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Variability in the growing season of selected European and East-Asian woody species in relation to air temperature changes

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Abstract

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Data series for leaf unfolding and leaf fall phenophases of European and East-Asian trees were analysed and related to air temperature at the Mlyňany Arboretum SAS. Over a period 1971–2011, annual mean air temperature (T_{am}) and mean spring air temperature (T_{24}) increased by 1.41 °C or 1.06 °C, respectively. The temperature increase affected onset of phenophases and length of growing season. Beginning of growing season (BGS) advanced by 19 days for European (1990–2011) and 9 days for Asian taxa (1991–2008). End of growing season (EGS) delayed by 2 or 4 days for European and Asian species, respectively. Length of growing season (LGS) extended by 10.31 or 7.58 day / decade for European and Asian species, respectively. The earlier onset of BGS was more prominent for European than Asian taxa and the difference was significant. On the other hand, a difference in EGS or LGS between European and Asian species was not significant. Relationships between BGS and T_{am} or T_{24} were significant for all species, and the relationships were closer for European species. Strong and significant correlation was detected between T_{am} and LGS of European trees, however it was weak and non-significant for Asian species.

Keywords
air temperature, climate change, Mlyňany Arboretum SAS, tree phenology

Introduction

In the temperate zone an annual timing of phenological events of woody plants is mainly driven by air temperatures after the plant dormancy is released. Phenological observations are one of the most sensitive data in identifying how plants respond to climate conditions and they are also used in the study of climate change and global warming (e.g. Chmielewski and Rötzer, 2001; Donnelly et al., 2006). In the last years number of papers on changes in timing of plant phenological events in response to changing climate is permanently increasing (Beaubien and Freeland, 2000; Menzel, 2000; Chmielewski and Rötzer, 2001; Braslavská and Kamenský, 2002; Chmeliewski, 2002; Bissolli et al., 2004; Donnelly et al., 2006; Škvareninová, 2007, 2008, 2009; Bednářová and Merklová, 2007; Ibáñez et al., 2010; Hájková et al., 2010, 2012; Škvareninová and Snopková, 2010). Recent results indicate that phenological trends of native trees in Europe correspond well with current climatic changes (Chmielewski and Rötzer, 2001; Chmeliewski, 2002). Seasonal timing of spring events such as budding, leafing or flowering of plants does depend highly on air temperature. In many studies a good correlation between the spring phenophases and air temperature was found (Walkovszky, 1998; Wielgolaski, 1999; Chmielewski and Rötzer, 2000; Sparks and Menzel, 2002; Donnelly et al., 2006). Average air temperature between February and April was proved to be decisive for onset of the spring phenological events of native trees in Europe (Chmielewski and Rötzer, 2000, 2001). A length of growing season is an important measure in agriculture, horticulture and forestry. One of the evidence that plants are responding to the current climate change in the temperate zone is the lengthening of their growing season (Menzel and Fabian, 1999; Chmielewski and Rötzer, 2001; Hájková et al., 2010; Ibáñez et al., 2010). In general, the observed extension of growing season is mostly the result of an advance of spring phenophases than a delay of autumn ones (Menzel, 2000; Chmielewski and Rötzer, 2001, Hájková et al., 2010). Not all plant species are responding similarly to the climate change and understanding of interspecific variation in changes of growing season length is limited. In most phenological studies a response of native plant species to temperature changes in particular geographic regions is studied. Here, we use a dataset of phenological events of native European and introduced East-Asian woody plant taxa in spring (leaf unfolding) and autumn (leaf fall) in the Mlyňany Arboretum SAS (south-western Slovakia) to study the length of growing season. Introduction and acclimatization of allochthonous woody species has been the primary field of dendrological research in the Mlyňany Arboretum SAS. Hundreds of non-native taxa of woody species has been intentionally introduced to the arboretum since its establishment at the end of 19th century and their acclimatization has been studied mostly for their use as ornamentals, (e.g. Benčať, 1961, 1967; Benčať et al., 1986; Tábor and Tomaško, 1992; Hoťka, 2004, 2005; Hoťka and Barta, 2012). During a scientific expedition to eastern China in 1960, seeds of many woody taxa were obtained from their natural habitats. A small part of the collected species was used to set up a specialized phenological garden in the arboretum to study their acclimatization (Benčať, 1961, 1962). The arboretum, as a member of the International Phenological Gardens (IPG) network, has also been recording phenological events on a collection of native trees. The opportunity of having data on phenology of European and East-Asian species allowed us to compare a response of these taxa to the local climatic changes.

The goal of this study was to evaluate the annual variability in leaf unfolding and leaf falling phenological events, delimiting the length of growing season, of selected woody taxa of European and East-Asian origin growing under conditions of the Mlyňany Arboretum SAS within a 20-year period. Our further aim was to study onset of beginning and end of the growing season in relation to air temperature.

Material and methods

To investigate the annual variability in the beginning and the length of growing season, phenology of 16 woody plant species, nine native European and seven introduced East-Asian taxa (Table 1) was studied. The main precondition for a choice of those species was a continuous set of phenological data for at least 20 consecutive years. The chosen native taxa were vegetatively propagated plants (clones) obtained from the International Phenological Gardens (IPG) network (Chmielewski, 1996) and each taxon / clone is identified by its particular IPG code. The plants of East-Asian species come from seeds collected at their natural area of distribution in eastern China in 1960. The phenological observations were carried out at the Mlyňany Arboretum SAS (MA SAS) (48°19'11.08" N, 18°22'08.30" E) (IPG garden no. 051) situated in south-western Slovakia. While the native taxa evaluated in this study are scattered in different parts of the arboretum, the introduced Asian species are grown in the Experimental phenological garden. This garden (approx. 0.4 ha) is located in the north-western part of the arboretum. To create a special microclimate, the garden is intentionally surrounded by stands of conifers. It is bordered by alleys of *Thuja occidentalis* L. 'Malonyana' (from the south side), *Thuja occidentalis* L. (from the east side) and *Thuja plicata* Donn ex D. Don (from the northern and western side). The longer side of the garden (approx. 107 m) is oriented approximately in the east-west direction.

Phenophases were specified according to the BBCH system (Meier, 1997). For the purpose of this study two phenological events were investigated, leaf unfolding (BBCH 11) and leaf fall (BBCH 95). Dates for the leaf unfolding event in the spring were used to define the beginning of the growing season (BGS) and for the end of the growing season (EGS) the timing of leaf fall event in the autumn was used. The length of the growing season (LGS) was determined from the number of days between BGS and EGS. For the purpose of the study the data sets of BGS, EGS and LGS were combined for native and East-Asian species separately to obtain mean BGS (mBGS), mean EGS (mEGS) and mean LGS (mLGS). The phenological analyses were performed on data collected between 1990 and 2011 for the native (IPG) taxa and between 1991 and 2008 for the East-Asian taxa. The data set of BGS and EGS used in the study are expressed in Julian day (JD) – the ordinal day in the year, when phenophase occurred.

Meteorological data (average daily air temperatures) were obtained from the local meteorological station situated at MA SAS (48°19'24.57" N, 18° 22'06.81" E, 190 m a.s.l.).

Table 1. List of tree species with their provenance included in the phenological study at the Mlyňany Arboretum SAS

Species	Provenance of plants
Betula pubescens Ehrh.	Vegetatively propag., IPG code 211, Germany
Fagus sylvatica L.	Veget. propag., IPG code 222, Düdelsheim, Germany
Populus × *canescens* (Ait.) Smith	Veget. propag., IPG code 231, Germany
Populus tremula L.	Veget. propag., IPG code 236, E-Poland
Prunus avium L.	Veget. propag., IPG code 241, Bovenden, Germany
Sorbus aucuparia L.	Veget. propag., IPG code 271, Czech Republic
Ribes alpinum L.	Veget. propag., IPG code 311, Austria
Salix × *smithiana* Willd.	Veget. propag., IPG code 324, Germany
Salix aurita L.	Veget. propag., IPG code 321, Germany
Acer davidii Franch.	Seeds collected in China, 1960
Acer grosseri Pax	Seeds collected in China, 1960
Magnolia denudata Desr.	Seeds collected in China, 1960
Magnolia liliiflora Desr.	Seeds collected in China, 1960
Magnolia officinalis var. *biloba* Rehd. et Wils.	Seeds collected in China, 1960
Spiraea thunbergii Sieb.	Seeds collected in China, 1960
Spiraea japonica L.	Seeds collected in China, 1960

For calculation of linear trends of phenological events the least-squares regression was used, with year as the independent variable and the day of phenophase occurrence (in JD) as the dependent variable. Linear regression was also used to test the relationships between BGS and spring temperature and annual mean temperature and to study the relationship between LGS and annual mean temperature. Pearson correlation analyses were used to test the sensitivity of phenophase occurrence (in JD) to spring air temperature and annual mean temperature. The spring air temperature was calculated as a mean air temperature from February to April. The regression and correlation analyses, including tests of significance, were performed by BioStat 2008® (© 2008 AnalystSoft Inc.).

Results and discussion

Over a 40-year period 1971–2011, annual mean air temperature (T_{am}) and mean spring air temperature (T_{24}, average February to April inclusive) increased by approx. 1.41 °C or 1.06 °C, respectively, at MA SAS. T_{am} increased on average by 0.35 °C/decade and T_{24} increased by 0.26 °C/decade within the period. Both the air temperatures showed a clear indication of warming over this period. The positive trends in T_{am} ($T_{am} = 0.0353 \times \text{year} – 60.418$, $p < 0.01$) and T_{24} ($T_{24} = 0.0264 \times \text{year} – 47.108$, $p > 0.05$) are displayed in Fig. 1. Figure 2 shows deviations of T_{am} and T_{24} over the 40-year period and it can be seen that positive deviations prevail mostly after 1989. On average, higher mean temperatures were recorded during 1989–2011, when compared with 1971–1988 period. Between 1971–1988 and 1989–2011, mean values of T_{am} and T_{24} increased by 0.85 °C and 0.96 °C, respectively. The differences between the means for both T_{am} and T_{24} were significant (T_{am}: $t_{1.684} = –3.480$, $p < 0.05$; T_{24}: $t_{1.684} = –2.335$, $p < 0.05$). The positive trend of T_{am} recorded in MA SAS is generally in accordance to the estimated increase of T_{am} (0.055 °C / decade) for the Northern hemisphere in the period 1861–2000 (Jones and Moberg, 2003). Similar change in T_{am} was also observed by Chmielewski and Rötzer (2000, 2001) in Europe during 1969–1998. Chmielewski and Rötzer (2000, 2001) also recorded noticeable increase in T_{am} after 1989 that corresponds well with the situation at MA SAS. Compared with the long-term T_{am}, most years after 1988 were warmer in Europe (Chmielewski and Rötzer, 2000, 2001; Chmielewski et al., 2012). As can be seen in Fig. 2, T_{am} and T_{24} deviations in MA SAS fully correspond with this general climate trend in Europe. Chmielewski and Rötzer (2000) explained the abrupt changes in T_{am} after 1989 by changes in the circulation pattern (North Atlantic Oscillation Index) over Europe.

Generally, seasonal timing of spring phenological events such as leaf unfolding of trees depends highly on air temperature. The temperature changes in Europe mentioned above affected BGS and after 1989 early dates of BGS onset prevail (Chmielewski and Rötzer, 2000). During a period of 1990–2011, when phenological observations were carried out in this study, T_{am} and T_{24} increased on average by 0.74 °C or 0.55 °C, respectively. To evaluate an impact of the temperature increase on BGS and LGS, data series for leaf unfolding

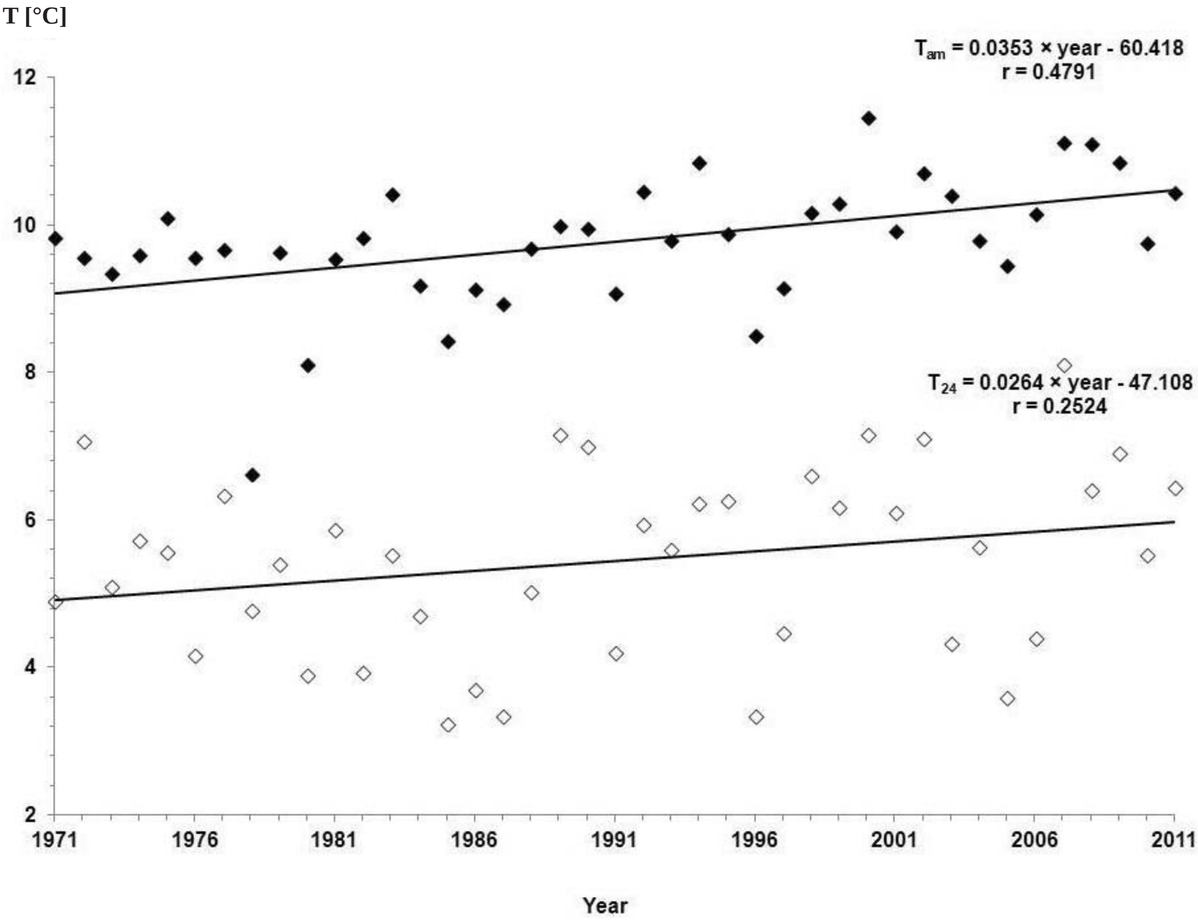

Fig. 1. Trends in annual mean air temperature (T_{am}) and mean air temperature from February to April (T_{24}) at the Mlyňany Arboretum SAS, 1971–2011.

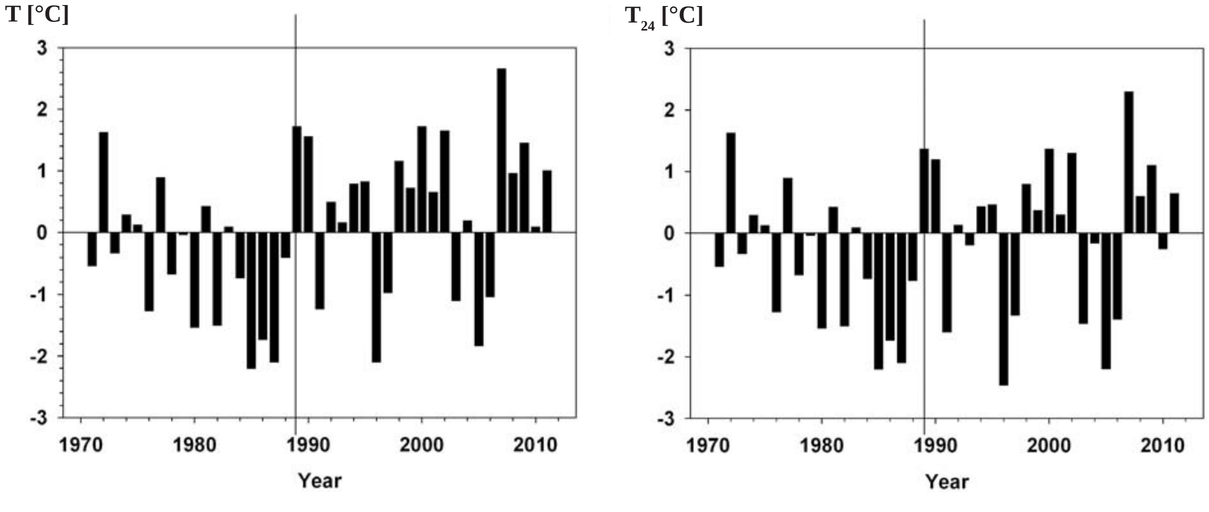

Fig. 2. Deviations of the mean annual air temperature (ΔT_{am}) and the spring air temperature (ΔT_{24}) at the Mlyňany Arboretum SAS, 1971–2011.

and leaf fall events for 9 European (IPG) and 7 East-Asian species growing at MA SAS were analysed and related to temperature series. Data for BGS, EGS and LGS of all the woody taxa are presented in Table 2. Over the evaluated period, BGS of IPG species varied between 10 (100 JD) and 29 April (119 JD), depending on species. mBGS based on combined data for the IPG taxa occurred on 23 April and during the 22-year period it advanced altogether by approx. 19 days. This corresponds to a significant trend ($r = –0.7704$, $p < 0.001$) of –8.85 day/decade. All IPG species showed a negative trend in the date of leaf unfolding occurrence over the period and the onset of BGS varied among years. The earliest start of growing season was observed in 2008 (11 April) and the latest occurred in 1993 and 1997 (5 May). Leaf fall event occurred between 3 November (307 JD) and 14 November (318 JD) depending on IPG species. For most species leaf fall occurrence delayed with years during the period, however this positive trend was not significant ($p > 0.05$). Negative trend in onset of EGS was only observed for *P.* × *canescens* and *R. alpinum*. mEGS of IPG taxa appeared on 9 November and over the 22-year period it delayed by approx. 2 days. Compared to mBGS, mEGS showed non-significant ($r = 0.1639$, $p > 0.05$) trend. mLGS of IPG trees, as indicated by the number of days between mBGS and mEGS, reached 199 days, however its value varied among species. The longest LGS was observed for *R. alpinum* with 210 days and the shortest for *S. aucuparia* with 189 days. All IPG species showed positive trends in LGS and mLGS significantly extended by approx. 1 day each year ($r = 0.7525$, $p < 0.001$).

mBGS of East-Asian taxa occurred on 19 April (109 JD) and varied between 8 (98 day) and 26 April (116 day), depending on species. Over the evaluated period (1991–2008), mBGS of the introduced taxa significantly advanced by 5.11 day/decade ($r = –0.6528$, $p < 0.05$). The negative trend was observed for all Asian species (Table 2). mBGS appeared 4 days earlier (19 April) when compared with IPG species, however the difference is not significant ($t_{2.035} = –1.441$, $p > 0.05$). mEGS of Asian species fell on the same day (9 November) as that of IPG species and our analysis revealed a positive trend in the leaf fall event occurrence within the evaluated period for all the species. On average, mEGS delayed by 2.47 day/decade ($r = 0.4212$, $p > 0.05$). mLGS of Asian taxa reached 204 days and significantly extended by 7.58 day/decade ($r = 0.6722$, $p < 0.05$). The extension of LGS was observed for all Asian species, but trends of individual species varied from 5.07 day/decade to 14.06 day/decade.

mLGS of Asian taxa was longer by 5 days than that of IPG species, however the difference was not significant ($t_{2.035} = 1.449$, $p > 0.05$). On the other hand, the mean trend in the growing season extension of IPG species was significantly stronger ($t_{2.145} = 2.318$, $p < 0.05$) than that of Asian taxa. In Europe, Chmielewski and Rötzer (2000) determined mBGS of native tree species

Table 2. Average beginning (BGS), end (EGS) and length (LGS) of growing season with linear trends (days/decade) of native (1990–2011) and East-Asian (1991–2008) species at the Mlyňany Arboretum SAS

Plant species	BGS ± SD	Trend	EGS ± SD	Trend	LGS ± SD	Trend
B. pubescens	110 ± 8.47	–9.381**	318 ± 7.67	+5.067	208 ±11.66	+14.448**
F. sylvatica	117 ± 8.11	–7.973**	312 ±12.10	+1.406	195 ±15.97	+10.078
P. × *canescens*	114 ± 8.47	–7.286*	313 ± 7.51	–2.338	199 ±12.28	+5.030
P. tremula	118 ±10.07	–13.797**	310 ± 8.82	+3.805	192 ±15.48	+20.826**
P. avium	113 ± 7.14	–6.506**	310 ± 7.05	+0.559	197 ± 8.35	+6.211
S. aucuparia	117 ± 8.61	–7.929	307 ± 8.59	+5.263	189 ±10.50	+14.088*
R. alpinum	100 ±15.04	–11.602*	310 ± 6.47	–2.925	210 ±15.91	+15.614*
S. aurita	119 ±11.91	–13.273**	317 ±10.00	+1.902	198 ±15.95	+15.256**
S. × *smithiana*	113 ±10.80	–10.956*	318 ±10.15	+0.441	205 ±10.81	+11.397*
Average for native trees	113 ± 7.38 (23 April)	–8.849**	313 ± 2.66 (9 Nov.)	+1.064	199 ± 8.93	+10.305**
A. davidii	110 ± 7.59	–8.910**	307 ± 5.00	+4.802*	197 ±12.10	+14.058**
A. grosseri	114 ± 5.81	–5.458*	313 ± 4.51	+3.470	200 ± 9.14	+9.125*
M. denudata	114 ± 4.88	–4.941*	311 ± 4.53	+1.271	197 ± 7.55	+6.212
M. liliiflora	116 ± 5.42	–5.315*	308 ± 6.06	+0.479	192 ± 9.10	+5.785
M. officinalis	105 ± 5.48	–4.459	309 ± 5.35	+0.610	204 ± 7.33	+5.069
S. thunbergii	98 ±10.06	–3.929	312 ± 9.69	+2.752	215 ±15.85	+6.681
S. japonica	109 ± 7.18	–2.791	329 ± 9.13	+3.275	220 ± 9.14	+6.066
Average for Asian species	109 ± 4.84 (19 April)	–5.106*	313 ± 3.63 (9 Nov.)	+2.474	204 ± 6.97	+7.580*

Significant at $^*P \leq 0.05$, $^{**}P \leq 0.01$, SD – standard deviation of a mean, BGS and EGS in Julian days.

on 23 April based on a long-term average (1969–1998) that corresponds with our observations. Chmielewski and Rötzer (2001) calculated that mLGS of native trees lasts 193 days in Europe with large regional differences. And for the region of Slovakia they estimated its length within a range of 180 and 200 days. The length of 199 days, calculated for native species in MA SAS, fits the range, although the mLGS of Asian taxa exceeded the range. Our observations indicate that LGS of both IPG and Asian species extended over the evaluated period as a result of earlier onset of BGS and delayed EGS. And it is evident that the extension was mainly the result of an earlier onset of spring phenophase than a later occurrence of leaf fall in autumn. The earlier onset of mBGS was more prominent for European than Asian taxa and difference between trends of these two groups of species was significant ($t_{2.145} = 3.970$, $p < 0.001$). On the other hand, a difference between mEGS of IPG and Asian species was not significant ($t_{2.145} = –0.739$, $p > 0.05$), although the trend of mEGS delay was stronger for Asian taxa. Our observations confirm results of other long-term phenological studies of woody plants, when the spring phenophases occurred earlier leading to extension of growing season. For example, spring phenophases of deciduous and coniferous trees occurred 7 days earlier in southern Norway during a period of 1971–2005 (Nordli et al., 2008). In Europe, leaf unfolding event advanced on average by 2.10 day/ decade, whereas autumn events, such as leaf colouring, delayed on average by 1.50 day/decade during 1959–1996 period (Menzel, 2000). Within a 30-year period (1969–1998), the beginning of growing season in Europe advanced altogether by 8 days (Chmielewski, 2002). In Czech Republic, a bud burst stage of European beech (*Fagus sylvatica* L.) appeared 5.70 days earlier and a leaf fall started 6.10 days later during a period 1992–2008 (Hájková et al., 2010). A bud burst stage of Norway spruce (*Picea abies* (L.) Karst.) growing up to 500 m a.s.l. started earlier by 3.30–8.50 days during a period 1996–2008 in Slovakia (Škvareninová and Snopková, 2010). Chmielewski et al. (2012) found out that the mLGS of native trees in Europe extended by approx. 14 days (1969–2010) with a significant trend of 3.26 day / decade. And a similar trend in LGS extension was detected by Menzel (2000), 3.60 days / decade within a period of 1959–1996, or by Menzel and Fabian (1999), 3.10 days/decade within a period of 1959–1993. Our analyses indicate greater extension of growing season, especially that of IPG species, when compared with abovementioned studies. This can be explained for example by shorter period of phenological observations evaluated in this study, by studying phenology in geographically rather small area of single locality, and finally by the fact that our observations were carried out during the period with significantly increased T_{am}. Nordli et al. (2008) pointed out that results of trend studies are very sensitive to a choice of starting year / decade. They found out that trends starting in cold decades were in most cases statistically significant, whereas those starting in warm decades were usually not. However, this was not our case. As presented in Fig. 2, we started phenological observations in warmer period (after 1989) and the trends for mBGS and mLGS of both IPG and Asian species were significant (Table 2). However, trends of individual species varied. While the trends of most IPG species were significant, only four or two Asian taxa showed significant trend in BGS or LGS, respectively.

Relationships between mBGS and mean temperature for February, March, April, May, February to March, February to April, February to May and annual mean temperature were tested (Table 3). Correlations for temperature in April (T_4), February to April (T_{24}) and annual mean temperature (T_{am}) were only significant ($p < 0.05$) for both groups of species, therefore the strength of a linear relationship between these three temperature parameters and BGS of individual species were evaluated (Table 4). Our results clearly demonstrate the effect of temperature increase in spring or mean annual temperature increase on advanced leafing of woody species during the evaluated period. An increase of 1 °C in spring temperatures (T_4 and T_{24}) and T_{am} resulted in an advance of mBGS of IPG trees by approx. 2 or 6 days, respectively. In case of Asian species, an increase of spring temperatures and T_{am} by 1 °C brought mBGS forward by 2 or 3 days, respectively. In many studies a good correlation between spring phenophases and air temperature was found (Walkovszky, 1998; Wielgolaski, 1999; Chmielewski and Rötzer, 2000, 2001; Sparks and Menzel, 2002). For example, a strong negative correlation between T_{24} and mBGS of native trees was detected during a 30-years period in Europe and an increase of the early spring temperature of 1 °C corresponded to an advanced BGS by approx. 7 days (Chmielewski and Rötzer, 2000). Although the effect of temperature was obvious for evaluated species in our analyses, the strength of relationship differed between native and introduced taxa. The relationship was closer for native species as demonstrated by correlation coefficients. A certain level of variability in the effect of temperatures on the start of growing season was recorded among individual species (Table 4). All correlations were negative except for that between BGS of *P. avium* and T_{24}, where even week positive relationship was observed, which, however, was not significant ($r = +0.0091$, $p > 0.05$). As presented above the starting dates for growth and development are species-specific and the effect of temperatures on the start of growing season may vary between species that was also de-monstrated in other phenological studies (Heide, 1993). In general, phenological phases of plants, such as leaf unfolding and leaf fall of trees, are driven besides temperature also by other environmental factors such as pests, diseases, competition, soil factors, genetics and age. Variability in BGS is often also found between cultivars or ecotypes within a plant species (Myking and Heide, 1995) and, due to genetic variations, even between individuals (Schirone et al., 1990) and with the age of trees (Ununger et al., 1988).

As mentioned above, mLGS in MA SAS lasts 199 days (for IPG species) or 204 days (for Asian taxa). There was a strong and significant correlation ($r = +0.5811$, $p < 0.001$) between T_{am} and mLGS of IPG taxa, however the relationship was weak and non-significant ($r = +0.1623$, $p > 0.05$) for Asian species. The regression equations indicate that 1°C increase in T_{am} is associated with an extension of mLGS by approx. 7 days for IPG species and 3.5 days for Asian species. These trends are very similar to results of phenological observations of native trees carried out in Europe during 30 years, which revealed that an increase of T_{am} by 1 °C led to an extension of LGS by 5 days (Chmielewski and Rötzer, 2001). Results of Pearson correlation between LGS of individual species and T_{am} are showed in Table 4. Correlation coefficients varied within an interval of +0.1438 and +0.6273, depending on species and the closest relationship was observed for *M. liliiflora* ($r = +0.6273$), *B. pubescens* ($r = +0.5820$) and *P.* × *canescens* ($r = +0.5241$). This indicates that different species respond to increasing T_{am} by lengthening their growing season with a different extent.

We can summarise that the air temperature increase recorded in the Mlyňany Arboretum SAS considerably influenced the length of growing season of both, native and introduce woody plants. Phenological observations revealed advanced onset of spring phenophases and delayed onset of autumn phenological events in all evaluated species, what finally lead to extension of growing season. The extension was mainly the result of an earlier onset of spring phenophase. The native species respond more considerably to the temperature increase by significantly earlier onset of mBGS and stronger trend in the growing season extension than introduced Asian taxa.

Table 3. Results of Pearson correlation between the mean beginning of growing season (BGS) and mean monthly temperatures in February (T_2), March (T_3), April (T_4), May (T_5), from February to March (T_{23}), from February to April (T_{24}), from February to May (T_{25}) and annual mean temperature (T_{am}) and between mean length of growing season (LGS) and (T_{am}) at the Mlyňany Arboretum SAS

	Correlations	r	P	a	b
IPG species	BGS vs.T2	–0.0028	0.9898	–0.0084	112.78
	BGS vs.T3	–0.2975	0.1580	–1.2882	119.48
	BGS vs.T4	–0.5665	0.0039	–2.4413	139.56
	BGS vs.T5	–0.1475	0.4916	–0.6833	123.42
	BGS vs.T23	–0.1521	0.4780	–0.6646	114.97
	BGS vs.T24	–0.3982	0.0450	–2.3654	126.58
	BGS vs.T25	–0.3847	0.0634	–2.5415	133.78
	BGS vs. T_{am}	–0.5450	0.0059	–5.7497	171.05
	LGS vs. T_{am}	+0.5811	0.0046	+7.1563	126.64
East-Asian species	BGS vs.T2	–0.1354	0.2161	–0.6309	110.16
	BGS vs.T3	–0.0141	0.6994	–0.3211	110.88
	BGS vs.T4	–0.4141	0.0176	–2.1221	131.92
	BGS vs.T5	–0.0256	0.6015	–0.4409	116.02
	BGS vs.T23	–0.1084	0.2721	–0.4192	111.82
	BGS vs.T24	–0.2852	0.0480	–1.8911	119.71
	BGS vs.T25	–0.1243	0.2374	–0.4558	116.78
	BGS vs. T_{am}	–0.2324	0.0495	–2.9308	138.68
	LGS vs. T_{am}	+0.1623	0.1722	3.5313	168.25

r – correlation coefficient, P – at 95% significance level, a – slope and b – intercept of linear regression equation.

Table 4. Results of Pearson correlation between beginning of the growing season (BGS) of individual tree species and average air temperature in April (T_4), from February to April (T_{24}) and mean air annual temperature (T_{am}), and correlation between length of growing season (LGS) and mean air annual temperature (T_{am})

Plant species	BGS/T_4	BGS/T_{24}	BGS/T_{am}	LGS/$_{\mathrm{Tam}}$
B. pubescens	–0.3991	–0.5089*	–0.5726**	+0.5820
F. sylvatica	–0.5426**	–0.4715*	–0.6038**	+0.3352
P. × *canescens*	–0.2533	–0.2744	–0.4836*	+0.5241*
P. tremula	–0.5396**	–0.3157	–0.5452**	+0.4421
P. avium	–0.3252	+0.0091	–0.2593	+0.1940
S. aucuparia	–0.1360	–0.1984	–0.0706	+0.1391
R. alpinum	–0.3278	–0.4530*	–0.4340*	+0.4859
S. aurita	–0.6423	–0.2318	–0.3615	+0.1438
S. × *smithiana*	–0.4847	–0.0567	–0.2645	+0.3208
A. davidii	–0.4178	–0.1740	–0.2179	+0.1759
A. grosseri	–0.5651*	–0.2149	–0.3477	+0.2974
M. denudata	–0.4676	–0.3749	–0.3335	+0.3385
M. liliiflora	–0.7469**	–0.6473*	–0.5810*	+0.6273*
M. officinalis	–0.5883*	–0.4092	–0.4033	+0.3075
S. thunbergii	–0.2727	–0.6012*	–0.2734	+0.1440
S. japonica	–0.4248	–0.2630	–0.4086	+0.2174

Significant at *$P \leq 0.05$, **$P \leq 0.01$.

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Variabilita vegetačného obdobia vybraných európskych a východoázijských drevín vo vzťahu k zmenám teploty vzduchu

Súhrn

V Arboréte Mlyňany SAV sme hodnotili nástup jarných a jesenných fenofáz a celkovú dĺžku vegetačného obdobia 9 druhov domácich (1990 – 2011) a 7 druhov východoázijských (1991 – 2008) drevín. Počas obdobia 1971 – 2011, priemerná ročná teplota vzduchu (T_{am}) v Arboréte Mlyňany SAV stúpla o 1,41 °C a priemerná teplota na jar (T_{24}) stúpla o 1,06 °C. Signifikantný ($p < 0{,}05$) nárast teplôt bol zaznamenaný v období 1989 – 2011. Nárast teplôt vzduchu ovplyvnil nástup jarných a jesenných fenologických fáz a dĺžku vegetačného obdobia hodnotených drevín. V priebehu hodnoteného obdobia nastal priemerný začiatok vegetačného obdobia domácich druhov drevín o 19 dní a východoázijských drevín o 9 dní skôr. Koniec vegetačného obdobia sa oneskoril v priemere o 2 dni pri domácich a 4 dni pri východoázijských druhoch drevín. Vegetačné obdobie sa predĺžilo v priemere o 22 dní u domácich a o 13 dní u introdukovaných druhoch. Skorší začiatok vegetačného obdobia bol výraznejší pri domácich druhoch a rozdiely medzi oboma skupinami drevín bol štatisticky preukazný. Na druhej strane neskorší koniec vegetačného obdobia nebol štatisticky preukazne rozdielny medzi domácimi a ázijskými taxónmi. Takisto nebol preukazný ani rozdiel medzi nárastom dĺžky vegetačného obdobia medzi oboma skupinami drevín, hoci trend vyjadrujúci nárast dĺžky vegetačného obdobia bol pri domácich druhoch štatisticky signifikantný. Pri všetkých hodnotených druhoch bola preukázaná závislosť medzi začiatkom vegetačného obdobia a priemernými teplotami T_{am} a T_{24}. Táto závislosť bola výraznejšia pri domácich taxónoch. Silná a štatisticky preukazná korelácia bola zistená aj medzi priemernou ročnou teplotou (T_{am}) a dĺžkou vegetačného obdobia domácich drevín, tento vzťah bol však v prípade východoázijských druhov iba mierny a štatisticky nepreukazný.

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Is there any relation between quantitative traits interesting for ornamental breeding and genome size in dog roses (*Rosa* sect. Caninae)?

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Abstract

Ferus, P., Pachl, Š., Ďurišová, Ľ., Bartošová-Krajčovičová, D., Rovná, K. 2013. Is there any relation between quantitative traits interesting for ornamental breeding and genome size in dog roses (*Rosa* sect. Caninae)? *Folia oecol.*, 40: 11–21.

To define participation of genome size as well as most important environmental factors in variability of quantitative characters interesting for ornamental breeding, a collection of wild dog roses (*Rosa* sect. Caninae) from Malé Karpaty mountains (localities Modra – Pažite and Vrbové – Baraní dvor) and Zobor hills (locality Zobor – Lyžiarska lúka) were analysed. We found a large variability in percentage of leaves longer than 70 mm (16–58%) and those of dark-green colour (28–78%), portion of half-full flowers (0–6%) and those of intense pink colour (0–100%), and percentage of hips longer than 20 mm (0–45%) and those of intense red colour (18–48%), among shrubs. Their genome size ranged from 2.33 to 2.92 pg. Our map survey revealed stagnieutric cambisols in Modra – Pažite, haplic luvisols on loess in Vrbové – Baraní dvor, and rendzic/chromi-rendzic leptosols in Zobor – Lyžiarska lúka (increasing soil quality from stand to stand). Leaves and flowers grew in conditions of average temperature 15.3 °C (Modra – Pažite and Zobor – Lyžiarska lúka) and 14.5 °C (Vrbové – Baraní dvor). Precipitation ranged from approximately 300 mm in Modra – Pažite to 400 mm in Zobor – Lyžiarska lúka. Average temperature for hip formation varied from Zobor – Lyžiarska lúka (19.6 °C) to Modra – Pažite (20.4 °C). In this period, precipitation sum was round 200 mm in Zobor – Lyžiarska lúka and approximately 250 mm in the rest two stands. Quantitative traits of all dog roses were generally less correlated to genome size and environmental factors. However, in *R. canina* genotypes, leaf length was determined mainly by genome size ($r = 0.437$) and temperature ($r = –0.316$), and leaf colour by temperature ($r = 0.777$) and precipitation ($r = 0.557$), flower richness only by temperature ($r = –0.320$), flower colour by temperature ($r = 0.606$) and soil quality ($r = –0.559$), and hip colour was defined mainly by precipitation ($r = 0.588$), then by temperature ($r = 0.427$) and genome size ($r = –0.362$); but no factor had important influence on hip length. We can conclude that except for leaf size, all analysed quantitative traits were mainly determined by environmental factors.

Keywords

dog roses with breeding potential, quantitative traits, genome size, environment

Introduction

Roses are jewels of gardens, arboretums and urban vegetation for centuries (Kordes, 1966; Krüssmann, 1986). Till today, thousands of rose cultivars with different habitus, phenology, flower, leaf and prickle dimensions, shapes and colours have been bred. As summarises Gudin (2000), present rose breeding focusses on flower production, post-harvest longevity, resistance to pests and diseases, and to environmental constraints (particularly drought, cold), as well as cultivar-rootstock compatibility.

Dog roses (sect. Caninae) represent a specific group of roses with leaning liana or geyser shrub habitus, spiny sprouts, straight or hooked prickles, leaves of ±3 leaflet pairs, lobed outer sepals, pink or white petals, free style and irregular meiosis (2n = 28, 35, 42, 49). They can be found in sunny stands – forest edges and clearings, balks, fallows, dams, along road and railway communications, on rocks – in scrub communities (order Prunetalia), eventually grass communities (alliance Bromion erecti) (Větvička and Bertová, 1992; Větvička, 1995).

Many of them are attractive for breeders. MacPhail and Kevan (2009) list research teams from 60ties of the last century till present, analysing hip / flower percentage and ways of seed establishment (agamospermy, autogamy, geitonogamy, xenogamy) in different cross combinations between wild roses. Van Huylenbroeck et al. (2007) refer to test crosses of European wild roses with tetraploid cultivated roses. Interspecific hybridisation can occur among rose species at all ploidy levels (Nybom et al., 2005) but, as indicate Grossi and Jay (2002), best success can be expected in situations: parents of the same chromosome number, or triploid female and tetraploid male. In more works (Kroon and Zeilinga, 1974; Jičínská, 1976; Nybom et al., 1997; Olsson et al., 2000; Werlemark and Nybom, 2001), morphological consequences of hybridisation in offspring generations, were studied, as well.

Qualitative and quantitative traits interesting for rose breeding have recently been studied particularly using genetic markers (Debener, 1999; Crespel et al., 2002). However, despite of many indicia from agricultural crop breeding (Laptev, 1988) and numerous karyological and cytometrical surveys in Rosaceae family and particularly genus *Rosa* have been accomplished (Dickson et al., 1992; Yokoya et al., 2000; Roberts et al., 2009; Jedrzejczyk and Sliwinska, 2010; Jian et al., 2012), there is almost no data on relation between quantitative characters and genome size. To ascertain the influence of genome size as well as the most important components of environment on leaf, flower and hip mass and their colour intensity, we analysed dog roses from western Slovakia.

Table 1. Taxonomic determination of selected wild roses from three research localities in western Slovakia

Locality	GPS coordinates	Height above sea level	Individual	Taxon
Modra – Pažitie	N 48°20'46.13" E 17°19'33.38"	229 m	1	*R. canina* L. *var. canina*
			2	*R. corymbifera* Borkh.
			3	*R. canina* var. *dumalis* Baker non Bechst.
			4	*R. canina* L. var. *canina*
Vrbové – Baraní dvor	N 48°37'23.3" E 17°41'29.98"	298 m	1	*R. canina L. var. canina*
			2	*R. canina var. dumalis* Baker non Bechst.
			3	*R. canina L. var. squarosa* Rau
			4	*R. canina var. dumalis* Baker non Bechst.
			5	*R. tomentosa* Sm.
Zobor – Lyžiarska lúka	N 48°20'56.27" E 18°05'47.71"	414 m	1	*R. canina* L. var. *squarosa* Rau
			2	*R. micrantha* var. *perparva* (Borbás) R. Keller in Asch. and Graeb.
			3	*R. dumalis* Bechst.
			4	*R. canina* var. *lapidicola* Heinr. Braun
			5	*R. canina* L.

