FOLIA OECOLOGICA – vol. 37, no. 2 (2010). ISSN 1336-5266

Response of European beech radial growth to shelterwood cutting

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Abstract

Barna, M., Sedmák, R., Marušák, R. 2010. Reponse of European beech radial growth to shelterwood cutting. *Folia oecol.*, 37: 125–136.

There were investigated possibilities of varying cutting intensities and cycles optimization within shelterwood system applied in beech stands growing in a suitable site conditions. The study was based on dendrochronological analysis of increments on radial discs taken from three different stem heights from sample trees representing the means for individual tree classes, selected on sample plots differing in cutting intensity (residual stocking 0.3–0.5–0.7 and control plot 0.9). The decrease in the stand density due to the cutting induced a significant radial growth increase in the sample trees, even in the advanced age (100 years). The decrease in stand stocking by 0.1 was reflected in a linear radial growth enhancement by on average 17%. The subdominant trees were best responding to the release (radial growth enhancement up to 200% after the heavy cut), followed by co-dominant and dominant trees (enhancement app. 45% and 25%). The period of the positive increment response depends on the cutting intensity, e.g. trees on the plot after heavy cut (stocking 0.3) showed a positive increment response over the whole 8 (7)-year period after the intervention across the whole stand profile, but trees on the plot after light cut (stocking 0.7) subjected to a light cut showed an increased increment only for 2–3 years, and no response was found in the subdominant trees.

Key words

annual ring index, dendrochronology, *Fagus sylvatica*, stand density, tree ring analysis

Introduction

Shelterwood regeneration is the most common and long-term applied method for natural regeneration of forest stands Central Europe (Gayer, 1898). The method is very suitable for regeneration of shade-tolerant species. The release of the main canopy layer and the decreased stand density has a considerable improving effect on increments and fertility in the residual trees and, at the same time, they support the regeneration and growth of the seedlings (Nyland 2003; Agestam et al., 2003; Pastur et al., 2000).

From the stand production view, the shelterwood regeneration is connected with losses in the volume increment of mature stands because even the higher increment in the residual trees cannot outweigh the losses due to the lower production base (Assmann, 1970). On the other hand, the higher light increment in the superior trees of the mature stand can considerably increase the value of production and, in such a way, minimise or even completely compensate losses in the volume production and the higher cost demands on the felling (Ashton et al., 2001; Korpeľ et al., 1991).

Another possibility how to shorten the rotation period is to shorten the regeneration period by increasing the intensity of the initial (preparation and seed) shelterwood cuttings. An ideal intensity of the initial cutting should ensure regeneration and optimum growing conditions for the young stand, and simultaneously induce the maximum light growth response in the residual mature trees – up to the successive release cutting. The period required for the shelter removal depends on the ecological and biological demands of the regenerated species. Saniga (2007) recommends releasing of the seedlings 3–5 years after the application of a moderate seed cutting (the intensity should not exceed the critical stocking of 0.6–0.7 according to Assmann, 1970).

In general, from the long-term production experiments it is known that the more intensive is the cutting intervention, the bigger and longer increment reaction of the parent stand can be expected – thanks to the lowered competitions for light, water and nutrients (Assmann, 1970; Peterson et al., 1997). Shelterwood cuttings, thinnings, respectively every reduction of the stand density change the way of its vertical distribution along the stem. In general, the highest diameter increment is allocated in low parts of the stem and decreases with increasing height up to a certain distance from the ground at which it reaches its minimum. Then it increases up to the crown base. In some species (beech, oak) it decreases again upwards the crown (Wenk et. al., 1990). The released trees show a tendency to shift the increment creation to the lower stem part – to the more extent the higher H/D ratio they have (Abetz, 1988). The values of the diameter increment along the stem are varying in dependence on the tree age, social status and site quality (Šmelko, 1982).

The absence of details about the changes in increments caused by a strong density reduction of mature stands results in practical absence of an exact recommendation for reaching a maximum yield from the parent stand in the last phases of its lifetime (Holgén et al., 2003). This has also been reflected in the lack of recommendation under what conditions and how is it possible to increase the intensity of the initial shelterwood cutting in such a way as to lower the risk of decreased production quality of the mature trees and to lower the overall costs connected with the stand regeneration. Quantification of the radial increment responses in a beech stand growing in good site conditions corresponding to the different intensities of the initial shelterwood cuttings and study of the influence of the tree social status on the radial growth responses in different stem parts was the principal objective of the presented study.

Area description

The study was conducted in the Western Carpathians – Kremnické vrchy Mts, Central Slovakia (48°38' N, 19°04' E). The subject was a mature beech stand with the mean age of 100 years at the establishment of experiment. The exposure is west, slope inclination up to 20º, altitude 470 m a.s.l., mean annual temperature 8.2 °C, mean temperature in the vegetation period 14.9 °C, mean annual precipitation sum 664 mm, mean precipitation sum in the vegetation period 370 mm. Before the research, the stand had been managed according to the common forestry practice. Over the 30 years preceding the research (1986) the stand was subjected three times to thinning treatments. The dominant tree species at the locality is common beech (80–95%); fir, oak and hornbeam are admixed species. The detailed site description can be found in Bublinec and Dubová (2003), Kellerová (2003, 2009), Kuklová et al. (2005), Schieber et al. (2009), Janík (2009), Mihál et al. (2009). The influence of different cutting intensity on the radial growth was studied on 4 permanent sampling plots, distinguished by the stocking, i.e. by the ratio between the actual and maximum stand basal area defined for the corresponding site quality and stand age (Assmann, 1970). The data of the Slovak yield table for beech were taken as the reference for stocking of 1.0. In February 1989 an initial shelterwood cutting of different intensity was executed. The original stocking of the stand with the value of 0.9 was changed after the cutting into: 0.3 on the plot H (heavy cut), 0.5 on the plot M (medium cut) and 0.7 on the plot L (light cut). The control plot

Table 1. Main characteristics of beech stands on research plots after cutting (1989) and sampling (1996) (H, High intensity cutting; M, Medium; L, Low and C, Control)

Plot	Year	Density stems [ha^{-1}]	Height [m]	DBH^{a} [cm]	Volume^{b} [m^{3} ha^{-1}]	Stand density
H	1989	160	27.7	32.0	193.7	0.3
	1996	160	29.3	37.5	280.2	0.4
M	1989	243	26.9	31.3	256.8	0.5
	1996	229	28.6	35.4	353.4	0.6
L	1989	397	25.4	29.4	398.9	0.7
	1996	363	28.2	32.7	497.1	0.8
C	1989	700	23.6	25.3	571.2	0.9
	1996	633	26.3	26.6	619.8	0.9

^{a}the mean diameter at breast height, ^{b}volume of large wood (>7 cm d.o.b. – diameter outside the bark).

C was left without intervention, with the original stocking of 0.9. The cutting was primarily focused on the admixed species, dying and ill trees and trees of a very low quality. The development of the basic stand variables after the cutting in February 1989 compared with the corresponding data from 1996 (sampling) is summarised in Table 1.

Methods

Experimental design

The diameter increment in beech trees after the application of a shelterwood cutting was analysed through a dendrochronological analysis performed on 12 sample trees. The selection of the trees was based on the dendrometric measurements of 316 beech trees from sample stands, each 0.35 ha in area. On each plot was selected a tree representing the mean for the given tree class. The tree classes were determined according to the Kraft´s classification system: dominant trees – with very well developed and large crowns, co-dominant trees – with well developed crowns; forming the main canopy level, subdominant trees – with irregularly developed, small crowns suppressed on one or several sides. The fallen sample trees were subjected to the detailed dendrometric measurements (Table 2). The stems were divided into three equal parts and radial discs were taken from the mid of medium and upper stem parts. From the lower parts, the discs were taken at a height of 1.3 m. Eventually, 36 radial discs were obtained. Annual radial increments were measured by a Digitalpositiometer in 4 selected directions, with an accuracy of 0.01 mm. The first direction was chosen randomly and second, third and fourth were obtained by 90 degrees rotation. All ring width series were cross-dated and synchronized with the help of pointer years within the system DAS (Dendrochronological Analysis System, Janíček, 1994). After the validation, individual tree ring series from the data for 4 radii were averaged. Finally, we obtained synchronized diagrams of tree rings for 12 sample trees at three different heights on stems, visualized on Fig. 1.

Quantification of changes in radial increment

Dendrochronological studies quantifying the influence of discrete events on the radial growth are based on the comparison of the tree ring widths before and after the beginning of presence of a specified controlled factor. In general, the quantification process consists of three phases (Cook and Kariukstis, 1990; Šmelko and Ďurský, 1999).

1. The first is the standardization of the original tree rings: where RW_t is the measured width of the annual ring at the age *t,* and A_t is the width of an annual ring expected for a given age, site quality, stand density and social position. The purpose of the standardisation is to eliminate the dimensional differences between the compared time periods, caused by the natural physiological growth processes closely related to the tree age (age trend) and tree social status.
2. Filtering from annual ring indexes the portion of variability caused by climate conditions and weather (Piovesan et al, 2003; Kucbel et al. 2009) in the years preceding and following the relevant

Table 2. Biometric characteristics of sample trees (H, M, L, C see Table 1)

Plot	Social status	Height	DBH*	Crown length	Crown projection	Age
		(m)	(cm)	(m)	(m^2)	(yr)
H	dominant	32.5	40.8	16.6	67.9	112
	co-dominant	27.1	30.2	12.1	45.7	100
	subdominant	19.6	20.2	13.5	52.1	98
M	dominant	29.3	42.3	14.0	76.8	97
	co-dominant	29.2	31.5	13.5	69.9	100
	subdominant	20.2	16.2	18.0	28.2	97
L	dominant	31.5	40.4	18.7	92.5	107
	co-dominant	29.7	29.4	12.3	73.0	99
	subdominant	24.9	19.0	18.6	33.7	97
C	dominant	31.3	39.8	17.0	68.1	98
	co-dominant	29.6	27.6	14.5	64.9	99
	subdominant	22.7	17.6	17.3	26.2	99

*diameter at breast height.

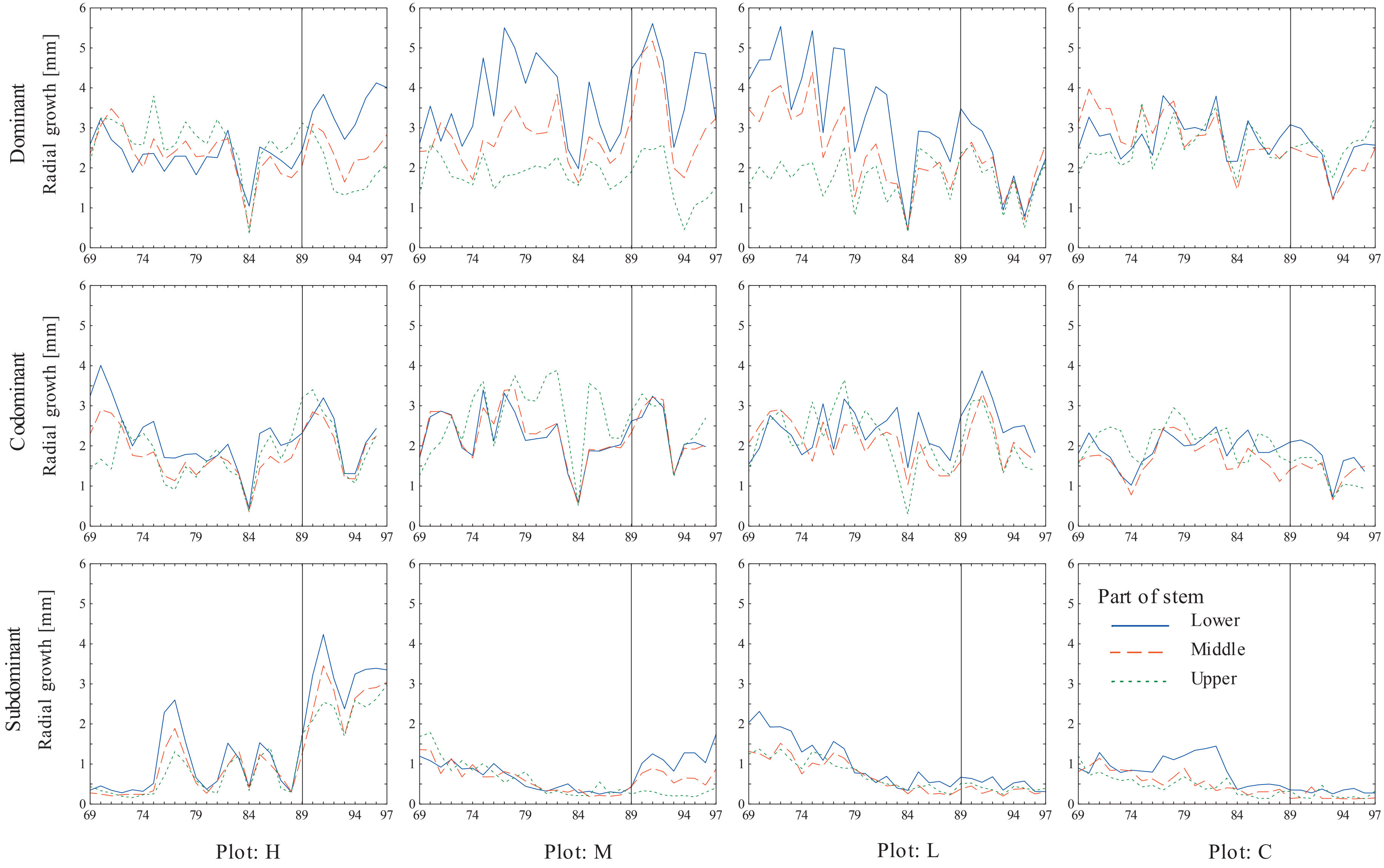

Fig. 1. Individual tree ring series stratified according to cutting intensity (H, M, L, C see Table 1) and social status, in year 1969–1997. Vertical line marks the year of cutting intervention.

event (Šmelko et al., 1992; Schweingruber, 1993). One possibility is to design a dendroclimatic model reflecting the connections between the selected climatic variables (air temperature, precipitation amount, soil water content) and annual ring indexes obtained in the first stage, and then to provide the primary and the model annual ring indexes with double indexing. More simple and more frequently used solution is a calculation of the mean values for the individual annual ring indexes over sufficiently long time periods before and after the event (Šmelko and Ďurský, 1999). The compared periods should not be shorter than 5 years (to ensure "smoothing" between the years with better and worse climate conditions; Gruber, 2002) and the most important condition for calculation of the simple means is a random fluctuation of climate effects in the compared periods.

3. The third phase is the classification of relative increment changes *CH%* based on the double indexing:

$$CH\% = \left(\frac{\bar{R}\overline{WI}_{t>t_0}}{\bar{R}\overline{WI}_{t<t_0}} - 1 \right) \cdot 100$$

where $\bar{R}\overline{WI}_{t>t_0}$ is the mean annual ring index in the studied period and $\bar{R}\overline{WI}_{t<t_0}$ is the mean annual ring index in the reference period preceding the relevant event at an age t_0.

The studied period after the cutting intervention in 1989 comprises 7 or 8 years, depending on the time when the relevant sample tree was cut (1996 or 1997). The corresponding reference period consists of 20 or 30 years before the cutting (according to the available length of the annual ring series). It is 3–5 times longer then the studied period, so as to obtain reliable estimates of the exponential smoothing parameters.

The method of simple non-seasonal exponential smoothing was used for standardization of the annual ring series and the derivation of annual ring indexes, because of relatively short time series and requirement to eliminate the combined age-increment trend in the different social groups. Parameters for the exponential smoothing were obtained by using the method of the network searching involving six optimization criteria – mean error, mean absolute error, sum of error squares, mean square error, mean relative error and mean absolute relative error.

The quantification of relative changes in the radial increment was made by using the method of double indexing; the statistical significance of the changes in increments between the studied and reference periods was tested using the *t*-test. More detailed analysis of interactions between the studied factors was done using the Duncan´s test. All analyses were conducted in the program Statistica (Tulsa, OK); modules Basic statistics, Time series analysis and anova.

Results

Regardless the cutting intensity, each intervention caused a significant increase in radial increments (Table 3A). Significant increases of increments ($P \leq 0.05$) were recorded almost in all social groups and at all selected positions on the stem (Tables 3B, C). The biggest positive increment response was recorded on the plot H (stocking reduction to 0.3) where the increments increased almost 2 times, on average (Table 3A). On the plots M and L (stocking reduction to 0.5 and 0.7), a linear decrease of positive increment response with decreasing cutting intensity was also recorded. An increment increase on the plot M was 64.6% and on the plot L 19.4%. In the case of the control plot C (without intervention), we expected that the relative change in radial increments would not significantly differ from 0. Nevertheless, there occurred a significant ~10% decrease that can be related to very unfavourable, dry wetter in years 1992 and 1993. Moreover, the higher competition pressure caused worsening of tree social status of subdominant trees that showed lesser increments in comparison with the expected age trend.

Analysis of the sample tree increment responses on the plots subjected to cutting intervention (H, M, L) according to the tree social groups (Table 3B) shows that each social group had a statistically significant positive increment response to cutting interventions. The worse is the tree social status the more significant is its positive increment response. The increments in subdominant trees after the cutting were more than two times higher (109.1%). On the contrary, the smallest increments were recorded in the dominant trees (24.6%), for which the release meant only 4× smaller benefit. The mean increase of increments in co-dominant trees was 42.7% – app. two times more than in the dominant tress, on the other hand, only one half compared to the subdominant trees.

The analysis of radial increments according to the cutting intensity and tree social groups in their interaction (Table 4A, Fig. 2) showed that the increments significantly increased in all social groups on the plots H and M. The most significant response was observed in the suppressed subdominant trees that increased their increments by 199.7 and 138.4%, respectively. From the practical viewpoint, however, the increase by 24.5 and 20.6% in dominant and the increase by 60.0 and 22.2%, in co-dominant trees is much more important – both concentrated in the lower stem parts. On the plot L we can observe a significantly positive increase in increments on the dominant and co-dominant sample trees (28.8 and 43.7%, respectively). However, we did not observe a positive impact of the cutting on the subdominant sample tree in which the increments decreased by 8.6%. This decrease is comparable to the sample trees on the control plot C, in general showing decreases up to 13.7%, caused primarily by adverse climate conditions in the years 1992 and 1993.

Table 3. Changes in radial growth on annual ring indexes before and after cutting: cutting intensity (A), social status (B), different stem part (C)

Treatment		Number of annual ring indexes		Mean annual ring index		Relative change [%]
		before cutting	after cutting	before cutting	after cutting	
A	Cutting intensity (Plot)					
	high (H)	229	69	1.039	2.057	**98.0***
	medium (M)	259	69	1.033	1.700	**64.6**
	low (L)	259	69	1.043	1.245	**19.6**
	control (C)	259	69	1.030	0.932	**–9.5**
B	Social status					
	dominant	239	72	1.010	1.258	**24.6**
	codominant	229	63	1.003	1.431	**42.7**
	subdominant	279	72	1.092	2.283	**109.1**
C	Stem part					
	lower	269	69	1.061	1.974	**86.1**
	middle	259	69	1.046	1.659	**58.6**
	upper	219	69	1.002	1.368	**36.5**

*Bold letters represent statisticaly significant differences in annual ring indexes before and after cutting ($P \leq 0.05$).

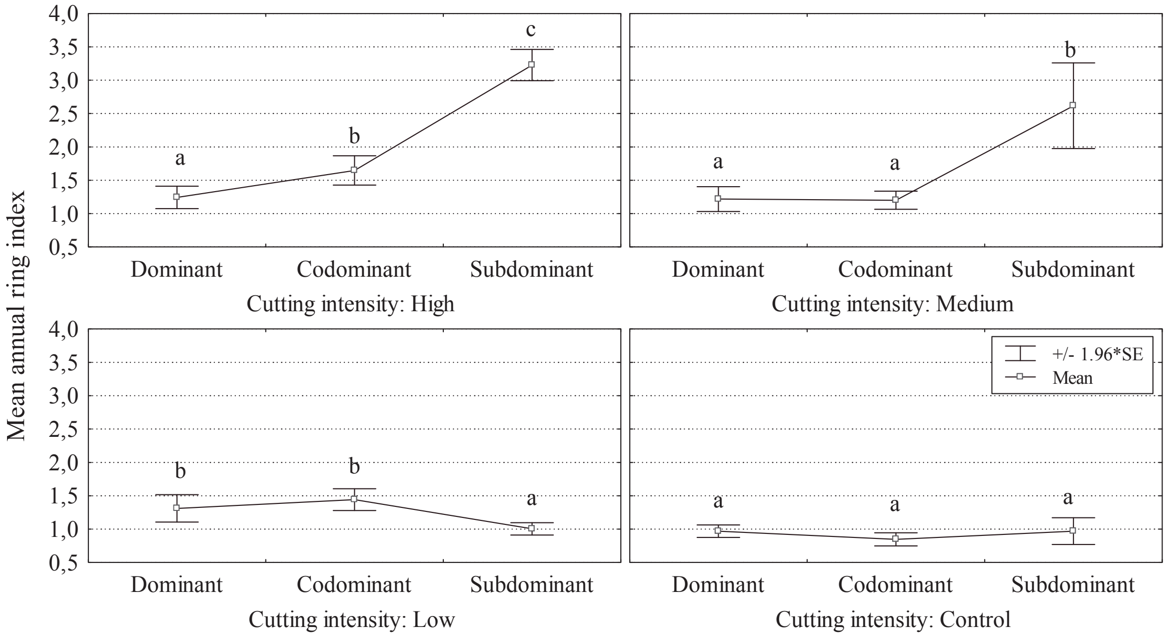

Fig. 2. Differences in mean annual ring indexes among different cutting intensity (H, M, L, C see Table 1) and social status. Different letters indicate statistically significant differences between the means; Duncan's test applied ($P \leq 0.05$).

Increment responses in dominant and co-dominant trees growing on the plots H, M and L are rather similar (Table 4), which means, that they are not close connected with the intensity of the cutting. A significant difference between the values of annual ring indexes in dominant and co-dominant trees on the plots subjected to cutting (H, M and L) was only found on the plot H (Fig. 2). Nevertheless, there are considerable differences between the lengths of enhancement increment period (Fig. 1). On the plots M and H were observed annual ring indexes considerably exceeding a value of one even after the growth depression in 1993, and they increased up to the end of the studied 7 or 8-year period after the cutting. This period of a higher increment was found through the whole stand profile, in all social groups. However, on the plot L we only detected a short 3 year period of positive increment reactions and, after the growth depression in 1993, the increment magnitude has not significantly over-passed the common age trend. The increment increase has not encompassed the whole stand profile, only dominant and co-dominant trees. On the other hand, the increment response in the first three years following the cutting was considerable. In spite of the fact that the increase proceeded for only a short time (three years), the impact of the annual rings in 1990-92 caused that the mean indexes of annual rings over the whole studied 7 (8)-year period are comparable with the mean indexes of the sample trees grown on the plots subjected to a heavier cutting treatment.

The evaluation of increment response corresponding to the individual stem parts is similar to evaluation according to the social groups: a statistically significant positive increment response to the cutting was observed in each stem part (Table 3C). The magnitude of increment enhancement decreased with increasing position on the stem; the differences between the enhancements were statistically significant. The highest positive response was identified in the lower stem parts (up to 86.1%), lower in the medium parts (58.6%) and the lowest in the upper parts (36.5%).

Interesting results were obtained after an analysis of the radial increment response according to the social groups and individual stem parts in their interaction (Table 4B). The most significant positive increment response was observed in lower parts of the subdominant trees (an increase up to 2.5 times), what well corresponds to the knowledge about the most pronounced increment response in suppressed subdominant trees and lower stem parts. In a similar manner, dominant trees also allocate the major part of their increments in the medium and lower stem parts; on the other hand, the upper parts remain without any substantial impact by the cutting intervention. Interesting situation is in the category of co-dominant trees, which show the increment uniformly distributed in all stem parts.

The interactions between the cutting intensity and the stem parts are not unambiguous (Table 4C), in spite of the expectations that the higher cutting intensity would shift the positive increment response to lower stem parts as it was observed on the plot M and partially L. There are contrary changes in increment allocation along the stem, in the plot C.

Discussion

The radial growth responses to the shelterwood cuttings of different intensity were evidently positive, in spite of the higher age of beech trees (100 years). Releasing of the tree crowns connected with a higher light supply and lowered competition for water and nutrients was reflected in a statistically significant increase in width of the annual rings in the years after the cutting treatment. Significant changes were recorded regardless the cutting intensity, almost in all social classes and stem parts. This effect has been known for a long time and it is described in the silviculture literature as light increment (Assmann, 1970; Nyland, 2002). Within the shelterwood system, it is applied in order to support the increments of the most quality trees in the mature stand over the regeneration period (Korpeľ et al., 1991; Schütz, 1999). The purpose is to reach a higher production value and, in such a way, to outweigh the higher expenses connected with the shelterwood cutting compared to clear-cut management (Holgén et. al., 2003).

Information about the magnitude of positive increment changes in mature stands is quite scarce. Certain information can be drawn from long-term dendrochronological reconstructions of growth history in the individual trees; however, commonly without an exact specification of the stand density or degree of the crown release and without any information about the cause of this release (Biondi, 1993; Nowacki and Abrams, 1997; Tokár and Krekulová, 2005). From the similar studies, we can mention the work Holgén et al. (2003), who recorded on the dominant trees in 140 year old spruce stands app. 40–48% increment enhancement as the response to the two types of shelterwood cutting (so called light and dense shelterwood cutting reducing the basal area of the mature stand to 50% and 75%, respectively). Latham and Tappeiner (2002) report that old co-dominant conifers (age ranging 158–650 years) in the Oregon area increased their radial increments after a lighter shelterwood cutting by 10% in 68% of cases and more than 50% in 30% of cases. Nowacki and Abrams (1997) detected an app. 25% increase in increments in the ancient oaks. Bebber et al. (2004) found for *Pinus strobus* L. a mean positive increment response up to 60% over the period of 9 years after shelterwood cutting, from which more than one half of the trees showed the responses over 100%, which is considered as a big increment response in the dendrochronology according to Lorimer and Frelich (1989).

The results of our research revealed a linear dependence between the positive increment responses and the cutting intensity. The stocking reduction by 0.1 (10%) induced a mean increase in the radial increment by about 17.5%. Increases in the radial increments occurred immediately the next year after the intervention (1990, Fig. 1). No negative effect (cutting shock) due to the sudden change in light conditions was detected (North et al., 1996). Equally, it has not been detected even time-delayed increment response triggered by the supposed transition period necessary for adaptation to the new microclimatic conditions; not even in the suppressed subdominant trees (Holgén et al., 2003; Latham and Tappeiner 2002; Shifley, 2004). The duration of positive increment response is also dependent on the cutting intensity. The plots H and M subjected to heavy and medium cuttings showed positive increment responses over the whole 8-year period after the intervention (except unfavourable years 1993 and 1994).

Table 4. Changes in radial growth (annual rings and ring indexes) before and after cutting, dependent on cutting intensity and social status (A); social status and different parts of stem (B); part of stem and cutting intensity (C)

Treatment			Number of annual rings		Mean annual ring (mm)		Standard deviation		Mean annual ring index		Relative change [%]
			before cutting	after cutting	before cutting	after cutting	before cutting	after cutting	before cutting	after cutting	by ring index
A	Cutting intensity	Social status									
	high (H)	dominant	73	24	2.404	2.614	0.568	0.854	0.998	1.243	**24.5***
		codominant	63	21	1.876	2.161	0.688	0.714	1.030	1.648	**60.0**
		subdominant	93	24	0.671	2.813	0.500	0.581	1.077	3.228	**199.7**
	medium (M)	dominant	83	24	2.665	3.069	0.890	1.511	1.011	1.219	**20.6**
		codominant	83	21	2.585	2.396	0.744	0.683	0.982	1.200	**22.2**
		subdominant	93	24	0.868	0.724	0.521	0.423	1.098	2.618	**138.4**
	low (L)	dominant	83	24	2.799	1.827	1.171	0.729	1.018	1.311	**28.8**
		codominant	83	21	2.202	2.367	0.591	0.744	1.004	1.443	**43.7**
		subdominant	93	24	1,080	0.402	0.525	0.126	1.100	1.005	–8.6
	control (C)	dominant	83	24	2.814	2.308	0.605	0.504	1.010	0.969	–4.1
		codominant	83	21	1.798	1.399	0.473	0.421	0.981	0.847	**–13.7**
		subdominant	93	24	0.878	0.239	0.532	0.109	1.090	0.970	–11.0
B.	Social status	Part of stem									
	dominant	lower	93	24	2.917	3.022	0.953	1.185	1.045	1.493	**42.9**
		middle	83	24	2.759	2.421	0.764	0.954	0.985	1.292	**31.2**
		upper	63	24	2.219	1.921	0.659	0.714	0.990	0.989	–0.1
	codominant	lower	83	21	2.012	2.246	0.615	0.738	1.009	1.394	**38.2**
		middle	83	21	1.980	1.990	0.598	0.711	0.982	1.458	**48.5**
		upper	63	21	2.173	2.006	0.770	0.824	1.023	1.440	**40.8**
	subdominant	lower	93	24	0.909	1.323	0.479	1.233	1.123	2.963	**163.8**
		middle	93	24	0.773	0.983	0.417	1.073	1.157	2.203	**90.4**
		upper	93	24	0.942	0.827	0.672	0.960	0.995	1.684	**69.2**
C.	Part of stem	Cutting intensity									
	lower	high (H)	23	83	1.713	0.903	3.055	0.777	1.120	2.320	**107.1**
	middle		23	73	1.427	0.909	2.432	0.592	1.103	2.011	**82.3**
	upper		23	73	1.504	1.039	2.149	0.632	0.882	1.839	**108.5**
	lower	medium (M)	23	93	1.970	1.237	2.604	1.500	1.006	2.344	**133.0**
	middle		23	93	1.901	0.962	2.120	1.402	1.028	1.704	**65.8**
	upper		23	73	1.772	0.958	1.422	1.099	1.074	1.051	–2.1
	lower	low (L)	23	93	2.279	1.235	1.700	1.134	1.062	1.257	**18.4**
	middle		23	93	1.997	1.045	1.433	0.993	1.018	1.262	**24.0**
	upper		23	73	1.6015	0.770	1.354	0.940	1.050	1.215	15.7
	lower	control (C)	23	93	1.790	0.861	1.422	0.960	1.000	0.822	**–17.8**
	middle		23	93	1.821	1.080	1.172	0.851	1.032	0.959	–7.1
	upper		23	73	1.769	0.936	1.341	1.051	1.064	1.016	–4.5

*Bold letters represent statisticaly significant differences in annual ring indexes before and after cutting ($P \leq 0.05$).

This result well corresponds to the knowledge in literature. Korpeľ et al. (1991) reports that the influence of a release maintains quite long, in fir and beech trees up to 30 years. Shifley (2004) reports a similar value – up to 20 years for oak stands. On plot L with low cutting intensity was the period of increased increment only 2–3 years; a similar response in the dominant and co-dominant trees was also found in the longitudinal increments on branches of the studied sample trees (Barna, 1999, 2000).

The magnitude of positive increment responses has been considerably influenced by the tree social status (Table 3, 4). In the category of dominant and co-dominant trees, there were no significant differences in the size of positive increment responses. Regardless the cutting intensity, the magnitude of positive increment response was ~25% in dominant trees and ~45% in co-dominant trees. According to the knowledge from the literature, the individual tree increment increases with the increasing growing space, until a certain saturation point is reached. After having exceeded this limit, there is no change in tree increment, the tree is provided with maximum usable energy supply (Utschig, 2002). This fact has been confirmed in the case of dominant and co-dominant trees. The crown releasing in dominant and co-dominant trees led to a rapid exceeding of the saturation point; consequently, there was no additional advantage for the trees growing on the plots M and H that show the positive growth responses comparable to the responses in trees growing on the plot L.

On the other hand, in the case of slight intervention into canopy, as it was the light shelterwood cutting on the plot L or any thinning from above not exceeding the critical stocking (for beech 0.6–0.7), there is no increment response in the subdominant trees. Dhote (1994) found that even after a removal of a lot of large, dominant trees by heavy thinning from above, there was no improvement of growing conditions for the subdominant trees (primarily light supply). Consequently, he concludes that the vertical structure of beech – a species with very dense foliage – is not very sensitive to cutting treatments, in terms of differentiation according to light availability. That is the probable reason to why most silvicultural instructions recommend to begin a shelterwood regeneration with a total removal of the subdominant trees (Nyland, 2003). Subdominant trees do not seem to respond to release of the upper tree layer – because the usually recommended reduction of stand density in the initial phases of shelterwood regeneration should not exceed the critical stocking (Korpeľ et al., 1991).

Analysis of the increment allocation along the stem revealed that the bigger increments were created on the lower stem parts, namely on the plots with a higher cutting intensity and in the dominant and subdominant trees (Fig. 1). On the plot L with a low cut, the trees did not show any significant changes in allocation of the increased increments along the stem. That corresponds to the observations made by Korpeľ et al. (1991) and Saniga (2000) according whom a lighter shelterwood cutting has no significant impact on the stem taper. Increased increments in the lower stem parts in the trees strong loaded by wind and by their own crown mass, after a sudden release, were frequently observed (Mitchell, 2000; Šmelko, 1982). In such cases, the trees respond to the growing space not only through increased increments; but also, according to the mechanical theory of the stem shape because of an increase of the mechanical stability, it puts them in the lower stem parts (Brüchert et al., 2000; Holgén et al., 2003). Both facts were well observable on the plots H and M treated with a heavier cutting. Overall, the significant changes in the stem shape are possible even in the advanced tree age. The cuttings could significantly deteriorate the stem taper. This fact can cause an overestimation of the tree volume and growing stock in the mature stand in later phases of the shelterwood cutting, what is especially important for the dominant trees that are the main production carriers in later phases of the shelterwood regeneration (Wenk et al., 1990).

Specific results were obtained in the category of co-dominant trees with increments distributed uniformly along the stem. Co-dominant trees are a transition social group from the viewpoint of success in competitions for the growing space. In comparison with the subdominant trees, they are able to gain a sufficient growing space and to allocate the increased increments in the lower stem parts, as required by the tree stability; on the other hand, the measure of crown suppression is considerably higher in comparison with the most successful dominant trees. Consequently, a cutting intervention into the canopy releases relatively suppressed crowns, substantially enhances their leaf area and causes remarkably enhanced increments in the crown, i.e. upper stem parts. Increased increments need not be allocated in the lower stem parts because the overstory trees can statically support each other.

Conclusions

Research on the radial increment response in the model beech stand to the different intensities of the initial shelterwood cuttings and study of the influence of the tree social status on the radial growth responses in different stem parts was the main intention of the presented study.

Dendrochronological analysis of the radial growth responses indicates that after the application of the classic seed cut of a low intensity (plot L, residual stocking 0.7), effect of the increased increments was evident only on the dominant and co-dominant trees and for three years.

The high initial cutting (plot H, residual stocking 0.3) fully maximises effects of the light increment –

increased increments were observed in all social groups and they proceeded over the whole period after the cutting (7–8 years).

Effect of the light increments on the plot M (residual stocking 0.5) has been maximised. It has been proceeding over the whole period after the intervention. The light increments in the dominant and co-dominant trees are comparable with the plot H and, unlike on the plot L, an increased increment creation is also evident in the subdominant trees. Number of the trees with the highest production is considerably higher than on the plot H (Table 1); consequently, it is possible to suppose a much higher increase in the total production value. The felling costs are comparable to the plot H because a stronger preparation cutting enables the concentration of regeneration cuttings into two phases (required by the regeneration success).

The study results present possibility to increase initial cutting intensity within the shelterwood regeneration in the unmixed even-aged beech stands in order to increase radial increments. Based on the obtained results, for mature beech stands growing in the mentioned natural conditions, we can recommend the shortened two-phase shelterwood system with heavier seed cutting. The application of the mentioned regeneration strategy should meet all silvicultural targets connected with regeneration and survival of young stands and it also enables maximisation of the production value for mature stands.

Acknowledgement

Supported by the Scientific Grant Agency – VEGA, Grants No. 2/0055/10, 1/0534/09.

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Odozva radiálnych prírastkov u buka na intenzitu clonného rubu

Súhrn

Štúdia bola založená na dendrochronologickej analýze radiálnych prírastkov na kotúčových výrezoch, odobratých z 3 častí kmeňa (horná, stredná, dolná) vzorníkov. Bukové vzorníky, ktoré reprezentovali stredné kmene stromových tried boli spílené a analyzované 8 (7) rokov po aplikácií clonného rubu rôznej intenzity (plochy: H – silný ťažbovo-obnovný zásah, zakmenenie 0,3; M – stredný, 0,5; L – mierny, 0,7 a C – kontrolná plocha, bez zásahu, 0,9). Pokles hustoty porastu vyvolal signifikantné zväčšenia radiálnych prírastkov bukových stromov aj vo vyššom fyzickom veku (priem. 100 rokov), a to vo všetkých sociálnych skupinách a vo všetkých výškach na kmeni. Zníženie zakmenenia o 0,1 prinieslo lineárne zväčšenie radiálneho prírastku priemerne o 17 %. Vplyv sily zásahu najlepšie dokumentovali podúrovňové stromy, ktoré zareagovali na presvetlenie najvýraznejšie (zväčšenie prírastkov až do 200 %). Pri predrastavých stromoch sa zväčšenia prírastkov pohybovali okolo 25 % a pri úrovňových 45 %. Prírastky sa vo zvýšenej miere ukladali v spodných častiach kmeňov, najmä na plochách po silnejších zásahoch a pri nadúrovňových a podúrovňových stromoch. Dĺžka trvania kladných prírastkových reakcií bola závislá od sily ťažbového zásahu, napr. na ploche so zakmenením 0,3 (H) trvali kladné prírastkové reakcie celé 8 (7)-ročné obdobie po zásahu, v celom porastovom profile, ale na ploche so zakmenením 0,7 (L) trvalo obdobie zvýšeného prírastku iba 2–3 roky a rast podúrovňových stromov nebol ovplyvnený vôbec.

Received May 20, 2010
Accepted September 30, 2010

FOLIA OECOLOGICA – vol. 37, no. 2 (2010). ISSN 1336-5266

Preliminary evaluation of insect-pathogenic Hypocreales against *Leptoglossus occidentalis* (Heteroptera: Coreidae) in laboratory conditions

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Abstract

Barta, M. 2010. Preliminary evaluation of insect-pathogenic Hypocreales against *Leptoglossus occidentalis* (Heteroptera: Coreidae) in laboratory conditions. *Folia oecol*., 37: 137–143.

Leptoglossus occidentalis, a species native to North America, is considered a major pest of conifer seed orchards in its natural area of distribution. Recently, the seed bug was accidentally introduced into southern Europe and its populations have been expanding throughout Europe. In the course of population study of this seed bug in Slovakia, two entomopathogenic fungi were identified from dead individuals, *Isaria fumosorosea* and *Beauveria bassiana*. In the present study, we evaluated pathogenicity of six indigenous isolates of three entomopathogenic fungi, *B. bassiana*, *I. fumosorosea* and *Metarhizium anisopliae*, to adults of the exotic coreid bug under laboratory conditions. All the isolates were virulent to the seed bug, but pathogenicity varied significantly among the isolates. Generally, isolates obtained from naturally infected *L. occidentalis* were more virulent than those isolated from soil samples. The LC_{50} values, as estimated by probit analysis, ranged from 0.86 to 84.68 × 10^5 conidia/ml and *I. fumosorosea* isolates reached the lowest median lethal concentrations. The results of this bioassay showed that *I. fumosorosea* a has potential as a microbial control agent of *L. occidentalis*.

Key words

Hypocreales, natural enemies, virulence, western conifer seed bug

Introduction

Leptoglossus occidentalis Heidemann (Heteroptera: Coreidae), the western conifer seed bug, is a species native to North America, is considered a major pest of conifer seed orchards (McPherson et al., 1990). This seed bug was first described from California in 1910 (Bernardinelli and Zandigiacomo, 2001) and since the second half of the last century its populations have been expanding eastward from its natural habitat on the west coast of North America (McPherson et al., 1990; Wheeler, 1992). In 1999, it was recorded from Europe, near the town of Vicenza in northern Italy, for the first time (Tescari, 2001). This first European record was soon followed by finds in further localities in Italy and other countries throughout Europe (e.g. Bernardinelli and Zandigiacomo, 2001, 2002; Gogala, 2003; Moullet, 2006; Aukema and Libeer, 2007; Lis et al., 2008). In Slovakia, the occurrence of the western conifer seed bug was studied in collections of conifers in the Arboretum Mlyňany SAS as well as in parks and public greenery of several settlements in south-western Slovakia during the summer 2008. During the survey, the seed bug was recorded feeding on 18 conifer species (Barta, 2009). In Slovakia, an appearance of natural enemies in population of this exotic species was also studied and two entomopathogenic fungi were identified from collected individuals; they were *Isaria fumosorosea* Wize and *Beauveria bassiana* (Balsamo) Vuillemin (Barta, 2009). In the literature, there is only limited information about activity of the entomopathogenic fungi in the populations of the seed bug. The

Slovak findings are probably the first records of natural infection of *L. occidentalis* by these fungi. However, in laboratory conditions this seed bug showed a susceptibility to an artificial inoculation with *B. bassiana* (Rumine and Barzanti, 2008).

