Centre of Excellence "Adaptive Forest Ecosystems", ITMS: 26220120049, supported by the Research & Development Operational Programme funded by the ERDF (50%) and of the project supported grant agency VEGA 2/0006/11 (50%).

References

Aslam, M., Tahir, M.H.N., 2003. Morpho-physiological response of maize inbred lines under drought environment. *Asian J. Pl. Sci.,* 2 (13): 952–954.

Čermák, J., Deml, M., Penka, M. 1973. A new method of sap flow rate determination in trees. *Biol. Plant.*, 15: 171–178.

Čermák, J., Kučera, J., Nadezhdina, N. 2004. Sap flow measurements with some thermodynamic methods, flow integration within trees and scaling up from sample trees to entire forest stands. *Trees*, 18: 529–546.

Čermák, J., Jeník, J., Kučera, J., Židek, V. 1984. Xylem water flow in a crack willow tree (Salix fragilis L.) in relation to diurnal changes of environment. *Oecologia*, 64: 145–151.

Cienciala, E., Kučera, J., Lindroth, A., Čermák, J., Grelle, A., Halldin, S. 1997. Canopy transpiration from a boreal forest in Sweden during a dry year. *Agric. Forest Meteorol.*, 86: 157–167.

Cochard, H., Coll, L., Le Roux, X., Améglio, T. 2002. Unraveling the effects of plant hydraulics on stomatal closure during water stress in walnut. *Pl. Physiol.*, 128: 282–290.

Ditmarová, Ľ., Kurjak, D., Palmroth, S., Kmeť, J., Střelcová, K. 2010. Physiological responses of Norway spruce (Picea abies) seedlings to drought stress. *Tree Physiol.*, 30: 205–213.

Fabrika, M., Střelcová, K., Magová, D. 2009. Empirický model transpirácie buka v rastovom simulátore SIBYLA [Empirical model for transpiration of beech in tree growth simulator]. *Acta Fac. for. Zvolen*, 51 (3): 99–112.

Goldstein, G., Andrade, J.L., Meinzer, F.C., Holbrok, N.M., Cavalier, J., Jackson, P., Celis, A., 1998. Stem water storage and diurnal patterns of water use in tropical forest canopy trees. *Plant, Cell Envir.*, 21: 397–406.

Hanson, P.J., Weltzin, J.F. 2000. Drought disturbance from climate change: response of United States forests. *Sci. total Environ.*, 262: 205–220.

Herzog, K.M., Thum, R., Kronfub, G., Heldstab, H.J., Hásler, R. 1998. Patterns and mechanisms of transpiration in a large subalpine Norway spruce (Picea abies (L.) Karst.). *Ecol. Res.*, 13: 105–116.

Houghton, J. 2005. Global warming. *Rep. Prog. Phys.*, 68: 1343–1403.

Kalina, J., Slovák, V. 2004. The inexpensive tool for the determination of projected leaf area. *Ekológia (Bratislava),* 23, Suppl. 2: 163–167.

Kincl, M., Krpeš, V. 2000. *Základy fyziologie rostlin* [Basic concepts in plant physiology]. Ostrava: Montanex. 221 p.

Kmeť, J. 1998. *Fyziológia rastlín* [Plant physiology]. Zvolen: Technická univerzita vo Zvolene. 164 p.

Kovalčíková, D., Kurjak, D., Střelcová, K., Ditmarová, L. 2010. *Charakteristiky vodného režimu sadeníc smreka v podmienkach stresu suchom* [Characteristics of water regime in spruce seedlings in conditions of a container experiment]. *Acta Fac. for. Zvolen,* 52, Suppl. 1: 57–70.

Kovalčíková, D., Střelcová, K., Kurjak, D., Ditmarová, Ľ., Baláž, P., Frič, M. 2011. Fyziologická reakcia sadeníc smreka na simulované sucho [Physiological response of spruce seedlings to simulated drought stress]. In Střelcová, K., Sitková, Z., Kurjak, D., Kmeť, J. (eds). *Stres suchom a lesné porasty: aktuálny stav a výsledky výskumu.* Zvolen: Technická univerzita. 266 p.

Krajmerová, D. 2007. *Vyhodnotenie niektorých rastových a adaptačných charakteristík poľských a slovenských proveniencií smreka obyčajného* [Evaluation of some growth and adaptation characteristics of Polish and Slovak proveniences of Norway spruce]. PhD thesis. Zvolen: Technical University in Zvolen, Faculty of Forestry. 168 p.

Lapin, M., Szemesová, J. 2009. Review of climate change and GHGs inventory in Slovakia. *Meteorol. Čas.*, 12: 151–155.

Liesebach, M. 2002. On the adaptability of Norway spruce (Picea abies (L.) Karst.) to the projected change of climate in Germany. *Forstwiss. Cbl.*, 121, Suppl. 1: 130–144.

Lindroth, A., Čermák, J., Kučera, J., Cienciala, E., Eckersten, H. 1995. Sap flow by heat balance method applied to small size Salix-trees in a short-rotation forest. *Biomass Bioenerg.,* 8: 7–15.

Masarovičová, E., 1989. Water uptake, carbon dioxide assimilation and growth of the common oak saplings (Quercus robur L.). *Biológia (Bratislava)*, 44: 827–836.

Masarovičová, E., Navara, J., Požgaj, J. 1989. Využitie kompenzačných lyzimetrov na stanovenie príjmu vody mladými stromami duba (Quercus cerris L.) [Use of compensation lysimeters in evaluating water uptake by young turkey oak (Quercus cerris L.) trees]. *Lesnictví*, 35 (5): 405–414.

Matejka, F., Střelcová, K., Hurtalová, T., Gömöryová, E., Ditmarová, Ľ. 2009. Seasonal changes in transpiration and soil water content in a spruce primeval forest during a dry period. In Střelcová, K., Matyas, C., Kleidon, A., Lapin, M., Matejka, F., Blaženec, M., Škvarenina, J., Holécy, J. (eds). *Bioclimatology and natural hazards*. Dordrecht: Springer. 298 p.

Novák, V. 2009. Physiological drought – how to quantify it? In Střelcová, K., Matyas, C., Kleidon, A., Lapin, M., Matejka, F., Blaženec, M., Škvarenina, J., Holécy, J. (eds). *Bioclimatology and natural hazards*. Dordrecht: Springer. 298 p.

Penka, M. 1985. *Transpirace a spotřeba vody rostlinami* [Transpiration and water use in plants]. Praha: Academia. 256 p.

Petráš, R., Košút, M., Oszlanyi, J. 1985. Listová biomasa stromov smreka, borovice a buka [Leaf biomass of spruce, pine and beech trees]. *Lesn. Čas.*, 31: 121–136.

ROBERTS, J. 1983. Forest transpiration: a conservative hydrological process? *J. Hydrol.*, 66: 133–141.

ROSE, L., LEUSCHNER, CH., KÖCKEMANN, B., BUSCHMANN, H. 2009. Are marginal beech (Fagus sylvatica L.) provenances a source for drought tolerant ecotypes? *Eur. J. Forest Res.*, 128: 335–343.

SALA, A., TENHUNEN, J. D. 1996. Simulations of canopy net photosynthesis and transpiration in Quercus ilex L. under the influence of seasonal drought. *Agric. Forest Meteorol.*, 78: 203–222.

SCHRAML, C., RENNENBERG, H. 2002. Ökotypen der Rotbuche (Fagus sylvatica L.) zeigen unterschiedliche Reaktionen auf Trockenstress. *Forstwiss. Cbl.*, 121 (2): 59–72.

SCHULZE, E.D., ČERMÁK, J., MATYSSEK, R., PENKA, M., ZIMMERMANN, R., VASÍCEK, F., GRIES, W., KUČERA, J. 1985. Canopy transpiration and water fluxes in the xylem of the trunk of Larix and Picea trees – a comparison of xylem flow, porometer and cuvette measurements. *Oecologia*, 66: 475–483.

SLOVÁKOVÁ, Ľ., MISTRÍK, I. 2007. *Fyziologické procesy rastlín v podmienkach stresu* [Physiological plant processes in stress conditions]. Bratislava: Univerzita Komenského. 240 p.

SOBÍŠEK, B., BEDNÁŘ, J., ČERNAVA, S., FLUX, J., FRÜHBAUER, J., GOTTWALD, A., HODAN, L., JURČOVIČ, P., KAKOS, V., KALVOVÁ, J., KOLDOVSKÝ, M., KOPÁČEK, J., KREJČÍ, J., KRŠKA, K., MUNZAR, J., NEDELKA, M., OTRUBA, A., PANENKA, I., PAPEŽSEN, A., PÍCHA, J., PODHORSKÝ, D., POPOLANSKÝ, F., PRETEL, J., PRIBIŠ, J., REIN, F., SETVÁK, M., SCHOBEROVÁ, E., SLABÁ, N., SLÁDEK, I., STRACHOTA, J., ŠTEKL, J., TÁBORSKÝ, Z., TREFNÁ, E., TRHLÍK, M., VESECKÝ, A., ZEMAN, M., ZIKMUNDA, O. 1993. *Meteorologický slovník výkladový a terminologický* [Meteorological dictionary terminological and explanatory]. Praha: Academia, Ministerstvo životního prostředí. 594 p.

ŠÚTOR, J., GOMBOŠ, M., IVANČO, J. 2004. *Impakt extrémnych meteorologických javov na vodný režim v prírodných podmienkach Východoslovenskej nížiny* [Impact of extreme meterological events to water regimen in natural conditions of the Východoslovenská nížina lowland] [cit. 2011-07-09]. http://fzki.uniag.sk/web/bpd2004/content/07Sekcia_agrohydrologie_a_ochrany_pody /Sutor.pdf

WULLSCHLEGER, S.D., MEINZER, F.C., VERTESSY, R.A. 1998. A review of whole-plant water use studies in trees. *Tree Physiol.*, 18: 499–512.

Meranie transpiračného prúdu sadeníc buka v podmienkach stresu suchom

Súhrn

V príspevku sú predložené výsledky z pilotného merania transpiračného prúdu na sadeniciach buka prostredníctvom „baby“ EMS 62 štandardného systému na meranie transpirácie vetiev alebo kmeňov s malými priemermi. Meranie prebiehalo v letnom období 2010 na 10 jedincoch buka vo veku 4 rokov. Jedince sme rozdelili na 2 skupiny: suchom stresované a pravidelne zavlažované (kontrolné). Súčasne bol zaznamenávaný vodný potenciál pôdy. Simulácia sucha začala 9. júla 2010, meranie transpiračného prúdu 20. augusta 2010. Nižšia transpirácia suchom stresovaných sadeníc bola samozrejme očakávaná. Za účelom zistenia schopnosti obnovy transpirácie bola 24. augusta na suchom stresované jedince aplikovaná zálievka. Na transpirácii stresovaných sadeníc sa však neprejavila, aj keď absolútna hodnota vodného potenciálu pôdy klesla na minimum. Fyziologické procesy rastlín neboli vzhľadom na dlhodobé negatívne pôsobenie sucha schopné obnovy a návratu k pôvodnej funkcii. Jednotková transpirácia suchom stresovaných sadeníc dosiahla za obdobie 26 dní 17,74 % z potenciálnej jednotkovej transpirácie, reprezentovanej jedincami pravidelne zavlažovanými. Zálievka suchom stresovaných sadeníc po viac ako 2 mesiacoch bez zalievania bola aplikovaná príliš neskoro a preto nespôsobila zvýšenie transpirácie suchom stresovaných sadeníc. Na suchom stresovaných sadeniciach sa prejavili v porovnaní s pravidelne zavlažovanými sadenicami pomerne veľké rozdiely v hodnotách biometrických veličín (plocha asimilačných orgánov, obvod kmienkov), ktoré pripisujeme dlhodobému negatívnemu vplyvu sucha. Zisťovali sme tiež závislosť transpirácie od meteorologických činiteľov, kontinuálne zaznamenávaných na mezoklimatickej stanici v Arboréte Borová hora. Rýchlosť transpirácie suchom stresovaných jedincov vykazovala v porovnaní s transpiráciou kontrolných jedincov nižšiu závislosť od meteorologických prvkov, vyjadrenú polynomickou regresnou funkciou druhého radu. Podľa priemerných koeficientov determinácie bolo možné prisúdiť vplyvu sýtostného doplnku u zavlažovaných sadeníc 36,19 %, ale v prípade suchom stresovaných sadeníc iba 10,39 %. Na základe zhodnotenia výsledkov z pilotného merania transpiračného prúdu na sadeniciach buka prostredníctvom „baby“ EMS 62 štandardného systému na

meranie transpirácie vetiev alebo kmeňov s malými priemermi možno skonštatovať, že namerané hodnoty sú v porovnaní s gravimetrickým meraním reálne, oproti gravimetrickému meraniu poskytujú však množstvo výhod, a to najmä nepretržitosť, časovú nenáročnosť merania a jednoduchosť inštalácie „baby senzorov“.

Received August 1, 2011
Accepted September 9, 2011

Concentration of nitrate and ammonium nitrogen in different ecosystems

Ľubomíra Kvetanová, Peter Ondrišík, Jana Porhajašová, Alena Rakovská

Department of Environmental Sciences and Zoology, Faculty of Agrobiology and Food Resources, Slovak University of Agriculture, Nitra, Tr. A. Hlinku 2, 949 76 Nitra, Slovak Republic,
e-mail: lubomira.kvetanova@gmail.com

Abstract

Kvetanová, Ľ., Ondrišík, P., Porhajašová, J., Rakovská, A. 2012. Concentration of nitrate and ammonium nitrogen in different ecosystems. *Folia oecol.*, 39: 45–52.

This work investigates the effect of forest, agricultural and human settlement ecosystems on the concentrations of N-NO_3^-, N-NH_4^+ in the water course Čaradický potok stream based on the data assembled between 2005–2010. The water flow has its springs in the Pohronský Inovec Mts, and then it crosses the districts Zlaté Moravce and Levice. Analysing the results obtained we can see that the lowest average concentrations of the monitored inorganic nitrogen forms within the whole study period were recorded in a sampling site situated under forest ecosystems of Pohronský Inovec. The average concentration of N-NO_3^- in the water Čaradice brook was 2.26 mg dm^{-3}. The highest average concentration for the whole monitoring period was observed in January, the lowest in August. The most remarkable increase in the concentrations of N-NO_3^- was found in September 2009, probably related to an intense rainfall before the sampling (20.5 mm on 29th September 2009). Among the sampling sites, the maximum average concentration of N-NO_3^- was measured in the sites located in ecosystems under direct influence of human settlements (the villages of Kozárovce and Čaradice). These high values were probably due to a secondary increase in nitrate nitrogen resulting from nitrification of ammonium nitrogen supplied with contaminated sewage effluents (no sewage tanks in these villages). The increase in the average concentration of N-NO_3^- in the studied water course was during the entire study period caused both by an permanent grassland agroecosystem (sampling site No. 2) and an arable land agro-ecosystem (sampling site No. 4) located in the water catchment basin. The asset of these agro-ecosystems, however, was lower than the one of the urban ecosystems. By variance analysis, were detected three statistically significant factors (year, season and site) affecting the concentration of nitrate nitrogen. The average concentration of amonium nitrogen during the whole monitoring period represented 0.20 mg dm^{-3}. The lowest concentrations were recorded in winter and the highest in summer. The minimum average concentration was measured in February, the maximum in July. Depending on the sampling site, the highest average concentration values throughout the whole monitoring period were obtained in the sampling sites under human settlements (villages of Kozárovce and Čaradice). The variance analysis for N-NH_4^+ revealed a statistically highly significant effects of sampling date (month) and site.

Key words

amonium nitrogen, nitrate nitrogen, water stream

Introduction

Nitrogen occuring in water in various forms is subject to a variety of macrobiological, chemical and physical processes (Bublinec, 1991; Bublinec et al., 1994). It belongs among the most important microbiogenic elements (Bublinec, 1992; Hruška et al., 2006) and the main nutrients limiting and supporting eutrophication processes of surface waters (Šileika et al., 2005). According to Pitter (2009), inorganically bound nitrogen is important summary indicator of contaminating sewage and surface water. Darrecq et al. (2008) and (Hruška, 2006) consider the following main sources of nitrogen: uncleaned sewage water, agricultural activities (incorrect application of fertilizers and unsuitable agro-technical measures) near water courses and contaminated precipitation. Nitrates are present in small concentrations in almost all surface waters (Stoddard, 2004; Campell, 2000). Ammonium nitrogen is a primary product of decomposition of organic nitrogenous substances of animal and plant origin (Buday, 2002). In waters at oxygen presence, is ammonium nitrogen unstable and easily susceptible to biochemical oxidation (nitrification) (Pitter, 2009).

Material and methods

Research area

The Čaradický brook has its springs in the Pohronský Inovec Mts, in the southern foothill of the mount Drienka (751.1 m a.s.l.) at about 600 m a.s.l. The studied brook Čaradický potok is a right tributary of the Hron river. It is long 11.1 km, and flows across the districts of Zlaté Moravce and Levice. The upper stream is flowing on the bottom of the Certova valley ended with an area with a holiday resort Calex, a hamlet named Široký prieloh and a castle. Above the village of Kozárovce, between the villages Čaradice and Kozárovce, there was built a uniform-shaped water reservoir – dam. The largest tributary of the Čaradický potok is the Svätý potok stream, flowing from the right side of the mount Sejovský (295.2 a.s.l.) On the left side, there are only short tributaries. The flow direction is predominantly north-south, being south-east in the downstream. The Čaradice brook is mouthing into the Hron river, in the so-called Slovakian gate 174 m above sea level, near the village of Kozárovce.

According to characteristics of the geological subsoil, the region is an interesting vast and old volcanic-type structure, which was formed by changing of several phases of volcanic activity and periods of destruction and denudation of volcanic complexes. Andesite, rhyolite rocks and Basalt neovolcanites are alternated in the locality. Beside the rocks of volcanic origin, nappe limestones can also be found (Konečný, 1998).

The studied area belongs to a warm and slightly dry sub-region. The average temperature was 9.1 °C in 2005, 9.7 °C in 2006, 8.9 °C in 2007, 9.4 °C in 2008 and 9.8 °C in 2009. The average rainfall represented 711.4 mm in 2005, 842.7 mm in 2006, 569.8 mm in 2007, 679.7 mm in 2008, and 684.4 mm in 2009 and 690.5 mm in 2010 (source: The rainfall measuring station Kozárovce).

The upper part of the water shed is covered with forest ecosystems and permanent grasslands. The major part of the water course passes through agro-ecosystems of agricultural crops on arable land. The dominant soil types in the area of interest are: brown soils; chernozem, brown soil; chernozem calcareous soil; chernozem and gley fluvial soil.

From an agricultural and industrial point of view, this territory is included in the corn- beet farming region. The crop production is mainly focused on cultivation of cereals (winter wheat, winter rye, spring barley, maize grain, maize silage), perennial forage (medicinal) and oilseeds (rape, sunflower). The livestock production is focused on cattle breeding. The cultivated land in the vicinity of the watercourse belongs to the Agricultural profit-sharing co-operative farm Volkovce.

Concerning industrial fertilizeres, in the course of the monitoring period was applied urea in a dose of (N = 46%), DAM 390 (N = 30%), NPK 15 : 15 : 15 at 200 kg ha^{-1} (N = 12%, P_2O_5 = 19%, K_2O = 19%), LAV at a dose of 350 kg ha^{-1} (N = 27%), DASA at 250 kg ha^{-1} (N = 26%, S = 13%). Nitrogen fertilizers were applied at an average dose of 138 kg ha^{-1} year^{-1}, phosphatic fertilizers at 39 kg ha^{-1} year^{-1} and potassium at 6.01 kg ha^{-1} year^{-1}. In the autumn of 2008 was applied ground limestone at a dose of 2 t ha^{-1}. As for the organic fertilizers, farmyard manure was applied in the root–crops in a dose of 40 t ha^{-1} year^{-1} (source: Co-operative farm Volkovce).

Sampling and processing of the material

Water samples were collected from 6 sampling sites along the water stream Čaradický brook, in the second decades of all calendar months in the years 2005–2010. The sampling sites were located in such a way as to comprise all the actual watercourse contamination.

Sampling site 1 – under the forest ecosystems Pohronský Inovec, 48˚ 22‘ 56“ N and 18˚29‘ 73“ E.
Sampling site 2 – above the village Čaradice, 48˚21‘91“ N and 18˚30‘53“ L.
Sampling site 3 – under the village Čaradice, 48˚21‘35“ N and 18˚30‘55“ E.
Sampling site 4 – in front of the water tank, 48˚19‘82“ N and 18˚30‘50“ E.
Sampling site 5 – the water tank above the village Kozárovce, 48˚19‘74“ N and 18˚ 30‘ 50“ E.
Sampling site 6 – the village Kozárovce, 48˚ 18‘ 77“ N and 18˚32‘25“ E.

In the collected water samples were determined concentration values of nitrate nitrogen N-NO_3^- (spectrophotometrically, using WTW nitrospectral in concentrated sulphuric acid, the method is analogous to DIN 38402 Part 51) and ammonium nitrogen N-NH_4^+ (spectrophotometric indophenol blue – Bertholot reaction method is analogous to DIN 38402 Part 51).

For evaluation of surface water quality indicators in terms of N-NO_3^- and N-NH_4^+ content is used the 90th percentile (P90) quantile calculated from the measured values and the subsequent comparison with the corresponding system of limit values given by the Government Decree of the Slovak Republic No. 269/2010 Coll.

The statistical evaluation was carried out with using the SAS statistical system. For the monitored variables were calculated their basic statistical characteristics of individual sets of values (Table 1). Analysis of variance was performed for three qualitative factors (year of collection, month of collection and sampling site) (Table 2).

Table 1. Basic statistic charakteristic of selected indicators

Indicator	$N\text{-}NO_3^-$	$N\text{-}NH_4^+$
Unit	mg dm^{-3}	mg dm^{-3}
Number	426	426
Mean	2	0.18
Minimum	9.3	1.27
Maximum	0.1	0.01
Std. deviation	1.2786175	0.1356676

Results and discussion

From the studied forms of inorganic nitrogen ($N\text{-}NO_3^-$, $N\text{-}NH_4^+$) in the water course, the most abundant was nitrate nitrogen. Its mean concentration ranged from 2.00 (2008) to 2.97 mg dm^{-3} (2010). For the entire monitoring period, it represented 2.26 mg dm^{-3} (Fig. 1). Lower average concentrations of $N\text{-}NO_3^-$ (1.0 mg dm^{-3}) were recorded by Krúpová in the upper part of the Hron river (2009); and by Bublinec and Dubová (1998a, 1998b) in surface water in the net of the Danube distributaries (1.9 mg dm^{-3}). Another signicantly lower average concentration of $N\text{-}NO_3^-$ (0.4 mg.dm^{-3}) was recorded by Bublinec and Gregor (2002) in the forest ecosystems. On the contrary, higher average concentrations were detected by McIssac and Libra (2003) in the water course Moines (6.3 mg dm^{-3}), Hruška et al. (2006) in the water course Blue brook (3.8 mg dm^{-3}) and Šileika et al. (2010) in water courses Graisupis brook (4.6 mg dm^{-3}), Vardas brook (3.6 mg dm^{-3}) and Lyzina brook (3.1 mg dm^{-3}).

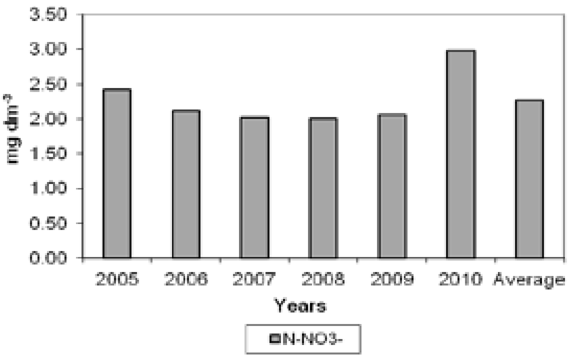


Fig. 1. Mean $N\text{-}NO_3^-$ concentrations in years 2005–2010 [mg dm^{-3}].

Depending on the sampling date, the highest average concentration for the whole period was recorded in the winter, and the lowest in the summer and the autumn season. The maximum average concentration was found in January (3.13 mg dm^{-3}) and the minimum in August (1.61 mg dm^{-3}) (Fig. 2). An analogous seasonal dynamics of these concentrations was recorded by Noskovič et al. (2008) in the water course Čabajský stream, and by Sebíň (2007) in the water stream Lesný. According to Sullivan et al. (2005) concentrations of $N\text{-}NO_3^-$ in surface waters in the summer period decline because they are pumped by phytoplankton. Molénat et al. (2002) suggest a hypothesis that higher concentrations of $N\text{-}NO_3^-$ occur in winter months and their decrease in the summer months is influenced by hydraulic pressure of groundwater level the level of which in soil is higher than is the water level in the water body. Thus, the soil water reaches the layers rich in $N\text{-}NO_3^-$, it enters watercourse with underground waters and, in such a way, acts as an important factor increasing

Table 2. Anova – Analysis of variance for $N\text{-}NO_3^-$ and $N\text{-}NH_4^+$

Source	Dependent variable	Type III Sum of squares	Df	Mean square	F	Sig.
Year	$N\text{-}NO_3^-$	48.06270	5	9.61255296	9.784819	9.01E-09
	$N\text{-}NH_4^+$	0.26601	5	0.05320279	3.308602	0.006201
Month	$N\text{-}NO_3^-$	144.29200	11	13.11750990	13.352590	2.38E-21
	$N\text{-}NH_4^+$	0.57746	11	0.05249721	3.264724	0.000285
Site	$N\text{-}NO_3^-$	90.29550	5	18.05910890	13.212750	6.67E-12
	$N\text{-}NH_4^+$	0.56442	5	0.11288569	6.619619	6.25E-06
Error	$N\text{-}NO_3^-$	347.76700	354	0.98239453		
	$N\text{-}NH_4^+$	5.69237	354	0.01608014		
Total	$N\text{-}NO_3^-$	2942.84000	426			
	$N\text{-}NH_4^+$	25.68	426			

the content of nitrate nitrogen in surface waters. On the contrary, when the ground water level begins to decline in the late spring, leaching of nitrogen from these layers rich in N-NO_3^- shows a decline too, which then results in a decrease in its content in the water course. The most significant increase in concentration of N-NO_3^-, depending on the sampling date was found in 2009 in September. Compared with August, the concentration was higher by 2.12 mg dm^{-3} (i.e. by 34.16%). We assume that this increase in concentration of N-NO_3^- was related to an intensive rainfall event before collecting the water samples (20.5 mm on 29 September 2009). The heavy rain flushed the surface soil layers away, and thus the nitrate nitrogen entered the watercourse. In addition, several authors declare that atmospheric precipitation is an important source of nitrogen (Bublinec and Dubová, 1993; Noskovič and Gábriš, 1995; Bublinec and Dubová, 1998c; Noskovič et al., 2000; Bublinec et al., 2002; Babošová et al. 2007; Pitter, 2009). There have not been recognised any regular seasonal patterns of the dynamics of N-NO_3^- concentration for the whole period of observations.

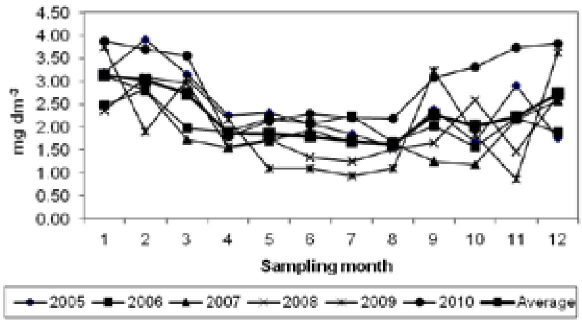


Fig. 2. Mean N-NO_3^- concentrations depending on sampling time [mg dm^{-3}].

Along the entire water course, the minimum average concentration of nitrate nitrogen for the whole period was recorded in the sampling site No. 1 (1.68 mg dm^{-3}), which was located under the forest ecosystem of the Pohronský Inovec Mts (Fig. 3). By analogy, the lowest average concentration of N-NO_3^- in the water course Hontiansky potok was detected by Noskovič (1999) in forest ecosystems. The maximum average concentration for the entire monitoring period was obtained in the sampling site No. 6 (under the village Kozárovce). In the above sampling site, as well as in the sampling site No. 3 (village Čaradice), were detected the most significant increases throughout the study period. Increases in these concentrations in the given ecosystems human settlements were probably caused by a secondary increase in nitrate nitrogen content, due to nitrification of ammonium nitrogen contained in the contaminated sewage water effluents (the village have no sewage tanks). The increase in the average concentration of N-NO_3^- in water course over the entire study period was mainly affected by the the agro-ecosystem of permanent grassland (sampling site No. 2) and arable land agro-ecosystem (sampling site No. 4) located in the water course-basin. The decrease under the agro-ecosystems observed was, however, lower compared to the human settlement ecosystem. Along the water course, under the water basin was observed a decrease in the average concentration of N-NO_3^- for the whole period. This decrease may be caused by a lower concentration of oxygen in the water basin, which probably reduced nitrification. With variance analysis (Table 2) applied for individual factors it was found out that all these three factors (year, month and place of collection) affected statistically significantly the concentration of nitrate nitrogen in water. According to the Government Decree of the Slovak Republic No. 269/2010 Coll., there is given a limit value for nitrate nitrogen making 5 mg dm^{-3}. The obtained 90 percentile values of this indicator were lower than the value recommended.