Material and methods

Experimental area and plant material

For this study, localities with tradition of botanical rose research were chosen (Svobodová et al., 2007; Eliáš jun., 2009). In Malé Karpaty region we analysed wild roses from Modra part Pažite and planted botanical ones in Vrbové part Baraní dvor (Table 1). The third stand with natural occurrence of wild roses was Zobor hill part Lyžiarska lúka, one of the highest peak of Zobor hills belonging to Tríbeč mountains. All of them represent open sunny and warm sites, meeting needs of roses (Kordes, 1966; Walter, 2011). Soil types with bonity categorisation (Granec and Šurina, 1999; Hanes et al., 1999), as well as most important meteorological parameters influencing leaf, flower and hip formation (temperature averages and precipitation sums for period June–August 2009 and April–June 2010) were provided by Soil Science and Conservation Research Institute of the Slovak Republic and Slovak Hydrometeorological Institute, respectively. Scoring of soils was adapted to substrate requests of roses (Kordes, 1966; Walter, 2011). Meteorological data from the nearest meteo-stations to the research localities were applied: 1. Modra – Pažite: station Slovenský Grob; 2. Vrbové – Baraní dvor: station Piešťany; and 3. Zobor – Lyžiarska lúka: station Nitra.

In the middle of June 2009 (the most adequate term according to Větvička (2001)), rose shrubs with patulous – pendulous habitus and potential for ornamental breeding were selected and determined (Table 1) using determination key of Kerényi-Nagy (2012).

Morphological analyses

In August 2009, hundred hips per analysed rose shrub were collected and divided into size/shape categories according to Bauer (2005):
A) – spheric, very little (4–10 mm)
B) – spheric, middle large (13–20 mm)
C) – oval, middle large (15–20 mm)
D) – oval, large (20–30 mm)
E) – hippy, long (10–30 mm)
F) – hippy, oblong (more than 30 mm)
G) – apple shaped – spheric, large (30–40 mm).

Thereafter we defined percentage of hips larger than 20 mm (categories D, F, G) per shrub.

From hips coloured in following colour spectrum (Royal Horticultural Society, London),
A) – N 30 A
B) – N 30 B
C) – N 30 C
D) – 40 A
E) – 40 B
F) – 40 C,
portion of those with most intense red tones (highest concentration of carotenoids; Méndez and Mínguez-Mosquera, 2000) was determined (category A and D).

Morphologic analyses continued in May–June 2010 when quantitative parameters of fifty flowers and leaves were ascertained (morphology of selected rose shrubs and their flowers see in Fig. 1).

For evaluation of flower richness scale of Větvička (2001) was followed:
A) – simple (of 5 petals)
B) – half-full (of 6–14 petals)
C) – freely or moderate full (of 15–20 petals)
D) – full (of 21–40 petals)
E) – dense full (of more than 40 petals).

Since we found only A and B category, percentage of half-full flowers was expressed.

Flower corolla colour in respective individuals ranged in following scale (Royal Horticultural Society, London):
A) – 68 B
B) – 68 C
C) – 68 D
D) – 69 A
E) – 155 A
F) – 155 B.

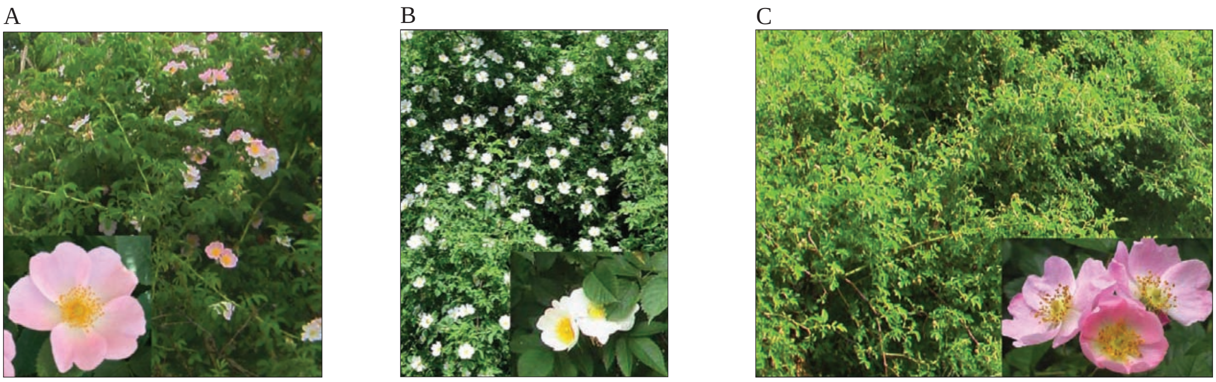


Fig. 1. Wild roses from Western Slovakia: a) *R. canina* var. *dumalis* Baker non Bechst. from Modra – Pažite; b) *R. canina* L. var. *canina* from Vrbové – Baraní dvor; and c) *R. canina* var. *lapidicola* Heinr. Braun from Zobor – Lyžiarska lúka.

We selected flowers of most intense pink tones (highest concentration of carotenoids and anthocyanins (Engster and Märki-Fisher, 1991); category A and B) and defined their portion in total number of analysed flowers.

Leaves were examined for length (Betten, 2003) and green colour intensity (Döpper and Unterlercher, 2007). Following leaf length and colour categories were identified:

A) – less than 40 mm – small
B) – 40–70 mm – middle large
C) – more than 70 mm – large

A) – dark green with glazy surface
B) – light green with glazy surface
C) – dark green with matt surface
D) – light green with matt surface.

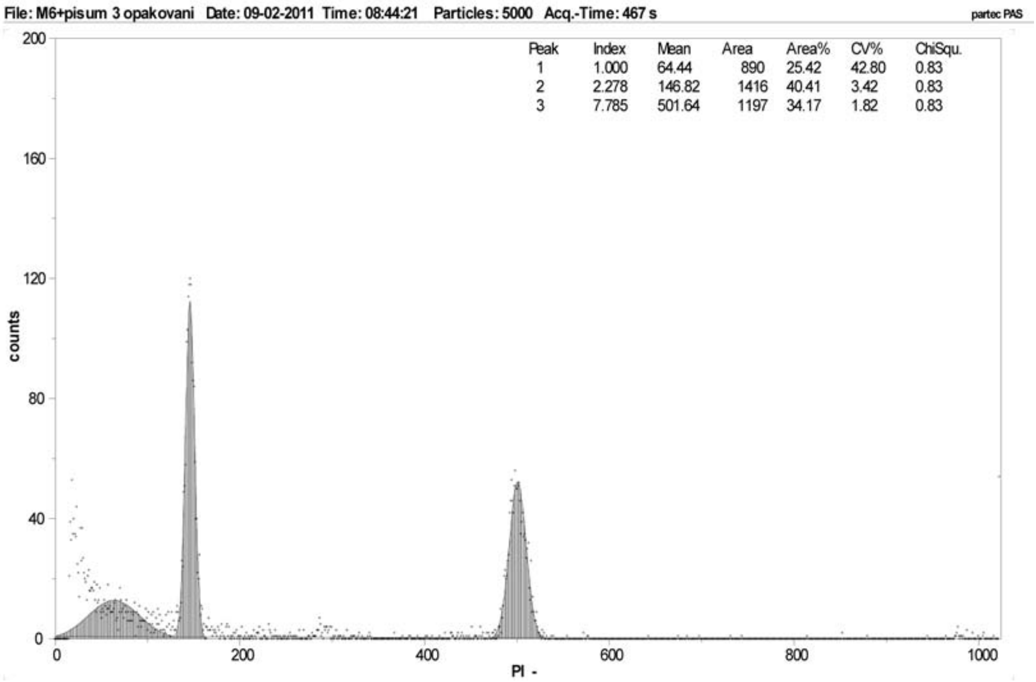
We were interested in portion of leaves larger than 70 mm (category C) and those of dark green colour (categories A and C) per shrub.

Determination of genome size and ploidy level

Nuclear genome size of rose leaf samples was determined by flow cytometry using CyFlow cytometer (Partec GmbH., Germany) with argon laser emitting green light of wavelenght 532 nm (Doležel et al., 2007). As an internal standard we used pea leaves (*Pisum sativum* L. ´Ctirad´) of genome size 9.09 pg.

Rose cuttings from one-year old sprouts were collected in September 2010 and let overwinter in greenhouse in perlite-sand substrate. In early spring 2011, cuttings were transferred into lab and let sprout in water. Pea plants were cultivated in laboratory conditions in soil substrate.

In sample preparation and staining we followed procedure defined by the producer of Partec-CyStain PI Absolut P kit (Partec GmbH., Germany). Segments of young but expanded rose leaves of area 0.5 cm^2 were cut (into 0.5 mm pieces) in Petri dishes with 500 µl extraction buffer using fresh razor blade, and let incubate at lab temperature for 60–90 seconds. Mixture was filtered through nylon mesh of 42 µm pore size. Then 2 ml of staining buffer containing propidium iodide (PI) and RNAse, as well as 100 µl 1% polyvinylpyrrolidone (PVP) for nuclei stabilisation (Yokoya et al., 2000), were added to the filtrate. Nuclei were stained at 4 °C in the dark for 60 minutes. The same method (except of addition of PVP and with 15 min staining time) was applied for pea standard preparation and just before cytometric analysis sample and standard were mixed together in ratio 1 : 1. As outputs we obtained fluorescence intensity histograms made from at least 5,000 particles (Fig. 2). Their analysis provided FloMax software (Partec GmbH., Germany). Every sample was examined three times on three consecutive days.



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File: M6+pisum 3 opakovani   Date: 09-02-2011  Time: 08:44:21   Particles: 5000   Acq.-Time: 467 s