The hypocrealean entomopathogenic fungi are ubiquitous organisms attacking various arthropods by causing acute mycoses. They can spread fast among insect populations horizontally via aerially produced conidia and infect its host by penetration of the cuticle with germ hyphae. After crossing the insect integument, the fungi grow within the internal fluids, sponging degraded proteins and fat bodies, and produce toxins which kill the host. After the host's death, the mycelium grows throughout the cadaver and protrudes outside completing the life cycle by rich conidial sporulation (Hajek and St Leger, 1994). Many strains of entomopathogenic fungi have been isolated and tested on different pests in a variety of cropping systems (e.g. Legaspi et al., 2000; Leland et al., 2005; Pu et al., 2005; Liu and Bauer, 2008). Selected strains have been successfully licensed for commercial use against whiteflies, aphids, thrips and numerous other insect pests in recent years (Shah and Pell, 2003). However, until now, the development of microbial control agents for *L. occidentalis* attracted only little attention (Rumine and Barzanti, 2008).

The main objective of this study was to evaluate the pathogenicity of indigenous Slovak isolates of hypocrealean insect-pathogenic fungi against the exotic coreid bug, *L. occidentalis*. Under laboratory conditions, we determined the susceptibility of adults to six fungal isolates belonging to three fungal species.

Material and methods

Insects

Adult individuals of *L. occidentalis* used in the bioassay were collected by sweep netting in the Arboretum Mlyňany SAS (48°19'12" N, 18°22'09" E) in Slovakia. All collected individuals were placed in a rearing cage (300 × 300 × 400 mm covered with fine nylon fabric) in the laboratory at 20 ± 2°C and 70 ± 10% relative humidity (RH) with a natural photoperiod. They were kept in the cage until their use in the bioassay (usually no longer than 48 h) and provided with fresh food (Douglas-fir cones).

Fungal isolates

The origin and hosts of 3 isolates of *B. bassiana*, 2 isolates of *I. fumosorosea* and 1 isolate of *M. anisopliae* used in this study are given in Table 1. The fungi were cultivated on Sabouraud-dextrose agar (SDA) in Petri dishes and incubated at 25 ± 2°C with a 16/8 (L/D) photoperiod. Aerial conidia were harvested from 15-day-old cultures and suspended in 100 ml of sterile distilled

Table 1. Fungal isolates assayed against adults of *L. occidentalis*

Beauveria bassiana	
Isolate	SUA a38
Host	*Galleria mellonella* (L.) (Lepidoptera: Pyralidae) as bait from soil
Site and date of origin	Slovakia (48°17'55.86" N, 19° 3'13.54" E), 2008
Isolate	SUA b38
Host	*G. mellonella* (L.) (Lepidoptera: Pyralidae) as bait from soil
Site and date of origin	Slovakia (48°07'43.62" N, 17°47’’03.85" E), 2008
Isolate	AMSAS 03
Host	*L. occidentalis* Heidemann (Heteroptera: Coreidae)
Site and date of origin	Slovakia (48°19'12.66" N, 18°22'08.51" E), 2009
Isaria fumosorosea	
Isolate	SUA f84
Host	*G. mellonella* (L.) (Lepidoptera: Pyralidae) as bait from soil
Site and date of origin	Slovakia (48°17'55.86" N, 19°33'13.54" E), 2008
Isolate	AMSAS 06
Host	*L. occidentalis* Heidemann (Heteroptera: Coreidae)
Site and date of origin	Slovakia (48°19'12.66" N, 18°22'08.51" E), 2009
Metarhizium anisopliae	
Isolate	SUA d26A
Host	*G. mellonella* (L.) (Lepidoptera: Pyralidae) as bait from soil
Site and date of origin	Slovakia (48°17'29.55" N, 18°07'20.80" E), 2008

water with 0.05% (v/v) Tween 80 (Sigma-Aldrich, India). The conidial suspensions were filtered through several layers of cheesecloth to remove mycelial mats. Conidial concentrations were adjusted to 1 × 10^8 conidia ml^{-1} (stock suspensions). Conidia in the suspensions were quantified by direct counting with an optical microscope using an improved Neubauer chamber. Viability of conidia was assessed before preparing of final suspensions in germinating tests. The stock suspensions (0.5 ml) for each isolate were pipetted on an SDA plate and incubated at 20 °C. After 24 h the rate of conidial germination was determined by counting 100 conidia in four different fields of view (400 spores per plate, magnification = 500×). The conidia were categorised into two groups: viable conidia identified by production of germ tubes, and non-germinating conidia. Only conidia with a germ tube longer than its width were considered germinated. Only fungal cultures in which more than 90% of the conidia germinated used in the bioassay.

Laboratory bioassay

For all test isolates, five aqueous suspensions were prepared from the stock in a logarithmic series from 1 × 10^8 to 1 × 10^4 conidia ml^{-1} in Tween 80 (0.05%, v/v). The concentrations were determined based on pre-tests, in which a concentration that would kill about 10% and another that would kill 90% of treated insects was identified. The other concentrations used were distributed between these extremes. For each concentration, a group of 20 *L. occidentalis* adults were treated by direct immersion in the conidial suspension for 10 s. A further 40 adults were immersed in 0.05% Tween 80 (v/v) alone as controls. The treated and control insects were incubated in groups of 20 in transparent polypropylene boxes (500 ml) for a period of 10 days at 23 ± 2°C, saturated RH and with a natural photoperiod. The test insects were observed at 24-h intervals to record mortality and fresh food (a Douglas-fir cone) was changed at 2-day intervals. All dead individuals were surface sterilised in a sodium hypochlorite solution (1%, w/v) for 30 s, rinsed twice in sterile distilled water and incubated individually in Petri dishes containing water agar (2%, w/v) for 7 days to stimulate development of mycosis and confirm infection by the test fungi. The bioassay was repeated 3 times at intervals of 1 week for all isolates.

Statistical analysis

Cumulative percentage mortality data from the bioassay (10 days after treatment) were corrected for natural mortality using Abbott's formula (Abbott, 1925) and analysed with the Probit analysis (Finney, 1971) in Minitab 14® (© 2004 Minitab Inc.) to estimate LC_{50} for each isolate. Analysis of variance (Anova) was used to determine the significant differences between the treatments. Tukey's HSD multiple comparison followed if significant differences were detected.

Results

Three isolates of *B. bassiana*, two isolates of *I. fumosorosea* and one isolate of *M. anisopliae* were screened for their virulence to adults of *L. occidentalis* in the laboratory. The basic measure of virulence generated in this study was the median lethal concentration (LC_{50}) expressed as conidia ml^{-1} of test suspension and based on mortality recorded 10 days post-inoculation. Our results indicate that the western conifer seed bug adults are sensitive to isolates of all the three hypocrealean fungi tested. In general, the percentage mortality of experimental insects increased with the concentration of conidia in the suspensions what allowed to estimate a median lethal concentration. Figure 1 shows the percentage mortality caused by the fungal isolates at different rates of conidial concentration. LC_{50} values for adult *L. occidentalis* are presented in Table 2. High inter-specific variability was recorded in virulence of test isolates and significant differences occurred among them ($F_{5.06} = 49.39$, $P < 0.01$). The LC_{50} values, as estimated by probit analysis, ranged from 0.86 to 84.68 × 10^5 conidia ml^{-1}. The mean spore viability of the test isolates was 91.00 ± 0.70% – 97.00 ± 0.91% (Table 2) during laboratory bioassays with significant differences among the five test isolates ($F_{4.25} = 5.47$, $P < 0.01$). However, no significant relationship was observed between conidial viability and median lethal concentration of the five isolates ($R^2 = –0.186$, $P = 0.72$). Mortality in the control groups ranged from 0 to 10% ($\bar{x}$ = 3.06 ± 0.90%, $n = 18$). The lowest LC_{50} values were obtained for *I. fumosorosea* isolates and the estimated LC_{50} for these isolates were significantly lower ($P < 0.05$), when compared with the remaining isolates. The least virulent isolate was that of *B. bassiana* species, isolate SUA a38. Virulence of *B. bassiana* isolates ranged from 10.35 to 84.68 × 10^5 conidia ml^{-1} and high intra-specific variation was observed. The intra-specific difference among *B. bassiana* isolates was statistically significant ($P <$ 0.05), however significant variability was not detected between *I. fumosorosea* isolates ($P > 0.05$). Generally, isolates obtained from naturally infected *L. occidentalis* (AMSAS 03 and AMSAS 06) were more virulent than those of the same fungal species but isolated from soil samples. Probit regression slopes in these assays varied from 0.20 to 0.50.

Discussion

The three fungal species tested in the present study are considered facultative insect pathogens (Bidochka et al., 2002; Cory and Ericsson, 2010) and we successfully

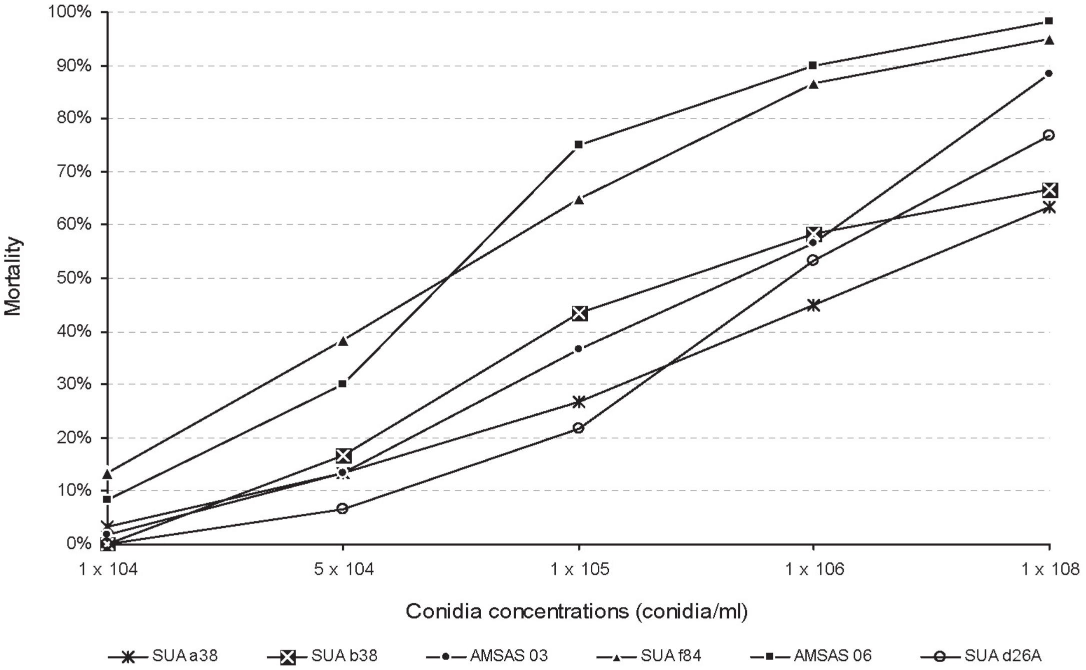

Fig. 1. Mean percentage mortality of *L. occidentalis* adults at different levels of conidia concentration 10 days after exposure to the six test isolates of entomopathogenic fungi in the laboratory bioassays.

Table 2. Probit analysis results for test isolates against adults of *L. occidentalis* evaluated 10 days after exposure to conidial suspensions

Isolate	LC$_{50}$ (x 105)[a]	95% fiducial CI (x 105)[a]	Slope ± SE	X^2[b]	P	Conidial viability
Beauveria bassiana						
SUA a38	84.68 d[c]	33.41–306.57	0.20 ± 0.03	2.38	0.000	91.50 ± 0.65% ab[c]
SUA b38	27.52 b	11.98–79.73	0.20 ± 0.02	2.08	0.000	97.00 ± 0.91% d
AMSAS 03	10.35 a	5.85–19.98	0.31 ± 0.03	3.60	0.000	92.50 ± 1.19% ab
Isaria fumosorosea						
SUA f84	1.08 a	0.63–1.83	0.34 ± 0.04	1.99	0.000	95.50 ± 1.44% cd
AMSAS 06	0.86 a	0.59–1.25	0.50 ± 0.06	3.36	0.000	91.00 ± 0.70% a
Metarhizium anisopliae						
SUA d26A	47.13 c	23.38–108.13	0.30 ± 0.03	3.61	0.000	94.00 ± 0.91% bc

[a]Values of median lethal concentration and 95% fiducial confidence intervals are expressed in conidia per millilitre.
[b]Pearson chi-square goodness-of-fit test on the probit model ($\alpha = 0.05$, df = 3).
[c]Values followed by the same letter in the column are not significantly different (95% Tukey's HSD test).

demonstrated their pathogenicity to the coreid bug, *L. occidentalis*. In the laboratory assays, we showed that adults of the western conifer seed bug are susceptible to all the test fungal species, although virulence varied greatly among the isolates. Based on data presented in this study, adults of *L. occidentalis* are significantly more susceptible to the isolates of *I. fumosorosea* than to the isolates of remaining two fungal species. The results showed that *I. fumosorosea* has a good potential to be considered a possible biological control agent of *L. occidentalis*. The use of entomopathogenic fungi in a pest management is not a new idea. The three fungal species tested in this bioassay are extensively studied. They are the most commonly used fungi for control of insect pests and form the basis of a number of commercially available pesticides (Shah and Pell, 2003). However, we did not find any studies determining pathogenic activity of the entomopathogenic fungi against *L. occidentalis* in the literature, except the preliminary results presented by Italian authors (Rumine and Barzanti, 2008). In the Italian bioassay, *B. bassiana* successfully manifested virulence to *L. occidentalis* under laboratory conditions. Several other coreid pest species were also tested for their susceptibility to entomopathogenic fungi. For instance, in Nicaragua, pathogenicity of *B. bassiana* and *M. anisopliae* was assessed against adults of another *Leptoglossus* species, *L. zonatus* Dallas, and application of these isolates was effective both in the laboratory and in field conditions (Grimm and Guharay, 1998). *B. bassiana* or *M. anisopliae* also successfully infected adults of other coreid bugs, *Riptortus linearis* (Fabricius) with LC_{50} of 1.1×10^6 conidia ml^{-1} (Hu et al., 1996), *Paradasynus rostratus* (Distant) (Mohan et al., 2001) and *Clavigralla tomentosicollis* Stål with LC_{50} ranging from 9.8×10^4 to 1.8×10^5 (Ekesi, 1999). According to data presented by the above authors, the hypocrealean entomopathogens have potential for their use in alternative control strategies of coreid bugs.

As observed in our bioassay, mortality of test insects increased with conidial concentration. Similar relationship is commonly observed in other dose-mortality studies (e.g. Hu et al., 1996; Ekesi, 1999; Eken et al., 2006; Rahman et al., 2010). We found out that conidial viability did not directly correlate with fungal virulence what was also observed for *B. bassiana* when tested against *Lygus lineolaris* (Palisot de Beauvois) under laboratory conditions (Liu et al., 2003). Mortalities in the control groups were low ($\bar{x}$ = 3.06%) in our bioassays confirming that the corrected mortalities obtained in the treatments were due to the pathogenicity of the entomopathogens rather than to other factors.

It is generally admitted that the most virulent fungal isolates are the ones isolated from the host (Papierok et al., 1984). This is true in many cases as some reported in works by Peña et al. (1996), Ekesi (1999), or Santoro et al. (2008), where fungal isolates that originated from particular insect species were more virulent to this species than those isolates obtained from other hosts. This was also the case in our study, where the most virulent isolates did originate from *L. occidentalis*.

In summary, these initial laboratory bioassays identified *I. fumosorosea* as a possible biological control agent of *L. occidentalis*. However, susceptibility of insects to entomopathogens demonstrated in laboratory usually do not relate to infection rate obtained in fields what pointing out differences between physiological and ecological susceptibility of insects. Therefore, further research is needed to verify *L. occidentalis* susceptibility in forest environment. As a matter of fact susceptibility relates to the physiology and behaviour of insect, which may encourage or discourage infection process. Moreover, since the entomopathogenic fungi are transmitted horizontally in the environment, they are depended considerably upon environmental conditions. Environmental factors may thus directly or indirectly influence host and pathogen populations as well as a means of inoculum transmission.

To our knowledge, this study is the first that demonstrate successful artificial inoculation of *L. occidentalis* with *I. fumosorosea* and *M. anisopliae*. According to our results, indigenous entomopathogenic mycoflora proved their capability of invading and killing this exotic coreid bug in the laboratory trials. However, additional field research is needed to determine how effective the test entomopathogens would be in controlling *L. occidentalis* populations under field conditions.

Acknowledgement

The author thanks J. Medo (Department of Plant Protection, Slovak University of Agriculture) for supplying of the following fungal isolates: SUA a38, SUA b38, SUA f84 and SUA d26A. This work was partly supported by the Slovak grant agencies VEGA, (project No. 2/0085/09) and APVV (project No. 0421-07).

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Predbežné výsledky hodnotenia entomopatogénnych húb z radu Hypocreales proti *Leptoglossus occidentalis* (Heteroptera: Coreidae) v laboratórnych podmienkach

Súhrn

Leptoglossus occidentalis, bzdocha pochádzajúca zo Severnej Ameriky, je považovaná za významného škodcu semenných porastov ihličnatých drevín v areáli svojho prirodzeného rozšírenia. V nedávnom období bola táto bzdocha náhodne zavlečená do južnej Európy a jej populácia začala expandovať do ostatných častí kontinentu. Počas prieskumu populácie bzdochy na Slovensku sme identifikovali na mŕtvych jedincoch dva druhy entomopatogénnych húb, *Isaria fumosorosea* a *Beauveria bassiana*. V tejto práci sme v laboratórnych podmienkach hodnotili patogenitu šiestich pôvodných izolátov troch entomopatogénnych húb, *B. bassiana*, *I. fumosorosea* a *Metarhizium anisopliae*, k dospelým jedincom tejto exotickej bzdochy. Všetky testované izoláty preukázali virulenciu voči bzdoche, jej miera však varírovala preukazne medzi jednotlivými izolátmi. Vo všeobecnosti, izoláty získané z prirodzene zabitých bzdôch *L. occidentalis* dosiahli vyššiu patogenitu než tie, čo boli izolované zo vzoriek pôdy. Hodnoty LC_{50} získané probitovou analýzou boli v rozsahu od 0,86 do 84,68 × 10^5 konídií ml^{-1} a izoláty druhu *I. fumosorosea* dosiahli najnižšie hodnoty strednej letálnej koncentrácie (LC_{50}). Výsledky laboratórnych pokusov naznačujú, že huba *I. fumosorosea* má potenciál ako mikrobiálny bioagens pre reguláciu bzdochy *L. occidentalis*.

Received June 23, 2010
Accepted August 12, 2010

FOLIA OECOLOGICA – vol. 37, no. 2 (2010). ISSN 1336-5266

Succesional development of vegetation on permanent plots in the High Tatra Mts

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Abstract

Chovancová, G., Križová, E. 2010. Succesional development of vegetation on permanent plots in the High Tatra Mts. *Folia oecol.*, 37: 144–151.

This paper deals with development of vegetation in the High Tatra Mts, following the wind storm on November 19, 2004. The issue has been discussed with data acquired from permanent plots established for this purpose on various windfall-affected sites allowing comparing among effects of various management treatments. The research plots series consists of a control plot unaffected by the windstorm (REF), a plot which the windthrown timber has been removed from (EXT), six plots affected by fire (FIR), a plot with windthrown timber, left to self-development (NEX), and a hydrologically managed plot (WTR). On these plots, phytosociological relevés were recorded from 2005 to 2008. The data were subjected to table analysis with using the Braun-Blanquet approach, and statistically processed with the CANOCO software. The communities were compared through PCA and CCA analyses. PCA has resulted in indicating as the most similar sites REF and NEX with typical forest plant species associated with moist, shady and cool sites, and acidic, nutrient-poor soils. The sites FIR, EXT and WTR showed opposite tendencies. Conditions typical for these sites were preferred by species indicating sunny and warm sites, richer in nutrients.

Keywords

CCA, Ellenberg indicator values, High Tatras Mts, PCA, succession, windfall

Introduction

For several decades, long-term changes in vegetation have become of considerable importance in ecological research, both theoretical and applied. An ecological succession is characterised by a distinctive course of structural and functional changes, as defined by Odum (1977) and other authors. A succession comprises several stages: initial, early, medium, and climax – forming a successional series. Individual stages differ in the species composition, spatial structure and environmental conditions (Križová et al., 2001). The development of vegetation after disturbances of forest ecosystems has been studied by several authors. Fischer (2002), for example, reports results from research plots established in 1988 in the Bavarian forest affected by windstorm. Neuhäuslová and Wild (2001) describe communities with dominant *Calamagrostis villosa* that represent the most common woodland clearing vegetation. Results of the research performed on the windfall plots in the High Tatras Mts were reported also by Šoltés et al. (2008). Papers devoted to vegetation dynamics emphasize the importance of herb vegetation as the bioindicator of medium-term and long-term changes in the forest ecosystems (Križová, 1996).

Material and methods

The initial data on permanent plots (Table 1) and phytocenological relevés recorded in 2005 and 2006 were taken over the from paper Šoltés et al. (2008). In 2007 and 2008, we collected phytosociological relevés from the same permanent plots (PPs) 20 × 20 m in area. The plots have been labelled as follows: REF – plot unaffected by the windstorm; EXT – wind-affected plot, windthrown timber removed; FIR – six plots affected by the fire, and NEX – wind-affected plot, windthrown timber kept – left to self-development; WTR – hydrologically managed plot (water was accumulated by little barriers), windthrown timber removed.

Phytosociological relevés on the above mentioned plots were made annually in July. Abundance and dominance of species were evaluated with the modified Braun-Blanquet scale (Barkman et al., 1964). The nomenclature follows Marhold and Hindák (1998). Phytosociological data were processed by table analysis (Braun-Blanquet, 1964). For the synthesis, however, was selected only the FIR site, plot 4 (Table 1), because this plot was the most similar to the other study plots in site conditions. There were processed herb layer species, moss layer species and woody plants up to 1.5 m in height from the natural regeneration. In the next step were applied Principal components analysis (PCA) and Canonical correspondence analysis (CCA), the CANOCO for Windows software (Ter Braak and Šmilauer, 1998) working with the percentage of species cover. The results were interpreted through ecological factors (light, temperature, continentality, soil reaction and nutrients) calculated as Ellenberg´s indicator values (EIV) (Ellenberg et al*.*, 1992).

Results and discussion

In comparison with the other plots, changes on the REF plot were slow and successional. The herb layer (including regenerated woody plants) consisted of species typical for the natural larch-spruce forest communities (group of forest types Lariceto-Piceetum): *Sorbus aucuparia, Picea abies, Larix decidua, Vaccinium myrtillus, Avenella flexuosa, Calamagrostis villosa, Maianthemum bifolium, Luzula sylvatica, Oxalis acetosella, Vaccinium vitis-idaea, Dryopteris dilatata, Melampyrum sylvaticum* and abundant moss layer. On the other hand, mosses, namely *Ptilium crista-castrensis, Polytrichum commune, Blepharostoma trichophyllum, Dicranum montanum*, *Hylocomnium splendens* and *Plagiomnium affine* were either missing or occurred very rarely on the other PPs (EXT, WTR, NEX, FIR). In the E_1 layer on REF plot, *Dryopteris filix-mas, Homogyne alpina, Gentiana asclepiadea, Trientalis europaea* were differential species missing on the other plots. The phytosociological Table 2 shows development of species composition and percentage on particular plots from 2005 to 2008, and the floristic differentiation of the plots. The NEX plot was the least floristically differentiated, and it was the most similar to the control REF plot. The significant increase in species diversity on the other PPs (EXT, WTR, FIR) was caused by the occurrence of clear-cut species and other heliophilous species such as *Chamerion angustifolium, Senecio viscosus, Taraxacum officinale, Senecio nemorensis* agg*.*, *Hieracium murorum, Rumex acetosella, Calamagrostis arundinacea, Veronica officinalis, Carex leporina,* pioneer tree species *Betula carpatica, Salix caprea*, and others. The above mentioned species were either missing or occurred very rarely on the control plot (REF). Some of them were found on the NEX site. Within the last two years, the expansion of *Calamagrostis villosa* was recorded on each plot (except of the FIR plot).

The results of PCA analysis (Fig. 1) showed the tendency of common occurrence of species and the floristic similarity of plots. The dependence of species on light, temperature and nitrogen content in soil is evident. The intensity of the above mentioned factors was influenced by management treatments. According to the second principal axis in the Figure 1, the typical forest species (herbs, mosses, and woody plants) such as *Vaccinium myrtillus, Vaccinium vitis-idaea, Maianthemum*

Table 1. Plots (20 × 20 m) established in 2005 and 2006 by the Research Station of TANAP (The High Tatras National Park)

Research site	Plot [No]	Locality	N	E	Altitude [m]	Inclination	Aspect
REF	1	Smrekovec	49º07.29'	20º06.23'	1,228	3º	S
EXT	2	Danielov dom	49º07.28'	20º09.77'	1,065	5º	S
FIR	4	Tatranské zruby	49º07.82'	20º11.80'	1,081	3°	S
	5	Tatranské zruby	49º07.95'	20º11.54'	1,071	10º	E
	6	Tatranské zruby	49º08.30'	20º10.93'	1,239	10º	E
	7	Tatranské zruby	49º08‘03'	20º12,11'	1,020	3º	S
	8	Tatranské zruby	49º08.20'	20º11.80'	1,074	10º	E
	9	Tatranské zruby	49º08.47'	20º11.55'	1,196	7º	EES
NEX	10	Jamy	49º09.57'	20º15.19'	1,196	10º	S
WTR	3	Horný Smokovec	49º08.77'	20º14.30'	1,109	10º	S

Table 2. Table of phytocenological relevés recorded in 2005–2008 on plots with different management treaments. Species covers are given in percentage.

Plots	REF				NEX				WTR				EXT				FIR			
Years	05	06	07	08	05	06	07	08	05	06	07	08	05	06	07	08	05	06	07	08
Dryopteris filix-mas	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Prenanthes purpurea	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ptilium crista-castrensis	3	3	3	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Polytrichum commune	3	3	3	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Blepharostoma trichophyllum	3	3	3	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Homogyne alpina	3	4	4	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Gentiana asclepiadea	1	3	3	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Trientalis europaea	3	3	3	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Dicranum montanum	3	3	3	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Plagiomnium affine	3	3	3	3	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.
Urtica dioica	3	3	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	2	2	2
Plagiothecium laetum	3	3	3	2	3	3	3	2	.	.	.	.	.	.	.	.	.	.	.	.
Pleurozium schreberi	68	68	68	64	1	1	1	3	.	.	.	.	38	.	.	.	2	.	.	2
Sphagnum capillifolium	3	3	3	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Dicranum scoparium	18	18	18	18	4	4	1	3	2	2	.	.	1	.	.	2	2	.	.	.
Taraxacum officinale	1	3	3	2	.	.	.	.	.	2	2	2	.	1	1	.	.	2	2	2
Melampyrum sylvaticum	3	4	4	4	.	.	.	.	1	2	.	2	3	1	1	2	.	.	.	.
Dryopteris dilatata	3	3	3	3	.	3	3	2	.	.	2	2	1	3	3	.	.	.	.	.
Hylocomium splendens	38	38	38	38	4	4	4	3	2	2	.	.	3	.	.	.	.	.	.	.
Vaccinium vitis-idaea	3	.	3	2	.	.	.	.	.	2	2	2	3	3	3	2	.	.	.	.
Sorbus aucuparia	3	3	3	.	.	.	3	2	2	3	3	3	3	3	3	2	.	.	.	.
Picea abies *	4	4	8	8	1	4	1	3	3	3	3	3	3	3	3	3	.	.	.	.
Vaccinium myrtillus	68	68	68	88	68	68	68	38	18	18	18	18	18	4	8	8	2	2	2	2
Avenella flexuosa	3	8	18	38	8	18	68	38	2	18	18	18	3	18	18	18	2	3	2	2
Calamagrostis villosa	8	18	38	18	3	68	86	88	3	38	68	64	18	68	68	64	2	8	8	8
Maianthemum bifolium	3	3	3	3	1	3	3	3	4	4	4	4	3	3	3	2	.	2	2	2
Luzula luzuloides	3	3	3	2	1	1	1	3	.	2	2	2	3	3	3	2	2	2	2	2
Oxalis acetosella	8	8	8	38	1	4	3	3	.	.	.	.	1	3	.	.	.	.	.	.
Picea abies•	18	18	18	.	4	1	.	.	.	.	.	.	3	3	3	.	.	.	.	.
Chamerion angustifolium	.	.	3	2	.	3	1	3	.	3	18	38	3	4	38	38	.	8	88	88
Larix decidua	.	.	3	2	.	.	.	2	.	2	.	.	.	.	.	.	.	.	.	.
Carex species	.	.	.	2	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.
Solidago virgaurea	.	.	.	2	.	.	.	.	.	.	.	.	3	1	1	.	.	.	.	.
Rubus idaeus	.	.	.	2	.	.	3	2	.	2	2	3	.	3	3	2	.	3	3	3
Calluna vulgaris	.	.	.	.	3	3	3	2	.	2	.	3	.	3	3	2	.	2	2	2
Dicranella heteromalla	.	.	.	.	.	3	3	2	.	.	.	.	.	.	.	.	.	.	2	2
Veronica officinalis	.	.	.	.	.	3	.	2	.	.	.	2	.	.	.	.	.	2	2	2
Carex leporina	.	.	.	.	.	3	4	.	.	.	.	2	1	.	.	.	.	.	.	.
Betula carpatica	.	.	.	.	.	.	3	2	.	.	.	3	.	.	.	.	.	.	.	.
Salix caprea	.	.	.	.	.	.	3	2	.	.	.	3	.	.	.	.	.	.	2	2
Mycelis muralis	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	2	2
Populus tremula	.	.	.	.	.	.	.	.	2	.	.	2	.	.	.	.	3	4	18	2
Calamagrostis arundinacea	.	.	.	.	.	.	.	.	.	2	2	18	3	3	38	18	2	3	3	3
Hieracium murorum	.	.	.	.	.	.	.	.	.	2	2	.	.	.	.	.	.	.	.	2
Senecio viscosus	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	2
Rumex acetosella s.lat.	.	.	.	.	.	.	.	.	.	2	2	.	.	.	.	.	.	.	.	.
Sambucus racemosa	.	.	.	.	.	.	.	.	.	.	3	3	.	1	1	2	.	2	4	4
Carex tomentosa	.	.	.	.	.	.	.	.	.	.	8	8	.	.	3	4	.	.	.	.
Senecio nemorensis agg.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	2	.	.	1	1
Polytrichum formosum	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	2
Viola reichenbachiana	.	.	.	.	.	.	.	.	.	.	.	.	.	3	1	.	.	.	.	.
Senecio sylvaticus	.	.	.	.	.	.	.	.	.	.	.	.	.	3	3	.	.	2	2	.
Carex digitata	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	.
Cirsium arvense	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.
Cirsium eriophorum	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.
Epilobium montanum	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	2	.	2	2	2
Hypericum maculatum	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	2	.	.	.	.
Galeopsis tetrahit	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	2	.
Trifolium repens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	2	.

Species not included in the table: *Juncus effusus* WTR/06,08:2, *Carex sylvatica* WTR/06:3, *Luzula multiflora* WTR/06:2. *Polygonum aviculare* EXT/06, 07:1, *Salix silesiaca* EXT/08:2, *Acer pseudoplatanus* WTR/07:1, *Atrichum undulatum* NEX/07:3, *Cladonia digitata* REF/08:2.

Abbreviations: *Height up to 1.5 m. •Height above 1.5 m.

bifolium, Melampyrum sylvaticum, Oxalis acetosella, Prenanthes purpurea, Avenella flexuosa, Gentiana asclepiadea, Homogyne alpina, Trientalis europaea, Ptilium crista-castrensis, Polytrichum commune, Blepharostoma trichophyllum, Dicranum montanum, Hylocomium splendens, Plagiomnium affine, Picea abies and *Larix decidua* and others had the optimum on the REF plots (Table 2). These species are typical for relatively moist, shady and cool sites with acidic, nutrient-poor soils. The NEX plot was very similar to the REF plot, regardless of the absence of its 'own' typical species. As for the second principal axis, WTR, EXT and FIR plots showed the contrary position – with light and temperature as significant factors. The species on the FIR plot indicated sunny and warm sites with higher contents of nutrients (including nitrogen) and soil reaction. These communities included species as *Chamerion angustifolium, Veronica officinalis, Rubus idaeus, Taraxacum officinale, Urtica dioica, Senecio viscosus, Senecio nemorensis* agg.*, Senecio sylvaticus, Trifolium repens, Galeopsis tetrahit, Epilobium montanum, Cirsium eriophorum, Cirsium arvense* and pioneer woody plants (*Sambucus racemosa, Salix caprea, Populus tremula*). *Calamagrostis villosa* manifested a special status. This characteristic species of indigenous communities responded to the better light conditions by expansive spreading on all the disturbed plots except the FIR plot (Table 2).

Based on the mean EIV (Table 3), we can assess significant changes in efficiency of principal ecological factors indicated by herb species on particular sites. The change in mean EIV by 0.5 is considered as a significant alteration according to Jurko et al. (1981). Succesional changes on the REF plot were not significant. On the NEX plot, significant changes of EIV were found in relation to light (+0.63) and moisture (+0.93) – due to the increase of *Calamagrostis villosa* cover. Significant increases of light (up to +1.82 of the EIV), soil reaction (+0.93) and nutrients (+1.59) were recorded on the WTR plot. Significant increases of light (+1.09), soil reaction (+0.51) and content of soil nutrients (+0.79) were found on the EXT plot. On the FIR plot, the herb layer indicated the highest light increase and the highest increase in the mean light value (+1.84). For the soil reaction, we also found an increase (+1.57). But the highest increase was recorded for nutrients (+3.37). A decrease (–0.56) was recorded only in case of moisture indicator value. Light was the factor with the most pronounced influence. In addition to direct effect on the vegetation, light significantly affects the process of litter biodegradation. Such

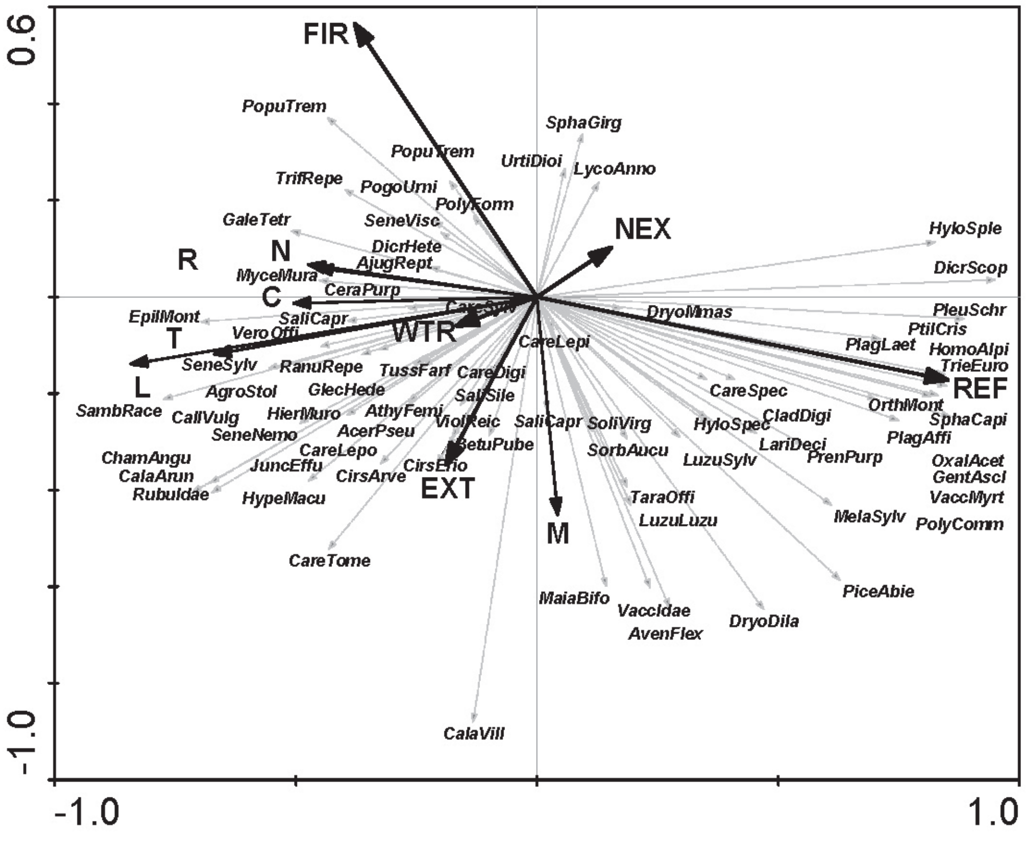

Fig. 1. PCA with supplementary variables indicating relations among plant species, environmental factors and differrent management treatments (T – temperature, R – soil reaction, C – continentality, M – moisture, N – nutrients, L – light).

factors such as the soil reaction value and the nutrients (nitrogen) content are also indirectly affected by light. The results of Ellenberg indicator value analysis confirmed the results obtained by PCA and CCA (Table 3).

Six permanet plots established on the FIR site were subjected to CCA analysis. We expected the most intensive succesional changes from the initial stage, as the vegetation cover was completely destroyed by the fire (in August 2005). The 'year' was used as the predictor, whereas mean EIV for light, temperature, continentality, moisture, soil reaction, nutrients and years (2005, 2006, 2007, 2008) were used as supplementary variables. Monte Carlo permutation test serving as tool for assessment of the predictor statistical significance showed that the variable "year" was significant. The level of significance P was 0.002, the species-data variation λ was 15%. To obtain a simpler, better readable graph, we selected a 5% threshold weight for each species (Fig. 2). Figure 3 shows only the species with the highest change rate from 2005 to 2008. This figure clearly indicates the time gradient of the species occurrence. The scores on principal axes determine the species optimum in relation to the predictor 'year' and to the supplementary variables. In 2005, several forest species with relatively higher moisture demands were the most frequent on this site, such as *Avenella flexuosa, Vaccinium myrtillus* and *Calamagrostis villosa*. In 2006, such species as *Epilobium montanum, Senecio sylvaticus, Galeopsis tetrahit, Taraxacum officinale, Urtica dioica, Tussilago farfara,* and *Cirsium arvense* appeared.

In 2007, the most significant increase in the coverage was found for *Chamerion angustifolium*. The cover of other humidestructive species as well as some forest species such as *Rubus idaeus, Veronica officinalis*, *Senecio nemorensis, Hypericum maculatum, Scrophularia nodosa, Mycelis muralis, Carex ovalis, Carex tomentosa, Calluna vulgaris*, *Maianthemum bifolium, Luzula luzuloides* and *Sambucus racemosa* increased too. When comparing year 2008 with the preceding year, no significant changes were recorded.

A detailed research on these sites was carried out also by botanists of the Research Station of TANAP (Šoltés et al., 2008). These authors found the most significant changes to the herb-layer on the FIR site – due to destructed herb layer, and patches of damaged organic litter. In the next years, the disappearance of *Chamerion angustifolium* and the appearance of nitrophilous vegetation of *Sambucus racemosa* and *Rubus idaeus* were recorded. Our findings from other sites related to the increase in species coverage are consistent with the results reported by Šoltés et al. (2008). The similar research is also performed in the Czech Republic with comparable conclusions. That research is focussing

Table 3. Mean EIV of environmental factors on permanent plots for period 2005–2008

Plot	Year	L	T	C	M	R	N
REF	2005	4.16	4.15	3.68	5.59	3.24	3.82
REF	2006	4.86	4.09	3.63	5.88	2.95	3.35
REF	2007	5.30	4.06	3.59	6.13	2.73	3.20
REF	2008	4.26	4.06	3.08	5.54	2.98	4.02
NEX	2005	5.17	4.00	3.00	5.75	2.35	2.91
NEX	2006	5.74	4.00	3.61	6.65	2.24	2.72
NEX	2007	5.90	4.09	3.21	6.61	2.21	2.68
NEX	2008	5.80	4.04	3.42	6.68	2.17	2.71
WTR	2005	4.60	4.00	4.50	5.75	2.40	2.60
WTR	2006	5.81	4.18	3.54	6.15	2.47	2.98
WTR	2007	6.18	4.24	3.92	6.34	3.02	3.39
WTR	2008	6.42	4.37	4.08	6.05	3.33	4.19
EXT	2005	5.33	4.11	3.93	5.93	2.73	3.36
EXT	2006	5.76	4.08	3.64	6.43	2.52	3.14
EXT	2007	6.33	4.40	3.98	5.91	3.34	4.29
EXT	2008	6.42	4.28	4.05	6.01	3.24	4.15
FIR	2005	5.50	4.33	3.00	5.67	3.00	3.50
FIR	2006	6.41	4.20	3.88	5.67	3.76	4.93
FIR	2007	7..36	4.39	4.65	5.19	4.63	6.94
FIR	2008	7.34	4.61	4.65	5.11	4.57	6.87

L – light, T – temperature, C – continentality, M – moisture, R – soil reaction, N – nutrients.

on communities with dominant species *Calamagrostis villosa* at clearings of mountain ranges in spruce and spruce-beech forests in the Czech Republic (Neuhäuslová and Wild, 2001). In the Junco effusi-Clamagrostietum villosae association, the authors found the herb layer divided into two sublayers. In the upper sublayer dominated *Calamagrostis villosa* with admixture of ferns (*Athyrium distentifolium, A. filix-femina* and *Dryopteris dilatata*), higher plants (*Chamerion angustifolium, Senecio hercynicus, S. ovatus*) and scrubs (*Vaccinium myrtillus, Rubus idaeus*) or *Juncus* species. In the lower sublayer, *Avenella flexuosa* dominated. On some localities, *Oxalis acetosella* and *Trientalis europaea* were dominant species. In juvenile stands (up to 5 years of age), remnants of synanthropic vegetation occurred, but they disappeared during the course of succession. According to our results, the distinct vertical stratification and high fern cover in the High Tatras Mts had not been developed until 4 years after the disturbation. Strong competition between the dominant species is in progress. *Chamerion angustifolium* is owergrowing *Calamagrostis villosa* in some places.