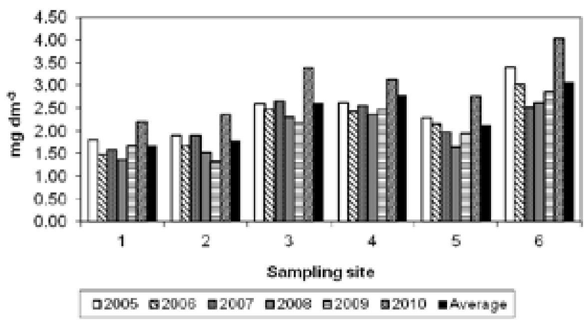


Fig. 3. Mean N-NO_3^- concentrations depending on sampling site [mg dm^{-3}].

The average concentrations of ammonium nitrogen in the studied years were within the range 0.17 (2007) –0.24 mg dm^{-3} (2005). For the whole period, the average concentration of this nitrogen form was 0.21 mg dm^{-3} (Fig. 4). A lower average concentration of N-$NH4^+$ (0.14 mg dm^{-3}) was recorded by Menyhártová (2010) in the Hraničný potok stream, while the highest values were obtained by Sullivan et al. (2005) in the water streams Loch brook (0.50 mg dm^{-3}) and Anrews brook (0.90 mg dm^{-3}). A lower average concentration of N-$NH4^+$ (0.15 mg dm^{-3}) was recorded by Bublinec and Gregor (2002) in the Biosphere Reserve Poľana Mts and by Menyhártová (2010) in the Hraničný potok (0.14 mg dm^{-3}). Another significantly lower average concentration of N-$NH4^+$ (0.02 mg dm^{-3}) was recorded by Bublinec et al. (2007) in water sampled from springs of the Biosphere Reserve Poľana, while the highest values were recorded by Sullivan et al. (2005) for the brooks Loch (0.50 mg dm^{-3}) and Anrews (0.90 mg dm^{-3}). The concentration of N-$NH4^+$ was significantly affected by the collection date, and this was confirmed statistically. Lower average concentrations for the whole monitoring period were recorded in the winter season, and higher in the summer season. The minimum was recorded in February (0.14 mg dm^{-3}) and maximum in July (0.28 mg dm^{-3}) (Fig. 5). Increases in the concentration of ammonium nitrogen in the summer monts were also observed by Beňačková and Noskovič (2004); Babošová and Noskovič (2007); Noskovič et al. (2008). This increase in concentration is probably related to higher water temperature and lower oxygen content, which does not provide favorable conditions for nitrification of ammonium nitrogen to nitrate and nitrite nitrogen (Babošová, 2005; Noskovič et al., 2010). The relationship between the average concentrations of both forms of inorganic nitrogen (N-NO_3^-, N-NH_4^+) in individual sampling months is fitted with a declining line, expressing their negative correlation (–0.92) (Fig. 6). The value of reliability (R^2 = 0.848) points to a close correlation between the concentrations of these two inorganic forms of nitrogen. Despite this, the concentration of nitrate nitrogen was always higher than the concentration of ammonium nitrogen. There has not been manifested seasonal regularity of the dynamics N-NH_4^+ concentration within the whole study period.

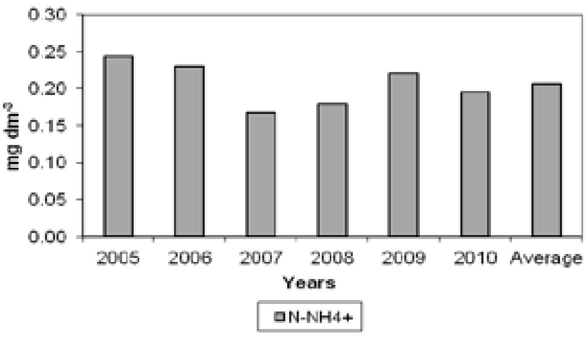


Fig. 4. Mean N-NH_4^+ concentrations in years 2005–2010.

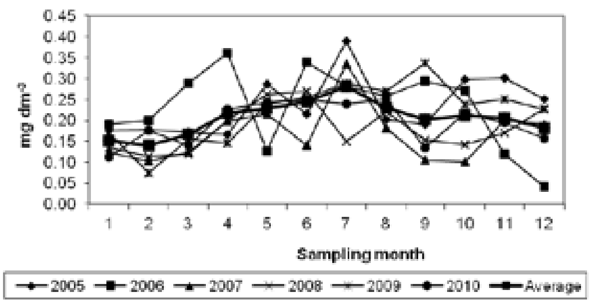


Fig. 5. Mean N-NH_4^+ concentrations depending on sampling time [mg dm^{-3}].

The average concentration of ammonium nitrogen along the watercourse was produced by human settlement ecosystems the water course is flowing through (Fig. 7) and in the water basin. The most significant increase in N-NH_4^+ concentrations depending on the sampling site was detected for the sampling site No. 3 (under the village Čaradice). Compared to the sampling site No. 2 (above the village Čaradice), its N-NH_4^+ concentration was higher by 0.07 mg dm^{-3} (73.07 %), probably due to uncleaned sewage effluents entering the watercourse (Virtanen, 2001; Noskovič, 1992). The analysis of variance (Table 2) for N-NH_4^+ revealed statistically significant effects of qualitative factors, such as month and sampling site. The 90th percentile values declared by the Government Decree of the Slovak Republic No. 269/2010 Coll. are lower than the environmental limit value set for ammonium nitrogen (1.0 mg dm^{-3}).

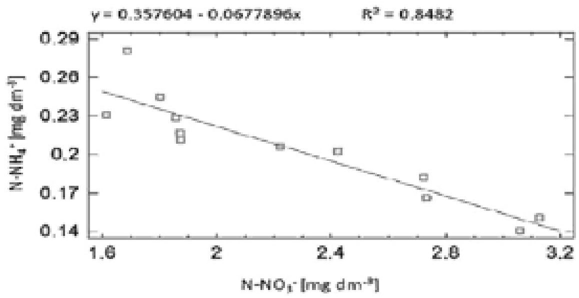


Fig. 6. Dependence of mean N-NO_3^- on N-NH_4^+.

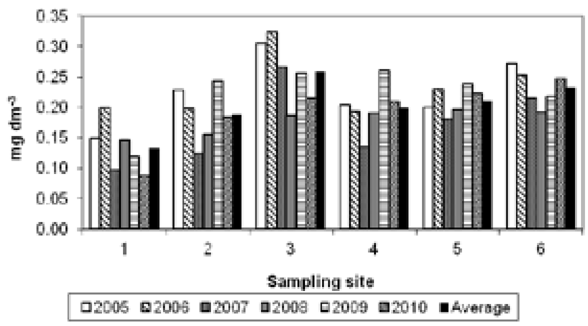


Fig. 7. Mean N-NH_4^+ concentrations depending on sampling site [mg dm^{-3}].

Acknowledgement

The present work was accomplished with the support from the grant project VEGA 1/0513/12.

References

Babošová, M. 2005. *Vplyv poľnohospodárskych a urbánnych ekosystémov na kvalitu vody vo vodnom toku Kadaň* [Influence of agricultural and urban ecosystems on water quality in the watercourse Kadaň]. PhD thesis. Nitra: Slovak University of Agriculture. 146 p.

Babošová, M., Noskovič, J. 2007. Koncentrácia nutrientov vo vode odtekajúcej z malého poľnohospodársky obhospodarovaného povodia [Concentration of nutriens in water drained from a small agriculturally managed watershed]. *Acta hydrol. slov.*, 8 (2): 153–163.

Babošová, M., Noskovič, J., Palatická, A. 2007. Inputs of nitrogen by precipitation into the soil in the agricultural region of the southwestern Slovakia. *Acta Fac. Ecol.*, 16, Suppl.: 101–105.

Beňačková, J., Noskovič, J. 2004. Evaluation of two inorganic forms of nitrogen in water of the Nature Reserve Žitavský luh. *Folia ocecol.*, 31: 67–71.

Bublinec, E. 1991. Annual course of acid throughall in forest ecosystems of Slovakia. In Reuther, M. *Expertentagung Waldschadensforchung im östlichem Mitteleuropa und in Bayern. Proceedings.* GSF Bericht 24/91. München, p. 407–412.

Bublinec, E. 1992. Depletion of N by harvesting timber from forest ecosystems depended on age and yield class of spruce. In *Les, drevo, ekológia. Zborník z medzinárodnej vedeckej konferencie.* Zvolen: Technická univerzita, p. 49–54.

Bublinec, E., Dubová, M. 1993. Wet deposition in beech-wood ecosystems of Slovakia. In *Lesníctvo a výskum v meniacich sa ekologických podmienkach v SR. Zborník z jubilejnej konferencie*. Zvolen: Lesnícky výskumný ústav, p. 10–15.

Bublinec, E., Dubová, M. 1998a. Monitoring and state of nutrients in surface water of Danube inland delta. In Kontrišová O., Bublinec, E. (eds). *Monitorovanie a hodnotenie stavu životného prostredia. Zborník referátov.* Zvolen: Fakulta ekológie a environmentalistiky Technickej univerzity vo Zvolene, p. 33–38.

Bublinec, E., Dubová, M. 1998b. Quality of surface waters stability in meadow ecosystems. In Vlavionos-Arvantis, A., Morovic, J. *Biopolitics. The bioenviromnent. Vol. VI.* Biopolitics International Organisation B.I.O., p. 160–164.

Bublinec, E., Dubová, M. 1998c. Long-term quantity changes of sulphur and nitrogen of beech ecosystems. In *Lesy a lesnícky výskum pre tretie tisícročie. Zborník z medzinárodnej vedeckej konferencie*. Zvolen: Lesnícky výskumný ústav, p. 297–301.

Bublinec, E., Gregor, J. 2002. Monitoring of the water streams chemistry in the Poľana biosphere reserve. In *Monitorovanie a hodnotenie stavu životného prostredia IV. Zborník referátov*. Zvolen: Technická univerzita vo Zvolene, 2002, p. 31–38.

Bublinec, E., Cicák, A., Dubová, M. 1994. Scientific underlying data managment ecologization under current emmision and ecological conditions. In *Ecological stability, diversity and productivity of forest ecosystem*. Zvolen: IFE SAS, p. 521–524.

Bublinec, E., Dubová, M., Kundrík, F. 2007. Odtok vody z prameňa a zmena jej chemizmu v lúčnom ekosystéme [Water discharge from a spring and changes of its chemistry in a meadow ecosystem]. In *Biológia v škole dnes a zajtra II*. Ružomberok: Edičné stredisko Katolíckej univerzity v Ružomberku, p. 89–103.

Bublinec, E., Kukla, J., Dubová, M. 2002. Fluxes of hydrogen ions and sulphur in a beech forested catchment in the Western Carpathians. *Silvia balc.*, 2 (1): 29–37.

Buday, J. 2002. *Intenzifikácia procesov odstraňovania dusíka z odpadových vôd – substrátová a produktová inhibícia nitrifikácie* [Intensification of the processes of nitrogen removal from waste waters – substrate and product inhibition of nitrification process]. Bratislava: Výskumný ústav vodného hospodárstva. 92 p.

Campell, D.H., Clow, D.W., Ingersoll, G.P., Mast, M.A., Sphar, N.E., Schuster, P.F. 2000. Controls on nitrogen flux in alpine/suobalpine water sheds. *Water Resour.*, 36: 49–62.

Darraeq, A., Lindgren, G., Destouni, G. 2008. Long-term development of phosphorus and nitrogen loads through the subsurface and surface water systems of drainage basins *Global biochem. Cycles,* 22: 1–9, doi: 10.1029/20007GB0032022.

Government Decree of the Slovak Republic No. 269/2010 Coll.

Hruška, J., Majer, V., Fottová, D. 2006. Vlyv kyslé depozice na chemizmus povrchových vod v Krkonoších [Influence of acid deposition on chemistry of surface waters in the Krkonoše Mts]. *Opera corcont.*, 43: 95–110.

Konečný, V. 1998. *Vysvetlivky ku geologickej mape Štiavnických vrchov a Pohronského Inovca (štiavnické stratovulkány)* [Explanatory notes to the geological map of the Štiavnické vrchy Mts and Pohronský Inovec Mts (štiavnické stratovolcanic areas)]. Bratislava: Geologická služba Slovenskej republiky, Vydavateľstvo Dionýza Štúra v Bratislave. 473 p.

Krúpová, K. 2009. Sledovanie vybraných ukazovateľov kvality povrchových vôd v hornom úseku Hrona [Monitoring of selected markers of surface water quality in the upper part of the Hron River]. In *21. konferencia mladých hydrológov. Zborník súťažných prác mladých odborníkov*. Bratislava: Slovenský hydrometeorologický ústav, p. 23–31.

Mcisaac, G.F., Libra, R.D. 2003. Surface water quality. Revising nitrate concentrations in the Des Moines River. *J. Environ. Qual.*, 32: 2280–2289.

Molénat, J., Durand, P., Gascuel-odoux, CH. 2002. Mechanisms of nitrate transfer from soil to stream in an agricultural watershed of French Britany. *Wat. Air Soil Pollut.*, 133 (1–4): 161–183.

Menyhártová, Z. 2010 Monitoring akosti vôd v Hrabičnom potoku [Monitoring of water quality in the Hrabičný potok, stream]. Zlín: Univerzita Tomáše Bati. 83 p.

Noskovič, J. 1992. Dynamika dusíka a fosforu v povrchových vodách rôznych ekosystémov [Dynamics of nitrogen and phosphorus in surface waters in diverse ecosystems]. In *Zborník Ekologizácia úprav vodných tokov*. Bratislava: Pobočka Slovenskej vodohospodárskej spoločnosti pri Povodí Dunaja, p. 7–12.

Noskovič, J. 1999. *Vplyv rôznych ekosystémov a urbanizovaných celkov na akosť vody vo vodnom toku* [Influence of various ecosystems and urbanised areas on water quality in waterstreams]. Inaugural dissertation. Nitra: Slovak University of Agriculture in Nitra. 120 p.

Noskovič, J., Gábriš, Ľ. 1995. Vstupy dusíka zrážkami do pôdy v oblasti mesta Nitry [Nitrogen input in atmospheric precipitation into the soils around the Nitra town]. In Šiška, B. (zost.). *Modelovanie bioklimatických procesov. Zborník prác z Bioklimatických pracovných dní, organizovaných 17.–19. 8. 1994 v Nitre*. Bratislava: Slovenská bioklimatologická spoločnosť SAV, Štátna veterinárna správa SR. 239 p.

Noskovič, J., Babošová, M., Porhajašová, J. Palatická, A. 2008. Hodnotenie koncentrácie dusičnanového a amónneho dusíka vo vodnom toku v poľnohospodárskej krajine [Assessment of nitrate and ammonium nitrogen concentration in a water stream in agricultural landscape]. *Acta hydrol. slov*., p. 98–105.

Noskovič, J., Babošová, M., Urminská, J., Ondrišík, P. 2000. Monitoring vstupov dusíka mokrou depozíciou do pôdy v oblasti mesta Nitry [Monitoring of nitrogen input in the form of wet deposition into the soils around the Nitra town]. In *Aktuálne problémy riešené v agrokomplexe. Zborník z medzinárodného vedeckého seminára*. Nitra: Slovenská poľnohospodárska univerzita v Nitre, p. 148–149.

Noskovič, J., Beňačková, J., Urminská, J., Szombathová, N. 2010. *Prírodná rezervácia Žitavský luh – abiotické zložky: vedecká momografia* [The Nature Reserve Žitavský luh – abiotic components: scientific monograph]. Nitra: Slovenská poľnohospodárska univerzita v Nitre. 157 p.

Pitter, P. 2009. *Hydrochemie* [Hydrochemistry]. Praha: VŠCHT.

Sebíň, M. 2007. Vplyv využitia krajiny na kvalitu vody v toku v poľnohospodársky využívanom a zalesnenom mikroprostredí [Effects of land use on water quality in a water stream in agriculturally managed and forested micro-territories]. *Acta hydrol. slov*., 8 (2): 22–28.

Stoddard, J.L. 2004. Long-term changes in watershed retention of nitrogen: its causes and aquatic consequences. In Baker, L.A. (ed.). *Environmental chemistry of lakes and reservoirs*. Advances in Chemistry Series, no. 237. Washington: American Chemical Society, p. 781–786.

Sullivan, T.J., Cosby, J.B., Tonnessen, K.A., Clow, D.W. 2005. Surface water acidification responses and critical loads of sulphur and nitrogen depositon in Loch Vale watershed, Colorado. *Wat. Mgmt and Engng,* 41, W01021: 1–15, doi: 10.1029/2004WR0031414.

Šileika, A.S., Kutra, S., Gaigalis, K., Berankiene, L., Šmitiene, A. 2005 Analysis of variation nitrogen and phosphorus concentration in the Nemus river. *Wat. Mgmt and Engng*, 2 (5): 15–24.

Šileika, A. S. 2010. Catchment model for assesing phosporus sources retention and reduction options in the river Nemunas. *Wat. Mgmt and Engng,* 37 (57): 34–45.

Virtanen, T. 2001. *Chémia vody* [Water chemistry]. Banská Bystrica: Univerzita Mateja Bela. 118 p.

Koncentrácia dusičnanového a amónneho dusíka v rozdielnych ekosystémoch

Súhrn

V priebehu rokov 2005–2010 sa hodnotil vplyv lesného, poľnohospodárskych a urbánnych ekosystémov na koncentrácie N-NO_3^-, N-NH_4^+ vo vodnom toku Čaradický potok. Vodný tok pramení v pohorí Pohronský Inovec a preteká územím okresov Zlaté Moravce a Levice. Na základe získaných výsledkov možno konštatovať, že najnižšie priemerné koncentrácie zo sledovaných anorganických foriem dusíka počas celého sledovaného obdobia boli v odberovom mieste lokalizovanom pod lesným ekosystémom Pohronský Inovec. Priemerná koncentrácia N-NO_3^- vo vodnom toku bola 2,26 mg dm^{-3}. Jeho najvyššia priemerná koncentrácia za celé monitorované obdobie sa zistila v mesiaci január a najnižšia v mesiaci august. Najvýraznejší vzostup koncentrácie N-NO_3^- sa zistil v mesiaci september v roku 2009, čo pravdepodobne súvisí s intenzívnou zrážkovou činnosťou pred odberom vzoriek (29. 9. 2009 napršalo 20,5 mm). V závislosti od odberového miesta boli maximálne priemerné koncentrácie N-NO_3^- v odberových miestach lokalizovaných pod urbánnymi ekosystémami (obce Kozárovce a Čaradice). Vzostup ich koncentrácie pod uvedenými obcami bol pravdepodobne zapríčinený sekundárnym zvýšením obsahu

dusičnanového dusíka, ktorý vznikal nitrifikáciou amónneho dusíka, nachádzajúceho sa v nevyčistených splaškových odpadových vodách (obce nemajú vybudované ČOV). Na zvýšení priemernej koncentrácie $N\text{-}NO_3^-$ vo vodnom toku za celé sledované obdobie participovali aj agroekosystém trvalých trávnych porastov (odberové miesto č. 2) a agroekosystém ornej pôdy (odberové miesto č. 4) nachádzajúce sa v povodí vodného toku. Vzostup pod uvedenými agroekosystémami bol však nižší ako pod urbánnymi ekosystémami. Analýzou rozptylu sa zistili štatisticky významné vplyvy všetkých troch kvalitatívnych faktorov (rok, mesiac a miesto odberu) na zmenu koncentrácií dusičnanového dusíka. Priemerná koncentrácia amónneho dusíka za celé monitorované obdobie reprezentovala 0,20 mg dm^{-3}. Najnižšie koncentrácie sa zaznamenali v zimnom a najvyššie v letnom období. Minimálna priemerná koncentrácia bola v mesiaci február a maximálna v mesiaci júl. V závislosti od odberového miesta jeho najvyššie priemerné koncentrácie počas celého sledovaného obdobia boli v odberových miestach lokalizovaných pod urbánnymi ekosystémami (obce Kozárovce a Čaradice). Analýzou rozptylu sa pre $N\text{-}NH_4^+$ potvrdil štatisticky vysoko preukazný vplyv kvalitatívnych faktorov mesiac a miesto odberu.

Received November 21, 2011
Accepted January 10, 2012

Species diversity, abundance and dominance of macromycetes in beech forest stands with different intensity of shelterwood cutting interventions

Ivan Mihál

Institute of Forest Ecology of the Slovak Academy of Sciences, Štúrova 2, 960 53 Zvolen, Slovak Republic,
e-mail: mihal@savzv.sk

Abstract

Mihál, I. 2012. Species diversity, abundance and dominance of macromycetes in beech forest stands with different intensity of shelterwood cutting interventions. *Folia oecol.*, 39: 53–62.

The aim of this work is to enrich the knowledge of the dynamics of species diversity, abundance and distribution of fruiting bodies and dominance of macromycetes species in a mycocoenosis of beech forest stands. We studied the issue in beech stands in the Kremnické vrchy Mts (Central Slovakia), in the years 2007 and 2008. The experimental area consists of a series of four partial research plots (PRP) obtained by applying a series of regeneration cuts differing in intensity and a control intact plot in the original stand. Altogether we identified 154 species of macromycetes and one species of Fungi imperfecti. We obtained various values of abundance and distribution of fruiting bodies and species dominance on the particular partial plots. The species spectrum concerning the most dominant species was almost the same on each PRP. As for the ecotrophic demands of macromycetes, we can see that the abundance values in lignicolous species increased beginning with the plot with the heaviest intervention up to the intact control plot. On the other hand, the plot subjected to light cut and the control plot exhibited increased abundance of terrestrial saprophytes and ectomycorrhizal symbionts.

Key words

abundance, cutting interventions, dominance, *Fagus sylvatica* L., macromycetes, species diversity

Introduction

Beech covering 31.2% of the total forest land in Slovakia was the leading woody plant in the country in the year 2008 (Collective, 2008). The species is of key importance both to landscape forming and to commercial forest management. Until recently, the damage and threat to beech trees by biotic agents – insects and fungi was not considered significant (Korpeľ et al., 1991). In the last years, however, a steep increase in biotic damage to beech is evident. This is true for increasing populations of insects feeding on leaves and of wood destroying insects as well as for fungal diseases – mycoses. Macromycetes (macrofungi) growing in beech forest stands build an intricate ecotrophic-ecotopic system linked with beech and with the beech-associated environment. Each mycocoenosis in beech stands is characterised by its species diversity and dominance, abundance, distribution and fruit bodies fructification of the individual fungal species.

Mycofloristic research, especially analysis of mycocoenoses in beech forest stands has been area of interest of several authors. Dynamics of species diversity, dominance, succession and production of macromycetes in beech forest stands in Slovakia and in the Czech Republic was studied, among others, by Adamčík et al. (2007), Čížková (2007), Holec (1992, 1994, 2008), Jančařík (2004), Lazebníček (1988), Mihál (1992, 1994, 1995a, b), Mihál and Bučinová (2005) Mihál et al. (2009), Pavlík (1997), Vaník (1970), in abroad by Adamczyk (1995), Andersson (1995), Grzywacz (1990), Matsuda (1994), Salerni and Perini (2004), Tratnik and Pohleven (1995), Tyler (1991), Willig and Schlechte (1995) and others.

The aim of this work is to contribute to the knowledge about dynamics of the species diversity, abundance and distribution of fruiting bodies and dominance of macromycetes in beech forest stands long term treated with applying regeneration cuts of various intensity.

Material and methods

The issue was studied on a permanent research plot series situated in beech stands of the Ecological Experimental Site (EES) Kováčová in the Kremnické vrchy Mts. The series consists of five partial research plots (PRP) with different densities obtained applying a series of regeneration shelterwood cuts with different intensities. The first cut series in March 1989 resulted in forming five PRPs with stocking densities scaled from clear cut to the original intact forest stand (control). The second cut series applied in March 2004 modified the stocking density values on individual plots in the way summarised in Table 1. Mycological research was pursued on four PRPs (except for clear cut), that means PRP H (heavy intervention), PRP M (medium intervention), PRP L (light intervention) and PRP C (control without intervention). Our research on these four PRPs was realised after the second series of regeneration cuts in 2004 leading to even more stocking density reduction (Table 1).

Table 1. Basic characteristics of the locality EES Kremnické vrchy Mts and the individual partial research plots (PRP)

Orographic unit	Kremnické vrchy Mts
Partial research plot	Ecological – Experimental Stationary Kováčová
Localisation	N – 48º38'10", E – 19º04'08"
Altitude [m a.s.l.]	470–490
Exposition	SW
Slope [º]	20
Geological substrate	Andesite, tuffaceous agglomerates
Soil type	Cambisol (andosol) saturated
Humus form	Mull
Throughfall [mm] *	653
Temperature [ºC] *	8.3
Forest type groups	Fagetum pauper inferiora
Vegetal association	Dentario bulbiferae – Fagetum Zlatník, 1936
	Carici pilosae – Fagetum Oberd., 1958
Tree composition of total EES [%]	Beech 95, fir 2, hornbeam 2, oak 1
Age of mature stand [years]	105–110
Stocking of stand [before 2004] **	0.3–0.5–0.7–0.9
Stocking of stand [since 2004] **	0.0–0.3–0.5–0.9
Crown canopy of total EES [%]	0.0–97.0
Area of total EES [ha^{-1}]	1.2

* Throughfall and Temperature: average values from 2003–2005.
** Stocking and Area of individual Partial Research Plots (PRP):

Before 2004

PRP: H (heavy cutting intervention), stocking: 0.3 area: 0.35 ha^{-1}
PRP: M (light cutting intervention), 0.5 ….. 0.35 ha^{-1}
PRP: L (mild cutting intervention), 0.7 ….. 0.35 ha^{-1}
PRP: C (control plot - without cutting intervention), 0.9 ….. 0.15 ha^{-1}

Since 2004

PRP: H (heavy – now clear cutting intervention), stocking: 0.0 area: 0.35 ha^{-1}
PRP: M (medium cutting intervention), 0.3 ….. 0.35 ha^{-1}
PRP: L (light cutting intervention), 0.5 ….. 0.35 ha^{-1}
PRP: C (control plot – without cutting intervention), 0.9 ….. 0.15 ha^{-1}.

The surveys were done monthly, in the growing seasons 2007 (May 4, June 7, July 13, August 14, September 21, October 17) and 2008 (May 6, June 11, July 8, August 8, September 23, October 16).

In the surveys we recorded the species diversity and abundance of fructification in macromycetes on the research plots. Moreover, there was recorded the fruiting bodies distribution, that means the number of occurrence spots of fruiting bodies across the given plot. In such a way, each species was assigned with a number of abundance A (number of fruiting bodies) and a number of distribution D (number of occurrence spots of the species). Summarizing the two characteristics A + D we obtained a number of dominance (Do), ranking the given species into the appropriate class at the scale of dominant species in the mycocoenosis on the given research plot. More details about the discussed methodical approach can be found in Mihál (1994, 1995b). It is necessary to add that in most fruticose and resupinate fruiting bodies of lignicolous species, the values of their abundance and distribution were identical, as the precise determining of the number of fruiting bodies in such species was not possible (such as *Bisporella citrina, Calocera viscosa, Durela commutata, Hypoxylon multiforme, Trametes versicolor* and others).

The species diversity was assessed according to the assessment keys assembled by Breitenbach and Kränzlin (1986), Červenka et al. (1971), Hagara et al. (1999), Jülich (1984), Moser (1983), Papoušek (2004), Veselý et al. (1972) and others. There were also used matching standards from the collection of the author of this paper. Selected species of the identified macromycetes have been deposed as exciccata by the author at the Institute of Forest Ecology SAS in Zvolen.

All the identified macromycetes have been ranked by their ecotrophic demands (growing substrate) in the individual ecotrophic groups – lignicolous found on wood substrate (parasitic and saprophytic), and terrestrial species growing from humus litter and soil horizons (saprophytic and ectomycorrhizal fungi), as well as the species parasitizing on herbs, fungi and epiphytic species.

Results

In the following we present the list of the identified macromycetes species together with abbreviated labels of the plots which the occurrence of the species was recorded on individual plots (for abbreviations of PRP see Table 1). The species were classified in Ascomycotina, Basidiomycotina and Deuteromycotina – Fungi imperfecti. Taxonomic nomenclature of macromycetes species is proposed by Lizoň and Bacigálová (1998) and Škubla (2003).

Ascomycotina:

Aleuria *aurantia* (Pers.) Fuckel – L, ***Ascocoryne*** *sarcoides* (Jacq.) J. W. Groves et D. E. Wilson – ML, ***Ascodichaena*** *rugosa* (L.) Butin – MLC, ***Bisporella*** *citrina* (Batsch) Korf et S. E. Carp. – ML, ***Dasyscyphus*** *ciliaris* (Schrad.) Sacc. – C, ***Diatrype*** *disciformis* (Hoffm.) Fr. – HMLC, *D. stigma* (Hoffm.) Fr. – HMLC, ***Durella*** *commutata* Fuckel – LC, ***Eutypella*** *quaternata* (Pers.) Rappaz – HMLC, ***Hypoxylon*** *fragiforme* (Pers.) J. Kickx f. – HMLC, *H. multiforme* (Fr.) Fr. – HMLC, ***Kretzschmaria*** *deusta* (Hoffm.) P. M. D. Martin – LC, ***Melanopsamma*** *pomiformis* (Pers.) Sacc. – HLC, ***Microsphaera*** *alphitoides* Griffiths et Maubl. – H, ***Nectria*** *cinnabarina* (Tode) Fr. – L, *N. cosmariospora* Ces. et De Not. – C, *N. episphaeria* (Tode) Fr. – L, *N. peziza* (Tode) Fr. – L, ***Peziza*** *arvernensis* Boud. – C, ***Rhytisma*** *acerinum* (Pers.) Fr. – HMLC, ***Valsa*** *ambiens* (Pers.) Fr. – HMLC, ***Xylaria*** *hypoxylon* (L.) Grev. – ML, *X. polymorpha* (Pers. ex Mérat) Grev. – HL.