Peak    Index    Mean     Area   Area%   CV%     ChiSqu.
 1      1.000    64.44     890   25.42   42.80   0.83
 2      2.278    146.82   1416   40.41   3.42    0.83
 3      7.785    501.64   1197   34.17   1.82    0.83
```

Fig. 2. Example of fluorescence histogram analysis in *R. canina* var. *dumalis* Baker non Bechst. from Modra – Pažite. From left: first wide peak of small subcellular particles binding PI, second peak – rose leaf cell nuclei, third peak – pea leaf cell nuclei. Determination accuracy is expressed by coefficients of variance (CV%), defining divergence from normal statistical distribution (CVs not exceeding 4% indicate clear genome size determination in Rosaceae family).

Genome size (pg) was calculated from relative peak position (fluorescence intensity) of standard and sample (Fig. 2), using formula:

$$\text{GS(sample)} = \frac{\text{RP(sample)} \,.\, \text{GS(standard)}}{\text{RP(standard)}},$$

where GS is genome size, RP is relative position of a peak and GS (standard) is 9.09 pg.

Ploidy level of rose samples we calculated from genome size determinations. In this case, *Rosa arvensis* Huds. (diploid (2x) of genome size 0.96 pg) served as standard. Stem cuttings, collected from Zobor hills in winter 2011, were let sprout as in analysed roses. Ploidy level calculation followed this form:

$$\text{PL(sample)} = \frac{\text{GS(sample)} \,.\, 2}{\text{GS(standard)}},$$

where PL is ploidy level, GS is genome size, GS (standard) is 0.96 pg, 2 – somatic tissues are diploid (2C).

Statistical analysis

Quantitative morphological parameters of dog roses from all three experimental sites were submitted to correlation analysis (application MS Excell 2010) in order to characterize participation of genome size, soil and weather conditions in their determination. Variability in genome size of respective rose samples was examined by analysis of variance (LSD-test; application Statgraphics Centurion XVI).

Results

Quantitative morphological traits

In hips we analysed size and red colour intensity (Table 2). Length exceeding 20 mm were found in 0–45% examined hips in roses from Modra – Pažite, 0–25% in roses from Vrbové – Baraní dvor, and 13–32% in those from Zobor – Lyžiarska lúka. Percentage of hips with intense red colour ranged in intervals 18–43, 30–48 and 19–36 in Modra – Pažite, Vrbové – Baraní dvor and Zobor – Lyžiarska lúka, respectively.

Most commonly, studied roses established simple 5-petal flowers. Only in some cases (Modra – Pažite: individual 3; Vrbové – Baraní dvor: individuals 2 and 3; Zobor – Lyžiarska lúka: individual 2), half-full flowers were formed but their frequency was low (2–6%). On the other hand, except for roses from Vrbové – Baraní dvor (three of five shrubs did not form any flower), flowers coloured by intense tones of pink colour were found relatively often. In roses from Modra – Pažite we found 60–98% of them and in Zobor – Lyžiarska lúka from 32 to 60%.

Table 2. Quantitative trait analysis in leaves, flowers and hips of respective rose individuals with different origin (as percentage of samples with specified attribute)

Locality	Shrub	Hip longer than 20 mm	Intense red hip colour	Half-full flower	Intense pink flower colour	Leaf longer than 70 mm	Dark-green leaf
Modra – Pažite	1	45	43	0	60	32	58
	2	8	40	0	72	26	42
	3	8	35	4	84	16	44
	4	0	18	0	98	30	62
Vrbové – Baraní dvor	1	3	34	0	0	48	40
	2	25	30	6	0	42	28
	3	12	41	2	0	22	48
	4	15	48	0	78	20	42
	5	0	30	0	100	30	64
Zobor – Lyžiarska lúka	1	13	20	0	58	22	70
	2	29	23	4	60	42	40
	3	27	36	0	44	58	50
	4	23	19	0	46	36	70
	5	32	28	0	32	24	78

Focussing on leaf length, in wild roses from Modra – Pažite we observed only 16–32% and in Vrbové – Baraní dvor 20–48% of leaves longer than 70 mm, respectively. The highest variability of this parameter (24–58%) exhibited roses from Zobor – Lyžiarska lúka. Portion of dark green leaves was generally much higher: in Modra – Pažite it ranged between 42 and 62%, in Vrbové – Baraní dvor 28 and 64% and in Zobor – Lyžiarska lúka it was in interval 40–78%.

Genome size and ploidy level

Analysis of variance in genome size of whole wild rose collection revealed more groups of individuals (Table 3). Both extremes (group *a* with values round 2.35 pg, and group *g* with value slightly exceeding 2.90 pg) were observed in Vrbové – Baraní dvor. This mirrored in calculated ploidy level (4.85x and 4.92x as minimum values and 6.07x as maximum value).

Environmental conditions

Soils in respective research localities showed relative homogenity (Table 4). Our soil map survey revealed stagni-eutric cambisols with unsaturated sorption complex, slightly acidic reaction and middle humus content in Modra – Pažite, haplic luvisols on loess with saturated sorption complex, neutral reaction and middle humus content in Vrbové – Baraní dvor, and rendzic/chromi-rendzic leptosols of saturated sorption complex, slightly basic reaction and high humus content in Zobor – Lyžiarska lúka.

Hip formation generally realized in relatively warm conditions – average June–August 2009 temperature ranged from 19.6 (Zobor – Lyžiarska lúka) to 20.4 °C (Modra – Pažite), and precipitation sum for the same period was 199–247.4 mm (Table 5). On the other hand, flowers and leaves grew in very wet conditions – average April–June 2010 temperature inVrbové – Baraní dvor was 14.5 °C, and for Modra – Pažite and Zobor – Lyžiarska lúka we calculated 15.3 °C. Precipitation sum for this period ranged between 305.7 mm in Modra –Pažite and 409.9 mm in Zobor – Lyžiarska lúka.

Relations

Comparing correlation analyses in *R. canina* individuals, only, and all roses, much stronger relations could be seen for the former ones (Table 6). The only exceptions were negative moderate correlations of hip size to average June–August 2009 temperature (r = –0.318) and precipitation sum for this period (r = –0.420), as well as positive moderate correlation of leaf size to soil quality (r = 0.351).

Table 3. Genome size and ploidy level (calculated using genome size of *Rosa arvensis* Huds. standard) of wild roses from traditional research localities in Western Slovakia. Letters indicate statistically significant difference at P < 0.05

Locality	Individual	Genome size [pg]	Calculated ploidy (x)
Modra – Pažite	1	*2.45 ± 0.05 ab	5.09
	2	2.70 ± 0.04 ef	5.62
	3	2.52 ± 0.12 bc	5.25
	4	2.70 ± 0.02 ef	5.61
Vrbové – Baraní dvor	1	2.92 ± 0.06 g	6.07
	2	2.62 ± 0.10 cde	5.45
	3	2.33 ± 0.03 a	4.85
	4	2.61 ± 0.08 cde	5.43
	5	2.36 ± 0.03 a	4.92
Zobor – Lyžiarska lúka	1	2.66 ± 0.03 def	5.54
	2	2.72 ± 0.05 ef	5.66
	3	2.53 ± 0.07 bcd	5.27
	4	2.53 ± 0.02 bcd	5.26
	5	2.79 ± 0.04 fg	5.80

* Average ± SD.

Table 4. Soil quality in studied locations. Soil bonity code comprises characteristics of climatic region (first two numbers), soil type determination (second two numbers), then slope, skelet content and grain size distribution (the last three numbers)

Locality	Soil bonity code	Soil type	SCS [%]	pH	HC [%]	Score
Modra – Pažite	0171232	Stagni-eutric cambisols	40	5.6–6.5	2	3
Vrbové – Baraní dvor	0244202	Haplic luvisols on loess	>75	6.6–7.2	2.5	5.31
Zobor – Lyžiarska lúka	0292682	Rendzic leptosols and chromi-rendzic leptosols	>75	7.3–7.7	5.5	5.84

SCS, sorption complex saturation; HC, humus content in the soil. Soil scoring adapted to rose requests (Kordes, 1966; Walter, 2011): SCS 40% – 1, SCS > 75 – 2.125; pH 5.6–6.5 – 3, pH 6.6–7.2 – 2, pH 7.3–7.7 – 1; HC 2 – 1, HC 2.5 – 1.25, HC 5.5 – 2.75.

Table 5. Average air temperatures (t) and precipitation sums (p) in analysed locations in periods important for formation of respective plant organs (June–August 2009: hips; April–June 2010: leaves)

Locality	June–August 2009		April–June 2010	
	t [°C]	p [mm]	t [°C]	p [mm]
Modra – Pažite	20.4	247.4	15.3	305.7
Vrbové – Baraní dvor	20.0	240.0	14.5	346.7
Zobor – Lyžiarska lúka	19.6	199.0	15.3	409.9

Table 6. Correlation coefficients (r) between quantitative morphological traits of roses and their genome size as well as soil and weather conditions during formation of respective plant organs

Trait	Genome size	Soil quality	Temperature	Precipitation
Rosa canina				
Hip size	–0.294*	0.049	–0.148*	–0.232*
Hip colour	–0.362**	–0.217*	0.427**	0.588***
Flower richness	–0.268*	–0.117*	–0.320**	–0.294*
Flower colour	–0.070	–0.559***	0.606***	–0.277*
Leaf size	0.437**	0.166*	–0.316**	0.01
Leaf colour	0.075	0.139*	0.777***	0.557***
All analysed roses				
Hip size	–0.077	0.176*	–0.318**	–0.420**
Hip colour	–0.280*	–0.251*	0.410**	0.517***
Flower richness	–0.069	–0.014	–0.174*	–0.073
Flower colour	–0.158*	–0.463**	0.376**	–0.289*
Leaf size	0.160*	0.351**	–0.026	0.348**
Leaf colour	–0.088	0.146*	0.435**	0.365**

*** strong (1 > r ≥ 0.5), ** moderate (0.5 > r ≥ 0.3) and * weak linear correlation (0.3 > r ≥ 0.1).

Despite of weak relations, hip size in *R. canina* individuals was mostly determined by genome size (r = –0.294) and precipitation sum (r = –0.232). On the other hand, its colour was strongly correlated to precipitation sum (r = 0.588) and moderately to average temperature and genome size (r = 0.427 and r = –0.362, respectively). Flower richness seemed to be dependent mainly on temperature (r = 0.320) and less on genome size (r = –0.268). However, most important influence on flower colour intensity had soil quality (r = –0.559) and temperature (r = 0.606). Although leaf size was determined mostly by genome size (r = 0.437) and temperature (r = –0.316), leaf colour intensity mostly by atmospheric conditions (r = 0.777 for average temperature and r = 0.557 for precipitation sum).

Discussion

Rosa sect. Caninae comprises alloploid species resulting from unbalanced, so called caninae meiosis, autopolyploidisation, hybridisation and apomixis. They transmit only seven chromosomes (from seven bivalents) through pollen whereas 21, 28 or 35 chromosomes (from seven bivalents and 14, 21 or 28 univalents (depending on ploidy level)) come from egg cell. Therefore, most of genetically determined traits are expected to be matroclinally inherited (Nybom et al., 2004, 2006; Popek, 2007; Wissemann and Ritz, 2007; Kovarik et al., 2008; Ritz et al., 2011). Present knowledge on maternal and paternal inheritance of rose characters review Wissemann and Ritz (2007). From those related to traits analysed by us, leaf shape, epicuticular waxes as well as hip form and size were inherited maternally, and colour and size of flowers were of intermediate inheritance. As indicate Pécrix et al. (2011), high temperature has potential to increase gamete ploidy level in roses. Decrease in pollen viability, pollen ectexine defects and appearance of diploid pollen grains as a result of spindle misorientation in telophase II, were induced by temperature 36 °C during early meiosis. Formation of unreduced gametes is often associated with spontaneous hybridisation (Ritz and Wissemann, 2011) of commonly selfing dog roses (Nybom et al., 2005). Ueda and Akimoto (2001) refer to breaking down self-incompatibility in the genus *Rosa* with polyploidisation. Heterogamy and apomixis in *R. canina* rootstocks was widely described in a morphological and cytological work of Kroon and Zeilinga (1974). Recently, Werlemark (2000) pointed to possible occurrence of apomixis when in 10% of progenies coming from reciprocal crosses between *R. dumalis* and *R. rubiginosa* (both from sect. Caninae) was not found any of RAPD marker from pollen donor plant. Using the same methodology, Nybom et al. (2006) detected 5% of apomicts and 49% of hybrids in interspecific crosses of dog roses. Moreover, level of sexual reproduction in dog roses, as facultative apomicts, can be strongly affected by environmental factors, as well (Marshall and Brown, 1981).

In our study, ploidy level of 4.85–6.07x was calculated for wild roses. Since a classical karyological work of Májovský and Murín (1987) indicates 2n = 35 chromosomes in all analysed taxa, this large variation in calculated ploidy level could be explained by different length of repeating non-coding DNA sequences – retrotransposons (Vitte and Panaud, 2005; Bennetzen et al., 2005), modifying nuclear genome size. As review Kumar and Bennetzen (1999), retrotransposon length depends on numerous biotic and abiotic stress factors (high temperature among them). Our data on genome size are relatively consistent with literature. Genome size survey in angiosperms made by Bennett and Leitch (1995) revealed 2.90 pg for *R. canina*. Yokoya et al. (2000) analysed a scale of rose species from different sections and their result for *R. canina* genome size was very similar (2.91 pg). Roberts (2007), testing effects of plant part selection as well as tissue herbarisation on genome size in more species, obtained the same values. Next work of Roberts et al. (2009) added information on genome size of *R. corymbifera*, *R. dumalis* and *R. micrantha* – 2.82–3.11 pg, 2.83–3.09 pg and 2.78 pg, respectively (higher than in our study). However, among *R. canina* clones they also identified such ones with genome size ranging in interval 3.38–3.55 pg, and took them for hexaploids. This result support our notion that calculated ploidy levels nearing to 6x do not mean real hexaploidy but are consequents of longer retrotransposon chains and use of concrete standard karyotype for calculation (genome size of *R. arvensis* varies as well (1.12 pg in work of Yokoya et al., 2000)). Thus, it is difficult to determine rose ploidy level from genome size because of high genomic diversity (Roberts et al., 2009).

Zlesak (2009) tested possibilities to define sporophytic and gametophytic ploidy levels in diverse rose genotypes from pollen diameter and guard cell length. He found out that polled diameter was useful in gametophyte ploidy prediction, only, but because of large variability, guard cell length cannot serve for any ploidy level estimation. This is partly consistent with generalisation of Knight and Beaulieu (2008) that genome size correlations are relatively strong at the cellular level (guard and epidermal cell size) but decrease in predicting power with increasing phenotypic scale (stomatal density, seed mass, leaf mass/area and wood density, photosynthetic rate, maximum height). From studied quantitative traits, only hip colour intensity and leaf size of *R. canina* genotypes were determined by genome size in larger extent. Soil quality significantly influenced flower colour intensity, only. The widest effect among factors had temperature. It importantly affected all traits, except for hip size. Precipitation had marked effect on hip and leaf colour intensity. Thus, the effect of environmental factors was decisive for almost all studied quantitative traits interesting for ornamental breeding, except for leaf size.

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Sú kvantitatívne znaky divo rastúcich ruží (*Rosa* sect. *Caninae*), zaujímavé pre okrasné šľachtenie, určené veľkosťou genómu?

Súhrn

Za účelom definovania podielu veľkosti genómu ako aj významných environmentálnych faktorov na variabilite kvantitatívnych znakov zaujímavých pre okrasné šľachtenie ruží, boli analyzované divo rastúce ruže (*Rosa* sect. Caninae) z Malých Karpát (lokality Modra – Pažite a Vrbové – Baraní dvor) a Zoborských vrchov (lokalita Zobor – Lyžiarska lúka). Medzi krami bola zistená značná variabilita v podiele listov dlhších ako 70 mm (16 – 58 %) a listov tmavozelenej farby (28 – 78 %), v podiele poloplných kvetov (0 – 6 %) a kvetov intenzívnej ružovej farby (0 – 100 %), ako aj v podiele šípok dlhších ako 20 mm (0 – 45 %) a šípok intenzívnej červenej farby (18 – 48 %). Veľkosť genómu študovaných ruží sa pohybovala v intervale 2,33 – 2,92 pg. Prieskum pôdnych máp odhalil kambizeme pseudoglejové na lokalite Modra – Pažite, hnedozeme typické na sprašiach vo Vrbovom na Baraňom dvore a rendziny typické na výrazných svahoch na lokalite Zobor – Lyžiarska lúka (rastúcu bonitu pôdy od lokality k lokalite). Listy a kvety rástli v podmienkach s priemernou teplotou 15,3 °C (Modra – Pažite a Zobor – Lyžiarska lúka) resp. 14,5 °C (Vrbové – Baraní dvor) a úhrnom zrážok od 300 mm (Modra – Pažite) do 400 mm (Zobor – Lyžiarska lúka). Priemerná teplota pre obdobie formovania šípok sa pohybovala medzi 19,6 °C pre Zobor – Lyžiarsku lúku a 20,4 °C pre Modru – Pažite, pričom suma zrážok dosiahla asi 200 mm na Zobori – Lyžiarskej lúke a 250 mm na ostatných dvoch lokalitách.

Kvantitatívne znaky analyzovaných ruží vykazovali relatívne slabé vzťahy k veľkosti genómu a environmentálnym faktorom. Ak sme však analýzu obmedzili na genotypy *R. canina*, korelačné koeficienty vzrástli. Z nich vyplynulo, že veľkosť listov bola v rozhodujúcej miere určená veľkosťou genómu (r = 0,437) a teplotou (r = –0,316), farba listu predovšetkým teplotou (r = 0,777) a množstvom zrážok (r = 0,557), plnosť kvetu hlavne teplotou (r = –0,320), jeho farba teplotou (r = 0,606) a kvalitatívnymi vlastnosťami pôdy (r = –0,559), a farba šípky sumou zrážok (r = 0,588), teplotou (r = 0,427) a veľkosťou genómu (r = –0,362). Žiadny z faktorov však nemal významný vplyv na dĺžku šípky. Tieto výsledky naznačujú, že okrem veľkosti listov, sú analyzované kvantitatívne znaku závislé takmer výhradne od environmentálnych faktorov.

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Molecular identification of *Fomes fomentarius* in hosts from urban and suburban areas in Slovakia

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Abstract

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Intraspecific, genetic diversity was studied in the wood-decaying fungus *Fomes fomentarius* using the internal transcribed spacer region (ITS) sequence analysis. Fourteen different isolates originating from six host plant genera from the Slovakian urban and suburban areas (Central Europe) were compared. Based on ITS sequences comparison, two different genotypes were found. Genotype A consists of the two isolates from *Fagus sylvatica* and *Negundo aceroides*, whereas genotype B consists of isolates from all host plants (excluding *Negundo aceroides*). There only exists one host tree species (*Fagus sylvatica*) that hosts both fungal genotypes. Moreover, this host clearly represents two different genotypes from the same kind of urban and suburban habitat. Our study appears to be the first report of the heterogeneity within the ITS region of *F. fomentarius* from urban trees. Our data indicate that the occurrence of *F. fomentarius* genotypes is affected by characters such as host plant species and kinds of urban habitats, but not by geographical location.

Keywords

Fomes fomentarius, hosts, ITS region, urban habitats

Introduction

Fomes fomentarius (L.) J. Kickx f. is one of the most important fungi in the temperate and boreal forests of the northern hemisphere causing white rot in forest trees. On healthy *Fagus sylvatica* trees it can also operate as an endophyte (Baum et al., 2003). Although there are some studies on *F. fomentarius* in the forest ecosystems (Baum et al., 2003; Schwarze et al., 2004; Schmidt, 2006), there is little information available about properties of this polypore collected from urban and suburban areas. Between 1999 and 2001 a pilot study was carried out within COST Action E-12 on the main pests and diseases in urban forests and trees in 18 European countries. From 8 of them it has been reported among fungi causing decay mentioned as important (Konijnendijk et al., 2005). The occurrence of *F. fomentarius* basidiomes in urban Slovakia during the years 1982–2010 has been described previously and account of its localities have been presented (Gáperová and Gáper, 2011; Gáper et al., 2011). Some trees were common hosts wherever they occurred (e.g. *Aesculus hippocastanum*, *Acer* spp., *Populus* spp. and *Tilia* spp.). Other trees, although widespread and common (e.g. *Negundo aceroides*), hosted this polypore only occasionally. The aim of the present study was to analyze intraspecific variability in *F. fomentarius* isolates using molecular methods based on available ITS sequences from the Slovakian urban and suburban areas. We questioned also whether the host ranges, geographical factors, and kinds of urban habitat of *F. fomentarius* reflect its genetic diversity.

Material and methods

Isolates

Fomes fomentarius basidiomes were collected from a living or dead tree trunks and stumps within the capital city Bratislava (Western Slovak Region, specimens no. 2, 4) and the Central Slovak Region (the others specimens). Localities within Central Slovak Region were distant from each other by 0.5–79.2 km. Urban and suburban habitats are divided into five categories according to the placement and function they have (Jeffrey, 2002; Konijnendijk et al., 2005; Kunca, 2009; Modranský, 2012): (1) Urban "Public" open city spaces (public parks, pocket parks, both paved and non-paved squares and pockets of greenery in the cities and towns: planted streets, promenades, tree-lined allees, courtyards and patios), (2) Urban "Public" open village spaces (public parks, pocket parks, both paved and non-paved pockets of greenery in the villages: planted streets, tree-lined allees), (3) Quasi-natural habitats associated with engineered features (transport corridor verges: roadsides), (4) Suburban Gardens and residential landscaping: private garden areas, (5) Nearly natural habitats: foothills of settlement Mountains.

Isolations were performed within 24 hours of the collection of samples in the field. All pure cultures were obtained on 2% malt extract agar in a Petri dish from trama of basidiomes (Júdová et al., 2012). The cultures were incubated at 24 ± 1°C in darkness. The remaining part of each specimen was dried and stored as voucher specimens. Herbarium specimens are deposited in the herbarium of the Department of Biology and General Ecology, Faculty of Ecology and Environmental Sciences, Technical University in Zvolen (KBVE). Pure cultures were isolated from 14 specimens growing on *Acer platanoides* L., *Aesculus hippocastanum* L., *Fagus sylvatica* L., *Negundo aceroides* Moench, *Populus alba* L., *Populus tremula* L., *Populus* sp. and *Tilia* sp. Cultures are preserved at the Mycological laboratory of the University of Matej Bel in Banská Bystrica, Slovakia under numbers 1 FF001AP–ITS14 FF014PA. Obtained ITS sequences were deposited in GenBank database (Accession Nos. FJ865438–FJ865443 and GQ184597–GQ184604).

Specimens and isolates examined

No. 1: Starohorské vrchy Mts.: the Laskomerská dolina valley, the Laskomer private garden area, ca. 2.5 km NE of the town of Banská Bystrica, 20 Oct., 2008, (KBVE 1293, 1 FF001AP); no. 2: the city of Bratislava, the municipal part of Petržalka, Janko Kráľ Park, 11 Nov., 2007, (KBVE 1294, ITS2 FF002AP); no. 3: the town of Banská Bystrica, Štadlerovo nábrežie promenade, 2 June, 2008, (KBVE 1295, ITS3 FF003Tsp); no. 4: the city of Bratislava, the municipal part of Petržalka, Janko Kráľ Park, 10 Nov., 2007, (KBVE 1296, ITS4 FF004Tsp); no. 5: in the village of Horný Tisovník in the Veľký Krtíš District, 25 March, 2008, (KBVE 1297, 5 FF005Psp); no. 6: the roadside near the village of Senné in the Veľký Krtíš District, 15 April, 2008, (KBVE 1298, ITS6 FF006PT); no. 7: the roadside near the town of Zvolen, 25 June, 2007, (KBVE 1299, 7 FF-007NA); no. 8: in the village of Dolná Strehová in the Veľký Krtíš District, I. Madácha Park, 31 Aug., 2005, (KBVE 1300, ITS8 FF008AH); no. 9: ibid., 31 May, 2008, (KBVE 1301, 9 FF009AH); no. 10: Starohorské vrchy Mts.: the Laskomerská dolina valley, foothills of Starohorské vrchy Mts., ca. 4.5 km NE of the town of Banská Bystrica, 31 May, 2008, (KBVE 1302, 10 FF010FS); no. 11: ibid., ca. 4 km NE of the town of Banská Bystrica, 22 Oct., 2008, (KBVE 1994, ITS11 FF011FS); no. 12: ibid., ca. 4.5 km NE of the town of Banská Bystrica, 31 May, 2008, (KBVE 1304, ITS12 FF012FS); no. 13: in the village of Kováčová in the Zvolen District, Spa Park, 19 Sept., 2008, (KBVE 1305, 13 FF013Tsp); no. 14: the roadside near the village of Mýtna in the Lučenec District, 19 Sept., 2008, (KBVE 1306, ITS14 FF014PA).

To the aim of our research, we compared our data with three other ITS sequences available in Genbank.

DNA isolation, amplification and analysis

Total genomic DNA of *F. fomentarius* isolates was prepared using microwave treatment according to Goodwin and Lee (1993) with small modifications. PCR was performed in a MJ Mini Personal Thermal Cycler (Bio-Rad Laboratories, Richmond, USA). The reaction mixtures (50 µl) contained 200 µM of each deoxynucleotide triphosphate, 1 µM of each primer, 1.25 U Taq DNA polymerase (Invitrogen, Paisley, UK), 5 µl 10x PCR buffer (Invitrogen, Paisley, UK), 2 mM $MgCl_2$, and 50 ng template DNA. For amplification of ITS1-5.8S-ITS4 nuclear DNA region ITS1 and ITS4 primers were used (White et al., 1990). The PCR cycling conditions involved an initial cycle of 94 °C for 5 min, followed by 35 cycles of 94 °C for 30 s, 52 °C for 45 s, and 72 °C for 45 s, with a final cycle step at 72 °C for 10 min.

Amplification products were visualized by electrophoresis through 0.8% agarose gels. A 1 kb DNA or 100 bp DNA ladders (invitrogen) were used as a molecular mass standard. ITS amplicons were purified using Wizard® SV Gel and PCR Clean-Up System (Promega, USA) and sequenced in both directions using the same primer pair as for PCR at Macrogen sequencing facility (Macrogen, Seoul, South Korea). Sequences obtained were compared against GenBank database using blastN algorithm (Altschul et al., 1990). The sequences were typed into A and B genotype based on the absence or presence of 7 bp signature sequence TCGTTTG (Júdová et al., 2012).

Results

To evaluate phylogenetic relatedness among *Fomes fomentarius* isolates ITS region from all 14 urban strains was amplified by PCR and sequenced. Continuous ITS sequences of at least 730 bp were obtained from every isolate analysed and deposited in GenBank database under accession numbers FJ865438–FJ865443 and GQ184597–GQ184604 (Tables 1–2). Comparison of sequences with ITS sequences available in GenBank indicated that all isolates belong to the *F. fomentarius* species with sequence similarity values to other isolates of this species higher than 97% (data not shown). Three additional sequences originated, however, from natural habitat, available in GenBank, were used in the analysis from Slovakia for comparison purpose (Tables 1–2): KYJ3: Vihorlat Mts.: Kyjovský prales primeval forest reserve, ca. 60 km NE of the town of Košice; 980706.7: Kremnické vrchy Mts.: Badínsky prales primeval forest reserve, ca. 10 km SW of the town of Banská Bystrica; KYJ7: Vihorlat Mts.: Kyjovský prales primeval forest reserve, ca. 60 km NE of the town of Košice.

Analysis on ITS sequence data clearly indicated the presence of two sequence types (genotypes) in studied *F. fomentarius* isolates. All isolates typed to the B genotype showed the presence of 7 bp signature sequence TCGTTTG in ITS1 region while isolates typed to the A genotype lack this sequence (data not shown). The absence or presence of this sequence was used for discrimination of *F. fomentarius* genotypes from natural forest reserves in Vihorlat Mountains (Júdová et al., 2012).

The majority of our urban and suburban isolates formed large group together with the strain KYJ7 isolated from basidiome collected in the Kyjovský prales primeval forest reserve on adult *Fagus sylvatica* (genotype B, Table 1). The rest our urban and suburban

Table 1. List of the 13 isolates of *Fomes fomentarius* (genotype B), of which 12 are used in the study (shown in bold) and 1 is additional sequence available from Slovakia in GenBank

Strain No.	Slovak Region	Host	Habitat*	Accession No.
1 FF001AP	**Central**	***Acer platanoides***	**(4)**	**FJ865438**
ITS2 FF002AP	**Western**	***Acer platanoides***	**(1)**	**GQ184597**
ITS3 FF003Tsp	**Central**	***Tilia* sp.**	**(1)**	**GQ184598**
ITS4 FF004Tsp	**Western**	***Tilia* sp.**	**(1)**	**GQ184599**
5 FF005Psp	**Central-southern**	***Populus* sp.**	**(2)**	**FJ865439**
ITS6 FF006PT	**Central-southern**	***Populus tremula***	**(3)**	**GQ184600**
ITS8 FF008AH	**Central-southern**	***Aesculus hippocastanum***	**(2)**	**GQ184601**
9 FF009AH	**Central-southern**	***Aesculus hippocastanum***	**(2)**	**FJ865441**
10 FF010FS	**Central**	***Fagus sylvatica***	**(5)**	**FJ865442**
ITS11 FF011FS	**Central**	***Fagus sylvatica***	**(5)**	**GQ184602**
13 FF013Tsp	**Central**	***Tilia* sp.**	**(2)**	**FJ865443**
ITS14 FF014PA	**Central-southern**	***Populus alba***	**(3)**	**GQ184604**
KYJ7	Eastern	*Cerasus avium*	(6)	HQ189535

*Habitat: (1) – Urban “Public” open city space; (2) – Urban “Public” open village space; (3) – Quasi-natural habitat associated with engineered features; (4) – Suburban Garden and residential landscaping; (5) – Nearly natural habitat; (6) – Natural habitat.

Table 2. List of the 4 isolates of *Fomes fomentarius* (genotype A), of which 2 are used in the study (shown in bold) and 2 are additional sequences from Slovakia available in GenBank

Strain No.	Slovak Region	Host	Habitat*	Accession No.
7 FF007NA	**Central**	***Negundo aceroides***	**(3)**	**FJ865440**
ITS12 FF012FS	**Central**	***Fagus sylvatica***	**(5)**	**GQ184603**
KYJ3	Eastern	*Fagus sylvatica*	(6)	HQ189534
980706.7	Central	*Fagus sylvatica*	(6)	EU162056

*Habitat: (3) – Quasi-natural habitat associated with engineered features; (5) – Nearly natural habitat; (6) – Natural habitat.

strains (7 FF007NA and ITS12 FF012FS) fell to the two sequences (HQ189534 and EU162056) originating also from *Fagus sylvatica* host collected in the Kyjovský prales primeval forest reserve and Badínsky prales primeval forest reserve (genotype A, Table 2).

This study demonstrates that both fungal genotypes are widespread on different hosts over large areas. The genotype B (Table 1) consists of thirteen fungal strains from six host genera, among which are three from *Tilia* spp., two from *Acer platanoides*, *Aesculus hippocastanum* and *Fagus sylvatica*, and are each from *Cerasus avium* (from natural forest only), *Populus alba*, *Populus tremula* and *Populus* sp. The genotype A (Table 2) consists of four strains from two host genera, among which are three from *Fagus sylvatica* (the one of its from natural forest) along with one from *Negundo aceroides*. Yet only one woody host plant (*Fagus sylvatica*) has both fungal genotypes. Moreover, there is the observation, that different European beech trees growing within a few meters of each other have different fungal genotypes (Accession Nos. FJ865442, GQ 184602, GQ 184603), so it is likely that the geographical features do not reflect the genetic diversity of *F. fomentarius*.

In view of the urban habitats, the majority of our isolates originating from the Western Slovak Region and the Central Slovak Region and from all urban and suburban habitats fell to the genotype B (Table 1). Two other isolates (genotype A) come from two different urban habitats ("Quasi natural habitat associated with engineered features" and "Nearly natural habitat" respectively) within the Central Slovak Region (Table 2). The host *Fagus sylvatica* clearly represents two different genotypes (Accession Nos. FJ 865442 and GQ184603) from the same kind of urban habitat ("Nearly natural habitat").

In summary, our results indicate that at least in the two above mentioned kinds of urban and suburban habitat both the genotypes are found sympatrically, so it is likely that the *Fomes fomentarius* includes two cryptic species. The data suggest that genotype A seems to be linked preferably with natural like habitats. No sequence originated from *Fomes fomentarius* basidiomes grown within the "Urban public open spaces" was observed. In contrary, from 12 our sequences of genotype B only 5 sequences originated from *Fomes fomentarius* strains grown within natural like habitats.

Discussion

The nuclear ribosomal, particularly highly variable ITS regions are highly variable sequences widely used in distinguishing fungal species. The ITS regions are highly conserved within most species – with intraspecific similarities usually higher than 99% – but are variable between species, making it suitable for use in taxonomy (Gomes et al., 2002). In natural forest reserves in Vihorlat Mountains (Eastern Slovakia), it consists of two sequence types (genotypes) showing different host preferences. The genotype A is a pathogen of *Fagus sylvatica* and *Betula pendula*, and the genotype B occurs on *Fagus sylvatica*, *Quercus robur* and *Cerasus avium*. Both the genotypes were found sympatrically, so it is likely that the *Fomes fomentarius*, a single described morphological species, should include two sympatric cryptic species (Júdová et al., 2012). Molecular analysis of *F. fomentarius* strains from urban and suburban areas in Slovakia also clearly identified two genotypes of strains with overall ITS sequence similarity values 97% only (data not shown), indicating complex genetic structure of *F. fomentarius* population.

Among polypores it is common to find species complexes within the traditional morphological species (Holdenrieder and Greig, 1998; Kraj and Kowalski, 2010; Tomšovský et al., 2010; Vasaitis et al., 2009 and others). For example, the ribosomal DNA sequences, including sequences from the internal transcribed spacer (ITS) and also large subunit (LSU) regions, have been used to define species and infer phylogenetic relationships in genus *Laetiporus* and to confirm the existence of cryptic species described with mating compatibility, ITS-RFLP, morphology and host preference data

(Vasaitis et al., 2009; Lindner and Banik, 2011 and others). According to the data made available here, it is the first report of the heterogeneity within the ITS region among *F. fomentarius* isolates from urban areas within different kinds of urban habitats in Slovakia. Our findings are of high importance for polypore ecology and proper procedures aimed at the control and restriction of the epidemic spread of fungi over large urban areas. Similarly, our previous analysis of *F. fomentarius* basidiomes from Slovakia´s natural forests (Júdová et al., 2012) clearly identified two genotypes based on ITS sequence comparisons. ITS sequence variability observed in these experiments must be further analysed. The general line of investigation will continue to obtain valuable data regarding the association between *F. fomentarius* genotypes and various woody plant species within different kinds of habitat, including forest ecosystems, in Europe. There are two main questions. First, why is there only one tree species that has two *F. fomentarius* genotypes? Second, why are there only three kinds of habitat associated with both fungal genotypes occurring?

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Molekulárna identifikácia *Fomes fomentarius* na drevinách v urbánnom a suburbánnom prostredí na Slovensku

Súhrn

Drevokazný trúdnik *Fomes fomentarius* je bežne sa vyskytujúcou hubou na celom území Slovenska. Najčastejší je v bukových porastoch, často kolonizuje aj dreviny v mestskom prostredí, môže rásť aj endofyticky. Skúmaním 14 izolátov metódou založenou na PCR amplifikácii ITS sekvencií a ich následnom štiepení sme v urbánnom a suburbánnom prostredí Slovenska detekovali jeho dva genotypy. Údaje o genetickej typizácii sme spracovali tabelárne. Genotyp A kolonizuje *Fagus sylvatica* a *Negundo aceroides*, genotyp B má širší okruh hostiteľských drevín. *Fagus sylvatica* je jediným druhom, ktorý kolonizujú obidva genotypy. Genotyp B rastie vo všetkých kategóriách urbánnej vegetácie, pravdepodobne na celom území Slovenska.

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Anatomic-morphological characteristic of fungus *Coniochaeta prunicola* isolated from *Prunus cerasus* leaves

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Abstract

Ivanová, H. 2013. Anatomic-morphological characteristic of fungus *Coniochaeta prunicola* isolated from *Prunus cerasus* leaves. *Folia oecol*., 40: 28–33.

Prunus cerasus L. is selected tree of genus *Prunus* susceptible to various pathogens, which caused discoloration, brown spots, blight symptoms and necroses, affecting their aesthetic value. The symptoms of infection observable from spring to autumn are increased, when the plants are in bloom – resulting in dieback and leaf drop. The damage is caused by fungus *Coniochaeta prunicola* Damm & Crous (Coniochaetales, Sordariomycetes, Ascomycota). The present work tries to specify – on the basis of light-microscopical morphological studies – the fungus *C. prunicola* that was isolated from *Prunus cerasus* symptomatic leaves from district Nitra and propose, for the first time, as a causative agent of sour cherry damage. The specific differences in spore size and anamorph morphology to the similar *C. velutina* could be confirmed. *C. prunicola* is characterized by dark brown ascomata clothed with setae, the fasciculate, unitunicate, cylindrical asci and broadly almond-shaped, ellipsoidal ascospores with a longitudinal germ slit.

Keywords

anatomic-morphological characteristic, *Coniochaeta prunicola,* sour cherry

Introduction

Coniochaeta species had been found on many different substrates and hosts (on wood and bark, leaves and leaf litter of different trees, in dung of various animals, and in soil and water). This species was isolated from various parts of the genus *Prunus*, too. Decaying bark of *Prunus avium* L. in the Netherlands (CBS 178.75) enabled isolation the *Coniochaeta ligniaria* (Grev.) Massee, fruit trees (dry twigs of apricot, plum, pear, apple and cherry) in Moldavia isolation *Coniochaeta ambigua* (Sacc.) Cooke, *Coniochaeta calva* Tode, *Coniochaeta velutina* (Fuckel) Munk and *Coniochaeta ligniaria* (Grew.) Masse (Popushoi, 1971), necrotic wood samples of *Prunus armeniaca* and *Prunus salicina* in South Africa isolation *Coniochaeta velutina* (Fuckel) Munk and *Coniochaeta prunicola* Damm & Crous (Damm et al., 2010), leaves of *Prunus persica* in Slovakia isolation *Coniochaeta prunicola* Damm & Crous (Ivanová and Bernadovičová, 2012).

According to Mahoney and LaFavre (1981) *Coniochaeta* species are of low virulence on most hosts, usually appearing on dead tissue or as opportunistic invaders of previously infected, wounded or senescent tissue.

The genus *Coniochaeta* (Sacc.) Cooke belong to the family Coniochaetaceae. Their ascomata are perithecial, solitary, subglobose to pyriform, ostiolate with or without setae, ascospores are dark brown, discoid, nearly globose or ellipsoidal (Mahoney and LaFavre, 1981; Hanlin, 1990). Only 21 *Coniochaeta* species were included in the DNA phylogeny of the ascomycetous genus *Coniochaeta* (Asgari et al., 2007). *Coniochaeta* traditionally accommodates species with 4- to 8- or multi-spored asci. Their *Lecythophora* anamorphs are phialidic (Weber, 2002; Asgari and Zare, 2006) or polyblastic, nodulisporium like (Hawksworth, 1978; Asgari and Zare, 2006; Asgari et al., 2007). This genus represents the order Coniochaetales (class Sordariomycetes). Molecular studies have then demonstrated the taxonomic relevance of anamorphs in the Xylariales (Sánchez-Ballesteros et al., 2000; Weber et al., 2002).

During an investigation on mycoflora of sour cherry trees growing in urbanized area the ascomycetous fungus *Coniochaeta prunicola* (Coniochaetaceae, Coniochaetales) that affects leaves of the host trees was noticed. This is the first record of this fungus as a pathogen of *Prunus cerasus* L. in Slovakia. The incidence of disease is sporadic, the infected trees showed relatively low damage.

The recently-noticed new disease of sour cherry trees becomes an especially relevant issue. The aim of our study was to isolate *Coniochaeta* species as a once in a factors involved in health state decline of *Prunus cerasus* and to present morphological description with distinctive features.

Material and methods