Conclusions

Based on the obtained results, it can be concluded that the initial successional changes on the studied sites occurred just in 2006, but the most significant changes to the vegetation were found in the third year after the windstorm disturbance (in 2007).

The site affected by the fire (FIR) was occupied predominantly by heliophilous, nitrophilous and humidestructive species such as *Chamerion angustifolium, Veronica officinalis, Rubus idaeus, Urtica dioica, Senecio viscosus, Senecio nemorensis* agg., *Senecio sylvaticus* and others species. The EXT plot from which the windthrown timber had been removed was progressively colonised by *Calamagrostis villosa* and other species such as *Calamagrostis arundinacea*, *Calluna vulgaris, Ajuga reptans, Galeopsis tetrahit, Trifolium repens Epilobium montanum, Cirsium eriophorum, C. arvense* or pioneer tree species (*Sambucus racemosa, Salix caprea, Populus tremula* and others). Changes found on the NEX plot with the lying timber, left to self-development, were less intensive. This site was floristically most similar to the control REF plot. No spreading nitrophilous species were found on the REF plot. The characteristic species for this plot are e.g. *Picea abies, Vaccinium myrtillus, Avenella flexuosa, Calamagrostis villosa, Maianthemum bifolium, Luzula luzuloides, Oxalis acetosella* and *Dryopteris dilatata*. The moss-layer is abundant.

Natural regeneration of tree species was observed on each site. After initial absence of herb competition, *Populus tremula* had been established on the nitrogen-rich site (the FIR plots). On the other hand, *Picea abies* and *Sorbus aucuparia* were missing. In the last years,

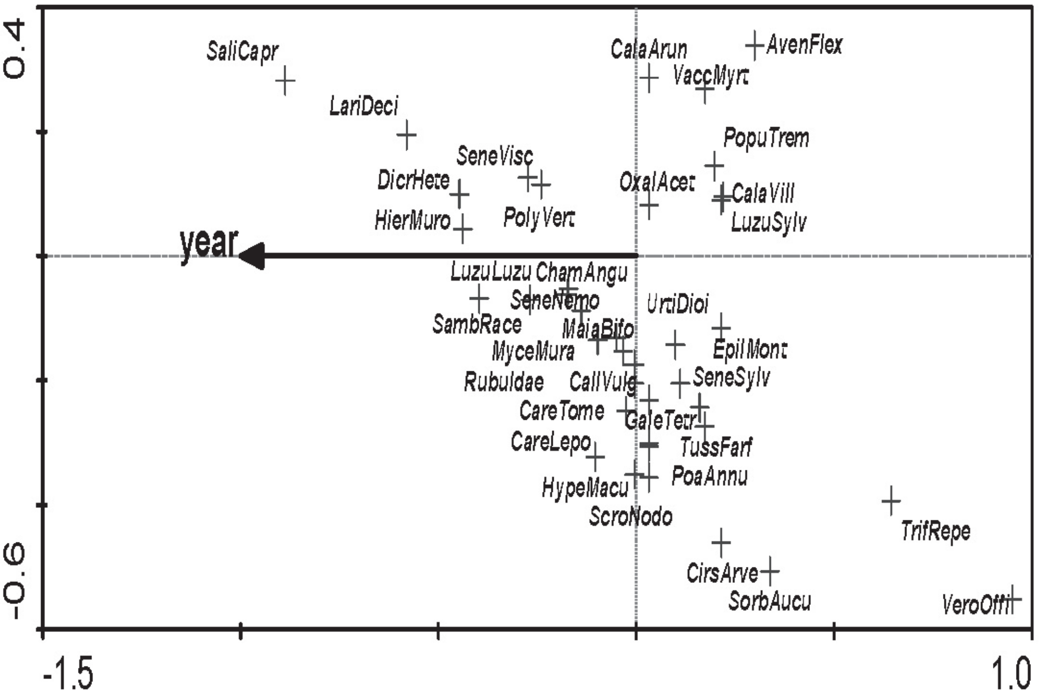

Fig. 2. Species response to temporal gradient on FIR plot. CCA, Monte Carlo test indicate relations of species to the variable 'year'. Species with weight less than 5% are not plotted.

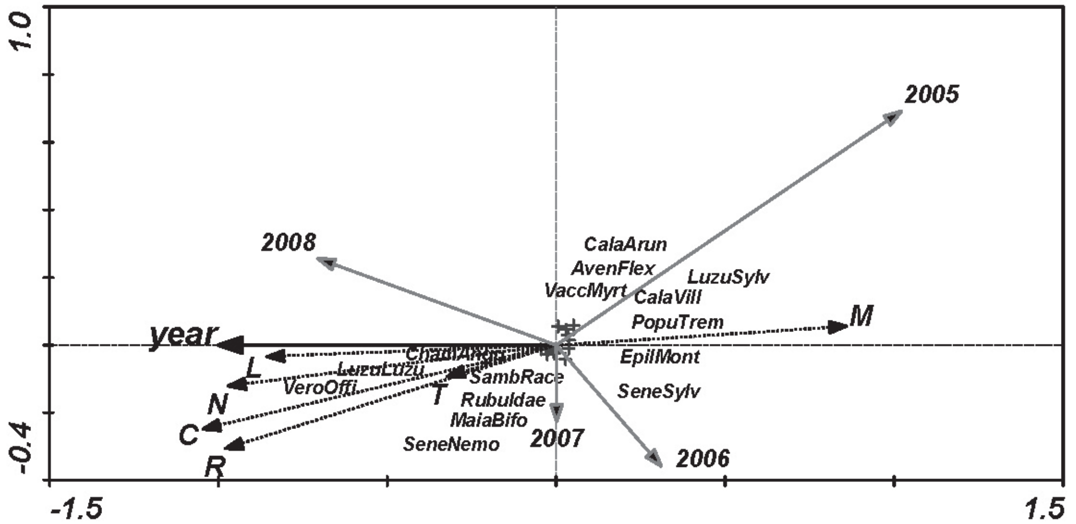

Fig. 3. Environmental changes on FIR plot according to mean Ellenberg indicator values in CCA. The predictor variable is “year“ and supplementary variables are T – temperature, R – soil reaction, C – continentality, M – moisture, N – nutrients, L – light, sampling years 2005, 2006, 2007, 2008.

Sambucus racemosa has been spreading through the majority of sites. On the relatively moist sites, it has been *Betula carpatica*. An increase in moisture preferring species was observed on the hydrologically managed site (*Juncus effusus, Carex tomentosa, Luzula multiflora*).

Translated by Jaroslav Ďurkovič

Acknowledgement

This research was supported by the Slovak Grant Agency for Science (grant VEGA No. 1/0831/09).

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Sukcesný vývoj vegetácie na trvalo monitorovaných plochách vo Vysokých Tatrách

Súhrn

Práca podáva výsledky z trvalo monitorovaných plôch (TMP) na území po vetrovej kalamite z 19. novembra 2004 vo Vysokých Tatrách. Pre sledovanie dynamiky vegetácie boli založené TMP s rôznym manažmentom: referenčná plocha – REF, nepostihnutá kalamitou (Vyšné Hágy); plocha so spracovaným kalamitným drevom – EXT (Danielov dom); plocha postihnutá požiarom – FIR (Tatranské Zruby); plocha s nespracovaným kalamitným drevom, ponechaná na samovývoj – NEX (Jamy) a plocha s hydrologickým manažmentom WTR. Zo získaných výsledkov vidno, že zmeny vegetácie na sledovaných TMP sa začali prejavovať už v roku 2006, ale najvýznamnejšie zmeny vo vývoji vegetácie boli zaznamenané v roku 2007, a to najmä na plochách so spracovanou kalamitnou hmotou. Na ploche po požiari (FIR) prevládli svetlomilné, nitrofilné, humideštruktívne druhy, napr: *Chamaerion angustifolium, Veronica officinalis, Rubus idaeus, Taraxacum officinale, Urtica dioica, Senecio viscosus, Senecio nemorensis* agg., *Senecio sylvaticus* atď. Zatiaľ čo plochy s vyvezenými vývratmi expanzívne ovládol vlhkomilný a svetlomilný druh *Calamagrostis villosa* a ďalšie ako *Calamagrostis arundinacea*, *Calluna vulgaris, Ajuga reptans, Galeopsis tetrahit, Trifolium repens, Epilobium montanum, Cirsium eriophorum, Cirsium arvense)* a prípravné dreviny (*Sambucus racemosa, Salix caprea, Populus tremula)* a iné. Plocha ponechaná na samovývoj (NEX) bola čo do druhového zloženia najviac podobná porovnávacej ploche REF. V bylinnej etáži na NEX ploche prevažovali druhy pôvodného lesa, *Picea abies, Vaccinium myrtillus, Avenella flexuosa, Maianthemum bifolium, Luzula luzuloides, Oxalis acetosella, Dryopteris dilatata.* V dôsledku presvetlenia sa zvýšila pokryvnosť *Calamagrostis villosa.* Nitrofilné druhy a humideštruktívne druhy sa uplatňovali ojedinele.

Na všetkých plochách bolo zaznamenané aj prirodzené zmladenie drevín. *Populus tremula, Sambucus racemosa, Salix caprea* pri zmladzovaní na kalamitných plochách uprednostňujú presvetlené stanovištia obohatené dusíkom, zatiaľ čo napr. *Betula carpatica* preferuje vlhkejšie stanovištia. V zárastoch *Chamaerion angustifolium* vôbec nezmladzuje *Picea abies* a *Sorbus aucuparia*. Nárast vlhkomilnej vegetácie bol zaznamenaný na hydrologicky manažovanej ploche *(Juncus effusus, Carex tomentosa, Luzula multiflora*).

Received December 3, 2009
Accepted August 28, 2010

FOLIA OECOLOGICA – vol. 37, no. 2 (2010). ISSN 1336-5266

Assessment of vegetative phenological phases of European beech (*Fagus sylvatica* L.) in relation to effective temperature during period of 1992–2008 in Czechia

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Abstract

Hájková, L., Nekovář, J., Richterová, D. 2010. Assessment of vegetative phenological phases of European beech (*Fagus sylvatica* L.) in relation to effective temperature during period of 1992–2008 in Czechia. *Folia oecol.*, 37: 152–161.

The paper presents the results of long-term phenological observations of European beech (*Fagus sylvatica L.*) running in years 1992–2008 across the phenological network of the Czech Hydrometeorological Institute, abbr. CHMI, in original language Český hydrometeorologický ústav. The data assembled over this period were used for identification of timing of the following vegetative phenophases: bud burst (BBCH 07), first leaves 100% (BBCH 15), leaf colouring 10% (BBCH 92), leaf fall 100% (BBCH 97). The stations are situated at altidudes from 165 m (Lednice) to 1,102 m (Modrava). The mean date obtained for onset of bud burst is from April 12th to May 7th (on average April 22nd), the mean date for onset of the first leaves 100% is from April 29th to May 17th (on average May 7th), the mean date for onset of leaf colouring is from September 12th to October 14th (on average September 24th), and the mean date for onset of leaf fall 100% is from October 9th to December 8th (on average November 7th). The trend analysis of bud burst stage showed a declining trend – that means a shift of phenological phases towards earlier date (5.7 days). On the other side, the phenophase of leaf fall 100% manifested an increasing trend – that means a shift of phenological phase to later date (6.1 days). The vegetation season is getting longer. The totals of effective temperatures were used as a bio-climatological criterion for assessment of dependence of phenological phases on meteorological variables. The above mentioned totals were obtained as subtotals of average daily temperatures higher than 0 °C, 5 °C, 8 °C and 10 °C (TS0, TS5, TS8, TS10). The average temperature total for bud burst TS0 was found from 286.2 °C (Lednice, 165 m a.s.l.) to TS0 = 144.2 °C (Modrava, 1,102 m a.s.l.). The other effective temperature totals for the average day of bud burst are: TS5 = 71.5 °C; TS8 = 21.4 °C; TS10 = 7.2 °C (Lednice); TS5 = 20.0 °C; TS8 = 4.4 °C; TS10 = 1.6 °C (Modrava). The highest temperature total for leaf fall was from TS0 = 3,822.4 °C (Lednice); the lowest TS0 = 1845.9 °C (Modrava).

Key words

BBCH code, beech, Czech phenology, effective temperature, phenophase

Introduction

The natural distribution area of European beech covers the whole of Central Europe including Czechia. Phenological observations of this species can be a useful bioindicator tool for detecting environmental changes. European beech is a deciduous tree, up to 40 m high and with an average stem circumference of 1 m. The crown is ball-shaped, the wood is skin-rose. European beech is a wood species associated with oceanic and suboceanic climate, sensitive to drought and late frost. It occurs across the whole Czechia from 300 to 1,000 m a.s.l. *Fagus sylvatica* L. has been included into the CHMI phenological observation programme to monitor these phenophases: bud burst, first leaves (10, 50, 100%), fully developed leaves, flower buttons visible, beginning of flowering (10, 50, 100%), end of flowering, bud creation (10%), first fruits visible (10%), green sprouts begin to lignify (10%), colouring of leaves (10, 100%), falling of leaves (10, 100%) and fully ripeness (10%). Bednářová and Merklová (2007) monitored and evaluated spring and autumnal phenological characteristics of *Fagus sylvatica* L. in the Drahanská vrchovina hills from 1991 to 2006. A large range was noted in spring phenophases, autumnal phases showed a more regular course. In the recent years, the sum of effective temperatures displayed an evident growth. The sum of effective air temperatures for budbreak had increased from 10.9 °C to 135.6 °C, for leaf fall from 1,308.0 °C to 2,341.0 °C. Merklová and Bednářová (2007) evaluated phenological and growth phases of European beech in relation to the microclimate in a stand in the Drahanská vrchovina. The beginning of autumnal phenological phases depended more on the precipitation amount during the summer and autumn months. Hanousková (2010) executed temporal variability of European beech from phenological stations Lednice (165 m a.s.l.) and Chřibská (350 m a.s.l.) including influence of meteorological parameters (air temperature, precipitation and sunshine duration) on phenophase onset in period 1991–2009. During the observed period the starts of vegetative phenological phases set on average in April (bud burst) and in May (first leaves 100%). The variation coefficients of vegetative phenophases (sprouting, first leaves 100%, leaves colouring 10% and leaf fall) ranged from 4.0% to 5.6% at Lednice station and from 5.2% to 11.1% at Chřibská station. The mean daily air temperature was found considerably affecting bud burst of oak (*Quercus robur L.*) in a flood plain forest of southern Moravia in period 1961–2007 (Bartošová et al., 2008). Škvareninová (2008) studied the start of spring phenophases in *Quercus robur L.* in relation to temperature sums in period 1987–2006 in the Zvolenská kotlina basin at altitudes about 300 m a.s.l. The values of variation coefficients of all vegetative phenophases ranged from 4.04% to 6.03%, the variation range was 20–27 days. The values of temperature sums (TS0 = 241.3 °C – leaf bud swelling, TS0 = 380.6 °C – leaf bud burst, TS0 = 530.7 °C – leaf unfolding). Škvareninová (2007) also studied the onset of generative phenophase of *Alnus glutinosa* (L.) Gaert. at the Arboretum Borová hora in relation to effective temperatures in 1987–2006 (TS0 = 102.8 °C – beginning of flowering, TS0 = 191.1 °C – bud burst, TS0 = 369.7 °C – fully leaved, TS0 = 3,214 °C – leaves unfolding).

Material and methods

The onset of bud burst (BBCH 07), first leaves 100% (BBCH 15), leaf colouring 10% (BBCH 92) and leaf fall 100% (BBCH 97) was analysed for the period 1992–2008 with the data provided by 27 CHMI phenological stations situated from 165 to 1,102 m a.s.l. There were selected stations with complete time series. The phenological data were obtained according to CHMI methodical instructions, number 10 (2009). The patterns of phenophases are illustrated in the Phenological atlas Coufal et al. (2004). The phenophase onset was expressed as the corresponding growing-degree day. The stations were analyzed separately and according to altitude. We have also evaluated the following inter-start intervals: bud burst – leaf fall 100% (length of vegetation period of European beech in Czechia), bud burst – first leaves 100%, leaf colouring 10% – leaf fall 100%. All the types of analysis were made in Excel and by AnClim programme. The effective temperatures totals (subtotals of average daily air temperatures above 0 °C (TS0), 5 °C (TS5), 8 °C (TS8) and 10 °C (TS10)) were as the most suitable meteorological characteristics when dealing with phenological data. The characteristics of phenological and climatological stations are in Table 1.

Table 1. Characteristics of phenological (P) and climatological (C) stations

Station	Altitude	Longitude	Latitude
Lednice (P)	175	16°48'	48°48'
Přibyslav (P)	533	15°45'	49°35'
Modrava (P)	1,102	13°31'	49°02'
Lednice (C)	176	16°47'	48°47'
Přibyslav (C)	530	15°45'	49°34'
Kvilda (C)	1,059	13°34'	49°01'

Table 2 represents annual meteorological characteristics for meteorological stations Lednice (176 m a.s.l), Přibyslav (530 m a.s.l) and Kvilda (1,059 m a.s.l).

All CHMI phenological stations have been provided with metadata of Phenodata-Oracle database.

The beech observation site Lednice is situated in the Lednice Castle Park, southern Moravia, the river basin of Dyje. The trees are observed at the locality with the following site characteristics: vegetation unit – dispersed green vegetation, macrorelief – flat ground, microrelief – flat ground, geological substrate – clayey drift and combined soil, slope – up to 5 degrees, light conditions – full illumination, humidity conditions – hygromesophyte, initial stand age – 80–100 years, level of protection – the other categories of non forest land.

The station Přibyslav is situated in the Vysočina region, the river basin of Sázava. Beech trees are observed at the locality 7 with the following characteristics: vegetation unit – dispersed green vegetation, macrorelief and microrelief – flat ground, geological substrate – underground volcanic rocks, slope from 5 to 10 degrees, exposition – southwest, light conditions – full illumination, humidity conditions – mesophyte, initial age – 80–100 years, level of protection – the other categories of non forest land.

The station Modrava is situated in the Šumava Mts, the river basin of Vltava. Beech trees are observed at the locality 4 with these characteristics: vegetation unit – dispersed green vegetation, macrorelief – flat ground, geological substrate – underground volcanic rocks, slope from 30 to 40 degrees, exposition – southwest, light conditions – full illumination, humidity conditions – hygromesophyte, initial stand age 100–150 years, level of protection – National Park.

Results and discussion

The onset and duration of phenological phases in beech differed considerably between the years. Together with genetics factors, air temperature and soil temperature are critical for the start of spring phenological phases (Bednářová and Kučera, 2002.). Statistical data for the selected stations are in Tables 3, 4. On the basis of the results obtained, we can report that the average timing of bud burst in the 17-year research period in Czechia was the 22nd April, average timing of first leaves (100%) was the 7th May, average timing of leaf colouring (10%) 24th September, and average timing of leaf fall (100%) 7th November. Statistical characteristics of bud burst, first leaves (100%), leaf colouring 10% and leaf fall (100%) for the whole Czechia are given in Table 5. The earliest bud burst in the station Lednice was found on 1st April with the sum of effective temperatures TS5 = 55.0 °C, and at the latest was on the 20th April with the sum of effective temperatures TS5 = 148.2 °C.

In the Modrava station the earliest bud burst was recorded on 25th April with the sum of effective temperatures TS5 = 6.3 °C, and at the latest was on the 12th May with the sum of effective temperatures TS5 = 32.5 °C.

Table 2. Annual meteorological characteristics at the stations Lednice, Přibyslav and Kvilda

Meteorological characteristic	Abbreviation	Unit	Lednice	Přibyslav	Kvilda
Mean annual air temperature	T	°C	10.2	7.5	3.3
Average sum of active temperatures above 5 °C	ΣT > 5 °C	°C	3,716.4	2,864.8	1,709.7
Average sums of active temperatures above 10 °C	ΣT > 10 °C	°C	3,263.0	2,361.4	1,137.9
Average annual maximum air temperature	TMA	°C	15.1	12.0	9.9
Absolute maximum air temperature	TMA MAX	°C	38.1	35.8	31.4
Average active sum of maximum air temperature above 5 °C	ΣTMA > 5 °C	°C	5,452.9	4,372.1	3,648.7
Average active sum of maximum air temperature above 10 °C	ΣTMA > 10 °C	°C	5,047.3	3,945.5	3,196.8
Average annual minimum air temperature	TMI	°C	5.1	3.2	–2.8
Average annual sunshine	SSV	hour	1,832.8	1,737.2	Not observed
Average annual precipitation total	SRA	mm	535.7	683.3	1,226.7
Average annual number of days with daily precipitation total above 0,1 mm	SRA > 0.1 mm	day	114.6	168.1	192.1
Average annual number of days with daily precipitation total above 1 mm	SRA > 1 mm	day	81.7	111.8	155.8
Average annual number of days with daily precipitation total above 5 mm	SRA > 5 mm	day	31.1	40.9	77.8

The earliest first leaves (100%) were found on 24th April (Lednice station) with the sum of effective temperatures TS5 = 226.0 °C, and on 4th May (Modrava station) with the sum of effective temperatures TS5 = 179.9 °C. The latest first leaves (100%) were on 11th May (Lednice station) with the sum of effective temperatures TS5 = 259.0 °C, and on 29th May (Modrava station) with the sum of effective temperatures TS5 = 187.8 °C.

The earliest leaf colouring (10%) was found on 2nd September (Lednice station) with the sum of effective temperatures TS5 = 2,488.5 °C, and on 26th August (Modrava station) with the sum of effective temperatures TS5 = 933.5 °C. The latest leaf colouring (10%) was observed on 21st October (Lednice station) with the sum of effective temperatures TS5 = 2,588.3 °C, and on 2nd October with the sum of effective temperatures TS5 = 990.4 °C.

The earliest leaf fall (100%) were found on 3rd November (Lednice station) with the sum of effective temperatures TS5 = 2,358.0 °C, and on 20th September (Modrava station) with the sum of effective temperatures TS5 =1,052.1 °C. The latest leaf colouring (10%) was on 23rd December (Lednice station) with the sum of effective temperatures TS5 = 2,373 °C, and on 30th October (Modrava station) with the sum of effective temperatures TS5 = 881.4 °C. Statistical characteristics for onset of phenophase bud burst and leaf fall are

Table 3. Statistical characteristics of bud burst and leaf fall (100%) phenophase onset in European beech

Bud burst	Lednice	Přibyslav	Modrava
Average	14. 4.	13. 4.	6. 5.
Median	16. 4.	14. 4.	7. 5.
Upper q.	10. 4.	6. 4.	2. 5.
Lower q.	18. 4.	20. 4.	10. 5.
Standard deviation	5.3	9.0	5.2
Min.	1. 4.	27. 3.	25. 4.
Max.	20. 4.	26. 4.	12. 5.
Variation range	19	30	17
Variation coefficient	5.1	8.7	4.1
Leaf fall (100%)	Lednice	Přibyslav	Modrava
Average	23. 11.	30. 10.	9. 10.
Median	21. 11.	29. 10.	9. 10.
Upper q.	14. 11.	26. 10.	26. 9.
Lower q.	29. 11.	6. 11.	17. 10.
Standard deviation	14.3	10.6	14.0
Min.	3. 11.	15. 10.	20. 9.
Max.	23. 12.	26. 11.	30. 10.
Variation range	50	42	40
Variation coefficient	4.4	3.5	4.9

Table 4. Statistical characteristics of interphase intervals (Bud burst – Leaf fall 100%, Bud burst – First leaves 100%, Leaf colouring 10% – Leaf fall 100%) in European beech

Bud burst – Leaf fall 100%	Lednice	Přibyslav	Modrava
Average	223	201	156
Median	220	201	147
Upper q.	215	194	152
Lower q.	230	208	144
Standard deviation	15.4	12.8	12.4
Min.	200	173	142
Max.	255	225	183
Variation range	55	52	41
Variation coefficient	24.6	6.4	8.0

Table 4. Continued

Bud burst – First leaves 100%	Lednice	Přibyslav	Modrava
Average	20	19	9
Median	21	20	6
Upper q.	16	15	5
Lower q.	22	23	13
Standard deviation	3.7	6.4	6.5
Min.	14	9	2
Max.	27	24	22
Variation range	13	25	20
Variation coefficient	18.7	33.9	69.2
Leaf colouring 10% – Leaf fall 100%			
Average	55	45	26
Median	55	44	26
Upper q.	40	41	12
Lower q.	79	48	40
Standard deviation	23.9	12.6	14.0
Min.	16	19	5
Max.	104	75	47
Variation range	88	56	42
Variation coefficient	43.1	28.3	53.3

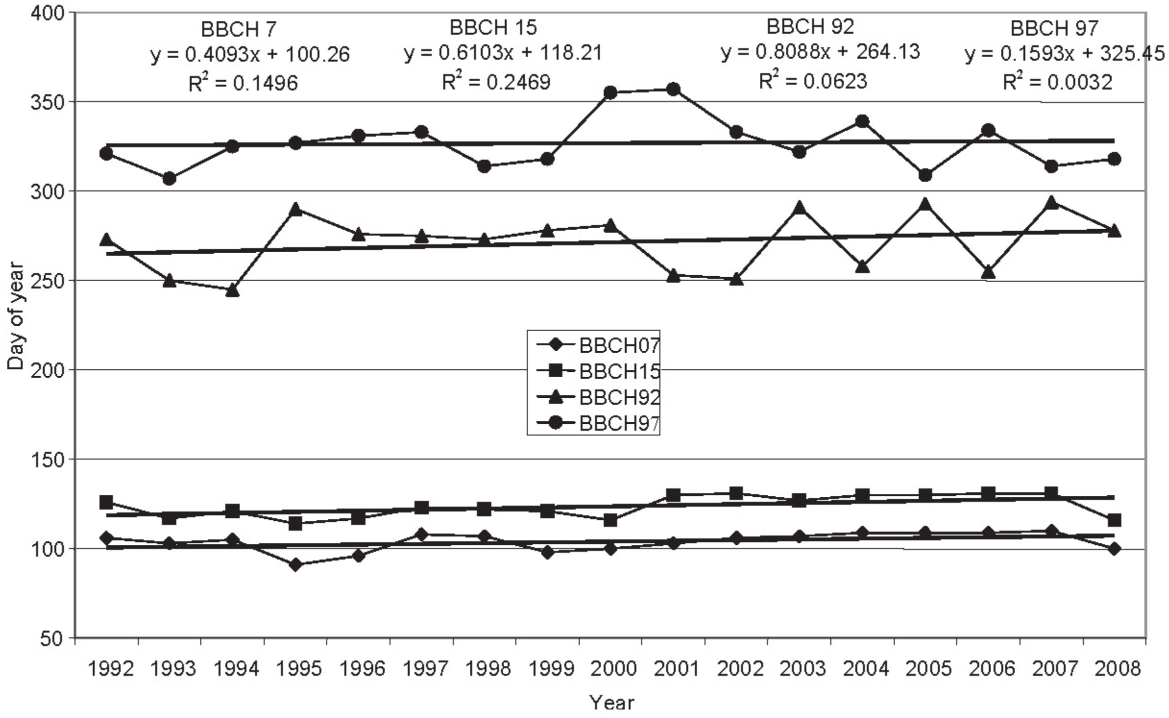

Fig. 1. The trend of onset of phenological phases European beech in 1992–2008 at Lednice station (165 m a.s.l.).

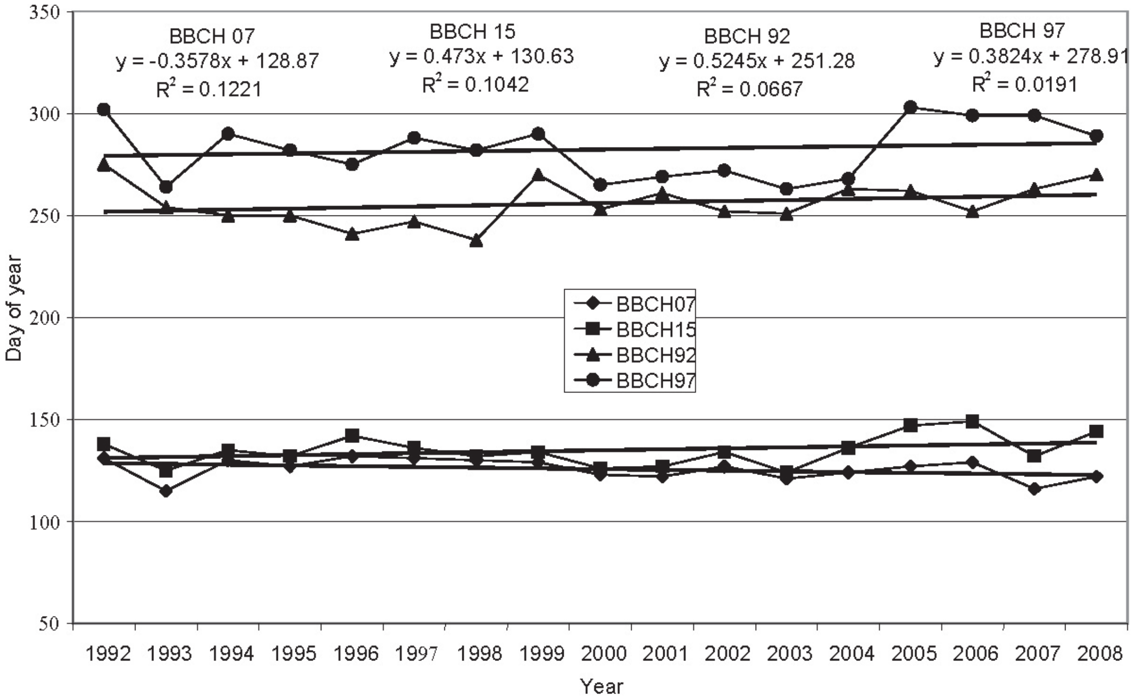

Fig. 2. The trend of onset of phenological phases in European beech in 1992–2008 at Modrava station (1,102 m a.s.l.).

given in Table 3. Relative variation coefficients at all three stations were low – unlike in interphase interval – especially at the mountain station. Statistic description of interphase duration is in Table 4. Figs 1 and 2 illustrate the trends of onset of spring and autumn phenological phases in the lowland and in the mountain. We have found positive trends in all phenophases at Lednice station – the highest in leaf colouring 10%. The trends observed at the mountain station Modrava were also positive, except bud burst in which the onset was found earlier.

The phenological data from all 27 phenological stations were evaluated statistically. The results are summarized in Tables 5, 6. The onset of bud burst was on average on 22nd April, of the first leaves 100% on 7th May, of leaf colouring 10% on 24th September, and of leaf fall 100% on 7th November.

The sums of effective temperatures were calculated for each selected station (Lednice, Přibyslav and Modrava) according to the representative climatological stations (Lednice, Přibyslav and Kvilda stations) from the beginning of year to the particular phenophase onset. The average sums of effective temperatures are given in Table 7. In Table 8 are summarised statistical characteristics of sums of effective temperatures above 5 °C. Variation coefficients in autumnal phenological phases were smaller than in spring phenological phases. Fig. 3 represents course of sums of effective temperatures above 5 °C in autumnal phenological phases with regression equation in the European beech at different altitudes during period 1992–2008.

Table 5. Statistical characteristics of selected phenophases from all phenological stations for European beech in Czechia

Fagus sylvatica L. 1992–2008 Phenophase	Statistical characteristics					
	X	s_x	R	Min.	Max.	s_x%
Bud burst (BBCH 07)	112	8.4	25	102	127	7.5
First leaves 100% (BBCH 15)	127	8.0	18	119	137	6.3
Leaf colouring 10% (BBCH 92)	267	17.8	32	255	287	6.6
Leaf fall 100% (BBCH 97)	311	17.4	60	282	342	5.6

X – arithmetic mean, $s_{x,}$ – standard deviation, R – variation range, Min. – minimum, Max. – maximum, s_x% – variation coefficient.

Table 6. Statistical characteristics of selected interphases from all phenological stations of European beech in Czechia

Fagus sylvatica L. 1992–2008	Statistical characteristics					
Interphase	X	s_x	R	Min	Max	s_x%
Bud burst – first leaves (100%)	14.1	1.5	5.4	11.7	17.2	10.9
Bud burst – leaf fall 100%	198.3	5.1	20.9	185.8	206.8	2.6
Leaf colouring 10% – leaf fall 100%	43.6	3.7	13.6	39.0	52.6	8.5

X – arithmetic mean, s_x – standard deviation, R – variation range, Min. – minimum, Max. – maximum, s_x% – variation coefficient.

Table 7. Average sums of effective temperatures for selected phenological phases in European beech

Phenophase	TS0		TS5		TS8		TS10	
	Lednice	Kvilda	Lednice	Kvilda	Lednice	Kvilda	Lednice	Kvilda
Bud burst (BBCH 07)	287.5	143.7	71.6	20.2	21.3	4.6	7.0	1.7
First leaves 100% (BBCH 15)	611.2	403.0	250.3	134.6	126.2	56.7	72.1	27.8
Leaf colouring 10% (BBCH 92)	3,384.3	1,730.2	2,413.9	871.5	1,758.0	483.8	1,365.3	288.8
Leaf fall 100 % (BBCH 97)	3,838.4	1,856.1	2,461.6	904.9	1,774.3	492.5	1,372.4	291.2

Table 8. Statistical characteristics of sum of effective temperatures above 5°C for bud burst, first leaves 100%, leaf colouring 10% and leaf fall in European beech

Bud burst	Min.	Max.	R	s_x	s_x%
Lednice	1.2	148.2	147.0	34.0	47.5
Kvilda	3.5	52.8	49.3	14.6	72.3
First leaves					
Lednice	143.9	377.7	233.8	58.8	23.5
Kvilda	66.4	193.5	127.1	33.6	24.9
Leaf colouring					
Lednice	2,165.2	2,605.2	440	121.4	5.1
Kvilda	622.6	1,037.6	415	107.1	12.3
Leaf fall					
Lednice	2,245	2,687	442	123.3	5.0
Kvilda	647.3	1,052.1	404.8	105.4	11.7

Min. – minimum, Max. – maximum, R – variation range, s_x – standard deviation, s_x% – variation coefficient.

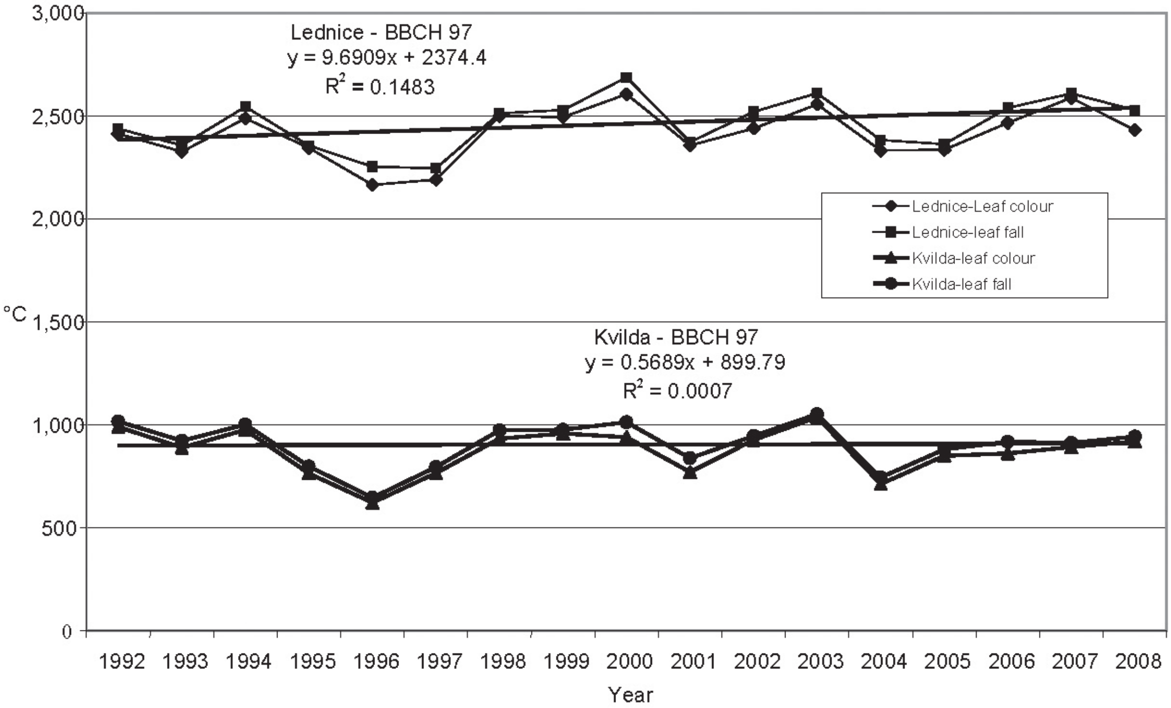

Fig. 3. Sums of effective temperatures above 5 °C for the autumnal phenological phases in the European beech in the years 1992–2008.

Finally, Fig. 4 represents average vegetation season length for all phenological stations according to altitude.

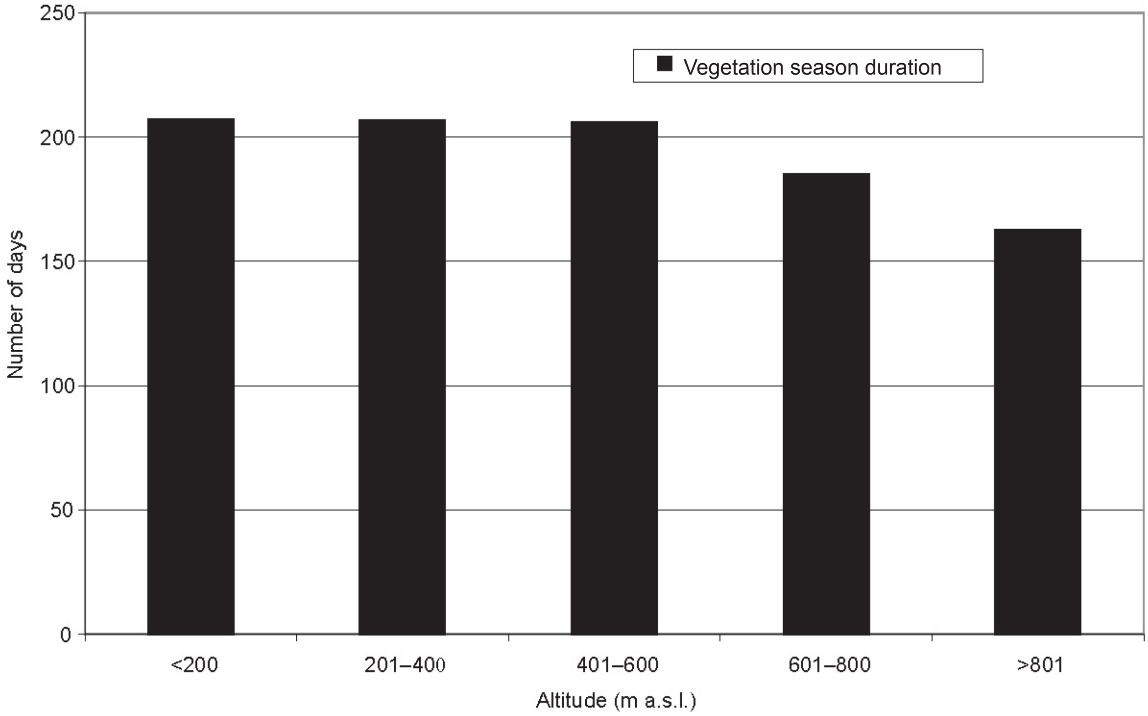

Fig. 4. Vegetation season length dependent on altitude in European beech in Czechia in 1992–2008.