Basidiomycotina:

Agaricus *essettei* Bon – L, *A. silvaticus* Schaeff. – M, ***Amanita*** *phalloides* (Fr.) Link – L, *A. vaginata* (Bull.) Lam. – HL, ***Armillaria*** *ostoyae* (Romagn.) Herink – HML, ***Auricularia*** *mesenterica* (Dicks.) Pers. – HML, ***Bjerkandera*** *adusta* (Willd.) P. Karst. – HMLC, ***Calocera*** *cornea* (Batsch) Fr. – ML, *C. viscosa* (Pers.) Fr. – ML, ***Cantharellus*** *cibarius* Fr. – MC, ***Chondrostereum*** *purpureum* (Pers.) Pouzar – ML, ***Chrysomphalina*** *chrysophyllum* (Fr.) Clémençon – L, ***Clavariadelphus*** *pistillaris* (L.) Donk – C, ***Clavicorona*** *pyxidata* (Pers.) Donk – L, ***Clitocybe*** *fragrans* (Sowerby) P. Kumm. – H, *C. nebularis* (Batsch.) P. Kumm. – LC, ***Coprinus*** *disseminatus* (Pers.) Gray – L, *C. domesticus* (Bolton) Gray – L, *C. micaceus* (Bull.) Fr. – L, ***Cortinarius*** *duracinus* Fr. – ML, *C. multiformis* (Fr.) Fr. – C, ***Craterellus*** *cornucopioides* (L.) Pers. – HMLC, ***Cyathus*** *striatus* (Huds.) Willd. – HM, ***Dacrymyces*** *stillatus* Nees. – HMLC, ***Daedalea*** *quercina* (L.) Fr. – HM, ***Daedaleopsis*** *confragosa* (Bolton) J. Schröt. – C, ***Exidia*** *glandulosa* (Bull.) Fr. – HMLC, *E. pithya* (Alb. et Schwein.) Fr. – MLC, ***Fomes*** *fomentarius* (L.) J. Kickx f. – HMLC, ***Galerina*** *badipes* (Fr.) Kühner – L, *G. pumila* (Pers.) Singer – L, ***Gymnopilus*** *junonius* (Fr.) P. D. Orton – L, *G. penetrans* (Fr.) Murrill – L, *G. sapineus* (Fr.) Maire – LC, ***Gymnopus*** *peronatus* (Bolton) Antonín et al. – L, *G. fusipes* (Bull.) Gray – M, ***Hericium*** *clathroides* (Pall.) Pers. – C, ***Heterobasidion*** *annosum* (Fr.) Bref. – L, ***Hygrophorus*** *eburneus* (Bull.) Fr. – HL, *H. poetarum* R. Heim – M, ***Hymenochaete*** *rubiginosa* (J. Dicks.) Lév. – HMLC, ***Hypholoma*** *fasciculare* (Huds.) P. Kumm. – ML, *H. sublateritium* (Schaeff.) Quél. – HL, ***Inocybe*** *asterospora* Quél. – L, ***Inonotus*** *nodulosus* (Fr.) P. Karst. – C, ***Kuehneromyces*** *mutabilis* (Schaeff.) Singer et A. H. Sm. – L, ***Laccaria*** *amethystina* (Huds.) Cooke – L, *L. laccata* agg. – L,

Lactarius *blennius* (Fr.) Fr. – LC, *L. fuliginosus* (Fr.) Fr. – L, *L. piperatus* (L.) Gray – HMLC, *L. pterosporus* Romagn. – LC, *L. salmonicolor* R. Heim et Leclair – HL, *L. volemus* (Fr.) Fr. – ML, ***Lentinus*** *strigosus* (Schwein.) Fr. – HML, *L. torulosus* (Pers.) Lloyd – ML, ***Lenzites*** *betulina* (L.) Fr. – ML, ***Lepiota*** *clypeolaria* (Bull.) P. Kumm. – L, *L. cristata* (Alb. et Schwein.) P. Kumm. – L, ***Lycopedon*** *perlatum* Pers. – MLC, *L. pyriforme* Schaeff. – LC, *L. umbrinum* Pers. – L, ***Lyophyllum*** *loricatum* (Fr.) Kühner – L, ***Marasmiellus*** *foetidus* (Sowerby) Antonín et al. – LC, ***Marasmius*** *alliaceus* (Jacq.) Fr. – HLC, *M. bulliardii* Quél. – LC, *M. rotula* (Scop.) Fr. – LC, ***Megacollybia*** *platyphylla* (Pers.) Kotl. et Pouzar – MLC, ***Mycena*** *alcalina* (Fr.) P. Kumm. – LC, *M. crocata* (Schrad.) P. Kumm. – L, *M. epipterygia* var. *viscosa* (Maire) Ricken – HL, *M. filopes* (Bull.) P. Kumm. – LC, *M. haematopus* (Pers.) P. Kumm. – ML, *M. polygramma* (Bull.) Gray – LC, *M. pura* (Pers.) P. Kumm. – L, *M. stipata* Maas Geest. et Schwöbel – L, *M. stylobates* (Pers.) P. Kumm. – LC, ***Omphalina*** *epichysium* (Pers.) Quél. – L, ***Oligoporus*** *stipticus* (Pers.) Gilb. et Ryvarden – LC, *O. subcaesius* (A. David) Ryvarden et Gilb. – L, *O. tephroleucus* (Fr.) Gilb. et Ryvarden – C, ***Panellus*** *stipticus* (Bull.) P. Karst. – HMLC, ***Phanerochaete*** *laevis* (Pers.) J. Erikss. et Ryvarden – L, ***Phellinus*** *hartigii* (Allesch. et Schnabl) Pat. – C, ***Phlebia*** *radiata* Fr. – L, ***Pholiota*** *squarrosa* (Weigel) P. Kumm. – L, ***Pleurotus*** *pulmonarius* (Fr.) Quél. – HMLC, ***Pluteus*** *atromarginatus* (Konrad) Kühner – L, *P. cervinus* (Schaeff.) P. Kumm. – ML, *P. romellii* (Britzelm.) Sacc. – L, *P. salicinus* (Pers.) P. Kumm. – L, ***Polyporus*** *arcularius* (Batsch) Fr. – M, *P. brumalis* (Pers.) Fr. – L, *P. melanopus* (Sw.) Fr. – MLC, *P. varius* (Pers.) Fr. – HMLC, ***Psathyrella*** *piluliformis* (Bull.) P. D. Orton – L, *P. spadiceogrisea* (Schaeff.) Maire – M, ***Pseudocraterellus*** *undulatus* (Pers.) Rauschert – ML, ***Pycnoporus*** *cinnabarinus* (Jacq.) P. Karst. – M, ***Rickenella*** *fibula* (Bull.) Raithelh. – ML, ***Russula*** *aeruginea* Lindblad – LC, *R. aurea* Pers. – HMC, *R. chloroides* (Krombh.) Bres. – LC, *R. cyanoxantha* (Schaeff.) Fr. – HML, *R. fellea* (Fr.) Fr. – MLC, *R. foetens* (Pers.) Fr. – HMLC, *R. heterophylla* (Fr.) Fr. – M, *R. nigricans* (Bull.) Fr. – L, *R. nobilis* Velen. – LC, *R. olivacea* (Schaeff.) Pers. – MLC, *R. vesca* Fr. – MC, ***Schizophyllum*** *commune* Fr. – HMLC, ***Schizopora*** *flavipora* (Berk. et M. A. Curtis ex Cooke) Ryvarden – HML, *S. radula* (Pers.) Hallenb. – L, ***Scleroderma*** *citrinum* Pers. – HL, ***Stereum*** *gausapatum* (Fr.) Fr. – M, *S. hirsutum* (Willd.) Gray – HMLC, *S. rugosum* (Pers.) Fr. – MC, ***Trametes*** *gibbosa* (Pers.) Fr. – HMLC, *T. velutina* (Planer) G. Cunn. – HML, *T. versicolor* (L.) Pilát – HMLC, ***Trechispora*** *cohaerens* (Schwein.) Jülich et Stalpers – L, ***Tremella*** *mesenterica* Retz. – ML, ***Trichaptum*** *abietinum* (J. Dicks.) Ryvarden – MLC, ***Tricholoma*** *album* (Schaeff.) P. Kumm. – L, *T. imbricatum* (Fr.) P. Kumm. – L, *T. terreum* (Schaeff.) P. Kumm. – L, ***Tricholomopsis*** *rutilans* (Schaeff.) Singer – L, ***Xerocomus*** *chrysenteron* (Bull.) Quél. – L, ***Xerula*** *melanotricha* Dőrfelt – L, *X. radicata* (Relhan) Dörfelt – HML.

Deuteromycotina – Fungi imperfecti:

Bispora *antennata* (Pers.: Fr.) E. W. Mason – HMLC.

The total amount of fungal species identified in the stand at the EES over the whole study period was 154 macrofungal species and one imperfect fungus (Fungi imperfecti), from which 23 belonged to Ascomycotina and 131 to Basidiomycotina. The abundance values of the species identified on the individual PRPs in Table 2 show trends increasing from the least stocked plots to the plots with the highest stocking density. The only exception is the lower species abundance on the intact control plot C. The lower number of the species on plot C may follow from the fact that the area of this plot is smaller compared to the other as well as from rather stable and uniform climatic and ecological conditions on the plot C – unlike on the other plots where these conditions were close dependent on the cutting intensity. The highest number of macrofungal species was recorded on the PRP L offering the most favourable conditions: optimal stocking density, sufficient wood substrate and probably also the highest proportion of fir (17%) compared to the other partial plots.

Table 2. Number of fungi species on individual partial plots (PRP) during 2007–2008

Years / PRP	H	M	L	C	Total in years
2007	28	49	97	44	120
2008	30	51	90	46	113
Total in PRP	44	67	128	65	155

Similar trend as in the species abundance was observed in dynamics of abundance and distribution of fruiting bodies and dominance of macromycetes (Table 3). The table illustrates the interannual decrease in values on the least stocked plots H (heavy cut) and M (medium cut) and increased on the plots L (light cut) and C (no cut – control) with the highest stocking density. In general, in the year 2008 were higher also the values of abundance of fruiting bodies. The highest values of abundance and distribution of fruiting bodies were observed always on plot L. On the other hand, the lowest values on plot C reflect the conditions on this plot, being also in accordance with the low number of the species recorded on the control plot.

The information about the 10 most dominant macrofungal species on the individual PRPs in year 2007 is in Table 4, in year 2008 in Table 5. Due to the limited space, there are presented only the first 10 most dominant species representing from 10% to 37% of the all species spectrum determined on individual partial plots. The two tables exhibit practically the same species spectrum of the leading macromycetes – reflecting the well-balanced mycocoenosis in the whole beech stand at the EES and only slight differences in the species diversity between the plots. Both tables show that the most dominant were lignicolous macrofungi occurring, unlike terrestrial saprophytes and ectomycorrhizal symbionts, in large amounts on wood substrate over the whole study period and affected the species composition of the group of the most dominant macromycetes.

The abundance of species in individual ecotrophic groups on individual PRPs is illustrated in Table 6 – showing that the ratio between the lignicolous species (51.3% from the total species number) and terrestrial species (46.1%) is almost 1 : 1 – pointing at rather favourable climatic, ecological and soil–humification conditions for fructification of terrestrial macromycetes. In presence of sufficient supply of wood substrate

Table 3. Values of abundance of fruitbodies (A), distribution of ones (D) and species dominance (Do) on individual partial plots (PRP) in the EES Kremnické vrchy Mts during 2007–2008

Years	2007			2008			2007 + 2008		
PRP	A	D	Do	A	D	Do	A	D	Do
H	1,708	1,575	3,283	1,194	1,109	2,303	2,902	2,684	5,586
M	1,781	1,090	2,871	1,680	1,081	2,761	3,461	2,171	5,632
L	4,075	1,540	5,615	7,271	1,651	8,922	11,346	3,191	14,537
C	1,028	637	1,665	2,364	784	3,148	3,392	1,421	4,813
Total	8,592	4,842	13,434	12,509	4,625	17,134	21,101	9,467	30,568

Table 4. The most dominant species of macromycetes on partial plots (PRP) in 2007

PRP	Species of macromycetes	Do total
H	*Schizophyllum commune* (602), *Hypoxylon fragiforme* (568), *Trametes versicolor* (440), *Bjerkandera adusta* (250), *Trametes velutina* (244), *Stereum hirsutum* (232), *Hypoxylon multiforme* (196), *Exidia glandulosa* (172), *Diatrype disciformis* (120), *Diatrype stigme* (112)	2,936
M	*Panellus stipticus* (433), *Trametes versicolor* (320), *Bjerkandera adusta* (280), *Trametes velutina* (248), *Hypoxylon fragiforme* (172), *Cyathus striatus* (162), *Schizophyllum commune* (140), *Stereum hirsutum* (120), *Trametes gibbosa* (120), *Trichaptum abietinum* (116)	2,111
L	*Panellus stipticus* (963), *Armillaria ostoyae* (891), *Hypoxylon fragiforme* (372), *Trametes versicolor* (352), *Bjerkandera adusta* (260), *Exidia glandulosa* (222), *Stereum hirsutum* (204), *Gymnopilus sapineus* (203), *Diatrype disciformis* (144), *Trametes velutina* (144)	3,755
C	*Hypoxylon fragiforme* (192), *Panellus stipticus* (153), *Marasmiellus foetidus* (135), *Diatrype disciformis* (120), *Trametes versicolor* (108), *Stereum hirsutum* (84), *Lactarius piperatus* (70), *Bjerkandera adusta* (60), *Exidia glandulosa* (56), *Lycoperdon pyriforme* (54)	1,032

Do, number of dominance (in the parenthesis).

Table 5. The most dominant species of macromycetes on partial plots (PRP) in 2008

PRP	Species of macromycetes	Do total
H	*Trametes versicolor* (480), *Hypoxylon fragiforme* (444), *Hypoxylon multiforme* (240), *Trametes velutina* (216), *Stereum hirsutum* (180), *Diatrype disciformis* (120), *Trametes gibbos*a (108), *Valsa ambiens* (84), *Diatrype stigme* (72), *Eutypella quaternata* (72)	2,016
M	*Craterellus cornucopioides* (406), *Panellus stipticus* (268), *Trametes versicolor* (228), *Hypoxylon fragiforme* (216), *Trametes velutina* (192), *Bjerkandera adusta* (186), *Trametes gibbosa* (144), *Stereum hirsutum* (108), *Trichaptum abietinum* (92), *Diatrype disciformis* (84)	1,924
L	*Panellus stipticus* (3818), *Hypoxylon fragiforme* (456), *Trametes versicolor* (360), *Craterellus cornucopioides* (268), *Armillaria ostoyae* (261), *Marasmius rotula* (248), *Trametes gibbosa* (248), *Stereum hirsutum* (216), *Trametes velutina* (216), *Bjerkandera adusta* (192)	6,035
C	*Craterellus cornucopioides* (1289), *Hypoxylon fragiforme* (312), *Panellus stipticus* (244), *Lactarius blennius* (175), *Stereum hirsutum* (160), *Trametes versicolor* (144), *Valsa ambiens* (112), *Diatrype disciformis* (96), *Trametes gibbosa* (84), *Eutypella quaternata* (72)	2,688

Do, number of dominance (in the parenthesis).

produced by regeneration shelterwood cutting, the highest portion of lignicolous macromycetes is corresponding to presumptions. Relatively low presence of ectomycorrhizal symbionts (22.7%) can be assigned to the negative influence of cutting interventions (especially in year 2004) removing trees as mycorrhizal partners of symbiotic fungi and resulting in considerable stand opening, soil dessication, weed succession and formation of connected shrub and herb layer hindering, to a large extent, fructification in symbiotic macromycetes. Step-by-step increase in symbiotic species from PRP H (new-created clearing) to PRP L (stocking 0.5 and presence of fir) corresponds to the micro-environment. This trend is to large extent followed also by terrestrial saprophytic macromycetes.

During the whole study period we recorded rather few lignicolous species occurring in the stands at EES as parasites (Table 7). The major part of lignicolous macromycetes on the individual PRPs were saprophytes on abundant dead wood substrate left after the cutting, especially on plots H, M and L. From the parasitic species listed in Table 7, the species *Microsphaera alphitoides* was recorded only on plot H – parasitizing on oak leaves in the undergrowth. Another plant-parasite *Rhytisma acerinum* was found growing on sycamore leaves on all PRPs. There was also recorded the species *Heterobasidion annosum* parasitizing on fir root buttresses on plot L, the species *Nectria cosmariospora* was observed on the fruiting bodies of *Inonotus nodulosus* and *Nectria episphaeria* on the fruiting bodies of *Eutypella quaternata* and *Diatrype disciformis*.

The overall dynamics of the mycoceonosis at the EES over the whole study period is summarised in Table 8 – showing in all the studied factors the trends increasing from the lowest stocked partial plots to the densest ones. The brackets in case of plots C and L underline the special features of these two plots: the plot C (control) having smaller area than the other plots and the plot L almost optimally stocked, having the highest presence of fir. The just mentioned general increase of selected factors can be considered as the natural process of development of the mycocoenosis at the EES where the values of the studied factors reflect the suitability of climatic, ecological and soil-humification conditions on individual PRPs in dependence on intensity of the applied regeneration cut. The species spectra of the most dominant macromycetes on the individual PRPs were almost identical, independent from the degree of canopy opening in the parent stand. Presumption of substantial changes in the species diversity in the dominant macromycetes could be well-reasoned in case of strongly reduced compactness of the forest stand or in case of harvesting all trees and replacing them with other woody plants (e.g. spruce, pine, self seeding pioneer species).

Table 6. Number of macromycetes species within the ecotrophic groups on the partial plots (PRP) during investigated period

	Lignicolous species		Terrestrial species		Herbo-parasite	Myco-parasite	Epiphyte
PRP	PA	SA	SA	EC			
H	0	30	3	9	2	0	0
M	1	45	5	14	1	0	1
L	4	62	31	28	1	1	1
C	3	34	10	15	1	1	1
Total	5	74	36	35	2	2	1
Total	79		71		2	2	1

PA, parasitic species; SA, saprophytic ones; EC, ectomycorrhizal ones. Epiphyte: *Ascodichaena rugosa.*

Table 7. Parasitic macromycetes determined on partial plots (PRP)

PRP	Species of macromycetes
H	*Microsphaera alphitoides* (HP), *Rhytisma acerinum* (HP)
M	*Fomes fomentarius* (LP), *Rhytisma acerinum* (HP)
L	*Armillaria ostoyae* (LP), *Heterobasidion annosum* (LP), *Kretzschmaria deusta* (LP), *Nectria episphaeria* (MP), *Rhytisma acerinum* (HP)
C	*Fomes fomentarius* (LP), *Inonotus nodulosus* (LP), *Kretzschmaria deusta* (LP), *Nectria cosmariospora* (MP), *Rhytisma acerinum* (HP)

HP, herboparasite; LP, lignicolous parasite; MP, mycoparasite.

Table 8. Dynamics of investigated factors by the individual partial plots

Factors	H → M → (L) → (C)
Number of species	rising data
Abundance of fruit bodies	rising data
Distribution of fruit bodies	rising data
Values of dominance	rising data
Most dominant species	well-balanced species spectrum of macromycetes
Parasites	rising data
Saprophytes	rising data
Ectomycorrhizal symbionts	rising data

(L) and (C) – see text in Results.

Discussion

Several of the most dominant macrofungal species listed in Tables 4 and 5 were identified in similar beech stands also by other authors. Tratnik and Pohleven (1995) report the species *Hypoxylon fragiforme* as frequently occurring on dead wood in beech forest stands. Andersson (1995) describes the species *Xylaria hypoxylon* as the most frequent in beech stands; the characteristic species according to this author are also *Hypoxylon fragiforme, Kretzschmaria deusta, Polyporus varius, Pseudovalsa spinifera* and *Stereum hirsutum*. Similarly, Lazebníček (1988) and Vaník (1970) classify the species *Diatrype disciformis, Fomes fomentarius, Hypoxylon fragiforme, Kretzschmaria deusta*, *Stereum hirsutum, Trametes versicolor* as typical macromycetes species of beech stands. The species *Schizophyllum commune, Trametes velutina* a *Trametes versicolor* are reported by Willig and Schlechte (1995) as the species with the highest abundance of fruiting bodies and frequency occurrence on dead beech wood. Adamczyk (1995), apart from the just mentioned species, ranked to the most dominant species of beech stands also *Marasmius alliaceus*, *Marasmius rotula, Mycena galericulata* and *Rhodocollybia butyracea* f. *asema*. These species, together with *Marasmius rotula*, *Cyathus striatus*, *Valsa ambiens*, *Mycena renati* and others are considered as dominant macromycetes in beech ecosystems exposed to airborne pollution in various degrees and managed in various ways (e.g. Mihál, 1992, 1995a, 1995b; Mihál and Bučinová, 2005). Comparing the species diversity of dominant macromycetes at the EES in the earliest 1990s (Mihál, 1992) with the today state we can see that the species *Armillaria ostoyae*, *Hypoxylon fragiforme*, *Schizophyllum commune* and *Trametes velutina* have been among the most dominant macrofungal species at EES already since 1990. Some typical dominant macromycetes occur in beech stands as parasites: *Armillaria ostoyae*, *Fomes fomentarius*, *Kretzschmaria deusta*, species of the genus *Nectria* and other reported by Jančařík (2004), Čížková (2007), Grzywacz (1990), Mihál et al. (2009) as frequent parasites in beech forest stands.

As for the number of the species in the individual ecotrophic groups (Table 6), it is necessary to point out that the species number at the EES was in each group limited by the environmental conditions on the separate plots modelled by a series of cuts with different intensities. Holec (1992) suggests that terrestrial fungal species are associated with a certain layer of cover humus and substrate in this layer, mycorrhizal species are most affected by the presence of their partner and by the site climate, and the occurrence of lignicolous fungi requires wood in various phases of decay – in close correlation with the degree of naturaleness of the forest and supply of wood substrate. These conditions were overlapping on all partial plots, dependent on its stocking density. General retreat in mycorrhizal symbionts from the most disturbed PRPs (low stocking → removal of trees as symbiotic partners) was also observed in different managed spruce forests by Mihál and Gáper (1995), who speaking about decrease of symbiotic macromycetes and increase of lignicolous saprophytic fungi in a spruce monoculture affected by snow and wind disturbance. In case of lignicolous saprophytes, the dead wood substrate in appropriate amounts is considered as the factor limiting occurrence of these fungi. Vaník (1970) declares lignicolous fungi in beech stands to be useful saprophytes releasing dry branches from beech stems, decomposing stumps, facilitating, in such a way, the "self–cleaning" process in the forest. The same species, however, may turn to harmful parasites when the forest is weakened by long lasting drought or by other harmful factors (insects, mechanical injury).

In case of terrestrial saprophytes, apart from the microclimate, additional limiting factors are humification of organic matter in soil and thickness of humus and leaf and wood debris layer. Holec (1994) means that the thickness of forest litter and the humus form control the abundance of both saprophytic and ectomycorrhizal fungi as well as their mutual proportion. For example, in beech stands with mull humus form, saprophytic macrofungi are more abundant than ectomycorrhizal. Murphy and Miller (1993) found out the saprophytic species *Collybia subnuda* among the dominant fungi in deciduous forests. Likewise, Tyler (1991), studying the effect of removing forest litter on fruiting bodies production, observed that on the plot with forest litter maintained was the fructification more abundant in the saprophytic species *Mycena cinerella, Mycena galopoda* and *Rhodocollybia butyracea* f. *asema*; on the plots with forest litter removed was the fructification more abundant in the species belonging to the genera *Lactarius* and *Russula*. Contrarily, Salerni and Perini (2004) studying the production dynamics in the ectomycorrhizal species *Boletus edulis* observed the most abundant fruiting bodies were produced exactly on the plots with the thickest forest litter layer.

Conclusions

In this work we present the results of a study focussed on the dynamics of species diversity, abundance and distribution of fruiting bodies and dominance of macromycetes in a mycocoenosis of beech forest stands long–term managed by applying series of shelterwood regeneration cuts of various intensities. The problem was investigated at the Ecological Experimental Site (EES) Kováčová in the Kremnické vrchy Mts, in the years 2007 and 2008. The site consists of five partial research plots (PRP) obtained by applying regeneration shelterwood cuts of various intensities. The first important regeneration harvesting in March 1989 resulted in modelling five PRPs with densities from the clear cut up to the control without intervention. The second cut series in March 2004 modified the stocking density values on the individual PRPs – for the applied approach see Table 1. The total number of fungal species identified at the EES over the study period was 154 macromycetes (Ascomycotina, Basidiomycotina) and one species of Fungi imperfecti. The trend in species diversity was increasing from the least stocked PRPs up to the densest stocked plots. Similar trend as in the species diversity was observed in the dynamics of abundance and distribution of fruiting bodies and in the values of dominance of macrofungi. In the both study years, the species composition of the most dominant macromycetes seemed practically the same on all plots – exhibiting a species–balanced mycocoenosis across the whole stand at the EES and only slight differences in the species diversity among the plots. The major part of the group of the most dominant species consisted of lignicolous macromycetes. The mutual proportion of lignicolous (51.3% of the total species number) and terrestrial species (46.1%) was practically 1 : 1 – pointing to relatively favourable climatic, ecological and soil-humification conditions for fructification of terrestrial macromycetes. The highest portion of lignicolous macromycetes, thanks to abundant wood substrate remained after the cutting intervention, was consistent with presumptions. Relatively low presence of ectomycorrhizal symbionts (22.7%) may follow from negative impact of cutting interventions (especially in 2004) removing trees as mycorrhizal partners of symbiotic fungi and considerable opening of forest stand canopy resulting in soil desiccation on the individual PRPs.

Acknowledgement

The author thanks D. Kúdelová for translation of the paper. This publication is the result of the project implementation: Centrum of excellence of biological methods of forest protection (ITMS: 26220120008), supported by the Research & Development Operational Programme funded by the ERDF.

References

Adamczyk, J. 1995. Ecological groups of macrofungi in beech forest on Częstochowa Uplands, Southern Poland. *Feddes Repert.*, 106: 303–315.

Adamčík, S., Christensen, M., Heilmann-Clausen, J., Walleyn, R. 2007. Fungal diversity in the Poloniny National Park with emphasis on indicator species of conservation value of beech forests in Europe. *Czech Mycol.*, 59: 67–81.

Andersson, H. 1995. Untersuchungen zur Pilzflora von Fagus sylvatica – Stubben [Investigations concerning the fungal flora of stumps of Fagus sylvatica]. *Z. Mykol.*, 61: 233–244.

Breitenbach, J., Kränzlin, F. 1986. *Fungi in Switzerland, Ascomycetes. Vol. 1*. Luzern: Verlag Mykologia. 412 p.

Collective 2008. *Správa o lesnom hospodárstve Slovenskej republiky v roku 2008: zelená správa* [Report of the Forest Management of the Slovak Republic 2008: Green Report]. Bratislava: Ministerstvo pôdohospodárstva Slovenskej republiky; Zvolen: Lesnícky výskumný ústav. 168 p.

Červenka, M., Fassatiová, O., Holubová-Jechová, V., Svrček, M., Urban, Z. 1972. *Kľúč na určovanie výtrusných rastlín. II. Slizovky a huby* [Key to the determination of sporulating plants. II. Myxomycetes and Fungi]. Bratislava: SPN. 392 p.

Čížková, D. 2007. Houboví patogeni buku [Fungal pathogens of beech trees]. In Pešková, V., Holuša, J., Liška, J. (eds). *Aktuální problémy ochrany lesa*. *Zprav. Ochr. Les.*, 14: 24–26.

Grzywacz, A. 1990. Ważnejsze choroby infekcyjne [The serious infection diseases]. In Bialobok, S. (ed.). *Buk zwyczajny – Fagus sylvatica L. Proc. Nasze drzewa lesne. Monografie popularnonaukowe. Tom 10*. Warszawa – Poznan: PAN, p. 525–553.

Hagara, L., Antonín, V., Baier, J. 1999. *Houby* [The fungi]. Praha: Aventinum. 416 p.

Holec, J. 1992. Ecology of macrofungi in the beech woods of the Šumava mountains and Šumava foothills. *Česká Mykol.*, 46: 162–199.

Holec, J. 1994. Houby šumavských bučin [Fungi of the Šumava Mts beech stands]. *Živa*, 2: 52–54.

Holec, J. 2008. Interesting macrofungi from the Eastern Carpathians, Ukraine and their value as bioindicators of primeval and near-natural forests. *Mycol. balc.*, 5: 55–67.