The issue was studied on samples of *Prunus cerasus* leaves showing blight symptoms. The samples were gathered from plants growing in private gardens of the town Nitra, during spring-autumn 2012. The samples of plant material were deposed at the Institute of Forest Ecology of the Slovak Academy of Sciences, Branch for Woody Plant Biology in Nitra.

For isolation and obtaining pure cultures we used classical phytopathological approaches. Leaf parts cut from the diseased plants were surface-sterilized in a sodium hypochlorite solution (1% available chlorine) for 20 minutes, rinsed twice or three times with sterile distilled water and placed in Petri dishes with a 3% potato-dextrose agar (PDA). Petri dishes were cultivated at 24 ± 1 °C and 45% air humidity in dark conditions in a versatile environmental test chamber MLR-351H (Sanyo). Pure fungal cultures were obtained by multiple purifications. The obtained isolates were transferred on 3% PDA medium to induce sporulation. The fungal structures were examined with a clinical microscope BX41 (Olympus) under a 400× and 1,000× magnification.

The isolated fungus was identified by microscopic analyses based on the morphological characteristics of the fruiting bodies, spore bearing organs and reproduction organs. The identification was performed using morphological keys according to Hawksworth and Yip (1981), Ellis and Ellis (1987), Checa et al. (1988), Romero et al. (1999), Asgari et al. (2007) and other reference guides in Mahoney and La Favre (1981), Hanlin (1990), Weber (2002) and Damm et al. (2010).

Results and discussion

Concerning all morphological characteristics and determined differences, the fungus under investigation in our study isolated from blighted leaves of sour cherry trees (Fig. 1a) was identified as *Coniochaeta prunicola*.

Coniochaeta prunicola Damm & Crous isolated from *Prunus cerasus* L. – anatomical-morphologically characteristics. Ascomata immersed or superficial on PDA medium developing after about 1 week were perithecial, solitary, subglobose to pyriform with a central ostiole, 188 (220) × 137 µm, neck 35–40 µm long (Fig. 1b). Peridium was pseudoparenchymatous, outer wall consists of dark brown angular cells (Fig. 1c), with setae. Setae were brown (or hyaline), straight, cylindrical, smooth-walled, 2–3 µm wide, up to 30–52 µm long (Fig. 1c, d). Prominent feature of the most *Coniochaeta* species are setae, but some species are described as lacking setae (Romero et al., 1999). Most of the described setae are dark brown to black rigid hairs, straight or bent, unbranched with a sharp apex. They may be scattered over the perithecial wall or concentrated in its upper portion (Mahoney and La Favre, 1981). According to Damm et al. (2010) subglobose to pyriform ascomata of the fungus *C. prunicola* isolated from branches of *Prunus armeniaca* and *P. salicina* formed pseudoparenchymatous peridium wide 20–25 µm with 5–8 layers, outer wall consists of dark brown textura angularis, with setae. Setae were brown (or hyaline), straight, cylindrical, tapering to a round tip, smooth-walled or granulate, 2–3.5 µm wide, up to 80 µm long. Ascomata reached 200–250 µm in diameter, neck 50–60 µm long. Comparison of morphological characteristics of *Coniochaeta prunicola* isolated from different *Prunus* species and from examined material of *P. cerasus* are included in Table 1.

Unitunicate, fasciculate cylindric asci size 67 (92) × 5 (10) µm with truncate apex and small apical ring long 8 × 4 µm (Fig. 1e, f) form rosettes (Fig. 1e, h). Less numerous hyaline, septate paraphyses size 65 × 9 µm are formed between the asci (Fig. 1h). Each ascus contained eight ascospores, which were brown, onecelled, ellipsoidal, smoothwalled without ornamentation of the ascospore wall and with granular contents (Fig. 1h). Mature ascospores were broadly almond-shaped, ellipsoidal with a longitudinal germ slit 8–10 µm long (Fig. 1i). The key in Asgari et al. (2007) leads to *C. velutina*, except that the ascospores of that species have guttules and these isolates produce smaller ascospores compared to *C. prunicola* with larger ascospores (Fig. 1g). Ascospore shape is a valuable criterion for distinguishing species. Ascospores of *C. velutina* were ellipsoidal, brown, flattened with longitudinal germ slit and 2 large guttules, 6–8 × 4–5 × 3.2–4.0 µm size (Weber, 2002). Ascospores of *Coniochaeta ligniaria* (Grev.) Cooke are broadly spindle- or lemon-shaped, with tapering ends, size 14.5–16.0 × 7–8 × 6 µm. Colonies derived from ascospores became brownish and had sparse, thick walled chlamydospores with age (Holm and Ryman, 1977). Ascospores size in our experiments with *P. cerasus* isolates was 9 (10)–12 × 4 (5)–7 µm. Colonies appeared white at first, than turned on pale buff to white, chlamydospores absent. These ascospore features are comparable to those provided by Munk (1957), where isolates from *Prunus* sp. produced ascospores 6–8 × 4–6 × 3–4 µm. Isolates from *Prunus laurocerasus* L. produced ascospores 9–10.5 (12.5) × 5 (7.5) µm in size (Ivanová and Bernadovičová, unpublished yet), from *Prunus persica* (L.) Batsch 9 (10)–12 × 5 (6) µm (Ivanová and Bernadovičová, 2012) or by description in Damm et al. (2010) isolates from *Prunus armeniaca* L. and *Prunus salicina* L. formed ascospores (7.5–) 8.5–10 (–11) × (5–) 6–7.5 (–8) × (3–) 4–5 µm in size.

The anamorph of *C. prunicola* is similar to that of *C. velutina*, but the collarette in the latter is shorter, up to 1 µm long and vegetative hyphas have 2–4 (–5) µm wide, are hyaline to olive, multiguttulate, chlamydospores absent (Weber, 2002; Damm et. al., 2010). Vegetative hyphae of *C. prunicola* isolated from *P. cerasus* were 3–4 µm wide, hyaline, without guttules and chlamydospores (Fig. 1j). Conidiophores formed directly on hyphae, mostly reduced to conidiogenous cells. Phialides were either short cylindrical or ampulliform (Fig. 1l). Collarettes were usually inconspicuous. Conidia obtained from pure culture of *C. prunicola* formed on hyphal coils (Fig. 1k). Conidia are hyaline, one-celled, cylindrical, mostly allantoid, 2–6 × 1–2 µm sizes (Fig. 1m). In anamorph stage of *Coniochaeta velutina* described from various tree and shrub hosts in *Lecythophora* genus, sizes of conidia obtained from pure cultures varied: 3–6 × 2–4 µm (Taylor, 1970), 2.5–3.5 × 1.5–2 µm (Udagawa and Horie, 1982), 2–4 × 1–2.5 µm (Hutchinson and Reid, 1988), (3–) 3.5–6 (–7) × (1–) 1.2–2 µm (Weber, 2002) and 3–8 µm long (Kirschner, 1998). Conidia of this species are mostly biguttulate or with some small guttules, but conidia of *C. prunicola* are without guttules (Damm et al., 2010; Ivanová and Bernadovičová, 2012). This fact was also confirmed in our study.

Similarly in anamorph stage of *Coniochaeta ligniaria* (Grev.) Cooke conidia ellipsoidal to cylindrical, often somewhat curved, hyaline, one-celled, smooth-walled, mostly biguttulate, (3–) 3.5–6 (–8) × (1–)

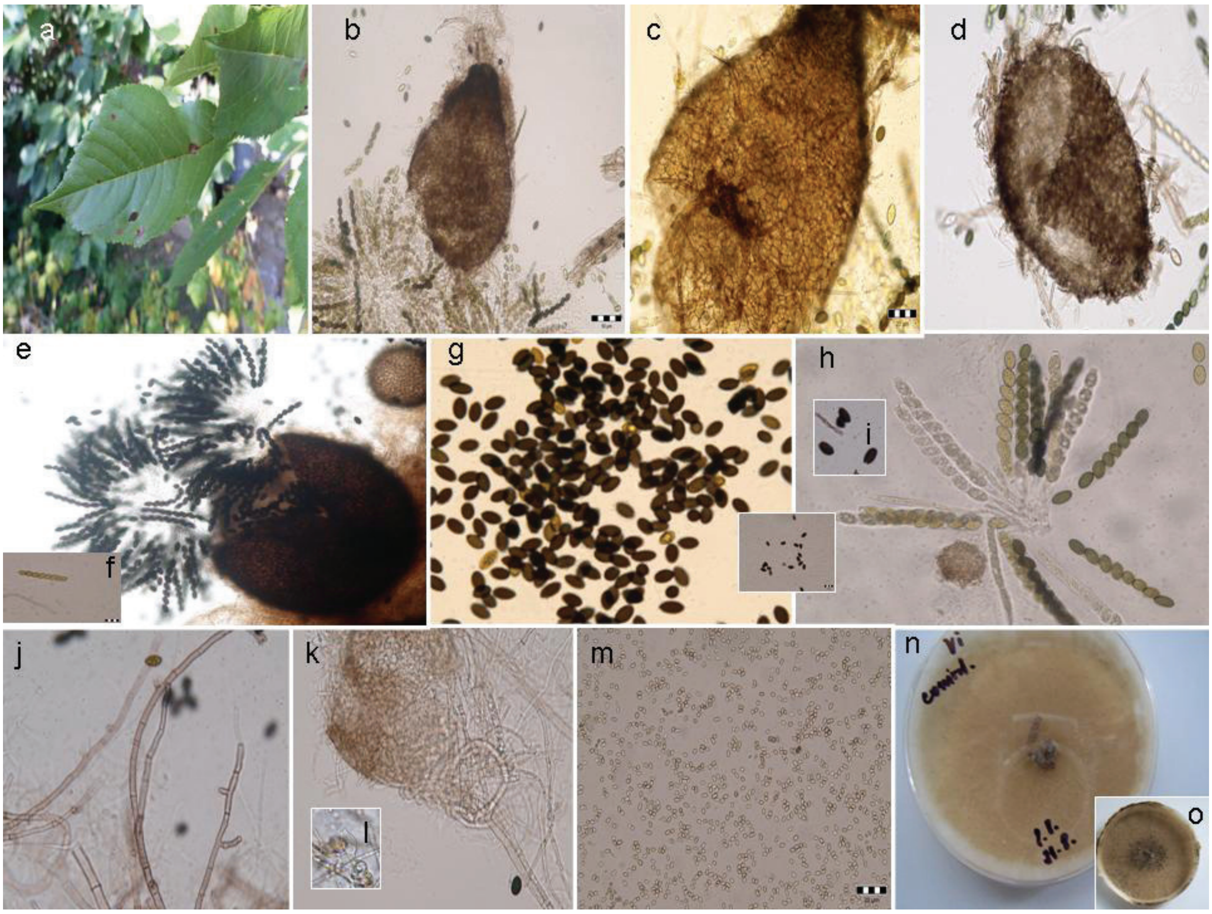

Fig. 1. *Coniochaeta prunicola* on *Prunus cerasus*. **a** affected leaves of *P. cerasus*, Teleomorph (**b–i**): **b** ascocarp with neck; **c–e** ascocarps in dehiscence; **c** peridium; **b–d** peridial setae; **f** 8-spored ascus, **g** ascospores, **e, h** rosettes of asci with paraphyses; **i** ascospore germ slit. Anamorph (**j–o**): **j** hyphas with collarettes, **k** hyphal coil, **l** ampulliform phialides, **m** conidia, **n** colony on PDA after 24 days; **o** colony on PDA after 1 week. Scale bars: c, d, f–m = 20 µm; b, e = 50 µm.

Table 1. Comparison of biometric characteristics and morphological features of fungus *Coniochaeta prunicola* on different species of genus *Prunus*

Authors	**Ours experiments**	**Ivanová, Bernadovičová 2012**	**Ivanová, Bernadovičová,** unpublished	**Damm et al. 2010**
Hosts / plant part	*Prunus cerasus* leaves	*Prunus persica* leaves	*Prunus laurocerasus* leaves, twigs	*P. armeniaca*, *P. salicina* wood
Causal agent	***C. prunicola***	***C. prunicola***	***C. prunicola***	***C. prunicola***
Ascomata	Perithecial, solitary, subglobose to pyriform, 188(220) × 137 µm, neck 35–40 µm	Perithecial, solitary, subglobose to pyriform, 125–173(265) × 95–145(229) µm, neck 31–42 µm	Perithecial, solitary, 162–221 × 119–159 µm, subglobose to pyriform, neck 38–42 µm	Perithecial, solitary, subglobose to pyriform with a central ostiole, 200–250 µm diam., setose, neck 50–60 µm
Setae	Hyaline or brown smooth walled setae, 2–3 × 30–52 µm	Hyaline or brown setae, smooth walled, 3–4.5 × 21–29 µm	Hyaline or brown setae, smooth walled, 3–4.5 × 35–51 µm	Brown or hyaline setae, straight, cylindrical, tapering to a round tip, smooth-walled or granulate, 2.5–3.5 µm wide, 80 µm long
Paraphyses	Hyaline, septate, 65 × 9 µm	Hyaline, septate, 63 × 3–4 µm	Hyaline, septate, 74–78 × 3–4 µm	Hyaline, septate, 60–100 × 2–3 µm
Asci	Unitunicate with obtuse end, 8 ascospres / ascus, apedicillate, 67(92) × 5(10) µm	Unitunicate with obtuse end, 8 ascospores / ascus, cylindrical, 58–68(94) × 8–10 µm	Cylindrical, unitunicate with obtuse end, 8 ascospores / ascus, 68–81 × 8–10 µm	Unitunicate, cylindrical, apedicillate, 8 ascospores / ascus, 63–73 × 8–10 µm
Ascospores	Uniseriate, 1-celled, green to brown, smooth walled with granular content, 9(10)–12 × 4(5)–7 µm, longitudinal germ slit 8(10) × 5 µm	Uniseriate, 1-celled, smooth-walled with granular content, 9(10)–12 × 5(6) µm, longitudinal germ slit 8 × 5 µm, green to brown	Uniseriate, 1-celled, smooth-walled with granular content, brown, 9(10–)13 × (5–)6–7(–8) µm, longitudinal germ slit 7 × 6 µm	Uniseriate, 1-celled, brown, smooth-walled, broadly ellipsoidal in top view and reniform from the side, dimensions (7.5–)8.5–10(–11) × (5–)6–7.5(–8) × (3–)4–5 µm with granular content, germ slit
Guttules	Absent	Absent	Absent	Absent
Hyphae	Hyaline, 3–4 µm wide	–	Hyaline, 2–3 µm wide	Hyaline, 1–4 µm wide
Conidia	Hyaline, 1-celled, cylindrical to ovoid, 2–6 × 1–2 µm	Hyaline, 1-celled, smooth walled, cylindrical to ovoid, (2–)3–6(–7) × 1–2 µm	Hyaline, 1-celled, smooth walled, cylindrical to ovoid, sometimes allantoid (2–)3–4(–7) × 1–2 µm	Hyaline, 1-celled, smooth-walled, mainly allantoid, sometimes cylindrical to ovoid (2.5–)3.5–6(–8) × 1–2(–3) µm
Colonies on PDA	White, later pale buff to white, flat, with aerial sparse mycelium	Pale saffron, pale buff to white, flat, with sparse aerial mycelium	Pale buff to white, flat, with sparse aerial mycelium	Flat with sparse aerial mycelium, pale saffron, pale buff to white, 28 mm diam in 2 wk.
Chlamydosp.	Lacking	Lacking	Lacking	Lacking

1.5–2.5 µm, in the centre of the colonies conidia often larger, up to 7–8 (–11) × 4 µm (Weber, 2002).

Causal organism was systematically isolated from leaf tissue showing rusty to brown coloured blight symptoms and necroses in combination with fungus *Stigmina carpophila* (Lév.) M. B. Ellis (Ivanová and Bernadovičová, 2009) and *Blumeriella jaapii* (Rehm) Arx. (Ivanová and Bernadovičová, 2011). Colonies appeared white at first, than turned on pale buff to white (Fig. 1n). Conidia were produced abundant in culture media. Perithecia developed on PDA after about 1 week (Fig. 1o). Cultures of *Coniochaeta prunicola* do not turn dark as *Coniochaeta velutina* cultures (Weber, 2002; Damm et al., 2010) or do not turn more or less salmon-coloured as *Coniochaeta ligniaria* cultures (Weber, 2002). This fact was also confirmed in our study with isolates of fungus *C. prunicola* from peach trees (Ivanová and Bernadovičová, 2012), cherry laurel shrubs (Ivanová and Bernadovičová, unpublished yet) and with isolates from sour cherry in this study (Table 1).

The fungus *Coniochaeta prunicola* was found in the examined samples relatively uncommonly. Important finding is that *C. prunicola* was identified for the first time as a new pathogenic fungus associated with affected leaves of *P. cerasus* in Slovakia. Further studies are required for determination of pathogenicity and relevance of *Coniochaeta* infection in connection with sour cherry damage.

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Anatomicko-morfologická charakteristika huby *Coniochaeta prunicola* izolovanej z listov *Prunus cerasus*

Súhrn

Prunus cerasus L. je drevina náchylná na ochorenie vyvolané škodlivými činiteľmi, spôsobujúcimi rôzne farebné zmeny a škvrnitosti listov, opad listov, usychanie a nekrózy konárov. Pri monitorovaní zdravotného stavu vybraných drevín v podmienkach mesta Nitry sme zaznamenali symptómy dobre viditeľné od jari do jesene, ktoré sa v čase kvitnutia zvyšovali. Na vzniku infekcie sa podieľa aj huba *Coniochaeta prunicola* Damm & Crous (Coniochaetales, Sordariomycetes, Ascomycota). Predkladaná práca špecifikuje príčinu poškodenia *Prunus cerasus* na základe mikroskopicko-morfologických štúdií huby *C. prunicola* izolovanej zo symptomatických listov danej dreviny. Potvrdzuje rozdiely vo veľkosti spór a v morfológii anamorfy vzhľadom k hube *Coniochaeta velutina*. *C. prunicola* je charakterizovaná tmavohnedými plodničkami pokrytými vláskami, jednovrstvovými cylindrickými vreckami vyrastajúcimi medzi málopočetnými parafýzami. Vrecká sú usporiadané do ružíc a obsahujú osem svetlohnedých, v dospelosti tmavohnedých, hladko-stenných elipsoidných, vo vnútri zrnitých vreckospór, ktoré klíčia pozdĺžnym klíčnym otvorom. Výskyt ochorenia je sporadický, často je spojený s výskytom huby *Blumeriella jaapii* (Rehm) Arx. (Ascomycetes) podieľajúcej sa na vzniku nápadnej škvrnitosti listov a huby *Stigmina carpophila* (Lév.) M. B. Ellis (Deuteromycetes) spôsobujúcej dierkovitosť alebo suchú škvrnitosť listov *Prunus cerasus*.

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Black alder (*Alnus glutinosa* (L.) Gaertner) and its bank-protective effect on the banks of water flows quantified by method BSTEM

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Abstract

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The present article reviews the significance of Black alder (*Alnus glutinosa* (L.) Gaertner) in the riparian stands of torrent Hučava (Protected Landscape Area Poľana) in connection with bank stability of water flows and resistance of the banks of the bed against the erosion. Riparian stands are nature nearest reinforcement of the banks of water flows with accent of nature and landscape protection and biodiversity. Riparian vegetation increases the bank stability and erosion resistance of the banks of water flows. In the geomorphological unit Poľana (Central Slovakia) were investigated and compared 22 of experimental sections and profiles of torrent Hučava. On these experimental sections was analyzed the stability and erosion resistance of the banks on the both sides of the bed in connection with different density of stems of Black alder. The factor of stability Fs of the banks of water flow was calculated according to Bank Stability and Toe Erosion Model (BSTEM). The results indicated close correlation between the density of the stems of Black alder and factor of stabilty Fs (correlation coefficient is $I_{yx} = 0.964$ for the right banks and $I_{yx} = 0.952$ for the left banks). The calculated results of Fs are in accordance with existing erosion damages of the banks which were determined in terrain. The analysis confirms the influence of alder stands to stability and erosion resistance of the banks of water flows. The results were validated by statistical testing.

Key words
bank stability, Black alder, riparian stands

Introduction

Riparian stands (RS) are continuous, aggregated forest stands or their parts, groups, belts of trees, shrubs, grass and herbaceous vegetation. RS grow on the banks of water flows and water reservoirs and in the near of these localities (Valtýni, 1981). Some authors use the term riparian vegetation (Wynn, 2004; Wynn and Mostaghimi, 2006). The bank protection through the vegetation is the nature nearest way of reinforcement of the banks of water flows with accent of nature and landscape protection and biodiversity. RS increase the stability of the banks and anti-erosion resistance and they are the most significant elements of natural protection on the banks of water flows. In connection with the presence or absence of RS are these processes of erosion significantly limited (reduced or increased). Grešková and Lehotský (2007) suggest that the riparian stands through their root system reinforce the banks of water flows and protect the banks against the erosion and negative effects of streaming water. Valtýni (1981) defines the soil-protection function of RS as a reinforcement of the banks by root systems also as of inhibition of soil-erosion and of disturbances on the banks of water flows and reservoirs. Novák et al. (1986) analyze the influence of trees on the banks of water flows in connection with their location on the banks of water flows and their bank-protection function. Valtýni (1974), Šlezingr and Úradníček (2009) deal with the using of several species of woody plants in various ecological conditions. The importance of riparian vegetation with the accent on the soil-protection function confirm Simon et al. (2009). The authors suggest that the soil-loss of stream banks can be up 90% of total cubature of eroded material in the watershed per year. Rosgen (2002) suggests that in some cases the soil-loss caused by erosion of the banks of water flows can be up 80% of total eroded material in watershed per year. Pollen et al. (2004) suggest that this share can be more than 50% of total eroded material in watershed per year. Simon et al. (2011) confirm that by erosion of the banks is damaged averagely 52% of the banks of water flows. According to Beeson and Doyle (1995), Huang and Nanson (1997), Hession et al. (2003), Allmendinger et al. (2005) etc. are analyzed the issues of influence of riparian stands on the widening of the beds of water flows by erosion. The influence of root systems of riparian stands of water flows on stability of the banks and their soil protection function analyze Abernethy and Rutherfurd (2000), Micheli and Kirchner (2002), Simon and Collison (2002), Easson and Yarbrough (2002), Pollen et al. (2004) etc. These authors confirm the positive influence of the roots of the vegetation on stability of the banks and indicate that the stability of the bank is in correlation with indicators of density of vegetation inclusive number of stems and standing biomass per unit area. Black alder is representative tree of riparian stands on the banks of water flows, which grows in optimal condition to a height of 20–30 m. Lukáčik and Bugala (2009) mention that the typical vertical extension of Black alder in the Slovak Republic is 700–750 m a.s.l., somewhere also higher. Area of expansion of the initial alder stands is declining due to anthropogenic activities. In the lowlands due to negative changes of water flows and in the mountainous areas due to conversion on the agricultural lands (Bugala and Pitner, 2010). The biological balance of this environment was disturbed with various negative consequences and attendant phenomenons (for example increasing erosion of the banks of water flows). Black alder is very important amelioration tree with various positive properties (improves soil structure and the quality; has a positive impact on the additional properties such as cohesion of soil with the roots and mechanical reinforcement of banks of water flows etc.). Mentioned properties and other (frost resistance, resistant to moisture of soil and flooding etc.) confirm the importance for the reinforcement of the banks of water flows. Novák et al. (1986) confirm that the stands of Black alder are more resisting to damages and they are resistant to 15–20 days flooding in the vegetation period and to 20–30 days flooding in unvegetation period without damages. In the toe of the banks of water flows have the ability to grow up to the bottom (Novák et al., 1986). Black alder can mitigate the bottom-erosion, too. The subsurface root system reinforcements the gravel layers of the bottom (Kremer, 1995).

Material and methods

The characteristics of the experimental torrent and watershed Hučava

The research was conducted on the torrent Hučava. The experimental watershed Hučava is situated in the center of the geomorphological unit Poľana, subunits Detvianske predhorie and Vysoká Poľana. The watershed Hučava belongs to the watershed of river Slatina and general watershed of river Hron. Torrent Hučava has the hydrologic number of 4-23-03-070 in the Slovak Rebublic. The coefficient of torrent activity of the watershed is $K_b = 0.330$. The closing flow profile is situated near the locality Hrochoťský mlyn at the stream gauge station (523 m above sea level). This closing flow profile has the river log 0.000 km. The torrent Hučava rises at height of 1,285 m a.s.l., between the locations Dudáš and Na mesiac. Total lenght of torrent Hučava (from the riverhead to the closed flow profile) is 14.28 km. The highest point of the watershed is peak Poľana (1,458 m a.s.l.). The lowest point of the watershed is the bottom of closed flow profile (523 m a.s.l.). The absolute difference of altitude the torrent Hučava is 762 m and the absolute difference of altitude the watershed Hučava is 935 m. The mean longitudinal gradient of torrent Hučava is 5.33%. The mean above sea level of the watershed is 922 m. The mean slope of the banks of the watershed is 32.3%. The mean gradient of the thalweg is 6.21%. The forest coverage of the watershed is 82.4%. The average annual precipitation amount in the watershed is 937 mm, average annual evaporation is 409 mm and average annual temperature in the watershed is 4.65 °C.

Methods

On the straight stretch of torrent Hučava were established experimental sections (ES) with lenght of 20 m in different distances from the closed flow profile of the watershed.

Selection of ES was performed taking into account of the conditions along the length of the torrent Hučava. Approximately in the middle of ES were estabilished experimental flow profiles (EP). The orientation of the banks of experimental water flow was designated along a stream (right, left). The selection of ES was taking into account to different number of tree stems of Black alder on the banks of water flow. Through the levelling were measured the geometric characteristics of EP: B (m) – witdh of the flow profile inside the banks, width of the bottom b (m), median depth of the flow profile H (m). Accordig to cross sections of EP were determined partial wetted perimeters O_1 and O_2 and the slopes of the both banks. Through the leveling were determined the values of lungitudinal gradients i (%) on the ES. Input data about EP were determined for BSTEM – Bank Stability and Toe Erosion Model (Simon et al., 2009). Model BSTEM was analyzed in detail in separate paper (Jakubisová, 2011). In terrain were evaluated all of stems of Black alder and were plotted in a situation in scale 1 : 100. Numbers of Black alder stems were determined for all of experimental banks (EB). The areas of EB were calculated as the product of the sides of rectangle with the sides L_{ES} (L_{ES} – lenght of experimental section – 20 m) and Y_{ES} (Y_{ES} – width of the experimental bank from the toe of the bottom to the point of the riparian edge). According to the BSTEM – Bank Stability and Toe Erosion Model was calculated factor of stability Fs for all of the right (22) and all of the left (22) banks of ES (EB), the total number of evaluated banks is of 44. The computed results by BSTEM were compared with recent erosion of the experimental banks in terrain. The effect of root systems to the stability of the banks of water flow was calculated with using of Rip-Root-Reinforcement model (Pollen-Bankhead and Simon, 2009) including the value of the additional cohesion – c_r. The authors deal in this work with the determination of the additional cohesion for various trees, shrubs and plants. The calculated values of Fs – factor of stability of the bank is valuated in three levels: if Fs > 1.3 – the bank is stable, if Fs is from 1.0 to 1.3 – the bank is conditionally stable, if Fs < 1.0 – the bank is unstable. Basic geometric characteristics of the EP are listed in Tables 1a, 1b. The input characteristics for the analyses are listed in Tables 2a, 2b.

Table la. Geometric characteristics of experimental flow profiles

No. EP	Sp [km²]	DFCP [km]	a.s.l. [m]	B [m]	H [m]
1	41.158	0.015	523	10.3	1.15
2	39.048	1.425	554	9.9	1.15
3	38.153	2.020	568	9.7	1.10
4	37.582	2.532	575	9.0	1.00
5	37.307	2.820	582	8.8	1.10
6	36.651	3.310	602	8.7	1.00
7	36.085	3.755	620	8.7	1.05
8	35.304	4.210	625	8.7	1.10
9	34.575	4.600	640	8.5	1.00
10	32.901	5.060	656	8.6	1.05
11	32.207	5.340	662	8.2	1.00
12	31.763	5.745	670	8.0	0.95
13	30.534	6.155	681	7.9	1.00
14	29.100	6.645	695	8.0	0.95
15	27.033	7.100	711	7.8	0.90
16	26.801	7.490	728	7.6	0.90
17	24.552	7.865	740	7.1	0.95
18	23.765	8.235	755	6.8	0.90
19	20.469	8.715	765	6.6	0.85
20	19.431	9.160	775	6.0	0.80
21	12.633	9.620	785	5.2	0.75
22	9.713	10.100	810	3.9	0.65

Table lb. Geometric characteristics of experimental flow profiles

No. EP	S_{pp} [m²]	O_1 [m]	O_2 [m]	O [m]	R [m]	Q_k [$m^3 s^{-1}$]
1	9.2	6.8	4.3	11.1	0.829	17.30
2	8.9	6.7	4.1	10.8	0.824	16.90
3	8.5	6.7	3.7	10.4	0.817	16.41
4	7.8	6.6	3.6	10.2	0.765	16.51
5	7.5	6.3	3.8	10.1	0.743	16.26
6	7.3	6.2	3.5	9.7	0.732	15.66
7	7.0	6.1	3.9	10.0	0.700	15.32
8	6.8	5.6	3.8	9.4	0.723	14.72
9	6.8	5.6	3.9	9.5	0.716	15.33
10	6.7	5.5	3.5	9.0	0.744	15.16
11	6.5	5.3	3.7	9.0	0.722	14.22
12	5.8	5.2	3.5	8.7	0.667	12.19
13	5.7	5.1	3.7	8.8	0.648	11.78
14	5.8	5.3	3.6	8.9	0.652	11.65
15	5.3	5.1	3.2	8.3	0.639	11.17
16	5.1	4.8	3.6	8.4	0.607	10.35
17	4.8	4.6	3.3	7.9	0.623	10.62
18	4.3	4.6	2.9	7.5	0.573	10.13
19	4.1	4.5	2.7	7.2	0.569	9.38
20	3.4	4.2	2.1	6.3	0.540	8.25
21	3.0	3.5	2.1	5.6	0.536	7.06
22	1.9	2.9	1.8	4.7	0.404	3.59

Explanatory notes to Tables 1a, 1b

No. EP, serial number of experimental profile; S_p, watershed area; DFCP, distance from closed profile; B, width of the flow profile inside the banks; H, hight of the flow profile; S_{pp}, flow profile area; O_1, O_2, O, partial and total wetted perimeter; R, hydraulic radius; Q_k, bankfull discharge.

Table 2a. Characteristics to calculation of Factors of safety of experimental banks of the bed

No. EP	Y_{RB} [m]	S_{RB} [m^2]	BA_R [No.]	BA_R/m^2 [No.]	Fs_{RB}
1	2.3	46	20	0.43	8.71
2	2.1	42	14	0.33	5.57
3	2.0	40	18	0.45	8.33
4	1.8	36	8	0.22	4.55
5	1.9	38	12	0.32	5.03
6	1.7	34	12	0.35	7.60
7	1.9	38	7	0.18	3.37
8	2.0	40	15	0.38	6.17
9	1.9	38	14	0.37	7.40
10	1.8	36	9	0.25	3.26
11	1.8	36	7	0.19	4.30
12	1.8	36	10	0.28	5.04
13	1.8	36	4	0.11	1.20
14	1.8	36	12	0.33	6.30
15	1.5	30	3	0.10	1.27
16	1.6	32	5	0.16	2.11
17	1.6	32	9	0.28	3.88
18	1.3	26	6	0.23	3.48
19	1.3	26	7	0.27	4.50
20	1.0	20	2	0.10	0.91
21	1.0	20	1	0.05	0.63
22	0.9	18	1	0.06	0.51

Table 2b. Characteristics to calculation of Factors of safety of experimental banks of the bed

No. EP	Y_{LB} [m]	S_{LB} [m^2]	BA_L [No.]	BA_L/m^2 [No.]	Fs_{LB}
1	2.0	40	11	0.28	6.27
2	2.0	40	8	0.20	3.03
3	1.7	40	7	0.21	3.10
4	1.8	36	15	0.42	9.30
5	1.9	39	10	0.26	5.94
6	1.8	36	6	0.17	1.90
7	2.0	40	12	0.30	6.11
8	1.8	36	14	0.39	9.07
9	2.0	40	4	0.10	1.01
10	1.7	34	10	0.29	4.90
11	1.9	38	9	0.24	3.66
12	1.7	34	8	0.24	3.17
13	1.9	38	7	0.18	2.42
14	1.8	36	9	0.25	4.10
15	1.7	34	9	0.26	4.25
16	2.0	40	8	0.20	3.82
17	1.7	34	3	0.09	1.22
18	1.6	32	7	0.22	2.91
19	1.4	28	4	0.14	1.30
20	1.1	22	1	0.05	0.90
21	1.1	22	1	0.05	0.68
22	0.9	18	1	0.06	0.77

Explanatory notes to Table 2a, 2b
No. EP, serial number of experimental flow profile; RB, right bank of the experimental flow profile; LB, left bank of the experimental flow profile; Y_{RB}, width of the right bank of the bed; S_{RB}, area of the right bank of experimental flow profile; BA_R, number of Black alder on the area of rigth bank; BA_R/m^2, number of Black alder per m^2, on the right experimental bank; Fs_{RB}, factor of safety of the right experimental bank; Y_{LB}, width of the leftt bank of the bed; S_{LB}, area of the left bank of experimental flow profile; BA_L, number of Black Alder on the area of left bank; BA_L/m^2, number of Black Alder per m^2 on the left experimental bank; Fs_{LB}, factor of safety of the left experimental bank.

Results and discussion

The theoretical analysis confirms the close correlation between the number of stems of Black alder per m^2 (No. $BA_R\ m^{-2}$, No. $BA_L\ m^{-2}$) and factor of stability (Fs_{RB}, Fs_{LB}) for right and left banks. The results and statistical testing are listed in Table 3.

From the research is remarkable that between the density of Black alder on the bank of ES and the Factor of stability – Fs of the bank exists close correlation dependence. Analyse of the dependencies between density of stems of Black alder and values of Fs on the experimental banks proves that the calculated values of density of stems of Black alder per m^2 on the right experimental bank are in the interval from 0.05 (EP 21) to 0.45 (EP 3). The values of Factor of stability Fs_{RB} are in the interval from 0.51 (EP 21) – unstable bank to 8.71 (EP 1) – stable bank. From the results of dependence $Fs_{RB} = f$ (No. $BA_R\ m^{-2}$) was derived (Fig. 1) the following equation:

$$Fs_{RB} = -0.7954 + 20.5183\ .\ (\text{No. } BA_R\ m^{-2}) \tag{1}$$

The calculated correlation coefficient for this dependence is $I_{yx} = 0.964$ and determination coefficient is $I_{yx}^2 = 0.930$.

The calculated values of density stems of Black alder per m^2 on the left experimental bank are in the interval from 0.05 (EP 20, EP 21) to 0.42 (EP 4). The values of factor of stability Fs_{LB} are the interval from 0.68 (EP 21) – unstable bank to 9.30 (EP 4) – stable bank. From the results of dependence $Fs_{LB} = f$ (No. BA_L/m^2) was derived (Fig. 2) the following equation:

$$Fs_{LB} = -1.3109 + 23.6240\ .\ (\text{No. } BA_L/m^2) \tag{2}$$

The calculated correlation coefficient for this dependence is $I_{yx} = 0.952$ and determination coefficient is $I_{yx^2} = 0.906$.

These analyses confirm that the density of stems of Black alder has weighty importance for the stability of the banks of water flows. These results were statistically tested. Statistical testing was conducted according to Šmelko (1991). Table 3 lists the regression equations with specific absolute and relative parameters for analyzed dependences, too. Simon and Collison (2002) confirm that the mechanical effect of the trees increase the safety factor of the banks of the bed of water flow about 32%. Wynn and Mostaghimi (2006) confirm that with change of vegetation from herbaceous riparian vegetation to trees was the erosion on the banks of water flows reduced up to 39%.

Table 3. Regression equations and statistical testing of analyzed dependences

Des.	Regression equation	I_{yx}	I_{yx^2}	SR	t	> = <	$t_{0.01}$ (20)
RB	Fs_{RB} = a0 – a1 . (No. BA_R)	0.964	0.930	0.059	16.34	>	2.845
	Fs_{RB} = –0.7954 + 20.5183 . (No. BA_R)						
LB	Fs_{LB} = a0 – a1 . (No. BA_L)	0.952	0.906	0.069	13.80	>	2.845
	Fs_{LB} = –1.3109 + 23.6240 . (No. BA_L)						

Explanatory notes to Table 3

RB, right bank of the flow profile; LB, left bank of the flow profile; $t_{0.01}$, critical value of Student t-distribution; I_{yx}, correlation coefficient; I_{yx2}, determination coefficient; $\mathrm{SR} = \sqrt{\frac{1 - I_{yx^2}}{n-2}}, t = \frac{I_{yx}}{S_R}$.

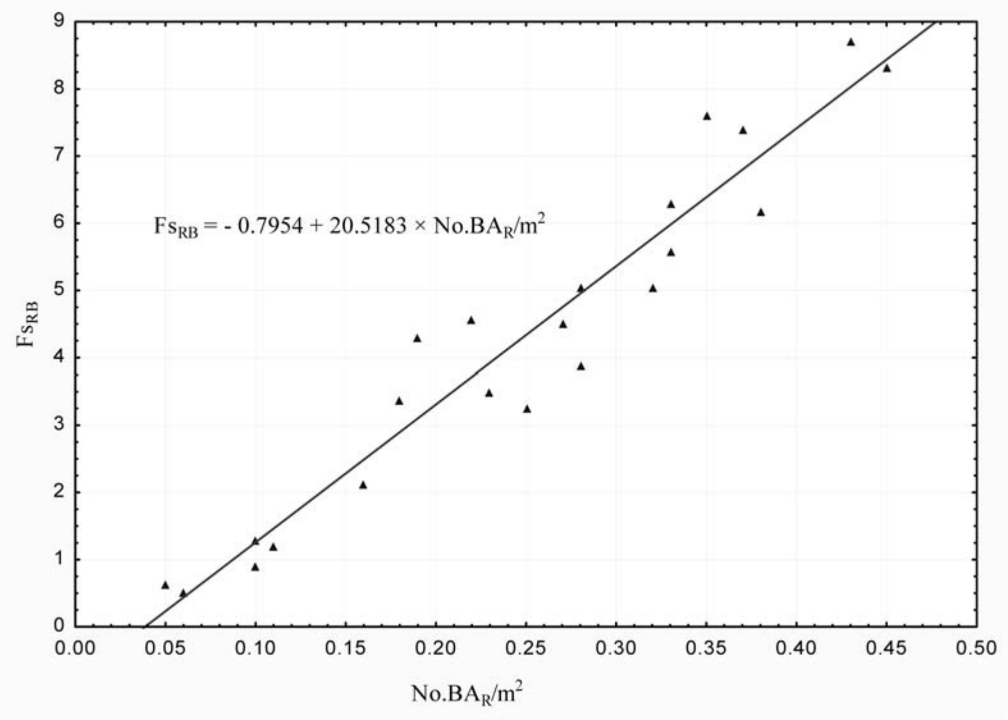

Fig. 1. Dependence between variables No. BA_R/m^2 and Fs_{RB}.

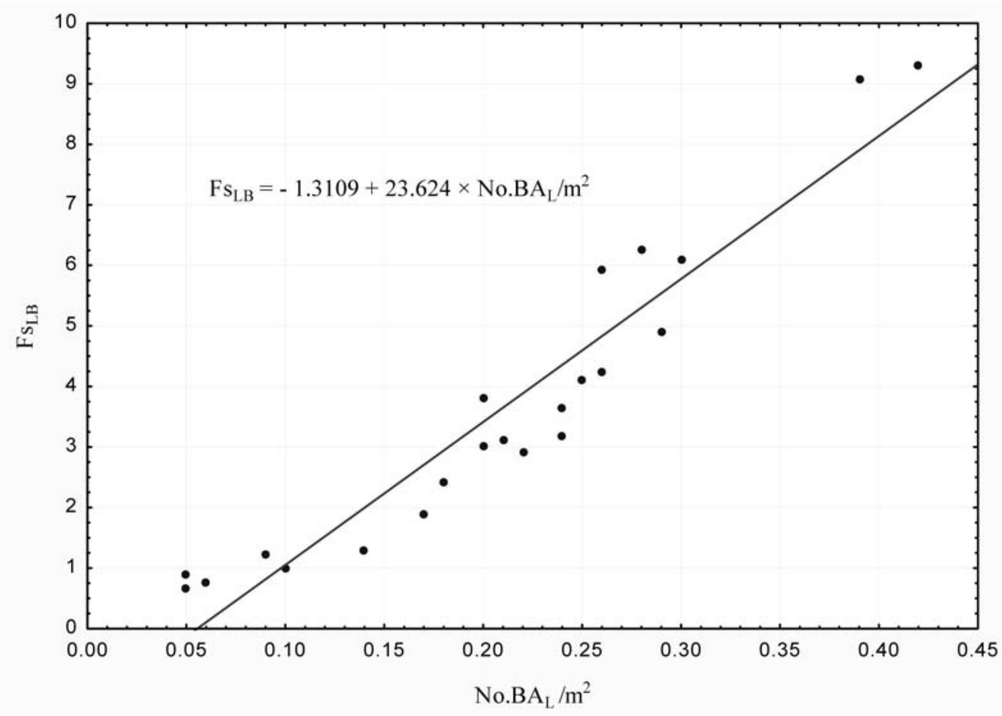

Fig. 2. Dependence between variables No.BA$_L$/m^2 and Fs$_{LB}$.

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Jelša lepkavá (*Alnus glutinosa* (L.) Gaertn.) a jej brehoochranný efekt na brehoch vodných tokov kvantifikovaný metódou BSTEM

Súhrn

Práca sa zaoberá významom jelše lepkavej (*Alnus glutinosa* (L.) Gaertn.) v brehových porastoch bystriny Hučava (CHKO Poľana) v súvislosti so zvyšovaním stability a protieróznej odolnosti brehov koryta. Vegetačné pozdĺžne spevnenia sú z hľadiska ochrany a tvorby krajiny a biodiverzity primárnym – prírode najbližším spôsobom spevňovania brehov vodných tokov. Zvyšujú ich stabilitu a odolnosť proti erózii. Na 22 pokusných úsekoch a profiloch bystriny Hučava (geomorfologický celok Poľana) bolo uskutočnené porovnanie stability a protieróznej odolnosti brehov v závislosti od hustoty kmeňov jelše lepkavej (Alnus glutinosa). Faktor stability brehu koryta Fs bol vypočítaný modelom BSTEM (Bank Stability and Toe Erosion Model). Analýza preukázala tesnú korelačnú závislosť medzi hustotou kmeňov jelše lepkavej na svahoch pokusných úsekov a faktorom stability brehu Fs (korelačný koeficient I_{yx} = 0,964 pre pravé svahy koryta a I_{yx} = 0,952 pre ľavé svahy koryta). Vypočítané výsledky faktora stability Fs korešpondujú s existujúcim poškodením brehov eróziou, ktoré bolo zistené v teréne. Analýza potvrdila význam jelšových porastov pre stabilitu a protieróznu odolnosť brehov vodných tokov. Výsledky boli potvrdené štatistickým testovaním.

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Phytopathological evaluation of woody plants in the Arboretum Včelárska paseka in Kráľová pri Senci, Slovak Republic

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Abstract

Juhásová, G., Meleg, J., Juhás, D., Adamčíková, K., Kobza, M., Ondrušková, E., Kadási Horáková, M. 2013. Phytopathological evalutation of woody plants in the Arboretum Včelárska paseka in Kráľová pri Senci, Slovak Republic. *Folia oecol.*, 40: 41–49.

We presented the results of an evaluation of woody plants health condition in the Arboretum Včelárska paseka in Kráľová pri Senci. The park has an area at about 7 ha with 954 woody plant species (1120 stems) belonging into 73 genera**.** The damage degree of the woody plants was classified according to a 6-point scale, from degree (0) representing healthy trees to 4 and 5 indicating the necessity of immediate sanitation. The classification was specified by appending of numerical evaluation ranging from 1 to 94 and the proposal of a sanitary measure selected from a 47-point list. Woody plants damaged in degrees 1 and 2 (533) were recommended as perspective, woody plants exhibiting damage degree 3 were recommended for further cultivation after an appropriate treatment (117). Not perspective species with damage degrees 4 and 5 were recommended to remove (91). We have found that severe damage of woody plants were caused by fungi of genera *Phellinus, Polyporus, Laetiporus, Schizophyllum, Vuilleminia, Trametes, Daedella, Armillaria.*

Keywords

fungal diseases, phytopathology, woody plants

Introduction

The surveillance of woody plants fitness in important dendrological objects is the aim of several authors in Slovakia and abroad too. These authors have created methods for assessment of health condition and vitality for trees and shrubs in such objects (Krištof, 2002; Pejchal and Šimek, 1997). Old trees were evaluated not only by the visual assessment, but also by instrumental measurements of trees stability (Juhásová et al., 2011a, b; Gáperová, 2009; Juhás and Kobza, 2011). Feriancová and Voskárová (2002) evaluated qualitative and quantitative functions of woody plants.

Phytopathological and enthomological assessment of woody plants, damage degree, vitality and stability were necessary to propose control measures (Richards, 1983; Juhásová et al., 2003; Juhásová et al. 2005, 2006a, b, 2011a; Juhásová and Praslička, 2002; Pastirčáková et al., 2006; Gáper, 1998; Gáperová, 2009; Gáperová and Gáper, 2009; Kováčová et al., 2011).

The presence of causal agents and damage symptoms has been pointed out by several authors also in the context with introduction of new pests associated with introduction of new woody plant species into the existing collections (Příhoda, 1957; Juhásová, 1995–1996; Tomiczek et al., 2005; Juhásová et al., 2005; Zúbrik et al., 2008). Dangerous pathogens and harmful agents are also wood-decaying fungi (Gáper, 1998; Gáperová, 2009). In this contribution we evaluated the current health condition and damage degree of the woody plants in the Arboretum Včelárska Paseka in Kráľová pri Senci. In the former years, a proposal of the revitalisation of this area was elaborated by Ďurišová (2009). The results of horticultural evaluation of the woody plants in this locality were published by Juhásová et al. (2011a).

In 2012, the Arboretum Včelárska Paseka in Kráľová pri Senci will celebrate 80th anniversary. In this occasion, in 2011, the woody plants were inventoried again (Juhásová et al., 2011a), together with evaluation of their health condition and damage degree.

Material and methods

The damage degree of woody plants was assessed. Following parameters were evaluated: woody plant species, stem diameter at 130 cm above the ground ($d_{1.3}$) and diameter at the stem base; overall vitality scaled from 0 to 5.

The six-point scale expressing the health condition and damage degree was elaborated by Juhásová et al. (2011b). Trees without visible damage had pointed by 0 and almost dry trees by 4 and 5. Trees belonging to the degrees 1–3 were recommended for further cultivation. The classification was specified by appending of numerical evaluation ranging from 1 to 94 and the proposal of a sanitary measure selected from a 47-point list.

Damage types – explanatory notes to the Table 3

Dry scaffold branches (2); thinned crown (3); dry top (4); wound on branch (5b); wound on stem (5c); wound on stem base (5d); hollow in stem (5a); open hollow in cm (7); closed hollow (7b), callus on borders (7c); hollow at a branching spot (8); asymmetrical crown (11); slanted tree (11a), flag-shaped habitus (11b); lower stability due to damage to crown (12a), stem (12b), stem base (12c); broken branches (13); broken branches representing a danger for residents´ security (13a); simple branch break (14); branch break with splitting (15); fungi of genera: *Nectria, Schizophyllum, Trametes, Phellinus, Fomes, Armillaria* and similar (24); fungi of genera: *Cytospora, Diplodia, Fusarium, Phoma* and similar (25); leaf blight caused by fungi of genera *Guignardia, Cylindrosporium, Marssonina, Gnomonia, Septoria,* and similar (27a); mildews (28); animal pests (31); *Corythucha ciliata* (36); unhealed wounds, branch snags broken or cut (44); poor quality cutting (48); not appropriately sawed long stubs (48c); forked crown (51); inappropriately branched crown (54); distorted branches (56); threat of crown break (57); cut surfaces only partly covered with callus (73a), cut surface distorted by dry rot (73d); tree growing in close proximity of a wire fence (74c).

Proposal of control methods – explanatory notes to Table 3

Pruning scaffold branches (2); hollows sanitation (4); crown equilibration (5), crown pruning (5a); sanitation of wounds after broken branches (6); recuperation of old cut wounds (7); chemical protection against animal pests (11); proposal for tree removal (13); tree left to die spontaneously (33); assessment of stem stability at the branching spot with an acoustic tomograph FAKOPP 3D (34d).

Samples of damaged woody plants were collected for the pathological investigation in the laboratory. The pathogens diagnosis, their isolation and cultivation were followed according to Ubrizsy (1952), Király et al. (1974), and Brandenburger, (1985). The nomenclature were assessed according to Lizoň and Bacigálová (1998), and the nomenclature for the woody plants by Červenka et al. (1986).

Results and discussion

In 2011 the woody plants in Arboretum Včelárska Paseka in Kráľová pri Senci were inventoried again. We recorded 945 woody plants belonging to 73 genera on the area of 7 ha. The purpose was to provide the background data for a revitalisation project for the Arboretum. Over-aged and damaged trees will be removed and replaced, together with supplementing the collections of new taxons profitable for apiculture. The assessment of the health condition, damage degrees of individual woody plants and the inventory were performed. In the case of multiple-stem trees, each of the stems was evaluated separately. The results have been summarised in Table 1.