Conclusions

European beech has been included into the phenological observation programme carried out across Czechia by the Czech Hydrometeorological Institute at its phenological stations. The results of phenological observations during 1992–2008 show considerable inter-annual differences in start and duration of individual phenophases. In the phase bud burst, the difference was 19–17 days (lowland station, mountain station), the lowest sum of effective temperature (TS5) for the phase start was 1.2 °C – lowland (3.5 °C – mountain), the highest was 148.2 °C – lowland (52.8 °C – mountain). Bednářová and Merklová (2007) studying European beech phenophases in the Drahanská vrchovina hills report for bud break the lowest sums of effective temperatures 10.9 °C, and the highest 135.6 °C . Hanousková (2010) calculated the average sums of effective temperatures to bud burst onset (123.7 °C – Lednice station, 112.5 °C – Chřibská station), to first leaves 100% onset (283.6 °C – Lednice station, 161.5 °C – Chřibská station) and to leaf fall onset (2,450.4 °C – Lednice station, 1,899.5 °C – Chřibská station).

The variation range for the 100% leaf fall was 50 days (Lednice) at the sum of effective temperatures 2,245.0 °C to 2,687 °C, and 40 days (Modrava) at the sum of effective temperatures 647.3 °C to 1,052.1 °C. The corresponding results from the Drahanská vrchovina hills (Bednářová and Merklová, 2007) were for the same phenophase in European beech 1,137.4 °C to 2,200 °C. We can see that altitude and locality has a considerable influence on phenophase onset.

The phenophase bud burst manifested higher relative variation coefficient than the phenophase leaf fall (100%); on the other hand, the variation range was larger in defoliation. The phenophase bud burst starts earlier in lowlands, leaf fall (100%) in mountains. The length of interphase interval bud burst – leaf fall (100%) was on average 223 days in the lowlands and 157 days in the mountains, length of interphase interval bud burst – first leaves (100%) was on average 19.8 days in the lowlands and 9.2 days in the mountains, and the length of interphase interval leaf colouring (10%) – leaf fall (100%) was on average 55.5 days in the lowlands and 26.4 days in the mountains.

The results show a high variability of phenophase onset during the last 17 years, in dependence on the weather course and location (altitude). The differences in totals of effective temperatures between lowlands and mountains were relatively high. The length of interval between bud burst – leaf fall (100%) (meaning the length of vegetation period) was 223 days in the lowlands and 157 days in the mountains. The sums of effective temperatures at the start of autumnal phenological phases in the recent years show an increasing tendency, resulting from gradual warming and thus prolongation of the growing season.

Acknowledgement

The authors gratefully thank to the Ministry of Education of the Czech Republic, Project Phenology Atlas of Czechia (number OC09029), for funding this research.

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Vývoj vegetativních fenologických fází buku lesního (*Fagus sylvatica L.*) ve vztahu k efektivním teplotám vzduchu za období 1992–2008 v Česku

Souhrn

Fenologické pozorování má v českých zemích dlouhou tradici. Vzhledem ke změně metodiky v 80. letech 20. století jsme pro zpracování využili výsledky fenologických pozorování lesních rostlin – buk lesní (*Fagus sylvatica L.*) vybraných vegetativních jarních a podzimních fenofází. I když je počátek fenofází podmíněn hodně genetickými vlastnostmi rostlinného druhu, počasí může ovlivnit nástup fenofází a tím narušit další vývoj rostlin. Z meteorologických prvků má největší vliv na počátek a trvání fenofází teplota vzduchu – za rozhodující charakteristiku lze považovat sumu efektivních teplot, která fázím předchází. Ve studii jsou ukázány výsledky sedmnáctiletého pozorování zvolených fenofází rašení, první listy (100 %), žloutnutí listů (10 %) a opad listů (100 %) jednak ze všech fenologických stanic ČHMÚ a detailně jsou zpracovány fenologické stanice v extrémně rozdílných nadmořských výškách (Lednice, 165 m n. m., Přibyslav 533 m n. m. a Modrava 1 102 m n. m.). Výsledky prokázaly vliv nadmořské výšky na nástupu fenofází, průměrné datum nástupu fenofáze rašení nastává na stanici Lednice (165 m n. m.) dne 14. 4. a na stanici Modrava (1 102 m n. m.) dne 6. 5., průměrné datum fenofáze prvních listů 100 % nastává dne 4. 5. (Lednice) a dne 15. 5. (Modrava), průměrné datum žloutnutí listů 10 % nastává dne 28. 9. (Lednice) a 13. 9. (Modrava) a průměrné datum opadu listí 100 % přichází dne 23. 11. (Lednice) a dne 9. 10. (Modrava). Průměrná suma efektivních teplot nad 5 °C je u nížinné stanice Lednice 71,6 °C (BBCH 07), 250,3 °C (BBCH 15), 2 413,9 °C (BBCH 92) a 2 461,6 °C (BBCH 97) a u horské stanice Kvilda 20,2 °C (BBCH 07), 134,6 °C (BBCH 15), 871,5 °C (BBCH 92) a 904,9 °C (BBCH 97). Průměrná délka vegetačního období je 198,3 dne v průměru ČR, v nížinných polohách 223 dní a v horských 157 dní. Suma efektivních teplot nad 5 °C vykazuje u podzimních fenofází stoupající tendenci, tedy prodlužování délky vegetačního období v posledních letech.

Received November 27, 2009
Accepted October 22, 2010

FOLIA OECOLOGICA – vol. 37, no. 2 (2010). ISSN 1336-5266

The black pine health condition in the Zoborské vrchy Mts

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Abstract

Hečková, Z., Adamčíková, K., Košťál, J., 2010. The black pine health condition in the Zoborské vrchy Mts. *Folia oecol*., 37: 162–167.

The introduced black pine (*Pinus nigra* Arnold) has been planted for its resistance to pollution and biotic harmful factors. However, nowadays the species appears drying up. The object of this paper is to assess the measure of damage, to identify the reason for its injury and to estimate the measure of the influence of the black pine stands in the Zoborské vrchy Mts in the years 2007 and 2008. An occurrence of the *Rhyacionia buoliana* (Denis & Schiffermüler), was identified on a tree shoot. On each spot, there have been assessed the degree of damage to the trees by all relevant harmful factors and intensity of infestation by the *Rhyacionia buoliana*. It has been found out, that the spots have different degree of damage by all harmful factors, as well as the intensity of infestation by the *Rhyacionia buoliana*.

Keywords

degree of damage, harmful factors, black pine, *Rhyacionia buoliana*

Introduction

The black pine (*Pinus nigra* Arnold) was introduced from the Mediterranean region. The introduction started in the 18th century. The first record of its presence is from the year 1769, when a seed from Lower Austria was sown in the Kremnica forests (Nožička, 1969). The species is one of the most intensively utilised introduced woody plants in Slovakia (Tokár and Krekulová, 2005). The black pine has primarily found use as an ameliorative woody plant in reforestation of erosion-exposed sites, deserted soils and infertile pastures. It was mostly planted as monoculture (Kunca et al., 2005). The survey of the species in the Malé Karpaty Mts revealed that for higher production and higher stem quality in black pine, it is essential to grow it in two-storey and three-storey mixed stands (Tokár 1985a, b, 1991). Recently, the black pine has suffered from new harmful factors causing premature drying up of the needles, terminal shoots and entire trees (Adamčíková and Juhásová, 2005). Unsuitable stand conditions are significant predisposition factors. A quantity of plants are grown out of their natural habitats, eventually they display the effects of stress factors as the pollution, and changes in water and wind regime (Jankovský, 2005). Black pine trees lose their dark green colour and begin darkening. The degraded tree health state is caused by weather fluctuations. Pine trees weakened in this manner become attractive for insect pests causing to them mortal damage. The needle litter change soil properties, and cause dieback of rare plants growing under the pines and overall changes in the vegetation. The black pine drying up becomes a problem primarily in old ornamental out plantings, but also in reforestation (Jankovský et al., 2000; Jankovský, 2005). The aim of this paper was to evaluate the black pine health condition in the selected spots in the Zoborské vrchy Mts, to find out the causes of its drying up, to assess degrees of damage and to compare them between the spots.

Material and methods

The issue was studied in black pine in four spots selected in the Zoborské vrchy Mts. The spots differed in orientation towards the world sides, in stand age and stand density.

1. Spot – Zoborská lesostep (forest-steppe): The spot is situated on a south-west facing slope of Zoborské vrchy, at 300–460 m a.s.l. The vegetation consists of xerotherm meadowlands bordered by thermophilic oak forests and oak-hornbeam forests (Querco-Fagetea). The soil is shallow, stony. The climate is the warmest and driest in this area. The soil-forming substrate is limestone in superincumbent beds. The stand age is 110 years; the stand is under-stocked in the southern part and well-stocked in the north.
2. Spot – The pine growth near the church of St. Michael by Dražovce: The spot is situated on the northwest facing slope, at 180–240 m a.s.l. The soil is sporadically shallow and stony. The substratum is limestone in superincumbent beds. The stand age is approximately 35 years; the stand is well-stocked (*Opis porastov a plán hospodárskych opatrení*, 2003).
3. Spot – Surroundings of a moor near Žirany: The spot is situated on a northeast facing slope of Vápeník. The vegetation consists of meadowlands and pastures growing one quartzit substrate (Hreško et al., 2006). The soil is shallow, stony. The altitude is 300–360 m a.s.l. The stand age is about 20 years. The stand is well-stocked.
4. Spot – Kolíňanský vrch: This spot is situated on a west facing slope, at 260–300 m a.s.l. covered with thermophilic shrubbery on limestone substratum. The soil is shallow, rocky, the stand is well-stocked. The stand age is approximately 110 years. The spot is situated close to a lime-pit and a stationary drill field of the Slovak Armed Forces.

Damage assessment

The damage to pine trees was assessed in the years 2007 and 2008. The primary method for assessment of the black pine health conditions was field examination. Two items were evaluated: the total tree habitus (degrees of damage) and the intensity of infestation (categories) by the pest *Rhyacionia buoliana* (Denis & Schiffermüller, 1775).

Total degree of damage

The degree of damage was evaluated in the field. Thirty trees were selected for observing changes in colour, occurrence of dry and damaged branches and evaluation of the overall tree habitus. The damage degrees in Table 1 summarize all pathogens because their influences are not possible to separate.

Rhyacionia buoliana intensity of infestation evaluation

A special method was used for evaluating the attack on shoots of *P. nigra* by the pest *R. buoliana*. On each of the 30 selected trees, number of damaged shoots was counted on 5 selected branches. The damage was classified into 6 categories according to the intensity of infestation (Table 2). The intensity of infestation was calculated with using the Towsendo-Heuberger formula:

$$P = \frac{(n \cdot V) \cdot 100}{6 \cdot N}$$

where P is the degree of damage (%), n is the number of category within a six-point scale, v is the numeric value of the damage category, N is the total number of branches, and ∑ is the total number of trees. Towsendo-Heuberger formula is used for determining the damage intensity to the leaves. In our case, the original formula has been modified to be used for shoots.

Table 1. Grading of six damage degrees used in total damage degree evaluation of the black pine

Degree of damage	Damage measure	Crown damage [%]
0	Undamaged tree	0
1	Slightly damaged tree	1–25
2	Moderately damaged tree	26–50
3	Heavily damaged tree	51–75
4	Caducous tree	76–99
5	Dried tree	100

Table 2. The grading of damage categories according that the branches damage caused by *Rhyacionia buoliana* was evaluated

Categories of infestation	Number of attacked shoots
0	0– no damaged shoot
1	1–5 damaged shoots
2	6–10 damaged shoots
3	11–15 damaged shoots
4	16–20 damaged shoots
5	More than 20 damaged shoots

Results

The total degree of damage on the studied spots

The evaluated spots were found different in the tree damage. The most intensive damage was the damage to the black pines on the spot Kolíňanský vrch where no tree could be classified with the degree of damage 0 (healthy or undamaged trees), and 10% of the evaluated trees were dry or dead (damage degree 5) (Table 3). Most trees were damaged more than 50% (Fig. 1). Similarly, there were no healthy trees in Dražovce and Zoborská lesostep. The trees in Dražovce were damaged to a slightly lower damage degree. The lowest degree of damage was found on the spot near the moor in Žirany, where no trees were classified in the degrees of damage 4 and 5, and 10% of the evaluated trees were found healthy (Table 3). In Žirany, the number of trees dama-ged to 50% and more was lower in both years. It was the only spot with occurrence of healthy trees (Fig. 1). On each spot, the damage degree in the year 2008 was found higher compared to the year 2007.

Intensity of infestation by *Rhyacionia buoliana*

Figure 2 illustrates the intensity of infestation (in percent). At the spot Kolíňanský vrch the highest intensity of infestation was noted, almost 60% of shoots were attacked. Very similar figures were obtained for the pots Dražovce and Zoborská lesostep, where the damage intensity was nearly 58% and 59%, respectively. At the spot Žirany was found a moderate infestation. Approximately 33% of shoots were infested. At all four spots a slight decrease in the attack intensity in the year 2008 was observed.

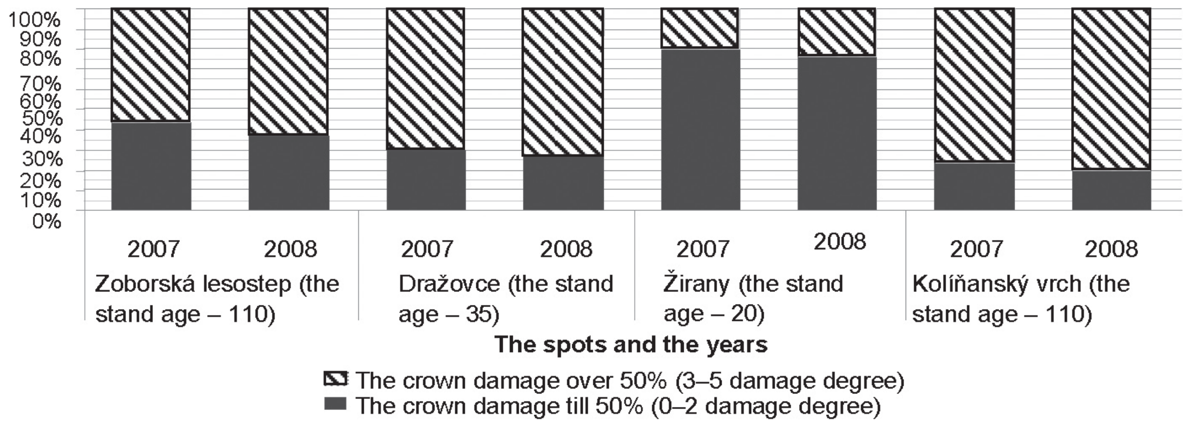

Fig. 1. The tree with the crown damage to 50% (damage degree 0–2) and over 50% (damage degree 3–5) representation on the spots in years 2007 and 2008.

Table 3. Percentual representation of trees in individual damage degree

Spot	Zoborská lesostep		Dražovce		Žirany		Kolíňanský vrch	
Damage degree / Year	2007	2008	2007	2008	2007	2008	2007	2008
	%	%	%	%	%	%	%	%
0	0	0	0	0	10	10	0	0
1	13.33	6.66	3.33	3.33	30	30	10	10
2	30	30	26.66	23.33	40	36.66	13.33	10
3	43.33	50	56.66	56.66	20	23.33	30	30
4	10	10	13.33	16.66	0	0	36.66	40
5	3.33	3.33	0	0	0	0	10	10

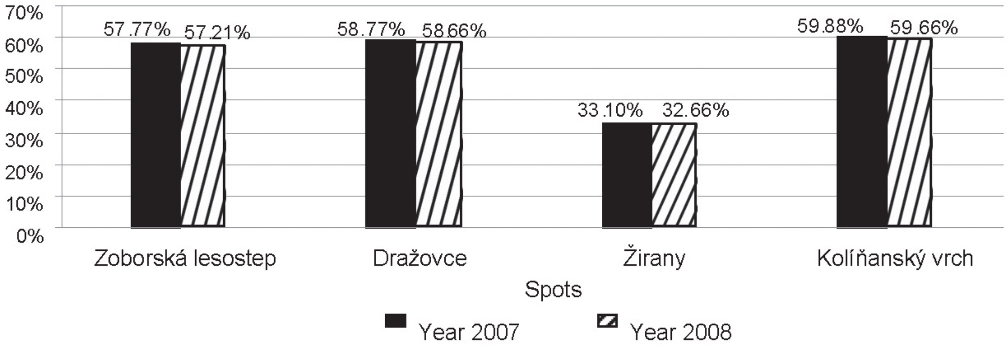

Fig. 2. Evaluation of the attack intesity caused by Rhyacionia buoliana in the year 2007 and 2008.

Discussion

The introduced black pine is in general considered as a woody plant with high resistance to pollution (Benčať, 1976), low demands on nutrient content in soil and high tolerance to dryness (Kunca and Leontovyč, 2005). The species can grow in extreme spots (Adamčíková and Juhásová, 2005), the number of its pests is very low (Kunca et al., 2005). It is very popular in out planting for its resistance towards particles, gaseous and aerosol pollution – permanently rising due to industrial production, traffic and fuel burning. In spite of the fact that the black pine has been recognised as resistant against pollution and dust, the highest degree of damage was observed at spots loaded with these factors. The most intensive damage was found at the spot Kolíňanský vrch, affected by several serious stress factors. The first is a lime pit producing dust that cover the assimilatory organs of trees and inhibit the assimilatory and respiration processes. The second is the pollution from the stationary drill field of the Slovak Armed Forces, contaminating plant organs and soil. The trees are similarly affected at the spot Dražovce. This spot is also severely loaded by stress factors influencing the black pine growth. The spot Zoborská lesostep is situated near the town of Nitra. The pollutants from the urban traffic, coupled with a very dry and warm climate with high evaporation and soil water content, are the driving stress factors weakening the black pine trees at this spot. The low degree of damage at the spot Žirany is possible because of the low stand age. At all the observed spots, was found a moderate increase in the intensity of infestation by *R. buoliana* in year 2008. The differences between years could be affected by climatic change – acting as a powerful stress factor. The most significant climatic factors, strongly influencing the health of woody plants are: air temperature, amount of precipitation and light conditions at the site (Hrubík and Kollár, 2008). The insufficient precipitation together with the high temperatures causes drought. The dryness is not the result of limited atmospheric precipitation alone, it is also affected by the precipitation and evaporation ratio of the stand. Moderate winters in the monitored years (Fig. 3) were lacking sufficient snow that means sufficient winter moisture for storing. The major amount of water was evaporated from the soil at the high temperatures (Fig. 3) in early summer through the middle of autumn in 2008. The drought impact was aggravated by high temperatures during the two years and the correct functioning of black pine vegetation organs was impaired and limited. The black pine's resistance to pathogens was weakened and the drought stress facilitated the progress of biotic infections. No control measures were made in the year 2007, so a poorer health state could be expected in the following years. But the infestation caused by the pest *R. buoliana* was slightly lower in 2008. This may be assigned to the temperature being higher in the spring 2007 than in 2008 (Fig. 3). At higher temperatures, the pest starts its activities earlier, and can eat more shoots. Jankovský and Palovčíková (2003) mention that the changing the black pines health state is possible due to the environmental pollution and partly by the climatic extremes or the climatic change.

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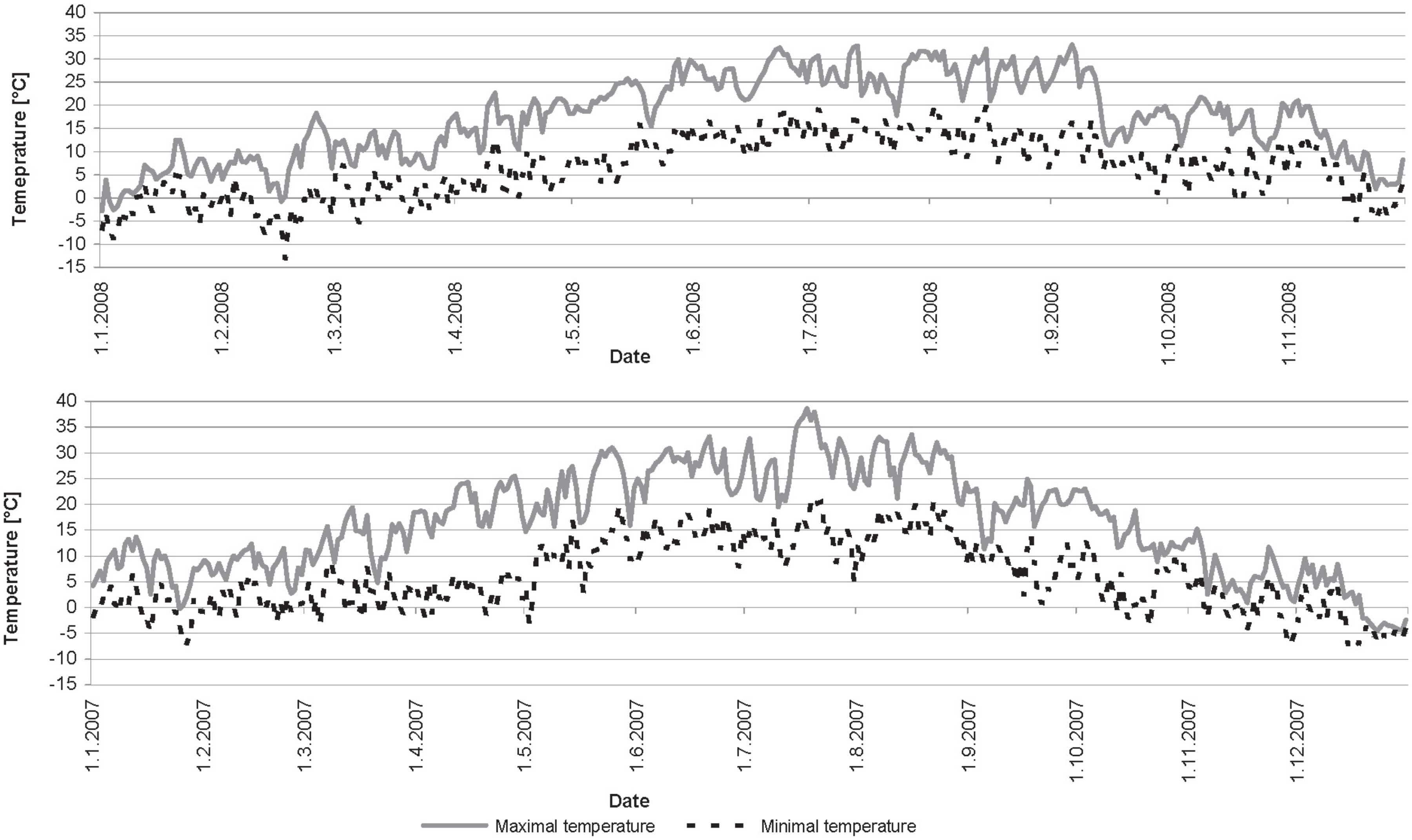

Fig. 3. Maximal and minimal daily temperatures in the years 2007 and 2008 (Source: Slovak Hydrometeorological Institute, meteorological station Nitra – Veľké Janíkovce).

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Zdravotný stav borovice čiernej v Zoborských vrchoch

Súhrn

Introdukovaná borovica čierna (*Pinus nigra* Arnold*)* sa začala pestovať ako veľmi odolná drevina voči imisiám a škodcom. Avšak v súčasnosti sa začalo objavovať jej usychanie. Cieľom bolo zmapovať rozsah jej poškodenia, zhodnotiť dôvod jej poškodenia a pokúsiť zistiť mieru vplyvu stanovištných podmienok na zdravotný stav v rokoch 2007 a 2008 v Zoborských vrchoch. Na výhonkoch bol zistený výskyt húseníc *Rhyacionia buoliana* Denis & Schiffermüler. Na každej lokalite bol určený stupeň poškodenia stromov a rozsah napadnutia živočíšnym škodcom *Rhyacionia buoliana.* Zistilo sa, že lokality majú rôzny stupeň poškodenia, ako aj rozsah napadnutia *Rhyacionia buoliana*. Najviac poškodenou v oboch hodnoteniach je lokalita Kolíňanský vrch, najmenej okolie vresoviska pri Žiranoch. Počas roku 2008 došlo k miernemu zvýšeniu poškodenia stromov, avšak napadnutie škodcom *Rhyacionia buoliana* sa mierne znížilo.

Received May 17, 2010
Accepted June 7, 2010

FOLIA OECOLOGICA – vol. 37, no. 2 (2010). ISSN 1336-5266

Species diversity of microscopic fungi on Austrian pines growing in urban greenery of Nitra town

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Abstract

IVANOVÁ, H., BERANDOVIČOVÁ, S. 2010. Species diversity of microscopic fungi on Austrian pines growing in urban greenery of Nitra town. *Folia oecol.*, 37: 168–180.

During the year 2009, complex mycoflora of Austrian pine trees (*Pinus nigra* Arnold) was monitored within a survey on health state of trees growing in urban environment. Four species of microscopic fungi were isolated and identified from samples collected from different part of Nitra town during the study period. This study reports the occurrence of the fungi *Camarosporium pini* (Westend.) Sacc., *Fusarium* sp. and *Mycosphaerella dearnessii* M.E. Barr on needles and *Sphaeropsis sapinea* (Fr.) Dyko & B. Sutton on needles and cones of *P. nigra*. Disease symptoms, some important characteristics in pure culture and distinctive morphological features are described. The presence of these fungi in host tissue of symptomatic trees has been described using classical phytopathological approaches and microscopical identification based on morphological keys. *Sphaeropsis sapinea* was identified on pine needles and cones in all examined samples with high frequency. The occurrence of *Fusarium* and *Camarosporium* fungi was relatively common. *Mycosphaerella dearnessii* was found as a fungal pathogen with sporadical incidence, its presence was noticed only in two cases from the all examined samples.

Key words

Camarosporium pini, Fusarium sp., microscopical characteristics, *Mycosphaerella dearnessii, Pinus nigra, Sphaeropsis sapinea*

Introduction

Recently, with regard to the expected global climate change, there is an increased risk of a shift of climatic barrier in Europe preventing penetration of many diseases and pests so far. At the same time, this change may cause the pathogens to adapt to the previously resistant species of woody plants (KOLÁŘÍK et al., 2005). In recent years, among urban trees Austrian pine also called European black pine (*Pinus nigra* Arnold) belongs to the particularly affected tree species. Austrian pine is a bold-textured and urban-tolerant pine having a broad-pyramidal growth habit with ascending branches and showy spring candles and often developing a flat-topped crown and ornamental bark with age. This evergreen tree in pine family is used either as a single specimen or in group or mass plantings as visual screens or windbreaks.

Numerous fungal diseases affect pine trees, including Austrian pine. Some of them are managed easily by applying chemical substances or biological means, the other spread rapidly through pine populations, as there have been no known means for controlling the fungal spread yet. Among pathogenic fungi, pathogens identified from the dead pine tissues include also *Sphaeropsis sapinea* (Fr.) Dyko & B. Sutton, *Camarosporium pini* (Westend.) Sacc., *Fusarium* sp. and *Mycosphaerella dearnessii* M.E. Barr (SINCLAIR et al., 1987). In connection with the occurrence of causal pathogens withering of branches and tree thinning was recorded in tree individuals in the lower parts of the tree crown as a beginning of woody plants weakening.

One of the most common and widely distributed pathogens of conifers worldwide, including European black pine is *Sphaeropsis sapinea* (Fr.) Dyko & B. Sutton, syn. *Diplodia pinea* (Desm.) J. Kickx f. (teleomorph in *Botryosphaeria*). It is a cosmopolitan fungus in Coelomycetes (Botryosphaeriales) identified in more than 50 countries of the world, on all continents but it is primarily the species of warm lands. The last decade is characterised by the fast movement of this pathogen from southern Europe to the north (Hanso and Drenkhan, 2009). This southern fungus moves north during drought periods: it is known that *D. pinea* can be released from its quiescent stage in the host by host water stress (Stanosz et al., 2001; Paoletti et al., 2001). Hard drought in last period encouraged *D. pinea* to become epidemic in Central Europe (Blaschke and Cech, 2007). Sphaeropsis tip blight, also called Diplodia blight is considered to be a "disfiguring disease" that attacks pine trees growing under stressful conditions. The fungus does not typically kill the tree but will significantly disfigure the tree if not properly cared for or controlled. The most endangered and frequent host coniferous plants are species in Pinaceae family – it occurs on 48 pine species, among which the most susceptible are *Pinus nigra* Arnold, *P. radiata* D. Don*, P. sylvestris* L., *P. ponderosa* Dougl. ex C. Lawson, *P. resinosa* Sol. ex Aiton, *P. mugo* Turra, *P. pinaster* Aiton and *P. elliotti* Engelm. (Milijašević, 2002). *Pinus nigra* is the most susceptible to *Diplodia* infection in spring when shoots are just elongating and not yet lignified. After the fungus has killed the host tissue, it can produce pycnidia which overwinter and can be a source of inoculum the following spring (Hartman, 2009). The first symptom may be exudation of a drop of resin from a small lesion, which enlarge quickly and infected buds or shoots cease growth before or during needle elongation. Tissues in lesions are resinsoaked and discolored dark reddish brown, and they often exude resin, which in time crystallizes, making the dead shoot hard and brittle (Sutton, 1980). The most conspicuous symptoms of this disease – brown, stunted new shoots with short, brown needles first appear on the newly elongating shoots in late April to early May. In late May the diseased tips are noticably necrotic and stunted. Progression of the fungus can lead to branch dieback and eventually death of the tree. Most trees escape infection for the first 15 to 20 years of life, only to develop symptoms after they reach maturity and begin to develop cones (Gregorová et al., 2006).

The genus *Fusarium* (Hyphomycetes, Hypocreales), (teleomorph in genus *Gibberella*, *Nectria*) contains many species that attack numerous hosts, including pine trees of all ages. Among the diseases caused by *Fusarium* sp. are root rots, blight and damping-off. Under optimum conditions, e.g. abundant fungal inoculum, high humidity and warm weather, susceptible pine species are likely to top blight (Affeltranger, 1983). The *Fusarium* species cause foliage diseases of pine trees. Symptoms of *Fusarium*-induced top blight often start at the growing tip of the plant, killing needles from the base upward. Under wet conditions the disease progresses laterally. *Fusarium* survives as resting or survival spores (chlamydospores) in organic matter and recently killed host tissues, particularly root pieces. Pathogen is spreading locally by the wind or insects. At greater distances it can be expanded through the contaminated seeds and seedlings. Branches and bark where the fungal spores are able to survive can also be the source of infection. Fungi in *Fusarium* attack the vegetative and generative plant organs and disease symptoms can occur in any season. *Fusarium* colonizes root system causing brown discoloration and decomposition of the surface layers of roots. The symptoms are not noticeable on tree aboveground part unless the fungus reaches the root collar and surrounds the tree stem. In the next phase there is a change in color of needles (yellowing to brown). Infection does not usually result in tree death, but deformed, slow-growing trees can be economically or aesthetically problematic.

The fungus *Mycosphaerella dearnessii* M.E. Barr (Ascomycetes, Dothideales), syn. *Scirrhia acicola* (Dearn.) Sigg., anamorph: *Lecanosticta acicola* (Thüm.) Syd., syn. *Septoria acicola* (Thüm.) Sacc. causes the disease called brown-spot needle blight. The fungus kills the foliage and retards the growth of many pine species. This fungus tends to infect pines from seedlings to eight years of age. Warm wet weather encourages infection progress. Disease usually takes several years to reach epidemic conditions. Thus allows enough time to prevent an epidemic outbreak. Brown-spot needle blight disease causes severe defoliation of pine trees where only last years needles remain on the branches that can be half dead from the late summer months. The disease is most evident on this year needles in summer period when the green needles are brown-spotted with yellow borders diffusing in brown, yellow-bordered stripes. Brown-spot needle blight is in Europe reported from Austria (Brandstetter and Cech, 2003; Kirisits and Cech, 2006), France (Chandelier et al., 1994), Italy (La Porta and Capretti, 2000), Germany (Pehl, 1995), Switzerland (Holdenrieder and Sieber, 1995), Bulgaria and formerly Yugoslavia (Holdenrieder and Sieber, 1995), Croatia (Novak-Agbaba and Halambek, 1997). Some new records origin from Slovenia (Jurc and Jurc, 2009) and Czech Republic (Jankovský et al., 2009).

Needle and shoot blights of pines caused by fungi in *Camarosporium* genus are doing more damage to coniferous foliage in Europa than any other group of fungi although literary records on these pathogens are rather insufficient. Within the diseases, fungus *Camarosporium pini* (Westend.) Sacc. (Coelomycetes, Pleosporales), syn. *Hendersonia pini* Westend. (teleomorph unknown) induces severe infection that can result in significant growth reduction. The micromycete parasitizes the needles of *Pinus nigra* weakened by the low temperatures in winter period and by the drought from the spring to summer season. On the dry needles, little back spots (pycnidia) arranged linearly and in parallel with the nervure can be noticed (Grove, 1922).

This study aims to describe the characteristic symptoms of fungal diseases and based on examination of growth and morphological attributes, the distinctive morphological features of studied microscopic fungi in *Sphaeropsis*, *Fusarium*, *Camarosporium* and *Mycosphaerella* genus are causative agents involved to a different degree in health state degradation of *Pinus nigra* Arnold in urbanized settings. For this purpose, some important characteristics as growth in culture, conidial formation and size differences in microscopical structures were studied in hyphal cultures of the examined pathogens isolated from symptomatic Austrian pine trees.

Material and methods

In the late summer and autumn 2009, damaged twigs with needles and cones had been taken from symptomatic Austrian pines growing in different parts of Nitra town. The material was collected at several locations from the diseased pine trees, in the areas of Nitra – Kynek, Nitra – Chrenová (Agrokomplex, Lidl, SPU – park, UKF – park) and Nitra – Zobor (private gardens). Altogether 128 trees were studied. The age of evaluated trees was between 15 and 70 years. The 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. The fungi were identified by microscopic analyses based on the appearance of the fruiting bodies, spore bearing organs (asci), reproduction organs (conidia and ascospores) and the appearance of the fungi in pure cultures. Classical phytopathological approaches were used to isolate and obtain pure hyphal cultures. Fungi were isolated from the needles first immersed for one minute into 70% alcohol and then for 15 minutes into sodium hypochlorite (1% available chlorine). After that, the needles were washed twice in sterilized distilled water and cut to fragments of 2–5 mm which were placed on the nutritive media, potato-dextrose agar (PDA) and Czapek-Dox agar (CzD). Petri dishes with the media and host fragments were incubated at 24 ± 1 °C and 45% humidity in dark in a versatile environmental test chamber MLR-351H (Sanyo). Pure fungal cultures were obtained using multiple purifications. The identification was performed using morphological keys according to Arx (1957, 1970), Hitchcock and Cole (1980), Nelson et al. (1983), Sutton (1980), Woodward (2001) and Tello et al. (2000). The fungi were identified based on colony development, sporulation and fructification in cultures, hyphal appearance, growth rate etc. Visual characteristics of symptomatic needles were examined with a stereomicroscope SZ51 (Olympus) and fungal structures observations were accomplished with a clinical microscope BX41 (Olympus) under a 400× magnification.

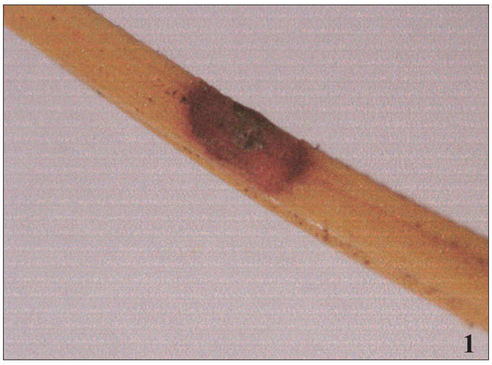
Results and discussion

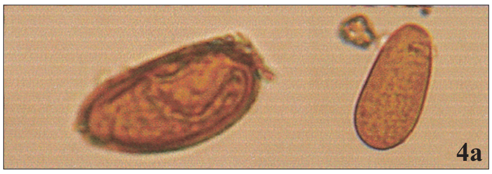
The fungus *Sphaeropsis sapinea* is worldwide in distribution and importance on a great number of coniferous, most often on pine species. It kills the pine shoots and needles, individual branches, tree tops or the entire plants, and also it causes dying of the young plants in nurseries. On *Pinus* species, the fungus *S. sapinea* is a typical parasite and it colonises the current-year shoots and needles. The study of morphological characteristics of the fungus on these host plants and the comparative analysis with the morphological characteristics of the same fungus on *Pinus* sp. shows a difference between them (Milijašević, 2003).

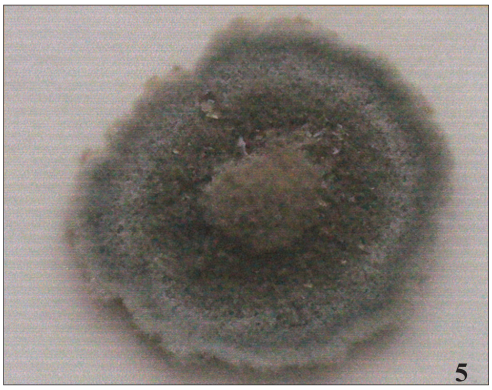
In our study, *Sphaeropsis sapinea* was identified on Austrian pine needles and cones from all examined samples with high frequency. The infected needles manifested presence of tiny black fruiting structures – pycnidia about 200 µm in diameter (Fig. 1). Pycnidia break throught the surfaces of killed needles, cone scales and the bark of twigs beginning in late summer in the year of infection and continuing the next spring. In cylindric-clavate, bitunicate 4–6(–8)-spored asci are formed reproduction organs (ascospores), brown, oblong to ovate, without septa, moderately thick-walled with smooth surface (Figs 2a, 2b). The fungus also produces spores in fruiting structures that develop on the second-year female cones (Fig. 3). Because most of spores are produced on the mature cones, tip blight often does not show up untill the trees are 15 to 20 years old and produce the large cones. Spreading through the whole tree organism can cause the eventual death of all infected branches and ornamental value of affected tree is significantly diminished (Engelbrecht, 2005). Pycnidia contain spores dispersed by rain splash and windblown rain. The spores require a high relative humidity to germinate and infect needles and shoots. A wet period of 12 hours at 12 °C to 36 °C is enough for spore germination and infection. In warm, moist weather symptoms appear in about three to four days. The *Sphaeropsis* conidia are generally dark brown and large, oblong to clavate, thick-walled, 0–1-septate. In our experiments conidia were 30–42 × 14–16 µm, were brown, oblong to clavate, thick-walled. Most conidia are unicellular (Fig. 4a) but some also two-celled (Fig. 4b).

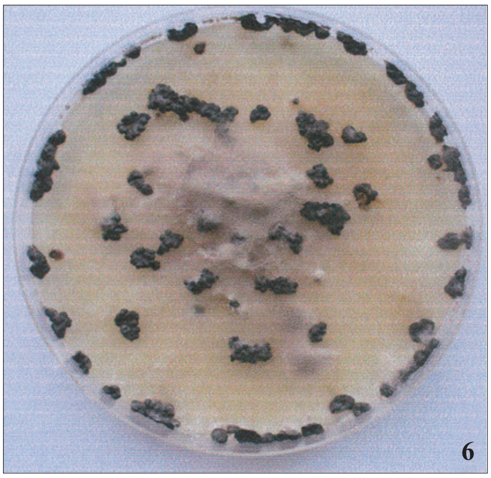
According to Palmer and Nicholls (1983), the fungus grows rapidly on standard mycological media, such as malt or potato-dextrose agar possible for isolation of *Sphaeropsis* and incubation in dark or light (at 20–25 °C for 2 or 4 days). According to Milijašević (2002), the optimal temperature for mycelial growth on the media PDA and MEA is 28 °C. Palmer and Nicholls (1983) observed that the fungus formed gray-green fluffy mycelium. Cultures of this fungus are first white, later then darken with age. *Diplodia* does not sporulate readily in culture. For positive identification authors suggest to place sterile pine needles over actively growing cultures and incubate them in light. Pycnidia and spores are usually produced in about 1 week. In our experiments potato-dextrose agar (PDA 3%) and Czapek-Dox agar (CzD 3%) were used for cultivation. Rapid growth rates we obtained by incubation in dark at 24 ± 1 °C for 5 days. The fungus formed white mycelium, becoming darker and gray-green with age (Fig. 5). The formation of fruiting bodies in the culture is in dark for two weeks (Fig. 6).

Comparison of biometric characteristics and morphological features of *Sphaeropsis sapinea* on *Pinus*









Sphaeropsis sapinea on *Pinus nigra:*
Fig. 1. The tiny black pycnidia on affected needle.
Fig. 2. Asci with ascospores (2a), detail of ascus (2b).
Fig. 3. Conidiomata on the cone scales of *P. nigra.*
Fig. 4. Unicellular (4a) and two-celled conidia (4b).
Fig. 5. Gray-green mycelium of fungus formed l days after inoculation on potato-dextrose agar (PDA).
Fig. 6. Fruiting bodies formation for 2 weeks on PDA.