Jančařík, V. 2004. Nekrotické choroby a jiné poškození kůry buku [Necrotic diseases and different damages of beech bark]. *Zprav. Ochr. Les.*, 10: 6–9.

Jülich, W. 1984. *Die Nichtblätterpilze, Callerpilze und Bauchpilze. Kleine Kryptogamenflora, Band IIb/1.* Jena: VEB Gustav Fischer Verlag. 626 p.

Korpeľ, Š., Peňáz, J., Saniga, M., Tesař, V. 1991. *Pestovanie lesa* [The silviculture]. Bratislava: Príroda. 492 p.

Lazebníček, J. 1988. Houby československých bučin [The macromycetes of the Czechoslovak beech forests]. In Kuthan, J. (ed.). *Houby bučin v Československu. Zborník referátů.* Praha: Československá vědecká společnost pro mykologii při ČSAV, p. 1–5.

Lizoň, P., Bacigálová, K. 1998. Huby [The fungi]. In Marhold, K., Hindák, F. (eds). *Zoznam nižších a vyšších rastlín Slovenska.* Bratislava: VEDA. p. 101–228.

Matsuda, Y. 1994. Seasonal occurrence and spatial distribution of fruitbodies of ectomycorrhizal fungi on the border of a man-made and naturally regenerated forest. *Bull. Nagoya Univ. Forest*, 13: 109–118.

Mihál, I. 1992. Frekvencia a stálost výskytu – metóda zistenia dominantných druhov húb v bučine po ťažbovom zásahu [Frequency and occurrence stability – metod of determination of dominant fungi species in beech wood after cutting operation]. *Česká Mykol.*, 46: 282–291.

Mihál, I. 1994. Problematika stanovenia abundancie a dominancie v mykocenologickom výskume [The problem of evaluation of abundance and dominance in mycocoenological research]. *Bull. Slov. Bot. Spol.*, 16: 8–12.

Mihál, I. 1995a. Príspevok k poznaniu mykoflóry bukových porastov severnej časti Štiavnických vrchov [Contribution to the knowledge of mycoflora of beech stands of the northern part in the Štiavnické vrchy Mts]. *Ochr. Prír.*, 13: 119–127.

Mihál, I. 1995b. *Abundancia a distribúcia plodníc húb v podmienkach prebierkovej bučiny* [Abundancy and distribution of fruitbodies of fungi under conditions of thinned beechwood]. *Lesnictví – Forestry*, 41: 218–223.

Mihál, I., Bučinová, K. 2005. Species diversity, abundance and dominance of macromycetes in beech forest stands. *J. Forest Sci.*, 51: 187–194.

Mihál, I., Gáper, J. 1995. *Mykocenologická charakteristika makromycétov smrekových lesných porastov v biosférickej rezervácii UNESCO Poľana na Slovensku* [Mycocoenological characteristics of macromycetes of spruce forest stands in the UNESCO Biosphere Reserve Poľana in Slovakia]. *Lesn. Čas. – For. J.*, 41: 119–130.

Mihál, I., Bučinová, K., Pavlíková, J. 2009. Mycoflora of beech forests in the Kremnické vrchy Mts (Central Slovakia). *Folia oecol.*, 36: 23–31.

Moser, M. 1983. *Die Röhlinge und Blätterpilze. Kleine Kryptogamenflora, Band II.* Jena: Gustav Fischer Verlag. 443 p.

Murphy, J.F., Miller, O.K. 1993. The population biology of two litter decomposing agarics on a southern Appalachian mountain. *Mycologia,* 85: 769–776.

Papoušek, T. 2004. *Velký fotoatlas hub z jižních Čech* [Large atlas of mushroom photographs from southern Bohemia]. České Budějovice: TISK Josef Posekaný. 819 p.

Pavlík, M. 1997. Druhové spektrum makromycétov ako odraz imisnej záťaže bukových porastov [Species spectrum of macromycetes as a result of air pollution pressure of beech stands]. In *Les – drevo – životné prostredie. Zborník referátov.* Zvolen: Technická univerzita, p. 253–260.

Salerni, E., Perini, C. 2004. Experimental study for increasing productivity of Boletus edulis s.l. in Italy. *Forest Ecol. Mgmt*, 201: 161–170.

Škubla, P. 2003. *Mycoflora Slovaca. Number of Copy 19*. Bratislava: Mycelium Edition. 1103 p.

Tratnik, N.V., Pohleven, F. 1995. Sukcesija in interakcija gliv povzročiteljic piravosti bukovine [Succession and interaction of white rot fungi on beech wood]. *Zbor. gozdarstva in lesarstva*, 46: 163–176.

Tyler, G. 1991. Effects of litter treatments on the sporophore production of beech forest macrofungi. *Mycol. Res.*, 95: 1137–1139.

Vaník, K. 1970. Príspevok k výskytu drevokazných húb na buku vo zvolenskej oblasti [Contribution to the occurrence of decay-producing fungi on beech in Zvolen area]. *Zbor. ved. Prác Lesn. Fak. VŠLD Zvolen*, 12: 91–108.

Veselý, R., Kotlaba, F., Pozar, Z. 1972. *Přehled československých hub* [Summary of fungi of the Czechoslovakia]. Praha: Academia. 424 p.

Willig, J., Schlechte, G.B. 1995 Pilzsukzession an Holz nach Windwurf in einem Buchennaturreservat. *Allg. Forstz.,* 15: 814–818.

Druhová diverzita, abundancia a dominancia makromycétov v bukových lesných porastoch s rôznou intenzitou ťažbovo-obnovných zásahov

Súhrn

V práci uvádzame výsledky štúdia dynamiky druhovej diverzity, abundancie, distribúcie plodníc a dominancie makromycétov v mykocenóze bukových lesných porastov, na ktorých sa dlhodobo aplikuje rôzna intenzita ťažbovo-obnovných zásahov. Problematiku sme skúmali na výskumnej ploche v bukových porastoch na Experimentálnom a ekologickom stacionári (EES) Kováčová v Kremnických vrchoch počas rokov 2007 a 2008. Stacionár pozostával z piatich čiastkových výskumných plôch (ČP), na ktorých sa aplikovala rôzna sila ťažbovo-obnovných zásahov. Prvým významným ťažbovo-obnovným zásahom z marca roku 1989 bolo vytvorenie piatich ČP s odstupňovaným zakmenením, od holiny až po kontrolu bez zásahu. Druhým ťažbovo-obnovným zásahom z marca roku 2004 bolo ďalšie odstupňovanie zakmenenia jednotlivých ČP v zmysle postupov, ktoré konkretizujeme v tabuľke 1. Celkovo sme počas doby výskumu v poraste EES zistili 154 druhov makromycétov a 1 druh nedokonalej huby (Fungi imperfecti). Zistili sme stúpajúci trend početnosti druhov od najmenej zakmenených ČP až po najviac zakmenené ČP, pričom najviac druhov bolo zistených na ČP L, so zakmenením 0,5. Podobný trend ako v prípade početnosti druhov sme zaznamenali aj v prípade dynamiky hodnôt abundancie a distribúcie plodníc a hodnôt dominancie makromycétov. V obidvoch rokoch výskumu sa na jednotlivých ČP vyskytovalo prakticky to isté druhové zloženie najdominantnejších makromycétov, čo svedčí o druhovo vyváženej mykocenóze celého porastu EES a minimálnych rozdieloch v druhovej diverzite vyskytujúcej sa na jednotlivých ČP. Skupina najdominantnejších druhov bola tvorená najmä lignikolnými makromycétami. Vzájomný pomer lignikolných druhov (51,3 % z celkového počtu druhov) a terestrických druhov (46,1 %) bol približne vyrovnaný, čo poukazuje na pomerne vhodné klimaticko-ekologické a pôdno-humifikačné pomery pre fruktifikáciu terestických makromycétov. Najvyšší pomer u lignikolných makromycétov je vzhľadom na dostatok drevného substrátu z ťažbovo-obnovných zásahov očakávaný. Pomerne nízke zastúpenie ektomykoríznych symbiontov (22,7 %) môžeme pripísať negatívnemu vplyvu ťažbových zásahov (najmä zásahu z roku 2004), kedy došlo k odstráneniu stromov ako mykoríznych partnerov symbiotických húb, značnému presvetleniu porastov a následnej desikácii pôdy na jednotlivých ČP.

Received August 30, 2011
Acccepted November 3, 2011

FOLIA OECOLOGICA – vol. 39, no. 1 (2012). ISSN 1336-5266

A preliminary study on physiological changes of Central European beech provenances in response to progressive drought stress

Eva Pšidová, Gabriela Jamnická, Ľubica Ditmarová

Institute of Forest Ecology of the Slovak Academy of Sciences, Štúrova 2, Zvolen, Slovak Republic,
e-mail: psidova@savzv.sk

Abstract

Pšidová, E., Jamnická, G., Ditmarová, Ľ. 2012. A preliminary study on physiological changes of Central European beech provenances in response to progressive drought stress. *Folia oecol.*, 39: 63–70.

Four-year seedlings of two European beech ecotypes (*Fagus sylvatica* L.) were grown under well-watered and drought conditions for 51 days. Two populations were from the same medium-wet climatic region, but they differed in altitude. The results showed that there were significant differences in responses to different watering regimes in both provenances tested. Drought reduced quantum yield of photosystem II (PS II), decreased electron transport rate (ETR) through photosystem II and photochemical quenching (qP). More dissipation of energy excess (qN) was found in PV1 under drought-stress conditions. Water-deficit was associated with increases in proline content. Moreover, drought-treated seedlings of both provenances had significantly decreased chlorophyll pigment contents (Chl *a*, Chl *b*, Chl *a* + *b*) and carotenoids (Car *x* + *c*). Drought also influenced the height and stem diameter of seedlings. However, the differences between the provenances were statistically significant in drought stressed plants only in case of proline content and fluorescence parameter qN.

Key words

beech provenances, chlorophyll fluorescence, drought stress, photosynthetic pigments, proline

Introduction

Growth and distribution of European beech (*Fagus sylvatica* L.) in Central Europe is considerably influenced by water availability. The current climate change is associated with more frequent drought periods (prolonged and repeated drought periods, primarily in spring and summer) – decreasing the tree tolerance against unfavourable environmental conditions. In relation to fact that European beech is rather sensitive to extreme drought, the identification of symptoms and effects of drought presence becomes extraordinary important in context of stability and further development of beech ecosystems. Eco-physiological approaches including tree growth assessments are necessary for determining the extent of drought-caused changes. As photosynthesis system plays a key role in plant life, evaluation of photochemical processes under progressive water stress has a great importance. Chlorophyll *a* fluorescence is a measure of photosynthetic performance because it shows a strong relationship with the quantum yield of CO_2 assimilation (Genty et al. 1989, Oxborough and Baker, 1997). Consequently, the processes of excessive energy dissipation, photo-inhibition avoidance and photo-oxidation under drought stress (Baquedano and Castillo, 2006) can be monitored through chlorophyll fluorescence parameters; photochemical efficiency of photosystem II (PSII) – as good indicator of photoinhibition, and non-photochemical quenching (NPQ) – as good indicator of excessive energy dissipation.

Valuable information on the plant adaptation to drought can be gained by assessment of contents and ratios of photosynthetic pigments controlling the absorption and dissipation of energy in plants (Baquedano and Castillo, 2006).

The aim of this study was evaluation of the (expected) differences in physiological parameters in response to drought stress in two populations of European beech. The objectives of this experiment were (i) to investigate progressive drought stress effects on growth, photochemical processes, and pigment and proline contents in the rather sensitive woody plant *Fagus sylvatica* at the seedling growth stage; and (ii) to evaluate the biochemical, ecophysiological and growth responses of two beech provenances from the Central-European region.

Materials and methods

Plant material and greenhouse experiment

Four-year-old beech seedlings, in plastic pots (7 dm^3) containing substrate based on peat and composed bark, were grown under greenhouse conditions from July 2010 to August 2010 (51 days). The nutrient contents in the substrate were (DM in %): N 0.3–1.2; P ca. 0.1; K ca. 0.2; moisture content (max.) 65.0%, pH value (aqueous extract) 5.0–6.5. The characteristics of the studied seedlings descended from two different ecotypes of European beech (*Fagus sylvatica* L.) are shown in Table 1. By ten plants per each provenance were grown under fully irrigated conditions (variant *control – K*), and other ten were maintained under drought conditions (variant *drought – S*). The modes of humidity, air temperature, adequate air circulation and light conditions were controlled throughout the entire experiment.

The plant water potential (ψ) was recorded during the whole experiment – as an indicator water status in plant. The leaf water potential was measured by psychrometric method with a PSY-PRO (Wescor, USA) via psychrometric chambers C-52. The measurements of leaf water potential were performed once a week during the entire experiment.

Pigment analyses and proline concentration

Five leaf samples per a provenance and treatment were collected at the beginning and at the end of experiment. One sample was composed of ten leaf discs carved from five leafs (two discs for a leaf). The leaf samples were wrapped in aluminium foil, quick frozen in liquid nitrogen and stored at –196 °C until the analysis in the laboratory. In the laboratory, the samples were extracted with a 80% aqueous solution of acetone, homogenised to suspensions and filtered. The contents of chlorophyll pigments (Chl *a*, Chl *b*, Chl *a* + *b*) and carotenoids (Car *x* + *c*) were determined with a spectrophotometer CINTRA 6.5, GBS, Australia. The methodology by Lichtenthaler (1987) was used to calculate the concentrations of photosynthetic pigments. The pigment concentrations have been expressed in the unit weight of dry matter (mg g^{-1}).

The measurement of proline was carried out spectrophotometrically, according to Bates et al. (1973). This methodology works with the evaluation of proline color reaction with ninhydrin.

Chlorophyll fluorescence parameters

Chlorophyll fluorescence emission was measured with using three fully expanded leaves of ten plants per a provenance and a treatment, at the beginning and at the end of the experiment. The measuring device was a MINI-PAM (pulse amplitude modulated portable fluorometer by Heinz Walz, Germany). The maximum fluorescence yield (Fm) of dark adapted leaves (30 minutes) and the minimum fluorescence yield (Fo) were used in calculation of the maximum photochemical efficiency of PSII (Fv/Fm). Moreover, the steady-state levels of NPQ and qN (non-photochemical quenching) were evaluated as well as qP values (photochemical quenching).

The photochemical efficiency of the open reaction centres of PSII (Fv´/Fm´) with the qN values was measured in the presence of actinic light. These parameters were estimated as Rapid Light Curves (RLC) expressing the response to photosynthetic active radiation (PAR). RLC allow an insight into the physiological flexibility enabling the plant to adapt its photosynthetic apparatus in response to rapid changes of light intensity. Hence, RLC contain information on the induction as well as saturation characteristics of photosynthesis (Walz, 1999). For measurement, there were set the following parameters: actinic intensity 3, length of the actinic-light-periods 0:15 min, saturation pulse intensity

Table 1. Characteristics of the studied beech provenances from Slovakia, Central Europe

	Provenance PV1	Provenance PV2
Location	Brezno (Central Slovakia)	Kriváň (Central Slovakia)
Climatic region	Medium wet climatic area	Medium wet climatic area
Altitude a.s.l. (m)	682 a.s.l.	525 a.s.l.
Longitude (°)	19°41´	19°37´
Latitude (°)	48°51´	48°28´
Annual mean rainfall (mm)	750 mm	750 mm

8, electronic signal damping 2, electronic signal gain 3 and intensity of measuring light 1.

Electron transport rate (ETR) was estimated as ETR = Yield (Fv´/Fm´) × PAR × 0.5 × ETR-factor (0.84). The standard factor corresponds to the fraction of incident light absorbed by a leaf.

Growth parameters

Biometrics parameters were evaluated for all seedlings, and then there were calculated the average values for the individual variants. Stem height was measured as the distance from root collar to the top (cm). Stem diameter was measured as an average diameter from two measurements with a slide calliper (mm). Seedling growth, stem diameter and height, were measured at the beginning and at the end of experiment. We determined height and diameter increment as the difference between the values at the beginning and at the end of the experiment (Table 2).

Data analysis

The results are expressed as arithmetic means with corresponding standard deviations. The significance of differences in the parameters was analysed using two-way ANOVA with two independent variables: *treatment* and *provenance*. When a factor was declared statistically significant (Provenance, Treatment and Provenance × Treatment interactions), post-hoc Tukey tests were used to determine differences between the means. Statistical probabilities at levels of $p < 0.05$, $p < 0.01$ and $p < 0.001$ were considered significant. The statistical analyses were carried out using STATISTICA 8.0 (StatSoft).

Results

Water potential

The values of water potential (ψ), recorded regularly throughout the experiment, provide an insight into the impact of progressive water stress to seedlings (assimilative apparatus). The course of water potential values in the control seedlings and the treated seedlings are shown in Fig. 1. The control seedlings were not affected by drought, as these seedlings were watered regularly. Values of ψ in control seedlings ranged between –0.4 MPa to –0.5 MPa. A significant decrease in water potential (–1.5MPa) was recorded in the middle of the experiment. At the end of the study, the leaf water potential for both provenances fell below the critical limit of –1.9 MPa for xylem embolism, and there was recorded a considerable decrease of water potential from –2.9 MPa to –3.0 MPa. There were not found statistically significant differences between the provenances in course of ψ values.

Table 2. Biometric characteristics of beech seedlings at the start and the end of experiment

	Diameter [mm]				Height [cm]			
	PV1		PV2		PV1		PV2	
	Drought	Control	Drought	Control	Drought	Control	Drought	Control
Start	7.49±0.44	7.69±0.87	6.85±0.36	6.97±1.37	71.80±5.19	71.55±5.59	38.63±5.63	44.88±5.02
End	7.78±0.44	8.46±1.02	7.25±0.31	8.33±1.05	72.90±5.53	73.95±5.24	40.5±5.73	50.38±6.56
Incr.	0.41±0.35c	0.77±0.35ab	0.40±0.32b	1.36±0.98c	1.80±1.49c	2.4±2.18b	1.88±1.25c	5.5±2.24a

Average values with their standard deviations.

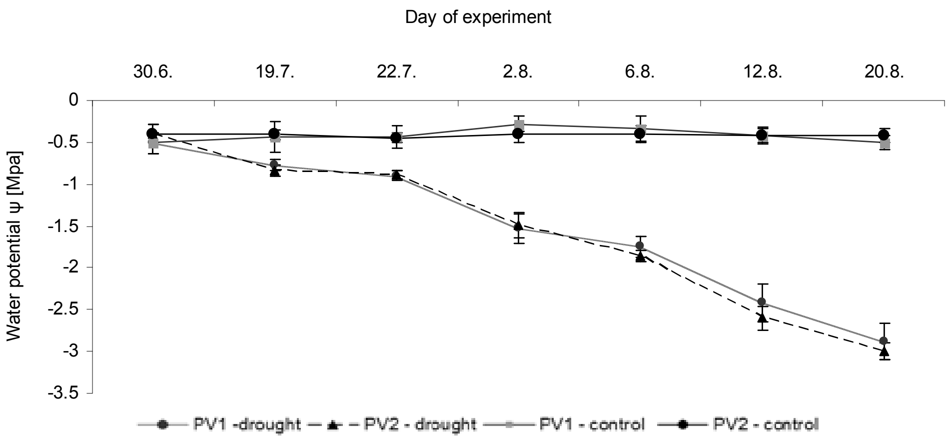


Fig. 1. Water potential values in PV1 and PV2 provenances during dehydration process.

Effect of drought on chlorophyll pigment and proline contents

The drought significantly decreased the contents of Chl *a*, Chl *b*, and the total chlorophyll content in both populations, at probability levels of P = 0.01 and P = 0.001 (Fig. 2a, b, c). The Chl *a* content decreased on average by 20%. A marked decrease was observed in content of Chl *b*: by 23% in PV1 and by 36% in PV2, and increased Chl *a*/*b* ratio in both provenances. There were recorded statistically significant differences in Car *x* + *c* content (Fig. 2 d); however the Chl/Car ratio was significantly affected only in PV2 in interaction with drought stress. A more decreasing trend in Chl *a* and Chl *b* – in comparison with the content of carotenoids, resulted in significant changes in Chl/Car ratio in PV2. A parallel decreasing trend in chlorophyll content and carotenoid content resulted in an insignificant change in Chl/Car ratio in PV1 (Fig. 3). There was revealed a significant interaction effect between the treatment and provenance in Chl *b*, Chl *a* + *b* and Chl/Car ratio.

a)
b)
c)
d)

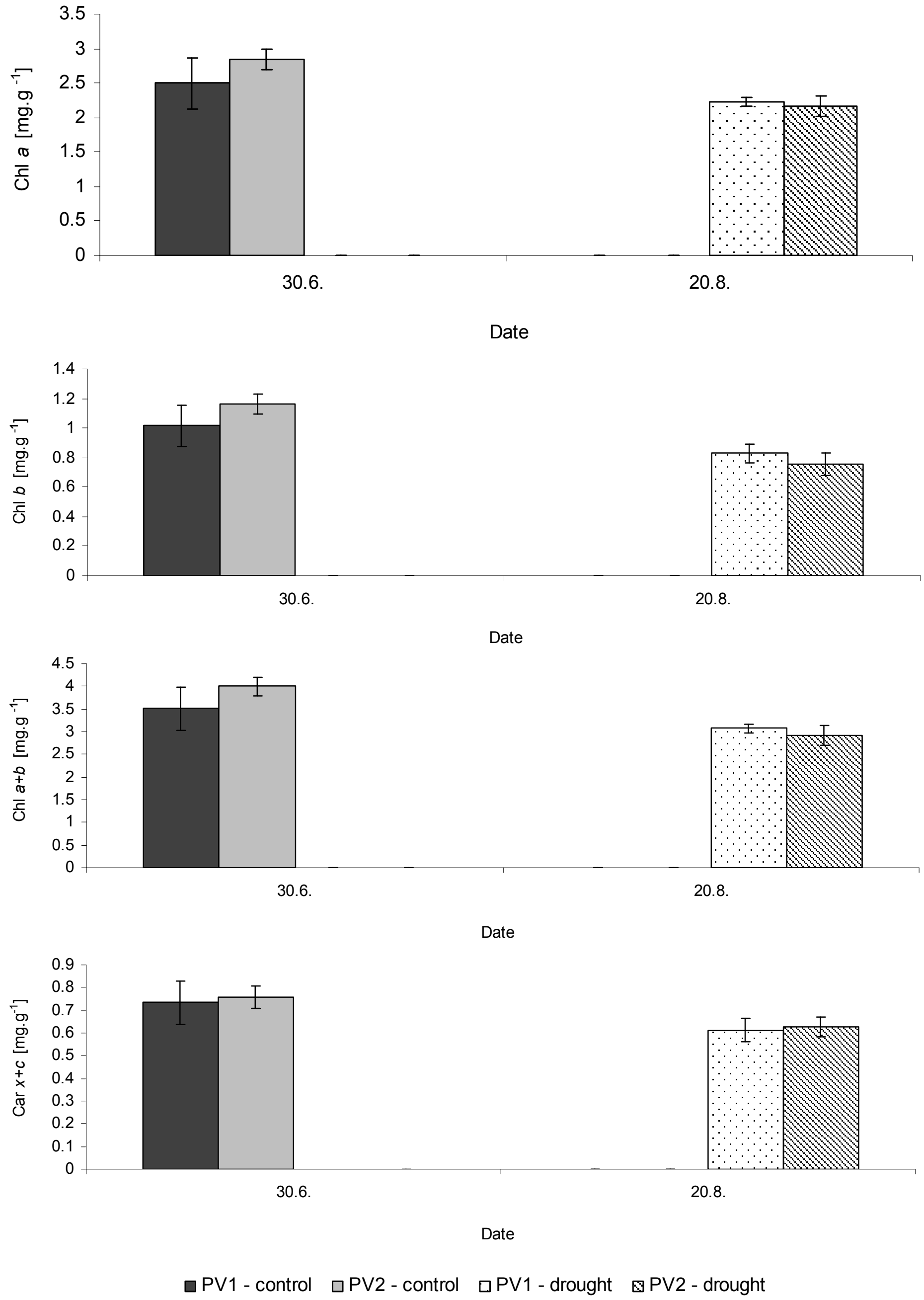


Fig. 2. Changes in pigments content in two beech provenances in response to water-stress, a) Chl *a*, b) Chl *b*, c) Chl *a* + *b*, d) Car *x* + *c*.

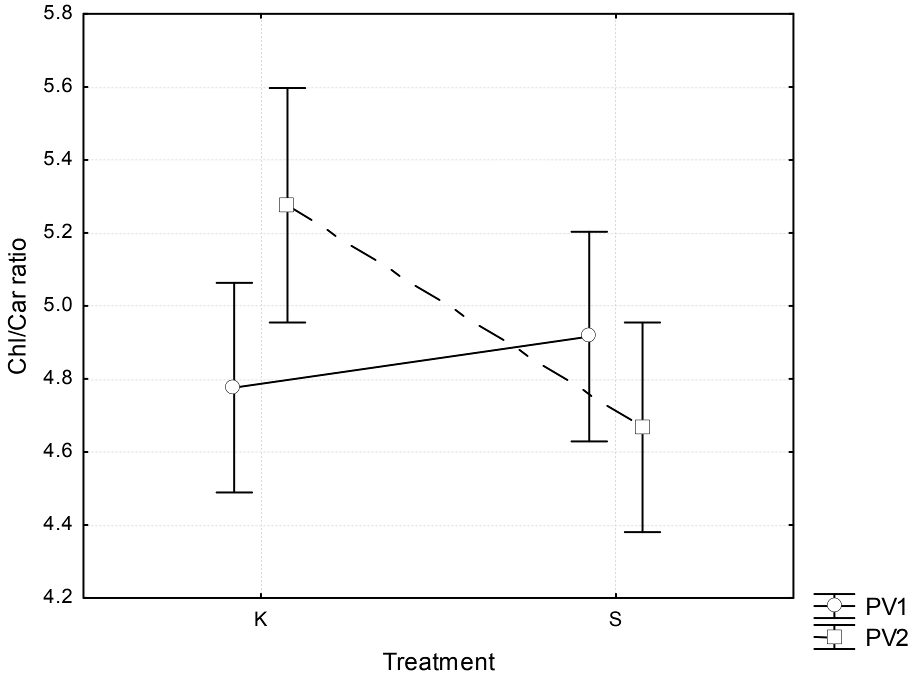


Fig. 3. Influence of progressive drought-stress on Chl/Car ratio in two beech provenances. K, control; S, stress.

The drought significantly increased the accumulation of free proline (P = 0.001) in both provenances, with more increasing PV2 towards the end of the experiment (Fig. 4).

Drought-affected chlorophyll fluorescence parameters

The drought-stress led to a decrease in Fv/Fm (a dark-adapted measurement), approximately from 0.8 to 0.7, but these changes were not statistically significant. Significant differences were recorded in case of ETR (from 5 to 2) and fluorescence quenching, non-photochemical as well as photochemical, at a significance level of P = 0.01 (Table 3). The only difference between the provenances was recorded in qN parameter. The RLC curves demonstrate (Fig. 5) more energy dissipation in PV1, while the photochemical efficiency of the open reaction centres of PSII was similar in both provenances.

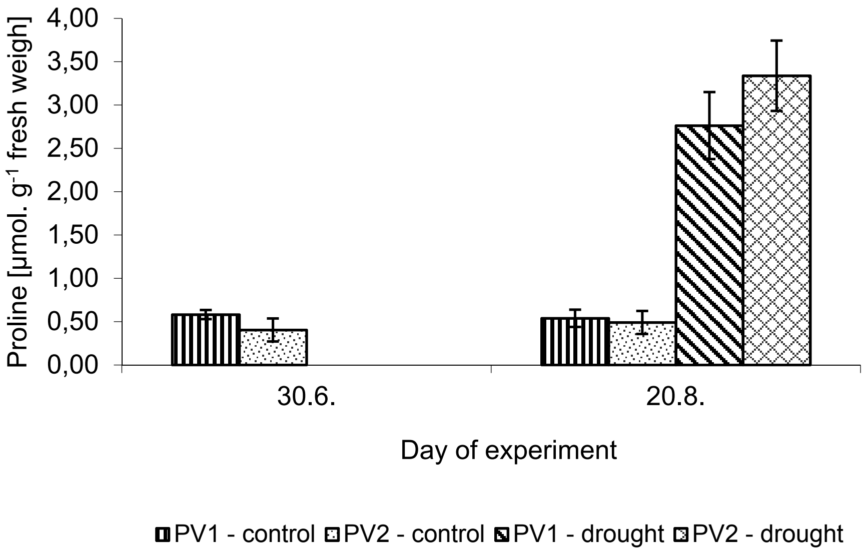


Fig. 4. Changes in proline content in two beech provenances (PV1, PV2) during the experiment.

Table 3. Changes in fluorescence parameters in response to drought stress

	Fv/Fm	NPQ	qN	qP	ETR
Provenance	0.224	0.756	0.044*	0.465	0.262
Treatment	0.051	0.001**	0.002**	0.001**	0.002**
Prov x Treat	0.713	0.282	0.681	0.145	0.304

Significant differences at * P < 0.05, ** P < 0.01, *** P < 0.001, two-way Anova.