Table 1. Damage degree evaluation of trees and shrubs in 2011

Total number of trees	Damage degree					
	0	1	2	3	4	5
1,120	379	376	157	117	61	30

The checklist of woody plants and their damage degree in the Arboretum Včelárska paseka in 2011 are included in Table 2.

The results of the phytopathological assessment in the Arboretum Včelárska Paseka in Kráľová pri Senci and the proposal of control measures are in Table 3.

The Arboretum Včelárska paseka was established 80 years ago. There were planted 23 lime trees during opening ceremony (Bizub, 2011). These lime trees are dominant in the trees collection up to the present. Another notable trees in the collection are *Acer campes-*

*tre, A. platanoides, A. pseudo*platanus, *Evodia danieli, Sophora japonica, Liriodendron tulipifera, Aesculus hippocastanum, Populus nigra* ´Italica´, *Platanus* × *hispanica, Robinia pseudoacacia,* and *Salix fragilis*. Trees and shrubs growing in the park are profitable for apiculture.

In the Arboretum Včelárska Paseka are woody plants of 78 genera. Table 4 presents a part of causal

Table 2. Checklist of woody plants and their damage degree in the Arboretum Včelárska Paseka in 2011

Taxon´s name	Number of trees and shrubs	Damage degree					
		0	1	2	3	4	5
Acer campestre	16	1	12	3			
Acer platanoides	7		5	2			
Acer pseudoplatanus	82	21	42	9	10		
Aesculus hippocastanum	13		5	4	3	1	
Ailanthus altissima	9	8	1				
Amorpha fruticosa	4	4					
Berberis julianae	2	1		1			
Berberis thunbergii	2	1	1				
Berberis thunbergii´Atropurpurea´	2	1	1				
Berberis vulgaris	2		2				
Betula alba	8	3	3	1	1		
Betula pendula	2		2				
Buddlea davidii	3	3					
Buxus sempervirens	4		4				
Caragana arborescens	3		3				
Carpinus betulus	2		1		1		
Cedrus atlantica	4	1	1	1	1		
Chamaecyparis lawsoniana	9					4	5
Chamaecyparis obtusa	71	8	57	1			5
Chamaecyparis pisifera ´Squarosa´	2				2		
Cornus alba	2		2				
Cornus alba ´Sphaeti´	4		1	3			
Cornus mas	13	2	9	2			
Coryllus avellana	8	1	3	4			
Cotoneaster dammeri	12	7	5				
Euonymus europaeus	2	1	1				
Evodia danieli	9	1	5	1	1	1	
Forsythia europaea	4	4					
Forsythia × intermedia	3	3					
Fraxinus excelsior	6	1	1	3	1		
Hibiscus syriacus	2	1	1				
Hypericum calicinum	2	2					
Juglans regia	4		1	1	2		
Juniperus × media	10		8	2			
Juniperus chinensis	3		1		2		
Kerria japonica	2	2					
Laburnum anagyroides	15				2	10	3
Larix decidua	6		1	3	1	1	
Ligustrum vulgare	10	4	5	1			

Table 2. Checklist of woody plants and their damage degree in the Arboretum Včelárska Paseka in 2011 – continued

Taxon´s name	Number of trees and shrubs	Damage degree					
		0	1	2	3	4	5
Liquidambar styraciflua	3	3					
Liriodendron tulipifera	2		2				
Lycium sp.	7	7					
Magnolia sp.	3	1	1	1			
Mahonia aquifolium	6		5	1			
Malus domestica	16	3	6	3	4		
Negundo aceroides	50	7	16	9	15	2	1
Philadelphus coronarius	10	6	4				
Picea abies	5	3		2			
Picea pungens	16	7	5	3	1		
Picea pungens ´Argentea´	5	2	3				
Pinus nigra	7		4	2	1		
Platanus × hispanica	4		3			1	
Platycladus orientalis	56	39	7	1	7	1	1
Populus canescens	8		1	4	2	1	
Populus nigra	3		1	2			
Populus nigra ´Italica´	4			2		2	
Populus simonii	4	4					
Prunus avium	8	1	5	2			
Prunus cerasifera	6	1	4	1			
Prunus domestica	24	6	12	1	1	4	
Prunus laurocerasus	5	2	2	1			
Prunus padus	2		1			1	
Pseudotsuga menziesii	8	2	3	1	2		
Pyracantha coccinea	1	1					
Pyrus communis	9	1	3		3	2	
Rhododendron × hybridum	3		2	1			
Ribes aureum	3	3					
Ribes sanguineum	2	2					
Robinia pseudoacacia	112	53	29	12	8	6	4
Rosa canina	2	1	1				
Salix fragilis	36		1	16	11	7	1
Sambucus nigra	13	5	7	1			
Sophora japonica	29		1	6	12	9	1
Spirea × van Houttei	6	6					
Symphoricarpos albus	4		2	2			
Syringa vulgaris	3		2	1			
Taxus baccata	5	1	4				
Thuja occidentalis	31	25	2	3		1	
Thuja occidentalis ´Malonyana´	13	1	5	5	2		
Thuja plicata	86	79	3	2			2
Tilia cordata	51	4	18	16	10	2	1
Tilia tomentosa	33	4	7	10	7	5	
Ulmus carpinifolia	3			3			

Table 2. Checklist of woody plants and their damage degree in the Arboretum Včelárska Paseka in 2011 – continued

Taxon´s name	Number of trees and shrubs	Damage degree					
		0	1	2	3	4	5
Ulmus laevis	13		6	1			6
Viburnum opulus´Roseum´	2	2					
Weigela floribunda	2	2					

In this table was not possible to present the species which had only 1 exemplar.

Table 3. Results of phytopathological assessment of woody plants in the Arboretum Včelárska Paseka in Kráľová pri Senci in 2011

No. of trees	Taxon´s name	Stem circumference [cm]	Damage degree	Damage types	Control method
1a	*Robinia pseudoacacia*	86	3	2,7a, c (89 × 18 × 5 cm), 11b, 24, 25, 27a, 28, 44	13
2	*Acer campestre*	66 m^2	1	2b, c, 27a, 28	2
3	*Spirea van Houttei*	598 m^2	1	2b, 27a	44
5	*Tilia cordata*	97	2	25, 27a, 48c, 56	5, 7
6	*Tilia cordata*	168	2	5, 8, 25, 27a, 48c	2, 5, 6
7	*Tilia cordata*	127	1	25, 27a, 48c, 56	2, 5, 6, 7
9	*Tilia cordata*	188	2	2, 13, 14, 25, 27a, 36, 52, 54	2
10	*Tilia cordata*	207	3	2, 11b, 13, 14, 25, 27a, 31, 3648c, 73a	2, 5, 6, 7
764	*Negundo aceroides*	46	3	2, 4, 5a, 24, 25, 27a, 54,7 4c (0 cm)	13
765	*Evodia danieli*	182	4	2, 3, 4, 13a, 14, 15, 73d, 74c (105 cm)	
773	*Salix fragilis*	290	2	2, 8, 9a, d (70 × 30 × 10), 11a, b, 12, 51, 57	2, 4

Table 4. Causal agents of woody plants damage in the Arboretum Včelárska paseka in 2011

Genus	Causal agent
Acer	*Didymosporina aceris* (Lib.) Höhn
	Marssonina truncatella (Sacc.) Magn.
	Gloesporium acericolum Allesch.
	Rhytisma acerinum (Pers. ex St. Amans) Fr.
	Sawadea bicornis (Wallr. ex Fr.) Lév.
	Discula campestris (Pass.) Arn.
	Verticillium alboatrum Reinke et Berthold
	Oxyporus populinus (Schumach.: Fr.) Cooke
Alnus	*Melampsoridium alni* (Thuem.) Diet
Aesculus	*Guignardia aesculi* (Pk.) Stewart
	Phyllosticta sphaeropsoidea Ell. et Ev.
	Septoria hippocastani Berk. et Broome
	Erysiphe flexuosa (Peck) U. Braun et S.Takamatsu
	Cytospora ambiens Sacc.
	Nectria cinnabarina (Tode ex Fr.) Fr.
	Vuilleminia comedens (Nees.) Maire

Table 4. Causal agents of woody plants damage in the Arboretum Včelárska paseka in 2011 – continued

Genus	Causal agent
Aesculus	*Phellinus pomacearus* Tode
	Ganoderma resinacearum Boud. in Pat.
	Cameraria ohridella (Deschka) Dimić
Catalpa	*Ascochyta catalpae* Tassi
	Macrosporium catalpae Ell.
	Erysiphe elevata (Burrill) U. Braun & S. Takamatsu
Euonymus	*Microsphaera evonymi* (DC. ex Mérat) Sacc.
	Cytospora evonymi Sacc.
Forsythia	*Ascochyta forsythiae* (Sacc.) Hohn
	Phyllosticta forsythiae Sacc.
Fraxinus	*Cercospora fraxini* (DC.) Sacc.
	Phyllactinia guttata (Wallr. ex Schlext.) Lév.
	Giberella baccata (Wallr.) Sacc.
	Fusarium lateritium Nees.
Juniperus	*Phomopsis juniperova* Hohn.
	Gymnosporangium sabinae Wint.
	Mycosphaerella juniperina (Ell.) Tomilin
	Lophodermium juniperi (Grev.) Darker
Laburnum	*Fusarium lateritium* Nees: Fr.
	Nectria cinnabarina (Tode: Fr.) Fr
	Tubercularia vulgaris Tode: Fr
	Cytospora leucosperma (Pers.: Fr.) Fr.
Magnolia	*Macrosporium cladosporoides* Desm.
	Colletotrichum magnoliae Camara
	Glomerella cingulata (Stan.) Spauld. et Schrenk
	Phyllostica magnoliae Sacc.
Mahonia	*Cumminsiella sanquinea* (Pk.) Art.
	Microsphaera berberidis (DC. ex Mérat) Lév.
Morus	*Mycosphaerella mori* Lév.
	Cylindrosporium mori (Lév.) Krenner
	Cercospora moricola (Pass)
	Septogloeum mori (Lev.) Bri. Et Cav.
	Fusarium lateritium Mori
Picea	*Diplodia piceae* Sacc.
	Cytospora piceae Sacc.
	Lophodermium piceae (Fuckel) Höhn.
Pinus	*Diplodia pinea* Desm. Kickx.
	Sphaeropsis sapinea (Fr.) Dyco and Sutton
	Cenangium ferruginosum Fr.
	Phacidium infestans P. Karsten
	Lophodermium pinastri (Schrad.: Fr.) Chev.
Platanus	*Gnomonia platani* Kleb.
	Gloeosporium platani (Mont) Aut.
	Gnomonia errabunda (Rob.) Auersw
	Discula platani (Peck.) Art.

Table 4. Causal agents of woody plants damage in the Arboretum Včelárska paseka in 2011 – continued

Genus	Causal agent
Platanus	*Cercospora platanicola* Ellis et Ever.
	Mycosphaerella platanifolia (Cooke) FA Wolf
Populus	*Melampsora populina* Kleb
	Drepanopeziza punctiformis Gremmen
	Marssonina brunnea Ell. e Lév
	Uncinula adunca (Wallr.) Lév
	Cryptodiaporthe populea (Sacc.) Butin.
	Cytospora chrysosperma (Pers.: Fr.) Fr.
	Fomes fomentarius (L. ex Fr.) Kickx
	Pholiota destruens Mushroon
	Chondrostereum purpureum (Pers.) *Pouzar Polyporus squamosus* Mushroon
	Trametes hirsuta (Wulfen) Pilát
	Trametes versicolor (L.) Lloyd
	Xanthomonas populi Ridé
Prunus	*Valsa cincta* Fr.
	Cytospora cincta Sacc.
	Coryneum beijerinckii Oud.
	Cryptocline phacidiella (Grove) Arx
Robinia	*Ascochyta robiniae* Sacc. et Speg.
	Cylindrosporium robiniae (Libert) Diedicke
	Camarosporium robiniae (Westend.) Sacc.
	Cucurbitaria elongata (Fr.: Fr.) Grev.
Salix	*Cryptodiaporthe salicella* (Fr.) Petr.
	Dothichiza populea Sacc. & Briard
	Laetiporus sulphureus (Bull. ex Fr.) Murr
Sophora	*Fusarium javanicum* Koorders
	Inonotus hispidus (Bull.) P. Karst
Thuja	*Pestalozzia funerea* Desm.
	Armillaria mellea (Vahl. et Kumm.) Fr.
	Keithia thujina E. J. Durand
Tilia	*Mycosphaerella millegrana* (Cooke) Schröet.
	Leptosphaeria vagabunda Sacc.
	Gnomonia tiliae Kleb.
	Gloeosporium tiliae Oud.
	Laetiporus sulphureus (Bull. ex Fr.) Murr.

The list has been limited to 12 woody plants.

agents of woody plants damage belonging to 34 genera.

Conclusions

Parasitic mycoflora of woody plants in the Arboretum Včelárska paseka had high diversity. The microscopic parasitical fungi caused premature drying of assimilatory organs, branches and also individual trees. The destruction effects of wood-decaying fungi result in various wounds, hollows; the mycelia decompose wood, heartwood included, and decrease the stability of stems and branches. We have confirmed necessity of the causal agents diagnosis of woody plants.

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Fytopatologické hodnotenie drevín v Arboréte Včelárska paseka v Kráľovej pri Senci, Slovenská republika

Súhrn

Predmetom štúdie bolo zhodnotiť zdravotný stav drevín v Arboréte Včelárska paseka v Kráľovej pri Senci. V areáli parku s rozlohou okolo 7 ha rastie 954 drevín (1 120 kmeňov) patriacich do 73 rodov. Stupeň poškodenia drevín bol klasifikovaný 6-bodovou stupnicou (od 0 predstavujúcej zdravé dreviny, po poškodené dreviny ohodnotené stupňom 5, ktoré sú navrhnuté na okamžitú sanáciu). Zdravotný stav drevín bol hodnotený číselnou stupnicou od 1 po 94 a návrh ochranných opatrení 47 bodovou stupnicou. Dreviny ohodnotené stupňom poškodenia 1 a 2 (celkovo 533 drevín) boli odporučené ako perspektívne, dreviny so stupňom poškodenia 3 (117 drevín) boli tiež odporučené na ďalšie pestovanie po realizácii vhodných ochranných opatrení. Neperspektívne dreviny so stupňom poškodenia 4 a 5 (91 drevín) boli navrhnuté na výrub. Najvážnejšie poškodenia na drevinách spôsobovali huby z rodov *Phellinus, Polyporus, Laetiporus, Schizophyllum, Vuilleminia, Trametes, Daedella, Armillaria.*

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Influence of vegetation on surface temperature in urban areas

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Abstract

Keresztesová, S., Rózová, Z. 2013. Influence of vegetation on surface temperature in urban areas. *Folia oecol.*, 40: 50–54.

There is an evident influence of vegetation on surface temperature and microclimate. To prove this statement, and to ensure the comparability, two areas with different ratio of the vegetation and the paved surface in the city of Nitra have been selected. The first area being assessed is almost fully covered by the vegetation; the second one is almost fully paved by the concrete and the asphalt. Both areas have been regularly observed during the period between March and June 2012. Taking into consideration different surfaces (paved area, turf surface, vegetation) as well as the correlation between the distance from the vegetation and its quantity, the surface temperature has been measured by tactile IR thermometer. Remarkable temperature differences between particularly observed spots as well as considerable differences between both researched areas have been noticed.

Keywords

microclimate, surface temperature, urban area, vegetation

Introduction

Shrubs, trees and vegetation cover in general have the importance and bring many benefits without any doubt. Many Slovak and foreign authors were dealing with different functions of vegetation. Classification of the various authors is not the same, but it can be said that the core of the evaluation must remain the same. The different is usually the order of importance of these functions, the hierarchy of the classification and the level of the punctuality (Supuka, 1993).

That is the reason why some of the authors evaluate the functions of vegetation according to different criteria, but none of them opposes that the vegetation is an irredeemable part of the urban organism. The greenery has a soil protecting (Lisický, 1991, Sláviková, 1992), water protecting (Punz, 1984), ecological (Young and Longcore, 2000) or even aesthetic (Supuka, 1993) function. The vegetation even creates some kind of spatial frame for social contacts so it bears even social function. In addition to the aforementioned attributes, greenery has as well as microclimatic function as it positively affects the local microclimate (Jasenka, 2011). The influence of the vegetation on the microclimate is more evident in tropical conditions, with the extreme climate and more evident differences, as Spangenberg et al. (2009) cite. The differences of the temperature of the surfaces closer to the greenery and the wholly paved surfaces without any greenery can be even up to 12 °C. In our climate conditions the authors mention smaller but evident differences between the temperature of the surrounding air of the streets with and without trees, from 0.5 °C (Grunow, 1932) up to 2.1 °C (Reháčková and Pauditšová, 2006).

The aim of the paper is to define the differences in the surface temperatures and in the relative air humidity between the spaces with plenty of greenery (City park – Mestský park) and the spaces without any greenery (space in front of the shopping mall OC Mlyny – OC Mlyny) in the period when the differences between the observed months could be quite different (from the beginning of frondescence up to the full leaf period).

Material and methods

The entries of the microclimate, such as the relative air humidity and the surface temperature, have been selected at two places in the intravilan of Nitra town from March to June 2012.

The observed areas have an allocation of 50 × 50 m. They have been selected according to very different conditions regarding to quantity and the distribution of greenery they are having.

Locality n. 1 (Fig. 1) Mestský park (City park) was selected as a representative sample for an area that is almost fully covered by greenery, with the greenery cover of 90–100%.

All elements of vegetation with all kinds of texture and structure in all of the etages are being presented on this locality. This locality has been compared with the locality n. 2 in front of the shopping mall OC Mlyny (Fig. 2). This is the area with different conditions created by the paved surface and the higher density of buildings surrounding this locality, mostly. There is minimum vegetation mostly represented by alley of de-

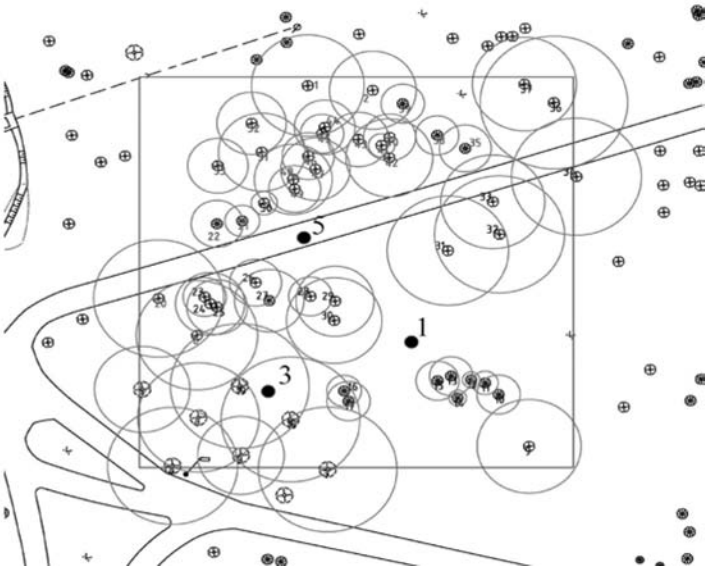

Fig. 1. Locality n. 1 Mestský park.

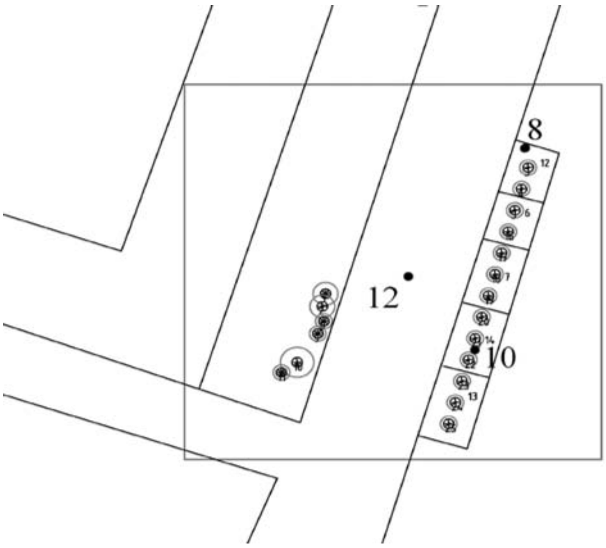

Fig. 2. Locality n. 2 OC Mlyny.

ciduous trees (*Betula pendula* Roth) with the rare subcanopy of evergreen shrubs *(Taxus baccata* L.). Both of the localities contain the grass area being in a different ratio with the built-up area and with the area with greenery.

Both of the localities were regularly monitored always in the same week of the month, starting with the second week of the month, from Monday, always at 8.00 am, 3.00 pm and 10.00 pm. The data about the relative air humidity and the surface temperature of the localities being monitored, were recorded each time at the same spots – sublocalities (Locality n. 1: spot n. 1 – spot with a grass surface, spot n. 3 – vegetation cover, spot n. 5 – paved surface; Locality n. 2: spot n. 8 – spot with a grass surface, spot n. 10 – vegetation cover, spot n. 12 – paved surface) with 5-time repeated frequency, that was later averaged. The data were measured with an infrared thermometer Testo 845 and statistically processed by the Statgraphics program by using the single factor (one way) analyses of ANOVA diffusion and LSD test.

Results and discussion

After testing the correlation of the sublocalities with surface temperatures of the monitored areas it has been found that there is not such the remarkable correlation. Based on this fact it can be alleged that the distance of the sublocality from the vegetation doesn´t have a crucial influence on the general relative air humidity (Fig. 3) or the differences are so minimal that the distance doesn´t affect the surface temperature of the monitored sublocalities at the same time (Fig. 4).

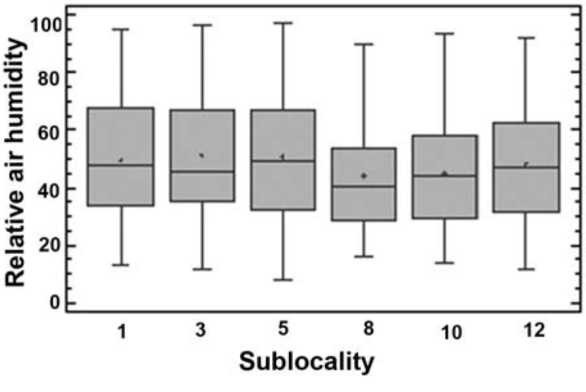

Fig. 3. Correlation of the sublocality and relative air humidity.

Arising from the sequential evaluation it can be stated that the general presence and the structure of the vegetation elements in the ratio to the built-up elements have the greater influence on the microclimate than the composition of these elements in the area. Such the ratio influences the microclimate remarkably.

The difference between the relative air humidity at the monitored period of two observed localities is remarkable – the relative air humidity at the loc. 1 Městský park (City park) is 6% higher than the relative air humidity at the loc. 2 OC Mlyny (Fig. 5).

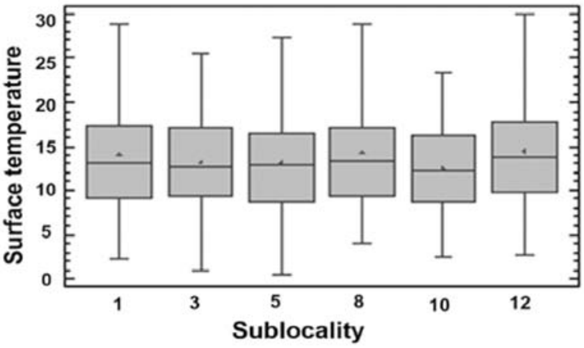

Fig. 4. Correlation of sublocality and surface temperature.

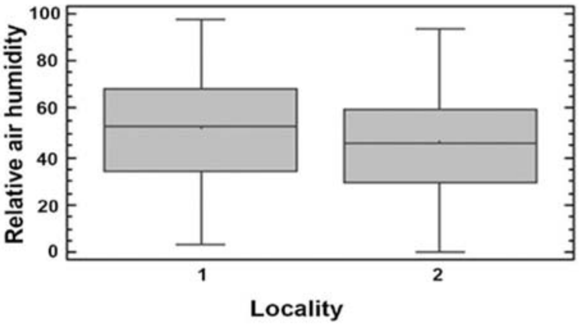

Fig. 5. Differences between the localities in relative air humidity.

The influence of the vegetation on the overall surface temperature in the monitored period is evident; the area with a higher proportion of greenery (Městský park) is 1 °C cooler comparing the area where the proportion of the greenery is minimal (OC Mlyny) (Fig. 6).

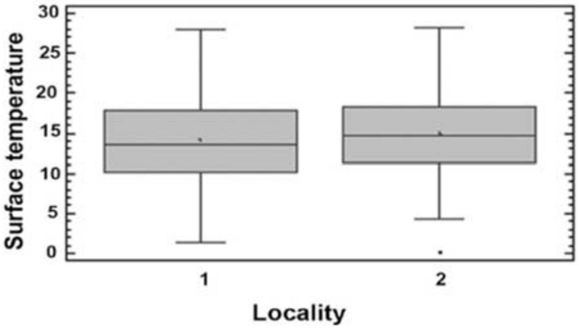

Fig. 6. Differences between the localities in surface temperatures.

The hypothesis that a particular phase of the day markedly affects the microclimatic conditions on both of the monitored areas was approved. Dealing with the relative air humidity, the air humidity at the Loc. 1 –

Mestský park (City park) is the highest in the morning, with 63% of the relative air humidity being measured. The lowest value, 20% lower than in the morning (41%) has been reflected during the lunch time. The value measured during the evenings was just a bit lower than the value measured during the mornings (61%) (Fig. 7).

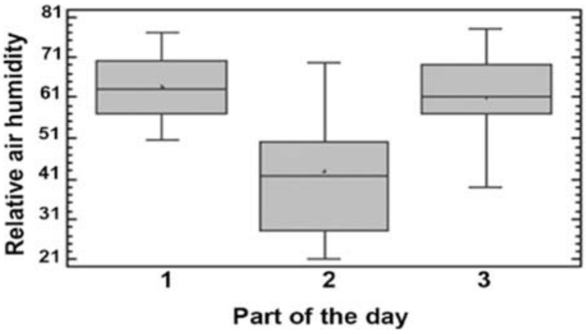

Fig. 7. Differences in relative air humidity between the phasis of the day.

The microclimatic data dealing with the relative air humidity being determined are in correlation with the changing temperature during the day – the surface temperature is higher thus the relative air humidity is lower. The surface temperature of the Loc. 1 Mestský park (City park) was the lowest one in the morning, with the average temperature of 7 °C being measured. In opposite, the highest average surface temperature reached 14 °C during the noon time. The average night surface temperature reached 9 °C (Fig. 8).

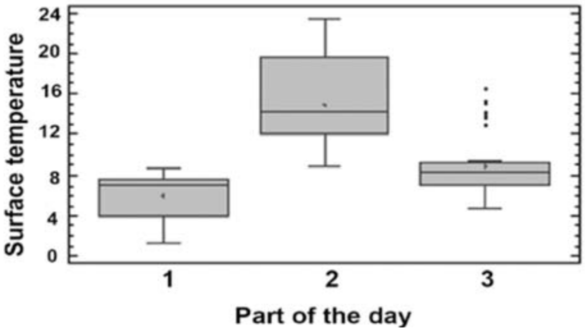

Fig. 8. Differences in surface temperature between the phasis of the day.

Similarly to the Loc. 1, the lowest average relative air humidity at the Loc. 2 – OC Mlyny, was reached during the noon time (36%), while the average relative air humidity during the morning and the evening was quite similar (50%) (Fig. 9).

Dealing with the average surface temperature in the monitored period, same as at the locality of Mestský park (City park), similarly at the locality of OC Mlyny, the highest value was reached during the noon time (18 °C). There were not such the evident differences between the average surface temperature being measured in the evening and the morning. The average surface temperature measured in the morning was 12 °C, while the average surface temperature measured in the evening was 13 °C (Fig. 10).

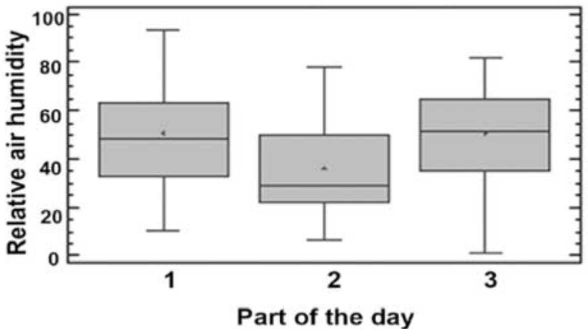

Fig. 9. Differences in relative air humidity between the phasis of the day.

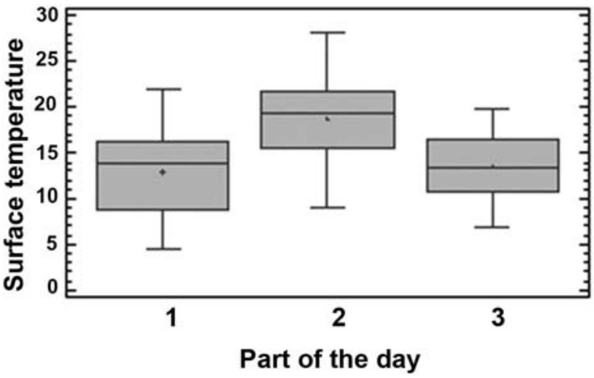

Fig. 10. Differences in surface temperature between the phasis of the day.

At the Loc. 1, same as at the Loc. 2, a relation between the diminishing relative air humidity and the increasing surface temperature was approved.

We may allege that even in the period at the very beginning of the vegetation ascend, with not so contrasting temperature amplitudes, there is a remarkable influence of vegetation on the surface temperature and the relative air humidity.

We expect that during the summer time, when the intensity of the solar radiance is higher, the differences will be even more evident. However, we may resume that the microclimatic function of the vegetation was approved and we can enhance the microclimatic conditions of the urbanized areas with correct landscaping.

Acknowledgement

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Vplyv vegetácie na teplotu povrchov v mestskom prostredí

Súhrn

Práca bola zameraná na štúdium mikroklimatických rozdielov v závislosti od množstva zelene, kde boli počas mesiacov marec – jún 2012 porovnávané dve plochy – plocha s vysokým zastúpením zelene a prevažne spevnená plocha s minimom zelene. Skúmali sa rozdiely v relatívnej vzdušnej vlhkosti a povrchovej teplote rôznych povrchov (tráva, porast, spevnená plocha), kde bol ešte sledovaný aj vzťah medzi pomerom vegetácie a spevnenej plochy ako aj vzťah medzi relatívnou vzdušnou vlhkosťou a povrchovou teplotou skúmaných povrchov. Zaznamenal sa preukázateľný vplyv vegetácie na miestnu mikroklímu, a to so zvyšujúcim sa množstvom zelene sa znižuje teplota povrchov ako aj sa zvyšuje relatívna vzdušná vlhkosť.

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Evaluation of woody species in the selected parts of south-western Slovakia

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Abstract

Kováčová. I., Benčať, T. 2013. Evaluation of woody species in the selected parts of south-western Slovakia. *Folia oecol.,* 40: 55–64.

The research was performed in the city parks of Želiezovce and Levice which are situated in the dry and warm climatic region of the south-western part of Slovakia. Inventory of woody plants was done in period of May–September 2011. In the city park Želiezovce were found totally 98 woody species, of which 80% were broadleaves and 20% were coniferous species. The proportion of indigenous species reached 45%, in the case of introduced species it was 55%. In the city park Levice were found totally 111 woody species, of which 78% were broadleaves and 22% were coniferous species. The proportion of indigenous species reached 41%, in the case of introduced species it was 59%. In both city parks dominate the introduced species together with broadleaves species. There are presented also the selected growth parameters of significant woody species individuals. The two protected woody species were found – *Quercus pedunculiflora* K. Koch in the city park Levice and *Taxodium distichum* (L.) Rich in the city park Želiezovce.

Key words

city parks, inventory, protected species, tree parameters, woody species

Introduction

Biodiversity of vegetation is our biggest and the least appreciated wealth. Lost species cannot be replaced but the losses may be delayed. Attempt to save biodiversity itself is useful (Križová et al., 2007). One of the tools is establishment and maintenance of green urban objects in the cities. Park and garden design is a form of art that developed because of the need of higher society to represent itself in every culture. History of park and garden art goes back to the very beginning of civilization. The development can be traced since ancient times (Supuka and Feriancová, 2008).

The problem of woody species within park objects is mentioned by many authors. Hermann (1993) deals with the park tree species in Berlin City. Schipperijn et al. (2009) investigate city greenery in Denmark. LaPaix and Freedman (2010) mention city parks composition within Halifax region (in Canada). Other authors (Gómez-Muňoz et al., 2009; Gulezian and Nyberg, 2010; Chiesura, 2004) emphasize the importance of urban parks and decorative trees for sustainable development of cities.

Aim of our research was to perform a detailed inventory of woody species in Želiezovce city park and Levice city park as they are considered to be historically and dendrologically very valuable park objects of Slovakia, in regard to introduced tree species. Part of the research was also dedicated to the measurement of dendrometric parameters of significant individual trees.

Material and methods

The research was realized within the localities of Želiezovce city park (48º02' N, 018º39' E) and Levice city park (48º12' N, 018º36' E) in south-western Slovakia. Inventory of woody species was performed in the park objects during May–September 2011. Parameters of significant woody plants were determined both for introduced and indigenous species. The most important were the trees with great dimensions. The collection of dendrometric data was oriented mainly on detection of the trunk girth (cm) and tree height (m), and also other qualitative parameters as horticulture value, health and vitality of the selected woody species according to Machovec (1987) and Pejchal (1996), modified by Modranský (2012). The soils were classified according to Bedrna et al. (2000). Plant taxa names are given according to Marhold and Hindák (1998) and cultivars according to Krüssmann (1984, 1985, 1986a, 1986b). Species origin is classified according to Gojdičová et al. (2002).

Ecological characteristics of the study area

The studied plots are located in the south-eastern part of Nitra region (Levice district, western Slovakia). Most of the district area is created with the Danube Lowland.

The localities are situated in the dry and warm climatic region with the mean annual temperature about 9.5 ºC and average annual precipitation 550–700 mm (Anonymus, 2005). The temperature and precipitation are connected with absolute altitude. The mountains in the north and north-east represent natural barrier against cold winds and significantly influence climatic conditions.

Within explored area predominate loamy and clay-loam soils. In the warmest parts of the area were from loess derived the luvisols (41.3%) and chernozems (26.2%) and along rivers there are eutric fluvisols (17.5%), mollic fluvisols (4.6%) and planosols (3.1%), (Anonymus, 2005). It is the territory that enables to the crops, even thermophilic ones, to grow in very favourable soil and climatic conditions. The vegetation belongs to the area of the middle-European and east-European thermophilic and xerophyte flora. Forest percentage is quite low, just 18.7%. Large forests occur within the adjacent Štiavnické vrchy Mts and Krupinská planina (plain). The fragments of floodplain forests may be found along the rivers Hron, Ipeľ, Krupinica, Sikenica and other smaller streams. On the warm southern slopes can be seen the introduced Black Locust stands (Anonymus, 2005).

In Želiezovce city park occurs floodplain forest with domination of Fluvisols and plant species *Aegopodium podagraria* Moench. Through the park flows the Vrbovec stream with the groundwater level depth of 2–3 m. In the soil profile can be seen small admixture of the quartz fragments. The litter fall is only sporadic. In Levice city park occurs the Fluvisols as well, with occurrence of small stones in profile. Nowadays in the territory of both park objects do not occur floods.

Results and discussion

The city park Želiezovce as a protected territory (3rd degree of protection) covers an area of 8 ha. Creation of the park dates back to the year 1875. It was established by Esterházy family as a free-style landscape park. The family built here a baroque castle in 1780. Many years Želiezovce city park was called Park of Franz Schubert in honour of important Austrian music composer. The park was created on the site of originally oak forest and it is one of the greatest historic parks of Slovakia accessible to the public.

In the park we recorded 1,123 specimens of woody species; 1,001 specimens belong to broadleaved and 122 specimens belong to coniferous taxa. According to the origin of woody species, we recorded 577 taxa of introduced species and 546 taxa of autochthonous tree species. Among the most remarkable trees in the park there are two specimens of *Quercus robur* L. considered as the oldest trees in the park (300–350 years old). Another remarkable tree is *Tilia cordata* Mill. (approximately 300 years old). It is followed by the group of introduced *Platanus* × *acerifolia* (Aiton) Willd. (200–250 years old). In the park may be also found alochthonous *Taxodium distichum* (L.) Rich which is the highest and the oldest protected bald cypress tree in Slovakia with the height of 24 m (approximately 200 years old). The tree comes from south-eastern part of the USA (Anonymus, 2010). Generally the trees in the park are in good condition. The most attention we paid to the dendrometrically significant trees (Table 1). We can conclude that the tree individuals with remarkable girth and height have average values of their horticulture value, health and vitality.

Inventory of woody species including growth parameters of the selected trees and their orchard value, health and vitality is shown in the Table 2. Based on the results of the field research we can conclude that in Želiezovce city park there are nowadays 98 woody species; 80% (78 species) are broadleaved and 20% (20 species) are conifers. From the number of 98 woody species, 45% (44 species) are autochthonous and 55% (54 species) are introduced tree species. Representation of the selected taxa groups of woody species in Želiezovce city park is shown in Figure 1.

In Želiezovce city park Benčať (1982) recorded woody species such as *Picea pungens* Engelm. cv. Argentea, *Thuja occidentalis* L., *Buxus sempervirens* L., *Aesculus hippocastanum* L., *Catalpa bignonioides* Walt., *Gleditsia triacanthos* L., *Sophora japonica* L., *Syringa vulgaris* L., *Celtis australis* L., *Fraxinus excelsior* L. cv. Nana, *Quercus rubra* L., *Tilia tomentosa* Moench and *Pseudotsuga menziesii* (Mirb.) Franco cv. Viridis, that were also recorded in 2011. Similarly like Benčať (1982) we also recorded robust individuals of the woody species *Gymnocladus dioicus* (L.) K. Koch and *Taxodium distichum* (L.) Rich. Benčať (1982) ex-

Table 1. Selected parameters of significant tree species individuals found in the studied city parks ($x \pm s_x$)

City park	Taxon	Origin	Girth	Height	Orchard	Health	Vitality
			[cm]	[m]	value		
Želiezovce	*Ginkgo biloba* L.	Introduced	188	22.5	5	5	5
	Gymnocladus dioicus (L.) K. Koch	Introduced	275	26.5	4	4	4
	Platanus × *hispanica* Münchh.	Introduced	300–418	38–46	3–5	3–5	3–5
	(12 trees evaluated)		348 ± 37	–	–	–	–
	Quercus robur L.	Native	338–570	18.5–29.5	3–5	3–5	3–5
	(3 trees evaluated)		445±117	25±6	4±1	4±1	4±1
	Rhamnus catharticus L.	Native	84	11.0	5	4	4
	Swida sanguinea (L.) Opiz	Native	67	12.5	5	3	3
	Taxodium distichum (L.) Rich	Introduced	387	24.0	5	5	5
	Ulmus laevis Pall.	Native	276	24	5	4	3
Levice	*Fagus sylvatica* L.	Native	283	28	1	2	2
	Negundo aceroides Moench	Introduced	197	10	3	4	4
	Platanus occidentalis. L.	Introduced	446	32	1	2	2
	Quercus pedunculiflora K. Koch	Native	450	28	2	3	3
	Quercus robur L.	Native	412	30	1	1	1
	Robinia pseudoacacia L.	Introduced	255.5	22	4	4	4
	Sambucus nigra L.	Native	131	9.5	1	2	2

Table 2. List of woody species in studied city parks

Taxon name	City parks	
	Želiezovce	Levice
	Number of specimens	
Abies alba Mill.	–	1
Abies concolor (Gord.) Lindl.	2	–
Acer campestre L.	134	6
Acer platanoides L.	106	142
Acer platanoides L. cv. Atropurpurea	–	2
Acer pseudoplatanus L.	49	28
Acer saccharinum L.	1	–
Acer tataricum L.	3	–
Aesculus hippocastanum L.	61	23
Ailanthus altissima (Mill.) Swingle	35	45
Alnus glutinosa (L.) Gaertn.	3	–
Aucuba japonica cv. Variegata	–	1
Berberis julianae Schneid.	–	1
Berberis thunbergii DC.	–	1
Berberis thunbergii cv. Atropurpurea	–	2
Betula pendula Roth	15	17
Buxus sempervirens L.	2	6
Buxus sempervirens L. cv. Aureovariegata	–	2
Buxus sempervirens L. cv. Variegata	2	–
Caragana frutex (L.) K. Koch	–	1
Carpinus betulus L.	1	1
Carpinus betulus L. cv. Pendula	–	1
Castanea sativa Mill.	–	1

Table 2. List of woody species in studied city parks – continued

Taxon name	**City parks**	
	Želiezovce	**Levice**
	Number of specimens	
Catalpa bignonioides Walt.	3	22
Celtis australis L.	37	1
Celtis occidentalis L.	–	1
Cerasus avium (L.) Moench	5	5
Cerasus serrulata (Lindl.) London	1	1
Chamaecyparis lawsoniana (Murrai) Parl.	–	20
Cornus mas L.	1	–
Corylus avellana L.	24	6
Corylus colurna L.	–	2
Cotoneaster dammeri C. K. Schneid.	–	1
Cotoneaster elegans Rehd. & Wils.	4	–
Cotoneaster henryanus C. K. Schneid.	–	1
Cotoneaster horizontalis Decne.	–	2
Cotoneaster microphyllus Wall. ex Lindl.	–	2
Cotoneaster salicifolius Franch. var. henryanus	2	–
Cotinus coggygria Scop.	–	1
Crataegus monogyna Jacq.	2	1
Cryptomeria japonica (L. f.) D. Don	–	1
Deutzia scabra Thunb.	4	–
Elaeagnus angustifolia L.	2	2
Euonymus europaeus L.	5	2
Euonymus fortunei (Turcz.) Hand. – Mazz.	–	1
Euonymus japonicus Thunb. cv. Albovariegatus	1	–
Fagus sylvatica L.	5	1
Fagus sylvatica L. cv. Atropurpurea	–	3
Forsythia × intermedia Zab.	–	3
Forsythia suspensa (Thunb.) Vahl.	–	2
Forsythia viridissima Lindl.	3	–
Fraxinus angustifolia Vahl	1	–
Fraxinus excelsior L.	18	17
Fraxinus nigra Marsh.	6	–
Fraxinus ornus L.	–	4
Ginkgo biloba L.	1	–
Gleditsia triacanthos L.	4	1
Gymnocladus dioicus (L.) K. Koch	37	–
Hedera helix L.	On several trees	On several trees
Hypericum patulum Thunb.	–	1
Juglans regia L.	7	1
Juniperus communis L.	1	–
Juniperus conferta Parl.	1	–
Juniperus horizontalis Moench	–	5
Juniperus sabina L.	–	8
Juniperus squamata Buch. – Ham. ex D. Don var. fargesii	–	2
Juniperus virginiana L. cv. Grey Owl	13	3

Table 2. List of woody species in studied city parks – continued

Taxon name	**City parks**	
	Želiezovce	**Levice**
	Number of specimens	
Kerria japonica (L.) DC.	1	3
Koelreuteria paniculata Laxm.	3	15
Larix decidua Mill.	–	3
Laurocerasus officinalis M. Roem.	4	Hedge
Ligustrum ovalifolium Hassk.	–	1
Ligustrum ovalifolium Hassk. cv. Aureum	–	7
Ligustrum vulgare L.	–	Hedge
Lonicera japonica Thunb. cv. Aureo-reticulata	–	1
Lonicera nitida Wils.	–	1
Lonicera periclymenum L.	–	1
Lonicera xylosteum L.	–	1
Lonicera sp.	1	–
Magnolia sp.	–	10
Mahonia aquifolium (Pursh) Nutt	–	4
Malus domestica Borkh.	–	1
Malus × *purpurea* (Barbier) Rehd.	–	1
Negundo aceroides Moench	51	12
Parthenocissus quinquefolia (L.) Planch.	–	2
Paulownia tomentosa (Thunb.) Steud.	5	–
Padus avium Mill.	12	12
Pentaphylloides fruticosa (L.) O. Schwarz	–	1
Phellodendron amurense Rupr.	–	1
Philadelphus coronarius L.	10	9
Physocarpus opulifolius (L.) Maxim.	–	2
Physocarpus opulifolius (L.) cv. Diabolo	–	1
Physocarpus opulifolius (L.) cv. Luteus	–	1
Picea abies (L.) H. Karst.	1	8
Picea glauca (Moench) Voss. cv. Conica	–	2
Picea omorika (Pančic) Purk.	–	2
Picea orientalis (L.) Link.	4	–
Picea pungens Engelm.	5	3
Picea pungens Engelm. cv. Argentea	1	1
Pinus mugo Turra	–	1
Pinus nigra Arnold	3	34
Pinus rigida Mill.	1	–
Pinus sylvestris L.	7	2
Pinus wallichiana A. B. Jacks.	–	1
Platanus × *acerifolia* (Aiton) Willd. (in the valuated group of 12 pieces 9 healthy and 3 damaged)	43	–
Platanus occidentalis L.	–	12
Platycladus orientalis (L.) Franco	2	6
Populus sp.	–	6
Populus alba L.	1	–

Table 2. List of woody species in studied city parks – continued

Taxon name	City parks	
	Želiezovce	**Levice**
	Number of specimens	
Populus balsamifera (F. Michx.) A. Gray	1	–
Prunus cerasifera Ehrh. cv. Atropurpurea	3	4
Prunus cerasifera, subsp. cerasifera	–	4
Prunus domestica L.	1	–
Prunus spinosa L.	2	–
Pseudotsuga menziesii (Mirb.) Franco	1	4
Ptelea trifoliata L.	1	–
Pyracantha coccinea Roem.	–	Hedge + 10
Pyrus pyraster (L.) Burgsd.	1	–
Quercus pedunculiflora K. Koch	2	2
Quercus robur L.	23	1
Quercus rubra L.	2	–
Rhamnus catharticus L.	1	–
Rhododendron sp.	–	1
Rhus typhina L.	–	6
Ribes sp.	–	1
Robinia pseudoacacia L.	105	13
Rosa sp.	–	5
Salix matsudana Koidz. cv. Tortuosa	–	6
Salix fragilis L.	3	–
Salix × *rubra* Huds.	–	2
Salix sepulcralis Simonk.	2	–
Sambucus nigra L.	30	7
Sarothamnus scoparius (L.) K. Koch	–	1
Sophora japonica L.	1	1
Sorbus aria (L.) Crantz. cv. Lutescens	–	1
Sorbus aucuparia L.	–	1
Spiraea douglasii Hook.	2	1
Spiraea media F. Schmidt	–	1
Spiraea × *vanhouttei* (Briot) Zab.	2	2
Swida alba L.	–	16
Swida sanguinea (L.) Opiz	11	–
Symphoricarpos albus (L.) S. F. Blake	–	6
Syringa vulgaris L.	5	3 bunches + 11
Syringa sp.	1	8 bunches + 14
Tamarix sp.	–	–
Taxodium distichum (L.) Rich	5	–
Taxus baccata L.	21	11
Thuja occidentalis L.	25	13
Thuja occidentalis L. cv. Aurea	–	2
Thuja occidentalis L. cv. Globosa	–	1
Thuja occidentalis L. cv. Douglasii Aurea	–	1
Thuja plicata D. Don	20	3
Thuja plicata D. Don cv. Zebrina	–	1

Table 2. List of woody species in studied city parks – continued

Taxon name	City parks Želiezovce	 Levice
	Number of specimens	
Tilia cordata Mill.	10	5
Tilia × euchlora K. Koch	8	1
Tilia × europaea L.	10	–
Tilia platyphyllos Scop.	–	23
Tilia platyphyllos Scop. subsp. platyphyllos	13	19
Tilia platyphyllos Scop. cv. Rubra	18	–
Tilia tomentosa Moench	8	–
Torreya taxifolia Arnott		1
Ulmus carpinifolia Gleditsch.	18	–
Ulmus laevis Pall.	8	5
Viburnum lantana L.	5	14
Viburnum × pragense Vik	6	20
Viburnum rhytidophyllum Hemsl.	14	13
Weigela florida Bge. A. DC.	–	2

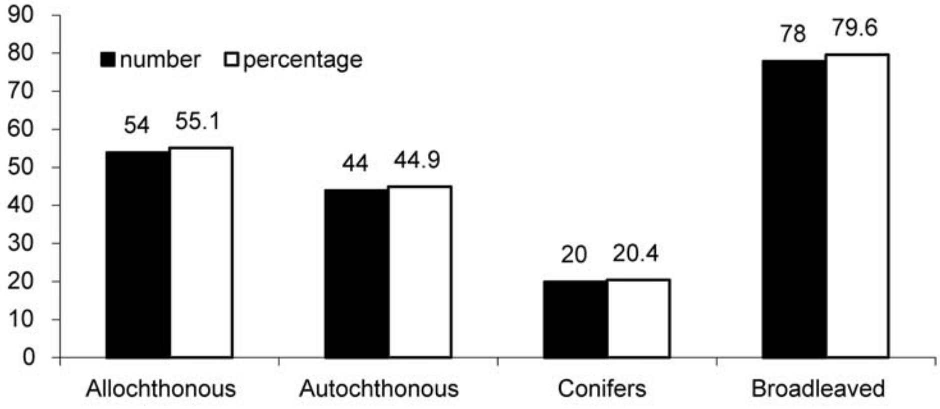

Fig. 1. Representation of selected taxonomic groups of woody species in the city park Želiezovce.

cept that also recorded species such *Pinus nigra* Arnold, *Chaenomeles speciosa* (Sweet) Nakai, *Juglans nigra* L., *Aesculus parviflora* Walt., *Corylus colurna* L., *Cotinus coggyria* Scap. and *Platanus orientalis* L., that we did not recorded in 2011 anymore.

Levice city park consists of an old and a new part. Historic part covers an area of 1.74 ha and it was created in 1879 (Tolnai, 2006). In this part can be found protected autochthonous tree *Quercus pedunculiflora* K. Koch. The old part is the source of valuable woody species, however, it is rather neglected.

The new part covers an area of 3.4 ha and it was created in 1997. Here may be seen the statue of M. R. Štefánik. Another attraction is a bridge over an artificial lake with a fountain and terrace for people. The new part is nowadays regularly maintained.

In both parts of Levice city park that are free accessible to the public there are growing altogether 880 specimens of woody species; 456 specimens belong to introduced trees and 424 specimens are autochthonous. Introduced woody species are represented by species such as *Negundo aceroides* Moench, *Platanus occidentalis* L., *Robinia pseudoacacia* L. and autochthonous species are represented e.g. by *Fagus sylvatica* L., *Sambucus nigra* L., *Quercus pedunculiflora* K. Koch and *Quercus robur* L. The most attention we paid to the dendrometrically significant trees (Table 1). We can state that the tree individuals with remarkable girth and height have average values of their garden value, health and vitality. Rather worse health was recorded e.g. for *Robinia pseudoacacia* L. On the other hand, specimen of *Quercus robur* L. (approximately 200 years old) is an example of longevity and resistance with relatively good health.