Table 1. Comparison of biometric characteristics and morphological features of *Sphaeropsis sapinea* on genus *Pinus* sp. reported by other authors and examined material from Slovakia

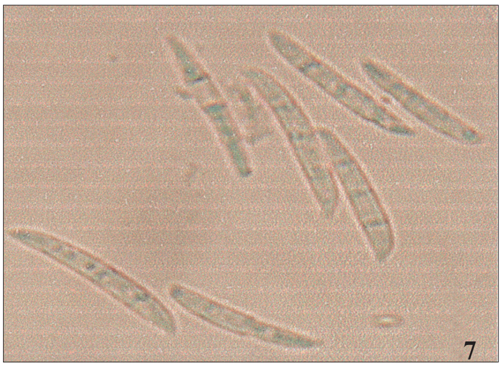
Author(s)	Host	Size of conidia (µm)	Conidia
Peterson (1977, 1978)	*P. sylvestris* *P. resinosa* *P. ponderosa* *P. radiata* *P. nigra*	absent	Conidia brown, one septate or withouth any cross walls (septa)
Sutton (1980)	*P. nigra* *P. ponderosa* *P. sylvestris*	30–45 × 10–16	Conidia dark brown, most unicellular, but a few are two-celled and large
Palmer, Nicholls (1983)	*P. sylvestris* *P. nigra* *P. resinosa* *P. banksiana*	22.5–44 × 9.5–18.5	Conidia brown, sometimes with one septation, rough-walled and elliptical in shape
Peterson, Nicholls (1989)	*P. nigra* *P. mugo* *P. resinosa* *P. ponderosa* *P. sylvestris* *P. radiata*	30–45 × 10–15	Spores are brown at maturity, ellipsoid, usually one-celled
Crous et al. (1990)	*Pinus sp.*	30–45 × 10–16	Conidia yelowisch to brown, oblong to clavate, rounted at apex with bunt basal end, 0–1-septate
Koltay (2001)	*P. nigra* *P. sylvestris*	35–40 × 15–20	–
Milijašević (2002)	*Pinus sp.*	14.8–51.4 × 9.7–20.2	–
Jankovský, Palovčíková (2003)	*Pinus sp.*	25–40 × 10–15	Conidia dark, 1 and 2-celled
Adamčíková, Juhásová (2005)	*P. nigra*	35–40 × 15–20	–
Phillips et al. (2005)	*Pinus sp.*	30–45 × 10–16	Conidia wall dark brown, internally ruoghened, sometimes with 1 septum, oblong to clavate, straight, thick-walled, ornamented on the inner surface of the wall
Juhásová et al. (2006)	*P. nigra*	33.2–41.2 × 16.6	Conidia dark, ovoid, elongate, 1-celled, mature 2-celled
Hanso, Drenkhan (2009)	*P. nigra*	30.6–44.7 (47.1) × (11.8) 14.1–16.8	Conidia brown
Examined material (2009)	*P. nigra*	30–42 × 14–16	Conidia brown, oblong to clavate, thick-walled 0–1-septate

species reported by other authors and examined material from Slovakia is shown in Table 1.

The occurrence of *Fusarium* and *Camarosporium* fungi in our survey was relatively common. Considerable damage to pine trees, especially *Pinus nigra* caused by fungi *Fusarium* isolated from damaged tissue of needles sampled during evaluation of the trees in urban greenery was noticed. Presence of typical macroconidia with 1–3 septa of *Fusarium* with dimensions 26–45 × 4–6 µm on damaged needles was observed (Fig. 7). Pure cultures with colonies of aerial, white (Fig. 8a) or slightly violet fungal mycelium (Fig. 8b) formed 10 days after inoculation on PDA medium.

Carlucci et al. (2007) noticed numerous trees of genus *Pinus* (*P. halepensis* Mill., *P. pinea* L.) in urban parks and gardens in Apulia showing crown decline as a consequence of dieback of twigs and branches and withering of needles. The needles of affected twigs and branches wilted, faded, turned yellow, then red, and were discarded. The species of *Fusarium* was consistently isolated from all infected tissues. Pure cultures were obtained by single hyphal tip transfers on PDA and synthetic nutrient agar medium. Colonies were incubated at 22 ± 3 °C for 7 to 10 days. The species was identified as *Fusarium circinatum* Nirenberg & O'Donnell on the basis of morphological and cultural characteristics. According to Britz et al. (2002) branches and stems of pine trees of any age may be infected. Infection usually begins as a canker and dieback of small branches. Needles wilt above the infection site (becoming chlorotic, then red and brown), and resin accumulates on the branch surface. Repetition of these symptoms throughthout the canopy may lead to extensive dieback. The trunk and larger branches may be in due course infected, producing copious amounts of resin, and accelerating the decline of the tree. Girdling of the main stem may lead to death of the tree. Zad and Koshnevice (2001) in study of damping-off collected samples from the roots of *Pinus nigra* seedlings from nurseries in the south of Iran. After disinfecting, standard media like PDA, MA and CLA were used and the following fungi were identified: *Fusarium solani* (Mart.) Sacc., *Fusarium oxysporum* (Schltdl.), *Fusarium sambucinum* Fuckel and others. Infection of *P. nigra* with *F. solani* and *F. oxysporum* was extensive. In Europe, disease caused by *F. circinatum* previously has been reported only from Spain on *P. radiata* and *P. pinaster* (Landeras et al., 2005). In Serbia, presence of *Fusarium* on Austrian pine needle litter was confirmed by Karadžić and Milijašević (2008). Our results are comparable with studies carried out for *Fusarium* on *Pinus* species in several other countries (Table 2).

Other damage to pine needles and shoots is caused by the fungus *Camarosporium pini* (Westend.) Sacc. Literary records on *Camarosporium* pathogens on conifers are rather insufficient. The fungi of genus *Camarosporium* cause more damage to deciduous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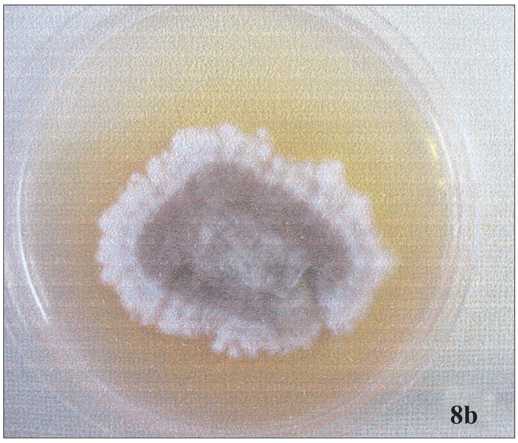
Fusarium sp. on *Pinus nigra*:

Fig. 7. Characteristic macroconidia of *Fusarium* (1–3 septate) isolated from infected tissues of Austrian pine needles.

Fig. 8. Hyphal cultures with aerial white (8a) or later sligtly violet (8b) fungal mycelium 10 days after inoculation on potato-dextrose agar.


8a


8b

trees in Europa. For example, the fungus *Camarosporium elaeagni* Potebnia with rather small, densely gregarious pycnidia was noticed on *Eleagnus angustifolia* L. On *Spirea callosa* Lindl. & Paxton, the fungus *Camarosporium spiraeae* Cooke with large pycnidia covered with elevated epidermis, and on *Salix alba* L. and *S. fragilis* L. *Camarosporium salicinum* (Vize) Grove with densely scattered, roundish pycnidia with a protruding ostiole occurred. On dead branches of *Robinia pseudoacacia* L. the fungus *Camarosporium robiniae* (Westend.) Sacc. was noticed (Juhásová et al., 2004).

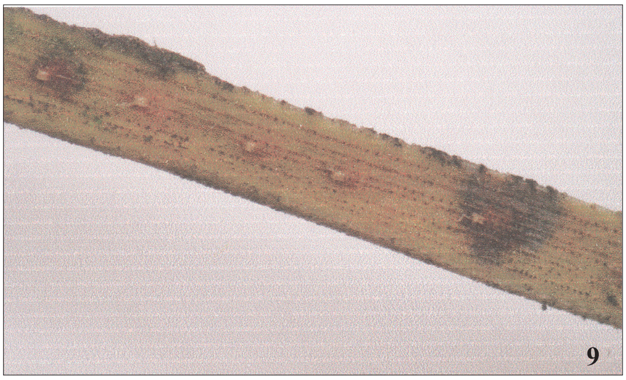
The micromycete *Camarosporium pini* parasitizes the needles of *Pinus nigra* weakened by low temperatures in winter and by drought in spring and summer. On the dry needles little black spots arranged linearly and in parallel to venation were observed (Fig. 9). These spots represent pycnidia of 180–300 µm in diameter, black, spherical swelling of the epidermis with pustules. Through the pycnidium pore there come out numerous oval brown conidia with three transversal walls and 1–2 vertical walls of sizes ranging between 18–20 × 9–10 µm. Pycnidia rather crowded, up to 500 µm diameter, very convex, roundish or elongated, black, covered by the epidermis, then bursting it irregularly or by a slit, texture thick and dark, indistinct, paler inwards. Spores oblong, rounded at both ends, often slightly curved, at first continuous, at length 3-septate, not or hardly constricted, with frequently one or two longitudinal divisions, 15–18 × 7–8 µm, cells uniformely brown, the central cells often shorter than the terminal ones, sporophores short and indistinct (Grove, 1922). Pycnidia were immersed in the bark, at first scattered, than arranged in line, up to 700 µm diameter, subglobose, brown, perforating the epidermis, ostiole subpapilliform. Spores elongate-oval, brown, 3–6-septate (or even 8-septate) and muriform, not constricted, 15–25 × 7–9 µm, sporophores indistinct (Dennis, 1964). Comparable results with the frequent fungi in *Camarosporium* genus occuring on fallen cones on Austrian and Scots pine were obtained by Karadžić and Milijašević (2008) in Serbia.

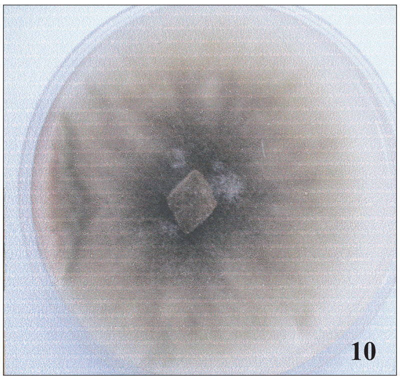
Cultures obtained during our cultivation from injured needles of *Pinus nigra* on PDA medium were initially white with abundant aerial mycelium, gradually becoming grey to dark grey (Fig. 10). The reverse side of the colonies is at first white, but after 2–3 days becoming dark green to olive green from the centre. This coloration gradually spreads to the edge and becomes darker from the centre until the entire underside of the colony is black. Conidia are pale brown, thin-walled, smooth, fusiform to fusiform-elliptical, straight, apex subobtuse, base truncate, 20–22 × 6–8 µm (Figs 11a, 11b).

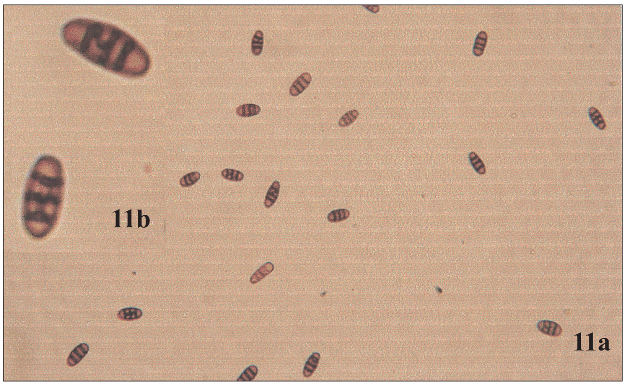
Table 2. Comparison of biometric characteristics and morphological features of *Fusarium* sp. on genus *Pinus* sp. reported by other authors and examined material from Slovakia

Author(s)	Hosts / pathogen	Size of conidia [µm]	Conidia, mycelium
Zad, Koshnevice (2001)	*P. nigra / F. solani*	M: 27–52 × 4.4–6.8	–
		m: 8–16 × 2–4	
Britz et al. (2002)	*Pinus sp./Fusarium sp.*	M: 32–48 × 3.3–3.8	M: typically 3-septate, with slightly curved walls
		M: absent	m: typically single-celled, ovoid (or nearly oval or allanoid), are borne in false heads on aerial polyphialides
			Mycelium: aerial on which they are borne, gives a distinctive colony, morphology. Aerial mycelium is white, or slightly violet. Colonies are frequently sectored
Landeras et al. (2005)	*P. radiate*	Absent	–
	P. pinaster / F. circinatum		
Carluci et al. (2007)	*P. halepensis* *P. pinea / F. circinatum*	Absent	M: typically 3-septate with slightly curved walls
			m: single-celled
			Mycelium: white aerial, violet pigment
Karadžić, Milijašević (2008)	*P. nigra / Fusarium sp.*	Absent	–
Examined material (2009)	*P. nigra / Fusarium sp.*	M: 26–45 x 4–6	M: 1–3-septate
		m: absent	Mycelium: aerial, white or slightly violet

M, macroconidia; m, microconidia.







Camarosporium pini on *Pinus nigra*:

Fig. 9. Fig . 9. Little black spots of the fungus arranged linearly and parallelly to the venation of damaged Austrian pine needle.

Fig. 10. Cultura of *C. pini* on potato-dextrose agar with abudant aerial mycelium gradually becoming gray.

Fig. 11. Thick-walled, brown, elliptical, straight conidia of *C. pini* (11a), detail of conidia (11b).

During the study period, the needle cast *Mycosphaerella dearnessii* was found as a fungal pathogen with sporadical incidence, its presence was noticed only in two cases from all examined samples. The first report of *M. dearnessii*, the causal agent of brown-spot needle blight was observed on the southern slopes of the Alps and in Italy on the *Pinus mugo* about 50 years old and 2.0 to 2.5 m high by La Porta and Capretti (2000). *P. mugo* exhibited extensive necroses and defoliation of the crown starting from the bottom upward especially on the shaded portions of infected trees. Symptomatic needles were confined to the 2–3 years old internodes. Infected needles had several dark to purplish-brown spots surrounded by green tissue and usually had dead tips. Pycnidia and conidia of *Lecanosticta acicola* were observed.

Dead or blighted one-year-old needles of *P. sylvestris* and *P. mugo* growing in Slovenia affected by *Lecanosticta acicola* (*Mycosphaerella dearnessii*) were found in 2008 and 2009. The results obtained by Jurc and Jurc (2009) represent a first report about this fungus in Slovenia. Recently, brown-spot needle blight associated with *Mycosphaerella dearnessii* on 10–40 years old *Pinus rotundata* in the Czech Republic has been recorded by Jankovský et al. (2009). The symptoms begin with the appearance of yellow and brown spots, later becoming bands on first-year needles that decline from the tip. Acervuli erupt from needles incubated for two to three days in a moisture chamber. After three weeks incubation of conidia at 21 °C on malt extract agar, dark green olive stromatic mycelial colonies produced conidia identical to those detected on incubated needles.

A presumptive indication of the presence of *M. dearnessii* in pine needles from Nitra town conditions is from early September where yellow, resin-soaked spots later becoming brown in the centre appeared (Fig. 12). Eventually, the needles turn all brown from the tip to the base. Some have a yellow patches or brown infected tissue (Figs 13a, 13b) and may fall off. Lower branches are more likely to be infected first due to less air circulation, and the infected needles fall on the ground. Infected needles droop and fall by September of the next year. If the infection is severe, whole needles are killed and drop, leaving bare branches. The disease can affect trees of any age but seedlings are most susceptible. On the brown-coloured dead parts of the needles, the black stromata 0.2–0.4 × 0.1–0.3 mm in size develop under the epidermis visible as round black spots. The oval-shaped fruit bodies are arranged parallelly to long axis of the needles. Under damp conditions, conidial masses protrude from both sides of the conidiomata (Fig. 14), and break the epidermis through opening by a 1–2 longitudinal slit. The conidia are olive-coloured, straight to curved, thick-walled, 1–3-septate, fusiform to cylindrical, with verrucose structure, 22–40 × 3.5–6 µm in size (Fig. 15). The fungus should be isolated from the affected needles with brown dead tissue (brown spots, dead parts with black stroma spots). After an incubation period of 2–3 weeks at 22 °C in dark, isolates can be examined. Slow-growing mycelia should be subcultured onto fresh PDA media. The fungus grows very slowly

Table 3. Comparison of biometric characteristics and morphological features of *Mycosphaerella dearnessii* on *Pinus* sp. reported by other authors and examined material from Slovakia

Author(s)	Host	Size of conidia [µm]	Conidia
Laut et al. (1966)	*P. concorta* var. *latifolia* *P. banksiana*	21–44.5 × 2.5–3.5	Conidia (0–)3(–4)
Sutton (1980)	*Pinus* sp.	15–35 × 3–4	1–3-septate, multicellular, olive-coloured spores
Jewell (1983)	*P. palustris*	Absent	Conidia have one to three walls or with or withouth several indistinst walls, rarely were mature conidia of less than four cells observed
Evans (1984)	*Pinus* sp.	(10)–12–45(–55) × 2–4.5	Conidia 1–5-septate, extremely variable in form, subhyaline to dark-brown, echinulate to verrucose or tuberculate, thick-walled
Li et al. (1986)	*P. elliottii* *P. massoniana* *P. thunbergii*	24.5–51 × 3.4–6.3	Conidia with 1–6 septa
Holdenrieder, Sieber (1995)	*P. mugo* *P. uncinata*	28–54 × 2.9–4.9	Conidia with 0–3 septa
Pehl (1995)	*P. mugo*	19.2–48 × 2.5–5.0	Conidia with 0–5 septa
Suto, Ougi (1998a, 1988b)	*P. thunbergii*	20–53 × 3.3–5.0	Conidia subhyaline to dark brown, verrucose, thick walled, straight to curved, 1–5-septate, fusiform to cylindrical with a round apex and truncate base
La Porta, Capretti (2000)	*P. mugo*	20–30 × 3–4	Conidia 4-celled, curved, pointed at one end and blunt at the other, pale olive-brown
Jurc, Jurc (2009)	*P. sylvestris* *P. mugo*	30 (16–42) × 4 (2–5)	Conidia are brown, strieght or curved, with a rounded apex and truncate base, thick and verrucose wall, and 0–6 septa
Jankovský et al. (2009)	*P. rotundata*	3–5 × 21–44	Conidia subhyaline, thick-walled, straight to curved, fusiform to cylindrical, with rounded apex and truncate base, with 1–5 septa, occasionally slightly constricted at the septa. The surface have small warts or spines
Examined material (2009)	*P. nigra*	22–40 × 3.5–6	Conidia olive-coloured, straight to curved, thick walled, 1–3-septate, fusiform to cylindrical

in culture, forming grey, brown or greenish-black stromatic colonies (Fig. 16) with slimy masses of pink-grey or greenish conidia. Some biometric characteristics and morphological features of *Mycosphaerella dearnessii* on pine trees noticed by several authors are in Table 3.

The presented results indicate that the health condition of Austrian pine trees in urban environment may be negatively affected by microscopic fungal pathogens which can cause individual tree subjects degrade to different degrees. In this study, the concerned fungi were identified with using morphological keys. However, characteristics of necrotic and chlorotic needles with fruiting bodies were examined with a stereo-microscope, and identification of isolates and fungal structures was made based on microscopical differentiation. This preliminary identification, however, needs using methods of molecular biology for confirmation, since the morphological characteristics alone may not be fully reliable for this purpose. The planned molecular analysis based on large subunit nuclear ribosomal DNA sequences is required for detailed study of the discussed pathogens.

Acknowledgement

This study was carried out with support from the scientific projects VEGA of the Slovak Academy of Sciences No. 2/0149/10 and APVV-0421-07.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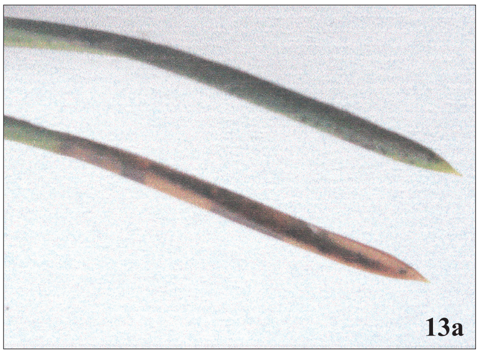
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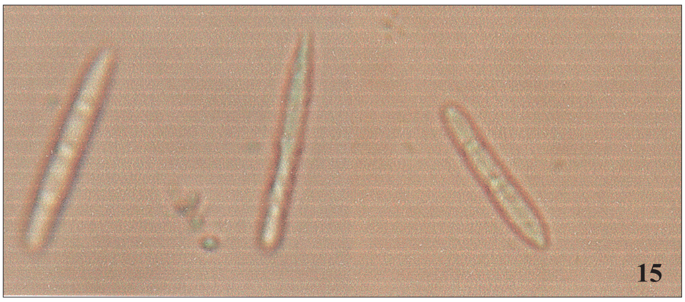
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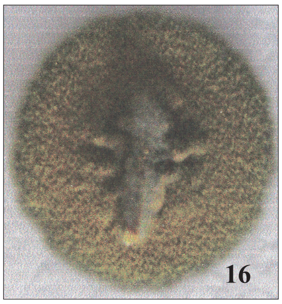
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Mycosphaerella dearnessii on *Pinus nigra*:
Fig. 12. Detail of yellow to brown resin-soaked spots on needle affected with brown-spot needle blight.
Fig. 13. Dead tips of damaged needles (13a), yellow patches or browning of infected tissue (13b).
Fig. 14. Conidial masses protruding from both sides of the conidiomata under damp conditions.
Fig. 15. Light brown conidia of the fungus with verrucose structure.
Fig. 16. Greenish-ochre stromatic cultura of *M. dearnesii* on potato-dextrose agar.

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Druhová diverzita mikroskopických húb borovice čiernej rastúcej v urbanizovanom prostredí Nitry

Súhrn

Príspevok prezentuje výsledky štúdia druhovej diverzity mikroskopických patogénov, ktorí sú pôvodcami hubových chorôb *Pinus nigra* Arnold rastúcej ako súčasť sídelnej vegetácie mesta Nitra. V priebehu vegetačného obdobia 2009 boli za účelom štúdia mykoflóry borovice čiernej v rámci výskumu zdravotného stavu drevín v urbanizovanom prostredí zaznamenané charakteristické symptómy chorôb, pôvodcami ktorých sú viaceré druhy mikroskopických húb. Zo vzoriek symptomatických stromov sme izolovali a mikroskopicky identifikovali huby *Camarosporium pini* (Westend.) Sacc., *Mycosphaerella dearnessii* M.E. Barr a *Fusarium* sp. na ihliciach a *Sphaeropsis sapinea* (Fr.) Dyko & B. Sutton na ihliciach a šiškách borovice čiernej. Huba *Sphaeropsis sapinea* bola identifikovaná ako patogén s najvyššou frekvenciou. Pomerne bežný bol výskyt druhov rodu *Fusarium* a *Camarosporium*. Huba *Mycosphaerella dearnessii* bola nájdená sporadicky. Práca na základe štúdia kulturálnych a morfologických vlastností skúmaných patogénov popisuje rozlišujúce morfologické znaky húb, ich anamorfných (acervuly, pyknidy, konídie) a teleomorfných (vrecká, askospóry) štádií a rastové charakteristiky na živnom médiu (rast v kultúre, vzhľad kultúry). Výsledky poukazujú na možnosť oslabenia zdravotného stavu borovice čiernej pôsobením patogénnych druhov mikroskopických húb podieľajúcich sa rozličnou mierou na poškodení hostiteľa, prítomnosť ktorých môže predstavovať zvýšené riziko šírenia hubových chorôb hlavne v kompaktnejších výsadbách druhov rodu *Pinus*.

Received April 8, 2010
Accepted May 23, 2010

FOLIA OECOLOGICA – vol. 37, no. 2 (2010). ISSN 1336-5266

Response of earthworms biomass and diversity to windthrow events and soil properties in Hyrcanian forests of Iran

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Abstract

Kooch, Y., Hosseini, S. M. 2010. Response of earthworms biomass and diversity to windthrow events and soil properties in Hyrcanian forests of Iran. *Folia oecol.*, 37: 181–190.

Uprooting is a major disturbance factor in most natural forests. Little work has been done concerning the effects of uprooting on soil properties and fauna. This paper focuses the effects of tree uprooting on some soil properties, earthworm biomass and species diversity in Sardabrood forests of Chalous in Hyrcanian forest, northern Iran. For this purpose, twenty seven single-tree gap sites in mixed beech forests were selected at 700–1,300 m altitude range, seventeen sites dominated by beech (*Fagus orientalis* Lipsky) and ten by hornbeam (*Carpinus betulus* L.). Four microsites were distinguished at each site: mound top (mound), pit bottom (pit), gap in the canopy (gap) and closed canopy (canopy). Soil samples were taken at 10 cm depth from all microsites. Earthworms were collected by hand sorting, simultaneously with the soil sampling. Soil acidity, water content, total carbon, total nitrogen and carbon to nitrogen ratio were measured in the laboratory. The impact of uprooting disturbance on soil properties was found significant. The total earthworm number and biomass differed significantly among the mentioned sites and microsites. The number and biomass amount of earthworms showed decreasing trend from undisturbed (closed canopy) to disturbed sites (gap, pit and mound). This trend is mainly caused by number and biomass of endogeic ecological group of earthworms. No earthworms were found in mound microsites. Thus, the windthrow generally reduced the activity and abundance of the earthworms. Our results suggest that windthrow should be considered effectively influencing soil diversity in context of forest ecology. This is significant for evaluating forest management policies and practices with respect to impacts on soil and also for the use of soils as indicators of forest ecosystems.

Key words

earthworms, gap, pit and mound, soil, uprooting

Introduction

In disturbance ecology, disturbances are considered as an important part of dynamics of plant communities (Samonil et al., 2009). The most important type of disturbances in the temperate forests is blowdown connected with the disturbance of soils (Ulanova, 2000). Tree uprooting has important influences on forest ecology and

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*Corresponding author´s address: Tarbiat Modares University, Noor, Mazandaran, Iran, P.O. Box 46414-356; tel.: +98-122-6253101-3; fax: +98-122-6253499; e-mail: hosseini@modares.ac.ir implications for forest management (Ulanova, 2000; Peterson, 2007; Phillips et al., 2008). Ice storms, firing and other factors may cause uprooting, but wind is the most common cause (Peterson, 2007). Windthrow events have significant impacts on forest structure, species composition, gap succession and microtopography (Peterson, 2007).

Soil formation processes are affected by different disturbances in forest ecosystems (Ulanova, 2000). One of the most important effects of windthrow is its influence on the rate and quality of soil formation processes (Samonil et al., 2008). Tree uprooting has different effects on the soil of forest ecosystems (Gabet et al., 2003). Tree uprooting is a pervasive source of bio-perturbation in forests, with significant direct effects on soils, as well as indirect effects on soil formation and sediment transport. The direct effects include soil mixing, soil profile inversion, local redistribution of sediment mass, and creation of characteristic pit and mound topography. Indirect effects include exposure of unprotected sediment to erosion and mass wasting, and creation of microscale differences in weathering, moisture flux, organic matter dynamics, and microclimate in the pit and mound topography (Phillips et al., 2008).

Because of the complexity of tree uprooting process and the time elapsed since uprooting, the size of pits and mounds varies greatly. Aproximately 10 to 50 percent of the forest floor in temperate forests may be covered by pit and mound topography (Schaetzl et al., 1990). Tree uprooting and pit and mound topography are not randomly distributed. They are strongly associated with ecosystems having parent material and soil favouring shallow rooting and systems with severe windstorms (Phillips and Marion, 2006). For ecosystems with wet mineral or organic soils (high water tables), rocky soils or soils developing root restricting horizons is typical high incidence of uprooting (Peterson, 2007). Tree uprooting and pit and mound features create heterogeneous conditions in soil ecosystem. In case of an uprooted mature tree, an average of 12 to 16 m^2 of soil to a depth of one meter or more may be disturbed (Norton, et al. 1989).

Soil processes are controlled by a set of relatively independent state factors including climate, organisms, relief, parent material, time and by a group of interactive controls such as disturbance regime and human activities (Scharenbroch and Bockheim, 2007). Forest gaps are a key component of the disturbance regime and examples of natural interactive controls with direct impacts on state factors including climate and organisms. Forest gaps represent dramatic top-down trophic interactions between vegetation and the soil microbial mediated processes (Chapin et al., 2002). Gaps may be responsible for the creation of nutrient hot spots or islands of fertility that increase forest productivity and overall soil diversity (Scharenbroch and Bockheim, 2007; Scharenbroch and Bockheim, 2008).

Earthworms are perhaps the most important soil organisms in terms of their influence on organic matter breakdown, soil structural development, and nutrient cycling, especially in productive ecosystems (Kooch et al., 2008). Aristole called them the “intestines of the earth” and the eminent nineteenth century biologist, Charles Darwin, spent many years observing their major influence on the soil humus formation and transport (Kooch and Jalilvand, 2008). Despite of the vast increase in scientific literature on earthworms in recent years, they are major gaps in knowledge of their basic biology and ecology (Nachtergale et al., 2002; Kooch et al., 2008). However, to determine relations among biomass and diversity of earthworms, pit and mound disturbances and soil properties is essential for management of forest ecosystems. The goal of this study was to investigate windthrow effects on soil properties, earthworm biomass and species diversity in Hyrcanian forests of Iran. The survey was the first of this type in these forests.

Material and methods

Study area

This research was performed in Sardabrood forests located in lowland and midland of the Mazandaran province in northern Iran (36˚37'30"–36˚40'52" N, 51˚7'50"–51˚12'51" E). The study area was 2,347 ha, the maximum elevation 1,400 m and minimum 50 m. The lowest temperature was measured in December (7.5 °C), the highest in June (24.6 °C). The data on mean annual precipitation of the study area: 47.5 to 237.6 mm were provided by the Noushahr city meterological station, which is 10 km far from the study area. The soils are deep, moderately well drained. Their texture is silty clay and clay loam, with pH of 4.9 to 6.3. The bedrock is sandstone with silting and argillite, and lime stone. Presence of logged and bare roots of trees indicates rooting restrictions and heavy soil texture (*Sardabrood Forest Management*, 2003).

Soil sampling and analysis

In the summer of 2008, twenty seven single-tree gap sites in mixed beech forests at 700–1,300 m altitude range were selected, seventeen sites dominated by beech (*Fagus orientalis* Lipsky) and ten by hornbeam (*Carpinus betulus* L.) (Table 1). In all the areas, the pit and mounds resulted from the fall of a single tree. At each site, four microsites were distinguished: mound top (mound), pit bottom (pit), gap in the canopy (gap) and closed canopy (canopy). Soil samples were taken at 10 cm depth from all microsites. Large live plant material (root and shoots) and pebbles in each sample were separated by hand and discarded. The soil samples were air-dried and sieved. Soil acidity (with an electrode), water content (by drying soil samples at 105 °C for 24 hours), total carbon (Walkey and Black method), total nitrogen (Kjeldahl method) and carbon to nitrogen ratio were measured in the laboratory (Scharenbroch and Bockheim, 2007).

Sampling and identification of earthworms

The earthworms were collected by hand sorting simultaneously with the soil sampling, washed in water and weighed with a milligram precision. Earthworm species were identified (epigeic, anecic, and endogeic) based on their external characteristics using the key of BOUCH (Edwards and Bohlen, 1996). Biomass was defined as the weight of the worms after drying for 48 hours on filter paper at room temperature (60 °C) (Edwards and Bohlen, 1996).

Data analysis

Kolomogorov-Smirnov test was used for testing normality and Levene test for data homogeneity testing. Analysis of variance (one-way ANOVA) and Duncan comparison were used to find differences in soil characteristics among the microsites. Nonparametric Kruskal-Wallis analysis of variance and Mann-Whitney comparison were used to find differences in earthworms number and biomass among sites and microsites, because in some cases the variance lacked homogeneity. Analysis of the whole data set was done in SPSS Ver. 13.5. Factor analysis is a statistic tool for exploring complex relationships among variables. Relationships between microsites and earthworms species were analyzed by Principle Component Analysis (McCune and Mefford, 1999).

Results

Soil properties

Analysis of variance has revealed significant differences in soil characteristics between the investigated microsites of beech and hornbeam sites (Table 2). The maximum and minimum acidity were observed in mound and canopy microsites, respectively, for both woody plants (Table 3). The highest water content (moisture) occurred in pit microsites and the least was observed on mounds (Table 3). In beech site, maximum amount of carbon related to canopy and the lowest was found in mound microsites; but in hornbeam site, the highest was observed in gap microsites (Table 3). Nitrogen manifested higher amounts in canopy microsites and the lowest value related to mound (Table 3). Carbon to nitrogen ratio was lower in canopy sites, the highest values were observed in pits for beech sites and on mound in hornbeam sites (Table 3).

Ecological groups of earthworms

Analysis of data showed that there were significant differences in number and biomass of earthworms ecological groups among the microsites (Table 4) and sites

Table 1. Characteristics of uprooted beech and hornbeam trees

Species	Tree number	Average D. B. H. [cm]	Average altitude [m]	Dominant slope	Slope aspect
Fagus orientalis Lipsky	17	45.35 (35–52)	1,202.1 (1,110–1,295)	40–50	Northeast
Carpinus betulus L.	10	48.60 (42–52)	771.5 (725– 910)		

Table 2. Analysis of variance for soil characteristics in study area

Soil character / Site	SS		DF		MS		F		Sig.	
	B	H	B	H	B	H	B	H	B	H
pH	7.99	0.76	3	3	2.66	0.25	35.92	7.98	0.000**	0.000**
Water content	15198.7	7674.17	3	3	5066.23	2558.05	128.20	33.36	0.000**	0.000**
Carbon	5.84	3.62	3	3	1.94	1.21	4.57	3.96	0.006**	0.015*
Nitrogen	0.15	0.17	3	3	0.05	0.05	72.89	125.16	0.000**	0.000**
Carbon to nitrogen ratio	665.69	663.96	3	3	221.89	221.32	7.29	9.69	0.000**	0.000**

**Difference is significant at the 0.01 level.
*Difference is significant at the 0.05 level.
DF, degree of freedom; B, beech site; H; hornbeam site.

(Table 5). Earthworms number and biomass displayed more amounts in canopy microsites, and the lowest were observed on mound microsites (Table 4). The hornbeam sites had more abundant earthworms in comparison to the beech sites (Table 5).

Table 3. Mean values of soil characteristics in different microsites of study sites

Site	Microsite	pH	Water content	Carbon	Nitrogen	Carbon to nitrogen ratio
Beech	Mound	6.82 (0.03)a	15.98 (0.84)d	2.59 (0.13)b	0.12 (0.006)c	21.05(1.39)ab
	Pit	6.11 (0.09)b	55.72 (1.97)a	2.68 (0.18)b	0.12 (0.003)c	22.00 (1.69)a
	Gap	6.68 (0.04)a	29.38 (1.26)c	3.00 (0.16)ab	0.17 (0.008)b	17.67 (1.37)bc
	Canopy	6.03 (0.07)b	43.80(1.75)b	3.34 (0.15)a	0.24 (0.006)a	14.04 (0.68)c
Hornbeam	Mound	7.66 (0.05)a	14.84 (0.84)c	2.35 (0.04)b	0.11 (0.005)b	20.37 (0.90)a
	Pit	7.43 (0.01)b	53.74 (4.32)a	2.37 (0.29)b	0.13 (0.007)b	18.67 (2.75)a
	Gap	7.65 (0.04)a	37.61 (2.39)b	3.04 (0.17)a	0.25 (0.006)a	12.05 (0.74)b
	Canopy	7.34 (0.08)b	37.49 (2.34)b	2.84 (0.03)ab	0.26 (0.007)a	10.95 (0.38)b

Values are the means ± St. error of the mean (in parentheses).
Within the same column the means followed by different letters are statistically different ($P < 0.05$).

Table 4. Kruskal-Wallis analysis for number and biomass of earthworms in different microsites

Site – Microsite /		Earthworm	Epigeic		Anecic		Endogeic	
Statistical character		Groups	Biomass	Number	Number	Biomass	Number	Biomass
Beech	Microsite	Mound	0	0	0	0	0	0
		Pit	1	10.47	0	0	0	0
		Gap	0	0	1.47	10.76	0	0
		Canopy	0.52	2.76	0	0	1.23	7.41
	Statistical characters	Chi square	15.242	15.849	30.477	30.459	19.404	19.398
		DF	3	3	3	3	3	3
		Sig.	0.002**	0.001**	0.000**	0.000**	0.000**	0.000**
Hornbeam	Microsite	Mound	0	0	0	0	0	0
		Pit	2.10	31	0.30	1	0	0
		Gap	1	5.50	2.80	34.30	0	0
		Canopy	1.30	10.40	4.50	13.20	2.80	26.90
	Statistical characters	Chi square	12.105	12.444	17.775	18.338	28.800	28.783
		DF	3	3	3	3	3	3
		Sig.	0.007**	0.006**	0.000**	0.000**	0.000**	0.000**

**Difference is significant at the 0.01 level.
DF, degrees of freedom.
Mean of earthworms' numbers presented in m^2 and biomass in mg m^{-2}.

Table 5. Mann-Whitney analysis for number and biomass of earthworms in study sites

Earthworm /	Epigeic		Anecic		Endogeic	
Statistical character	Number	Biomass	Number	Biomass	Number	Biomass
Mann-Whitney U	945	950.50	957.50	951.50	1207	1201
Wilcoxon	3291	3296.50	3303.50	3297.50	3553	3547
Z	–3.31	–3.26	–3.41	–3.46	–1.66	–1.733
Sig.	0.001**	0.001**	0.001**	0.001**	0.095 ns	0.083 ns

**Difference is significant at the 0.01 level.
ns, non significant differences ($P > 0.05$).

Earthworm groups and soil properties

In beech sites, principle component analysis showed that percentage of eigenvalue for the first and second axis were about 53.91% and 31.69%, respectively. PCA biplots of microsites, soil characteristics and earthworm species are presented in Figure 1. The number of epigeic is linked to positive direction of axis 1, but number and biomass of anecic are connected to negative direction of this axis. The negative direction of axis 2 is linked to epigeic biomass and positive direction to number and biomass of endogeic. Mound and gap microsites covered left part of axis 1 and pit microsite occupied left part of axis 2. Right part of axis 2 corresponded to canopy microsite. Carbon and nitrogen are related to negative direction of axis 1 and carbon to nitrogen ratio linked to right part of this axis. Acidity and water content (moisture) covered left and right parts of axis 2, respectively (Fig. 1).

In hornbeam site, the first second of the PCA accounted for 81.38% of the total variance; 48.13% by axis 1, 33.25 % by axis 2. PCA biplots of microsites, soil characteristics and earthworm groups for hornbeam site are displayed in Figure 2. The negative direction of axis 1 comprises numbers of anecic and endogeic species and biomass of endogeic species. Number and biomass of epigeics related to right part of axis 2 and anecic biomass linked to left part of this axis. Canopy microsite covered the negative direction of axis 1, the pit and gap microsites occupied right and left parts of axis 2, respectively. Mound linked to right part of axis 1 with eigenvector 1.46 and left part of axis 2 with eigenvector equal to –1.47. Carbon and nitrogen involved negative direction of axis 1 and carbon to nitrogen ratio lay in positive section of axis 1. Acidity and water content linked to left and right parts of axis 2, respectively (Fig. 2).