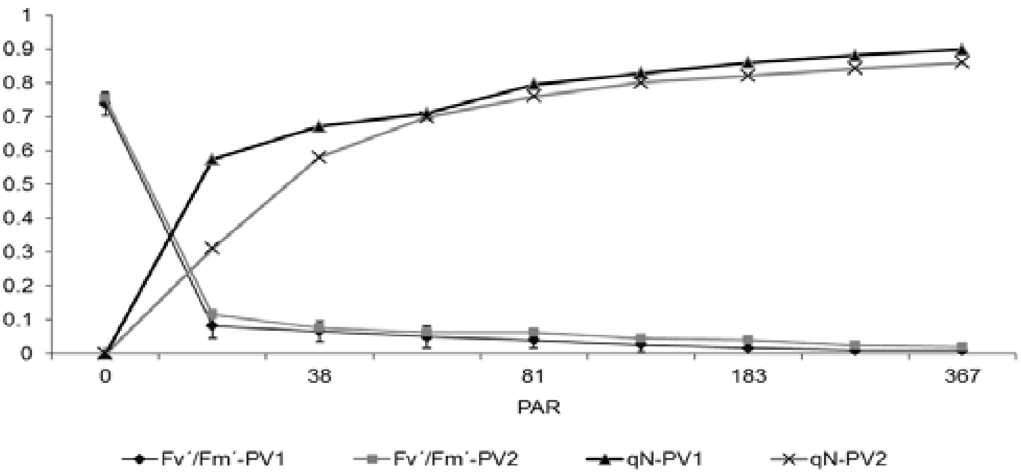


Fig. 5. Fluorescence parameters as Rapid Light Curves in response to photosynthetic active radiation at the end of experiment.

Changing growing parameters

The drought significantly decreased the height and the stem diameter of the seedlings (Table 2). The high increments were significantly affected by all the discussed factors, and also by the *Provenance × Treatment* interaction, while the diameter increments were affected only by the *Treatment*. In the *Treatment K,* the differences in height increments between the two provenances were statistically significant, while in the *Treatment S* the decrease rates in height increments were almost the same.

Discussion

Drought is one of the most important factors adversely affecting production and development of seedlings as well as adult trees, by restricting their nutrients uptake and growth. The water deficit persisting for 51 days resulted in a progressive limitation of water availability, which was reflected in the decline of water potential in the stressed beech seedlings. The leaf water potential ψ of the stressed plants decreased with increasing water stress (Pesoli et al., 2003). Moreover, all water-stressed plants slowered the tempo of their growth. In our case, the drought significantly reduced the height and the stem diameter of the studied seedlings. Czajkowski and Bolte (2006) observed minimum differences in mean dimensions (leaf area, plant shoot length, root collar diameter) and growth between a drought-exposed and control group of beech seedlings from eleven different provenances.

We observed an evident decrease in contents of pigments and carotenoids in both populations, while the drought-stressed plants exhibited less reduced carotenoid content than chlorophyll content – in accordance with observations of other authors (Baquedano and Castillo, 2006; Duan et al., 2005). The possible underlying cause of decrease of photosynthetic pigment contents is photo-oxidation. On the other hand, the photosynthetic machinery in green plants is protected by effects of carotenoid-mediated dissipation of excess radiation of and by xanthophyll cycle (Verhoeven et al., 1996). Gallé and Feller (2007) report that under a drought lasting 36 days, the content of chlorophylls (Chl *a* + *b*) per leaf area unit was lower in the stressed than in the control plants at the drought period (day 36). Progressively decreasing pigment contents were found by Ditmarová et al. (2009). These authors confirmed significant differences in Chl *a* + *b* content between the group of severely stressed seedlings and the other groups (seedlings subjected to mild drought stress and non-stressed seedlings) after 36 days of treatment.

At the end of the experiment, significant differences between the provenance were recorded in Chl *a/b* ratio per provenances, resulting from non-parallel decreasing contents of Chl *a* and Chl *b*. On the contrary, Lei et al. (2006) and Ditmarová et al. (2009) observed parallel decreasing trend in Chl *a* and Chl *b*, resulting in absence of significant changes in Chl *a/b*.

The most sensitive response to water deficit was found in parameters Chl *b* and proline content. Except to many other functions, proline serves an important role in osmosis protection. The protection effects of proline mean stabilization of membranes, proteins, and enzymes and reduction of free radicals (Okuma et al., 2004). In our case, the drought was associated with a large increase in proline content in leaves of both provenances. The similar results obtained Peuke et al., 2002, founding out a significant increase in proline content of different beech ecotypes under drought stress.

The drought did not have significant effects on Fv/Fm – which suggests a considerable resistance of PSII to water deficit (Duan et al., 2005; Lawlor and Cornic, 2002). However, significant differences between the provenances were found in qN under drought stress, indicating differences in capacity for non-radiative dissipation of excitation energy in form of heat. Moreover, among the fluorescence parameters, qN may be supposed to be the best indicator. It seems that the provenance PV1 from an altitude of 682 m a.s.l. has a higher photoprotective capacity than PV2 from 525 m a.s.l. However, these findings cannot affect the conclusions derived based on a comprehensive assessment of physiological responses to the drought stress, according to which there have been confirmed only insignificant differences between the two provenances.

Gallé and Feller (2007) ask a question about whether such physiological changes can provide an improved drought tolerance for following drought periods. Answering this question is a great challenge requiring more research aimed also to adult beech trees of contrasting provenances.

Conclusions

This study has shown that a progressive drought stress caused significant changes in photochemical processes, photosynthetic pigments and proline contents in beech seedlings. The difference in altitude (157 m) between the localities of the origin of the studied provenances did not cause significant differences between the two ecotypes coming from the same climatic region, representing optimum conditions for *Fagus sylvatica* L. (4th forest vegetation degree, medium wet climatic area, annual mean rainfall 750 mm).

Future research will focus on more contrasting beech provenances, originated not only from different altitudes, but also different climatic regions of Central Europe.

Acknowledgements

This research was supported by the Slovak Research and Development Agency, APVV – No. 0436/10 and from the Grant Agency VEGA – No. 2/0006/11.

References

Baquedano, F.J., Castillo, F.J. 2006. Comparative ecophysiological effects of drought on seedlings of the Mediterranean water-saver Pinus halepensis and water-spenders Quercus coccifera and Quercus ilex. *Trees*, 20: 689–700.

Bates, L.S., Waldren, R.P., Teare, I.D. 1973. Rapid determination of free praline for water-stress studies. *Pl. and Soil*, 39: 205–207.

Czajkowski, T., Bolte, A. 2006. Different reaction of beech (Fagus sylvatica L.) provenances from Germany and Poland to drought. *Allg. Forst Jagdztg*, 177 (2): 30–40.

Ditmarová, Ľ., Kurjak, D., Palmroth, S., Kmeť, J., Střelcová, K. 2009. Physiological responses of Norway spruce (Picea abies) seedlings to drought stress. *Tree Physiol.*, 30: 205–213.

Duan, B., Lu, Y., Yin, Ch., Junttila, O., Li, Ch. 2005. Physiological responses to drought and shade in two contrasting Picea asperata populations. *Physiol. Plant.*, 124: 476–484.

Gallé, A., Feller, U. 2007. Changes of photosynthetic traits in beech saplings (Fagus sylvatica) under severe drought stress and during recovery. *Physiol. Plant.*, 131: 412–421.

Genty, B., Briantais, J.M., Baker, N.R. 1989. The relationship between the quantum yield of photosynthetic electron transport and quenching of chlorophyll fluorescence. *Biochim. Biophys. Acta*, 42: 313–349.

Lawlor, D.W., Cornic, G. 2002. Photosynthetic carbon assimilation and associated metabolism in relation to water deficits in higher plants. *Pl. Cell Envir.*, 25: 275–294.

Lei, Y., Yin, Ch., Li, Ch. 2006. Differences in some morphological, physiological, and biochemical responses to drought stress in two contrasting populations of Populus przewalskii. *Physiol. Plant.*, 127 (2): 182–191.

Lichtenthaler, H.K. 1987. Chlorophylls and carotenoids: pigments of photosythetic biomembranes. *Meth. Enzymol.*, 148: 350–382.

Okuma, E., Murakami, Y., Shimoishi, Y., Tada, M., Murata, Y. 2004. Effects of exogenous application of proline and betaine on the growth of tobacco cultured cells under saline conditions. *Soil Sci. and Pl. Nutr.*, 50: 1301–1305.

Oxborough, K., Baker, N.R. 1997. Resolving chlorophyll a fluorescence images of photosynthetic efficiency into photochemical and non-photochemical components –´calculation of *qP* and Fv´/Fm´without measuring Fo´. *Photosynthesis Res.*, 54: 135–142.
Pesoli, P., Gratani, L., Larcher, W. 2003. Response of Quercus ilex from different provenaces to experimentally imposed water stress. *Biol. Plant.*, 46: 577–581.
Peuke, A.D., Schraml, C., Hartung, W. Rennenberg, H. 2002. Identification of drought sensitive beech ecotypes by physiological parameters. *New Phytologist*, 154: 373–387.
Verhoeven, A.S., Adams, W.W. Demmig-Adams, B. 1996. Close relationship between the state of xanthophyll cycle pigments and photosystem II efficiency during recovery from winter stress. *Physiol. Plant.*, 96: 567–576.
Walz, H. 1999. *Photosythesis yield analyzer MINI-PAM. Portable chlorophyll fluorometer. Handbook of operation*. Germany: Heinz Walz GmbH. 106 p.

Predbežná štúdia fyziologických zmien stredoeurópskych proveniencií buka lesného v reakcii na postupujúci stres zo sucha

Súhrn

V roku 2010 bol počas mesiacov jún až august realizovaný riadený experiment, v rámci ktorého sme otestovali dve proveniencie buka lesného (*Fagus sylvatica* L.) na základe vybraných fyziologických reakcií na postupujúci stres zo sucha. Rastlinný materiál reprezentovali 4-ročné sadenice buka pochádzajúce z rovnakého klimatického regiónu, ale z rozdielnych nadmorských výšok. V rámci každej proveniencie boli 2 varianty experimentu – sucho a kontrola. Po dobu 51 dní sme pravidelne v týždenných intervaloch sledovali hodnoty vodného potenciálu (ψ) listov, na základe ktorého bol sledovaný i priebeh postupujúcej dehydratácie. Klesajúca tendencia a záverečný pokles hodnôt ψ na –2,9 MPa až –3,0 MPa bol zaznamenaný u obidvoch proveniencií (varianty so suchom) spolu s prehlbujúcim sa suchom. Sucho výrazným spôsobom ovplyvnilo aj koncentrácie chlorofylov (Chl *a*, Chl *b*, Chl *a* + *b*) a karotenoidov (Car *x* + *c*). V rámci sledovaných parametrov fluorescencie chlorofylu *a* (Fv/Fm, NPQ, qN, qP, ETR) bolo pozorované pôsobenie vplyvu sucha ako stresového faktora, vplyvom ktorého hodnoty jednotlivých parametrov k záveru experimentu reagovali poklesom. Napriek tomu, že v priebehu pokusu boli potvrdené signifikantné zmeny vo fotochemických procesoch fotosyntézy, v obsahu fotosyntetických pigmentov a obsahu voľného prolínu u obidvoch proveniencií, nemožno z nich jednoznačne určiť ekotyp tolerantnejší voči suchu.

Received December 7, 2011
Accepted February 20, 2012

FOLIA OECOLOGICA – vol. 39, no. 1 (2012). ISSN 1336-5266

Visual attributes of vegetation in urban landscape

Zdenka Rózová[1], Erika Mikulová[1]

[1]Department of Ecology and Environmental Sciences, Faculty of Natural Sciences, Constantine the Philosopher University in Nitra, Tr. A. Hlinku 1, 949 74 Nitra, Slovak Republic,
e-mail: zrozova@ukf.sk, e-mail: emikulova@ukf.sk

Abstract

Rózová, Z., Mikulová, E. 2012. Visual attributes of vegetation in urban landscape. *Folia oecol.*, 39**:** 71–76.

The work deals with the evaluation of the visual attributes of vegetation composition such as dimension, shape, colour, texture, proportionality, structure and dominance. It is an attempt how to objectively evaluate the basic combinations of architectonic and vegetation elements. It is generally focused on vegetation areas serving several functions. The only differences are in determination of criterions needed for the evaluation and for the proposal of new composition. The methodology has been tested on the model area of the Pribina square in Nitra.

Key words

aesthetic function, structure,vegetation design, visual attributes

Introduction

The authors evaluate the quality and quantity of vegetation from such perspectives as structural attributes of vegetation in aesthetic and representative arrangement of family houses (in front yards) in different types of build-up areas elaborated by Rózová (2003). Pauleit (2001) takes into consideration spatially-planning structure as well as phytosociological, social, environmental and human aspects in the process of the frame evaluation of vegetation in urban settlements. Kuczman (2006) evaluates the image of rural residencies based on the three-dimensional analysis of components with abiotic and biotic character. Bihuňová et al. (2010) evaluate potential of town outskirt areas and characterize natural conditions as well as determining parameters for the individual activities. Petluš and Vanková (2010) evaluate potential of visual exposition on the principles of objective physiognomic structural landscape parameters selection.

Woody plants and other plants (lawns and flowers) are considered to be the most important elements of the landscape design. Planning complements are also a part of residential landscape design. These are all volume elements with different visual attributes from the art view (Finka, 1994). It was necessary to create a methodology for objective evaluation of combinations of architectural and vegetation constituent attributes. Therefore, this article has a methodical – applicative character and it is focused on the evaluation of the visual attributes of the landscape design such as size, shape, colour, texture, proportionality, structure and dominance. The method has been created on the basis of following methods: Machovec et al. (2000) aimed at landscape design and architectural evaluation of woody plants, Rózová (2003) (overgrowth structure evaluation), Supuka and Feriancová (2003) (compositional – aesthetic and environmental aspects of dendrological structure in urban greenery), Kuczman (2006) (the evaluation of the image of rural residence over three-dimensional analysis of components with abiotic and biotic character), Pauleit (2001) (evaluating the vegetation in urban settlements) and complemented with new evaluation of some of the aesthetic attributes in the way that makes objective evaluation of vegetation modifications with aesthetic and representative function possible. The methodology has been tested on a model area of the Pribina square in Nitra. This area has aesthetic – representative function and it consists of several vegetation elements, urban area (hard landscaping areas) and historical architectural elements (buildings) surrounding the square.

Material and methods

The studied area is situated in the historical centre in the Upper town (Horné mesto) part of Nitra town. According to the methodology – Determination of the visual vulnerability potential in the landscape (Petluš and Vanková, 2008), the area has a low potential of the visual vulnerability.

The area is surrounded by historical baroque buildings enclosing the square. Some of the facades have been reconstructed in classicistic and empire style. The square has been formed by building sanitation and two streets connection in the eighties of the Nineteenth Century.

The central point is represented by a circle paving stone patio with the dominating feature – the Statue of Pribina, surrounded by benches and completed by circle flower bed. There is another circle place with drinking fountain and benches at the end of designed area. Connection of two mentioned arrangement knots has been solved by landings placement. Vegetation of the square consists of coniferous and evergreen woody plants. The lawn is well-grown but of a low quality.

Space and structural analyse

The analysis was focused on the architectural elements (buildings, small architecture elements, reinforced surfaces, art elements, etc.) and vegetation elements (trees, shrubs, grassed areas).

Elements, groups and entire overgrowth were observed in the term of the following visual facilities needed for the evaluation of the landscape design composition performing aesthetic – representative function:

- Aesthetic: texture, colour, height, shape, dominance, space balance (Mikulová and Rózová, 2008)
- Structural: foliation, species diversity, density, cover (Rózová, 2003).

Results

By the synthesis of the analyzed features has been divided into three following groups with point of importance, expressing the suitability of the features for the harmonic effect in the composition (Tables 1–2):

- Combinations of features with harmonic effect (3 points)
- Combinations of features with partially harmonic effect (2 points)
- Combinations of feature without harmonic effect (1 point).

Table 1. Point evaluation of architectural elements

Solved area	A	B	C	D	E	F	Together
Pribina square	3	3	3	3	3	2	17

A, texture; B, colour; C, height; D, shape; E, dominant; F, balance; 3 points – attribute with harmonic effect; 2 points – attribute with partially harmonic effect; 1 point – attribute without harmonic effect.

The groups are used in the objective state evaluation of vegetation area by creating the following categories (Table 3) for the aesthetic – representative function:

- Designed area performs an aesthetic – representative function.
- Designed area partially performs an aesthetic – representative function.
- Designed area does not perform an aesthetic – representative function.

Proportionality between the dominant and other architectonical and vegetation elements arising from the analytical attributes (height, surface, distance) by using the rule of divine proportion has been also evaluated. By this rule, if we divide segment in two parts, so the length ratio of the bigger part ´b´ to the smaller part ´a´ was the same as the ratio of the whole segment ´a + b´ to

Table 2. Point evaluation of vegetation design

Solved area	Spring		Summer		Autumn		Winter											Together
	A	B	A	B	A	B	A	B	C	D		E	F	G	H	I	J	
Pribina square	3	2	3	2	3	2	3	2	1	3	3	3	2	3	3	3	1	42

A, texture; B, colour; C, height; D, crown shape and ground area shape; E, dominant; F, balance; G, foliation; H, species diversity; I, compactness; J, ratio of overgrow formation; 3 points – attribute with harmonic effect; 2 points – attribute with partially harmonic effect; 1 point – attribute without harmonic effect.

Table 3. The sum of visual attributes of architectural elements and vegetation overgrowth point values

Solved area	Architectural elements	Vegetation overgrowth	Together
Pribina square	17	42	59

It meets the aesthetic – representative function: 69–62 points.
It partially meets the aesthetic – representative function: 61–46 points.
It does not meets the aesthetic – representative function: 45–23 points.

the bigger part ´b´, i.e. (a + b) / b = b / a. It is so called divine ratio 1 : 1.618. We have modified the mentioned formula because of the needs of proportionality evaluation of the landscape design dominant:

$$d = v \times 1.618,$$

where d is the optimal distance of elements from the dominant and v is the dominant height.

Proportion evaluation of components in composition

The architectonic dominant of the Pribina square is the statue of Pribina and historical buildings surrounding the square. The height of the statue is 7 m. It is set in the reinforced area of the circled shape. The area is surrounded by the overgrowth and the road (i.e. the distance between the statue and the buildings is 30 m). The height of the historical buildings near the statue of Pribina is 10–13 m. The height of the vegetation overgrowth surrounding the reinforced area is 1.2 m. The average height of the shrubs in the square is 0.7–2 m, the height of the trees is 3–7 m, but the terrain undulation causes 2 m higher visual effect in the area. On the basis of the divine proportion rule, the optimal distance from the Pribina statue is 11.3 m, the optimal components height near the statue is 2.7 m, other dominant optimal distance from single-storied building is 16.2 m, from double-storied building 18 m (if we take into consideration 2 m terrain undulation) and 20 m (if the building is placed on the even grounds), and optimal components height near the buildings is 1.8–5 m (according to the buildings height and the terrain undulation). The result of the calculation is that the distance of historical buildings from the Pribina statue should be at least 11.3 m. The dominant fulfils this condition. Double-storied and single-storied buildings do not compete with the statue by their height. They are in the harmony with it (their optimal distance is about 16.2–20 m). The maximum overgrowth height around the Pribina statue is 2.7 m. The vegetation elements and other architectural components should not extend 3.8 m not to compete with historical buildings in the square. We need to modify this dimension in 2 m because of the terrain undulation, i.e. the elements height must not extend 1.8 m.

The next step was the creation of criterions from the feature combinations on the basis of the representative area landscape design keystones providing objective valuation of the concrete landscape design composition (the Pribina square in Nitra in this case).

Criterions of suitability for landscape design

The criterions of features suitability for the landscape design in the Pribina square in Nitra were elaborated on the basis of the composition elements proportionality evaluation of the analytical facilities of elements being found and on the basis of the representative areas creation principles. Specifics of the landscape design in front of the significant historical buildings have been considered. Mentioned criteria have been used for the evaluation of the relationship between architectural and vegetation elements as well as for the evaluation of the attributes suitable for the composition of the concrete aesthetic – representative area.

a) Feature combinations with harmonic effect:
- Architectural elements: natural materials, harmonic richness of colours – several colours combinations are in harmonic colour shades, the lower element (to 2.7 m heigh), geometric or organic shape, harmonic dominant is expressive in one or in more of its visual facilities, harmonic balance – the elements facilities are balanced by the other elements.
- Vegetation overgrowth: all types of texture, harmonic richness of colours – several colours combinations are in harmonic colour shades, the lower in the landscape design should be to 2.7 m heigh, natural shape and form of shape – without artificial interventions to the woody plants crowns and herbs shape or pruned shape, the ground area shape – circle, square, rectangle, polygon, line, harmonic dominant is expressive in one or in several of its visual facilities or neutral dominant – is the dominant on the basis of one inexpressive attribute, harmonic balance – the elements facilities are balanced by the other elements, foliation and species diversity does not affect, vegetation growth is continuous to the spacer, open and overgrowth surface ratio is 2 and more: 1.

b) Combinations of features with partially harmonic effect:
- Architectural elements: neutral richness of colours – elements are in neutral colour or in the shades of green, neutral dominant – is dominant on the basis of one inexpressive attribute, moderately disturbed balance – architectural element disturbing its balance only by one, less meaning feature situated in the landscape design.
- Vegetation growth: neutral richness of colours – the overgrowth is in unique green colour or in its shades, the ground area shape – oval, ellipsis, moderately disturbed balance – vegetation element, disturbing its balance only by one, less meaning feature is situated in the landscape design.

c) Combinations of features without harmonic effect:
- Architectural elements: the artificial materials and combined artificial and natural materials of the elements, disharmonic richness of colour – many coloured elements disturbing the area by their colourfulness, middle – tall and tall element, combined shape – geometrical with organic, disharmonic dominant – there are two and more dominants competing with each other in the landscape design, evidently disturbed balance – there are elements strongly invading the balance of the sides in the landscape design by the visually expressive attributes.

- Vegetation growth: disharmonic richness of colours – many coloured landscape designs invading the area by their colours, middle – tall and tall overgrowth, various shape, disharmonic dominant – there are two and more dominants competing each other in the landscape design, evidently disturbed balance – there are vegetation elements strongly invading the balance of the sides in the landscape design by the visual expressive attributes, strewed vegetation design, open and overgrow surface ratio is 1 : 1 to 1 : 2 and more.

Compositional – aesthetic evaluation of landscape design in the Pribina square in Nitra

The evaluation rises from the given criteria that have been elaborated for this concrete landscape design on the basis of attributes combination included into categories (Tables 1–2, Fig. 1).

The architectural elements are made from natural materials mainly, that is suitable because of the historical character of the square. Architectural elements are in the harmonic colour (combinations of colours in the building facades). Overgrowth texture is various (it indicates representation of leafy species with soft leaf area – *Spiraea bumalda* ´Anthony Waterer´, evergreen species with thick leaves – *Pyracantha coccinea* Roem., *Mahonia aquifolia* (Pursh) Nutt, and coniferous trees – *Pinus nigra* Arnold, *Abies alba* Mill.). Colour of vegetation overgrowth is neutral in all seasons. Woody plants bloom in the spring or the summer, mainly, but their flowers are small and plain (white, yellow, pink). The autumn effect of leaf colour change is almost unnoticeable (red-green only). The fruits of woody plants in the vegetation overgrowth have less attractive colour as well (brown, red, black, orange, blue and purple). The majority of architectural elements rise to 1 m. The highest and the superficial largest elements are buildings and the Pribina statue. The overgrowth is divided into the middle-tall category on the basis of the height. The terrain undulation causes overlap of the buildings and this fact is considered to be undesirable. The shape of architectural elements is geometrical. Vegetation elements have natural shape given by the cultivar. The ground of the vegetation design is rectangle and circle – the ground plan is dominant. The architectural elements domination is harmonic – buildings that do not compete with each other but create the unique integrity are dominant in the design. The dominant is the statue of Pribina. The overgrowth does not have the vegetation element acting as the dominant one. The dominant is neutral in the category that helps the overgrowth not to compete with architectural dominants. The balance of architectural elements is partially disturbed. The overgrowth is of three-etage, continuous, with large species richness (species number is 24) and ratio of opened and over browned areas 1 : 1 (Figs 2–3).

From the view of the aesthetic effect of the composition were attached points to visual attributes of architectural elements and vegetation growth in the Pribina square in Nitra (the architectural elements – 17 points, Table 1, vegetation growth – 42 points, Table 2). By the summary (Table 3) was determined, that the landscape design in the Pribina square in Nitra performs aesthetic – representative function partially.

Element with harmonic effect (3 points)

Element with partially harmonic effect (2 points)

Element without harmonic effect (1 point)

Fig. 1. Compositional – aesthetic evaluation of landscape design.

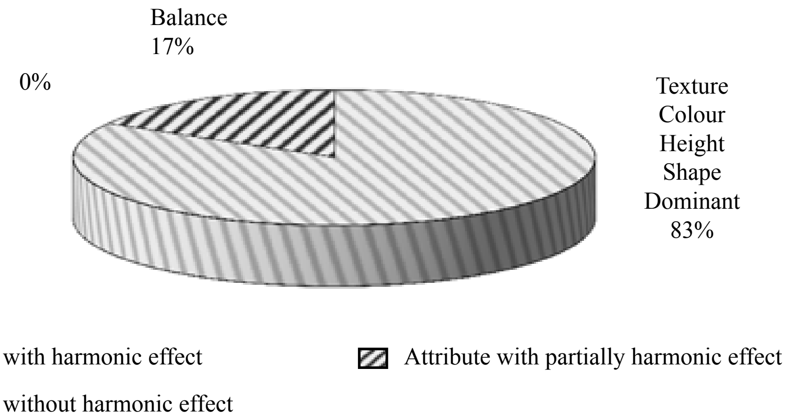


Fig. 2. Percentage representation of the architectural elements and their individual attributes.

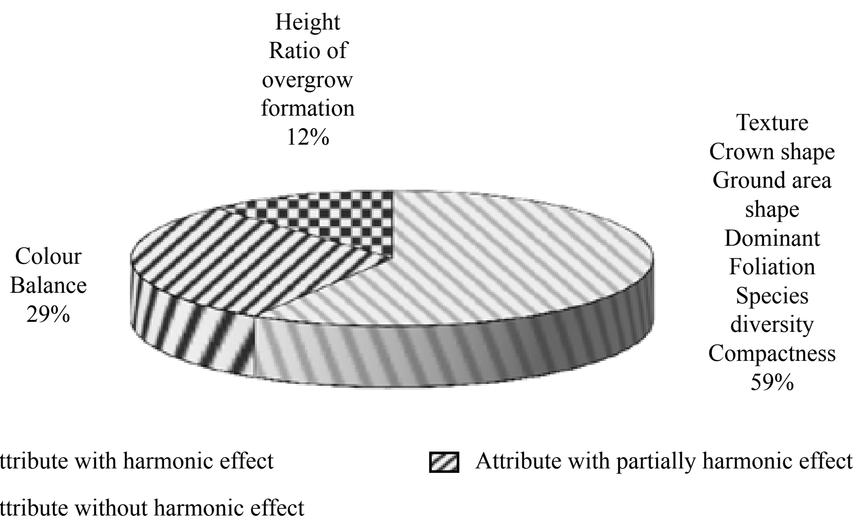


Fig. 3. Percentage representation of the vegetation elements and their individual attributes.

Conclusions

The subjective evaluation of aesthetic – representative landscape design composition can consist of various levels. The individual taste is something unique for everyone. The feeling and the beauty perception are subjective. The methodology being used was oriented to the increase of the objectivity within the basic principles evaluation of the landscape design with aesthetic – representative function. The methodology is in the general position for the vegetation areas with various functions. There are differences in the determination of the criterions required for the evaluation and for the proportion of the existing landscape design only. It is the basis of the landscape design basic principles defining. It is illustrated on the concrete landscape design example in Nitra town.

The measures improving the vegetation area state with the aesthetic – representative function has been suggested after consideration of the landscape design composition on the basis of determined criteria. Proposals are aimed to:

- o the support and the emphasis of the elements with suitable features indicated as the suitable dominants
- o the dominant supplementation
- o the alternation in the element proportionality so that they do not compete with each other
- o the visual attributes alternation of the arrangement (colour, texture, height, shape, etc.).

Acknowledgement

This work has been elaborated with the support of FCVV (Fund to Support Research and Development Centres) and ASFEU OPVaV EU Environmental aspects of the urbanized environment ITMS 26220220110.

References

Bihuňová, M., Hrebíková, D., Mišovičová, R. 2010. *Krajinno-ekologické a rekreačné hodnotenie potenciálu kontaktných zón miest a krajiny* [Evaluation of the landscape-ecological and recreational potential of the contact zones between towns and landscape]. Nitra: Slovenská poľnohospodárska univerzita. 320 p.

Finka, M. 1994. *Architektonická kompozícia – architektonická kompozícia a estetika* [Architectural composition – architectural composition and aesthetics]. Bratislava: STU. 162 p.

Kuczman, G. 2006. *Obraz sídla vidieckeho typu* [Image of a settlement of rural type]. PhD thesis. Nitra: Slovak University of Agriculture in Nitra. 114 p.

Machovec, J., Hrubík, P., Vreštiak, P. 2000. *Sadovnícka dendrológia:* (*hodnotenie biotických prvkov)* [Landscape gardening of the dendrology: (assessment of biotic elements)]. Nitra: Slovenská poľnohospodárska univerzita. 228 p.