Inventory of woody species including growth parameters of the selected trees and their garden value, health and vitality is shown in the Table 2. We can conclude that in Levice city park there are growing today altogether 111 woody species; 78% (87 species) are broadleaved and 22% (24 species) are conifers. From the number of 111 woody species, 41% (46 species) are autochthonous and 59% (65 species) are introduced tree species. Representation of the selected taxa groups of woody species in Levice city park is shown in Figure 2.

In Levice city park Benčať (1982) recorded woody species such as *Pinus strobus* L., *Pinus cembra* L., *Pinus ponderosa* Dougl. ex Laws., *Iberis sempevirens* L., *Chaenomeles speciosa* (Sweet) Nakai, *Polygonum baldschuanicum* Regel., *Cercis siliquastrum* L., *Gymnocladus dioicus* (L.) K. Koch, *Hydrangea arborescens* L., *Cephalotaxus harringtonia* cv. Fastigiata, *Santolina chamaecyparissus* L., *Stranvaesia davidiana* Decne. and *Jasminum nudiflorum* Lindl., that we did not recorded in 2011 anymore.

In Želiezovce and Levice city parks we recorded together 28 significant trees with remarkable dendrometric parameters that are shown in Table 1. From this number, 21 trees were recorded in Želiezovce city park and 7 ones in Levice city park. In Želiezovce city park, very valuable was the group of 12 trees of *Platanus × acerifolia* (Aiton) Willd. and three specimens of *Quercus robur* L.

Regarding to the origin of woody species, in Želiezovce park were recorded four native tree species interesting with their growth parameters (*Quercus robur* L., *Rhamnus catharticus* L., *Swida sanguinea* (L.) Opiz, *Ulmus laevis* Pall.) and four interesting introduced species (*Ginkgo biloba* L., *Gymnocladus dioicus* (L.) K. Koch, *Platanus x acerifolia* (Aiton) Willd., *Taxodium distichum* (L.) Rich). In Levice city park there were found four significant specimens of native tree species with remarkable growth parameters (*Quercus robur* L., *Quercus pedunculiflora* K.Koch, *Fagus sylvatica* L., *Sambucus nigra* L.) and three specimens of interesting introduced species (*Negundo aceroides* Moench, *Platanus occidentalis*. L., *Robinia pseudoacacia* L.).

Among woody species from America belong: *Juniperus horizontalis* Moench, *Gleditsia triacanthos* L., *Robinia pseudoacacia* L., *Negundo aceroides* Moench, *Catalpa bignonioides* Walt., *Mahonia aquifolium* (Pursh) Nutt, *Parthenocissus quinquefolia* C. K. Schneid., *Pseudotsuga menziesii* (Mirb.) Franco, *Picea pungens* Engelm., *Quercus rubra* L., *Symphoricarpos albus* (L.) S. F. Blake, *Abies concolor* (Gord.) Lindl., *Thuja occidentalis* L., *Acer saccharinum* L., *Rhus typhina* L. and *Chamaecyparis lawsoniana* (Murrai) Parl. From Asian regions originate following tree species: *Berberis thunbergii* DC., *Pyracantha coccinea* M. Roem., *Corylus colurna* L., *Ginkgo biloba* L., *Prunus cerasifera* Ehrh., *Swida alba* (L.) Opiz, and *Kerria japonica* (L.) DC. Of Japan origin is the species *Weigela florida* Bge. A. DC. and *Lonicera japonica* Thunb. cv. Aureo-reticulata. Among Chinese species recorded in studied parks there are growing *Platycladus orientalis* L., *Berberis julianae* Schneid., *Viburnum rhytidophyllum* Hemsl., *Ailanthus altissima* (Mill.) Swingle and *Cerasus serrulata* (Lindl.) London.

In studied park objects grow following invasive neophytes: *Robinia pseudoacacia* L., *Negundo aceroides* Moench and *Ailanthus altissima* (Mill.) Swingle. Among potential (regional) invasive species were included: *Elaeagnus angustifolia* L., *Mahonia aquifolium* (Pursh) Nutt., *Parthenocissus quinquefolia* (L.) Planch., *Rhus typhina* L. and also *Gymnocladus dioica* (L.) K. Koch. Frequently escaping species were: *Aesculus hippocastanum* L., *Cotoneaster horizontalis* Decne., *Gleditsia triacanthos* L., *Quercus rubra* L. and *Syringa vulgaris* L.

As regards growth parameters, i.e. girths and heights of the mentioned significant trees, to the tallest tree specimens belonged certainly *Quercus robur* L. (with average girth 445 ± 117 cm and height 25 ± 6 m)

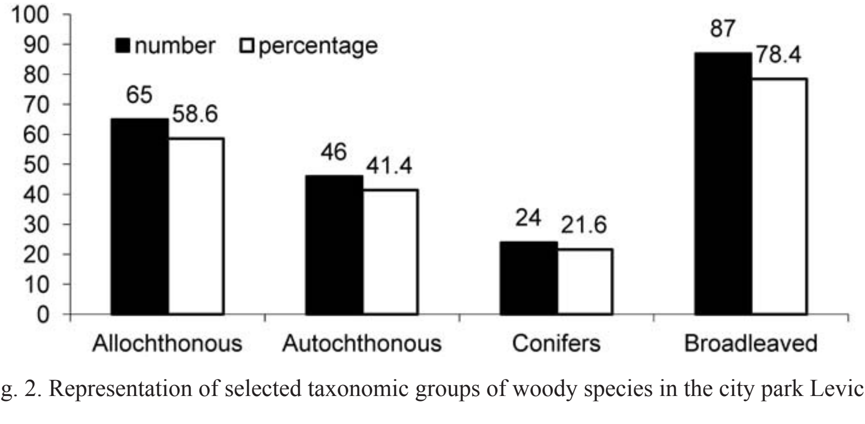

Fig. 2. Representation of selected taxonomic groups of woody species in the city park Levice.

and *Platanus* × *acerifolia* (Aiton) Willd. (with average girth 348 ± 37 cm and height 32 m) in Želiezovce city park (Table 1). Both trees have relatively favourable garden value, health and vitality. Moreover, specimens of two protected woody species were found. The first one belongs to *Quercus pedunculiflora* K. Koch (with girth 450 cm and height 28 m) in Levice city park, and another one is *Taxodium distichum* (L.) Rich (with girth 387 cm and height 24 m) in Želiezovce city park.

Conclusions

During May–September 2011 we performed inventory of woody species in Želiezovce city park and Levice city park. The representation of introduced and autochthonous woody species was determined and processed in tables. In Želiezovce city park we recorded 1,123 specimens of woody species; 577 specimens of introduced species and 546 specimens of autochthonous species. In both parts of Levice city park there were altogether growing 880 specimens of woody species; 456 specimens belonged to introduced trees and 424 specimens were autochthonous.

Together 28 significant trees with remarkable dendrometric parameters were recorded in both park objects. We recorded robust native woody species (*Quercus robur* L., *Rhamnus catharticus* L., *Swida sanguinea* (L.) Opiz, *Ulmus laevis* Pall.) as well as interesting introduced tree species originating from North America and Asia (Japan and China). Moreover, in the parks were found individuals of invasive neophytes, potential (regional) invasive species and also frequently escaping ones. Two protected woody species were found, Pedunculate Oak (in Levice city park) and Bald Cypress (in Želiezovce city park).

We can conclude that in both studied parks there predominated native tree species. From introduced trees there predominated species originating especially from North America. The research results showed that allochthonous woody species are important elements of both investigated parks. The results were compared with data issued in the work of Benčať (1982).

The territory of south-western Slovakia is very suitable place for the growth of many tree species because of suitable climatic and soil conditions. Investigation of exotic tree species ought to be performed permanently in both park objects.

Acknowledgement

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Dendrologicko-ekologické zhodnotenie drevinového zloženia vo vybraných parkoch juhozápadného Slovenska

Súhrn

V práci sme sa venovali dendrologicko-ekologickému výskumu drevinového zloženia vo vybraných parkových objektoch juhozápadného Slovenska (mestský park Želiezovce a Levice) s dôrazom na výskyt introdukovaných drevín. Vyhodnotili sme rastové parametre vzrastovo nadpriemerných jedincov (obvod kmeňa, výška), ich sadovnícku hodnotu, zdravotný stav a vitalitu. Získané výsledky sme porovnali s údajmi uvedenými v práci BENČAŤA (1982).

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Soil and its properties in the urban environment

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Abstract

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Soils in the urban environment have a character antrosoils, technosoils, at best case cultisoils. They are formed most often by reclamation of areas devastated by construction activities (antrosoils). They therefore have a wide range of properties, often unfavorable for the growth of plants. The work states optimal, permissible and undesirable texture, structure, moisture, biotic and some pedochemical features (pH, humus content, Na^+, Mg^{2+}). The following are criteria for evaluating the nutrient content of the soil (N, P, K, Ca, Mg, $CaCO_3$, C_{tot}) and their optimal ratios and limits for 23 other risk elements including heavy metals in the soil. The importance, functions and deficiency of physiologically important trace elements in plants and their contents in the soil are also discussed.

Keywords

greenery of housing estate urban soils, heavy metals, macronutrients, micronutrients

Introduction

Trees in the urban environment perform multiple public benefit functions and are an important component of residential green, serve as edificator and are crucial for improving the human environment. Form an integral organic part of the internal structure of housing estate (Noskovič et al., 2011). Particular attention must be paid to soils of parks, estate and streets, green land of school, medical, military and recreational sports facilities, soils with greenery in enterprises and institutions, greenery of internal housing estate, accompanying greenery and soils along roads (roads, railways), soils with green insulation in manufacturing and technological equipment (industrial green). However, its growth, especially the growth of trees is usually limited by a wide range of negative factors. These primarily include unfavorable soil properties (Nádašský et al., 2003).

Material and methods

Soils in the urban environment have character of antrosoils, technosoils, i.e. man-made soils, at best in situ reformulation soils, thus of cultisoils. The most often they are formed by reclamation of land devastated by construction activities (antrosoils). The field and laboratory investigation of soil properties enable to get a picture of the state of the soil in terms of trees (Szombathová et al., 2007). In the following, the results of our previous research and generalized knowledge of literature are evaluated (Supuka et al., 1991; Macko et al., 2012). Soil characteristics are evaluated from the point of optimal, permissible and undesirable characteristics in relation to the growth of trees in the urban environment.

Results and discussion

The basic soil properties are mainly granularity which is greatly influenced by humidity conditions, the structure, the amount of nutrients bound in the soil and after the plant growth (Craul, 1982; Kuhns, 1987). Optimal soil should be loamy, i.e. the coarse clay, i.e. fraction < 0.01 mm should be between 20 and 45% (Table 1). Admixture of dust fractions (0.01 to 0.05 mm) in the soil is beneficial. Transitions of particle soil composition between planting hole and its surroundings should be gradual or texture would be identical, otherwise problems arise in the supply of water in plant root growth (significant at replanting risen trees). Skeleton content, i.e. fragmentary rock > 2 mm should not be the more than 50% (preferably below 25%). This applies to the rock skelet weathering of which may release nutrients, but not for a variety of quartz gravel and construction residues (fragments of concrete, bricks, etc.). The share of these contaminants should be no more than 30% of the soil (preferably below 10%).

Form and size of aggregates influence the porosity and pore size distribution in soils (Harris, 1992). Crumbing structure with the size of aggregates 1–5 mm is considered for optimum soil structure. The lower limit is more appropriate to drier, upper to humid areas. The proportion of aggregates from 1 to 10 mm should be above 75% in optimal soils and their water stability greater than 50% (Table 1). Most favourable ratio between solid, liquid and gaseous components is 50%: 30 %: 20 % of the soil volume.

Loamy soil should have an optimum moisture content from 20 to 30%, depending on the course of the weather. The wetter the soil, the resilient the foliage to toxicity of easy soluble salts. Water storage capacity should be at least 12% (found in sand), optimum around 20 to 25% (loamy soil) of the volume. To obtain such capacity, porosity should be between 35–50% for the corresponding bulk density of not more than 1.33 for the lower and 1.7 g cm^{-3} for the upper limit (Craul, 1982). The depth of 130–200 cm can be considered as groundwater optimum for tree plants. If it is higher, the trees may suffer from water logging and a lack of air. It is also important to know the capillary uplift which is in the sand and loamy sand 30 cm, in loamy and silty sands from 30 to 80 cm, in sandy loams 80 to 150 cm, in loams 150 to 300 cm, in clay loam 300 to 400 cm and in clays from 400 to 600 cm. In the last two cases, however, capillary lift is so little, that despite its height is less significant to plant due to its slowness. Physiological soil depth should be at least 60 cm for successful growth of trees. Humus content is crucial to soil fertility. It is a source of nitrogen and its high sorption capacity binds other nutrients and microorganisms. In the root zone it should be at least 5%, C:N ratio in the organic-mineral horizon is appropriate below 20. Ratio of bacteria, fungi and actinomycetes should be about 20:1:2. Even azotobacter presence is the indicator of favourable soil (pH above 6).

Table 1. Optimal, permissable and undesirable values of physical and some other soil properties up to 30 cm soil depth

Characteristics	Optimal	Permissable	Undesirable
Carbonate content [%]	1.0–3.0	0.3–5.0	>5.0
Humus content [%]	35– 0	2.0–10.0	<2.0 or >10.0
Skelet content [%]	<25	25–50	>50
Extranous inert skelet	<10	10–30	>30
Skelet size [cm]	<05	0.5–15	>15
Bulk density [g cm^{-3}]	0.8–1.2	1.2–1.5	<0.8 or >1.7
Minimal airiness [%]	15–25	10–15	<10 or >25
Clay content < 0.01 mm [%]	20–45	10–60	<10 or >60
Aggregates share 1–10 cm [%]	>75	50–75	<50
Agregates watersteadyness [%]	>50	20–50	<20
Water table [cm]	130–200	60–130 (200)	<60
Water content in loamy soil [%]	20–30	15–35	<15 or >35
Soil depth [cm]	>60	30–60	<30
B* : H* : A* share	20 : 1 : 25	(10–20) : 1 : (1–2)	<10 : 1 : 1
pH	5–6.5	3.5– 8.5	< 3.5 or >8.5
Water leachate evaporite [%]	<0.3	0.3–0.5	0.5
Na^{+} of value T [%]	<5	5–15	>15
Mg^{2+} of value T [%]	<15	15–40	>40

B*, bacteria; H*, mushrooms; A*, actinomycetes.

Soil reaction (pH soils) is summary measures of physical and biological condition of soil. pH in a range of 5–7 may be considered as optimal value for the growth of green vegetation. Unlike agricultural crops, most plants grow well in the acidic region. Coniferous species prefer soil reaction in a range of pH (H_2O) = 5–6, broadleaves pH (H_2O) = 5.5–6.5. For all plants pH below 3.5 or above 8.5 is harmful (indicates presence of mineral acid or increased sodium in the soil sorption complex). If the weight of the water leachate evaporite exceeds 0.5%, the soil is saline, over 1.0% is the heavily salted. If the soil contains more than 0.5% of soluble salts is not suitable for the growth of plants without amelioration. Soils intact by salting contain less than 100 mg dm^{-3} Na^+ (Horký and Soukup, 1975). Soils with withering trees damaged very heavily by winter salting of roads contain over 1,000 mg dm^{-3}. Soda Na_2CO_3, bicarbonates and chlorides are the most dangerous for plants. Over the year, the soil in not totally desalinated (Noskovič and Rakovská, 1986). During the year, Cl^- ion content does not fall more than 10–50% of its initial state (Suchara, 1983). Na^+ in the soil increased chemically lead to alkalization of soil pH and with the carbonates easily creates the mentioned soda. Next Na^+ ion causes peptization of mineral and organic colloids, eroding soil structure, rapid changes in soil moisture and volume, creating drought, muddy, eventually excessive compation (Supuka et al., 1983). Chlorides have the highest proportion of anions (after HCO_3^- which is understandable). Soils with higher salt content should be meliorated by ground gypsum. Acid precipitation and mainly high content of suphates worsen soil properties and damage vegetation (Babošová et al., 2006).

Plants for their growth and development need large amounts of mineral elements that largely derive from the soil. Out of the total number of elements found in the earth's crust only a small portion is needed for plant and animal life. It relates to so-called essential elements. The life cycle of plants without them will not be completed, can not be replaced by another element, and the element is directly involved in the metabolism of plants. They can be divided according to different criteria, and in some respects. The most appropriate classification is according to their content in plants. According to this criterion 14 essential elements are to be essential to higher plants, classified as macronutrients – N, P, K, Ca, Mg, S occurring in higher concentrations (typically over 1% = 10,000 ppm) and micronutrients – Fe, Mn, Cu, Zn, Mo, B, Se and Cl occuring in trace amount.

Macronutrients in organisms are usually involved in the construction of tissues, microelements fulfill specific functions in them. For animals is essential even Ni and Cr. Other elements which are able to compensate the toxic effects of other elements or needed for less specific functions (such as maintenance of osmotic pressure) are classified as useful. Among them belong Na, Si, Co, I and V. Finally, there are the elements harmful, toxic to plants and operating at a minimum rate. These include in particular Cd, Pb, As, Hg (for plants too Cr and Ni).

From the viewpoint of successful plant growth is still interesting, how much nutrients soil contains (Table 2). Out of these, nitrogen is the element which acts most intensively on the growth of plants (Gábriš et al., 1995; Noskovič et al., 2000). Nitrogen supplies are assessed by its total or accessible form, eventually according to the ecological quality of humus (C/N ratio). The content of other nutrients is too important (Table 2).

Table 2. Criteria for evaluating the nutrient content of the soil

Parmeters		Method	Supply			
			Insuficient	Medium	Good	Surplus
C_{Org}	[%]	Tjurin	< 2	2–4	>4	>6
N_{tot}	[%]	Kjeldahl	<0.1	0.1–0.4	>0.4	>1.2
$N_{Available}$	[mg kg^{-1}]	Pazler	<40	40–80	>80	>450
Ratio C/N			>20	10–20	<10	<5
$P_{Available}$	[mg kg^{-1}]	Mehlich III	<55	101–170	171–245	>245
		Mehlich II	<35	75–125	126–160	>160
		Egner-Riehm	<13	13–35	>35	>350
		1% Lemon Acid	<45	45–90	>90	>450
$K_{Available}$	[mg kg^{-1}]	Mehlich III	<130	131–260	261–400	>540
		Mehlich II	<80	131–200	201–300	>300
		Schaschsabel	<50	50–90	>90	>415
		1% Lemon Acid	<60	60–115	>115	>460
$Mg_{Exchangeable}$	[$cmol^+$ kg^{-1}]	NH_4Cl extract	<0.08	0.08– 0.12	>0.12	>2.47
$Ca_{Exchangeable}$	[$cmol^+$ kg^{-1}]	NH_4Cl extract	<1	1–3	>3	>10

Respective supply levels of exchangeable Mg are as follows (insufficient, medium, good in mg kg^{-1}) <20, 20–30 and >30 mg kg^{-1}. Ca content in exchangeable form should be at least 3 $cmol^{+}$ kg^{-1}. The content of carbonate ($CaCO_3$) should not exceed 5%.

In the residential and productive country in which pollution or overload by some element is assumed, the soil should be checked for relative proportions of nutrients or their ratio to carbon. The violation of the natural balance of nutrients leads to their mutual antagonism, despite their sufficient amounts in the soil (Bublinec, 1976; Supuka, 1983). Optimal ratios of elements are as follows in Table 3 (Ratios of oxides were transformed to ratios of element, because current methods provide element concentrations).

Table 3. The optimum ratio of elements in the soil (Weight ratio)

Oxides (Elements)		Ratio	Elements		Ratio
MgO:	CaO	(3–6) : 10	Mg:	Ca	1.5 : 3
	K_2O	3–6		K	4.5–8.5
	P_2O_5	1–5		P	3–14
	N_{Av}	<3		N_{Av}	<2
CaO:	K_2O	5–15	Ca:	K	2–25
	P_2O_5	7–11		P	23–36
	N_{Av}	<10		N_{Av}	<7
C:	N	<20	N:	S	>(4– 5)
	S	>50			

$N_{Av} = N_{Available}$.

In the urban soil, especially the ratio of calcium and magnesium to potassium is disrupted. These ratios and the value of available nutrients must be optimized not only for new plantations, but also at a later stage of development, in the maintenance of greenery. In intoxicated urban soils and along the roads, it is recommended to plant deep rooting tree species. Excessive (toxic) values of other elements in the soil (mg kg^{-1}) in 1 M HCl extract are shown in Table 4. Readings indicate really high element concentrations in the soil. Eight elements (Fe, Mn, Cu, Zn, Mo, B, Cl, Se) stated in the Table 4 form physiologically essential microelements. The values above are a sign of toxic, harmful effects.

Table 4. Above limit levels of other elements [mg kg^{-1}] in the soil releasable in 1 M HCl

Chemical element [mg kg^{-1}]	Above limit value in soil [mg kg^{-1}]
Iron (Fe)	>10,000
Manganese (Mn)	> ,000
Aluminium (Al) – by Sokolov	>800
Chlorine (Cl) – a total content	>460
Zinc (Zn)	>200
Copper (Cu)	>100
Lead (Pb)	>100
Vanadium (V)	>100
Sulphur (S)	>100
Nickel (Ni)	>40
Cobalt (Co)	>40
Arsenic (As)	>30
Chromium (Cr)	>30
Antimony (Sb)	>30
Florine (F)	>20
Selenium (Se)	>20
Molybdenum (Mo) – leachate $(COOH)_2 + (COONH_4)_2$	>10
Boron (B)	>10
Tin (Sn)	>10
Mercury (Hg)	>4
Cadmium (Cd)	>2
Beryllium (Be)	>2
Sodium (Na)	> 30% of T value (from maximum sorption capacity)

Iron in the soil is mostly found in the form of insoluble polymeric compounds (FeOOH), therefore to ensure its required amount the plants must increase secretion of H^{+} leading to lower pH values in the immediate vicinity around the roots. Because remobilization of Fe in the plant is very low, its deficiency is primarily reflected in the young leaves. The manganese content in plants is given by its presence in the soil. Its deficiency in the plant is manifested as chlorosis and necrosis of the leaf veins and tip sheets. According to the type of plant the young as well as older leaves may be affected.

Copper is mainly bound up in various low molecular organic compounds. The function of Cu is given by the ability of Cu^{2+} cation to be reduced even in the presence of very weak reducing agents. Plants take Cu^{2+} from the soil by several types of membrane transporters. Lack of Cu is at first seen as a dark necrotic spots on young leaves. Later there is the onset of a total necrosis and leaf fall, accompanied by racking leaves. Plants take zinc from the soil in the form of Zn^{2+} cation and its content in them is mainly given by the availability of soil Zn. Deficiency is manifested by changing plant habit. The leaves are small with a wavy blade. The initial chlorosis passes to white necrotic spots.

Unlike other micronutrients, the availability of Mo increases with increasing pH. While the soil fertilization by phosphorus increases Mo intake by plants, sulfur fertilization reduces this intake. Its deficiency is commonly manifested by assimilation organs yellowing and dwarfed plants. Actually it is a nitrogen deficiency caused by its reduced income. In the soil with a pH < 7, boron occurs in the form of boric acid H_3BO_3, in a alkaline range creates the borate anion $B(OH)_4^-$ which is easily absorbed by the soil particles and passes to an inaccessible form to plants. Reduced B availability to plants leads to disturbances in their nutrition. Boron deficiency symptoms depend on the age and the plant type. It especially relates to the dark necrosis occurring on young leaves bases and on apical buds, creates fruit distortions and produce growth inhibition.

Although chlorine is classified as a micro-nutrient, plants receive it in amounts comparable to those of macronutrients. It comes from many sources and therefore its deficiency in plants occurs sporadically. Plants take it in the form of Cl^- anion, in which it is also distributed. Chlorides have long been considered nonessential element for plants, but recent results of their application have shown the increased plant production and higher resistance of plants to disease. In the natural cycle Cl^- do not release chlorine and do not act harmfully to soil organisms. In the soil Cl is distributed in a relatively wide concentration range of 20 to 900 mg kg^{-1} with an average value of 100 mg kg^{-1}. Selenium is essential to some plants – has antioxidant properties, affects the course of some enzymatic reactions. In the case of plants, Se occurs mainly in organic form and at higher concentrations of 2 mg kg^{-1} begins to be toxic.

What relates to other elements, it should be noted that the contents of sodium, aluminum and silicon, i.e. elements with a concentration of above 100 ppm, but also of elements that occur in assimilation organs in minimal amounts (below 1 ppm) are very fluctuating and exhibit high variability. Since they are ballast elements, from the viewpoint of nutrition they can be tolerated.

Availability of elements to plants is influenced by several factors, forefront of which is their contents in the soil and soil properties. Elevated concentrations of monitored elements are assessed according to the limit values with new knowledge continuously regulated. Limits used are imposed by the Act no. 220/2004 of Laws “The conservation and use of agricultural land“ (Table 5). Limits represent the values of maximum levels of hazardous substances in agricultural soil and contamination level (in mg kg^{-1} dry mater, decomposition by aqua regia, at Hg a total contain). They are divided according to soil type, i.e. grain size, into three groups. The lighter the soil, thus more sandy, the less the soil buffering. Thus in light soils, risk element limits are lower, and vice versa in heavy soils higher.

Previously, the rate of soil contamination with heavy metals was assessed by the highest available levels of harmful substances in accordance with the decisions of the Ministry of Agriculture no. 531/1994-540. These two criteria declare very similar limits, but the former standard takes into account the presence of humus, content of which is particularly important for forest soil.

Table 5. The limit values of risk substance in agricultural soil

Soil type	As	Cd	Co	Cr	Cu	Hg	Ni	Pb	Se	Zn	F
	[mg kg^{-1}]										
Sandy, loamy-sand	10	0.4	15	50	30	0.15	40	25	0.25	100	400
Sandy-loam, loamy, clay-oam	25	0.7	15	70	60	0.5	50	70	0.40	150	550
Loamy-clay, clayey, clay	30	1.0	20	90	70	0.75	60	115	0.60	200	600

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Pôda a jej vlastnosti v urbánnom prostredí

Súhrn

Optimálne pôdy pre rast drevín sú hlinité s obsahom hrubého ílu (frakcia menšia ako 0,01 mm) 20 – 40 %, s obsahom skeletu pod 25 %, odrobinkovitej štruktúry o hrúbke 1 – 5 mm. Takéto pôdy by mali mať vlhkosť 20 – 30 %, s kapilárnou kapacitou 20 – 25 %, s objemovou hmotnosťou v rozpätí 1,33 – 1,70 g cm^{-3}. Optimálna hĺbka podzemnej vody pre stromovú vegetáciu sa odporúča 130 – 200 cm, hĺbka pôdy by mala byť aspoň 60 cm, s obsahom humusu v koreňovej zóne okolo 5 % a pomerom C/N pod hodnotou 20. Hodnotu pH považujeme za optimálnu pre rast stromovej zelene v rozpätí 5 – 7. Pre ihličnaté dreviny sú vhodné hodnoty okolo spodnej hranice rozpätia, pre listnaté horná hranica. Pre všetky dreviny je škodlivé pH pod 3,5 a nad 8,5. Ak hmotnosť odparku vodného výluhu prevyšuje 0,5 %, pôda je zasolená a nie je vhodná bez meliorácie pre rast drevín. Kriteriálne hodnoty obsahu C, N, P, K, Mg a Ca sú v tab. 2, nadlimitné obsahy 23 ďalších prvkov v tab. 3 a limitné hodnoty rizikových prvkov (As, Cd, Co, Cr, Cu, Hg, Ni, Pb, Se, Zn, F) sú v tabuľke 4.

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Pollen quality in some representatives of the genus *Pinus*

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Abstract

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During spring 2012 pollen quality of 12 pine species (*P. cembra* L., *P. armandii* Franch., *P. wallichiana* A.B. Jacks., *P. strobus* L., *P. bungeana* Zucc. ex Endl., *Pinus nigra* J.F. Arnold, *P. sylvestris* L., *P. mugo* Turra, *P. coulteri* D. Don, *P. jeffreyi* Balf., *P. ponderosa* Douglas ex C. Lawson, *P. rigida* Mill.) growing in Mlyňany Arboretum was investigated. Pollen germination was tested at 25 °C on medium consisting of 1.5% agar and 10% sucrose. Each sample was triplicated. After 48 hours the number of germinating pollen was recorded from a sample of 100 pollen grains, whereas the pollen tube length in a sample of 30 pollen grains of each Petri dish. Data on average daily temperatures were taken from the local meteorological station in Mlyňany Arboretum. In general, all the analyzed pine species showed high levels of germination ranging from 85% in *P. ponderosa* to 98.89% in *P. cembra*. The pollen tube length averaged between 57.11 µm in *P. bungeana* and 139.2 µm in *P. mugo*. Both these pollen viability parameters were compared by Duncan test and variation analysis (anova). Our results indicate that pollen quality characteristics are more similar in closely related species of pines with pollen shedding in the same period than in systematically distant species with different periods of their pollen shedding. We suppose annual variation in the pollen quality of systematically related species that are shedding their pollen at the same time and which show similar behaviour in several aspects of pollen development. Expected impact of other factors is discussed.

Key words

Pinus species, pollen quality, temperature

Introduction

The genus *Pinus* with 116 species is the largest genus in the family Pinaceae. This genus is divided into subgenus *Strobus* with 43 species and subgenus *Pinus* with 73 species (Businský, 2008). Pines exhibit the greatest diversity of habitat and distribution of the needle-type evergreens, being scattered throughout the Northern Hemisphere from the Arctic Circle to Guatemala, the West Indies, North Africa, and Malayan Archipelago (Dirr, 1975). Only one species, *P. merkusii* Jungh et de Vriese, 1845 in Sumatra, has crossed the equator (Everett, 1981). The processes of introduction and acclimatization of exotic woody plants are often investigated in the arboretums including those pine species which does not occur together naturally.

Pollen size, its germination and pollen tube length are the variable characters of pollen which are sometimes used in studies an introduction (Skogsmyr and Lankinen, 2002). Although they depend in a large degree on the environmental factors (Young and Stanton, 1990; Quesada et al., 1995; Delph et al., 1997; Travers, 1999; Parantainen and Pulkkinen, 2002) the decisive role of the genotype is undeniable (Skogsmyr and Lankinen, 2002). This implies that pollen quality parameters depend primarily on the species. However, this aspect of pollen biology is not investigated enough. Chira´s works (1963, 1964, 1964b, 1965, 1967a, 1967b) are rather descriptive, referring to relationship of the pollen quality and temperature. It is ledged generally that changes in environmental conditions may affect the reproductive process of plants.

Based on the assumptions given above we tried to describe the relationship between pollen quality of pine species growing on common area and systematic position of the tested species. By comparing the observed results with average daily temperatures, we tried to answer the question how the increase of temperature can affect the reproductive process of woody plants.

Material and methods

The study on pollen viability has included 12 species of pines growing in Arboretum Mlyňany SAS and belonging to the two subgenera of the genus *Pinus*. The species of the subgenus *Strobus* were represented by *P. cembra, P. armandii, P. wallichiana, P. strobus* and *P. bungeana,* whereas those of the subgenus *Pinus* by *Pinus nigra, P. sylvestris, P. mugo, P. coulteri, P. jeffreyi, P. ponderosa* and *P. rigida* (Businský, 2008). The pollen samples of analyzed species were collected in spring 2012 using three individuals of each species. The only exception was *P. ponderosa* represented by two individuals. Pollen was extracted from dessiccated microstrobili on May 4 in *P. sylvestris* and *P. nigra*, on May 10 in *P. rigida* and *P. ponderosa*, on May 11 in *P. mugo* and *P. cembra*, on May 21 in *P. jeffreyi, P. wallichiana, P. strobus* and *P. bungeana* and on May 30 in *P. armandii* and *P. coulteri*. Mature but still unopened compact microstrobili of individual trees were harvested shortly before shedding of pollen and transferred to the laboratory. The dry pollen was stored in a desiccator over silica gel at 4 °C for the period of 3 weeks and then used in germination test. Pollen germination was tested at 25 °C on medium consisting of 1.5% agar and 10% sucrose. Each sample was triplicated. After 48 hours the number of germinating pollen was recorded from a sample of 100 pollen grains, whereas the pollen tube length in a sample of 30 pollen grains of each Petri dish. The differences in pollen size and in pollen tube length and percentage between trees and individuals were tested by nested anova. Because the percentages were bimodally distributed, the germination data were transformed using the arcsin transformation ($p' = \arcsin \sqrt{p}$). All calculations were done using the GLM procedure of SAS (SAS 1988).

Results

We have revealed a high level of pollen germination in all the analyzed pine species (Table 1). The variability between trees is manifested in the pollen tube length rather than in the pollen germination percentage (Table 2). Our results showed that species from the subgenus *Strobus* were characterized by a higher pollen germination rate, whereas species from the subgenus *Pinus* by longer pollen tubes. There were only two exceptions to this finding (*P. mugo* in value of pollen germination and *P. ponderosa* in the length of pollen tubes).

Table 1. Pollen germination percentage in individual trees of pine species

Species	Tree	N	Mean ± SD [%]	Duncan test
Pinus cembra	1	3	98.67 ± 0.58	
Pinus cembra	2	3	98.33 ± 0.58	
Pinus cembra	3	3	99.67 ± 0.58	
Pinus cembra	Sum	9	98.89 ± 0.78	A
Pinus mugo	1	3	98 ± 2	
Pinus mugo	2	3	97.33 ± 1.15	
Pinus mugo	3	3	99.67 ± 0.58	
Pinus mugo	Sum	9	98.33 ± 1.58	AB
Pinus bungeana	1	3	99 ± 1	
Pinus bungeana	2	3	96.33 ± 2.08	
Pinus bungeana	3	3	97 ± 1	
Pinus bungeana	Sum	9	97.44 ± 1.74	BC
Pinus strobus	1	3	96 ± 2.65	
Pinus strobus	2	3	98 ± 1	
Pinus strobus	3	3	98 ± 1	
Pinus strobus	Sum	9	97.33 ± 1.8	C
Pinus wallichiana	1	3	96 ± 2	
Pinus wallichiana	2	3	98 ± 1	
Pinus wallichiana	3	3	95 ± 1	
Pinus wallichiana	Sum	9	96.33 ± 1.8	CD
Pinus armandii	1	3	95 ± 3	
Pinus armandii	2	3	96.67 ± 1.53	
Pinus armandii	3	3	94.67 ± 2.08	
Pinus armandii	Sum	9	95.44 ± 2.19	DE
Pinus nigra	1	3	96.67 ± 0.58	
Pinus nigra	2	3	90 ± 5	
Pinus nigra	3	3	97.33 ± 1.15	
Pinus nigra	Sum	9	94.67 ± 4.36	DE

Table 1. Pollen germination percentage in individual trees of pine species – continued

Species	Tree	N	Mean ± SD [%]	Duncan test
Pinus sylvestris	1	3	93.33 ± 2.89	
Pinus sylvestris	2	3	95 ± 0	
Pinus sylvestris	3	3	95 ± 0	
Pinus sylvestris	Sum	9	94.44 ± 1.67	DEF
Pinus coulteri	1	3	96.67 ± 1.53	
Pinus coulteri	2	3	94 ± 2	
Pinus coulteri	3	3	91 ± 1	
Pinus coulteri	Sum	9	93.89 ± 2.8	EF
Pinus rigida	1	3	91 ± 1.73	
Pinus rigida	2	3	91.33 ± 5.51	
Pinus rigida	3	3	94 ± 1	
Pinus rigida	Sum	9	92.11 ± 3.26	F
Pinus jeffrey	1	3	86.67 ± 1.53	
Pinus jeffrey	2	3	77 ± 2.65	
Pinus jeffrey	3	3	95 ± 2	
Pinus jeffrey	Sum	9	86.22 ± 8.01	G
Pinus ponderosa	1	3	89.67 ± 3.06	
Pinus ponderosa	2	3	80.33 ± 6.81	
Pinus ponderosa	Sum	6	85 ± 6.96	G

SD, standard deviation.

Table 2. Pollen tube length in individual trees of pine species

Species	Tree	N	Mean ± SD [µm]	Duncan test
Pinus mugo	1	90	115.03 ± 39.83	
Pinus mugo	2	90	162.88 ± 37.78	
Pinus mugo	3	90	139.68 ± 33.57	
Pinus mugo	Sum	270	139.2 ± 41.87	A
Pinus jeffrey	1	90	101.98 ± 41.32	
Pinus jeffrey	2	90	131.47 ± 52.16	
Pinus jeffrey	3	90	152.73 ± 52.67	
Pinus jeffrey	Sum	270	128.73 ± 53.08	B
Pinus coulteri	1	90	127.12 ± 41.36	
Pinus coulteri	2	90	127.12 ± 38.15	
Pinus coulteri	3	90	127.6 ± 41.14	
Pinus coulteri	Sum	270	127.28± 40.09	B
Pinus sylvestris	1	90	89.9 ± 40.62	
Pinus sylvestris	2	90	89.42 ± 41.43	
Pinus sylvestris	3	90	129.53 ± 39.11	
Pinus sylvestris	Sum	270	102.95 ± 44.44	C
Pinus nigra	1	90	111.17 ± 41.81	
Pinus nigra	2	90	86.03 ± 31.26	
Pinus nigra	3	90	108.75 ± 36.45	
Pinus nigra	Sum	270	101.98 ± 38.34	C
Pinus rigida	1	90	87.97 ± 32.59	
Pinus rigida	2	90	95.7 ± 42.36	
Pinus rigida	3	90	96.18 ± 34.81	
Pinus rigida	Sum	270	93.28 ± 36.88	D
Pinus cembra	1	90	105.37 ± 36.29	
Pinus cembra	2	90	83.62 ± 34.65	
Pinus cembra	3	90	89.9 ± 34.99	
Pinus cembra	Sum	270	92.96 ± 36.36	D
Pinus armandii	1	90	51.38 ± 21.32	
Pinus armandii	2	90	133.92 ± 31.19	
Pinus armandii	3	90	90.48 ± 33.6	
Pinus armandii	Sum	270	91.93 ± 44.57	D
Pinus wallichiana	1	90	86.52 ± 31.43	
Pinus wallichiana	2	90	98.6 ± 31.14	
Pinus wallichiana	3	90	87.97 ± 34.49	
Pinus wallichiana	Sum	270	91.01 ± 32.71	D
Pinus strobus	1	90	73.95 ± 30.2	
Pinus strobus	2	90	89.42 ± 37.1	
Pinus strobus	3	90	73.62 ± 28.04	
Pinus strobus	Sum	270	78.97 ± 32.72	E
Pinus ponderosa	1	90	39.29 ± 22.02	
Pinus ponderosa	2	90	89.34 ± 37.07	
Pinus ponderosa	Sum	180	64.32 ± 39.42	F
Pinus bungeana	1	90	36.83 ± 14.25	
Pinus bungeana	2	90	65.54 ± 14.54	
Pinus bungeana	3	90	68.94 ± 25.66	
Pinus bungeana	Sum	270	57.11 ± 23.73	G

SD, standard deviation.

The species *P. mugo*, *P. sylvestris* and *P. nigra* represent in the experiment taxonomic section *Pinus*. The longest pollen tubes were found in *P. mugo* (Table 2). Duncan tests confirmed greater similarity between pollen quality parameters of *P. sylvestris* and *P. nigra* than between *P. sylvestris* and *P. mugo* or *P. nigra* and *P. mugo*.

The species *P. ponderosa*, *P. jeffreyi* and *P. coulteri* represent section *Pseudostrobus* (Businský, 2008). With this group of species similar values of pollen germination were observed between the species *P. jeffreyi* and *P. ponderosa*. On the other hand, *P. jeffreyi* and *P. coulteri* showed a great similarity in pollen tube length. Individuals of *P. jeffreyi* and *P. ponderosa* showed the greatest variability in pollen germination of all the analyzed species (Table 1).

The species *P. wallichiana*, *P. strobus*, *P. armandii* and *P. cembra* represent section *Strobus* (Businský, 2008). Almost all these species were characterized by comparable levels of pollen germination (Table 1) and length of their pollen tubes (Table 2). The species *P. cembra* was an exception exhibiting other character value of pollen germination. Likewise, *P. strobus* was exceptional by its longer pollen tubes (Tables 1 and 2).

P. bungeana from the section *Gerardiae* and *P. rigida* from section *Trifoliae* were heavier compared to other analyzed pine species. Our results showed that pollen quality parameters of *P. rigida* are more similar to species from the subgenus *Pinus* and pollen quality parameters of *P. bungeana* are more similar to species from the subgenus *Strobus*.

Discussion

Among factors affecting pollen quality parameters external factors influencing pollen development during maybe mentioned on the first place microsporogenesis (Chira, 1965).