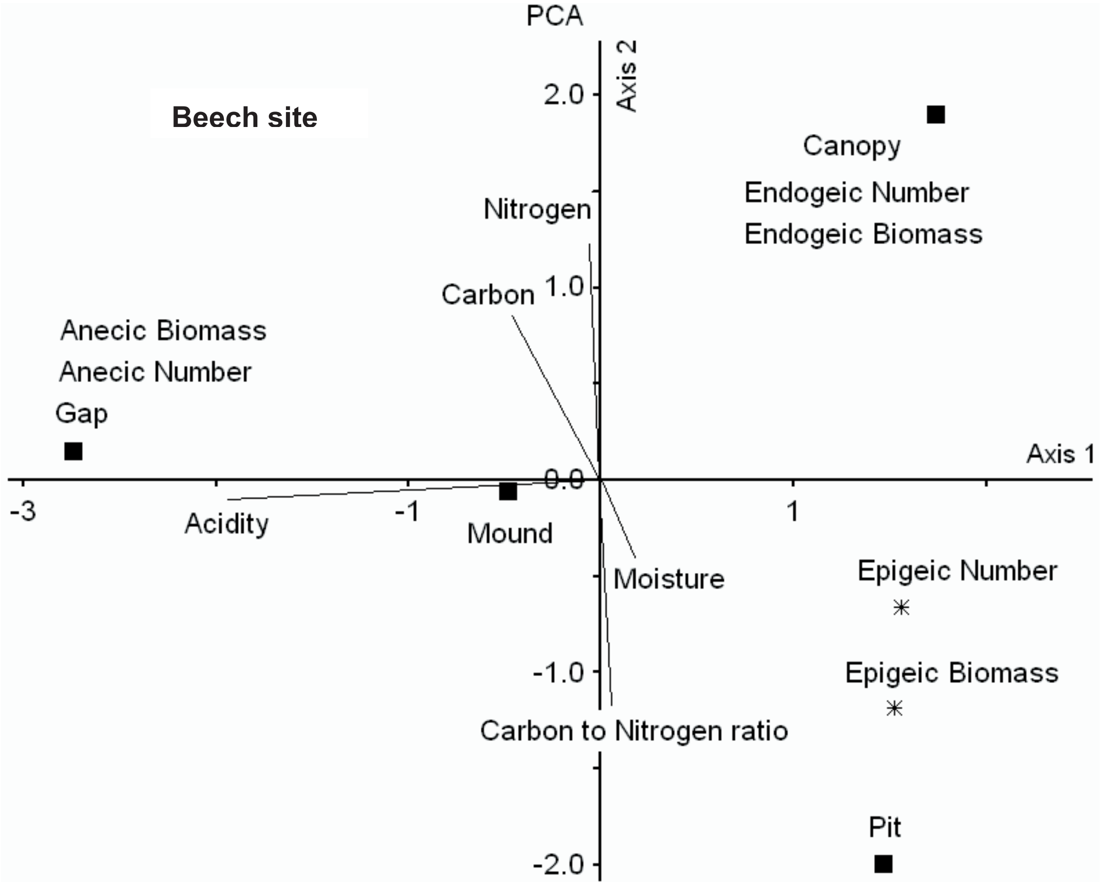

Fig. 1. PCA biplots of microsites, soil characteristics and earthworm species (**PC1:** eigenvalue = 3.23, percent of variance = 53.91, cumulative variance percent = 53.91 and **PC2:** eigenvalue = 1.90, percent of variance = 31.69, cumulative variance percent = 85.60).

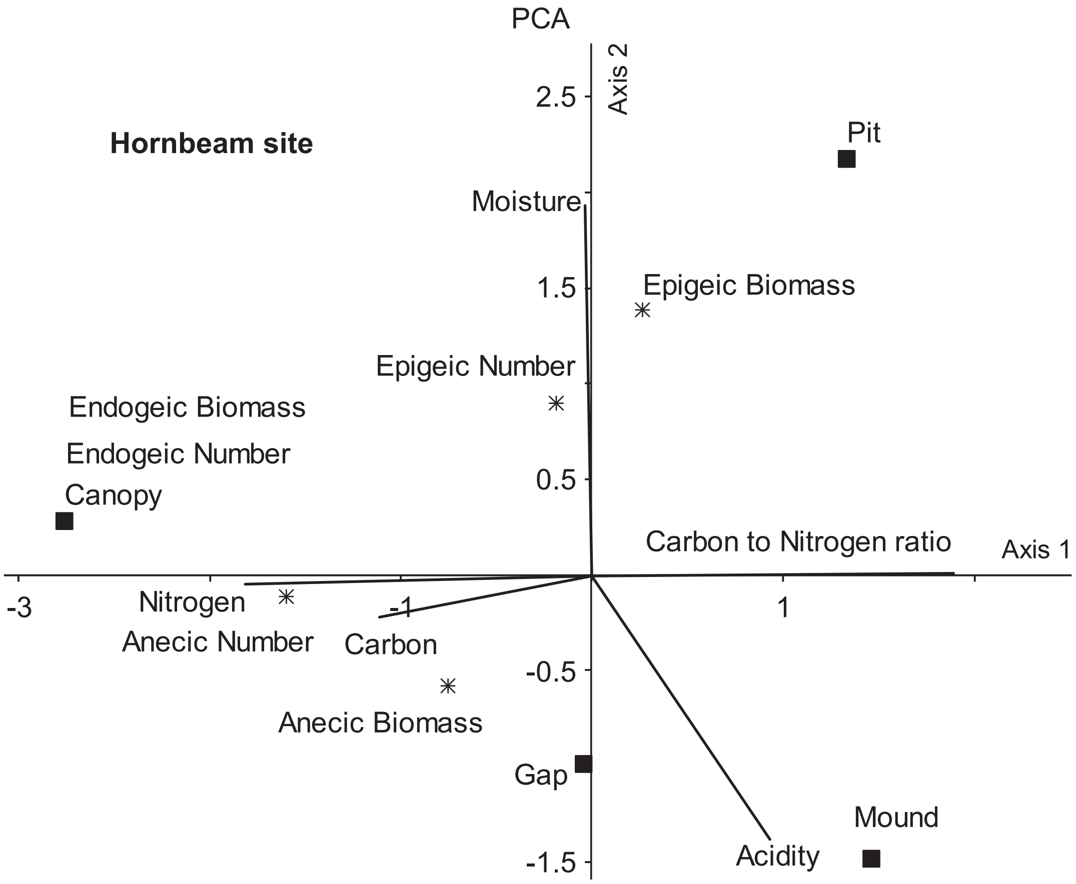

Fig. 2. PCA biplots of microsites, soil characteristics and earthworm species (**PC1:** eigenvalue = 2.88, percent of variance = 48.13, cumulative variance percent = 48.13 and **PC2:** eigenvalue = 1.99, percent of variance = 33.25, cumulative variance percent = 81.38).

Discussion

Soil properties

Results of this research showed that all the studied properties were variable among investigated microsites (Tables 2 and 3). The most significant differences were found in pit, mound and canopy microsites (Table 3). Soil acidity manifested significant differences in microsites with the most and least amounts in mound and canopy microsites (Table 3). Thus, it is possible that gap creation increased soil acidity and lowered pH in canopy microsites. Beech litters have low pH values, but within gaps with occurrence of disturbances and extensive changes, the decomposition rate is higher and organic matter cycle are better in comparison to the canopy. Therefore, the soil pH values were higher in gap microsites, which is in accordance with the results of Muscolo et al. (2007).

The highest average moisture content was found in pits, the least water was in mound microsites (Table 3) – in accordance with Barton et al. (2000). The results of the current research show that pit and mound features were associated with basic changes in soil characteristics (Lutz 1940; Peterson and Pickett, 1990; Bormann et al., 1995; Peterson, 2000) and changes in soil moisture (Beatty and Stone, 1986). The gap creation decreased soil water content, and central areas of gaps (mound microsites) had less moisture than border areas (gap microsites). Water content changes are very variable in different forest ecosystems (Mc Donald and Abbott, 1994; Gagnon et al., 2003). Chen et al. (1999) mentioned that gap creation in forest ecosystems induces moisture decreasing and temperature increasing in superficial soils.

Beech twigs and leaves need more time for decomposition than hornbeam species. This is more evident in old forest stands with higher litter volume in understory (Huttl et al., 2000). Thick humus layers provide favourable conditions for moisture preservation in forest lands. Spongy character under closed canopy improves water and moisture preservation capacities in comparison with positions without closed canopy. Humus reduction within gaps can be related to more solar radiation and increased microclimate temperature (Page and Cameron, 2006). Gaps have more plant diversity than closed canopy (Shure et al., 2006). Colonisation by diverse plant species using different soil horizons is due to increased root respiration followed by increased temperature that can be effective in humus reduction.

In beech sites, the maximum values of carbon were found in canopy microsites, the lowest on mound microsites; whereas in hornbeam sites, the most amount of carbon was observed in gap microsites (Table 3). Clinton and Baker (2000) reported the following distribution pattern for organic carbon at Coweeta Basin in North Carolina one year after a windthrow event: 2.15% mound, 2.11% pit wall, 1.42% pit bottom, and 4.73% in the undisturbed area. Beatty and Stone (1986) report organic matter distribution as 5.7% (3.31% C) for mound, 17.8% (10.32% C) for pit, and 10.0% (5.8% C) for undisturbed sites. Thus, the changes in carbon amounts are different in diverse forest ecosystems. Nitrogen had higher values in canopy, and the lowest were related to mound (Table 3). It is worth to notice that soil characteristics had different responses to various microsites.

Nitrogen was significantly increasing with closing canopy cover. Soil nitrogen contents are controlled by several factors such as soil moisture and temperature, carbon accessibility, decomposers species, soil acidity, soil texture, the value of absorbed nitrogen by roots and its return to litter (Persson et al., 2000). It is possible that bacteria converting organic nitrogen to mineral form are activated in a specific temperature range. Therefore, soil temperature displays multiple effects which can explain different correlation values (from positive to negative) in nitrogen content mentioned in different studies (Schmidt et al., 2002). The presence of microbial agents and oozing of created acids by activity of these organisms have an important role in carbon storage (Frazer et al., 1990). Nachtergale et al. (2002) mentioned that mounds have low carbon and nitrogen contents due to leaching and drainage (mounds represent hilly areas on soil surface). This fact has been confirmed by our research, too (Table 3).

Carbon to nitrogen ratio, is an index for determination of humus and litter decomposition amount. Therefore, it is appropriate for calculation of litter volume and weight reduction (Taylor et al., 1989). Carbon to nitrogen ratio was found lower in canopy and the highest value was observed in pits for beech sites and mounds in hornbeam sites (Table 3). Barton et al. (2000) investigated the amounts of carbon, nitrogen and values of carbon to nitrogen ratio in various microsites of pit and mound type. He found that the values of these characters were associated with undisturbed areas, and that there were significant differences between these and the other microsites.

Earthworm ecological groups

In general, most earthworms are sensitive to soil acidity as their numbers and biomass are lower in soils with low pH. Several studies of the issue resulted in finding that earthworms preferred pH close to buffer (Neirynck et al., 2000). Deleporte (2001) introduced soil pH as an effective negative agent affecting earthworm abundance. The hornbeam site had higher pH values, so it provided more appropriate conditions for abundance and biomass of earthworm ecological groups (Tables 4 and 5). Rahmani and Saleh Rastin (2000) observed that number and biomass of earhworms in hornbeam stands were higher than in oak-hornbeam and beech stands. However, no significant difference between oak-hornbeam and beech stands was observed.

In the beech site, epigeic ecological groups (belonging to epi-anecic under-category) found in pit and canopy microsites (Table 4) were related to high moisture amounts in these microsites (Table 3). Almost 80 to 90% of earthworms´ fresh weight represents water, thus soil moisture is essential for their living, and soil drying can cause their death (Saleh Rastin, 1978). Considering the moisture of 55.72% in pit microsites (Table 3), this moisture amount is due to gathering more epigeics (Table 4). The most earthworms, especially anecic species, prefer positions with rich nutrient supply. These species consume litters with low C/N content. Endogeic and anecic species are more resistant to inappropriate soil textures and to drought. They can migrate in deeper layers and avoid soil drought, especially in summer season (Hale and Host, 2005).

In the hornbeam site, different earthworms groups were found in all studied microsites except of mound microsites (Table 4). The superficial soil with mounds is hilly, and has more volume and higher temperature in comparison to other surfaces (Londo et al., 2001). On the other hand, soil temperature exerts effects on earthworms number and biomass and on their distribution (Brady, 1990). Therefore, low moisture and high temperature represent fatal conditions for earthworms on mounds (Nachtergale et al., 2002), and, consequently, no earthworms were found in mound microsite in both of site types (Table 4). The high amount of epigeic biomass within the pits is related to hygrophillous earthworms. Some of earthworms are semi-aquatic and prefer positions with high moisture and deep water (Schwert, 1990).

Nachtergale et al. (2002) mentioned that the increase of epigeics biomass in pits is a response to more tree litter gathered within these microsites. Pits creation in forest floor produce an especial condition – due to increase of litter thickness and water content, thus the epigeics biomass will increase. Carbon to nitrogen ratio in closed canopy microsite results from assemblage of earthworms diverse groups in this hornbeam microsite. In summary, it seems that the suitable temperature and moisture, absence of inappropriate chemical substances such as tanin, polyphenol, and low carbon to nitrogen ratio (especially in closed canopy microsites) created favourable conditions for increasing biologic activities of earthworms in hornbeam site compared to the beech site. Therefore, the presence and abundance of earthworms diverse groups are more visible in the hornbeam site.

The results of PCA for the two sites indicated that the axis 1 and axis 2 accounted for most of the total variance. Also, position of microsites, soil characteristics and earthworm ecological groups manifest special conditions – due to gathering and abundance of earthworms. Closed canopy microsites in beech sites were associated with the highest density and biomass of endogeics, and had high correlation with positive direction of axis 2. Gap microsites had the most abundance of anecic species, and showed high correlation with negative direction of axis 1. Epigeic species occupied pit microsites and had high correlation with soil moisture. In hornbeam sites, presence of different factors and combination of environmental factors were an obstacle of complete differentiation of earthworms ecological groups in pit and gap microsites (Figs 1 and 2).

The results of this research show that the number and biomass of earthworms had decreasing trend from undisturbed (closed canopy) to disturbed sites (gap, pit and mound), and no earthworms were found in mound microsites. Saint-Germain and Mauffette (2001) suggest that the ice storms introduced disturbances and reduction in beetle populations in maple forest ecosystem. Bouget (2005) and Gandhi et al. (2008) mention that windthrows are associated with decrease in forest beetles populations. Furthermore, the created disturbance had the most impact on endogeic ecological group of earthworms. These earthworms group were not visible in disturbed areas (gap, pit and mound). It is supposed that this earthworms groups are more sensitive to severe light conditions and higher temperature within gaps in comparison to the other earthworm groups. As individuals belonging into this group have more excavation abilities than the other groups (Kooch and Jalilvand, 2008; Kooch et al., 2008), they migrate to deeper layers of soil and no endogeic was found in 0–10 cm depth. On the other hand, in closed canopy, with less light supply and moderate temperature conditions on soil surface, endogeics were found migrating to soil surface.

Conclusions

The results of this study show that earthworms can serve as bioindicators for evaluation of changes in forest stands after disturbance events. The windthrow generally reduced the activity and abundance of earthworms. Our results suggest that windthrow should be considered as an effective factor influencing soil diversity in context of forest ecology. This is significant for evaluating forest management policies and practices with respect to impacts on soil and also for the use of soils as indicators of forest ecosystems.

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Reakcia biomasy a diverzity dážďoviek na vývraty a pôdne vlastnosti v hyrkánskych lesoch v Iráne

Súhrn

Vývraty spôsobujú významné škody vo väčšine prírodných lesov. V oblasti skúmania vplyvu vývratov na vlastnosti lesných pôd a na lesnú faunu sa však doposiaľ urobilo dosť málo. Táto práca sa zaoberá vplyvom vývratov na určité vlastnosti pôd a na biomasu dážďoviek a ich druhovú diverzitu na lokalite Sardabrood v údolí Chalous v hyrkánskych (kaspických) lesoch v severnom Iráne. Za týmto účelom bolo vybraných 27 stanovíšť s porastovými medzerami o šírke jedného stromu v zmiešaných bukových lesoch v nadmorskej výške 700 – 1 300 m. Na 17 z týchto lokalít dominoval buk, na 10 hrab. Na každej z lokalít boli rozlíšené štyri mikrolokality: vrchol kopy (mound), dno jamy (pit), medzera v korunovom zápoji (gap) a uzatvorený zápoj (canopy). Zo všetkých štyroch mikrolokalít boli odobrané vzorky pôdy z hĺbky 10 cm.

Dáždovky sa vyberali ručne počas odberu pôdnych vzoriek. V laboratóriu sa určovali tieto pôdne parametre: kyslosť pôdy, obsah vody, obsah celkového uhlíka a dusíka a pomer C/N. Zistili sme, že vývraty významne ovplyvňujú vlastnosti lesných pôd. Rozdiely v celkovom počte dážďoviek a v ich biomase medzi danými lokalitami a mikrolokalitami boli významné. Počet dážďoviek ako aj ich biomasa vykazovali klesajúci trend od nenarušených lokalít k najviac narušeným (medzera, kopa, jama). Tento trend bol výsledkom najmä počtu a biomasy dážďoviek patriacich do endogeickej ekologickej skupiny. Na mikrolokalitách s kopou neboli nájdené žiadne dážďovky. Z toho vyplýva, že vývraty vo všeobecnosti znižujú aktivitu a abundanciu u dážďoviek. Naše výsledky naznačujú, že vývraty možno považovať za významný faktor ovplyvňujúci pôdnu diverzitu v rámci ekológie lesa. Toto má význam pre posudzovanie lesohospodárskych opatrení vzhľadom na ich vplyv na pôdu a tiež aj pre využívanie pôd ako indikátorov stavu lesných ekosystémov.

Received April 14, 2010
Accepted May 17, 2010

FOLIA OECOLOGICA – vol. 37, no. 2 (2010). ISSN 1336-5266

Development and health condition of the root system of Norway spruce (*Picea abies* (L.) Karst.) in the region of the Jeseníky Mts

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Abstract

Mauer, O., Palátová, E. 2010. Development and health condition of the root system of Norway spruce (*Picea abies* (L.) Karst.) in the region of the Jeseníky Mts. *Folia oecol*., 37: 191–204.

The paper analyzes development and health condition of the root systems of visually healthy and declining Norway spruce (*Picea abies* (L.) Karst.) trees at three sites of the Jeseníky Mts. Affected by the decline were trees of all age classes. Unlike naturally regenerated trees, all of the analyzed declining trees had their root systems malformed into tangles. The root systems of all the declining and the majority of healthy trees were infested by honey fungus (*Armillaria* sp.). The declining trees did not show any nutritional deficiency. Up to the Forest Altitudinal Vegetation Zone 4 (GFT 4B), spruces do not grow in the ecological optimum. After weakening due water shortage, the root systems become infested by honey fungus which induces root, stem base and bole rots. As a result of malformations, the declining trees in Forest Altitudinal Vegetation Zones 7 and 8 (forest type group 7S, 8S) have always significantly smaller root systems colonized by honey fungus and characteristic lower rooting depth. Honey fungus does not affect root, stem base or bole rots. The declining trees have less biomass, lower vitality and suffer from mycorrhizal infection of fine roots.

Key words

decline, deformation, fine roots, honey fungus, Norway spruce, root system

Introduction and objectives

The intense industrial development since the 1950s has been associated with increase in noxious agents emitted into the atmosphere. These harmful substances caused damage to and dieback of forest stands – primarily in the mountain areas in the North of the Czech Republic. Kubačka (1992) notes that the air pollution damage in the Jeseníky Mts started to appear from the mid- 1970s, particularly in locations loaded by a combined effect of the air pollution and adverse climatic or microclimatic conditions. The most affected were windward localities such as ridges, isolated tops (even at lower elevations) and sites with permanent air streaming. The long-term SO_2 concentration averages from 1983 to 1993 at the Rejvíz station situated at 760 m a.s.l. amounted to ca. 19 $\mu g\ m^{-3}$ (Balcar and Vacek, 1994). Chmelíček (1992) states that between 1982 and 1984, the damage was noticeably aggravated as a consequence of the impact of the previous stress factors (an abrupt fall in temperature at the turn of the years 1978/1979 and dry years 1981–1983). While the strong damage to forest stands in the region of the Hrubý Jeseník Mts in 1980 affected 50 ha, the total acreage of strongly and more damaged stands in 1984 amounted even to 5,212 ha (Balcar et al., 1994). The damage was evident on desiccation of individual trees and consequently on the dieback and disintegration of entire stands. Chmelíček (1992) suggests that the majority of the seriously damaged and declining stands were of unsuitable provenance. Also Kubačka

(1992) states that the autochthonous stands were more resistant to damage than the introduced ones. The total acreage of stands logged as the result of the air pollution disaster in the Hrubý Jeseník Mts was estimated at roughly 1,000 ha (Balcar et al., 1994). Between 1985 and 1991, the immission impacts were mitigated by aerial liming applied on 12,850 ha on which soil analyses detected deficiency of Mg, Ca, K and N. The liming was complemented with additional aerial spraying with liquid foliar fertilizers (Kubačka, 1992). The initial steep increase in damage gradually was damped thanks to favourable wet years without considerable climatic fluctuations. In the early 1990s, the decline of stands stagnated and their condition improved also visually (Chmelíček, 1992). Approximately in the last ten years, however, the decline of Norway spruce stands of all age classes started to reappear in all Forest Altitudinal Vegetation Zones in the Jeseníky Mts. The symptoms and progress of the decline vary according to the elevation. Rusting of the assimilatory apparatus, rapid defoliation and a relatively fast dieback of trees (a fairly healthy tree dies over a period of several months) occur in lower Forest Altitudinal Vegetation Zones (up to FAVZ 5). In higher Forest Altitudinal Vegetation Zones, yellowing of the assimilatory tissue (mainly after the winter season) takes place too, but defoliation is rather slow, the trees die gradually and the decline intensity (yellowing) varies from year to year. Since it is a well known fact that the root systems of trees tend to be affected earlier and more than their above-ground parts and that the belowground part are subjected to bigger changes (Mauer and Palátová, 1988; Mauer, 1989a, b; Murach, 1991; Mauer et al., 2004, 2008), the objective of this paper was to discuss whether an interrelationship exists between the decline, development and health condition of the root system of this tree species.

Material and methods

The surveys were realized in stands of FAVZ 4–8 in four forest districts of the Forest Administrations of Město Albrechtice and Karlovice LČR a.s. The characteristics of the surveyed stands are listed in Table 1. The objective of the survey was to compare the development and health condition of the root systems between healthy and declining trees of the same height (change in the assimilatory apparatus of 40–60%). Healthy trees served as a control (standard). The analyzed stands were monocultures of identical density growing on a slight slope (of up to 10%). Only non-marginal, co-dominant, trees undamaged by game and bark beetles were selected for partial analyses. The analysis in each stand included 6 to 30 declining and healthy trees.

Analyses of above-ground parts

The above-ground parts of the assessed trees were analyzed for the total height (from the ground surface up to the tip of terminal increment), stem diameter at $d_{1.3}$, terminal shoots lengths in 2007, 2008, 2009 and the length of needles (measured halfway the length of the last increment on the branch of the third whorl from above). Chemical analyses determining the content of the essential biogenic elements (N, P, K, Ca, Mg) in the last two generations of the assimilatory apparatus in stands 5-D-21-H, 5-D-21-D, 7-O-19-H and 7-O-19-D were conducted in an accredited laboratory. The occurrence of bole rots was evaluated on stem cross-sections (at the stem base and five other equal-length sections).

Analyses of root system architecture and health condition

All root systems were lifted by hand (archaeological method). After cleaning, each of them was assessed for the following characteristics: number and diameter of horizontal skeletal roots (diameter was assessed in self-seeded plants at a height of 10 cm, in 10-year old trees at 20 cm, in 15-year old trees at 40 cm, in 40-year old trees at 60 cm and in 70-year old trees at a height of 80 cm from the stem base); number and diameter of anchoring roots (diameter was measured at 5 cm from the setting point); number and diameter of substitute taproots, i.e. primary root branches shooting from anchor roots (diameter was measured at 5 cm from the setting point) and number and diameter of horizontal non-skeletal roots shooting from the stem base. Area index (hereinafter Index P, in the table of results I_p) was calculated from the measured values as the ratio of the sum of root cross-sectional areas of all skeletal roots (mm^2) to the tree height (cm). Index P expresses the relation between root system development and shoot development: the higher the value of Index P, the larger the tree root system. Functionality of the root system is, however, adversely affected by root rots and fungal pathogens, so the Index P was calculated in three ways: first as the total I_p (the calculation includes all roots in the root system); I_p of healthy roots (only healthy roots without rots were included) and I_p of functional roots (all roots without rots and with resin exudation of up to the 2nd degree inclusive were included). The rooting depth (perpendicular distance from the ground surface to the deepest reaching root segment) was determined first as the total rooting depth (the calculation involves all roots of the root system) and functional rooting depth (including only roots unaffected by rots and with resin exudation up to the 2nd degree inclusive). The lifted root systems were also surveyed for the occurrence of malformation into a tangle.

Health condition of the roots (incidence of rots) was assessed on a longitudinal section through each root and resin exudation was identified on each skeletal root and categorized as follows: 0 – without resin exudation, 1 – surface resin exudation of maximum ¼ of the root girth, 2 – surface resin exudation of maximum ½ of the root girth, 3 – surface resin exudation of up to

¾ of the root girth, 4 – surface resin exudation of above ¾ of the root girth.

Analyses of fine roots

There were analysed roots of less than 1 mm in diameter – which are decisive for nutrition and water uptake. In the selected stands (chiefly in healthy and declining trees), 30 soil cores to the depth of 20 cm were lifted by a soil pit of 5 cm in diameter. The cores were divided into humus and humus-enriched horizons and homogenized with respect to these layers. The fine roots were separated manually from soil samples (each with 100 ml of soil) taken by 6 from each homogenate. After cleaning, the biomass of fine roots (weight of fine roots after drying at 85°C in 100 ml of soil homogenate – the table of results shows the weight of fine roots in all humus and humus-enriched horizons) and their vitality (Joslin and Henderson, 1984) were determined and mycorrhizal infection was established quantitatively (Vignon et al., 1986).

Weather analyses

The assessment of weather history between 1961 and 2006 was carried out based on the data from the hydrometeorological station Karlova Studánka (780 m a. s.l.) of the Czech Hydrometeorological Institute (CHI). The measured daily values were smoothed with a regression line (linear regression, the method of least squares).

Statistical evaluation

The Results acquired in the individual stands were subjected to t-test. The results are graphically displayed in the tables of results: + significant difference (α – 95%), – insignificant difference.

Note

For better legibility, the analyzed stands were allocated codes that are used in the text as well as in the tables. The first code position means the number of the analyzed stand in the forest district, the second position is a letter identifying the surveyed locality in the region of the Jeseníky Mts (D – Dobrá voda, forest district Dobrá voda, O – Orlík, forest districts Polom and Drakov, S – Sokolí skála, forest district Vidly), the third position digit indicates the height of the analyzed tree in metres and the letters H and D in the fourth position stand for healthy and damaged trees, respectively. The addition of letter N to this position also means that the analyzed stands were regenerated naturally.

Results

The analyzed spruce stands manifested these common features: they grew on fertile (B) or fresh (S) sites (Table 1); on all monitored localities all of the declining as well as healthy trees were infested by honey fungus (*Armillaria* sp.) and nearly all healthy and declining trees (except for naturally regenerated stands) had root systems malformed into tangles. Nutrition deficiency was not identified in any of the localities. The state of the root system and response of the above-ground parts of the declining trees varied among the localities.

Table 1. Characteristics of the analyzed stands

Stand code	Forest district	Stand number	Forest Type Group	Stand age	Altitude [m]	Danger Zone
1-D-3-H	Dobrá voda	112B1b	4B	16	750	C
1-D-3-D	Dobrá voda	112B1b	4B	16	750	C
2-D-5-H	Dobrá voda	111C2/1c	4B	20	650	C
2-D-5-D	Dobrá voda	111C2/1c	4B	20	650	C
3-D-6-HN	Dobrá voda	112B3	4B	30	720	C
3-D-6-DN	Dobrá voda	112B3	4B	30	720	C
4-D-9-H	Dobrá voda	120C2b	4B	24	730	C
4-D-9-D	Dobrá voda	120C2b	4B	24	730	C
5-D-21-H	Dobrá voda	120C4	4B	47	780	C
5-D-21-D	Dobrá voda	120C4	4B	47	780	C

Table 1. Continued

Stand code	Forest district	Stand number	Forest Type Group	Stand age	Altitude [m]	Danger Zone
1-O-2-H	Drakov	419E2	7S	25	1,150	B
1-O-2-D	Drakov	419E2	7S	25	1,150	B
2-O-4-H	Polom	317B1	7S	16	1,040	B
2-O-4-D	Polom	317B1	7S	16	1,040	B
3-O-5-H	Drakov	420B2	7S	21	1,060	C
3-O-5-D	Drakov	420B2	7S	21	1,060	C
4-O-9-H	Drakov	419F1a	7S	10	1,050	B
4-O-9-D	Drakov	419F1a	7S	10	1,050	B
5-O-3-H	Polom	317F1a	7S	13	1,030	B
5-O-3-D	Polom	317F1a	7S	13	1,030	B
6-O-5-HN	Polom	317B2	7S	27	1,080	B
6-O-5-DN	Polom	317B2	7S	27	1,080	B
7-O-19-H	Drakov	419E7/1b	7S	73	1,110	B
7-O-19-D	Polom	318B7	7S	72	1,120	B
1-S-1-H	Vidly	725B2	8S	14	1,180	B
1-S-1-D	Vidly	725B2	8S	14	1,180	B
2-S-2-H	Vidly	725A2	8S	14	1,170	B
2-S-2-D	Vidly	725A2	8S	14	1,170	B
3-S-4-H	Vidly	725J2	7S	14	1,080	B
3-S-4-D	Vidly	725J2	7S	14	1,080	B

Dobrá voda locality (GFT 4B)

Statistically significant decrease in terminal increment was identified only in some of the analyzed stands, and no shorter needles were found in any of them (Table 2). Root rot was detected in almost all declining trees, and to a great extent (16–100%) also in healthy trees. In stands with the above-ground part over 5 m in height, at least 50% of injured trees showed stem base or bole rots; a high incidence (up to 66%) of these rots was found also in healthy trees (Table 2).

The root systems in all healthy and declining trees had horizontal skeletal roots infested by honey fungus, whilst the degree of infestation in declining trees was considerably higher than in healthy ones. In declining trees, between 20 and 68% of horizontal roots suffered from rots; rots of horizontal roots in healthy trees were exceptional (Table 3). Anchor roots in declining as well as healthy trees were colonized by honey fungus, and the degree of infestation was significantly higher in declining trees. In declining trees, 37 to 55% of sinker roots were attacked by rot; the range in sinker roots of healthy trees was between 10 and 34% (Table 4).

The rooting depth in healthy and declining trees did not differ. No crucial differences were found between the total rooting and rooting in functional roots in healthy trees. In declining trees, the rooting depth in functional roots was up to one half smaller than the total rooting depth (Table 4).

No marked differences in the total I_p values were identified between the healthy and damaged trees. Contrarily, the I_p values for healthy roots and primarily functional roots manifested decrease in all healthy trees. Identical tendency of decreasing values of the healthy roots I_p and of functional roots I_p was identified also in the damaged trees but with a much greater range of variance (the value of healthy roots I_p was ca. one half of the total I_p, the value of functional roots I_p amounted to ca. one half of the healthy roots I_p). It is statistically significant that all declining trees had lower biomass of the fine roots but more vital and extensive mycorrhizal infection (Table 5).

Table 2. Shoot increments, root system malformations and incidence of rots in visually healthy and declining Norway spruce trees

Stand code	Terminal increments [cm] 2009	2008	2007	Trees with a tangle [%]	Trees with rot Stem base [%]	Stem [%]	Roots [%]
1-D-3-H	23.7±6.0	33.0±4.5	40.8±11.5	100	16	16	16
1-D-3-D	19.0±7.9–	22.7±8.9+	29.7±9.7+	100	0	0	100
2-D-5-H	84.7±13.0	93.3±7.6	77.0±6.5	100	25	0	25
2-D-5-D	82.0±13.1–	92.0±9.6–	64.0±12.5–	100	50	50	75
3-D-6-HN	56.6±8.5	64.2±5.1	45.8±5.7	0	20	20	20
3-D-6-DN	14.4±7.7+	16.6±7.7+	38.4±12.4–	0	0	0	100
4-D-9-H	31.4±18.4	45.2±6.6	40.2±14.8	100	66	66	100
4-D-9-D	14.0±9.8+	20.0±2.4+	24.0±4.8+	100	60	60	100
5-D-21-H	51.6±9.1	40.8±8.3	99.2±16.6	100	20	20	60
5-D-21-D	58.0±12.4–	56.7±8.4+	65.0±13.2+	100	60	60	100
1-O-2-H	48.0±9.2	37.3±12.3	27.5±5.6	100	0	0	0
1-O-2-D	7.0±1.7+	11.3±8.6+	19.3±5.4+	100	0	0	0
2-O-4-H	61.8±12.9	65.4±7.7	61.0±7.0	100	0	0	0
2-O-4-D	52.4±5.6+	40.8±11.5+	44.6±5.7+	100	0	0	0
3-O-5-H	47.3±13.3	44.7±6.4	43.7±6.3	100	0	0	0
3-O-5-D	25.6±6.1+	20.2±14.5+	30.2±7.9+	100	0	0	0
4-O-9-H	49.6±15.4	52.6±12.3	54.0±10.9	80	0	0	0
4-O-9-D	24.6±14.2+	38.4±7.9+	40.6±5.1+	100	0	0	0
5-O-3-H	58.6±12.9	49.2±9.2	41.2±12.4	80	0	0	0
5-O-3-D	40.8±3.8+	27.2±6.7+	22.4±12.9+	100	0	0	0
6-O-5-HN	57.4±3.2	58.0±4.6	53.2±7.1	0	0	0	0
6-O-5-DN	36.0±12.5+	61.7±8.1+	35.0±13.1+	0	0	0	25
7-O-19-H	25.7±5.1	31.0±4.1	23.2±7.5	60	0	0	20
7-O-19-D	8.0±2.8+	9.2±2.1+	10.0±2.8+	100	0	0	40

Table 2. Continued

Stand code	Terminal increments [cm]			Trees with a tangle [%]	Trees with rot		
	2009	2008	2007		Stem base [%]	Stem [%]	Roots [%]
1-S-1-H	33.5±3.2	22.8±6.3	20.0±3.7	100	0	0	0
1-S-1-D	23.7±3.8+	18.5±6.2–	18.2±7.7–	100	0	0	0
2-S-2-H	32.5±6.9	42.8±8.9	35.8±3.7	100	0	0	0
2-S-2-D	18.2±8.2+	17.7±7.8+	22.1±8.1+	100	0	0	0
3-S-4-H	51.4±6.8	65.4±9.2	64.5±6.8	100	0	0	0
3-S-4-D	40.0±10.4-	60.5±7.2-	58.4±5.5-	100	0	0	0

Table 3. Health condition and rooting depth in horizontal roots of visually healthy and declining Norway spruce trees

Stand code	Trees affected by rot of horizontal skeletal roots (HSR) [%]	HSR with rot [%]	Trees affected by honey fungus in HSR [%]	HSR infested by honey fungus [%]	Honey fungus infestation [degree]	Rooting depth [cm]
1-D-3-H	16	0	100	64	1.9±0.9	10.0±1.0
1-D-3-D	100	20	100	92	0.8±0.7+	10.0±1.0–
2-D-5-H	0	0	100	89	1.1±0.6	9.4±1.6
2-D-5-D	20	21	100	100	2.2±0.7+	10.0±1.0–
3-D-6-HN	0	0	100	70	1.0±0.2	10.1±0.7
3-D-6-DN	100	68	100	79	1.5±1.2+	9.8±1.2–
4-D-9-H	25	7	100	98	1.9±0.6	10.1±0.9
4-D-9-D	50	30	100	100	2.5±0.8+	9.8±0.9–
5-D-21-H	20	12	100	77	1.1±0.7	14.5±1.2
5-D-21-D	80	47	100	96	2.7±1.2+	14.9±3.2–
1-O-2-H	0	0	100	45	0.5±0.5	12.3±1.9
1-O-2-D	0	0	100	100	2.2±0.6+	11.1±1.6–
2-O-4-H	0	0	100	65	0.9±0.8	10.7±1.1
2-O-4-D	0	0	100	100	1.8±0.6+	10.6±0.9–
3-O-5-H	0	0	100	60	0.7±0.7	13.3±1.5
3-O-5-D	0	0	100	100	2.3±0.7+	11.3±1.9–
4-O-9-H	0	0	100	67	0.8±0.7	8.6±1.6
4-O-9-D	0	0	100	93	1.6±0.7+	10.4±1.1–
5-O-3-H	0	0	100	62	0.7±0.6	12.1±1.8
5-O-3-D	0	0	100	100	2.0±0.7+	12.7±2.7–

Table 3. Continued

Stand code	Trees affected by rot of horizontal skeletal roots (HSR) [%]	HSR with rot [%]	Trees affected by honey fungus in HSR [%]	HSR infested by honey fungus [%]	Honey fungus infestation [degree]	Rooting depth [cm]
6-O-5-HN	0	0	100	72	0.9±0.7	13.9±1.9
6-O-5-DN	25	3	100	94	1.8±0.9+	11.3±1.7–
7-O-19-H	20	1	100	64	0.7±0.7	21.8±6.7
7-O-19-D	0	0	100	100	2.4±0.6+	16.1±3.6+
1-S-1-H	0	0	100	64	1.2±0.4	8.6±1.3
1-S-1-D	0	0	100	81	1.5±0.6+	8.4±1.1–
2-S-2-H	0	0	100	69	1.6±0.7	8.4±1.3
2-S-2-D	0	0	100	85	1.8±0.8–	8.8±1.5–
3-S-4-H	0	0	100	63	1.4±0.6	10.2±0.9
3-S-4-D	0	0	100	83	1.6±0.9-	10.0±0.9-

Table 4. Health condition and rooting depth in anchor roots in visually healthy and declining Norway spruce trees

Stand code	Trees with anchor roots [%]	Trees affected by rot of anchor roots [%]	Anchor roots affected by rot [%]	Trees infested by honey fungus in anchor roots [%]	Anchor roots infested by honey fungus [%]	Honey fungus attack [degree]	Total rooting depth [cm]	Rooting depth of functional roots [cm]
1-D-3-H	100	33	10	100	100	1.3±0.7	34.8±8.9	33.2±8.6
1-D-3-D	100	50	42	100	100	2.8±0.9+	25.9±7.2+	15.4±8.2+
2-D-5-H	100	25	17	100	100	1.7±0.5	39.0±17.7	39.0±16.5
2-D-5-D	100	75	37	100	100	2.3±0.6+	46.7±5.2–	17.7±4.8+
3-D-6-HN	100	20	7	80	100	1.4±1.0	37.5±10.8	35.2±11.2
3-D-6-DN	100	100	55	100	100	1.5±1.0–	37.8±13.8–	28.2±12.2–
4-D-9-H	100	100	34	100	100	1.7±0.6	47.6±12.9	43.3±11.2
4-D-9-D	100	100	52	100	100	2.7±1.1+	51.7±18.8–	17.5±6.6+
5-D-21-H	100	60	17	100	100	1.7±0.9	60.7±22.8	56.2±21.6
5-D-21-D	100	100	39	100	100	2.5±1.2+	64.3±18.3–	28.9±10.3+
1-O-2-H	0	0	0	0	0	0	0	0
1-O-2-D	0	0	0	0	0	0	0	0
2-O-4-H	0	0	0	0	0	0	0	0
2-O-4-D	0	0	0	0	0	0	0	0

Table 4. Continued

Stand code	Trees with anchor roots [%]	Trees affected by rot of anchor roots [%]	Anchor roots affected by rot [%]	Trees infested by honey fungus in anchor roots [%]	Anchor roots infested by honey fungus [%]	Honey fungus attack [degree]	Total rooting depth [cm]	Rooting depth of functional roots [cm]
3-O-5-H	33	0	0	100	100	3.0±0.7	56.0±4.2	0
3-O-5-D	0	0	0	0	0	0	0	0
4-O-9-H	100	0	0	100	94	1.7±0.6	43.3±12.2	25.0±0.8
4-O-9-D	100	0	0	100	100	3.1±1.0+	44.7±9.3–	0
5-O-3-H	80	0	0	80	83	1.1±0.6	40.1±6.4	38.1±2.8
5-O-3-D	0	0	0	0	0	0	0	0
6-O-5-HN	40	0	0	40	100	1.8±0.4	62.5±0.7	54.4±10.5
6-O-5-DN	100	25	20	100	100	2.6±1.3+	26.0±6.6+	0
7-O-19-H	100	0	0	100	84	1.3±0.8	59.5±17.8	55.7±9.5
7-O-19-D	100	40	29	100	100	3.3±1.0+	42.0±10.3+	0
1-S-1-H	66	0	0	33	60	1.0±0.3	21.6±1.8	21.6±1.8
1-S-1-D	33	0	0	33	66	1.4±0.2–	18.0±6.9–	18.0±6.9–
2-S-2-H	50	0	0	0	0	0	23.5±3.5	23.5±3.5
2-S-2-D	16	0	0	16	25	1.1±0.2	23.5±4.8–	23.5±4.8–
3-S-4-H	50	0	0	50	66	1.0±0.3	35.3±8.3	35.3±8.3
3-S-4-D	33	0	0	33	100	1.5±0.7–	22.3±4.5+	22.3±4.5+

Table 5. Index P, biomass, vitality and mycorrhizal infection of fine roots in visually healthy and declining spruce trees

Stand code	Total I_p	I_p of healthy roots	I_p of functional roots	Biomass [g 100 ml^{-1} of soil]	Vitality [in % of control]	Mycorrhizal infection [µg of glucosamine . g of dry matter^{-1}]
1-D-3-H	5.1±1.3	4.4±1.1	4.0±1.0	*	*	*
1-D-3-D	4.4±0.9–	2.2±0.6+	0.9±0.4+	*	*	*
2-D-5-H	5.8±2.7	4.9±1.6	4.1±1.3	*	100	11.94±0.59
2-D-5-D	5.4±1.8–	3.3±0.9–	2.4±0.8+	*	121	11.54±0.53–
3-D-6-HN	8.7±1.8	8.6±1.8	8.6±1.8	0.653±0.008	*	*
3-D-6-DN	7.6±1.4–	3.5±0.7+	3.1±0.7+	0.478±0.011+	*	*
4-D-9-H	16.0±4.4	13.1±3.8	10.6±1.8	0.512±0.014	100	11.04±0.48
4-D-9-D	15.7±4.3–	8.7±2.6+	4.9±1.1+	0.429±0.007+	118	13.37±0.35+

Table 5. Continued

Stand code	Total I_p	I_p of healthy roots	I_p of functional roots	Biomass [g 100 ml^{-1} of soil]	Vitality [in % of control]	Mycorrhizal infection [µg of glucosamine . g of dry matter^{-1}]
5-D-21-H	21.6±5.7	17.0±4.1	12.8±2.7	0.372±0.011	100	9.57±0.64
5-D-21-D	17.6±3.6–	10.2±2.8+	5.8±0.9+	0.464±0.010+	133	11.54±0.56+
1-O-2-H	7.37±1.52	7.37±1.52	7.37±1.52	*	*	*
1-O-2-D	3.22±0.66+	3.22±0.66+	1.99±0.86+	*	*	*
2-O-4-H	7.82±2.50	7.82±2.60	7.82±2.50	0.561±0.008	100	*
2-O-4-D	3.33±2.05+	3.33±2.05+	3.14±1.19+	0.475±0.010+	68	*
3-O-5-H	9.19±2.59	9.19±2.59	7.59±0.18	0.508±0.012	100	12.20±0.70
3-O-5-D	3.48±0.52+	3.48±0.52+	2.05±0.56+	0.365±0.005+	81	11.27±0.45+
4-O-9-H	8.50±2.24	8.50±2.24	7.54±2.07	*	*	*
4-O-9-D	5.78±3.24+	5.78±3.24+	4.96±1.85+	*	*	*
5-O-3-H	4.95±1.18	4.95±1.18	4.95±1.18	0.726±0.008	100	11.94±0.55
5-O-3-D	2.82±0.87+	2.82±0.87+	2.18±0.18+	0.514±0.006+	82	9.02±0.48+
6-O-5-HN	9.67±2.56	9.67±2.35	9.48±2.41	0.929±0.011	100	12.57±0.44
6-O-5-DN	4.92±1.45+	4.54±1.47+	3.82±2.08+	0.749±0.011+	64	11.79±0.53+
7-O-19-H	29.02±7.90	28.23±2.45	23.36±1.97	0.937±0.006	100	11.95±0.64
7-O-19-D	9.11±2.85+	4.54±1.47+	3.82±2.08+	0.552±0.010+	57	10.95±0.51+
1-S-1-H	2.98±0.83	2.98±0.83	2.98±0.83	*	*	*
1-S-1-D	1.55±0.66+	1.55±0.66+	1.55±0.66+	*	*	*
2-S-2-H	3.96±0.81	3.96±0.81	3.96±0.81	*	*	*
2-S-2-D	2.28±0.76+	2.28±0.76+	2.28±0.76+	*	*	*
3-S-4-H	2.67±0.84	2.67±0.84	2.67±0.84	*	*	*
3-S-4-D	1.16±0.34+	1.06±0.46+	1.06±0.46+	*	*	*

*Not determined.