Mikulová, E., Rózová, Z. 2008. Kompozično-estetické vlastnosti vegetačných úprav [Composite-aesthetic properties of landcape design]. *Život. Prostredie*, 5: 256–260.

Pauleit, S. 2001. *Urban tree planing practises in European cities and towns*. Report of Cost E-12. Florencia: WG2. 5 p.

Petluš, P., Vanková, V. 2010. Využitie potenciálu vizuálnej exponovanosti pri hodnotení krajinnej štruktúry urbanizovaného prostredia [Potential of visual exposure used in assessement of urbanise landscape structure]. *Život. Prostredie*, 4: 204–208.

Rózová, Z. 2003. *Funkčné zmeny štruktúry pozemkov a vegetácie vo vidieckych sídlach* [Functional changes in land segmentation and in vegetation structure in rural settements]. Nitra: Univerzita Konštantína Filozofa. 75 p.

Supuka, J., Feriancová, Ľ. 2003. Kompozično-estetické a environmentálne aspekty dendrologickej štruktúry sídelnej zelene [Compositional-aesthetic and environmental aspects of tree and shrub structure urban greenery]. In Juhásová, G. (ed.). *Dreviny vo verejnej zeleni. Zborník z konferencie s medzinárodnou účasťou*. Košice: Univerzita Pavla Jozefa Šafárika, p. 38–45.

Vizuálne vlastnosti vegetácie v urbanizovanom prostredí

Súhrn

Práca je zameraná na problematiku hodnotenia vizuálnych vlastností vegetačných úprav ako je veľkosť, tvar, farba, textúra, proporcionalita, štruktúra a dominanta. Je pokusom o objektívne zhodnotenie základných kombinácií vlastností architektonických a vegetačných prvkov. Metodika je postavená všeobecne pre vegetačné plochy s rôznou funkciou, odlišnosti sú iba v stanovení kritérií potrebných pre hodnotenie a návrh danej kompozície. Je to podklad pre definovanie základných princípov kompozície vegetačnej plochy. Metodický postup bol overený na modelovej ploche Pribinovho námestia v Nitre. Na základe analýzy vlastností jedincov a vegetačnej úpravy sme zistili, že tieto vlastnosti nepostačujú na to, aby táto plocha dostatočne plnila esteticko-reprezentačnú funkciu. Je potrebná zmena v oblasti štruktúry, druhového zloženia porastu a celkovej kompozície. Vegetačná úprava len čiastočne plní esteticko-reprezentačnú funkciu.

Received May 5, 2011
Accepted November 3, 2011

FOLIA OECOLOGICA – vol. 39, no. 1 (2012). ISSN 1336-5266

Growth responses of a Norway spruce (*Picea abies* [L.] Karst.) small pole-stage stand in a region exhibiting extensive decline of allochthonous spruce forests to differentiated thinning

Igor Štefančík[1, 2], Slavomír Strmeň[1], Vilém Podrázský[2], Stanislav Vacek[2]

[1]National Forest Centre-Forest Research Institute in Zvolen, T. G. Masaryka 22, SK-960 92 Zvolen, Slovak Republic, e-mail: stefancik@nlcsk.org; strmen@nlcsk.org
[2]Faculty of Forestry and Wood Technology, Czech Agriculture University in Prague, Kamýcká 1176, CZ-165 21 Prague 6 – Suchdol, Czech Republic,
e-mail: podrazsky@fld.czu.cz; vacekstanislav@fld.czu.cz

Abstract
Štefančík, I., Strmeň, S., Podrázský, S., Vacek, S. 2012. Growth responses of a Norway spruce (*Picea abies* [L.] Karst.) small pole-stage stand in a region exhibiting extensive decline of allochthonous spruce forests to differentiated thinning. *Folia oecol.*, 39: 77–87.

The paper deals with assessment of the growth responses of a 26-year old Norway spruce (*Picea abies* [L.] Karst.) small pole-stage stand, situated in a region affected by mass dying of spruce monocultures, dependent on the different treatment intensity. The intervention was realized at a stand age of 22 years – in order to decrease its density to 1,600 and 1,100 individuals per hectare. Characteristics of quantitative production (number of trees, basal area, stand volume, diameter increment) were analysed and compared among the presented variants of treatment. The special attention was paid to the assessment of target trees (400 individuals per hectare). The results have confirmed correctness of heavy treatments in spruce forests of younger growth stages also for the regions showing mass decline and dying of spruce forests.

Key words
forest decline, forest structure, Norway spruce, stand stability, tending

Introduction

Decline and/or extensive dying of spruce monocultures (monocoenoses) are undoubtedly the most serious problem for forestry not only in Slovakia, but also in the Czech Republic (Hlásny et al., 2011; Kuneš et al., 2011; Mauer and Palátová, 2010; Vacek et al., 1999; Vacek and Lepš, 1987, 1991) and Poland (Magnuski et al., 2001; Skrzyszewski and Skrzyszewska, 2004). This phenomenon is supposed caused by the synergic effect of a complex of abiotic (wind, snow, rime, temperature and moisture extremes), biotic (insect, fungi) and physiological (dry stress, moisture deficit) harmful agents, including impacts of anthropogenic factors (air pollution), especially in the past (Vacek et al., 2007; Hlásny et al., 2010). Apart from these causes, the decisive fact is unfavourable health condition of allochtonous spruce forests, very probably caused by the ongoing climate change impact (Vacek and Matějka, 2010). Premature regeneration and/or reconstruction of damaged, declined and disintegrated spruce monocultures is mostly realized in order to address this serious problem (Pecháček et al., 2011; Novák et al., 2011; Remeš et al., 2004; Magnuski et al., 2001; Skrzyszewski and Skrzyszewska, 2004; Košulič, 2010). There still remains an open question: whether it is possible to influence the dying of spruce stands by tending at younger age.

Although tending of spruce stands meets multiple goals (Slodičák and Novák, 2007), the main focus is on strengthening the stand stability in order to get resistant against unfavourable harmful agents, and, at the same time, to serve the required forest functions. Very important is defining the stand age and intensity optimal for treatment of spruce stands. Most of the authors suggest that the tending in spruce forests (especially from natural regeneration) should start as soon and as intensively as possible (Mráček and Pařez, 1986; Slodičák and Novák, 2001; Chroust, 1997; Štefančík and Kamenský, 2009, 2011). However, the forest practice exhibits just the reverse approach,: interventions applied in the youngest growth stages are either very limited and delayed or not realized at all (Slodičák and Novák, 2007; Štefančík and Kamenský, 2011). In accordance with this fact, Slodičák and Novák (2007) stated, that delayed intervention realised in stands are very laborious and expensive also from the viewpoint of their economic effectiveness.

The problem of spruce stand tending effectiveness is topical also today, especially in relation to the so called "novel spruce forest decline", markedly manifested in Slovakia during the last decade (Hlásny et al., 2009), with spruce stands in the Kysuce and Orava regions most suffering from this damage (Hlásny and Sitková, 2010; Kulla and Sitková, 2010). In spruce stands affected seriously, the most frequent question is either it is possible to eliminate and/or reduce their disintegration by applying certain measures (tending) or premature cutting (artificial regeneration) is necessary. Answering this principal question requires to think about multiple factors and circumstances – natural, ecological, technological and economical. The damage degree, stand age and estimated time of its disintegration and/or survival are considered to be the crucial facts. In many cases when the assumed lifetime exceeds some limit, conversion of these spruce stands is realised.

The consistent, systematic and intensive stand tending at the youngest growth stages is supposed to be a possibility how to reduce and/or delay the current extensive disintegration of spruce monocultures (Štefančík and Kamenský, 2009, 2011).

In accordance the above-mentioned facts, the aim of our research discussed in this paper was to study how the growth reponses in a spruce small pole-stage spruce stand situated in a region affected by the mass dying of spruce stands were influenced by the treatment intensity.

Material and methods

The research was carried out on two experimental plots, established in a stand located in a model area situated in the Kysuce region, Slovakia. The basic mensurational stand characteristics are presented in Table 1.

The stand age on the experimental plots at their establishment in 2006 was 21 years. The area of each plot is 0.18 hectare. Two variants with different stand density and/or treatment intensity were investigated on both plots. In one part of the first plot (EP 1) we selected and marked 1,600 the most perspective spruce trees per hectare (Variant A). Similarly, in another part of this plot, (EP 1), there were selected 1,100 individuals per hectare (Variant B). Several other tree species (beech, fir and larch) were also chosen to maintain. All the other individuals were removed in order to investigate responses to the intervention applied. The EP 1 also includes a part without any treatment (control plot – marked as EP 1/0) with stand density 2,500 trees per hectare. The second experimental plot (EP 2) was segmented by the same way, at which 2,500 individuals per hectare were left for comparison as a control plot (EP 2/0).

The investigated stand originated from natural regeneration (the 2nd generation of allochthonous spruce monoculture), and later it was subjected to silvicultural measures. The experimental plots were established by applying a single silvicultural intervention with light intensity (cleaning), with the aim of sanitary selection.

The biometric measurements (in 2007 and 2011) comprised these characteristics: the total number of trees and the number of trees in the main stand, as well as the diameter at the breast height and the tree height. Consequently, the basic stand characteristics (basal area, stand volume) were calculated and converted to the values per hectare. On each plot, there were selected and marked 400 target (crop) trees per hectare, with crowns released from 90 to 100%, by a treatment in 2007. The calculation of the results was performed by standard methods for tending evaluation and production-silviculture relations (Štefančík, 1974). To find out the statistical significance of the differences, the single-factor analysis of variance (anova) was used.

Results and discussion

The tree species composition in terms of basal area (G) during the investigated period before and after intervention and 4 years after the treatment is presented in Table 2.

On the treated plots (EP I – Variant B and EP II – Variant A) is dicernible a mild increase in fir and beech proportion, which could be favourable for the desired decrease of spruce proportion and increase of share of other tree species (mainly fir and beech). It has been mainly influenced by intervention with positive selection – to prefer all admixed species, in order to increase their proportion and to decrease the spruce share. This has also been confirmed by typological proposals of the tree species composition (Hančinský, 1972), which presents, for the given forest type, spruce proportion of 25–40%, followed by fir 20–30%, beech 30–40% and valuable broadleaved species 5–10% with rare occurrence of larch. The latest models, which take into account altered site conditions, including climate change (Rizman et al., 2007), present spruce proportion of 5–45%, fir 5–25%, beech

Table 1. The basic mensurational characteristics of the given compartment on the model area for management-plan area (Forest management plan 2000–2009)

Compartment (part of a stand)	5299b
(Characteristic)	(PS: 3)
Area [ha]	4.78
Age [years]	15
Stocking	9
Exposure	SE
Inclination (in percentage)	40
Altitude a.s.l. [m]	780–800
Forest category	H (commercial)
Silvicultural system	V (high forest)
Rotation [years]	100
Management complex of forest types	511 (fertile fir beechwood)
Management complex of stand types	21
Management complex	55
Zone of air pollution	D
Forest type	5301–90%; 5302–10%
Tree species composition	
(in percentage)	Beech – 5
	Birch – 10
	Fir – 5
	Sycamore maple – 5
	Larch – 5
	Spruce – 70

5301 – Lowherb fir beechwood, low tier (*Asperula odorata, Oxalis acetosella, Senecio nemorensis, Prenanthes purpurea*).
5302 – Nitrophile lowherb fir beechwood, low tier (*Asperula odorata, Oxalis acetosella, Senecio nemorensis, Mercurialis perennis, Prenanthes purpurea*).

Table 2. Tree species composition according to basal area (G)

Plot	Variant	Age [years]	Stand	Tree species in %			
				spruce	fir	larch	beech
EP I	A	22	Total	98.3	–	1.7	–
			Main	100	–	–	–
		26	Main	100	–	–	–
	B	22	Total	91.9	–	3.6	4.5
			Main	88.9	–	3.6	7.5
		26	Main	88.7	–	1.5	9.8
	0	22	Total	100	–	–	–
		26	Main	100	–	–	–
EP II	A	22	Total	88.5	4.7	3.9	2.9
			Main	87.6	5.4	3.6	3.4
		26	Main	89.2	6.4	–	4.4
	B	22	Total	93.8	–	6.2	–
			Main	94.7	–	5.3	–
		26	Main	100	–	–	–
	0	22	Total	94.6	–	1.7	3.7
		26	Main	94.3	–	1.7	4.0

Variant A → plot with 1,600 pcs ha^{-1} of spruce trees after the 1st intervention. Variant B → plot with 1,100 pcs ha^{-1} of spruce trees after the 1st intervention. Variant 0 → plot without intervention (control).

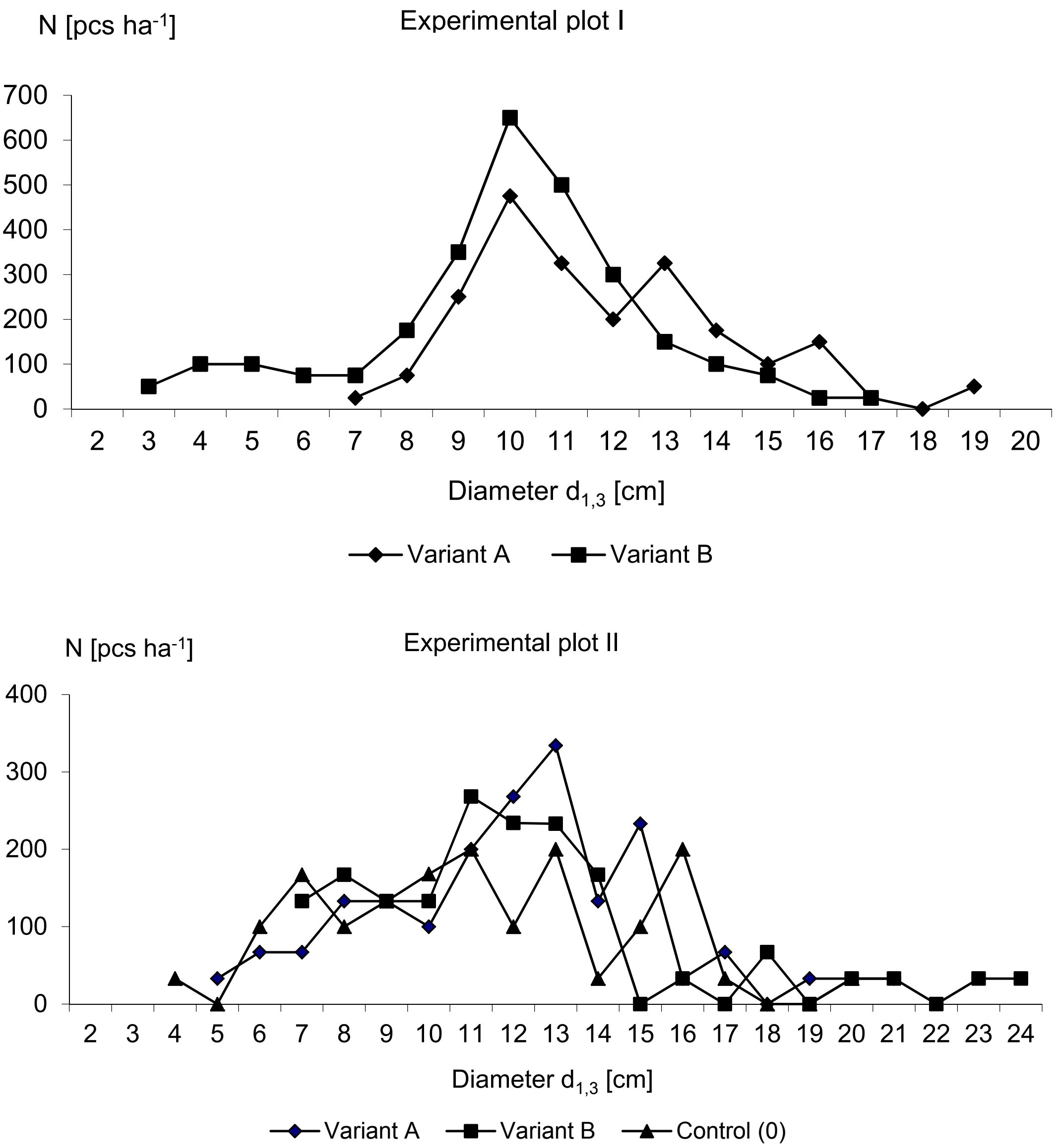
45–60% and valuable broadleaved species up to 10%. From this trend it is clear, the interventions planned in the future should interfere in favour of other species, especially beech and fir.

Diameter structure

The diameter development of the investigated stands is characterized by the diameter frequency distribution (Fig.1 and Fig. 2), as well as by the values of mean diameter (d_g) presented in Table 3.

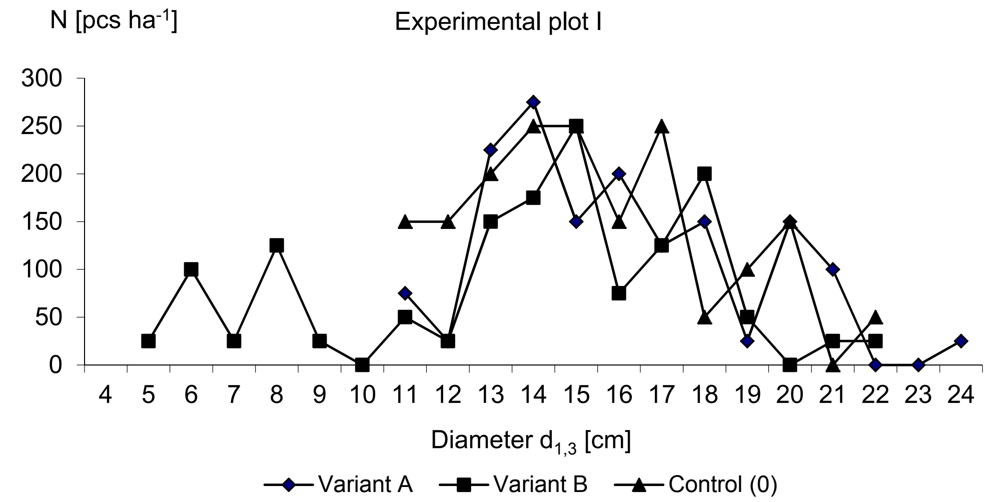
In the initial stage of the research, the course of curves of diameter frequency distribution was found somewhat different, the testing, however, of statistical significance of the d.b.h. differences in individual plots unveiled significant differences on the level α = 0.05 only between the Variant A and Variant B on EP I. It is more or less symmetric distribution, as for frequency distribution. The highest values of mean d.b.h. were found for Variant A, on both experimental plots.

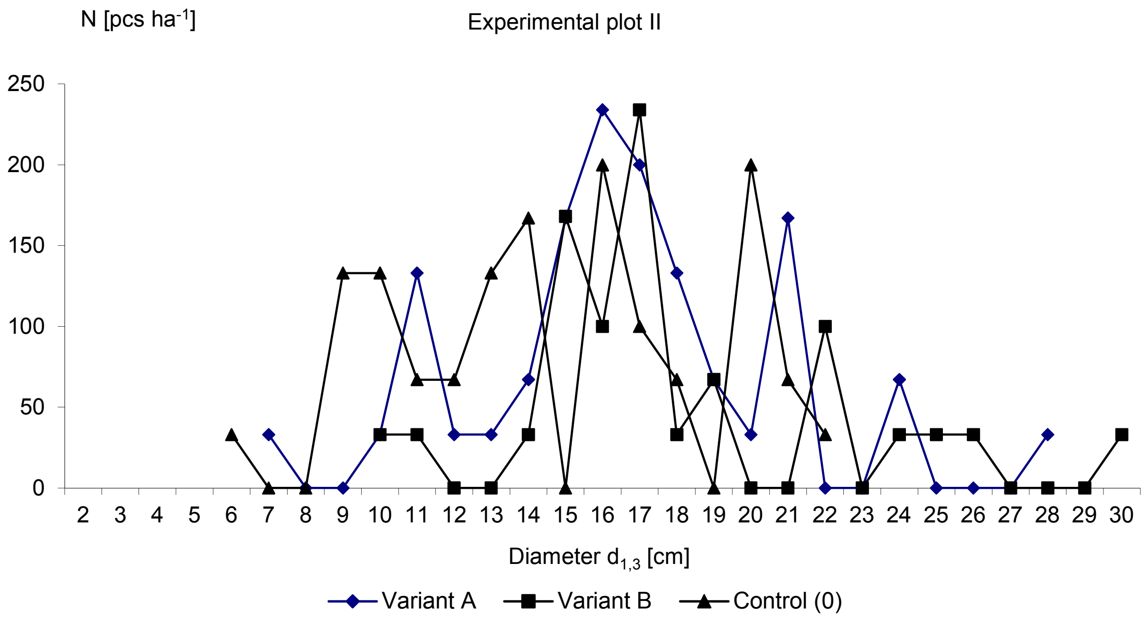
After the intervention, purposed for reducing the density of the main stand to 1,600 (Variant A) and 1,100 (Variant B) spruce trees per hectare, the changes were found only on EP II where the mean d.b.h. was found the highest in Variant B. The mentioned trend was the same also 4 years after treatment. The diameter fre-



Variant A → plot with 1,600 pcs ha^{-1} of spruce trees after the 1st intervention. Variant B → plot with 1,100 pcs ha^{-1} of spruce trees after the 1st intervention. Variant 0 → plot without intervention (control).

Fig. 1. Diameter frequency distribution on plots at the initial stage of the research in 2007.





Variant A → plot with 1,600 pcs ha^{-1} of spruce trees after the 1st intervention. Variant B → plot with 1,100 pcs ha^{-1} of spruce trees after the 1st intervention. Variant 0 → plot without intervention (control).

Fig. 2. Diameter frequency distribution on investigated plots in 2011 (4 years after intervention).

quency distribution (Fig. 2) remained symmetric on the treated plots.

Our results are similar to the values published by Chroust (1997), recorded on the experimental object "Sedloňov", with two cleaning variants peformed on a 12-year-old stand. On the plots treated by heavy intervention, the number of trees of 1,750 individuals per hectare was registered at the stand age of 22 years, with the mean diameter (d_g) of 11.90 cm. At the stand age of 26 years, it was 1,610 pcs ha^{-1} and (d_g) 14.5 cm. During the first years after the treatment, a slightly higher increase in the mean diameter was found in the thickets treated by heavy intervention, what was found true in our investigated plots. Four years after the treatment, the mean diameter increased mostly in Variant B (on both plots): by 36.0% on EP I and by 35.3% on EP II. Consequently, in Variant A it was only 28.4% and 31.0%.

Height structure

The height structure of the investigated plots was expressed by the relative number in the growth (tree) classes (Table 4). The proportion of trees in the crown level of the stand (1st + 2nd growth class) and the suppressed level of the stand (3rd to 5th growth class) is very important from the silvicultural point of view. Since the data from the first measurement are not available, only the results 4 years after the intervention are presented.

The differences in the height structure (proportion of the crown level and the suppressed one) among the plots and/or variants were well discernible. The highest proportion of crown level was found on EP I, for Variant A (86.9%), and the lowest for Variant B (56.9%). This result is logical, because the more intensive intervention, aimed at decreasing the number of trees to 1,100 individuals per hectare, required to remove more trees from the crown level of the stand. The opposite was found on EP II, where the proportion of the crown level was the highest for Variant B (1,100 pcs ha^{-1}), reaching 82.2%. This may follow from lower number of trees on EP II (in comparison to EP I), where mostly co-dominant trees remained in the stand after intervention. Significant role represents also shifts in height, very frequent and distinctive in Variant with stronger intervention, also confirmed by the values of mean height (Table 3) at the age of 26 years, i.e. 4 years after the treatment. This has also been confirmed by statistical testing significance of the differences (at level α = 0.05) in the mean height between the variants (Table 3).

The height values were found higher in comparison with those presented by Chroust (1997): 8.6 m and 11.0 m, obtained in the Experimental object Sedloňov, on a plot treated by heavy intervention at the stand age of 22 and 26 years. They are more similar to the values found on the treated plot Machov I, being 13.6 cm at the age of 24 years, and the plot Zaječiny, with the values on treated plots 13.6 cm, 14.4 cm and 15.2 cm.

Development of quantitative production

The development of stand characteristics before and after the intervention is presented in Table 3. At establishment of the plots, the highest initial number of trees (N) was found on EP I, representing 2,750 pcs ha^{-1} and the lowest on control plot (EP II). We can see that on EP I (Variant A) was reached the final number N 1,600 of individuals per hectare, but for Variant B it exceeded 425 trees – as a consequence of a higher beech proportion (Table 1). Consequently, it was almost the same in comparison with the planned reduction of stand density on EP II.

The stand density found on the discussed plots is in accordance with the long-term research results on spruce stands (mainly in Bohemia). Many authors (Mráček and Pařez, 1986; Slodičák, 1987; Chroust, 1997, Slodičák and Novák, 2007) recommend heavy reduction of N to 1,600 trees per hectare and less, especially in spruce stands cultivated in areas endangered by snow break, what is also the case of the investi-

Table 3. Development of stand characteristics

Plot/Variant	Stand	Age	N	G	V_{7b}	Mean	
		[year]	[pcs ha^{-1}]	[m^3 ha^{-1}]	[m^3 ha^{-1}]	diameter $d_{1,3}$ [cm]	height [m]
EP I	Total	22	2,175	25.277	121.250	11.91^{a}	10.22^{a}
Variant A	Main	22	1,600	20.474	82.075	12.52^{a}	10.52^{a}
	Main	26	1,525	31.986	247.025	16.07^{a}	15.26^{a}
EP I	Total	22	2,750	23.415	99.800	10.06^{b}	9.39^{b}
Variant B	Main	22	1,525	13.930	60.675	10.26^{b}	9.65^{b}
	Main	26	1,450	24.055	149.400	13.95^{bc}	12.05^{b}
Control (0)	Main	26	1,750	33.725	224.200	15.39^{ac}	13.05^{c}
EP II	Total	22	1,900	24.097	109.767	12.26^{a}	9.11^{a}
Variant A	Main	22	1,600	21.595	100.767	12.69^{a}	9.33^{a}
	Main	26	1,433	32.933	219.000	16.63^{ab}	12.8^{a}
EP II	Total	22	1,700	21.433	104.433	12.22^{a}	9.93^{a}
Variant B	Main	22	1,133	17.205	88.033	13.38^{a}	10.46^{b}
	Main	26	933	25.448	183.300	18.10^{a}	14.31^{b}
Control (0)	Total	22	1,600	17.560	80.000	11.28^{a}	9.30^{a}
	Main	26	1,400	25.771	181.867	14.74^{bc}	13.18^{ab}

N, number of trees; G, basal area; V_{7b},volume of the timber to the top of 7 cm.
The values with the same letter are not significantly different on the level α = 0.05.
Variant A → plot with 1,600 pcs ha^{-1} of spruce trees after the 1st intervention. Variant B → plot with 1,100 pcs ha^{-1} of spruce trees after the 1st intervention. Variant 0 → plot without intervention (control).

Table 4. Relative number according to the growth classes

Plot/Variant	Stand	Age	Growth class				
		[year]	1	2	3	4	5
EP I /A	Main	26	32.8	54.1	13.1	–	–
EP I /B			12.1	44.8	36.2	5.2	1.7
EP I /0			28.6	37.1	31.4	2.9	–
EP II /A	Main	26	32.6	39.5	20.9	7.0	–
EP II /B			28.6	53.6	14.3	3.5	–
EP II /0			23.8	33.3	23.8	16.7	2.4

Variant A → plot with 1,600 pcs ha^{-1} of spruce trees after the 1st intervention.
Variant B → plot with 1,100 pcs ha^{-1} of spruce trees after the 1st intervention.
Variant 0 → plot without intervention (control).

gated plots. Mráček and Pařez (1986) informed that a decrease of N to 2,600-1,600 trees already by the first cleaning during the period of closer canopy formation is characterized by many advantages, mainly by a very favourable effect on static stability. The mentioned authors also stated that a decrease to 1,600 individuals and less is especially important in areas endangered by snow, comprising in Slovakia localities situated at about 800–850 m a.s.l., i.e. plots assessed by this paper.

Therefore, in relation with the above-mentioned facts, the values of slenderness quotient are especially significant (not presented in Table). More favourable values were found on EP II (0.819 for Variant B and 0.789 for Variant A) than on EP I with 0.970 for Variant A) and 0.915 for Variant B), what indicates a good static stability of these stands. It is evident that the intervention was found resulting in decreasing slenderness quotient (except for EP I, Variant). This was caused "numerically" – as a consequence of removing thinner and lower trees. The goal of the mentioned intervention was to decrease stand density to the desired number of trees. Due to the short period after the intervention, the stand did not manifest much effect. As for the absolute values of slenderness quotient, they are comparable to those published by Chroust (1997), investigating a stand aged of 26 years in the experimental object Sedloňov (plot with heavy treatment), with the values of 0.756 in the original stand, followed by 0.801 on plot subjected to light treatment and 1.023 on the control plot.

Similar values, ranging from 0.830 to 0.890, were also found on treated plots in the experimental object Zaječiny at a stand age of 24 years. Consequently, Mráček and Pařez (1986), as well as Slodičák and Novák (2007) ascertained similar values, 0.850–0.880 after 40-year tending in numerous experiments carried out in spruce forests in the past.