As shown by Chira (1964a), the development of pollen is most profoundly affected by ambient temperature. Each stage of pollen development exhibits different sensitivity to external temperature fluctuations (Chira, 1964a). Mitotic division of PMCs in archesporial tissue begins in July last year. This stage is less sensitive to low temperatures (Konar, 1960; Chira, 1965). Cold reduces activity of the cells in the archesporial tissue to a minimum. PMCs are further divided, when temperature rises above 2 °C (Chira, 1965). Archesporial tissues are resistant to cold, unless temperature does not fall below –20°C (Chira, 1965). Chira (1965) reported that low temperatures are particularly harmful to PMCs of *P. jeffreyi* and *P. coulteri*. When heterotypic prophase of PMCs starts, the period of development associated with increased sensitivity of dividing cells to temperature fluctuations begins (Chira, 1963, 1965). If the temperature rises above 5 °C, heterotypic prophase of PMCs starts. The process of prophase observed in PMCs of pine species lasted from 2 to 14 days as compared with several hours duration of homeotypic prophase (Chira, 1965). The period from the heterotypic metaphase to the tetrad formation lasted 2–6 days. Subsequent formation of complete pollen lasted from 4–13 days. After this division mature pollen is released from microstrobili in sunny days (Chira, 1965). Expect for microsporogenesis variation considerable interannual variability of the pollen quality parameters was detected (Chira, 1963). While in 1961 the average daily temperature has not fallen below 6 °C during the critical months leaving unaffected the course of pollen development and germination percentage of mature pollen ranging from 25% in *P. edulis* to 85% in *P. wallichiana, P. coulteri, P. nigra* ssp. *Pallasiana* in 1963 a sudden temperature drop below 0 °C for more than 15 days during meiosis caused an absolute sterility of *P. nigra* pollen and 83% sterility of *P. sylvestris* pollen (Chira, 1963). The temperatures below 5 °C adversely affect the course of pollen development in *P. sylvestris* and *P. nigra* during prophase provided the temperature decline is longer (2 °C for 3 days does not affect the course of meiosis) (Chira, 1965). In other of pines species normal development of pollen was detected. This finding is explained by a sufficiently high temperature (above 0 °C) during the relevant period. Therefore, the author believes that low temperature is a major cause of abnormal development of pollen in studied pine species. Curiously, the high temperatures can also affect adversely the pollen development (Chira, 1965). The author writes that the increase in temperature to 18 °C during tetrad development in *P. bungeana* caused a strong plasmolysis and significant deformation of the cells nuclei (Chira, 1965). Inhibition, resulting from lower average daily temperature (below –1 °C) as well as accelerating pollen development by higher temperatures (above 18 °C) during the initial division of the heterotypic prophase after the third mitotic division in PMCs cause reduction percentage of pollen germination and in some cases its complete sterility (Chira, 1965). Temperatures from 5 °C to 15 °C are optimal conditions for pollen development of most pine species (Chira, 1965). Some interspecies variation may be expected in the range of these temperatures. For example, *P. edulis* pollen germination in 1961 was 25% only, while for other pine species was significantly higher (up to 85% in *P. wallichiana*, *P. coulteri* and *P. nigra* ssp. *pallasiana*) (Chira, 1963). However, meiosis in *P. edulis* begins when exposed to the temperatures of 10–15 °C for 5–6 days (Chira, 1967a). Therefore, we assume that the temperatures above 5 °C may have a negative impact on the pollen development of this species. The species *P. sylvestris* and *P. nigra* may represent a similar example. These two species have shed their pollen about the same time but their germinations were 17% and 0% only. Our results indicate that pollen quality characteristics are more similar in pine species with pollen shedding in the same period than in pine species with different periods of their pollen shedding. This assumption is supported by Chira´s (1963) findings. When we compare the author´s observations in 1961 and 1962, we see that percentage of pollen germination of pine species that shed their pollen in the same period show the same direction of changes (increase or decrease). We assume that the process of meiosis of pine species that shed pollen in the same period is synchronized. By comparing the average daily temperature in 2012 with that given by Chira (1963, 1965), we can conclude that temperatures during the spring months of 2012 were optimal for pollen development of pines (Fig. 1). Although high percentages of pollen germination in all analyzed species were observed, Duncan test revealed differences between them. These results indicate that percentages of pollen germination are more similar in closely related species of pines than in systematically distant species (*P. strobus* and *P. wallichiana*, *P. nigra* and *P. sylvestris*, *P. jeffreyi* and *P. ponderosa* are typical examples). Synchronization of pollen shedding was observed in the first two pairs of these species. Shedding of *P. jeffreyi* and *P. ponderosa* pollen was not synchronous. This result indicates that under optimal weather conditions, they react similarly. The species *P. cembra* and *P. mugo* are the exceptions. They shed their pollen during the same period of time, but more closely related pine species shed in different periods. The variability in the pollen tube length is relatively high, but Duncan's test revealed a similar dependence as in pollen germination. Our results indicate that length of pollen tubes are more similar in closely related species of pines with pollen shedding in the same period than in systematically distant species with different periods of their pollen shedding. According to some authors (Kelly et al., 2002; Dufay et al., 2008) the size of pollen serve as an indicator of its viability. Some authors (van Breukelen, 1982; Lord and Eckard, 1984; Perez and Moore, 1985; Gore et al., 1990; Manicacci and Barrett, 1995) found a positive correlation between the length of pollen and length of pollen tubes, but other researchers (Cruzan, 1990; Pietarinen and Pasonen, 2004) did not confirm this dependence. We can compare one results with those presented by Chira (1964c). The above mentioned dependence is valid for the species *P. coulteri*, *P. jeffreyi* and *P. ponderosa* of the section *Pseudostrobus*. The author has found a relatively large size of pollen in *P. coulteri* and *P. jeffreyi* (112.4 µm and 102.1 µm) as compared with the reduced pollen size in *P. ponderosa* (84.4 µm). We have not measured pollen size in our experiment but pollen tube length parameters correlate well with the data given by Chira (1964). The pollen tube length in *P. ponderosa* has accordingly deviated statistically from the corresponding parameter of pollen in *P. jeffreyi* and *P. coulteri* the same applies for *P. strobus* and *P. wallichiana* of the section *Strobus* the pollen tube length of which has not deviated significantly from each other. Also pollen size of these species was nearly identical with the data published by Chira (1964) (81.4 µm resp. 83.3 µm). On the contrary, such a tendency has not been proved for the species *P. mugo*, *P. nigra* and *P. sylvestris* of the section *Pinus*. Both *P. nigra* and *P. sylvestris* shoved similar pollen size exhibiting simultaneously non significant difference in their pollen tube length as compared with *P. mugo* which has differed in both pollen characteristics from the pair of species given above.

Presented results indicate similarity of the pollen viability characteristics in taxonomically related species of pines growing on the same locality and shedding their pollen in the same period of time as compared with the corresponding characteristics of pollen in taxonomically distant species shedding their pollen in different periods of the flowering time. Annual variation in pollen quality of taxonomically related species shedding their pollen in the same period of time is expected to exhibit the same tendency. There exist a correlation between pollen size and pollen tube length in *Pinus* species belonging to the same section (*Pseudostrobus* and *Strobus*). However, this correlation has not been proved for the species of the section *Pinus*. Under conditions of a global warming, we expect increase in pollen quality of the species indigenous for the warmer regions of the world.

It is necessary to evaluate critically both the obtained results and conclusions drawn so far. We have subjected to analysis a relatively small number of pine individuals. In the next years, it would be necessary to carry out additional experiments with pine species growing in other localities. The attention would be paid primarily to the related pine species.

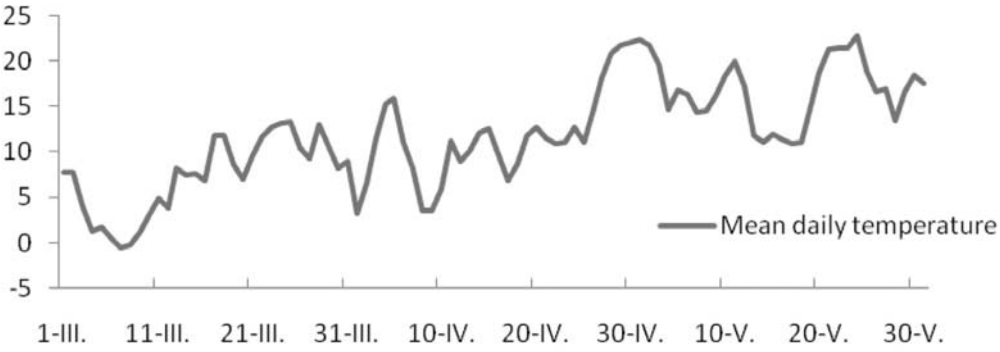

Fig. 1. Mean daily temperature variation in Arborertum Mlyňany during spring months 2012
(Source: Meterological station in Arboretum Mlyňany).

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Kvalita peľu vybraných zástupcov rodu *Pinus*

Súhrn

Počas jari 2012 sme skúmali kvalitu peľu 12 druhov borovíc (*P. cembra* L., *P. armandii* Franch., *P. wallichiana* A.B. Jacks., *P. strobus* L., *P. bungeana* Zucc. ex Endl., *Pinus nigra* J.F. Arnold, *P. sylvestris* L., *P. mugo* Turra, *P. coulteri* D. Don, *P. jeffreyi* Balf., *P. ponderosa* Douglas ex C. Lawson, *P. rigida* Mill.) rastúcich v Arboréte Mlyňany. Klíčivosť peľu bola analyzovaná pri teplote 25 °C na médiu s 1,5 % agaru a 10 % sacharózy. Každá vzorka peľu bola analyzovaná v trojnásobnom opakovaní. Klíčivosť bola hodnotená na vzorke 100 peľových zŕn, kým dĺžka peľových vrecúšok bola meraná iba z 30 peľových zŕn na každej Petriho miske po 48 hodinách kultivácie. Údaje o priemerných denných teplotách boli získané z meteorologickej stanice Arboréta Mlyňany SAV. Vo všeobecnosti všetky analyzované druhy borovíc vykazovali vysoké hodnoty klíčivosti (od 85 % pre *P. ponderosa* do 98,89 pre *P. cembra*). Hodnoty dĺžok peľových vrecúšok sa pohybovali v rozmedzí od 57,11 µm pre *P. bungeana* do 139,2 µm pre *P. mugo*. Hodnoty klíčivosti a dĺžky peľových vrecúšiek boli porovnané Duncanovým testom a variačnou analýzou (ANOVA). Naše výsledky naznačujú, že pokiaľ skúmame na jednej lokalite viaceré príbuzné druhy borovíc, ktoré v danom roku prášia v rovnakom období, tak charakteristiky kvality ich peľu budú podobnejšie ako pri systematicky vzdialených druhoch prášiacich v inom období. Predpokladáme, že medziročná zmena smeru kvality peľu bude pri systematicky príbuzných druhoch prášiacich v rovnakom období prebiehať rovnakým smerom. Predpokladaný vplyv ďalších faktorov je uvedený v diskusii.

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Concentration of oxygen dissolved in Water Nature Reserve Alúvium Žitavy in the southwestern part of Slovak Republic

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Abstract

Noskovič, J., Babošová, M., Porhajašová, J. 2013. Concentration of oxygen dissolved in Water Nature Reserve Alúvium Žitavy in the southwestern part of Slovak Republic. *Folia oecol.*, 40: 78–83.

Over the years 2009–2010, the concentrations of dissolved oxygen depending on sampling time and sampling site in the water of the Nature Reserve (NR) Alúvium Žitavy, which is situated in the southwestern part of the Slovak Republic, were evaluated. On the basis of the results we achieved we can state that its mean concentration in the water of the Nature Reserve over the whole monitored period was 5.98 mg O_2 dm^{-3}. Depending on the time of collection, the highest average oxygen concentration for the whole period of study in March (14.36 mg O_2 dm^{-3}) was found, which is probably related to a high flow and due to turbulent stirring of water as well. For the whole period of study the lowest average concentrations in the water of the Alúvium in the summer period were observed with a minimum value being in July (3.36 mg O_2 dm^{-3}). It is supposed that the decrease in oxygen concentration in the summer period with a higher temperature of water and more intensive decomposition of organic matter by microorganisms was linked. Depending on the collection places, the highest average concentrations were in collection sites no. 1 (8.57 mg O_2 dm^{-3}), which being located on the inflow of the river Žitavy to the Alúvium and no. 4 (8.24 mg O_2 dm^{-3}), which was located in the narrowest place of the Alúvium with the fastest water flowing. The lowest average concentrations for the whole period of study in sampling sites of wetland nature (sampling site no. 2, 3, 5 and 6) were discovered, the lowest average value being in the sampling site no. 6 (5.31 mg O_2 dm^{-3}). The calculated value of the 10th percentile of this indicator was lower in all sampling sites when compared with that recommended by order of the Slovak Government No. 269/2010 Coll.

Key words

dissolved oxygen, nature reserve, water quality

Introduction

An important indicator of the purity of surface waters is the concentration of dissolved oxygen (Pitter, 1999). Most biochemical processes are influenced to a great extent by oxygen amount in water, it is a limiting factor for the life of organisms, determining by aerobic or anaerobic processes will be under way in water (Heteša and Kočková, 1997). The main source of oxygen in surface waters is the level transfer from the atmosphere and photosynthesis of aquatic plants (Maidment, 1993; Ambrožová, 2003). As the movement of the water is slowed down, the transfer of oxygen from the atmosphere into the water is decreased too (Metějko, 1981). Its solubility in water depends on the temperature and pressure, to a lesser extent also on the content of salts in water (Šulvová et al., 2009). Water oxygen is consumed by bacteria decomposing organic matter present in the flow (Langhammer, 2002). It is inevitable for fish life and self-cleaning processes in surface waters. If it is depleted from water, environment becomes anoxic (Pitter, 2009).

Material and methods

Research area

The Nature Reserve (NR) Alúvium Žitavy is situated in the cadastral land of the town Hurbanovo and the village Martovce in the southwestern part of the Slovak Republic (*Krajinno-ekologický plán obce Martovce*, 2006). Its area is 32.53 hectares, and it was established as the Nature Reserve in 1993. The Alúvium lies in the interperineal area of the river Žitava, from its present estuary of the river Nitra to the village of Veľký Vék (assumed air line) (Szabóová, 1989). It is closely adjacent surrounding agrocenosis with remainders of meanders of the original water course of the rivers Nitra and Žitava. There is an open water line of the canal with dense bank vegetation in the central part of the Reserve. The northern part is enlarged and there is continuous vegetation of riparian forest. Wetland ecosystems are situated mainly in terrain depression at the edge of the alluvium of the river Žitava (Bridišová et al., 2006).

Its larger part is flooded along the year, but especially in spring. There are different biotopes, aquatic, wetland and riverine vegetation. Riverine forests, particularly willow stands, almost along alluvium provide suitable ecological conditions for nesting and roosting of avifauna. There are more than 76 bird species occurring in this area (*Prírodná rezervácia Alúvium Žitavy*, 2006). Furthermore is very important for conservation of fauna and flora genetic resources (*Štátny zoznam osobitne chránených častí prírody a krajiny Slovenskej republiky*, 2007).

The NR Alúvium Žitavy is a part of the Protected Landscape Area Dunajské luhy (*Krajinno-ekologický plán obce Martovce*, 2006). The aim is to protect biotopes of European importance (riverine willow-poplar and alder wood forests) and the species of European importance (*Proterorhinus* sp., *Rhodeus amarus*, *Gobio albipinnatus*, *Bombina bombina*, *Lutra lutra*, *Citellus citellus*, species of national importance *Microtus oeconomus*) (Bridišová et al., 2006). Concurrently, NR Alúvium Žitavy is a part of the Special Protection Area SKSPA 005 Dolné Považie to which also belongs the proposed habitat of European importance 0159 Alúvium Žitavy (*Krajinno-ekologický plán obce Martovce*, 2006). The rare species of avifauna are for example *Ardea* sp., *Remiz* sp., *Botaurus* sp., *Circus* sp., *Anas* sp., *Acrocephalus* sp., *Charadrius* sp., *Locustella* sp., etc. In term of protected flora, there are *Leucojum aestivum* growing almost over the whole area of the NR and *Nuphar lutea* on water surface. *Ceratophyllum* sp., *Lemna minor* and *Lemna trisulca* form a typical green cover on the water surface. Along the interperineal area of the river Žitava, there is wetland vegetation from which communities of *Phragmites australis*, *Typha latifolia*, *Carex* sp. and *Scirpus* sp. are dominant (*Prírodná rezervácia Alúvium Žitavy*, 2006).

Sampling and processing of the material

Water sampling was carried out from the 6 sampling sites in the NR. The water samples were taken regularly during the years 2009–2010, on the 15th day of each month. The sampling sites were proposed to obtain the best possible data for the evaluation of changes in dissolved oxygen concentrations in water in dependence on the sampling time and site. We have established the following 6 sampling sites:

Sampling site No. 1 (47°51'88" N, 18°09'89" E, 121 m a.s.l.) – inflow of the river Žitava into the Alúvium. *Phragmites australis* and *Salix* sp. grow along the river Žitava. The average depth is 0.32 m.

Sampling site No. 2 (47°51'92" N, 18°09'25" E, 111 m a.s.l.) and **No. 3.** (47°51'83" N, 18°09'25" E, 117 m a.s.l.) – these sampling sites are typical wetland ecosystems. There is a very dense vegetation of *Phragmites australis* and *Salix* sp. in this part of the NR. The water surface is covered by *Lemna minor*. Water in these sites flows very slowly, and the height of its level change is in dependence on weather during the year. The average depth is 0.30 m.

Sampling site No. 4 (47°51'58" N, 18°08'38" E, 129 m a.s.l.) – is situated near a bridge on a road to the village of Martovce. It is also the narrowest part of Alúvium; where the water in the river Žitava flows most rapidly. There is a typical vegetation of *Phragmites australis*, *Salix* sp. and *Alnus* sp. on the banks of the river Žitava. The average depth is 0.40 m.

Sampling site No. 5 (47°51'09" N, 18°07'99" E, 116 m a.s.l.) and **No. 6** (47°50'81" N, 18°07'67" E, 121 m a.s.l.) – typical wetland ecosystems. Here, the river Žitava flows out of its watershed during rapid snow melting in spring and intensive precipitation events in summer. In comparison with the second and the third sampling site, the river floods the whole depression between the two slopes. In dry summer the water level decreases by about a few metres. This part of Alúvium is represented mainly by an open water area. *Typha latifolia*, *Phragmites australis*, *Alnus* sp. and *Salix* sp. grow along the river. The water surface in sampling site No. 6 is covered with *Lemna* sp. forming a typical green cover. Beyond this sampling site, the river Žitava flows into the river Nitra. The average depth in sampling site No. 5 is 0.26 m and 0.39 m in the sampling site No. 6.

Oxygen dissolved concentrations by the galvanic oxygen probe StirrOx (G) using the apparatus inoLab Multi Level 3 were determined in the water samples collected. Evaluation of surface water quality for dissolved oxygen was carried out using a value of the 10th percentile (P10), calculated from the values measured, and by subsequent comparing them with the corresponding system of limit values, which are set out in the Government regulations of the Slovak Republic No. 269/2010 Coll.

Results and discussion

The average values of dissolved oxygen during the period of study ranged from 1.02 (June 2010) to 19.83 mg O_2 dm^{-3} (March 2009). For the whole period of study its value represented 5.98 mg O_2 dm^{-3} (Fig. 1). The highest average concentration for the whole period of study was discovered in March (14.36 mg O_2 dm^{-3}, Fig. 2), which is probably related with a higher flow of water (Fig. 3), in which its turbulence has increased, which according to LANGHAMMER (2002) contributes to a water oxygen saturation. Since the month of March the average oxygen concentration for the whole period of study was decreasing gradually until the month of July, when its minimum value was found (3.36 mg O_2 dm^{-3}). In the following months until the month of October its rise was observed. From the results of the average oxygen concentrations for the whole period of study, depending on the sampling time at the same time it follows that their lowest values were in the summer period. We assume that the low oxygen concentrations in the summer period are related with warmer temperature of water (Fig. 4). An opinion of several authors has, as a result, been confirmed (AMBROŽOVÁ, 2003; PITTER, 2009; NOSKOVIČ et al., 2010) that at higher temperatures the solubility of oxygen in water lowers. In addition, the decrease in oxygen concentration in the summer period may have been related with a more intensive decomposition of organic substances by microorganisms.

Except for the months of February, June, July and August in 2010, with respect to fish life, detected oxygen concentrations in water in the alluvium of Žitava may be considered to be still more satisfactory, because as stated by LELLÁK and KUBÍČEK (1991) a critical limit for most of the species makes 3–4 mg O_2 dm^{-3}.

The influence of sampling site on dissolved oxygen concentrations is shown in Fig. 5. The highest average concentrations have been measured in sampling sites no. 1 (8.57 mg O_2 dm^{-3}), no. 4 (8.24 mg O_2 dm^{-3}). Lower concentrations were shown in sampling sites. 2, 3, 5 and 6, with the lowest average value for the whole period of study being found in the sampling site no. 6 (5.31 mg O_2 dm^{-3}). We assume that this is related with the nature of these sampling sites. They are wetland habitats with slow-flowing or even stagnant water surface, which facilitated for a thick layer of sediments rich in organic substance from dead macrophytes to be created that form dense growth in these places. Due to this also increased the concentration of organic substances in water, by decomposition of which dissolved oxygen was consumed, which has resulted in its concentration decrease. In similar habitats as were in the locations no. 2, 3, 5 and 6 low oxygen dissolved content was also found out by SEDLÁKOVÁ (2004) in nature reserve Parisian swamplands and BEŇAČKOVÁ (2007) in nature reserve Žitavský wetland.

In the requirements on the quality of surface water in the Regulations of the Slovak Government No. 269/2010 Coll., the value for dissolved oxygen makes more than 5 mg dm^{-3}. The values calculated of the 10th percentile of this index indicator in all sampling sites were lower than those recommended in the Regulations of the Slovak Government.

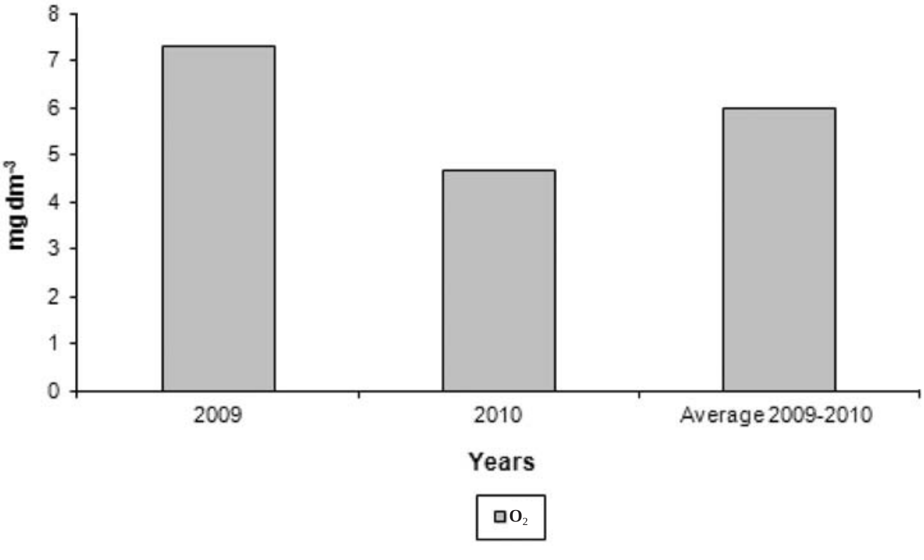

Fig. 1. Mean concentrations of dissolved oxygen in the water of Alúvium Žitavy in years 2009–2010 [mg O_2 dm^{-3}].

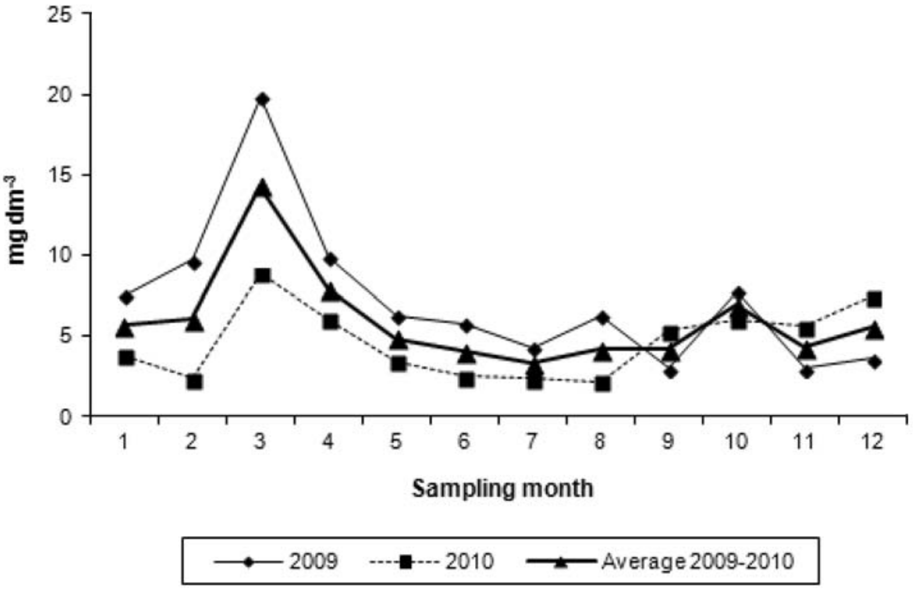

Fig. 2. Mean concentrations of dissolved oxygen in depending on sampling time.

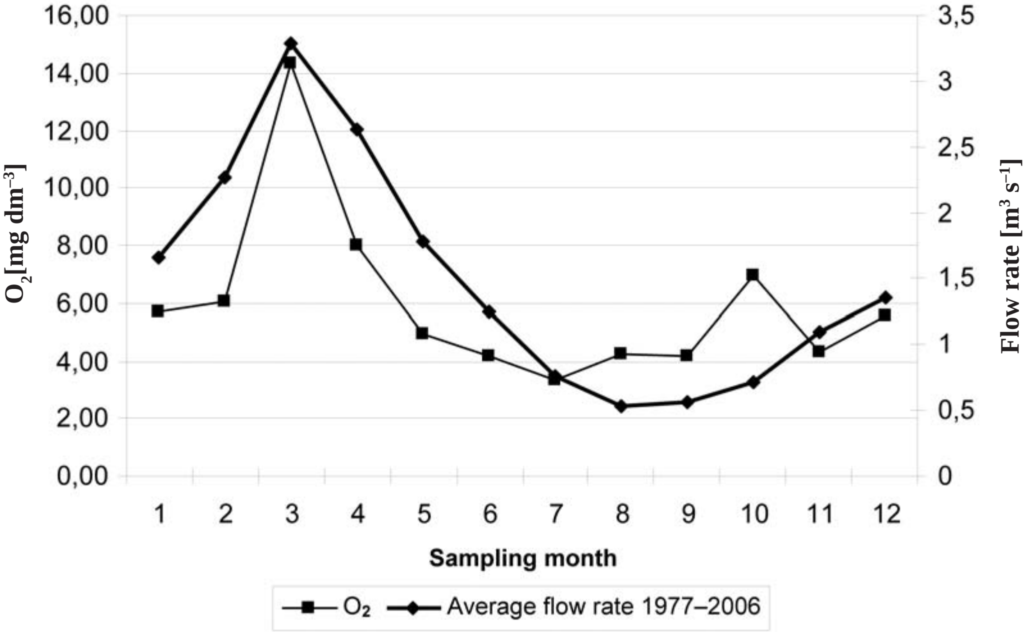

Fig. 3. The relationship between concentration of dissolved oxygen and flow rate
(Vieska nad Žitavou gagin station).

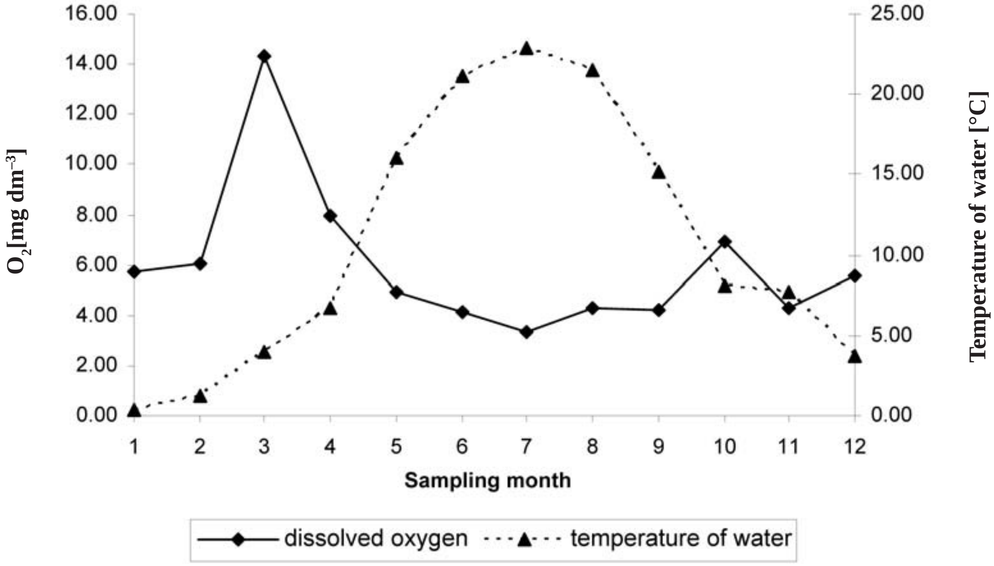

Fig. 4. The relationship between concentration of dissolved oxygen and temperature of water.

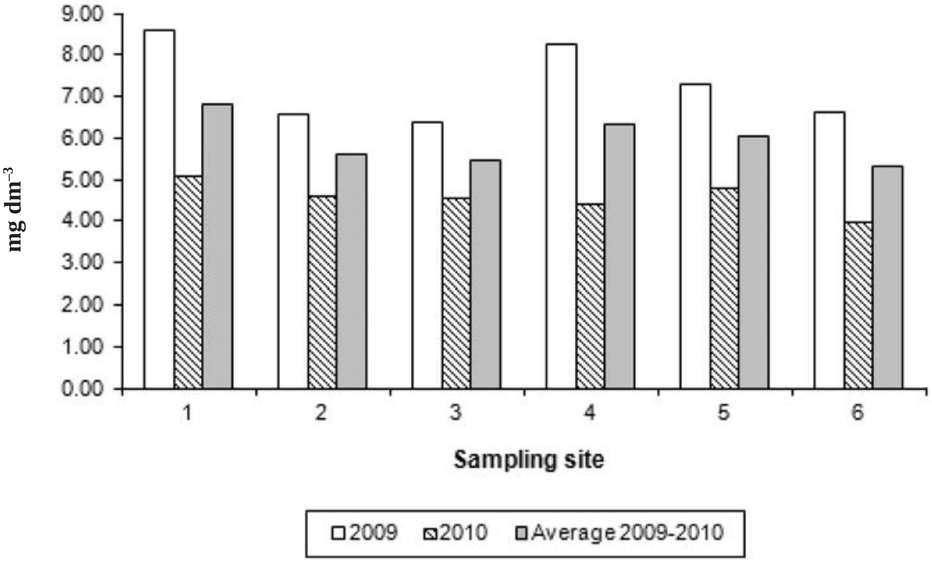

Fig. 5. Mean concentrations of dissolved oxygen in depending on sampling site.

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Koncentrácia rozpusteného kyslíka vo vode Prírodnej rezervácie Alúvium Žitavy, juhozápadné Slovensko

Súhrn

V priebehu rokov 2009 – 2010 sa vo vode Prírodnej rezervácie Alúvium Žitavy, ktorá sa nachádza v juhozápadnej časti Slovenskej republiky, hodnotili koncentrácie rozpusteného kyslíka v závislosti od času a miesta odberu. Na základe získaných výsledkov môžeme konštatovať, že jeho priemerná koncentrácia vo vode PR za celé sledované obdobie bola 5,98 mg O_2 dm^{-3}. V závislosti od času odberu najvyššia priemerná koncentrácia kyslíka za celé sledované obdobie sa zistila v mesiaci marec (14,36 mg O_2 dm^{-3}), čo pravdepodobne súvisí s vysokým prietokom a tým aj turbulentným premiešavaním vody. Najnižšie priemerné koncentrácie za celé sledované obdobie vo vode Alúvia boli v letnom období s minimálnou hodnotou v mesiaci júl (3,36 mg O_2 dm^{-3}). Predpokladáme, že pokles koncentrácie kyslíka v letnom období súvisel s vyššou teplotou vody a intenzívnejšou dekompozíciou organických látok mikroorganizmami. V závislosti od miesta odberu najvyššie priemerné koncentrácie sa namerali v odberových miestach č. 1 (8,57 mg O_2 dm^{-3}), lokalizovanom na vtoku rieky Žitavy do Alúvia a č. 4 (8,24 mg O_2 dm^{-3}), ktoré sa nachádzalo v najužšom mieste Alúvia s najrýchlejším prúdením vody. Nižšie priemerné koncentrácie za celé sledované obdobie boli v odberových miestach mokraďového charakteru (odberové miesto č. 2, 3, 5 a 6) s najnižšou priemernou hodnotou v odberovom mieste č. 6 (5,31 mg O_2 dm^{-3}). Vypočítané hodnoty 10. percentilu tohto ukazovateľa vo všetkých odberových miestach boli nižšie ako odporúčaná hodnota v Nariadení vlády SR č. 269/2010 Z. z.

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Spatial occurrence and abundance of five phloeophagous beetle species (Coleoptera) in Scots pine trees (*Pinus sylvestris*) growing on sandy soils

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Abstract

Olšovský, T., Zach, P., Kulfan, J., Juríkova-Matulová, Z. 2013. Spatial occurrence and abundance of five phloeophagous beetle species (Coleoptera) in Scots pine trees (*Pinus sylvestris*) growing on sandy soils. *Folia oecol*., 40: 84 –90.

Spatial occurrence and abundance of *Ips sexdentatus, Phaenops cyanea, Pissodes piniphilus, Tomicus minor* and *Ips acuminatus* (Coleoptera: Curculionidae, Buprestidae) were examined in mature Scots pine trees (*Pinus sylvestris*) growing on poor sandy soils in Záhorská nížina lowland in western Slovakia, Central Europe. In the study area, the five given phloeophagous species are secondary pests of Scots pine spatially separated in pine trunks. Early in March 2006, each of them was recorded in 10 different Scots pine trees, in the lower, middle and upper parts (sections) of the trunks, each section being 4.0 m long. The study was made to clarify in more detail (1) as to whether and to which extent studied species occur in the middle trunks and (2) how their abundance (density) is differing among particular trunk sections of infested trees. All studied species were recorded in the middle trunk sections. However, the four of them, *I. sexdentatus, P. piniphilus, T. minor* and *I. acuminatus*, were less frequent here than in the other sections (lower or upper) they were preferring. Abundance of each species per 1,000 cm^2 significantly differed among the trunk sections ($p < 0.001$, Kruskal-Wallis anova). Particular species avoided extreme situations, that is, species inhabiting the lower trunks (*I. sexdentatus* and *P. cyanea*) were not recorded in the upper trunks and those colonizing the upper trunks (*P. piniphilus, T. minor, I. acuminatus*) were not documented to be developing in the lower trunks. In each species, variability in abundance was greatest in most densely colonized (preferred) parts of the trunks. The results give the evidence that high number of individuals of studied species are developing in dying mature pine trees in a mixed oak-pine forest in Central Europe.

Keywords

Central Europe, phloeophagous beetles, *Pinus sylvestris*, Scots pine, spatial occurrence

Introduction

Scots pine (*Pinus sylvestris* L.) is the most widely distributed conifer species in the world (Nikolov and Helmisaari, 1992), with an extensive natural range stretching from Spain to Norway and from Scotland to Siberia (Mason, 2000). Among numerous other organisms it hosts many insects, often beetles (Coleoptera), many of which occupy subcortical niche in dying or dead trees (Hussler and Müller-Kroehling, 2007).

The main features of distribution of phloeophagpus beetles within a tree are known for a long time in the case of Scots pine, however, they have been studied only extensively (Sauvard in Lieutier et al., 2004). Resource (niche) partitioning in phloeophagous beetle species developing in Scots pine has been documented by qualitative (e.g. Schedl in Freude et al., 1981; Kudela, 1970; Bílý, 1989) and quantitative data mostly available for few pest species, often bark beetles (e.g. Bakke, 1968; Randuška, 1983; Saarenmaa, 1983;

Bouhot et al., 1988; Schroeder and Eidmann, 1993; Amezaga and Rodríguez, 1998), or for assemblages of phloeophagous beetles from different taxonomical groups (Olšovský, 2008; Foit, 2007, 2010).

This study explores spatial occurrence and abundance of *Ips sexdentatus*, *Ips acuminatus*, *Tomicus minor* (Curculionidae, Scolytinae), *Pissodes piniphilus* (Curculionidae, Pissodinae) and *Phaenops cyanea* (Buprestidae) in mature Scots pine trees maintaining the stability of poor sandy soils in western Slovakia in Central Europe. The five given phloeophagous species are common, widely distributed pests of Scots pine (Apel et al., 1999; Dajoz, 2000; Sowińska, 2006; Borkowski, 2007; Colombari et al., 2012) which are known to be spatially separated in pine trunks (e.g. Bakke, 1968; Olšovský, 2008). We clarify in more detail (1) as to whether and to which extent the five studied species are also occurring in the middle trunks of Scots pine trees and (2) how abundance of these species differs among the lower, middle and upper parts of the trunks infested. We expected that studied species primarily will occupy, depending on their specific habitat requirements, the subcortical niche in the lower (*I. sexdentatus, P. cyanea*) or upper trunks of infested trees (*P. piniphilus*, *T. minor*, *I. acuminatus*) and, possibly, the niche in the middle trunks too.

Material and methods

Study area

Acording to the evidence by the National Forest Centre, Scots pine forests maintaining the stability of sandy soils in Záhorská nížina lowland in western Slovakia cover the area of approximately 50,000 ha. Study was carried out within this large forest area, in a mixed oakpine stand (*Pineto-Quercetum*, 30 ha, 227 to 238 m a.s.l., south-east aspect, pine trees approximately 145 years old, 48°36'14" N, 17°19'19" E). Scots pine dominates (90%) the sessile oak (*Quercus petraea*) and other tree species. The herb-layer mostly consists of *Calluna vulgaris, Carex ericetorum, Corynephorus canescens, Thymus serpyllum*, *Euphorbia cyparissias* and *Festuca ovina*. The biotope is classified as Ls6.1 „Acidophilous pine and oak-pine forest“ (Stanová and Valachovič, 2002). The area is characterized by poor dry sandy soils, although moist sites are also present locally (Baňacký and Sabol, 1973). It is climatically warm, with average temperatures in the range from 9 to 10 °C and rainfall between 450 and 700 mm (evidence by the Slovak Hydrometeorological Institute).

Host trees

A total of 10 mature, tall, straight-trunked Scots pine trees with few side branches were examined separately for the occurrence of each of the folowing five beetle species, all phloeophages: *I. sexdentatus, P. cyanea, P. piniphilus*, *T. minor* and *I. acuminatus*. The trees were infested by beetles over the growing season 2005 and felled in February 2006. To document occurrence of beetle species in the trunks of infested trees, each trunk was divided into the three distinct, spatially separated sections with the following diameters and distance from the tree base or cut area, respectively: lower section (diameter: 0.30–0.42 m, distance: 0.0 m), middle section (0.22–0.30 m, 8.0 m) and upper section (0.12–0.17 m, 16.0 m), each section being 4.0 m long. Thickness of the bark was measured at the beginning, in the centre and at the end of each section. Average thickness of the bark was calculated for each section as the mean of the three measurements.

To obtain beetles the bark was carefully and completely peeled away from each trunk section early in March 2006. The bark and beetles were sampled, those beetles present in the bark were separated from the breeding substrates in the laboratory. Then, larvae and/or beetle adults (depending on species) were counted and identified. As the scolytid *T. minor* does not overwinter in the breeding substrates, number of individuals of the beetle was detected indirectly, by counting emergence holes on the bark, this being combined with a thorough examination of the beetle galleries under the bark.

Data analysis

Frequency of occurrence of a beetle species in a given trunk section was calculated as the ratio between the observed number of occurrences and the number of all possible occurrences of this species in particular section (n = 10). For comparative purposes, the number of beetles collected from each trunk section was related to the area of 1,000 cm^2. It was compared among the trunk sections by the nonparametric Kruskal-Wallis anova test (Zar, 2010). Significant differences in beetle densities among particular trunk sections were detected by multiply comparisons in K-W anova. Data analysis was performed in the program Statistica (StatSoft Inc., 2005). Presence of studied species related to the trunk diameter and thickness of the bark was shown in the form of scatterplot made in the program R.

Results

The occurrence of *I. sexdentatus*, *P. cyanea*, *P. piniphilus*, *T. minor* and *I. acuminatus* in particular trunk sections of Scots pine trees, characterized by particular trunk diameters and bark thickness, is shown in Fig. 1. All species were recorded in the middle section of the trunks examined. Except for *P. cyanea*, they were less frequent in this section compared to the other sections (lower or upper) they were preferring. The bark beetle *I. sexdentatus* was most frequent in the lower, while the jewel beetle *P. cyanea* was found most frequently in the lower and middle section. The weevil *P. piniphilus* and the two scolytid species, *T. minor* and *I. acuminatus*, occurred most frequently in the upper section. No of the five studied species was recorded in each trunk section (Figs 1, 2).

A total of 666 adults of *I. sexdentatus* were obtained from the middle trunk sections (n = 10), against a total of 4,289 adults collected from the lower sections (n = 10). The number of adult beetles varied between 0 and 170 in the middle and between 220 and 660 in the lower section. Number of adults per 1,000 cm^2 significantly differed among the sections ($H_{(2, N = 30)} = 24.1188$, $p < 0.001$, K-W ANOVA) (Fig. 3).

The middle trunk sections (n = 10) yielded a total of 819 larvae of *P. cyanea*, and a total of 3,156 larvae were obtained from the lower sections (n = 10). The number of larvae varied from 29 to 188 in the middle and from 151 to 490 in the lower section. Number of larvae per 1,000 cm^2 was significantly different among the sections ($H_{(2, N = 30)} = 25.8969$, $p < 0.001$, K–W ANOVA) (Fig. 3).

A total of 482 larvae of *P. piniphilus* were recorded in the middle trunk sections (n = 10), and a total of 1,194 individuals were documented in the upper sections (n = 10). Number of larvae varied from 0 to 113 in the middle and from 38 to 214 in the upper section. Number of larvae per 1,000 cm^2 significantly differed among the sections ($H_{(2, N = 30)} = 23.7771$, $p < 0.001$, K–W ANOVA) (Fig. 3).

Based on the counts of emergence holes, the middle trunk sections (n = 10) produced a total of 3,711 adults of *T. minor* at least, while the upper sections (n = 10) supported at least 12,737 adults. The number of emergence holes varied from 0 to 1,130 in the middle and between 603 and 2,135 in the upper section. There was a significant difference in the number of emergence holes per 1,000 cm^2 among the sections ($H_{(2, N = 30)} = 23.9517$, $p < 0.001$, K–W ANOVA) (Fig. 3).

In the case of *I. acuminatus*, the middle trunk sections (n = 10) yielded a total of 2,882 adults, and as many as 16,148 adults were obtained from the upper sections (n = 10). The number of adults varied from 0 to 785 in the middle and from 980 to 2,669 in the upper section. Number of adults per 1,000 cm^2 significantly differed among the sections ($H_{(2, N = 30)} = 24.0209$, $p < 0.001$, K–W ANOVA) (Fig. 3).

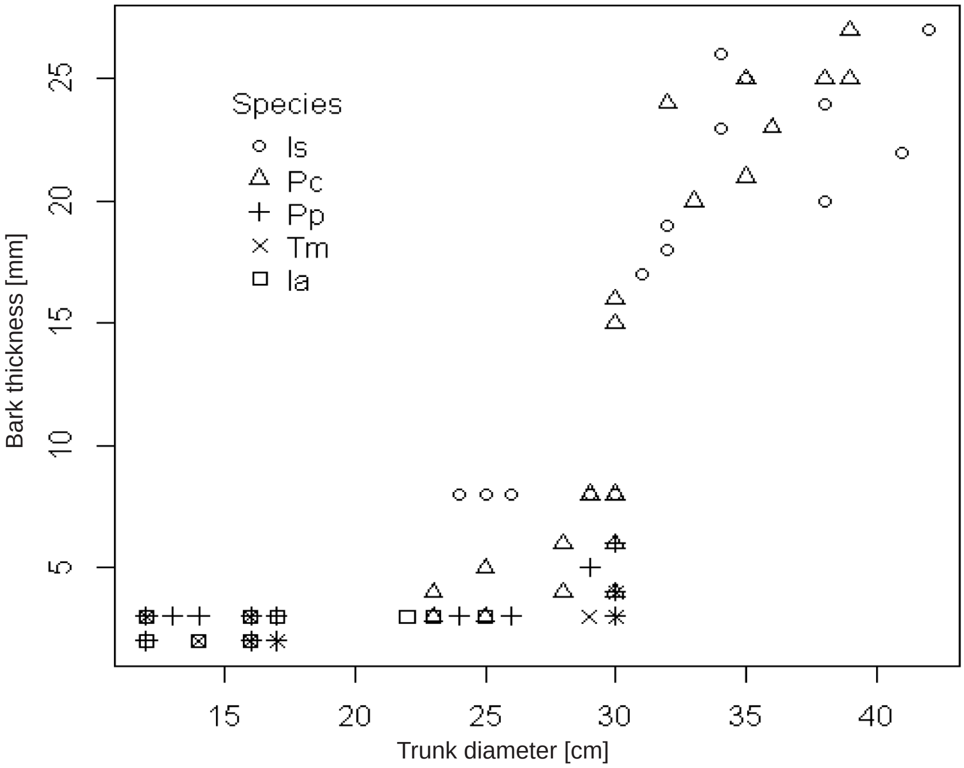

Fig. 1. The occurrence of *Ips sexdentatus* (Is), *Phaenops cyanea* (Pc), *Pissodes piniphilus* (Pp), *Tomicus minor* (Tm) and *Ips acuminatus* (Ia) in mature Scots pine trees related to trunk diameter and bark thickness. Three distinct groups (from left to right) represent the upper, middle and lower section of the 10 tree trunks examined separately for the presence of each species. Species data is overlapping, especially in the middle and upper trunk sections. Záhorská nížina lowland, western Slovakia, March 2006.

Discussion

Scots pine tolerates a wide range of growing conditions, occupying sites unfavourable to other tree species, often characterised by poorer sandy soils (Mason, 2000). Despite this, mature pine trees die frequently on dry sandy soils in the study area (Olšovský, 2008) where the five studied beetle species affect the health of Scots

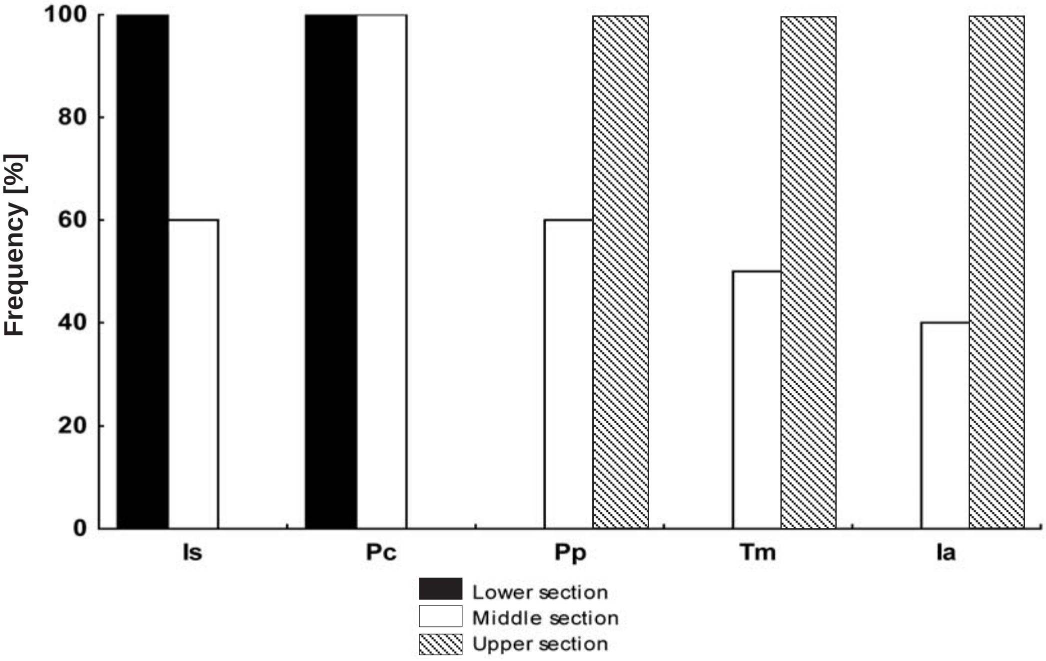

Fig. 2. Frequency of occurrence of *Ips sexdentatus* (Is), *Phaenops cyanea* (Pc), *Pissodes piniphilus* (Pp), *Tomicus minor* (Tm) and *Ips acuminatus* (Ia) in three trunk sections of the 10 mature Scots pine trees examined separately for the presence of each species. Záhorská nížina lowland, western Slovakia, March 2006.

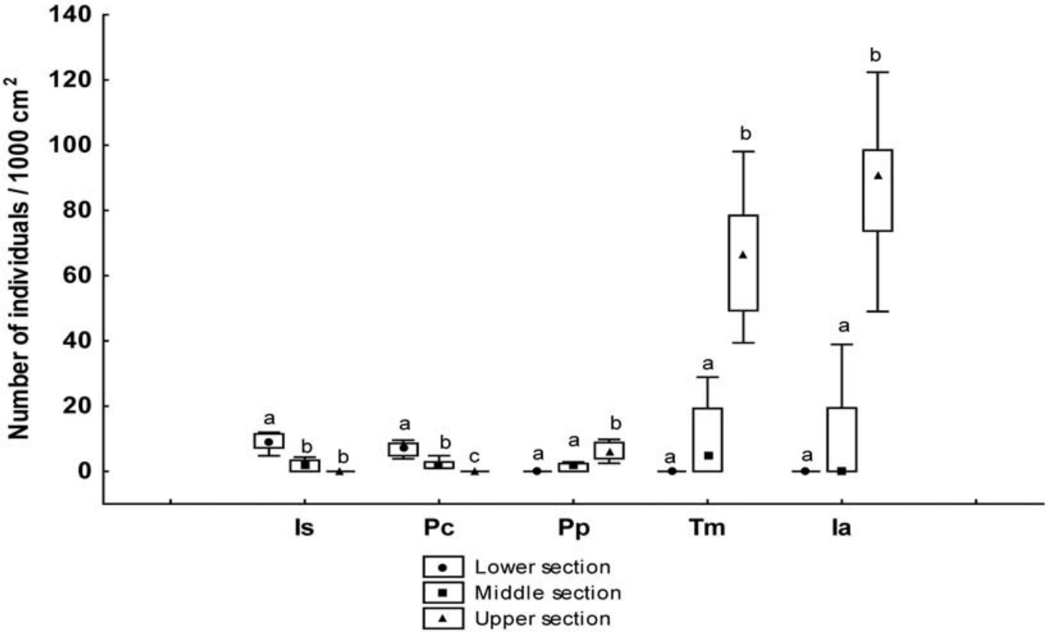

Fig. 3. Variation in abundance (ind./1000 cm^2) of *Ips sexdentatus* (Is), *Phaenops cyanea* (Pc), *Pissodes piniphilus* (Pp), *Tomicus minor* (Tm) and *Ips acuminatus* (Ia) in three distinct trunk sections of the 10 mature Scots pine trees examined separately for the presence of each species. Different letters indicate significant differences at $\alpha = 0.05$ (multiply comparisons in K–W anova). Box and whisker plots – box: median, 1st and 3rd quantile, whiskers: non-outlier range (minimum and maximum). Záhorská nížina lowland, western Slovakia, March 2006.

pine secondarily, together with other phloeophagous (e.g. *Tomicus piniperda*, *Pityogenes quadridens*, *Pityogenes chalcographus*) and phyllophagopus beetles (Holecová and Kulfan, 2010), moths (Kulfan and Holecová, 2010), sawflies (Kulfan et al., 2011) and other insects. They all are frequently (Fig. 2) and abundantly (Fig. 3) developing in the trunks of infested trees, increasing in number after warm and dry weather and/or after wind and snow disturbances, forest fires and anthropogenic impacts (e.g. tree felling) modifying the canopy cover. In the study area they greatly increase their abundance locally, as documented, for example, in the case of *I. sexdentatus* in France (Dajoz, 2000), *P. cyanea* in Germany (Apel et al., 1999), *Tomicus* spp. in Poland (Borkowski, 2007) and *I. acuminatus* in Switzerland (Colombari et al., 2012).

Knowledge of spatial occurrence of the given five beetle species in the trunks of mature Scots pine trees presented here is in agreement with that in the literature (e.g. Bakke, 1968; Randuška, 1983; Foit, 2007). All studied species were documented to occupy the subcortical niche in the middle trunks of infested trees. However, *I. sexdentatus*, *P. piniphilus*, *T. minor*, *I. acuminatus*, were less frequent here compared to their preferred locations in the lower or upper trunks (Fig. 2). All species were always (in each tree) less abundant in the middle part of the trunk than in their preferred (lower or upper) location (Fig. 3). Thus, the middle trunks, if 20–30 cm thick, may be considered as being less favourable but not unimportant for the development of studied beetle species. As expected, they all avoided extreme situations. That is, the species *I. sexdentatus* and *P. cyanea*, developing in the lower and middle trunks, were not found in the upper trunks and the species *P. piniphilus*, *I. acuminatus* and *T. minor*, inhabiting the upper and middle trunks, were not recorded in the lower trunks (Figs 1–3). This gives a sound evidence of partitioning of the food and habitat resource (e.g. Bakke, 1968; Amezaga and Rodríguez, 1998) and, possibly, of the competitive interactions among co-occurring species. According to Sowińska (2006) and our knowledge, too, the bark beetle *I. sexdentatus* and the jewel beetle *P. cyanea* may co-occur in the lower and middle trunks. Two scolytid species, *T. minor* and *I. acuminatus*, often, consume much of the phloem in the upper trunks, the weevil *P. piniphilus* being their frequent but much less abundant associate here (Figs. 2, 3).