Orlík locality (GFT 7S)

At this locality, all the analyzed declining trees had evidently smaller terminal increments compared to the healthy trees (Table 2). In one of the stands, there were observed also significantly shorter needles (values not given). In the declining trees, root rot was detected only in two of the seven analyzed stands, in the extent of up to 40%. The proportion of horizontal and anchor roots affected by rots was nonetheless fairly low (not exceeding 3% in horizontal roots and 30% in anchor roots). Stem base or bole rots were not identified in any of the analyzed either healthy or declining trees (Table 2).

Honey fungus infestation was identified in horizontal skeletal roots of all healthy and declining trees, but the degree of attack was significantly higher in the declining than in the healthy trees. In the damaged trees, the level of infestation of horizontal skeletal roots by honey fungus (Table 3) reached 100% and in healthy trees 50%. As a result of malformation into tangle, not all the analyzed trees had developed sinker roots. The developed sinker roots in healthy as well as declining trees were infested by honey fungus. The degree of attack in declining trees mostly exceeded the value of 3 (Table 4). The absence of anchor roots or their high infestation by honey fungus severely limited the rooting depth in functional roots in the declining trees (Table 4).

In all declining trees, the identified value of total I_p was up to 50% lower than in healthy trees. With regard to the low incidence of root rots and the 3rd-degree and higher infestation of the roots by honey fungus, the total I_p, I_p of healthy roots and I_p of functional roots in healthy and declining trees did not vary in most stands. The overall trend was however preserved – I_p values of healthy roots and of functional roots in declining trees were roughly half of the healthy trees values. All the declining trees had significantly lower biomass of fine roots, lower vitality, and they suffered from mycorrhizal infection (Table 5).

Sokolí skála Rock locality (GFT 7S, 8S)

In the selected stands at the locality Sokolí skála Rock, we detected a decrease in the terminal increment and changes in the needle length. In contrast to the locality in FAVZ 4, this site did not have any incidence of root, stem base or bole rots in either healthy or declining trees (Table 2). The horizontal skeletal roots of all healthy and declining trees were infested by honey fungus. In healthy trees, honey fungus infestation affected ca. 60% of the roots, and in declining trees ca. 80%. In both cases, the degree of honey fungus infestation was identical and did not exceed 1.8 (Table 3). The incidence of honey fungus in anchor roots of healthy and declining trees was more or less the same. No significant differences in the degree of anchor roots infestation by honey fungus were identified, and its value in healthy and declining trees did not exceed 1.5 (Table 4). Nevertheless, the total I_p value in declining trees amounted only to one half of the healthy trees. Since the roots were not attacked either by rot or by honey fungus of the 3rd degree or higher, the same trend and absolute values were detected for the I_p of healthy roots and I_p of functional roots (Table 5).

Discussion

According to Latner (1994), the damage to the forests in the Hrubý Jeseník Mts became apparent since the turn of the years 1978/1979 when an extreme drop in temperature caused the latent syndrom turn into obvious symptoms. The damage to the stands culminated in 1985 (Balcar et al., 1994). Henžlík (1994) states that medium up to severe damage occurred in the area from Keprník to Praděd and in the direction toward Loučná, while more severe damage was identified around Medvědí vrch Hill and Orlík. In the early 1990s, the decline of stands stopped, and their condition was improved (Chmelíček, 1992). According to Vacek et al. (1994), 28% of the acreage of montane forests was classified into the pollution damage zone B and 71.9% of the area into zone C. Roughly in 2000, the damage to the Jeseníky Mts could be noticed again. At present, some parts of the mountain range are classified in the pollution damage zone B (the pollution damage zone nevertheless does not express the degree of air pollution load but assess the tree species growth on the site in a complex manner).

The decline of spruce stands occurring in numerous regions of the country from the 1970s onwards was manifested in various ways. Materna (1994) described defoliation induced by increased concentrations of sulphur dioxide, and subsequent dieback of stands, as well as manifold colour changes in needles either across the whole crown or only on several branches – affecting equally all generations of needles or only some of them and apparent throughout the whole year or only in some seasons. The author also characterized the type of colour changes which impacted older generations of needles with increasing intensity, and colour transition from green in the youngest generations to gradual yellowing and browning in older generations and their premature shedding. He pointed out that this trend may lead to the dieback of individual trees and their entire groups. The author notes that such cases were known from the ridges of the Šumava Mts, Jeseníky Mts and the western Krušné hory Mts. Apart from this particular type of yellowing, there was also distinct uniform yellowing of spruce needles associated with more extreme manifestations with a smaller increment present in mountain locations, chiefly at exposed sites or secondarily impoverished soils. Affected were especially young plantations and young-growth stands before canopy closing. Colour changes in needles were linked with disorders in mineral nutrition, especially with the lack of basic cations of Mg and Ca washed out from the soil due to the long-term impact of acidic depositions (Zöttl and Hüttl, 1986; Blanck et al., 1988; Schulze et al., 1989; Block, 1991; Evers, 1994; Hüttl and Schaaf, 1997 and others). The fact that the principal cause was the nutritional deficiency in magnesium was verified by the positive response to fertilization by magnesium in different forms (Materna, 1994). This cause of decline does not seem likely in the analyzed stands since the concerned sites were fertile or fresh (4B, 7S, 8S) and leaf analysis did not ascertain any deficiency of Mg in the needles.

The assessed stands are situated at altitudes of 650–1180 m a.s.l., i.e. in FAVZ 4–8, while the intensity and progress of decline in lower and higher Forest Altitudinal Vegetation Zones varied. Our analyses determined also altitude-based variations in development and health condition of the root system.

The root systems of declining trees at the Dobrá voda locality (GFT 4B) were seriously infested by honey fungus, and had a large share of roots attacked by rot. Root rot affected primarily anchor roots, which resulted in the significantly decreased rooting depth of functional roots and reduced capacity of trees to use groundwater. Gradual loss of functionality of the individual roots due to rot renders the tree incapable of ensuring sufficient water uptake, and the tree quickly dies back. This fact followed out from the analysis of climatic data from the hydrometeorological station Karlova studánka (780 m a.s.l.). The data smoothed by linear regression show that between 1961 and 2007, the mean air temperature in the period April–September increased by 1.3 °C, precipitation totals for the same period decreased by 113.5 mm, mean annual temperature rose by 0.8 °C, annual hours of sunlight increased by 265 hours and potential transpiration increased, too. All of these phenomena may induce spruce weakening, and represent predisposition factors of its decline. Also Latner (1994) drew attention to the increase in average monthly air temperatures and adverse precipitation conditions, chiefly in the area of the Jeseníky Mts in 1993. Similar symptoms of decline and infestation by honey fungus of trees hitherto visually healthy – in connection with the rise of mean temperatures and fall of precipitation, were detected on fertile sites in the Bohemian-Moravian Upland (Mauer et al., 2008).

In higher Forest Altitudinal Vegetation Zones (Orlík and Sokolí skála Rock localities), spruces grew on fresh sites (GFT 7S and 8S). In contrast to lower altitudes, declining trees at these localities had significantly smaller root systems than healthy trees (see Table values of total I_p). The small root systems of declining trees were always caused by their malformation into tangle which did not develop only in naturally regenerated trees. Root system deformations are irreversible and can arise during incorrect cultivation of containerized, ball and balled planting stock (Mauer, 1999; Jurásek and Martincová, 2001; Pampe and Häseker, 2003; Jurásek et al., 2004) or at inappropriately chosen outplanting method (Sauer, 1984; Strohschneider, 1987; Jurásek et al., 1999; Nörr 2003a, b, 2004). The state of the analyzed stands in which the tangle malformation originated cannot be identified with certainty but the concerned trees may suffer very serious consequences. According to Jurásek and Martincová (2001), the deformations increase the risk of honey fungus infestation due to higher concentration of saccharides in the bends of malformed roots. Sauer (1984) equally assumes that malformations lead to physiological weakening of the plants (even though this is not obvious from the growth of shoots at first) which heightens the risk of attack on the tree by secondary harmful agents. Both healthy and declining trees had horizontal skeletal roots decayed by honey fungus, anchor roots were not always attacked, and the intensity of the 3rd degree and higher was reached only in isolated cases. Due to malformations in some stands (particularly at the Orlík locality), the root systems did not develop any anchor roots at all. This led to low rooting depth and a limited possibility of water uptake from deeper soil layers. Compared to lower altitudes, in these localities the root systems of declining trees were not impacted by rots to a greater extent. It can be thus said that the health condition of root systems in higher altitudes was better than in lower situated sites. Insufficient water to trees resulting from the deteriorated health condition of their root system is not probable. This means that the decline of spruce stands in higher Forest Altitudinal Vegetation Zones of the Jeseníky Mts is probably also due to another stress factor with a long-lasting effect. High shoot increments together with lower levels of biomass and mycorrhizal infection of the fine roots could indicate increased nitrogen depositions (Heinsdorf, 1991). We cannot even exclude the possibility that the decline is attributed to soil microorganisms inducing changes to fine roots – which would conform to the assumption of Nechwatal and Osswald (2003) made based on their experiments.

The identified changes to the root system and expected future climate trend suggest for the field forestry measures excluding spruce from regeneration aims on fertile sites up to FAVZ 4 inclusive. At present, the reconstruction of spruce stands runs with broadleaved species of a wide ecovalence. For lower altitudes may be recommended pine and oak, for higher altitudes beech and sycamore maple. During regenerations, a proper care is to devote to bio-technique of planting (elimination of root system deformations) and spruce cultivation manner assuring the largest possible root system.

Conclusions

The paper analyzes the development and health condition of the root system of healthy and declining Norway spruce trees at three localities in the Jeseníky Mts. The analyzed stands in all locations are situated on fertile sites with no detected nutritional deficiency. The decline was manifested in all age classes of naturally as well as artificially regenerated trees. All of the analyzed trees were affected by root system malformation into tangle and infested by honey fungus (*Armillaria* sp.).

Up to FAVZ 4 (GFT 4B), spruce trees do not meet their ecological optimum. After their weakening by water deficiency, the root system becomes aggressively infested by honey fungus which is fast to induce rots of the roots, stem base and stem. The weakened trees become attacked by bark beetle, too.

In FAVZ 7 and 8 (GFT 7S, 8S), declining trees always have a substantially smaller root system characterised with smaller rooting depth and colonized by honey fungus – as a consequence of malformations. Honey fungus does not cause rots of the roots, stem base or stem. Declining trees have lower biomass, vitality and suffer from mycorrhizal infection of fine roots.

Acknowledgement

The paper forms a part of the research programme MSM 6215648902 and was elaborated with the financial support from the QG 60060 project of the National Agency for Agriculture Research (NAAR). The authors of this paper would like to express their thanks to all workers at the Regional Directorate of the Forests of the Czech Republic in Krnov and Forest Administrations of Město Albrechtice and Karlovice LČR a.s. for their assistance in elaborating this study.

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Vývin a zdravotní stav kořenového systému smrku ztepilého (*Picea abies (*L.) Karst.) v oblasti Jeseníků

Souhrn

V posledních přibližně deseti letech se v Jeseníkách začalo opět projevovat chřadnutí porostů smrku ztepilého. Protože je známo, že kořenový systém bývá často dříve a více ovlivněn než nadzemní část stromu, cílem práce bylo posoudit, zda existuje vzájemný vztah mezi chřadnutím a vývinem a zdravotním stavem kořenového systému této dřeviny.

Šetření byla realizována v celkem 16 porostech na LS Město Albrechtice a Karlovice LČR s.p. V každém porostu byly vzájemně srovnávány stejně vysoké zdravé a chřadnoucí stromy (změna asimilačního aparátu 40–60 %). Kontrolou byly stromy zdravé. Na nadzemní části každého analyzovaného stromu byly měřeny a hodnoceny: celková výška, tloušťka kmene v $d_{1,3}$, délka terminálních výhonů v letech 2007, 2008, 2009 a délka jehlic. Ve vybraných porostech byly realizovány chemické analýzy dvou posledních ročníků jehlic. Na příčných řezech kmenem byl zjišťován výskyt hnilob kmene. Kořenové systémy byly vykopány ručně a na každém z nich byly zjišťovány: počet, tloušťka a délka horizontálních kosterních kořenů, počet a tloušťka kotevních kořenů, počet a tloušťka panoh a počet a tloušťka nekosterních horizontálních kořenů vyrůstajících z báze kmene. Z naměřených hodnot byl vypočítán Index ploch. Na vyzvednutých kořenových systémech byl zjišťován výskyt deformace do strboulu. Zdravotní stav kořenů (výskyt hnilob) byl posuzován na podélném řezu každým kořenem. Ve vybraných porostech byla zjišťována biomasa, životnost a mykorhizní infekce jemných kořenů.

Ze šetření vyplynuly následující závěry:

Na všech lokalitách rostly analyzované porosty na živných stanovištích, kde nebyla zjištěna deficience ve výživě. Chřadnutí se projevovalo u stromů všech věkových tříd, a to jak u stromů z přirozené tak i z umělé obnovy. Všechny analyzované stromy měly kořenové systémy deformovány do strboulu a byly napadeny václavkou (*Armillaria* sp.).

Do 4. lesního vegetačního stupně (SLT 4B) nerostou smrky v optimu ekovalence. Po jejich oslabení nedostatkem vody je kořenový systém agresivně napadán václavkou, která rychle vyvolává hniloby kořenů, báze kmene i kmene. Oslabené stromy jsou napadány i kůrovcem.

V 7. a 8. lesním vegetačním stupni (SLT 7S, 8S) mají chřadnoucí stromy vždy v důsledku deformací podstatně menší kořenový systém, který je kolonizován václavkou a má menší hloubku prokořenění. Václavka nevyvolává hniloby kořenů báze kmene nebo kmene. Chřadnoucí stromy mají nižší biomasu, životnost a mykorhizní infekci jemných kořenů.

Received April 13, 2010
Accepted May 28, 2010

FOLIA OECOLOGICA – vol. 37, no. 2 (2010). ISSN 1336-5266

Harvestmen (Arachnida, Opiliones) with notes on their habitat requirements in selected areas of Central Slovakia

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Abstract

Mihál, I., Gajdoš, P. 2010. Harvestmen (Arachnida, Opiliones) with notes on their habitat requirements in selected areas of Central Slovakia. *Folia oecol.,* 37: 205–211.

In some areas of Central Slovakia, the occurrence of harvestmen (Opiliones) species has been investigated fairly well; however, the data from other parts of the country are both scarce and out-of-date, or they have not been published yet. This work presents a summary of harvestmen species identified in the material sampled over the period 2003–2009, in 13 selected localities in the following geomorphological units in Central Slovakia: the Cerová vrchovina Hills, Horehronské podolie Valley, Hornonitrianska kotlina Basin, Poľana Mts, Revúcka vrchovina Hills, Slovenský kras Karst, Strážovské vrchy Mts and Zvolenská kotlina Basin. Altogether there have been identified 21 harvestmen species – representing 63.6% of the Slovak opiliofauna. There have been recorded thermophilous species like *Dicranolasma scabrum*, *Egaenus convexus* and *Zacheus crista*, as well as invasive thermophilous *Nelima semproni*. The work is the most recent and most comprehensive contribution to the knowledge of harvestmen species diversity, especially in the Hornonitrianska kotlina Basin and several mountain units in Central Slovakia.

Key words

Arachnida, Central Slovakia, faunistics, harvestmen, Opiliones

Introduction

Unlike spiders (Araneae), harvestmen (Opiliones) have not been well recognised in Slovakia until now. More intensive research on harvestmen is evident since the 1990s (Astaloš et al., 1998; Mašán and Mihál, 1993; Mihál, 1997). At present, harvestmen are studied by several authors (Astaloš and Mihál, 2009; Jarab and Kubovčík, 2002; Mašán, 2005; Mihál et al., 2009; Stašiov and Maršálek, 2002 and others). The most complete summary of the recent research of harvestmen from the Slovak Republic can be found in a comprehensive monograph by Stašiov (2004).

The nature in Central Slovakia is characterised by a high diversity of harvestmen fauna associated with warm habitats in lowlands and low hills, habitats in forests in mountain and river valleys at medium altitudes as well as cold mountain habitats. In the past, the harvestmen fauna in Central Slovakia was studied by several authors in various localities: Mihál (1998) in the Poľana Mts, Roušar (1999) in the Strážovské vrchy Mts, Mašán and Mihál (1993) in the Revúcka vrchovina Hills, Stašiov and Snopková (2002) in the Low Tatras Mts, Mihál et al. (2009) in the Cerová vrchovina Hills, and others.

The occurrence of harvestmen has been investigated in detail in several parts of Central Slovakia. However, the data from the other parts of the country are either scarce or out-of-date and some of them have not been published yet. This work presents harvestmen species identified in the material sampled in selected geographical units in Central Slovakia by six persons, contributing to knowledge of harvestmen occurrence and distribution in Central Slovakia.

Material and methods

The harvestmen (Opiliones) were sampled over the vegetation periods 2003–2009, at irregular time intervals. The sampling ran in 13 localities situated in the Cerová vrchovina Hills, Horehronské podolie Valley, Hornonitrianska kotlina Basin, Poľana Mts, Revúcka vrchovina Hills, Slovenský kras Karst, Strážovské vrchy Mts and Zvolenská kotlina Basin. Here the harvestmen were also collected by P. Gajdoš (2007–2009), V. Hrúz (2006, 2007), S. Korenko (2005), I. Mihál (2007, 2009), A. Mock (2003) and V. Papáč (2006–2008). The material was obtained by hand-picking from soil surface, under stones, from wood parts, tree stumps, ground vegetation, also by extraction (sieving) from leaf litter, and obtaining through soil pitfall formaline traps. The harvestmen were identified and processed (det. et coll. I. Mihál in years 2008, 2009). The identification was made according to Martens (1978) and Šilhavý (1956, 1971) and, also, using reference samples in the collection of I. Mihál. The major part of the sampled material has been kept in 70% ethanol in collection of the first author of this paper and is deposited in the Institute of Forest Ecology, Slovak Academy of Sciences in Zvolen.

Description of localities

Note that the following abbreviations were used in the description of localities below**:** locality (L1–L13), cadastral area (CA), morphological unit (MU), quadrate code in the Databank of Fauna in Slovakia (DFS), altitude (ASL), exposition (EXP - Ø is used for a locality situated in a flatland, in the bottom of a valley or in a cave), habitat type (H), sampling date (D), sampled by: lgt.

L1 – **Žíhlavník**, CA: Omšenie, MU: Strážovské vrchy Mts, DFS: 7175, ASL: 800–955, EXP: various, H: thermophilous meadows and pastures on limestone substrate, D: 31st August 2005, lgt. S. Korenko

L2 – **Koš**, CA: Koš, MU: Hornonitrianska kotlina Basin, DFS: 7277, ASL: 260–270, EXP: various, H: waterlogged weed communities with willow and poplar natural regeneration in depressions, D: 15th May 2007, lgt. P. Gajdoš

L3 – **Bystrianska jaskyňa Cave**, CA: Bystrá, MU: Horehronské podolie Valley, DFS: 7183, ASL: 565, EXP: NW, H: cave entrance area, the concrete wall facing the entrance, D: 8th October 2003, lgt. A. Mock

L4 – **Hrochotská dolina Mountain Valley**, CA: Hrochoť, MU: Poľana Mts, DFS: 7382, ASL: 600–700, EXP: various, H: mesophilous meadows and pastures and spruce forest margins on a slope above the village of Hrochoť, D: 15th May 2005, lgt. V. Hrúz, S. Korenko

L5 – **Príslopy**, CA: Dúbravy, MU: Poľana Mts, DFS: 7382, ASL: 860–950, EXP: S, H: mesophilous meadows and pastures and spruce forest margins, D: 7th June 2007, lgt. V. Hrúz

L6 – **Zadná Poľana**, CA: Detva, MU: Poľana Mts, DFS: 7382, ASL: 1250–1350, EXP: SE, H: natural climax spruce forest on andesite substrate, D: 18th August 2006, lgt. V. Hrúz, I. Mihál

L7 – **Kriváň**, CA: Kriváň, MU: Zvolenská kotlina Basin, DFS: 7482, ASL: 450, EXP: NW, H: outside the village, margins of agrocoenoses and surroundings of a house in construction,

D: 8th August 2009, lgt. I. Mihál

L8 – **Zvolen**, CA: Zvolen, MU: Zvolenská kotlina Basin, DFS: 7480, ASL: 290, EXP: SW, H: inside the town, concrete wall of a garage, D: 22nd August 2007, lgt. I. Mihál

L9 – **Domica**, CA: Kečovo, MU: Slovenský kras Karst, DFS: 7588, ASL: 340, EXP: S, H: xerotherm vegetation and pastures on limestone, D: 6th May 2004, lgt. P. Gajdoš

L10 – **Obrovská priepasť Abyss**, CA: Jablonov nad Turňou, MU: Slovenský kras Karst, DFS: 7389, ASL: 540, EXP: Ø, H: surroundings of the cave entrance, dysphotic (twilight) cave part, D: 13th April 2006, lgt. V. Papáč

L11 – **Šingliarova priepasť Abyss**, CA: Rožňavské Bystré, MU: Revúcka vrchovina Hills, DFS: 7388, ASL: 740, EXP: NE, H: surroundings of the cave entrance, dysphotic (twilight) cave part, D: 11th October 2003, lgt. A. Mock

L12 – **Podbanište Cave**, CA: Slizké, MU: Revúcka vrchovina Hills, DFS: 7486, ASL: 370, EXP: Ø, H: surroundings of the cave entrance, dysphotic (twilight) cave part, D: 23rd July 2007, lgt. V. Papáč

L13 – **Nyáriho jaskyňa Cave**, CA: Stará Bašta, MU: Cerová vrchovina Hills, DFS: 7885, ASL: 570, EXP: SE, H: surroundings of the cave entrance, dysphotic (twilight) cave part, D: 2nd October 2008, lgt. V. Papáč.

Results

In total, there have been identified 1,878 individuals of harvestmen, of this 602 females, 730 males, 425 subadults and 121 juveniles. They have been represented by 21 species belonging to four families.

The list below gives the identified species. In the list, the following abbreviations were used: ♀ – female, ♂ – male, subad. – subadult individual, juv. – juvenile individual.

Palpatores Thorell, 1879

Nemastomatidae Simon, 1879

1. *Mitostoma chrysomelas* (Hermann, 1804)

Locality: **L2** – 1♂, 16th July 2008, lgt. A. Gajdoš,

L10 – 1♀, 2 subad., 13th April 2006, lgt. V. Papáč, **L11** – 1♀, 11th October 2003, lgt. A. Mock

2. *Nemastoma lugubre* var. *bimaculatum* (Müller, 1776)
   Locality: **L2** – 1♀, 29th May 2008, 1♀, 1♂, 15th October 2008, 1♀, 13th May 2009, 1♀, 13th September 2009, 1♀, 16th September 2009, 1♀, 13th October 2009, lgt. P. Gajdoš, **L12** – 1♀, 23rd July 2007, lgt. V. Papáč

Dicranolasmatidae Simon, 1879

3. *Dicranolasma scabrum* (Herbst, 1799)
   Locality: **L2** – 1♂, 16th July 2008, lgt. P. Gajdoš, **L13** – 1♂, 2nd October 2008, lgt. V. Papáč

Trogulidae Sundevall, 1833

4. *Trogulus nepaeformis* (Scopoli, 1763)
   Locality: **L2** – 1♀, 29th May 2008, 1♂, 2 subad., 13th September 2009, 1♂, 2 subad., 16th September 2009, lgt. P. Gajdoš, **L6** – 1♀, 1st July 2009, lgt. I. Mihál
5. *Trogulus tricarinatus* (Linnaeus, 1767)
   Locality: **L2** – 1♂, 4th December 2007, lgt. P. Gajdoš

Phalangiidae Simon, 1879

6. *Phalangium opilio* Linnaeus, 1761
   Locality: **L1 –** 1♂, 31st August 2005, lgt. S. Korenko
7. *Opilio parietinus* (De Geer, 1778)
   Locality: **L7** – 1♀, 1♂, 22nd August 2009, lgt. I. Mihál
8. *Opilio saxatilis* C. L. Koch, 1839
   Locality: **L5** – 1♂, 7th June 2007, lgt. V. Hrúz
9. *Platybunus bucephalus* (C. L. Koch, 1835)
   Locality: **L2** – 6 subad., 3 juv., 15th May 2007, 21 subad., 14 juv., 19th March 2008, 9 subad., 1 juv., 29th May 2008, 1 subad., 17 juv., 13th May 2009, lgt. P. Gajdoš, **L6 –** 1♀, 3♂♂, 18th August 2006, lgt. V. Hrúz, 1♂, 1st July 2009, lgt. I. Mihál
10. *Rilaena triangularis* (Herbst, 1799)
    Locality: **L2 –** 1♀, 6♂♂, 20 subad., 5 juv., 15th May 2007, 2♀♀, 1♂, 1 subad., 4 juv., 29th May 2008, 2♀♀, 1♂, 16th July 2008, 1♂, 12th August 2008, 2 juv., 9th December 2008, 7 subad., 7 juv., 13th May 2009, lgt. P. Gajdoš, **L4** – 1♂, 13th May 2005, lgt. S. Korenko, **L6** – 1♂, 18th August 2006, lgt. V. Hrúz, **L9 –** 1♂, 6th May 2004, lgt. P. Gajdoš
11. *Lophopilio palpinalis* (Herbst, 1799)
    Locality: **L2** – 6 subad., 21 juv., 15th May 2007, 6 subad., 1 juv., 23rd August 2007, 1♀, 1♂, 4th December 2007, 1♀, 2♂♂, 19th March 2008, 5 subad., 1 juv., 29th May 2008, 1♀, 6♂♂, 4 juv., 16th July 2008, 2♀♀, 3♂♂, 6 subad., 2 juv., 20th August 2008, 1 subad., 15th October 2008, 2♀♀, 6♂♂, 3 subad., 9th December 2008, 3♂♂, 1 subad., 13th May 2009, 3♂♂, 8 subad., 3 juv., 12th August 2009, 6 subad., 16th September 2009, 1♀, 3♂♂, 2 subad., 13th October 2009, lgt. P. Gajdoš, **L4** – 1 juv., 7th June 2007, lgt. V. Hrúz
12. *Zacheus crista* (Brullé, 1832)
    Locality: **L4** – 6♀♀, 6♂♂, 6 subad., 7th June 2007, lgt. V. Hrúz, **L5** - 2♀♀, 7♂♂, 7 subad., 6 juv., 7th June 2007, lgt. V. Hrúz
13. *Egaenus convexus* (C. L. Koch, 1835)
    Locality: **L2 –** 1 juv., 20th August 2008, lgt. P. Gajdoš, **L9** – 3 subad., 6th May 2004, lgt. P. Gajdoš
14. *Oligolophus tridens* (C. L. Koch, 1836)
    Locality: **L2** – 7♀♀, 6♂♂, 11 subad., 23rd August 2007, 6♀♀, 2♂♂, 1 subad., 4th December 2007, 1♂, 19th March 2008, 4♀♀, 16th July 2008, 4♀♀, 5♂♂, 6 subad., 1 juv., 20th August 2008, 4♀♀, 1♂, 3 subad., 15th October 2008, 2 juv., 13th May 2009, 3♀♀, 5♂♂, 9 subad., 12th August 2009, 1♀, 1♂, 1 subad., 16th September 2009, 6♀♀, 3♂♂, 13th October 2009, lgt. P. Gajdoš, **L4** – 1♂, 5th October 2005, lgt. S. Korenko, **L6** – 1♂, 18th August 2006, lgt. V. Hrúz
15. *Lacinius ephippiatus* (C. L. Koch, 1835)
    Locality: **L2** – 6 juv., 15th May 2007, 5♀♀, 5♂♂, 9 subad., 23rd August 2007, 3♀♀, 1♂, 2 subad., 4th December 2007, 3 subad., 29th May 2008, 4♀♀, 3♂♂, 1 juv., 16th July 2008, 2♀♀, 1♂, 20th August 2008, 1♀, 1♂, 1 subad., 25th August 2008, 1♀, 1♂, 4 subad., 15th October 2008, 1♂, 1 subad., 13th May 2009, 1♀, 3♂♂, 1 juv., 12th August 2009, 2♂♂, 2 subad., 16th September 2009, 2♂♂, 13th October 2009, lgt. P. Gajdoš, **L6** - 1 subad., 1st July 2009, lgt. I. Mihál
16. *Mitopus morio* var. *morio* (Fabricius, 1799)
    Locality: **L2** – 1♀, 12th August 2009, 1♀, 2♂♂, 13th September 2009, 1 subad., 16th September 2009, lgt. P. Gajdoš, **L6** – 33♀♀, 44♂♂, 7 subad., 18th August 2006, 20♀♀, 152♂♂, 7th November 2006, lgt. V. Hrúz
    Mitopus morio var. *alpinus* (Fabricius, 1799)
    Locality: **L6** – 38♀♀, 29♂♂, 13 subad., 18th August 2009, 24♀♀, 9♂♂, 7th November 2006, lgt. V. Hrúz
17. *Gyas titanus* Simon, 1879
    Locality: **L3** – 1 subad., 8th October 2003, lgt. A. Mock
18. *Astrobunus laevipes* (Canestrini, 1872)
    Locality: **L2** – 5♀♀, 10♂♂, 5 subad., 15th May 2007, 12♀♀, 2♂♂, 26th July 2007, 35♀♀, 32♂♂, 17 subad., 23rd August 2007, 75♀♀, 77♂♂, 4th December 2007, 11♀♀, 8♂♂, 2 subad., 29th May 2008, 3♀♀, 1♂, 3 juv., 16th July 2008, 31♀♀, 27♂♂, 39 subad., 6 juv., 20th August 2008, 11♀♀, 24♂♂, 10 subad., 25th August 2008, 46♀♀, 39♂♂, 54 subad., 15th October 2008, 1♀, 1♂, 1subad., 9th December 2008, 2♀♀, 1♂, 13th May 2009, 4♀♀,

6♂♂, 3 subad., 3 juv., 12th August 2009, 103♀♀, 100♂♂, 45 subad., 3 juv., 16th September 2009, 50♀♀, 46♂♂, 39 subad., 13th October 2009, lgt. P. Gajdoš

19. *Leiobunum* aff. *rupestre* (Herbst, 1799)
Locality: **L4** – 2♀♀, 2♂♂, 5th October 2005, lgt. S. Korenko

20. *Leiobunum rotundum* (Latreille, 1798)
Locality: **L2** – 1♀, 4♂♂, 3 juv., 12th August 2009, 1 subad., 16th September 2009, lgt. P. Gajdoš

21. *Nelima semproni* Szalay, 1951
Locality: **L2** – 1♀, 2 subad., 23rd August 2007, 1♀, 15th October 2008, lgt. P. Gajdoš, **L7** – 4♀♀, 4♂♂, 8th August 2009, lgt. I. Mihál, **L8** - 1♀, 22nd August 2007, lgt. I. Mihál.

Discussion

The 21 harvestmen species represent 63.6% of the total species number identified in Slovakia up to now (S = 33, according to Bezděčka, 2009; Stašiov, 2004). The highest number of harvestmen species was found in the localities No. 2 (Koš, 15), No. 6 (Zadná Poľana, 6) and No. 4 (Hrochotská dolina, 5 species). The number of occurrence localities frequency was the highest in case of the species *Rilaena triangularis* (found in 4 localities), *Mitostoma chrysomelas*, *Oligolophus tridens* and *Nelima semproni* (3 localities). In *Astrobunus laevipes*, the heighest number of the individuals caught was documented (993 individuals and 52.9% of the total number of harvestmen recorded).

A more detailed overview of the species richness of harvestmen fauna recorded in particular localities in the selected morphological units of Central Slovakia is given in Table 1. It can be seen that the long-term and intensive inventory has resulted in finding most species in the geomorphological unit Hornonitrianska basin where the harvestmen fauna has not been studied yet. The literature (Stašiov, 2004) reports only two harvestmen species indentified in this unit (*Dicranolasma scabrum* and *Platybunus bucephalus*), and the occurrence of *Opilio saxatilis*, *Lacinius ephippiatus* and *Leiobunum rotundum* in the Hornonitrianska basin have not

Table 1. The occurrence of harvestmen species (Opiliones) recored in selected morphological units in Central Slovakia

Species	A	B	C	D			E		F		G		H
	1	2	3	4	5	6	7	8	9	10	11	12	13
Mitostoma chrysomelas		*								*	*		
Nemastoma lugubre		*											*
Dicranolasma scabrum		*										*	
Trogulus nepaeformis		*				*							
Trogulus tricarinatus		*											
Phalangium opilio	*												
Opilio parietinus							*						
Opilio saxatilis					*								
Platybunus bucephalus		*				*							
Rilaena triangularis		*		*		*			*				
Lophopilio palpinalis		*		*									
Zacheus crista				*	*								
Egaenus convexus		*							*				
Oligolophus tridens		*		*		*							
Lacinius ephippiatus		*				*							
Mitopus morio		*				*							
Gyas titanus			*										
Astrobunus laevipes		*											
Leiobunum aff. *rupestre*				*									
Leiobunum rotundum		*											
Nelima semproni		*					*	*					

A – Strážovské vrchy Mts, B – Hornonitrianska kotlina Basin, C – Horehronské podolie Valley, D – Poľana Mts, E – Zvolenská kotlina Basin, F – Slovenský kras Karst, G – Revúcka vrchovina Hills, Cerová vrchovina Hills, 1–13: number of localities.

been published till now (Novikmec, unpubl.) The locality Koš in this unit is strongly modified by human activities – water logged weed communities with natural seeding of willow and poplar in depressions. Here, a total of 15 harvestmen species were recorded, of which *Astrobunus laevipes*, *Lacinius ephippiatus*, *Nemastoma lugubre*, *Oligolophus tridens* and *Trogulus nepaeformis* are frequent in moist habitats. The high abundance of *Astrobunus laevipes* (altogether 993 individuals of all development stage) is suprising, indicating favourable conditions for the species in waterlogged habitats in the locality Koš. Similar results have been obtained by Gajdoš (2008), who studied araneofauna in this locality and who identified a total of 49 spider species, mostly hygrophilous ones, occurring in wetlands and waterlogged habitats.

As expected, the thermophilous harvestmen species like *Dicranolasma scabrum*, *Egaenus convexus*, *Opilio saxatilis* and *Zacheus crista* were recorded in localities in the south-situated morphological units where the occurrence of harvestmen occurrence is relatively frequent (Mihál, 1995, 1998; Mihál et al., 2009). These ponto-mediterranean thermophilous species have their northern limit of distribution in the country (Mihál et al., 2003; Stašiov, 2004). The thermophilous species *Nelima semproni*, also, belongs to this group. It prefers open and warm oak-hornbeam forests, fields and black locust woods in lowlands. It is also frequent in dry weed communities. The first record of *Nelima semproni* in Slovakia was made in the south-western Slovakia in 1987 (Mašán and Mihál, 1993). Since then, the species has been documented from 8 localities in 5 morphological units. Its habitats are very diverse, however, it seems to prefer urban environments and roads and riparian stands as corridors. *Nelima semproni* is likely to be an invasive species spreading to new localities and sites in Central and Eastern Slovakia (Mihál et al., 2003; Stašiov et al., 2010).

In the study, harvestmen were sampled also from the surroundings of caves and from the inside of caves. In five localities the five harvestmen species (*Dicranolasma scabrum*, *Egaenus convexus*, *Gyas titanus*, *Mitostoma chysomelas* and *Nemastoma lugubre*) were recorded. Central Slovakia is rich in karst and pseudokarst caves and abysses where research on opiliofauna has been conducted recently. Up to now, the opiliofauna associated with caves has been only marginally studied. The publication by Gulička (1985) is the only exception of this, representing knowledge of soil micro-fauna, harvestmen included, in the surroundings of caves in the Slovenský kras Karst and the Muránska planina plateau. Faunistic data on harvestmen occurrence in such habitats can be also found in the work by Košel (1984). More comprehensive summary of the knowledge of opiliofauna in the caves in Slovakia was published by Stašiov et al. (2003), who listed a total 11 harvestmen species occurring in caves, including most species identified in this study (except for *Nemastoma lugubre*).

Acknowledgement

This study was supported by the financial mechanism of EEA, project No. 2008-03-09 „Development scenarios of representative landscape ecosystems in the Slovak Republic considering global changes“. The authors thank to V. Hrúz, S. Korenko, A. Mock and V. Papáč for their assistance with field studies.