For the other stand parameters (basal area – G and timber to the top of 7 cm o.b. – V_{7b}), at the initial stage of the research, we obtained the highest values on both plots in Variant A (1,600 pcs ha^{-1}) and the lowest (Variant B – 1,100 pcs ha^{-1}) on the control plot. The situation had not been changed even 4 years after the intervention; on EP I, however, we found the highest values of G on control plot (with the highest N), while on EP II (for almost the same N) it was by 27.8% more at Variant A than on control plot. Comparisons of G and V_{7b} in term of growth index values, always showed markedly higher values in Variant A than in Variant B. It may be explained by the fact that the stand with only sanitary selection applied in the past, the responses to heavy intervention by intense height increment and/or also diameter increment were shifter later. This has been confirmed by our results presented in the section discussing the height increment, when on EP I after 4 years it was 45.1% (Variant A) and 24.9% (Variant B), while on EP II it was 37.2% and 36.8%, respectively. The same results were also published by Slodičák (1987) who observed that the diameter increment decreased, as a rule, in spruce stands older than 15 years, contrarily to the height increment, that culminated or even increased. Consequently, the slenderness quotient exhibited an increasing trend, what was also confirmed on the investigated plots.

Similarly, the mean annual basal area increment (i_G) was also found higher on both plots in Variant A (1,600 pcs ha^{-1}) in comparison with Variant B (1,100 pcs ha^{-1}). On EP I it was 2.878 and 2.531 m^2 ha^{-1} year^{-1}; on EP II 2.061 m^2 ha^{-1} year^{-1}. The mentioned values are comparable to those obtained by Chroust (1997), ranging from 2.70 to 2.93 m^2 ha^{-1} year^{-1}, at age of 24 years on the treated plots in the experimental object Zaječiny.

Development of target (crop) trees

Development of target trees (TT), representing qualitative production in commercial forests are illustrated in Table 5. TT are especially important for static stability, therefore silviculturists primarily focus their efforts on these trees. In spruce stands, 400 TT per hectare are usually selected (Mráček and Pařez, 1986; Slodičák and NOVÁK, 2007). It is not always possible to find and select the required number of TT, as they do need not meet the relevant criteria. For example, SLODIČÁK and NOVÁK (2007) presented only 360–380 TT per hectare on the IUFRO series Vítkov 13. The quantitative parameters (basal area, timber to the top of 7 cm o.b., mean diameter and height) in the initial stage of the research, exhibited the highest values for the same number of TT (400 pcs ha^{-1}) on plots EP I (Variant A – 1,600 pcs ha^{-1}) and EP II (Variant B – 1,100 pcs ha^{-1}) and the lowest values on the control plot.

The same tendency was recorded in years after the intervention. As for G and V_{7b}, the highest percentage of increase was found on EP I (Variant A) and the lowest on EP II (Variant B). The proportion of TT expressed by the percentage out of the main stand was found out always higher in the variant with lower stand density (Variant B) than in the denser stand (Variant A), which gives evidence for advantage of heavier treatment.

The mentioned results have also been confirmed with the values of the mean annual diameter increment – i_d (Table 6). They were always higher on the plot treated by stronger intervention (Variant B) compared to the lighter (Variant A), the differences, however, were neither high, nor statistically significant. The same trend was also ascertained by comparing i_d only for trees belonging to the crown level of the stand (1st and 2nd tree class), except for EP I where the differences between the variants were found out significant (α = 0.05).

Analysis of silvicultural treatment

The heaviest intervention was realized on EP I (Variant B), with an intensity (out of number of trees) of 44.5%, followed by EP II (Variant B) with intensity 33.4%. Contrariwise, the lowest intensity of the intervention was applied in Variant A (EP I – 26.4% and EP II 15.8). The same trend hold in the thinning intensity according to the basal area (Fig. 3).

We may suggest that both variants of treatment favourably influenced stand development, especially its static stability, considered to be crucial in this growth stage. From the plot treated by heavier intervention (Variant B), mostly suppressed trees were removed from the lower stand layer, but less interventions were realized in the crown level of the stand in comparison with Variant A (stand with higher density). SLODIČÁK and NOVÁK (2007) concluded from their own experiments that heavy intervention in the suppressed level of the stand was completely able to eliminate snow damage 15 years after the intervention. This fact is in accordance with our results obtained on experimental plots in the Kysuce region, with a single snow-broken individual found four years after the treatment.

Conclusions

There were studied growth responses of a 26-year old spruce stand located in an allochthonous site in the Kysuce region, four years after an intervention with diversified intensity, manifested by changes in the stand diameter and height structure. Due to the short period, there have hitherto been registered only little changes in quantitative parameters and slenderness values. More intensive intervention resulted in a favourable diameter increment in the target (crop) trees in comparison with lower thinning intensity. The interventions in stands

Table 5. Development of target (crop) trees

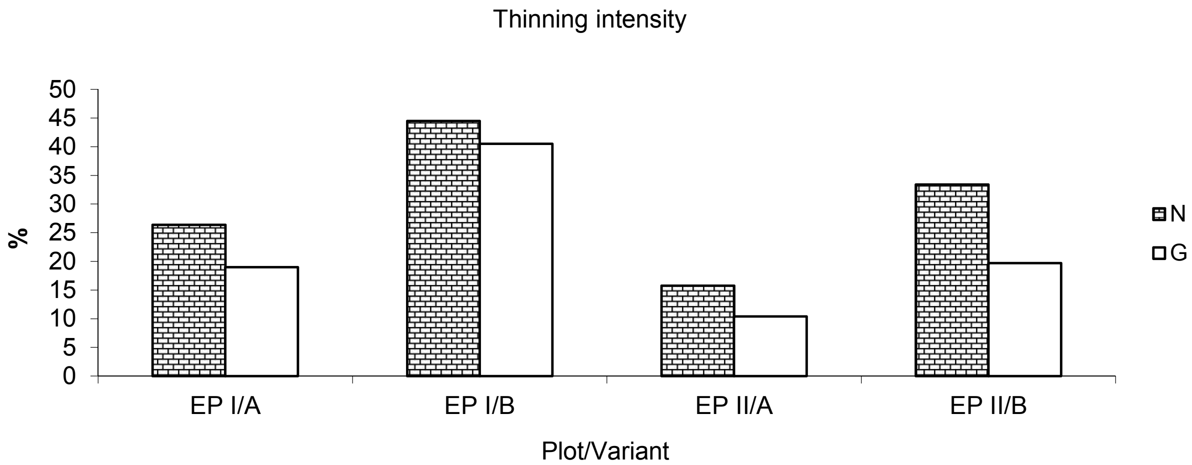
Plot/Variant	Age	N	G		V_{7b}		Mean	
				% out of		% out of	diameter $d_{1,3}$	height
	[y.]	[pcs ha^{-1}]	[m^2 ha^{-1}]	main stand	[m^3 ha^{-1}]	main stand	[cm]	[m]
EP I /A	22	400	6.508	31.8	34.575	42.1	14.22	10.99
	26	400	11.241	35.1	90.575	36.7	18.71	16.34
EP I /B	22	400	4.535	32.6	20.500	33.8	11.95	10.74
	26	400	9.215	38.3	61.550	41.2	16.97	13.97
EP II /A	22	400	8.239	38.2	42.267	41.9	15.88	10.45
	26	400	13.528	41.1	96.933	44.3	20.44	14.30
EP II /B	22	400	8.867	51.5	49.767	56.5	16.26	11.34
	26	400	14.327	56.3	106.667	58.2	20.90	15.25
Control (0)	22	367	6.025	34.3	31.133	38.9	14.28	10.60
	26	367	10.611	41.2	81.133	44.6	19.05	14.85

N, number of trees; G, basal area; V_{7b}, volume of the timber to the top of 7 cm.
The values with the same letter are not significant on the level α = 0.05.
Variant A → plot with 1,600 pcs ha^{-1} of spruce trees after the 1st intervention. Variant B → plot with 1,100 pcs ha^{-1} of spruce trees after the 1st intervention. Variant 0 → plot without intervention (control).

Table 6. An average annual diameter increment (i_d) with standard deviation of the target (crop) trees and trees from crown level of the stand (mm)

Plot/Variant	EP I /A	EP I /B	EP II /A	EP II /B	Control (0)
i_d (2007–2011)	11.23 ± 1.99^{a}	12.55 ± 3.04^{a}	11.40 ± 3.48^{a}	11.61 ± 2.71^{a}	11.91 ± 1.51^{a}
Crown level	9.38 ± 2.29^{a}	12.33 ± 2.89^{bc}	10.15 ± 3.33^{a}	11.33 ± 2.10^{ab}	10.46 ± 2.37^{ab}

The values with the same letter are not significant on the level $\alpha = 0.05$.
Variant A → plot with 1,600 pcs ha^{-1} of spruce trees after the 1st intervention. Variant B → plot with 1,100 pcs ha^{-1} of spruce trees after the 1st intervention. Variant 0 → plot without intervention (control).



Variant A → plot with 1,600 pcs ha^{-1} of spruce trees after the 1st intervention. Variant B → plot with 1,100 pcs ha^{-1} of spruce trees after the 1st intervention.

Fig. 3. Thinning intensity according to the number of trees (N) and the basal area (G).

resulted in their diameter and height differentiation, as well as spatial arrangement of target (crop) trees – the bearers of the static stand stability. The static stand stability is the primary prerequisite for survival and fitness of trees growing under threat of abiotic injurious agents, especially snow.

Acknowledgement

This paper was supported by the project ITMS 26220220026 “Demonstration Object on the Transformation of Declining Spruce Forests into Ecologically More Stable Multifunctional Ecosystems“ supported by the ERDF-funded operational programme „Research and Development“.

Európska únia
Európsky fond regionálneho rozvoja
Operačný program VÝSKUM a VÝVOJ

References

Hančinský, L. 1972. *Lesné typy Slovenska* [Forest types in Slovakia]. Bratislava: Príroda. 307 p.

Hlásny, T., Kulla, L., Bucha, T., Konôpka, J. 2009. Súčasný stav a prognózy vývoja hynutia smrečín na Slovensku [Present situation and prognosis of spruce decline development in Slovakia]. *Les – Slov. Letokruhy*, 65/8 (3–4): 12 p.

Hlásny, T., Kulla, L., Barka, I., Turčáni, M., Sitková, Z., Koreň, M. 2010. The proposal of biotic hazard zones in selected spruce dominated regions in Slovakia. *J. Forest Sci.,* 56: 236–242.

Hlásny, T., Sitková, Z. (eds) 2010. *Spruce forests decline in the Beskids*. Zvolen: National Forest Centre. 182 p.

Hlásny, T., Holuša J., Štěpánek, P., Turčáni, M., Sitková, Z., Zajíčková, L. 2011. Expected impacts of climate change on forests: Czech Republic as a case study. *J. Forest Sci.*, 57: 422–431.

Chroust, L. 1997. *Ekologie výchovy lesních porostů: smrk obecný – borovice lesní – dub letní – porostní prostředí – růst stromů – produkce porostu* [Ecology of stand tending: Norway spruce – Scots pine – pedunculate oak – stand environment – tree growth – stand yield]. Opočno: Výzkumný ústav lesního hospodářství a myslivosti, Výzkumná stanice Opočno. 277 p.

Košulič, M. 2010. Zahájení přestavby smrčin v mladém věku [Initiation of spruce conversion in young age]. *Lesn. Práce*, 89: 236–237.

Kulla, L., Sitková, Z. (eds) 2010. *Hynutie a rekonštrukcie smrečín na Slovensku* [Dying and reconstruction of spruce stands in Slovakia]. Recenzovaný zborník odborných prác vydaný na DVD. Zvolen: NLC – LVÚ. 242 p. + 16 príloh.

Kuneš, I., Koňasová, T., Balcar, V., Baláš, M., Zahradník, D., Kacálek, D., Vítámvás, J., Jakl, M., Jaklová-Dytrtová, J. 2011. Growth response of Alnus viridis to application of crushed limestone and amphibolite and forestry potential of the species in harsh acidic mountain sites. *J. Forest Sci.,* 57: 200–209.

Magnuski, K., Jaszczak, R., Malys, L. 2001. Struktura cech biometrycznych jodly pospolitej (Abies alba Mill.) pochodzacej z podsadzenia w przebudowywanym drzewostanie swierkowym (Picea abies (L.) Karst.) o ropznym stopniu przerzedzenia [Structure of biometric traits in common fir (Abies alba Mill.) derived from underplanting in a reconstructed spruce (Picea abies (L.) Karst.) stand with varying canopy opening]. *Sylwan*, 145: 5–13.

Mauer, O., Palátová, E. 2010. Decline of Norway spruce in the Krkonoše Mts. *J. Forest Sci.,* 56: 361–372.

Mráček, Z., Pařez, J. 1986. *Pěstování smrku* [Silviculture of spruce]. Praha: SZN. 203 p.

Novák, J., Slodičák, M., Dušek, D. 2011. Aboveground biomass of substitute tree species stand with respect to thinning – European larch (Larix decidua Mill.). *J. Forest Sci.,* 57: 8–15.

Pecháček, J., Vavříček, D., Samec, P. 2011. Soil environment and nutrient status of Norway spruce (Picea abies [L.] Karst.) underplantings in conditions of the 8th FAZ in the Hrubý Jeseník Mts. *J. Forest Sci*., 57: 141–152.

Remeš, J., Ulbrichová, I., Podrázský, V. 2004. Využití podsadeb a meliorace půdy při umělé obnově [Underplanting and soil amelioration in artificial regeneration]. *Lesn. Práce*, 83: 352–356.

Rizman, I. 2007. Poznatková báza o zastúpení drevín v lesných typoch Slovenska, základný predpoklad pre tvorbu modelov TUOL [Knowledge basis of tree species composition of forest types in Slovakia, the fundamental assumption for designing Sustainable management models]. In Rizman, I. (zost.). *Lesnícka typológia a zisťovanie stavu lesa vo väzbe na trvalo udržateľné obhospodarovanie lesov. Zborník prezentácií a príspevkov zo seminára konaného 3. 12. 2007 vo Zvolene.* Zvolen: Národné lesnícke centrum. 1 electronic optical disk (CD-ROM).

Skrzyszewski, J., Skrzyszewska, K. 2004. Species conversion of spruce stands in the Wisla Forest District. *Dendrobiology,* 51, Suppl.: 95–99.

Slodičák, M. 1987. Výchova mladých smrkových porostů ohrožených sněhem a její vliv na růst a statickou stabilitu stromů různých stromových tříd [Tending of young spruce stands jeopardized by snow breaks and the influence of tending measures on the growth and static stability of trees belonging to various tree classes]. *Lesnictví,* 33: 1091–1106.

Slodičák, M., Novák, J. 2001. Zásady výchovy smrkových porostů v podmínkách antropogenně změněného ekotopu [Thinning principles for Norway spruce stands in conditions changed by anthropogenic influences]. In Slodičák, M. and Novák, J. (eds). *Současné otázky pěstování horských lesů: Actual problems of silviculture in mountain forests. Sborník z III. česko-slovenského vědeckého sympozia pedagogickovědeckých a vědeckovýzkumných pracovišť oboru Pěstování lesa. Opočno 13. 9.–14. 9. 2001*. Opočno: Výzkumný ústav lesního hospodářství a myslivosti, Výzkumná stanice Opočno, p. 351–370.

Slodičák, M., Novák, J. 2007. *Růst, struktura a statická stabilita smrkových porostů s různým režimem výchovy* [Growth, structure and static stability of spruce stands under different tending regimes]. Folia Forestalia Bohemica, 3. Kostelec nad Černými lesy: Lesnická práce. 144 p.

Štefančík, I., Kamenský, M. 2009. Výskum prirodzenej obnovy a výchovy v odumierajúcich smrečinách v oblasti Kysúc [Research on natural regeneration and tending in dying spruce forests of the Kysuce region]. In Štefančík, I., Kamenský, M. (eds). *Pestovanie lesa ako nástroj cieľavedomého využívania potenciálu lesov. Zborník recenzovaných príspevkov z medzinárodnej vedeckej konferencie konanej dňa 8. a 9. septembra 2009 vo Zvolene*. Zvolen: Národné lesnícke centrum – Lesnícky výskumný ústav, p. 158–171.

Štefančík, I., Kamenský, M. 2011. Vychovávame smrekové porasty dostatočne intenzívne? [Do we tend our spruce stands with sufficient intensity?]. *Les – Slov. Letokruhy,* 67 (10): 2–15.

Štefančík, L. 1974. *Prebierky bukových žrďovín* [Thinning in beech pole stands]. Lesnícke štúdie, č.18/74. Bratislava: Príroda. 141 p.

Vacek, S., Lepš, J. 1987. Changes in the horizontal structure in a spruce forest over a 9-year period of pollutant exposure in the Krkonoše Mountains, Czechoslovakia. *Forest Ecol. Mgmt*, 22: 291–295.

Vacek, S., Lepš, J. 1991. Použití Leslieho matic pro predikci vývoje smrkových porostů pod vlivem imisí [The use of Leslie´s matrices for the prediction of development of spruce stands exposed to air pollution stress]. *Lesnictví,* 37: 133–150.

VACEK, S., BASTL, M., LEPŠ, J. 1999. Vegetation changes in forests of the Krkonoše Mts over a period of air pollution stress (1980 – 1995). *Pl. Ecol.*, 143: 1–11.

VACEK, S., MATĚJKA, K., SIMON, J., MALÍK, V., SCHWARZ, O., PODRÁZSKÝ, V., MINX, T., TESAŘ, V., ANDĚL, P., JANKOVSKÝ, L., MIKESKA, M. 2007. *Zdravotní stav a dynamika lesních ekosystémů Krkonoš pod stresem vyvolaným znečištěním ovzduší* [Health status and dynamics of forest ecosystems under air pollution stress in the Giant Mts]. Folia Forestalia Bohemica, 4. Kostelec nad Černými lesy: Lesnická práce. 216 p.

VACEK, S., MATĚJKA, K. 2010. Health status of forest stands on permanent research plots in the Krkonoše Mts. *J. Forest Sci.,* 56: 555–569.

Rastové odozvy smrekovej žŕdkoviny na rozdielny zásah v oblasti hromadného odumierania nepôvodných smrekových porastov

Súhrn

Príspevok sa zaoberá zhodnotením rastovej reakcie 26-ročnej smrekovej žŕdkoviny nachádzajúcej sa v oblasti hromadného odumierania smrekových porastov v závislosti od rozdielnej sily vykonaného zásahu. Zásah sa vykonal vo veku porastu 22 rokov tak, aby sa znížila jeho hustota na 1 600 ks ha^{-1}, resp. 1 100 ks ha^{-1}. Analyzovali a porovnali sa charakteristiky kvantitatívnej produkcie (počet stromov, kruhová základňa, objem hrubiny, hrúbkový prírastok) podľa uvedených variantov vykonaných zásahov. Osobitná pozornosť sa venovala vyhodnoteniu cieľových stromov (400 ks na 1 ha). Výsledky po štyroch rokoch po vykonanom zásahu rozdielnej sily ukázali zmeny v hrúbkovej i výškovej štruktúre sledovaných plôch. Zmeny v kvantitatívnych parametroch, resp. hodnotách štíhlostného kvocientu sa vzhľadom na krátky čas prejavili zatiaľ v menšom rozsahu. Silnejší zásah sa priaznivejšie prejavil na hrúbkovom prírastku cieľových stromov v porovnaní so slabším zásahom. Vykonaným zásahom sa dosiahla určitá hrúbková a výšková diferenciácia porastu a tiež priestorové rozmiestnenie cieľových stromov, ktoré tvoria základ statickej stability porastu, ktorá je najdôležitejšou zložkou jeho existencie v daných podmienkach ohrozenia abiotickými škodlivými činiteľmi, najmä snehom. Výsledky potvrdili opodstatnenosť silných zásahov v smrečinách v mladších rastových fázach aj v oblastiach ich hromadného odumierania.

Received December 8, 2011
Accepted March 15, 2012

Influence of nitrogen and phosphorus content in soil on yield of selected rapeseed varieties

Zuzana Tatarková[1], Ľubica Malovcová[2], Zoltán Bedrna[1], Elena Masarovičová[1]

[1]Department of Soil Sciences, Faculty of Natural Sciences, Comenius University, Mlynská dolina, SK-842 15 Bratislava, Slovak Republic,
e-mail. tatarkova@fns.uniba.sk
[2]Plant Production Research Centre, Bratislavská cesta 122, SK-921 068 Piešťany, Slovak Republic

Tatarková, Z., Malovcová, Ľ., Bedrna, Z. Masarovičová, E. 2012. Influence of nitrogen and phosphorus content in soil on yield of selected rapeseed varieties. *Folia oecol.*, 39: 88–93.

There was conducted an experiment to determine the impact of nitrogen and phosphorus content in soil on yield and seed production of selected rapeseed varieties. Field survey was executed on plots of the Plant Production Research Centre – Plant Production Research Institute in Borovce near Piešťany. Soil samples were taken in spring, before the growing season. In homogenized soil samples were determined contents of phosphorus and inorganic-, nitrate- and ammonium nitrogen. The experiment plot was evaluated in terms of basic nutrients content. For examined rapeseed varieties, yield and seed production were determined. The highest sensitive response to the applied fertilization and N, P soil content in spring and consequently the highest yield and seed production has observed in the varieties Labrador (yield 4.68 t ha^{-1}, seed production 2.46 dkg plant^{-1}), Decade (yield 4.45 t ha^{-1}, seed production 2.66 dkg plant^{-1}), Verona (yield 4.10 t ha^{-1}, seed production 2.28 dkg plant^{-1}) and Champlain (yield 4.08 t ha^{-1}, seed production 2.46 dkg plan^{-1}). The most unfavourable results of yield and seed production were reached by the varieties Viking (yield 2.99 t ha^{-1}, seed production 1.36 dkg plant^{-1}) and Baldur (yield 2.88 t ha^{-1}, seed production 1.43 dkg plant^{-1}).

Key words
nitrogen and phosphorus nutrition, rapeseed varieties, seed production, yield

Introduction

Rapeseed (*Brassica napus* L. subsp. *napus*) is a demanding crop regarding soil, climatic conditions and agronomic methods used (Surovčík, 2000). The plant does well in regions with medium strong winters and long growing seasons, and requires loam-sandy to loam soil with neutral to weakly alkaline soil reaction (pH 6–7.2) and sufficient humus reserves. Therefore to achieve sufficiently high yield of oilseed and to prevent spread of pests, it is necessary to respect the rules of crop rotation, which means that oilseed can be cultivated on the same plot after passing a period of 4 to 5 years (in detail see Tatarková et al., 2010). Bokor (2011) recommend for crop rotation a minimum period of 8 years. Rapeseed is categorized among the most demanding crops in terms of nutrient demands. For the production of 1 ton seed and the corresponding amount of straw, the rapeseed plant takes an average of 50 kg nitrogen, 11 kg phosphorus, 50 kg potassium, 35 kg calcium, 6 kg magnesium, 18 kg sulphur, 0.3 kg boron (Varga et al., 2007). Additional fertilization with organic fertilizers, which is important for the maintenance of soil fertility, can be assured by plowing under straw and applying manure after harvesting the winter crop.

In general, nitrogen as the most important nutrient has an influence to growth of plants and their yield. The most important for plants is the nitrogen in nitrate (NO_3^-) and ammonium (NH_4^+) forms which plants take mostly from soil nitrate nitrogen. However, at very high concentration of nitrate nitrogen amount in soil, the intake of ammonium nitrogen by plants is limited.

According to Bielek (1998) plants usually uptake nitrogen from soil prior to uptake of nitrogen from fertilizers because fertilizer nitrogen shortly after application is not available to plants and only after remineralisation of the nitrogen compound is usable by plants. Surplus of nitrogen causes intensive plant growth and delay of flowering, deficiency of nitrogen exhibits with leaf yellowing.

Phosphorus is the basic plant nutrient that exists in a soil naturally in very little amount. Plants are taking it in form of organic phosphates, total intake of phosphorus depends on the amount and form of nitrogen in soil and on the soil reaction. If nitrate forms do dominate then the intake of phosphorus is blocked. Phosphor influences the root growing, flowering and protects plant during wintering. Too high contents of phosphorus in soil have a negative affect because of block boron intake, which is very important element for plant flowering. It is possible to fertilize the soil with phosphorus to the reserve for 3–4 years (Baier, 1962).

Considering the aspect of usability, rapeseed belongs to the crops that have an important position not only in food industry but also in chemical industry. Rapeseed also dominates in the production of biofuel pure rapeseed oil and FAME over ten years. FAME (fatty acid methyl ester) is component in diesel fuel. The rising demand for rapeseed is leading to pressure on the agriculture to produce sufficient rapeseed plants for both mentioned sectors of industry.

The aim of this work was the assessment of influence of nitrogen and phosphorus content in soil on the yield and seed production of selected rapeseed varieties.

Methods

For the experiment were used plots of Plant Production Research Centre – Plant Production Research Institute in Borovce near Piešťany (Slovakia). The locality Borovce is situated on the Podunajská downs on the right side of river Váh in altitude of 160 m above sea level. The year average air temperature is 9.2 °C, year average precipitation is 545 mm. In locality occur Chermozems on the loess with soil reaction 5.5–7.2 and humus content of 1.8–2%. According to soil portal www.podnemapy.sk in Borovce are fertile soils with production index IP-81-90 which are very suitable condition for rapeseed cultivation. The locality belongs to the maize production region.

The adaptation of soil for field experiment is as follows: after the harvest of preceeding crop, it was realized stubble incorporation with disc harrow, the soil was ploughed, rolled and fertilized with NPK in rate 15 : 15 : 15 with an amount of 200 kg ha^{-1}. Trifluex 48EC in amount of 2 l ha^{-1} against weed has been used. After sowing, the preparation "Butisan Star" (1.5 l ha^{-1}) and in Autumn the morpho-regulator "Caramba" (1 l ha^{-1}) have been applicated. After wintering the fertilizer "Sulfamo23" (23% N, 31% SO_3, 3% MgO) with consistence of 200 and 230 kg ha^{-1} has been added to the plants. Significant proportion of nitrogen was applied before sowing (150 kg N ha^{-1}) and the smaller part in spring before the growing season starts (80 kg N ha^{-1}) (in detail see Masarovičová et al., 2008).

Soil sampling: from the each plot with area 10 m^2 (1.25 × 8 m) were taken soil samples from three places from a deep of 10–20 cm. These three samples have been mixed into the one mixture soil sample. The soil samples were dried at laboratory temperature, crushed and sieved during riddle with sieve diameter of 2 mm. Acquired finesoil was analysed for: content of NH_4^+ (mg kg^{-1}), NO_3^- (mg kg^{-1}), N_{an} (mg kg^{-1}) and P (mg kg^{-1}). The analyses were done performed at the Central and Testing Institute of Agriculture in Zvolen, Slovak Republic.

Content of inorganic nitrogen was evaluated according to Fecenko and Ložek (2000), (Table 1), phosphorus content was determined by Kotvas (2007), (Table 2).

Table 1. Assessment of nitrogen content N_{an} in the soil (Fecenko, Ložek, 2000)

Content N_{an} [mg g^{-1}]	Assessment
< .0	Very little
5.1–10.0	Little
10.1–20.0	Middle
20.1–40.0	Good
>40	High

Table 2. Assessment of phosphorus content in middle heavy soil (Kotvas et al., 2007)

Content P [mg kg^{-1}]	Assessment
<50	Low
51–85	Suitable
86–125	Good
126–165	High
>165	Very high

In our experiment we tested selected rapeseed varieties (Table 3).

Results and discussion

The soil on the experimental plot in spring before growing season contained following nutrient contents (Table 4).

Content of inorganic nitrogen ($N_{an} = N_{NO3^-} + N_{NH4^+}$) was assessed as "good". It was dominated ammonium nitrogen, what is usual typically for low production soil.

Table 3. Tested rapeseed varieties

Variety	Type of variety	Height	Resistance against lodging	Resistance against winter killing	Growing suitability in production region (PR)
Labrador	Serotinous	Low	Medium	Suitable	All PR
Oponent	Serotinous	High	Medium	Suitable	All PR
Baldur	Medium serotinous	Medium high	Good	Very good	All PR
Champlain	Medium early	Medium high	Medium to high	Very high	All PR
Slogan	Medium early	Low	Medium	Suitable	All PR
Dekade	Medium early	Low	Good	Very good	MPR, RPR, PPR
Maplus	Data unavailable				
Viking	Medium early	Medium high	Good	Good	All PR
Verona	Serotinous	Medium high	Very good	Very good	MPR, PPR

Source: (www.uksup.sk)

For optimal fertilized soil is typical balanced proportion of $N_{NH_4^+}$ and $N_{NO_3^-}$.

Table 4. The basic statistic parameters of nitrogen content in soil in the spring period

	N_{an} [mg kg^{-1}]	$N_{NH_4^+}$ [mg kg^{-1}]	$N_{NO_3^-}$ [mg kg^{-1}]
Min. value	17.10	11.60	3.50
Max. value	34.50	26.50	8.00
Average	26.44	21.19	5.25
Median	26.20	21.65	5.25
Variance	12.83	12.98	1.04
Standard deviation	3.58	3.60	1.02
Number of samples	22	22	22

As far as the nitrate nitrogen has a higher value for the rapeseed, the existing quantity is essentially reduced what was caused by the increased demand of the rapeseed during the intensive growth in the spring period.

It was found that already in the fall the rapeseed extracts high amount of nitrate from the soil. According to the state of the crop that makes 50–100 kg ha^{-1} (Mráz, 2009). Because of this fact it is necessary to realize regenerative fertilization in the spring period. It is not possible to fertilize the soil with inorganic forms of nitrate "in advance" because it can be flushed out, mainly under rainy weather.

It could be stated that from the aspect of nitrate contents the experiment plot showed a high homogeneity degree. Thus, all sampled rapeseed varieties had the same starting conditions for yield formation.

Phosphorus reserve in a soil before growing season in spring did reach high variability, their content was in a range from 109 to 274 mg kg^{-1} (Table 5). In general the phosphorus content assessed as "high".

Table 5. The basic statistic parameters of phosphorus content in soil in the spring period

	P [mg kg^{-1}]
Min. value	109
Max. value	274
Average	158.36
Median	147
Variance	156.69
Standard deviation	39.59
Number of samples	22

The high phosphorus content probably relates with supplying this nutrient to the soil during last years. Phosphorus mobility in a soil is low, it migrates to the distance of 0.2–0.3 m from fertilize application place, so a loss of phosphorus from the soil is very low (Šoltýsová, 2007). Total phosphorus content in a soil to a certain degree depends on the mechanic soil composition and organic matter content (Šoltýsová, 2007). Grained, moderate heavy soils with a high percentage of humus – that also occur in Borovce – show a reserve of phosphorus which is naturally high. From the aspect of phosphorus disposing in the soil the plot showed lower degree of homogeneity than was found for nitrogen.

Harvest of crops sensitively responded to the nitrogen and phosphorus ratio. Disturbing of N : P ratio to an advantage of nitrogen leads to a gigantic growth and delayed flowering, while an prevailing proportion of phosphorus induces accelerating of growing while it dries out & lowers the quality of the fruits at the same time (Bedrna, 2009). It is known that favourable ratio of N : P is 1 : 1. In a spring period for sampling rapeseed varieties were established the following N:P ratios (Table 6).

Efficiency of spring nitrogen fertilization depends on the rapeseed variety, however it was established, that higher nitrogen amount effectively increases of yield and rapeseed production (Möllers et al., 1999, Budzyński and Jankowski, 2006). In our experiment by use of nitrogen amount of 80 kg ha^{-1} in spring the rapeseed varieties failed in use of the nitrogen as before which was reflected in the earnings.

Table 6. Ratio of nitrogen and phosphorus in soil in the spring period for tested rapeseed varieties

Variety	Content N_{an} [mg kg^{-1}]	Content P [mg kg^{-1}]	Ratio N : P
Labrador	23.4	194.5	1 : 8
Oponent	26.2	163.0	1 : 6
Baldur	25.85	153.5	1 : 6
Champlain	25.15	168.5	1 : 6
Slogan	27.25	149.0	1 : 5
Dekade	26.8	153.5	1 : 6
Maplus	27.95	133.5	1 : 5
Viking	26.3	126.0	1 : 5
Verona	27.4	165.5	1 : 6

Table 7. Values of yield (line up descending), nitrogen and phosphorus content in soil in the spring period

Variety	Yield [t ha^{-1}]	Content N_{an} [mg kg^{-1}]	Content P [mg kg^{-1}]
Labrador	4.68	23.40	194.5
Dekade	4.45	26.80	153.5
Verona	4.10	27.40	165.5
Champlain	4.08	25.15	168.5
Maplus	3.65	27.95	133.5
Slogan	3.46	27.25	149.0
Oponent	3.34	26.20	163.0
Viking	2.99	26.30	126.0
Baldur	2.88	25.85	153.5

In terms of climate conditions, all tested rapeseed varieties had the same suitable conditions for yield and seed production. The period from January to July was favourable for rapeseed growth. Average air temperature in January and February did not decrease under freezing point, what positively influenced a good wintering. In the time period from January to July did fall a total sum of precipitation of 616.9 mm, the greatest sum of precipitation did fall during the July (89.6 mm). In March, which is the revitalization time for rapeseed after wintering, 47.3 mm precipitation did fall and the average air temperature of 4.73 °C has been reached (Masarovičová et al., 2011).

The high yield of all tested varieties corresponded to the seed production. From this aspect it is possible to classify the studied rapeseed varieties into the following three categories – high, middle and low of production (Table 8).

Table 8. Values of yield (line up descending) and seed production for tested rapeseed varieties

Variety	Yield [t ha^{-1}]	Seed production [dkg plant^{-1}]
Labrador	4.68	2.46
Dekade	4.45	2.66
Verona	4.10	2.28
Champlain	4.08	2.46
Maplus	3.65	1.40
Slogan	3.46	1.63
Oponent	3.34	1.69
Viking	2.99	1.36
Baldur	2.88	1.43

Into the first category of high production varieties with both high yield and seed production can be categorized varieties – Labrador, Dekade, Verona and Champlain. The highest yield of 4.68 t ha^{-1} was reached by variety Labrador, regarding the aspect of seed production it is on second place. Yield of Labrador is comparable with results of work Bielíková et al. (2007), where in the time period of 6 years this cultivar did reached permanently high yield average 5.17 t ha^{-1}. The same seed production like the cultivar Labrador has been reached by the variety Champlain.

Comparing to the yield and seed production the best results have been achieved by the variety Dekade.

To the groups of middle production varieties belong Maplus, Slogan and Oponent. Smaller yield of Oponent in comparison to the other results (Koprna, 2006; Baranyk and Málek, 2009) probably relates with high phosphorus content in the soil and imbalance between nitrate and ammonium nitrogen concentrations. On the unsuitable one-way method of nitrogen fertilization and excessive phosphorus content in soil and their following decrease of the yield of rapeseed and their quality Matula (2009) already pointed out. The lowest values of studied production parameters were reached by the varieties Viking and Baldur (Fig. 1).

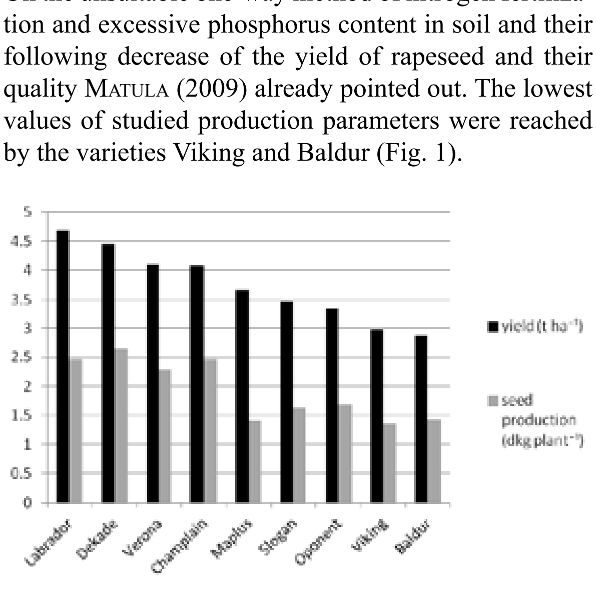


Fig. 1. Values of yield (t ha^{-1}) and seed production (dkg plant^{-1}) of tested rapeseed varieties.

Conclusions

All studied rapeseed varieties had the same conditions regarding soil, climatic conditions for yield formation and seed production, too. Different yield and seed production of individual rapeseed varieties were caused by the properties of genotype only. On the basis of our observations and results we classified the tested rapeseed varieties into the groups of high, middle and low production. The varieties Labrador and Dekade responded as best to the added restorative fertilization – both varieties reached the highest yield and seed production. The lowest yield and seed production had the varieties Viking and Baldur.

Acknowledgement

This study was in part financially supported by Association for Production and Use of Biofuels, Civil Society Organization, Bratislava, Slovak Republic.

References

Baier, J. 1962. *Abeceda výživy rostlin* [Basics of plant nutrition]. Praha: Státní zemědělské nakladatelství. 250 p.

Baranyk, P., Málek, B. 2009. Výsledky odrodových pokusov s repkou ozimnou v r. 2008 [Results of cultivar experiments with rapeseed in year 2008]. *Naše pole*, 1: 20–21.

Bedrna, Z. 2009. *Starostlivosť o pôdu v záhrade* [Care of garden soil]. Bratislava: Veda. 250 p.

Bielek, P. 1998. *Dusík v poľnohospodárskych pôdach Slovenska* [Nitrogen in agricultural soils of Slovakia]. Bratislava: Výskumný ústav pôdnej úrodnosti. 250 p.

Bielíková, L., Vencel, M., Šalom, P., Hrbáček, L., Horejsek, J. 2007. Náhled na výnosový potenciál odrůdy Labrador (Saatbau Linz ČR) v souvislosti s výsledky pokusů ÚKZÚZ v letech 2002 – 2007 [Insight on yield potential of cultivar Labrador (Saatbau Linz CR) in relation with results Of ÚKZÚZ experiments during 2002–2007]. In *Prosperujíci olejniny 2007. Zborník referátov z konferencie*. Praha: Česká zemědělská univerzita, p. 103–106.

Bokor, P. Fyziologické poruchy a choroby repky na jeseň [Physiological disorders and diseases of rapseed in autumn]. *Agromanuál. Region. Príl.,* 6: 4–5.

Budzyński, W.S., Jankowski, K.J. 2006. Vlyv hnojení dusíkem na výnos a kvalitu řepky ozimé [Effects of nitrogen fertilization on the yield and usability of winter rape seeds]. In *Řepka, mák, horčice 2006. Zborník referátov z konferencie*. Praha: Česká zemědělská univerzita, p. 71–78.

Fecenko, J., Ložek, O. 2000. *Výživa a hnojenie poľných plodín* [Nutrition and fertilization of agricultural crops]. Nitra: Slovenská poľnohospodárska univerzita v Nitre. 452 p.

Koprna, R. 2006. Oponent – nová liniová odrůda sdružení „Česká řepka" [Oponent – new line variety of the "Czech rapeseed" association]. In *Řepka, mák, hořčice 2006. Zborník referátov z konferencie*. Praha: Česká zemědělská univerzita, p. 133–135.

Kotvas, F., Koutný, B., Vojtek, R., Gáborík, Š. 2007. *Výsledky agrochemického skúšania pôd na Slovensku v rokoch 2000 – 2005* [Results of agrochemical soil testing in Slovakia in years 2000–2005]. Bratislava: Ústredný kontrolný a skúšobný ústav poľnohospodársky. 98 p.

Masarovičová, E., Kráľová, K., Malovcová, Ľ., Surovčík, J., Brestič, M., Olšovská, K. 2008. Genotypové rozdiely repky olejky z hľadiska obsahu oleja, kvality oleja a produkcie semien [Genotypic differences of rapeseed from the aspect of oil content, oil quality and seed production]. In *Nové poznatky z genetiky a šľachtenia poľnohospodárskych rastlín. Zborník referátov z konferencie*. Piešťany: SCPV – VÚRV, p. 19–22.

Masarovičová, E., Kráľová, K., Malovcová, Ľ. 2011. Production of some rapeseed genotypes under various climatic conditions of Slovakia. *Ekológia (Bratislava)*, 30: 360–368.

Matula, J. 2009. Význam základného hnojenia a diagnostiky výživového stavu pôdy pri výžive repky olejky. 2. časť [The importance of basic fertilization and diagnostics of nutrition state of soil at rapeseed nutrition. 2. part]. *Naše pole*, 3: 22–23.

Möllers, CH., Kahlmeyer, M., Kessel, B., Ossenkop, A., Becker, H.C. 1999. *Genotypic variation for nitrogen efficiency in winter rapeseed cultivars* [cit. 2011-06-24]. http://www.regional.org.au/au/gcirc/4/358.htm

Mráz, J. 2009. Podzimní aplikace dusíku v řepce – přednosti a rizika [Autumn application of nitrogen in rapeseed – advantages and risks]. In *Prosperující olejniny 2009. Zborník referátov z konferencie*. Praha: Česká zemědělská univerzita, p. 143–144.

Surovčík, J. 2000. Response of rapeseed yield to application of pesticides. In Šafránková, I., Salvet, V., Šefrová, H. (eds). *Sborník referátů z XV. české a slovenské konference o ochraně rostlin v Brně 12.–14. září 2000: Proceedings of the XVth Czech and Slovak Plant Protection Conference in Brno September 12.–14., 2000*. Brno: Publishing House Konvoj, p. 253–254.

Šoltýsová, B. 2007. *Fosfor v pôde* [Phosphorus in soil] [cit. 2011-06-24]. http://www.scpv-ua.sk/index.php/2007-pr-16/15--fosfor-v-prirode-a-v-pode

Tatarková, Z., Malovcová, Ľ., Bedrna, Z., Masarovičová, E., Kráľová, K. 2010. Production potential of rapeseed from the aspect of soil quality. *Phytopedon*, 1: 35–41.
Varga, L., Ducsay, L., Marček, M. 2007. *Optimalizácia výživy repky ozimnej* [Nutrition optimization of Rapeseed] [cit. 2011-06-24]. http://www.agromanual.cz/cz/clanky/vyziva-a-stimulace/hnojeni/optimalizacia-vyzivy-repky-ozimnej.html [cit. 2011-06-24].
http://www.podnemapy.sk [cit. 2011-06-24].
http://www.uksup.sk/download/odrody/20090728_opisy_repka.pdf [cit. 2011-06-24].

Vplyv obsahu dusíka a fosforu v pôde na úrodu vybraných odrôd repky olejky

Súhrn

Práca prezentuje výsledky výskumu, ktorý bol zameraný na reakciu deviatich sledovaných odrôd repky olejky, forma ozimná na aplikované regeneračné hnojenie (jarné obdobie). Experiment bol vykonaný na pokusných plochách Centra výskumu rastlinnej výroby – Výskumný ústav rastlinnej výroby Borovce pri Piešťanoch. Región spadá do kukuričnej výrobnej oblasti a tamojšie pôdy sú veľmi vhodné na pestovanie repky. Odber pôdnych vzoriek bol vykonaný na jar pred začiatkom vegetačného obdobia. Homogenizované pôdne vzorky boli analyzované na obsah anorganického (N_{an}), amónneho ($N_{NH_4^+}$), dusičnanového dusíka ($N_{NO_3^-}$) a fosforu (P). Na základe výsledkov skúmané odrody repky možno rozdeliť na vysoko, stredne a nízko produkčné. V jarnom období aplikovaný dusík a fosfor dokázali najlepšie využiť a tým pádom dosiahnuť najvyššiu úrodu a produkciu semena odroda Labrador s dosiahnutou úrodou 4,68 t ha^{-1} a produkciou semena 2,46 dkg rastlina^{-1}, nasledujú odrody Dekade (úroda 4,45 t ha^{-1}, produkcia semena 2,66 dkg rastlina^{-1}), Verona (úroda 4,10 t ha^{-1}, produkcia semena 2,28 dkg rastlina^{-1}) a Champlain (úroda 4,08 t ha^{-1}, produkcia semena 2,46 dkg rastlina^{-1}). K stredne produkčným odrodám začleňujeme odrody Maplus (úroda 3,65 t ha^{-1}, produkcia semena 1,40 dkg rastlina^{-1}), Slogan (úroda 3,46 t ha^{-1}, produkcia semena 1,63 dkg rastlina^{-1}) a Oponent (úroda 3,34 t ha^{-1}, produkcia semena 1,69 dkg rastlina^{-1}). Odrody Viking a Baldur dosiahli najnižšiu úrodu ako aj produkciu semena s nasledovnými hodnotami: Viking – úroda 2,99 t ha^{-1}, produkcia semena 1,36 dkg rastlina^{-1}, Baldur – úroda 2,88 t ha^{-1}, produkcia semena 1,43 dkg rastlina^{-1}.

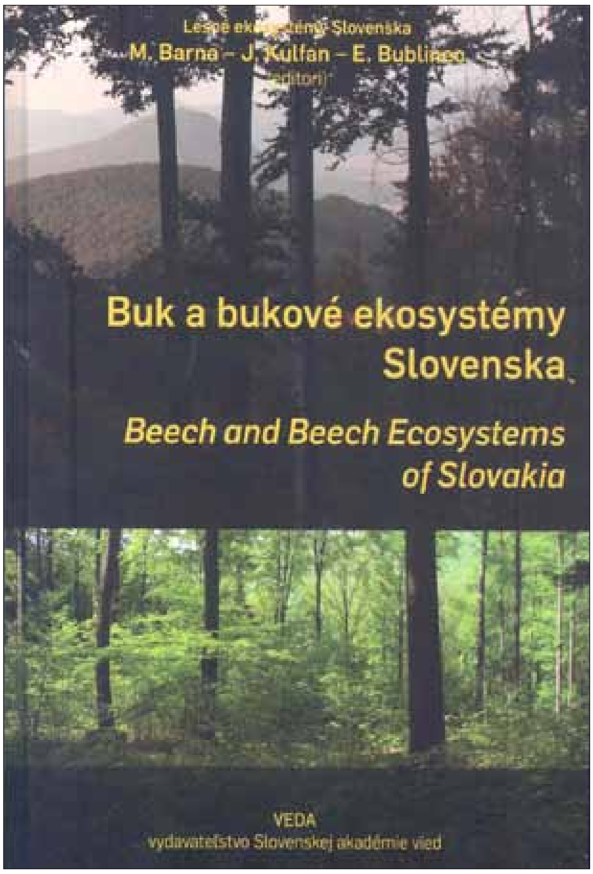
Received September 29, 2011
Accepted November 26, 2011

Book review

Buk a bukové ekosystémy Slovenska: Beech and Beech Ecosystems of Slovakia. Edited by Milan Barna, Ján Kulfan, Eduard Bublinec. 1st ed. Bratislava: VEDA, the publishing house of the Slovak Academy of Sciences, 2011. 634 p.: bibliographical references, summaries, tables, photos, figures, maps, graphs; 24 cm. Forest Ecosystems of Slovakia series. ISBN 978-80-224-1192-9.

Beech is an important woody plant improving stability of forest stands, especially mixed ones. Its significance is escalating today, when global changes may alter forest environment up to the risk of forest decline. In this context, beech is considered as a species for the future. In Slovakia, it is the most frequent woody plant, very abundant also in primeval forests.

The scientists working at the Institute of Forest Ecology of the Slovak Academy of Sciences in Zvolen have got several-decade experience in research on beech trees and beech ecosystems. They have published their original knowledge separately, mostly in scientific papers. Lastly they took opportunity to summarise this knowledge and present the synthesis in form of a monograph. The scientists of this institute constitute the major part of the authors' team, and at the same time, they are the sole editor of this book. The team also includes scientists from other Slovak research institutions. The list of references contains a large number of Slovak and foreign sources.



The book was published and pressed by Veda, the publishing house of the Slovak Academy of Sciences in December 2011.

This book fills the gap in publishing methodical knowledge of beech and beech ecosystems in Slovakia.

The monograph is not limited to meet the needs of experts and scholars in forestry, forest ecology and other branches related to beech in various aspects. It can also serve specialists implementing scientific knowledge in forest practice and also laymen seeking detail information on beech. The primary aim is scientific, but the style is accessible to a wider range of readers.

The text on the cover informs that the monograph summarises the current scientific knowledge of European beech and its ecological relationships with abiotic and biotic environment in forest ecosystems of Slovakia. "The life history of beech trees is followed from germinated seedlings up to adult trees. Analysed are functions of plants, fungi and animals occurring in beech forests, their relationships and the structure of their communities. There are outlined principles of optimum methods and approaches for tending of beech stands. Attention is also focussed on impact of anthropic activities on beech forests and organisms living in them. Included is information concerning the use of beech trees in urban greenery, beech wood properties, commercial importance, and prognosis of development for beech ecosystems".

The monograph is divided in six parts. Part I European beech consists of two chapters: 1. Taxonomy, phylogeny and distribution of beech in Europe and in Slovakia, 2. Morphology, anatomy, physiology and phenology of beech. Part II Beech and its abiotic environment has three chapters: 3. Light and thermal conditions in beech stands, 4. Soil and mineral nutrition, 5. Hydrological cycle. Part III Beech stands, their vegetation and mycoflora with 10 chapters represents the largest part of the book: 6. Beech – edificator of forest geobiocoenoses, 7. Classification of beech geobiocoenoses, 8. Syntaxonomical classification, 9. Classification of beech forests within the Natura 2000 network,

10. Primeval beech forests, 11. Natural regeneration of beech, 12. Growth, production and yield of mature beech stands, 13. Geo-phyto-chemistry – content of elements in particular parts of beech trees, 14. Phytometry and energy distribution in beech ecosystems, 15. Fungal communities and their roles in beech stands. Part IV Animals and their role in beech forests has three chapters: 16. Soil invertebrates, 17. Invertebrates associated with beech, 18. Vertebrates. Part V Forest management and use of beech comprises seven chapters: 19. Use of beech as the main species in forest management in Slovakia, 20. Silviculture of beech stands, 21. Impact of forest management on tree biomass production and natural regeneration in beech stands, 22. Impact of forest management on herb layer and fungi, 23. Effects of forest management on occurrence of animals, 24. Beech and its pests in urban greenery, 25. Beech wood, its importance and utilization. Part VI Effects of polluting substances and climate change on beech forests consists of four chapters: 26. Air pollution – harmful factor, 27. Heavy metals in beech ecosystems, 28. Precipitation chemistry, 29. Anticipated climate change impacts on beech stands in Slovakia.

The text is written in Slovak. To provide information also to foreign readers, the book's title, the content and the captions to the tables and figures are bilingual: Slovak-English, and each chapter ends with an English summary.

This monograph is the first one in the planned series Forest Ecosystems of Slovakia intended to present methodical knowledge of forest ecosystems in Slovakia, their components, processes, relations, response to external stimuli, to local and global changes, and similar issues.

The monograph summarises long run scientific efforts, and, at the same time, provides a challenge to push ahead the scientific research on beech ecosystems in the future. It has disclosed gaps in the existing knowledge not only in Slovakia but also in the global context.

Katarína Sládeková
Institute of Forest Ecology
of the Slovak Academy of Sciences
Štúrova 2
960 53 Zvolen
Slovak Republic
e-mail: sladekova@savzv.sk

Instructions for authors

Folia oecologica is a journal devoted to publishing original scientific papers from the fields of ecology of forest ecosystems, communities and populations of plants, fungi and animals associated with forest environment and also the ecology of woody plants growing in both forest and non-forest environment, human settlements included.

The journal also publishes short communications, methodological and survey papers in the area, book reviews, personalia and information about scientific events. The manuscripts are submitted to reviewers for evaluation of their significance.

Manuscript layout. The manuscripts should be written in English, well-arranged, not exceeding a maximum extent of 20 pages, including tables and figures. The authors are responsible for the quality of the text, manuscripts written in poor English will be returned. Please, send two copies of the manuscript (A4 format, type size 12 font Times New Roman, double-space lines, 3 cm margins on each edge of the page) together with all figures and tables (each on a separate sheet) to the editorial office. Avoid dividing the words, smoothing right text margins; do not define the styles and paragraphs. Do not use either spacing or tabulator for beginning of a paragraph. If the paper has been submitted for publication, send two printed copies and one copy in electronic form (CD or DVD) as a Microsoft Word file (DOC, or RTF format).

An original scientific paper should comprise: 1. The title. 2. The author's name: full first name and second name. 3. Address: complete address and e-mail address (if available) of all the authors. 4. Abstract: in one paragraph, without references to tables, figures and literature, not exceeding 15 lines (900 characters). 5. Key words (maximum 6). 6. Introduction. 7. Material and methods. 8. Results. 9. Discussion (or Results and discussion). 10. Acknowledgement. 11. References. 12. Summary in Slovak (or in Czech): not exceeding an extent of one page, including the title of the paper in Slovak.

In the papers, it is necessary to use SI symbols. Non-integer numbers should be provided with a decimal point, (e.g. 1.7), not a comma (1,7), the thousands (with exception of years) are separated with a comma: 5,600. The variables in mathematical formulae and expressions should be written in italics, the symbols for functions and constants in the normal font, the matrices in bold capitals, the vectors in bold small letters. Latin names of genera, species, subspecies and varieties are written in italics, the name of the author of the description (or his abbreviation) normally: e.g. *Lymantria dispar* (Linnaeus, 1758), *Lymantria dispar* (L.), *Abies cephalonica* Loud. var. *graeca* (Fraas) Liu. The names of cultivars are written normally, e.g. *Olea europea* L. cv. Chalkidikis. All the tables and figures must be referred to in the text: Table 1, Tables 2–4, Figs 2–4. The authors are asked to indicate placing of the tables and figures on the text margins.

Literature citations. The literature cited in the text should conform to the following patterns: one author – Funke (1971) or (Funke, 1971), two authors – Sokal and Rohlf (1995) or (Sokal and Rohlf, 1995), three and more authors – Alstad et al. (1982) or (Alstad et al., 1982). More than one work written by the same author is to be distinguished with small letters appended after the year: Novák (1950a, 1950b). If the document does not contain either the name of the responsible person or the corporation and if it is not possible to conclude about the author with certainty from other authorities, the work should be cited as written by an Anonymus.
References in the final list are to be provided with the full title and names of all authors; ordered alphabetically and according to the publication year. Latin names of genera, species and sub-species cited in the list of references are to be written in standard type. The titles are to be cited in the original language appended by an English translation (in brackets). The issue number (except the volume number) should be given (in parentheses) only in the case when the volumes are not paginated continually. The titles of periodicals should be cited in shortened form, according to the international rules, conform to the World list of scientific periodicals. The basic instructions can be found in Bojňanský et al. (1982) Periodiká z oblasti biologicko-poľnohospodárskych vied, ich citácia a skratky [Periodicals in area of biological and agricultural sciences, their citations and abbreviations]. Bratislava: Slovenská spoločnosť pre poľnohospodárske, lesnícke a potravinárske vedy pri SAV. 704 p. In the case of a possible ambiguity, cite the periodical under the full name. Titles in languages not using the Latin alphabet should be transliterated keeping with the British Standard 2979 (in the case of the Cyrilic e.g. ж = zh, х = kh, ц = ts, ч = ch, ш = sh, щ = shch, ю = yu, я = ya). (The basic rules can be found e.g. in Bojňanský et al. 1982).

The following form of citation should be used:

Work in a periodical

Sharov, A.A., Liebhold, A.M., Ravlin, F.W. 1995. Prediction of gypsy moth (Lepidoptera: Lymantriidae) mating success from pheromone trap counts. *Envir. Ent.*, 24: 1239–1244.

Eiberle, K., Nigg, H. 1984. Zur Ermittlung und Beurteilung der Verbissbelastung. *Forstwiss. Cbl.*, 103: 97–110.

Book

Szujecki, A. 1983. *Ekologia owadów leśnych* [Ecology of forest insects]. Warszawa: Państwowe Wydawnictwo Naukowe. 604 p.

Miller, J.R., Miller, T.A. (eds) 1986. *Insect-plant interactions*. New-York: Springer-Verlag. 342 p.

Work published in a book or in a proceedings

Basset, Y., Springate, N.D., Aberlenc, H.P., Delvare, G. 1997. A rewiew of methods for sampling arthropods in tree canopies. In Stork, N.E., Adis, J., Didham, R.K. (eds). *Canopy arthropods*. London: Chapman & Hall, p. 27–52.

Ciberej, J., Kováč, G., Bilá, A. 1999. Faktory ovplyvňujúce početný stav kamzíka vrchovského v TANAP-e [Factors influencing game populations in chamois (Rupicapra rupicapra L.) in the High Tatra National Park]. In Koreň, M. (ed.). *Päťdesiat rokov starostlivosti o lesy TANAP-u. Zborník referátov z konferencie*. Poprad: Marmota Press, p. 111–116.

Dissertation

Chromová, L. 2002. *Pôdne a vegetačné zmeny lesných spoločenstiev okolia obce Brusno (Veporské vrchy)* [Changes in soils and vegetation of forest communities of the Brusno village (the Veporské Mts.)]. PhD thesis. Bratislava: Comenius University, Faculty of Natural Sciences. 122 p.

Tables. The tables should be submitted on separate sheets, not included into the text. The sheets must not be folded. The tables are to be numbered, each after other, with Arabic numerals (Table 1, Table 2…). The text in the caption should always begin with a capital letter. The tables can be self-explicable, not requiring references in the text. The numbering and captioning should be placed over the table, commentaries, if any, under the table. Submitted are only tables prepared in Word and Excel, without vertical grid lines. Use the font size 9. Table width should be of one or two text columns (77 and 160 mm) or 235 mm. Avoid doubling the information in tables and plots.

Figures. Submitted are only high-quality drawings, plots and photographs in black, each on a separate A4 sheet. They can be prepared manually or printed with a laser or an ink printer. Please use only hatching, not shading. Avoid three-dimensional graphs, if possible. In captions use the Arial font. The font size should not exceed 11, the recommended size is 9. If possible, use the unified size. Figure width should be 77, 160 or if necessary, 235 mm. The lines must be well clean-cut and the written text must be distinctly readable also after the diminution. For the electronic version, only MS Excel is acceptable. The backside of sheet should be provided with the number of the figure and the author's name. The graphs and ink drawings must be self-explicable and readable with captions and appended keys of symbols only, without necessity to seek explanations in the text.

Off-prints. Each author and co-authors will obtain one electronic copy of the published paper.

Editorial office. Institute of Forest Ecology SAS, Centre of Scientific Information – Library, Štúrova 2, 960 53 Zvolen, Slovak Republic, e-mail: knizuel@savzv.sk Manuscripts should be sent to the editorial office.