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Kosce (Arachnida, Opiliones) vybraných území stredného Slovenska a poznámky k ich stanovištným nárokom

Súhrn

Na strednom Slovensku nachádzame územia, resp. orografické celky, ktoré sú z hľadiska opiliofauny dobre preskúmané, ale aj územia, z ktorých sú o výskyte koscov (Opiliones) známe iba skromné údaje staršieho dáta, prípadne viaceré údaje nie sú publikované. Táto práca podáva súhrn nálezov koscov z materiálu šiestich zberateľov z vybraných orografických celkov stredného Slovenska. Kosce boli odchytávané vo vegetačnom období nepravidelne počas rokov 2003–2009 na 13 lokalitách v orografických celkoch Cerová vrchovina, Horehronské podolie, Hornonitrianska kotlina, Poľana, Revúcka vrchovina, Slovenský kras, Strážovské vrchy a Zvolenská kotlina. Celkovo bolo determinovaných 21 druhov koscov, čo tvorí 63,6 % z celkovej druhovej diverzity opiliofauny Slovenska. Najviac druhov koscov bolo zistených na lokalitách č. 2 (lokalita Koš v Hornonitrianskej kotline, 15 druhov), č. 6 (Zadná Poľana, 6 druhov) a č. 4 (Hrochotská dolina na Poľane, 5 druhov). Najvyššiu frekvenciu výskytu v rámci lokalít mali druhy *Rilaena triangularis* (zistený na 4 lokalitách), *Mitostoma chrysomelas*, *Oligolophus tridens* a *Nelima semproni* (zistené na 3 lokalitách). U druhu *Astrobunus laevipes* bola zaznamenaná najvyššia početnosť chytených jedincov (až 993 exemplárov, čo tvorí 52,9 % z celkového počtu determinovaných koscov). Boli zaznamenané aj teplomilné druhy *Dicranolasma scabrum*, *Egaenus convexus* a *Zacheus crista*, ktoré na Slovensku dosahujú severnú hranicu svojho areálu rozšírenia, ako aj teplomilný a invázny druh *Nelima semproni*. Práca prináša najnovšie a najkomplexnejšie poznatky najmä o druhovej diverzite koscov Hornonitrianskej kotliny, obohacuje poznanie opiliofauny ďalších pohorí na strednom Slovensku a upresňuje ekologické nároky vybraných druhov koscov, najmä so zreteľom na typ habitatu.

Received May 17, 2010
Accepted July 20, 2010

FOLIA OECOLOGICA – vol. 37, no. 2 (2010). ISSN 1336-5266

The temporal variability of phenological stages of Norway spruce (*Picea abies* (L.) Karst.) in Slovakia

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Abstract

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

The paper informs about the evaluation of observed selected vegetative (bud burst beginning, the first May sprouts occurrence) and generative (the lasting male flowers and the general flowering) phenological stages of Norway spruce (*Picea abies* (L.) Karst.). There were analysed data from 38 phenological stations in Slovakia within the period 1996–2008. The stations were situated in the range from 100 m to 940 m a.s.l. and divided into 3 altitudinal groups. The mean onset date of the bud burst stage was from the 21st of April till the 6th of May, the first May sprouts occurred from the 2nd till the 18th of May. Male flowers were lasting from the 12th till the 19th of May, the general flowering lasted from the 17th till the 24th May on average. The shifts of observed vegetative phenological stages among particular altitudinal groups represented 7–9 days, and they kept their temporal succession. Generative phenological stages began with the differences among particular altitudinal groups approaching 2–5 days regardless the altitude itself. At lower situated stations, up to 500 m a.s.l., the vegetative phenological stages were observed shifted positively by 3.3–8.5 days, above 500 m a.s.l. these stages were delayed by 0.8–2.8 days. The generative phenological stages manifested a decreasing trend with a shift by 3.6–11.2 days sooner. The phenological phases shortens are shorter with increasing altitude.

Key words

Norway spruce (*Picea abies* (L.) Karst.), phenology, Slovakia

Introduction

The climate change present during the last years has manifested expressive impacts on forest ecosystems by the deterioration of their health and by the changes to the plant communities. The affected tree-species respond by decreasing their natural resilience and by weakening their resistance to both abiotic and biotic detrimental factors, but also by changes in their biological manifestations influencing the natural expansion of the concerned species. Phenological observations become an important bio-indicator of the current environmental changes. It is possible to apply them for recognition of mutual relationships between the phenological trends of plant populations and the development of the climate (Balut and Sabor, 2002; Bednářová and Merklová, 2007; Škvareninová, 2008), in course the phenological phases and diameter increment (Střelcová and Leštianska, 2009). The modelling of phenological stages of tree-species should serve for assessment of the possible impact of the climate change and for the forecast of their future spreading and vitality.

Spruce is growing in Slovakia also in areas outside its natural area of distribution. In such changed and less suitable sites, it becomes more vulnerable to attacks of both abiotic and biotic agents. Thus, it is necessary to pay an increased attention to its original populations and their phenological responses to the changed conditions in the environment in the new areas of its occurrence.

Data and methods

The data about the vegetative and generative phenological manifestations of spruce were obtained from the network of the Slovak Hydro-meteorological Institute (SHMI), where the selected altitudinal groups of spruce stands were observed in 38 sites situated from 105 m up to 940 m a.s.l. The phenological observations were carried out according to the methodological procedure elaborated by the SHMI (Braslavská and Kamenský, 1996). All the observed days were denoted by series numbers from the very beginning of a year (the growing degree day's method). The following phenological stages were evaluated:

- The bud burst (BB): the first buds have burst open, cover scales still remain, at the tops of buds are visible green ends of needles.
- The first May sprouts (MS): the first needles start to separate in the bottom parts of terminal buds; they already manifest their characteristic shape, but not yet the common magnitude and colour.
- The lasting male flowers (FL): the male flowers start to release pollen grains at least in the half of the population.
- The general flowering (GF): most flowers have been completely developed and male flowers release pollen intensively.

In order to identify the onset of particular phenological stages more precisely in relation to the sites altitude, the sample plots were divided into 3 groups according to altitudinal intervals covering the whole altitudinal range. The intervals were very similar in width. The provenances within these groups were distributed uniformly, as much as possible (Table 1).

Table 1. The distribution of phenological stations according to the altitudinal groups

Altitudinal groups	Locality	Orographic whole	Altitude (m a.s.l.)
1 100–300 m a.s.l.	Bánovce n. Ondavou	Východoslovenská rovina	105
	Kravany nad Dunajom	Podunajská rovina	110
	Kuzmice	Podunajská pahorkatina	160
	Lukáčovce	Podunajská pahorkatina	160
	Šaštín-Stráže	Borská nížina	180
	Trenčín	Strážovské vrchy	210
	Krásna nad Hornádom	Východoslovenská rovina	220
	Klátova Nová Ves	Tribeč	230
	Tesáre	Podunajská pahorkatina	230
	Plešivec	Slovenský kras	270
	Rimavské Brezovo	Revúcka vrchovina	275
2 310–500 m a.s.l.	Dolné Hámre	Žiarska kotlina	310
	Krásny Brod	Laborecká vrchovina	310
	Nitrianske Rudno	Hornonitrianska kotlina	310
	Ratková	Revúcka vrchovina	330
	Horná Breznica	Považské podolie	340
	Gemerská Poloma	Volovské vrchy	355
	Kysucké Nové Mesto	Kysucká vrchovina	355
	Košická Belá	Volovské vrchy	375
	Vyšný Medzev	Košická kotlina	390
	Slavošovce	Revúcka vrchovina	415

Table 1. Continued

Altitudinal groups	Locality	Orographic whole	Altitude (m a.s.l.)
2			
310–500			
	Lukov	Ondavská vrchovina	460
	Hriňová	Veporské vrchy	475
	Mošovce	Turčianska kotlina	480
	Smižany	Hornádska kotlina	490
3			
510–940			
m a.s.l.	Jasenie	Horehronské podolie	510
	Stará Ľubovňa	Spišsko-šariš. medzihorie	540
	Matiašovce	Spišská Magura	560
	Makov	Turzovská vrchovina	590
	Hranovnica	Hornádska kotlina	620
	Turček	Kremnické vrchy	660
	Lazisko	Nízke Tatry	675
	Oravská Polhora	Oravské Beskydy	700
	Rakúsy	Podtatranská kotlina	710
	Zakamenné	Pobeskydská vrchovina	715
	Pohorelá	Nizke Tatry	765
	Vyšný Slavkov	Levočské vrchy	770
	Liptovská Teplička	Nízke Tatry	940

Results and discussion

The start of the vegetative phenological stage of bud burst (Fig. 1, Table 2) during the analysed years was dated on average from the third decade of April till the first decade of May, with the coefficients of variation approaching 6.26–8.42%. The observed temporal shifts among particular altitudinal groups were 7–8 days. The earliest start of this phenological stage was recorded on 20. 03. 2007 in the station Ratková situated at 330 m a.s.l., the latest timing of the l stage start was recorded on 26. 05. 1997 in the site Liptovská Teplička (940 m a.s.l.).

The first May sprouts stage was lasting on average from the first till the second May decade (Fig. 2). The coefficients of variation approached values of 6.36–7.57 %, the temporal shifts among altitudinal groups were 7–9 days. The earliest start was recorded in Bánovce nad Ondavou (105 m a.s.l.) on 17. 04. 1999, the latest one in Vyšný Slavkov (770 m a.s.l.) on 18. 06. 2006.

Some of our results were compared with other Slovak authors. The phenological stage of the first May sprouts during the analysed period started on average on the 9th of May. Luknárová (2000) presents the 10th of May as the mean starting date for the period of 1961–1985 what corresponds not only with our results, but also with the results of Kurpelová (1963, 1972) concerning years 1931–1960. Luknárová also informs that the arithmetic mean for the period of 1986–1998 was shifted to the 17th of May, although at the altitude above 500 m a.s.l. was detected the start of this phenological stage from 11th till 30th of May. Our mean value for the start of this phenological stage fits the same time interval, because in sites situated above 500 m a.s.l., it was recorded on the 18th of May.

Figures 1 and 2 point out the preserved temporal succession of displayed phenological stages related to the ascending altitude. The presented findings are also in accordance with the results of Škvareninová (2009) who informs that this ability of gradual delayed starts is well preserved also after the transfer of the original populations of Norway spruce in new, but the same environmental conditions.

The generative phenostage of the lasting of male flowers took place on average during the second May decade when we detected shifts among particular altitudinal groups approaching 2–5 days (Fig. 3). The earliest was this phase in Trenčín (210 m a.s.l.) on 11. 04. 2007, the latest in Vyšný Slavkov (19. 06. 2008). The values of variation coefficients in this case were 6.89–9.55 % (Tab. 2).

The evaluated phenological stage almost continually passed into the next one – the general flowering, when the both types of flowers were observed. This

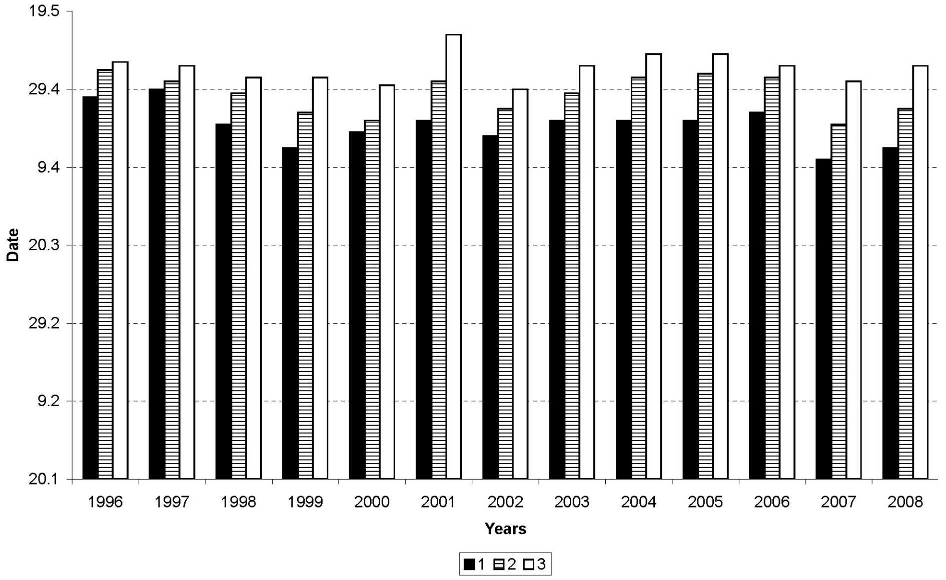

Fig. 1. The mean beginnings of the bud burst stage in the altitudinal groups during the period of 1996–2008.

Table 2. The statistical characteristics of particular phenostages in the observed altitudinal groups

Altitudinal groups	1 (100–300 m a.s.l.) n = 11				2 (310–500 m a.s.l.) n = 14				3 (510–940 m a.s.l.) n = 13			
Phenostages	Ø	Min.	Max.	s_x%	Ø	Min.	Max.	s_x%	Ø	Min.	Max.	s_x%
BB	21.4.	24.3.	5.5.	8.42	28.4.	20.3.	19.5.	8.26	6.5.	10.4.	26.5.	6.26
MS	2.5.	11.4.	25.5.	6.36	9.5.	20.4.	28.5.	7.57	18.5.	28.4.	18.6.	6.40
FL	12.5.	11.4.	16.6.	7.80	14.5.	21.4.	15.6.	6.89	19.5.	25.4.	26.6.	9.55
GF	17.5.	17.4.	21.6.	7.47	19.5.	2.5.	20.6.	6.66	24.5.	10.5.	23.6.	8.61

Ø – the mean beginning of flowering; Min. – the earliest beginning; Max. – the latest beginning; s_x% – the coefficients of variation.

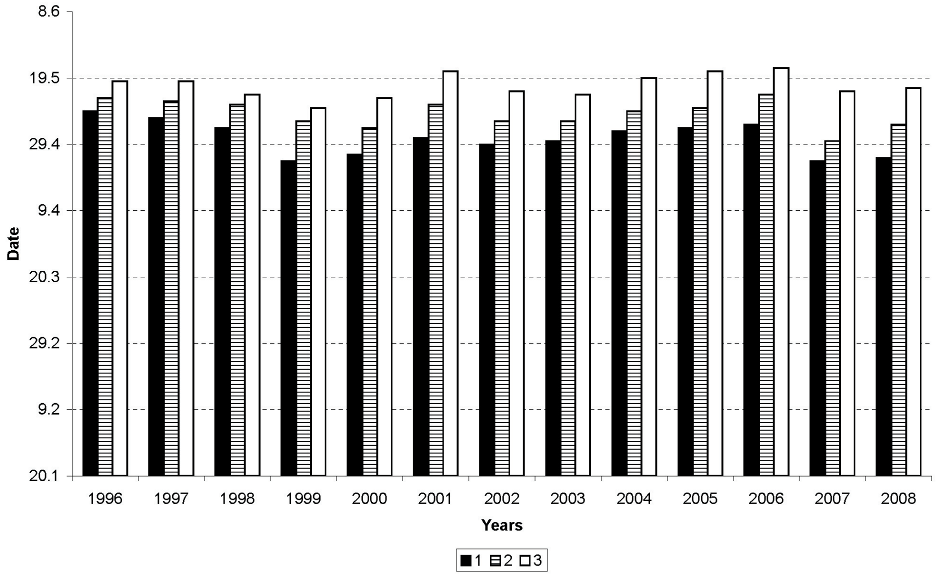

Fig. 2. The mean beginnings of the first May sprouts stage in the observed altitudinal groups during the period of 1996–2008.

phenological stage lasted from the second till the third decade of May, with the values of variation coefficients 6.66–8.61%. The delays of starts among particular altitudinal groups approached 2–5 days (Fig. 4). The earli-

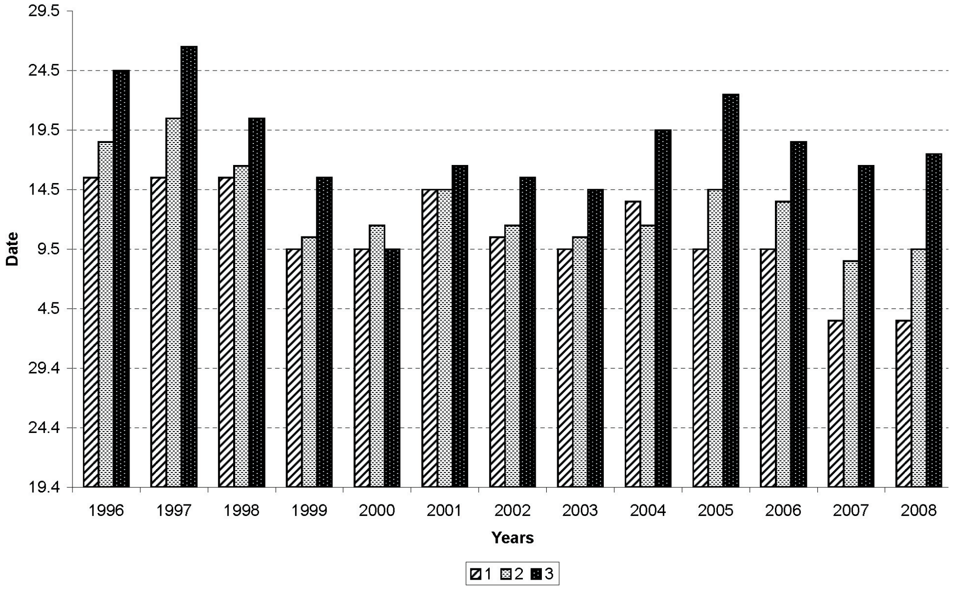

Fig. 3. The mean beginnings of the male flowers lasting stage in the altitudinal groups during the period of 1996–2008.

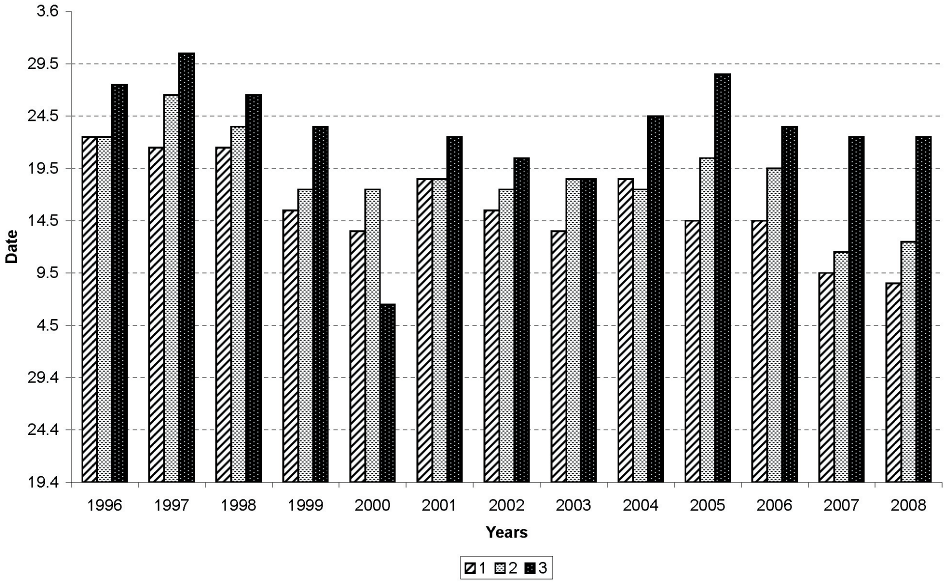

Fig. 4. The mean beginnings of the general flowering stage in the altitudinal groups during the period of 1996–2008.

Table 3. The temporal shifts of analysed phenostages in particular altitudinal groups (days)

Altitudinal groups	Phenostage			
	BB	MS	FL	GF
1	8.5	6.7	10.0	11.2
2	3.3	5.2	7.7	9.4
3	–0.8	–2.8	4.0	3.6

+ earling beginning; – later beginning.

est occurrence was observed on 17. 04. 2007 in Trenčín (210 m a.s.l.) and the latest one in Vyšný Slavkov and Liptovská Teplička on 23. 06. 2008 and 23. 06. 1997, respectively.

The phenological stage of the lasting male flowers can be coupled with the phenological stage of the flowering beginning as observed by Luknárová (2000). The author reports the start of this stage up to the altitude 500 m a.s.l. from the 3rd till the 19th of May, above 500 m a.s.l. from the 3rd till the 29th of May. According to our results, the mean starts up to 500 m a.s.l. were recorded on the 12th–14th of May and above 500 m a.s.l. on the 19th of May, what is in accordance with the data presented formerly. Figure 3 and 4 point out that the generative phenological stages in both the first and the second altitudinal groups do not preserve the temporal succession of their beginnings in relation to the increasing altitude.

The analysis of development trends of all investigated phenological stages also included their temporal shifts presented in Table 3.

The analyses of development trends in each altitudinal group have been carried out (Figs 5–7). It was found that the start of the bud burst up to 500 m a.s.l.

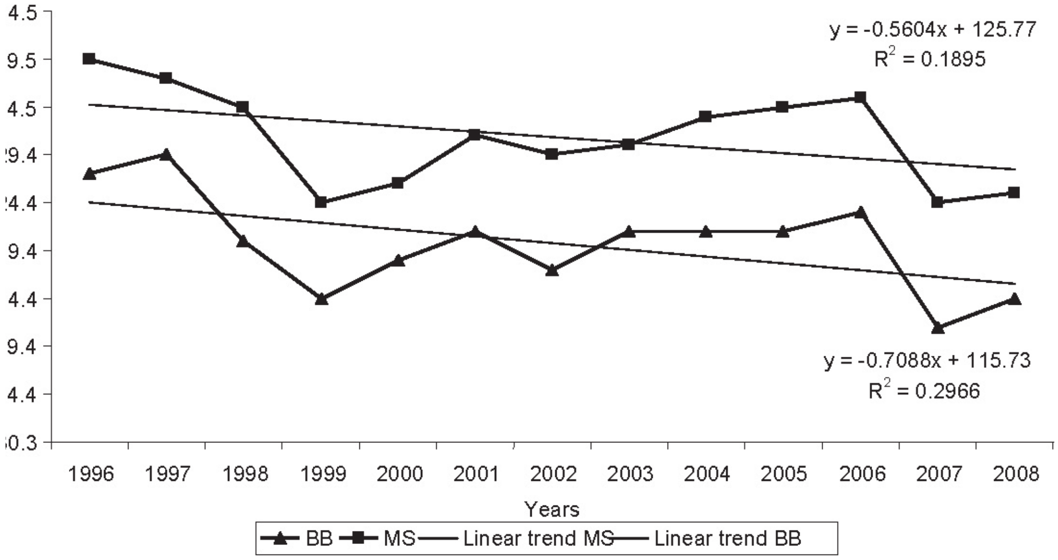

Fig. 5. The average starts of vegetative phenostages in particular years and their trends of development during the period of 1996–2008 in the 1st altitudinal group.

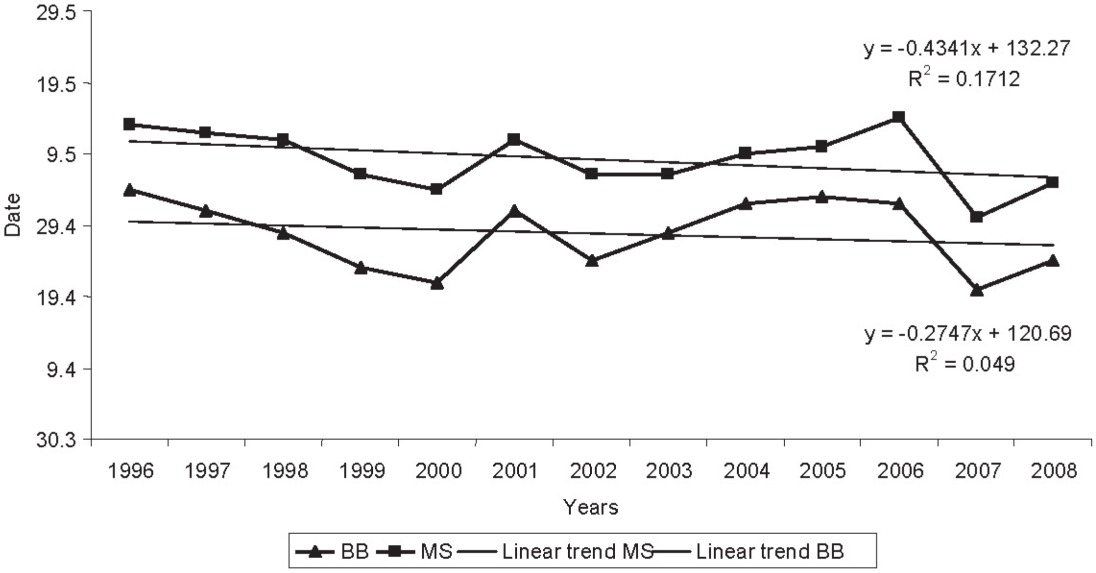

Fig. 6. The average starts of vegetative phenostages in particular years and their trends of development during the period of 1996–2008 in the 2nd altitudinal group.

occurred by 3.3–8.5 days sooner and the stage of the first May sprouts by 5.2–6.7 days sooner compared to higher situated sites. Unlike, spruce trees growing above 500 m a.s.l. manifested the bud burst stage and the first May sprouts stage delayed by 0.8 days and by 2.8 days, respectively. The coefficients of correlation point out the low degree of this dependence.

Both the generative and the general flowering phenostages manifested decreasing trends in all three altitudinal zones (Figs 8–10). The accelerations of the lasting male flowers by 4–10 days and the general flowering by 3.6–11.2 days have been detected. The correlation coefficients point out a stronger dependence when compared with the vegetative phenostages.

The comparison of these findings with the results of Luknárová (2000) informs about the change manifested by the sooner starts of all phenological stages during 1996–2008, probably caused by the assumed changes in temperature across the whole territory of Slovakia.

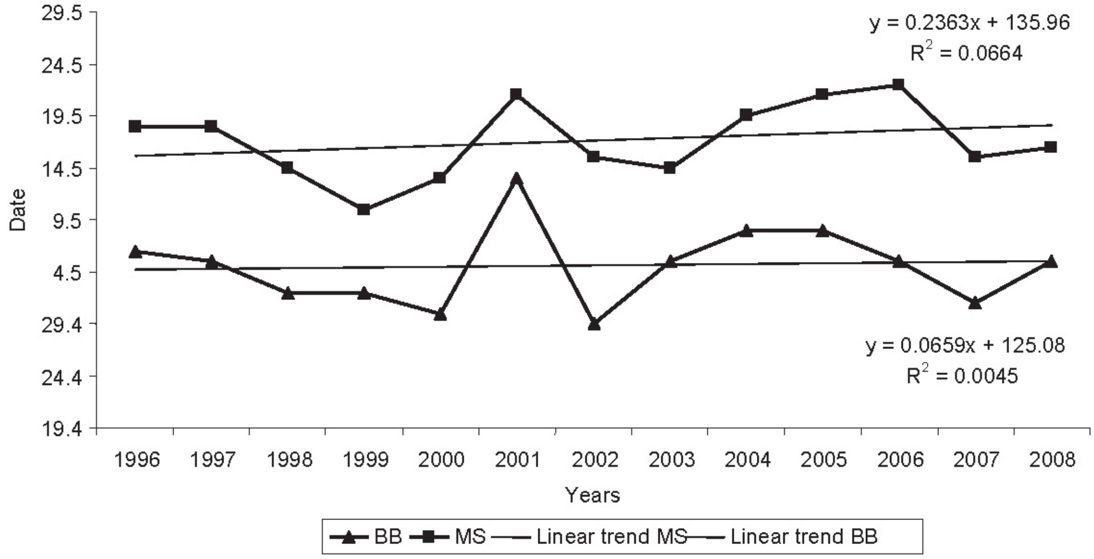

Fig. 7. The average starts of vegetative phenostages in particular years and their trends of development during the period of 1996–2008 in the 3rd altitudinal group.

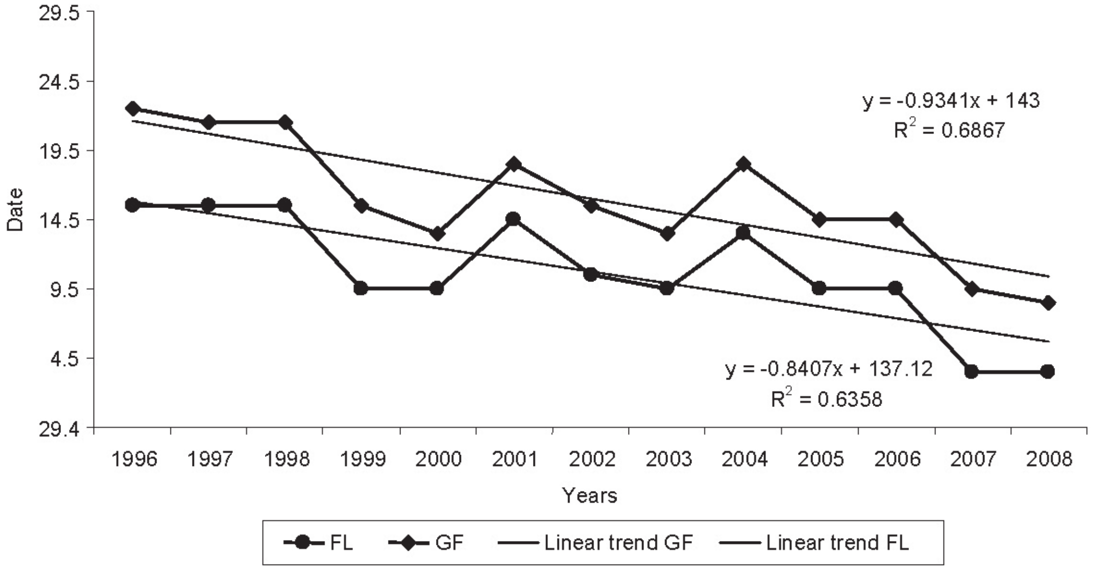

Fig. 8. The average starts of generative phenostages in particular years and their trends of development during the period of 1996–2008 in the 1st altitudinal group.

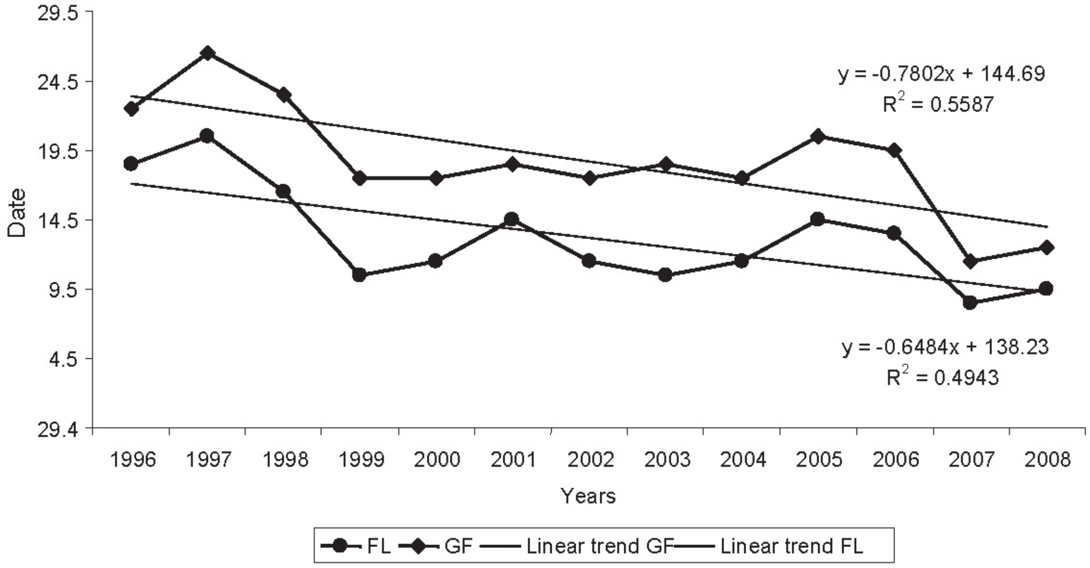

Fig. 9. The average starts of generative phenostages in particular years and their trends of development during the period of 1996–2008 in the 2nd altitudinal group.

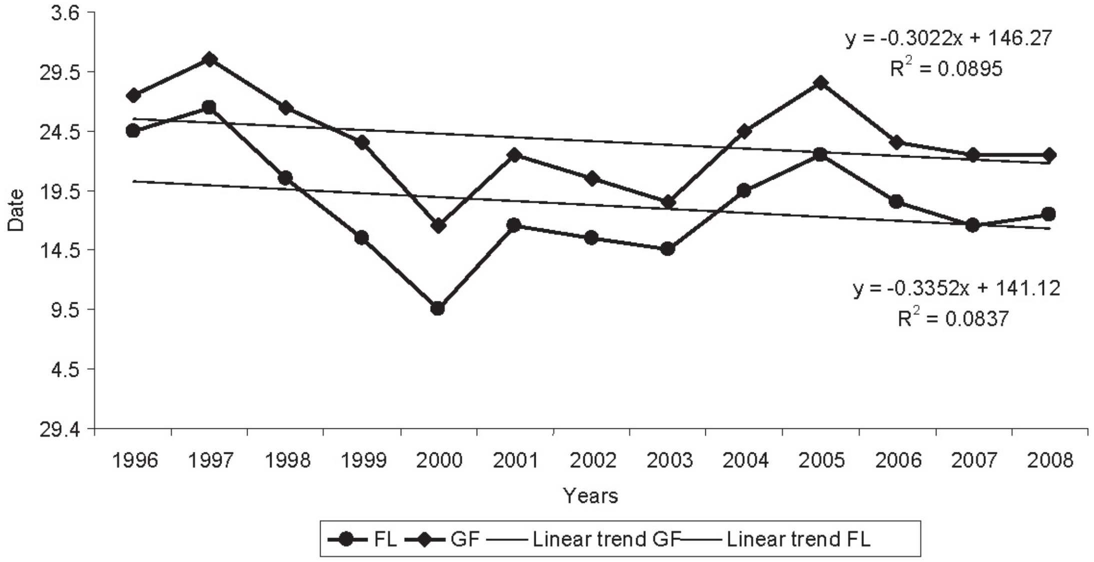

Fig. 10. The average starts of generative phenostages in particular years and their trends of development during the period of 1996–2008 in the 3rd altitudinal group.

Conclusions

There were evaluated selected vegetative (the bud burst and the general flowering) and generative (the lasting male flowers and the general flowering) phenological stages of Norway spruce in 38 stations monitoring forest phenology in Slovakia during the period 1996–2008. The observed sites were classified into 3 groups covering the altitudinal gradient 100–940 m a.s.l. The mean starting date of the bud burst stage was timed from 21st April till 6th May, and the first May occurred on average from 2nd till 18th May. The obtained variation coefficients reached the values between 6.26–8.42%. The temporal shifts in vegetative phenological stages among particular altitudinal groups were on average 7–9 days and their temporal succession related to the ascending altitude had been preserved.

The generative phenological stage of the lasting male flowers started on average from 12th till 19th May, and the general flowering from 17th till 24th May. The coefficients of variation fit the interval 6.66–9.55%, the observed differences in start timing among the particular altitudinal groups were 2–5 days. There was not observed a preserved succession of generative phenological stages in relation to the increasing altitude within the 1st and 2nd altitudinal groups.

The analyses of time series up to 500 m a.s.l. pointed out the tendencies of positive shifts in the both phenological stages by 3.3–8.5 days. Spruces growing above 500 m a.s.l. were in their trends delayed by 0.8–2.8 days. Generative phenostages manifested decreasing trends in all three observed altitudinal groups. The detected acceleration of the lasting male flowers approached 4–10 days and the general flowering occurred earlier by 3.6–11.0 days. The length of phenological stages was shortening with incresing altitude. However, it is necessary to realize that the observations series lasting 13 years represent, from the climatologic point of view, a comparatively short period. Unfortunately, due to the change in the methodology, there are not available longer time series of observations.

Acknowledgement

The authors gratefully thank to the Slovak Ministry of Education, Project VEGA No. 1/0515/08, 1/0557/10 for funding this research.

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Časová variabilita nástupu fenologických fáz smreka obyčajného (*Picea abies* (L.) Karst.) na Slovensku

Súhrn

V príspevku sú vyhodnotené výsledky priebehu vybraných vegetatívnych (začiatok pučania, prvé májové výhonky) a generatívnych (kvitnutie samčích kvetov, všeobecné kvitnutie) fenologických fáz smreka obyčajného (Picea abies (L.) Karst.). Analyzovalo sa 38 fenologických staníc Slovenska v rokoch 1996 – 2008. Stanice z nadmorských výšok od 100 m do 940 m n. m. boli rozdelené do troch výškových skupín tak, aby rozpätia nadmorských výšok mali približne rovnako veľký interval a pôvody boli rozmiestnené do skupín v čo najvyrovnanejšom počte.

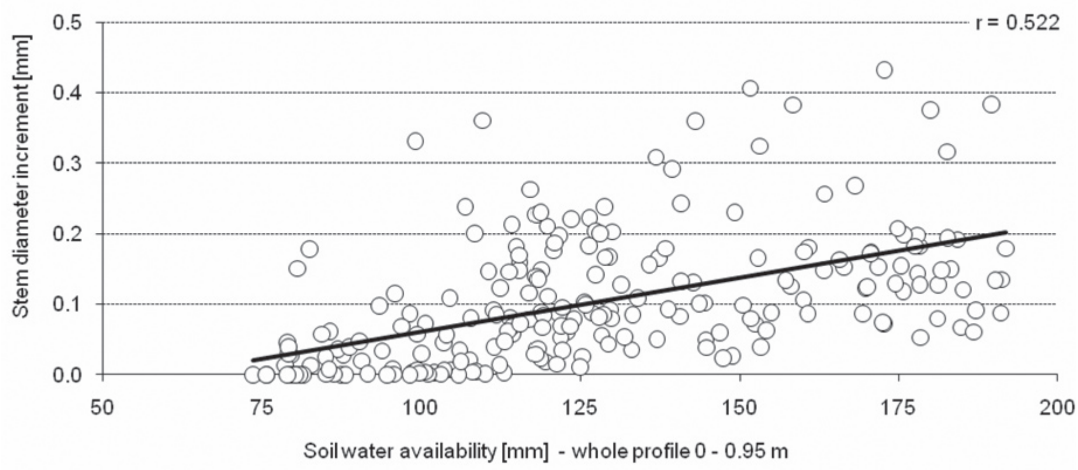
Priemerný nástup začiatku pučania bol 21. apríl – 6. máj, prvých májových výhonkov 2. – 18. máj. Kvitnutie samčích kvetov nastupovalo priemerne 12. – 19. mája, všeobecné kvitnutie 17. – 24. mája. Posuny vegetatívnych fenologických fáz medzi výškovými skupinami boli 7 – 9 dní a zachovali si časovú následnosť. Generatívne fenologické fázy nastupovali s rozdielom 2 – 5 dní medzi výškovými skupinami bez následnosti od nadmorskej výšky. Trendy nástupu vegetatívnych fenologických fáz do 500 m n. m. sa posúvajú do skoršieho časového obdobia o 3,3 – 8,5 dní, nad 500 m n.m. sa oneskorujú o 0,8 – 2,8 dňa. Generatívne fenofázy zaznamenali vo všetkých nadmorských výškach klesajúci trend s posunom o 3,6 – 11,2 dňa skôr. Dĺžka trendov fenofáz sa znižuje so stúpajúcou nadmorskou výškou. V 1. a 2. výškovej skupine nie je zachovaná postupnosť ich nástupu so stúpajúcou nadmorskou výškou. Treba však poznamenať, že 13-ročný rad pozorovaní je na určovanie trendov v klimatológii pomerne krátkym obdobím. Vzhľadom k zmene metodiky nie sú k dispozícii dlhšie rady pozorovaní.

Received December 4, 2009
Accepted July 22, 2010

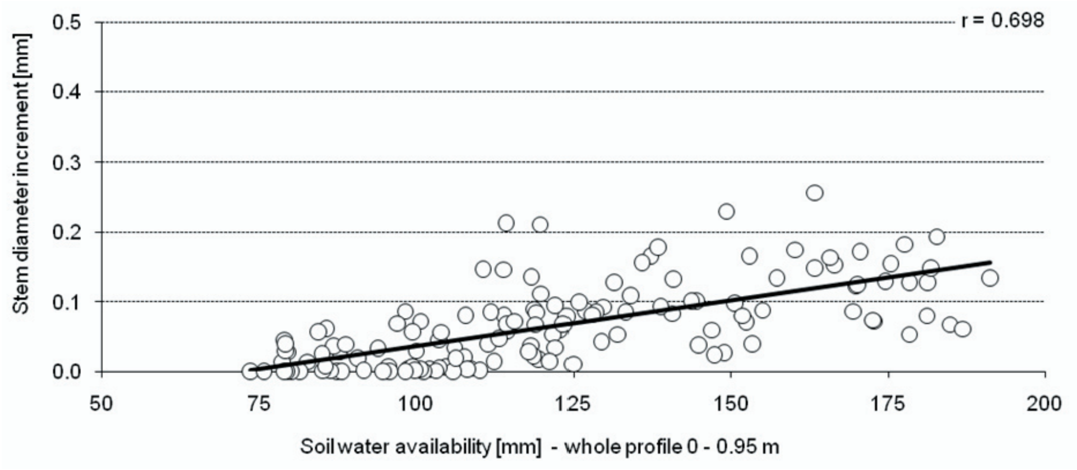
Erratum

The article by Fischer, M., Trnka, M., Kučera, J., Žalud, Z., Soil water availability in a short rotation poplar coppice (*Populus nigra* × *P. maximowiczii*) in Czech-Moravian Highlands (*Folia oecol*., 37: 23–34), contains figure imaging errors.

Page 30, Fig. 12 has not been fully imaged. In the right upper corner of the figure, „r = 0.522" should have been added, and the x-axis should have been lengthened to 200.



Page 31, Fig. 13 has not been fully imaged. In the right upper corner of the figure, „r = 0.698" should have been added.



The publisher apologises for any confusion caused.

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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.

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