Number of individuals of studied species developing within a particular trunk section was varying to some extent. In each species, great variation in abundance primarily was associated with the most densely colonized trunk sections (Fig. 3). Greatest variation in abundance was documented in the case of *T. minor* and *I. acuminatus* (Fig. 3). Numerous emergence holes produced by the adults of *T. minor* document successful development of the beetle in standing trees over the growing season 2005. Compared to other species in the study, the scolytid *T. minor* has a more complex biology (Kudela, 1970). According to Långström (1983) it overwinters in the litter. This explains its absence in the breeding substrates examined. In the study area, *T. minor* is among the most important insect pests of Scots pine, together with *I. acuminatus*. Although a large part of the adults of *I. acuminatus*, irrespective of generation, may leave the breeding substrates before hibernation (Colombari at al., 2012), many adults of the beetle still may be found overwintering in the trunks as shown in the results.

Thickness of the bark correlates with the trunk diameter and is varying greatly for certain trunk diameters in the case of Scots pine, especially in the lower and middle trunks (Fig. 1). Species data in Fig. 1 shows some overlap due to similar sizes of trunk sections and/or precision of measurement of bark thickness. Data from spatially separated trunk sections (Fig. 1) does not cover the whole gradient of the bark thickness with the presence of a certain beetle species. Therefore it is difficult to realistically judge here how abundance of any studied species depends on thickness of the bark. Nevertheless, thickness of the bark is known to be a good segregating variable explaining differences in within-tree distribution of phloeophagous beetle species in Scots pine (Saarenmaa, 1983; Amezaga and Rodríguez, 1998; Foit, 2010). In addition, microclimate, too, especially surface temperature of the bark during the colonization of a tree by phloeophagous beetles, may be influencing spatial occurrence of studied species in host trees. For example, the jewel beetle *P. cyanea* prefers sunny situations and/or sunny habitats (Apel et al., 1999); the trees colonized by it have higher surface temperature than those not inhabited (Sowińska, 2006). Frequent occurrence and high abundance of this buprestid in the colonized parts of the trunks (Figs 2, 3) indicate the influence of infrared (solar) radiation in a fragmented forest, the canopy of which was strongly modified (reduced) by tree felling. The scolytid *T. minor* occupies the lower surfaces in the top of pine trees and does not settle on the upper surfaces favoured by *I. acuminatus*; such distribution pattern, similarly, is explained by thermal preferences in these two co-occurring species (Bakke, 1968; Dajoz, 2000).

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Priestorový výskyt a početnosť piatich druhov floeofágnych chrobákov (Coleoptera) na borovici lesnej (*Pinus sylvestris*) rastúcej na piesočnatých pôdach

Súhrn

Práca hodnotí výskyt a početnosť piatich druhov floeofágnych chrobákov, *Ips sexdentatus, Phaenops cyanea, Pissodes piniphilus, Tomicus minor* a *Ips acuminatus* (Coleoptera: Curculionidae, Buprestidae), na borovici lesnej (*Pinus sylvestris*) rastúcej na piesočnatých pôdach Záhorskej nížiny na západnom Slovensku. Študované druhy sa tu uplatňujú ako sekundárne škodce borovice urýchľujúce odumieranie dospelých stromov a ich porastov. Kvantitatívne údaje boli získavané pre každý druh chrobáka osobitne na súbore 10 kmeňov dospelých borovíc spílených vo februári a analyzovaných začiatkom marca 2006. Priestorový výskyt jednotlivých druhov bol hodnotený v spodnej, strednej a hornej časti kmeňa, v sekciách charakterizovaných hrúbkou kmeňa a dĺžkou 4 m. Cieľom výskumu bolo objasniť, či a do akej miery sa uvedené druhy vyskytujú, vzhľadom na ich priestorovú separáciu, aj v strednej časti kmeňov borovíc a ako sa odlišuje ich početnosť medzi jednotlivými časťami (sekciami) kmeňa. Všetky študované druhy boli zaznamenané v strednej časti kmeňa s hrúbkou od 20 do 30 cm. S výnimkou krasoňa *P. cyanea* tu však boli menej časté ako v druhovo špecificky uprednostňovanej dolnej alebo hornej časti kmeňa. Detekované boli štatisticky signifikantné rozdiely v hustote kolonizácie porovnávaných sekcií borovicových kmeňov študovanými druhmi ($p < 0{,}001$, Kruskal-Wallis ANOVA). Druhy uprednostňujúce spodnú časť kmeňa (*I. sexdentatus, P. cyanea*) neboli zistené v hornej časti kmeňa a druhy uprednostňujúce hornú časť kmeňa (*P. piniphilus, T. minor, I. acuminatus*) neboli zaznamenané v spodnej časti kmeňa. Vysoká variabilita početnosti študovaných druhov bola dokumentovaná predovšetkým v častiach kmeňa s vysokou hustotou kolonizácie. Najväčšia variabilita početnosti bola zistená u druhov *I. acuminatus* a *T. minor* v hornej časti borovicových kmeňov. Podľa prezentovaných výsledkov v odumierajúcich dospelých boroviciach prebieha vývin mnohých jedincov študovaných druhov chrobákov. S výnimkou druhu *T. minor* tieto zimujú v mieste vývinu v hostiteľských stromoch.

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Soil subtypes classified in Nature Reserve Arboretum Mlyňany, Slovakia

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Abstract

Polláková, N. 2013. Soil subtypes classified in Nature Reserve Arboretum Mlyňany, Slovakia. *Folia oecol.*, 40: 91–96.

Main aim of this work was soil classification in Nature Reserve Arboretum Mlyňany. In Arboretum locality were dug nine soil pits and in detail characterized soil properties. Near each pit were made 3 soil bores which were analysed only for selected chemical properties. It was found that on the majority of Arboretum area was soil forming substrate loess without carbonates on which was developed Stagni-Haplic Luvisol. Carbonate loess was found at north part of area with East-Asiatic dendroflora, where was developed Haplic Luvisol. Cultivated Stagni-Haplic Luvisol was classified on the area with North-American dendroflora, which was until 1975 used as a vineyard and homogenization characters of ploughing horizon are still clear. Compared to the soil under the rest of natural Oak-hornbeam forest (control), anthropically changed type of vegetation significantly influenced soil chemical properties mainly in humus horizons. The heterogeneity of soil properties was also caused by heterogeneous soil forming substrate, different way of soil use before trees planting, and earth works during Arboretum establishment.

Key words

organic carbon, pH, soil classification, soil morphology

Introduction

Soil properties in the Arboretum have long been neglected, despite beside the climate, also soil significantly decides about growing and adaptation of exotic trees. Soil properties affect not only plants rooting and growth, but also their development, succession and health (Tokár and Kukla, 2008). On the contrary, plants significantly affect soil properties by their root secretions and penetration, plant residues, influence soil erosion and accumulation, soil structure, organic matter dynamics, soil chemical composition and hydrology (Konôpková and Tokár, 2000; Philips and Marion, 2004; Šimanský, 2011, 2012). Hence, the change of vegetation considerably influences soil.

Already Dr. Ambrózy and his gardener Mišák realized that properties of soil where they intended to establish Arboretum were not suitable for demanding Mediterranean trees. On some sites the soil was so poor for mineral nutrients that it had to be excavated and pits were filled by better soil transported from Čifáre. Macroclimatic disadvantages they mitigated by microclimate modification what was reached by various landscaping, soil transfers, creation of artificial slopes, hollows and terraces (Steinhübel, 1957).

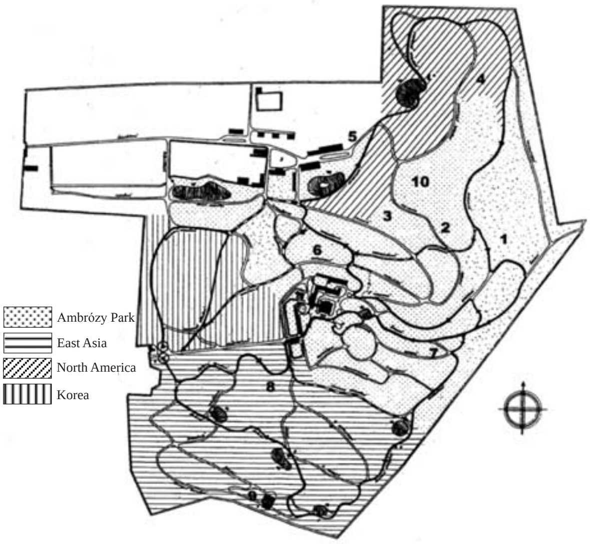
Basic soil survey in Arboretum was done by Cifra (1958), but in the past was valid old soil classification, many analyses were done by other methods and results were evaluated differently. Therefore, main aim of this work was soil survey and soil classification in Arboretum Mlyňany.

Material and methods

Arboretum Mlyňany (48º19' N, and 18º21' E) is located in southern Slovakia on the north edge of the Danubian Lowland, in the valley of Žitava river, on slightly undulated terrain, at an altitude of 165–217 m above sea level. It is situated on a late Tertiary geological formation, represented by Neogene clays, sands and rubble sands (Steinhübel, 1957). This substratum is almost all covered by wind-deposited loess, mostly without carbonates (Cifra, 1958). Mean temperature in the area is 10.6 °C and mean annual total precipitation is 541 mm (Hrubík et al., 2011).

Soil sampling and analyses

In Arboretum were dug nine soil pits in which were characterized soil morphological properties and were taken soil samples for physical and chemical analysing. Near each pit were made 3 soil bores which were analysed only for selected chemical properties. Soil pits were located sophistically, in order to classify soil in Arboretum and hereby to compare soil properties under different introduced and indigenous tree growths and grassland. On the area of original Ambrózy Park, natural vegetation was oak-hornbeam forest, therefore soil under the rest of this forest was chosen as control. Soil pits were dug under following plants: natural oak-hornbeam growth of oaks (*Quercus cerris,* L.) and hornbeams (*Carpinus betulus,* L.), under grassland, dense growth of spruces (*Picea abies,* (L.) Karsten), sugar maples (*Acer saccharinum,* L.), white fires (*Abies concolor,* Lindl. et Gord.), yews (*Taxus baccata,* L.), cherry laurels (*Prunus laurocerasus,* L.), Himalayan pines (*Pinus wallichiana,* Jacks.), Japanese cedars (*Cryptomeria japonica,* D. Don.). Under Jeffrey pines (*Pinus Jeffreyi,* Grev. et Balf.) were made only four soil bores (Fig. 1).



1, Grassland; 2, Spruces; 3, Oaks-hornbeams; 4, Sugar maples; 5, White fires; 6, Yews; 7, Cherry laurels; 8, Himalayan pines; 9, Japanese cedars; 10, Jeffrey pines.

Fig. 1. Location of stands (1–10) in Arboretum.

Total soil organic carbon content (C_T) was analysed by Tyurin method (Orlov et al., 1981); soil reaction – potentiometrically in H_2O, 1 mol dm^{-3} KCl (1:2.5); exchangeable base ions and hydrolytic acidity by Kappen's method (Fiala et al., 1999).

Each analysis was done in 3 repeats. Results shown in Table 1 represent the average values of the three soil bores and one soil pit made on particular stand. For statistical evaluation was used analysis of variance anova – Scheffe method.

Results and discussion

Evaluated soil profiles significantly differed in morphological characters, mainly in the horizons thickness, color, depth and rooting intensity. Under spruces, sugar maples, yews and cherry laurels was found also rounded gravel at size about 10–50 mm.

On the majority of Arboretum area was soil forming substrate loess without carbonates and loam on which was developed Stagni-Haplic Luvisol (soil under growth of oaks-hornbeams, grassland, spruces, white fires, yews, cherry laurels, Japanese cedars and Jeffrey pines). Carbonate loess was found at north part of area with East-Asiatic dendroflora (under Himalayan pines), where was developed Calcic Luvisol (WRB, 2006). Homogenization characters of ploughing horizon were still clear in soil, which was until 1975 used as a vineyard, therefore soil on the area with North-American dendroflora (under sugar maples) was classified as Stagni-Haplic Luvisol Anthric (WRB, 2006). Otherwise, soil under area with East Asiatic dendroflora, which was until 1960 used as an arable land had already indistinct homogenization characters of ploughing horizon, therefore soil under growth of Japanese cedars and Himalayan pines was not classified as Anthric subtype.

Soil texture in Arboretum was predominantly silt loam, loam and clay loam. The clay was markedly transferred from surface to subsurface horizons in illimerization process and the coefficient of textural differentiation in all profiles was higher than 1.2. The most significant illimerization was found under cherry laurels, where the coefficient between Bt-luvic and Btg-stagni-luvic horizon reached value 2 (Szombathová, 2010).

The average values of basic chemical properties (calculated from three soil bores and one soil pit made on particular stand) are written in Table 1. Obtained results showed that on some stands the soil properties were considerably heterogeneous. Great heterogeneity could be caused by various soil forming substrate, earthworks done before Arboretum establishment, due to various land use, or growing of different trees.

Table 1. pH values, organic carbon content and soil sorption characteristics

Horizon, depth	pH_{H_2O}	pH_{KCl}	C_T	H	S	CEC	BS
[m]			[g kg^{-1}]	[mmol kg^{-1}]			[%]
Grassland (1)							
Au 0.0–0.25	6.15±0.3	5.79±0.3	14.9±1.6	20.0±7.6	209.0±58.3	228.9±63.5	91.1±2.6
	c	d	a	a	bcd	ab	d
Bt 0.25–0.55	6.24±0.4	5.70±0.4	4.8±0.8	17.2±4.6	205.9±72.2	223.1±76.2	92.1±1.6
Btg 0.55–0.80	5.68±0.2	4.95±0.3	3.7±0.9	27.6±11.1	237.5±78.0	265.1±87.1	89.4±2.3
Spruces (2)							
Ao 0.0–0.15	4.43±0.2	4.19±0.1	20.5±4.2	109.2±30.2	93.1±39.9	202.3±61.7	44.9±11.7
	a	ab	ab	cd	ab	ab	ab
Bt 0.15–0.48	4.6±0.2	4.25±0.1	9.2±1.5	83.4±21.4	97.4±40.8	180.8±48.0	51.7±14.4
Btg 0.48–1.2	4.97+0.2	4.46±0.1	4.3±0.8	42.6±9.7	232.2±86.5	274.9±93.6	83.4±4.7
Oaks–hornbeams (3)							
Au 0.0–0.15	4.66±0.2	4.21±0.2	22.1±2.5	124.7±28.2	68.8±27.1	193.5±10.0	36.1±15.0
	a	ab	ab	d	a	ab	a
Bt 0.15–0.50	4.73±0.3	4.33±0.2	12.0±1.4	100.1±30.3	78.2±27.6	178.2±11.8	44.3±16.2
Btg 0.50–0.80	5.19±0.2	4.70±0.2	6.8±1.0	39.3±6.6	189.1±19.8	228.4±16.4	82.5±3.5
Sugar maples (4)							
Akp 0.0–0.20	4.73±0.3	4.23±0.4	23.5±3.3	66.4±12.2	114.4±27.8	180.8±16.1	62.4±9.9
	a	ab	ab	abc	abc	ab	abc
Bt 0.20–0.40	4.63±0.2	4.13±0.5	12.0±3.7	61.2±14.0	106.0±31.5	167.1±20.8	62.4±11.0
Btg 0.40–1.1	4.78±0.4	4.11±0.5	4.5±1.0	47.9±8.9	143.5±12.9	191.2±10.7	74.8+4.8
White fires (5)							
Ao 0.0–0.10	6.12±0.4	5.60±0.6	36.1±11.2	30.1±17.4	265.1±59.3	295.2±54.2	89.3±7.6
	c	cd	b	ab	d	b	d
A/Bt 0.10–0.40	6.02±0.5	5.60±0.7	20.9±6.7	25.2±15.2	228.9±57.2	254.2±50.2	89.1±7.8
Bt 0.40–0.75	6.07±0.2	5.44±0.6	5.3±1.2	16.0±6.1	196.6±42.5	212.6±40.3	92.1±4.0
Yews (6)							
Ao 0.0–0.20	4.44±0.2	3.98±0.3	22.5±2.1	73.8±4.9	119.3±16.6	192.9±14.3	61.4±4.4
	a	a	ab	bc	abc	ab	abc
Bt 0.20–0.60	4.47±0.3	3.87±0.4	11.1±1.5	63.0±15.7	123.6±32.0	195.4±18.0	66.3±11.4
Btg 0.60–0.9	4.57±0.2	3.80±0.3	5.1±0.4	49.1±5.8	204.4±33.5	253.5±30.7	80.2±4.3
Cherry laurels (7)							
Au 0.0–0.23	4.92±0.1	4.27±0.3	22.7±3.0	54.3±3.2	102.5±18.2	156.6±15.9	64.8±5.1
	a	ab	ab	ab	abc	a	bcd
Bt 0.23–0.60	4.8±0.2	3.88±0.3	9.4±0.7	50.1±9.7	80.6±18.3	130.7±9.1	60.8±10.5
Himalayan pines (8)							
Au 0.0–0.25	6.02±0.2	5.18±0.2	16.3±3.1	27.1±4.0	224.5±13.6	251.5±12.2	89.2±1.8
	bc	bcd	ab	ab	cd	ab	d
A/Bt 0.25–0.35	6.46±0.3	5.34±0.1	8.7±1.2	24.1±5.9	237.6±17.2	248.2±8.2	90.8±2.0
Bt 0.35–0.60	7.30±0.6	6.22±0.5	5.7±1.1	14.1±5.0	263.3±16.3	277.3±11.7	94.8±2.0
Japanese cedars (9)							
Au 0.0–0.20	5.06±0.2	3.37±0.1	17.4±3.5	49.1±11.2	190.6±25.2	239.7±18.5	79.2±5.3
	ab	a	a	ab	abcd	ab	cd
Btg 0.20–0.8	5.13±0.2	3.27±0.3	4.7±1.8	37.9±9.5	234.1±36.8	259.1±22.9	85.3±3.0

Table 1. pH values, organic carbon content and soil sorption characteristics – continued

Horizon, depth [m]	pH_{H2O}	pH_{KCl}	C_T [g kg^{-1}]	H	S [mmol kg^{-1}]	CEC	BS [%]
Jeffrey pines (10)							
Au 0.0–0.20	5.18±0.3	4.52±0.3	23.4±2.5	46.0±6.4	145.9±8.4	191.8±12.1	76.4±2.3
	abc	abc	a	ab	abcd	ab	cd
Bt 0.20–0.60	5.53±0.4	4.48±0.5	9.9±1.7	32.0±7.8	142.7±17.2	174.7±16.8	81.5±4.8
Btg 0.60–0.90	5.17±0.3	4.06±0.2	4.3±0.5	36.4±6.7	170.1±11.9	206.5±14.3	82.4±2.9
Scheffe < 0.05	0.9999	1.1517	16.387	46.931	125.86	126.61	26.45

Results in this table represent the average values of the three soil bores and one soil pit made on particular stand. Different letters (a–d) indicate, soil properties in A horizons are significantly different at $P < 0.05$ according to Scheffe test.
H, hydrolytic acidity; S, sum of bases; CEC, cation exchange capacity; BS, base saturation; C_T, soil organic carbon.

In Arboretum was also examined the influence of different vegetation on soil chemical properties. Differences were studied particularly between humus A-horizons which were the most affected by litter, root exudates and residues. Results showed that humus horizons were statistically significantly affected by vegetation type (Table 1).

Soil reaction is the most important indicator of the state, functioning and fertility of soil. In Arboretum profiles dominated slightly acidic to acidic active soil reaction, exchangeable soil reaction was acidic to strongly acidic. The type of vegetation had significant effect on changes of active soil reaction in A horizons, and the highest statistical difference was found between spruces and grassland. For exchangeable soil reaction the highest statistical difference was in A horizons between the cedars and grassland ($P < 0.05$). On the area of old Ambrózy Park, soil reaction of humus horizon significantly increased under grassland compared to the rest of original oak-hornbeam forest (Table 1).

Beside pH, usual indicators of soil acidity are cationic composition of sorption complex and soil saturation by aluminum. Porębska et al. (2008) stated that pH values can be considered as an indicator of overall soil acidification for a period of time, while changes in cationic composition of sorption complex reflect particular stages of this process. In Arboretum, high production of fulvic acids and low molecular organic acids during decomposition of poor quality residues provided by trees, resulted to very strong hydrolytic acidity (H), especially in the A and Bt horizons. Acids in the soil reacted with base cations and percolating water moved them from upper parts of profile to lower. Simultaneously, the sorption complex in A and Bt horizons was saturated by acidic cations, while in lower parts of profiles were accumulated base cations. This resulted to increased sum of exchange base cations (S) as well as the degree of sorption complex saturation by base cations (BS) in lower parts of profiles (Table 1).

In humus horizon, under the rest of original oak-hornbeam forest were recorded significantly ($P < 0.05$) the highest values of H and the lowest S, as well as BS (Table 1). Stronger soil acidity under oak-hornbeam growth was probably due to longer period of its influence on soil (Arboretum was established in year 1892 in the original oak-hornbeam forest). Since other tree species were younger, the duration of their action on soil was shorter therefore their influence on soil chemical properties was not so distinct. According to Hagen-Thorn et al. (2004), 40–50 years old trees in temperate regions distinctly influenced soil chemical properties in upper 0.0–0.1 m, less in layer 0.2–0.3 m. In Arboretum, the time of influence of particular trees on soil was different, because the area with East-Asiatic dendroflora was established in 1964, North American in 1975, and with Korean dendroflora in 1985.

The content of total organic carbon (C_T) in soil is regulated by the balance between biotic inputs and losses and abiotic conditions involving climate, topography and soil type. Plants belong to major source of carbon inputs to soil. The quality of plant residues significantly affects their decomposition and loss of carbon from soil (Vesterdal et al., 2008). In all studied profiles of Arboretum, the C_T content decreased with increasing depth (Table 1) and the type of vegetation had statistically significant effect on changes of C_T content in humus horizons. The highest statistical difference was found in A horizons between grassland and white fires ($P < 0.05$).

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Pôdne subtypy klasifikované v Prírodnej rezervácii Arborétum Mlyňany, Slovensko

Súhrn

Bol urobený pôdoznalecký prieskum a klasifikácia pôd v Prírodnej rezervácii Arborétum Mlyňany. V lokalite Arboréta bolo vykopaných deväť sond, v ktorých boli podrobne charakterizované morfologické, fyzikálne a chemické vlastnosti pôdy. V blízkosti každej sondy boli urobené tri pôdne vrty, v ktorých boli analyzované vybrané chemické vlastnosti. Bolo zistené, že na väčšine plochy Arboréta boli pôdotvorným substrátom odvápnené spraše a hliny, na ktorých sa vyvinula hnedozem pseudoglejová. Karbonátový sprašový substrát bol zistený v severnej časti plochy s východoázijskou dendroflórou, kde sa vyvinula hnedozem modálna. Subtyp hnedozem kultizemná pseudoglejová bol klasifikovaný na ploche so severoamerickou dendroflórou, ktorá sa do roku 1975 využívala ako vinice a homogenizácia ornicového horizontu je dosiaľ zreteľná. V porovnaní s pôdou pod zvyškom pôvodného

dubovo-hrabového lesa (kontrola), antropicky zmenený druh vegetácie preukazne ovplyvnil chemické vlastnosti pôdy najmä v humusových horizontoch. Heterogenita pôdnych vlastností bola zapríčinená aj rôznorodým pôdotvorným substrátom, rôznym spôsobom využívania pôdy pred výsadbou drevín, ako i zemnými prácami pri zakladaní Arboréta.

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Assessment of the impact of drought stress on particular biochemical and physiological characteristics of beech saplings leaves from different provenances

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Abstract

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There were studied particular biochemical and physiological characteristics of European beech (*Fagus sylvatica* L.) saplings of different origin, responding to different water supply. Three different provenances (PV1, PV2, and PV3) representing the lower margin, the upper margin of beech distribution range and the optimal growth and environmental conditions for this species were investigated in a control (well-watered) and a drought treatment. For each provenance, the water potential values (Ψw) towards the end of the experiment were found low, indicating a severe water stress. However, there were not observed significant differences in decreasing Ψw values between the studied provenances. There were also recorded significant decreasing osmotic potential values (Ψs) influenced by drought. In the saplings of the PV2 provenance, the plants deprived of watering (drought treatment) showed the largest decrease of osmotic potential values. All provenances showed significant impacts of drought on the content of assimilatory pigments (*Chl a*, *Chl b*, *Chl a + b*, *Chl a/b*, *Chl/Car*). Nevertheless, the observed changes in individual provenances did not differ significantly. The analysis of the response to the controlled water deficit confirmed that the proline content increased significantly for all provenances. The largest increase in the proline concentration was observed in PV2 provenance. These results imply that the most sensitive to water deficit was the provenance PV2 from the optimal ecological beech area.

Key words

assimilation pigments, drought stress, *Fagus sylvatica* L., proline, provenance, water and osmotic potentials

Introduction

Among the factors that determine plant distribution and life is important shortage of water – drought stress in the recent years. The phenomenon of drought and dry periods is linked to the ongoing climate change. In some parts of Central Europe, an increase in rainfall in the winter is expected, and, on the other hand, declining rainfall totals during the summer months are supposed just because of the global warming (Schär et al., 2004). At present research of the impact of climate change on forest ecosystems and their management is much needed from many points of view (Čaboun, 2008). The lack of water can disturb physiological activity and biomass production in trees. The weather conditions and climate change significantly affect the water availability. The same applies to the tolerance and resistance of plants to drought. In order to achieve high quality of production, cognition of critical effect of water deficit and identification of response mechanisms in forest trees is necessary. It is known that physiological and biochemical processes precede visible manifestations of primary damage. Therefore, methods for diagnosing changes in forest trees at the physiological level are essentially important. Our research plan is based on the knowledge presented in the papers Czajkowski et al., 2006; Czajkowski and Bolte, 2006; Rose et al., 2009. These papers consider forest tree provenances (species originated) from Central and Eastern Europe as a perspective source of ecotypes of forest trees resistant to both drought and frost.

Water deficit has a strong influence on physiological processes in plants. The assessment of physiological processes can be used in stress bio-indication at various levels in plants. Tree responses to drought are complex and varied, and they involve the entire tree (Ryan, 2011). Water deficit in plants reduces metabolic activity and stomatal conductance, and causes a decrease in the photosynthetic rate (Escós et al., 2000). The reduction of photosynthetic rate under drought stress can be ascribed to both, stomatal and non-stomatal factors. From a physiological perspective, leaf chlorophyll concentration is a parameter of significant interest in its own right (Anjum et al., 2011). The dynamic of pigment concentrations has a diagnostic value for a range of plant physiological properties and processes (Blackburn, 2007). Assimilation pigments rank among the important conditions for photosynthesis. As available water is necessary for biosynthesis of assimilation pigments, we monitored changes in their concentration – indicating water stress before visible symptoms. Chlorophylls have the dominant control over the amount of irradiance absorbed by leaves; therefore, foliar concentrations of chlorophylls control the photosynthetic potential and, consequently, the primary production in plants (Blackburn, 2007).

Among the many responses of plants to drought stress, we focused our study on the observation of increased proline accumulation in beech leaves. One of the essential tasks of increased proline accumulation is to maintain turgor in cytoplasm (Blum, 1999). Under water deficit and as a result of solute accumulation, the osmotic potential of the cell is lowered, which attracts water into the cell and helps with the maintenance of turgor (Farooq et al., 2009). Accumulation of proline is regarded as a means of providing biochemical adaptation during drought (Kandpal et al., 1981). In the studies Riazi et al. (1985); Krivosudská and Brestič (2010) are reported correlations between the osmotic potential and proline amino acids. Proline is a good marker of osmotic adjustment (*OA*). One of proline functions under stress is the role of mediating osmotic adjustment (Molinari et al., 2007).

In the present study we characterize selected provenances of European beech (*Fagus sylvatica* L.) in terms of their tolerance to drought. We describe the biochemical and physiological response, of beech seedlings at the level (i) changes in content of assimilation pigments and (ii) increased proline accumulation. At the end we propose one of the provenances as a suitable source of drought resistant beech ecotype.

Material and methods

Design of the experiment

A pot experiment for investigating the issue was established in the Arboretum Borová hora in Zvolen. We tested 4-year-old saplings of European beech (*Fagus sylvatica* L.) from three different beech provenances, by 30 ex. from each provenance. The characteristics of the studied beech provenances (PV1, PV2 and PV3) are in Table 1. These 30 samples were divided in two variants: control (15 samplings) and drought (15 samplings). The basic scheme of the experiment is in Fig. 1, the technical realization of the experiment is in Fig. 2. The saplings were planted into pots, each containing 7 litres of universal soil substrate KERA (Table 2). At the same time, the soil substrate of drought variants was supple-

Table 1. Characteristics of the studied beech provenances (PV1, PV2 and PV3)

	PV1	PV2	PV3
Location	Čierňany (region Ružomberok)	Banská Štiavnica	Divín
Altitude a.s.l. [m]	1116	710	400
Climatic region	Wet climatic area	Medium wet climatic area	Dry climatic area
Latitude [°]			48°33' N
Longitude [°]	48°58' N	48°28' N	19°36' E
	19°10' E	18°58' E	
Annual mean temperature [°C]	4.3	7.7	8.2
	(Štrbské pleso)		
Annual mean rainfall [mm]	1089		
	(Partizánska Ľupča)	610	627

*30-year averages for the years 1951 to 1980, data calculated from surrounding places.

mented with a soil adjuvant called Perlit, in a ratio of 10 : 3 (10 litres of soil and 3 litres of Perlit). Perlit is generally used as a controlling agent of soil moisture. A controlled regime of humidity, air temperature, air circulation and light conditions was provided over the whole experiment, and the saplings of drought variants were exposed to simulated drought conditions for 55 days. The saplings of control variants were irrigated

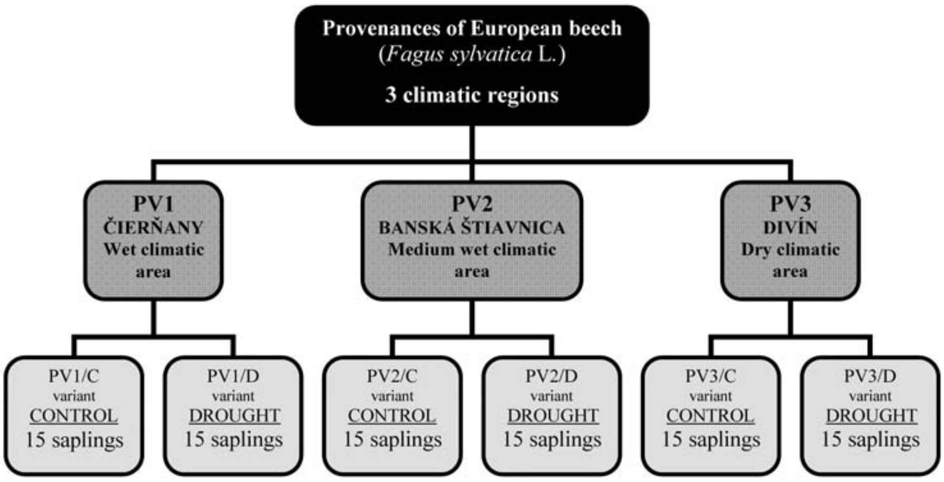


Fig. 1. Design scheme of experiment (PV1, provenance location Čierňany; PV2, provenance location Banská Štiavnica; PV3, provenance location Divín; C, variant of control; D, variant of drought).

Fig. 2. Technical realization of experiment (under the film – variants of drought, without film – variants of control).

Table 2. Chemical and physical properties of soil substrate KERA Universal

Property	Value
The content of total nitrogen as N in dry matter [%]	0.3–1.2
The content of total phosphorus as P_2O_5 [mg kg^{-1}]	100
The content of total potassium as K_2O [mg kg^{-1}]	200
Humidity [%], max.	65.0
Combustible substances in dry mater [%], min.	25.0
pH (aqueous extract)	5.0–6.5
Electrical conductivity mS/cm max. in aqueous extract 1 : 25	1.2
The content of particles larger than 20 mm [%], max.	5.0

following the requirements of the automatic irrigation system used.

Measurement methodology

The measurements of leaf water potential (Ψ_w) and leaf osmotic potential (Ψ_s) were carried out by psychrometric method, with a device PSYPRO (Wescor, USA). Leaf discs we put in psychrometrics chambers C-52 with thermocouples, components of the device PSYPRO. The measurements of leaf water potential (Ψ_w) were performed regularly on a weekly basis. In order to determine leaf osmotic potential (Ψ_s), leaf samples were taken, wrapped into an aluminium foil and stored in liquid nitrogen until the measurement. We determined Ψ_s in three points: start of the experiment, middle of the experiment (day 28 of experiment) and ending of the experiment (day 55 of experiment).

Pigment analyses and determination of proline concentration

In two points, start and termination of the experiment, determination of the concentration of assimilation pigments and free proline was performed by spectrophotometric method.

The concentration of assimilation pigments was determined by measuring the absorbance of the mixture of pigments at different wavelengths, corresponding to the absorption maxima of the individual components. We obtained extracts from assimilation organs of beech saplings. These extracts were analysed by means of spectrophotometer UV VIS Cintra 6.5 GBS (Australia). The absorbance values were defined at different wavelengths: 470.0 nm – carotenoids, 663.2 nm – chlorophyll *a*, 646.8 nm – chlorophyll *b*, 750.0 nm – reference values. We used the formulas modified by LICHTENTHALER (1987) to calculate the concentration of pigments.

Using the method according to BATES et al. (1973), we determined spectrophotometrically the free proline content in leaves of beech saplings. The principle of this method is the evaluation of a color reaction of proline with ninhydrin.

Data analysis

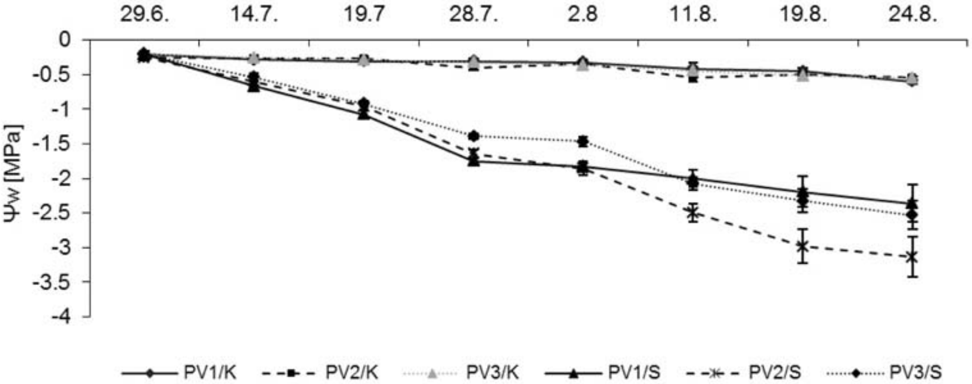
The initial statistical analysis of the data included basic statistical characteristics. We observed the effects of drought on concentrations of assimilation pigments and on free proline content. Statistically significant differences in leaf water potential (Ψ_w), leaf osmotic potential (Ψ_s), pigments content and proline content between provenances and treatments were revealed using multifactor analysis of covariance (MANCOVA) in the program SAS 6.03.

We considered three factors: 1. provenance (discrete factor), 2. drought (discrete factor) and 3. initial height of saplings (continuous covariate). The means were compared by using Tukey-Kramer test at significantly level $P < 0.05$.

Results

Water and osmotic potential

The values of Ψ_w for the control saplings (PV1, PV2 and PV3) during the whole study period were optimal and ranged from –0.2 MPa to –0.5 MPa. The saplings under the drought treatment responded to the controlled process of dehydration by decreasing their values of Ψ_w. The course of Ψ_w values in the control and drought treatment is presented in Fig. 3. On the day 14, the values were significantly reduced due to drought in the range from –0.53 MPa to –0.65 MPa. In the middle of experiment (day 28), there were recorded values below –1.5



Mean values (±SD).

Fig. 3. Values of water potential (Ψ_w) during progressive water deficit (K, variant of control; S, variant of drought).

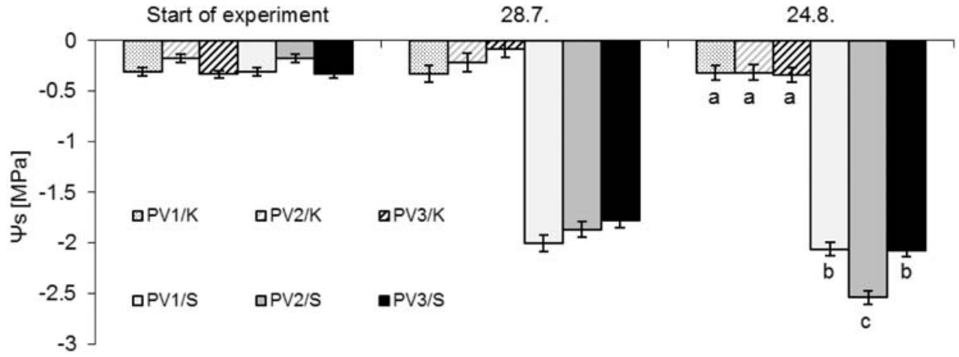
MPa, which is generally considered as the threshold value for severe stress for plants. On day 55, at the end of the experiment, we found Ψ_w values well below the optimum conditions for plant growth and development. The values of Ψw –2.4 MPa (PV1), –2.5 MPa (PV3), –3.1 MPa (PV2), indicated very severe stress causing adverse changes at the level of physiological parameters. Differences in Ψ_w were not statistically among the monitored provenances.

Osmotic potential

The osmotic potential was significantly reduced under drought stress conditions. There were found no significant differences between provenances (PV1, PV2 and PV3) under drought treatment in Ψ_s in the middle of the experiment. The Ψ_s of the stressed saplings in this term (day 28) decreased to the range from –1.8 MPa (PV3) to –2.0 MPa (PV1). Simulation of drought conditions for 55 days resulted in a large reduction of Ψ_s values in all studied provenances. Nevertheless, provenance PV2 responded to water deficit the most sensitively (Fig. 4) compared with the other two provenances (PV1 and PV3). At the end of dehydration period (day 55), PV2 achieved reduction of Ψ_s value to –2.0 MPa. The impact of drought to the values of Ψ_w and Ψ_s was proved to be significant. The interaction between drought and selected provenances was significant in Ψ_s, but not in Ψ_w values.

Effect of drought on assimilation pigments

All three tested provenances (PV1, PV2 and PV3) showed similar contents of assimilatory pigments. The chlorophyll content (*Chl a*, *Chl b*, *Chl a* + *b*) was significantly reduced in dry conditions. On the other hand, the drought stress treatment did not cause significant changes in the content of carotenoids. At the end of the experiment, we observed relevant decrease of *Chl a*, *Chl b* and *Chl a* + *b* content in sapling leaves due to water deficit (Table 3). Nevertheless, comparing the provenances (after 55 days drought treatment) did not show significant differences between them. The carotenoids content did not significantly decrease under the drought conditions



Mean values (±SD); $p < 0.05$, Tukey-Kramer test.

Fig. 4. Values of osmotic potential (Ψ_s) during progressive water deficit (K, variant of control; S, variant of drought.

Table 3. Pigment contents of European beech saplings exposed to drought stress for 55 days

Treatments		Chl *a* content	Chl b content	Chl *a* + *b* content	Chl *a*/*b*	Car (*x* + *c*) content	Chl/Car
		[mg g^{-1}]	[mg g^{-1}]	[mg g^{-1}]		[mg g^{-1}]	
PV1	0 day	2.83 ± 0.10	1.12 ± 0.05	3.85 ± 0.15	2.81 ± 0.09	0.82 ± 0.05	4.70 ± 0.12
	55 days control	2.81 ± 0.21	1.05 ± 0.08	3.86 ± 0.28	2.70 ± 0.13	0.76 ± 0.07	5.23 ± 0.30
	55 days drought	1.89 ± 0.21***	0.67 ± 0.07***	2.56 ± 0.27***	2.90 ± 0.13	0.72 ± 0.07	3.56 ± 0.29***
PV2	0 day	2.46 ± 0.1	1.02 ± 0.05	3.48 ± 0.15	2.41 ± 0.81	0.72 ± 0.05	4.86 ± 0.12
	55 days control	2.68 ± 0.22	1.03 ± 0.08	3.71 ± 0.28	2.59 ± 0.13	0.68 ± 0.07	5.46 ± 0.30
	55 days drought	1.79 ± 0.20***	0.82 ± 0.07***	2.61 ± 0.26***	2.23 ± 0.12	0.68 ± 0.07	3.89 ± 0.28***
PV3	0 day	2.72 ± 0.09	0.97 ± 0.05	3.69 ± 0.13	2.80 ± 0.07	0.80 ± 0.04	4.58 ± 0.11
	55 days control	3.10 ± 0.19	1.13 ± 0.07	4.23 ± 0.25	2.71 ± 0.12	0.79 ± 0.06	5.35 ± 0.27
	55 days drought	1.59 ± 0.19***	0.60 ± 0.07***	2.19 ± 0.25***	2.70 ± 0.12	0.52 ± 0.06	4.18 ± 0.27***

Each value represents the mean of five replicates (n = 5) and its standard deviation (±SD); *** significant effect of drought.

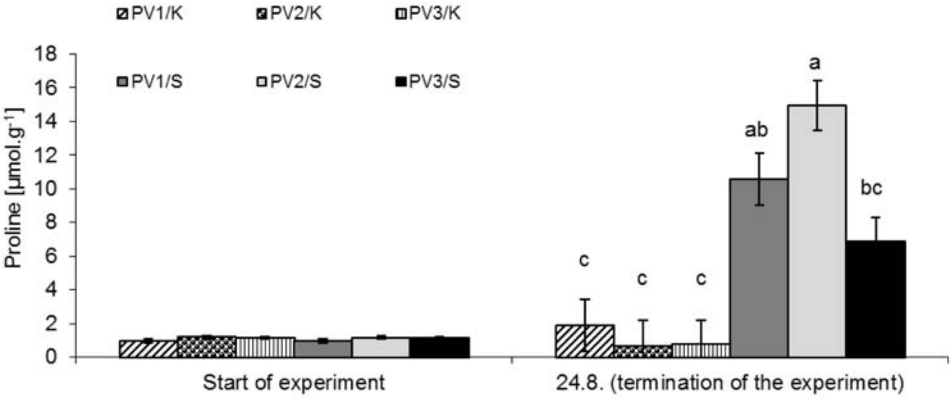
compared to the control saplings. The *Chl/Car* ratio followed the trends of its constituents. The drought affected this parameter, but provenances responded in the same manner. In summary, statistically significant differences at the level of assimilation pigments content among the monitored provenances responding to adverse humidity conditions were not recorded.

Proline content and osmotic adjustment

During the drought period, proline levels in leaves of beech saplings increased to a great extent. The changes in the content of amino acid proline at the end of the experiment are in Fig. 5. The initial proline concentrations ranged from 0.97 µmol g^{-1} (PV1) to 1.17 µmol g^{-1} (PV2). The Tukey-Kramer test informs about significant provenance-dependent differences in response to water deficit at the end of the experiment (Fig. 5). The most substantial and statistically significant increase in proline accumulation was observed in provenance PV2: from 1.174 µmol g^{-1} to 14.94 µmol g^{-1}, representing an 12.7-fold increase in proline content in the variant drought compared with the initial measurement. The analysis of covariance for the day 55 confirmed a significant impact of drought, provenance and their interaction (provenance × drought) to proline content in assimilation organs of beech saplings.

Osmotic adjustment

Accumulation of proline in plants is generally considered as their response to stress. Moreover, the increased accumulation of proline is one of the signals of osmotic adjustment (*OA*). Figure 6 shows the correlation values of the Ψ_s with the proline contents in beech saplings from provenances PV1, PV2 and PV3 under the drought treatment. With Ψ_s –0.5 MPa, there was no considerable accumulation of proline (0.97 µmol g^{-1}



Mean values (±SD).

Fig. 5. Changes in proline content in beech saplings during progressive water deficit (K, variant of control; S, variant of drought).

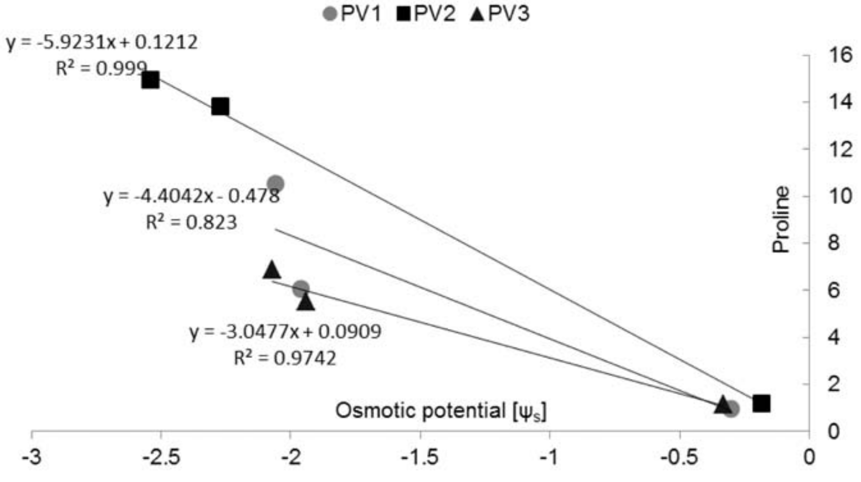


Fig. 6. Correlation between osmotic potential and proline content in leaves of European beech saplings under drought treatment (55 days).

(PV1) to 1.17 μmol g^{-1} (PV2)). The highest capacity to accumulate proline was in provenance PV2 (710 m a.s.l., medium wet climatic area). Among the observed provenances, the lowest value of Ψ_s recorded (–2.54 MPa) was linked with the most increased proline accumulation (up to 12.7-fold), which gives evidence for osmotic adjustment. Compared with provenance PV1 (1,116 m a.s.l., wet climatic area) the proline accumulation in PV2 was 30% higher, and compared with provenance PV3 (400 m a.s.l, dry climatic area) 54% higher.

Discussion

In the recent years, severe drought has become the leading environmental stress factor painstaking equally in cultivation of agricultural crops and in forestry. The stress resistance of plants depends, to a considerable extent, on how these can maintain their water balance by absorbing water with their roots and stalks and distributing it to the leaves (Tzvetkova and Anev, 2008). Adverse effects of water deficit in plant organisms are present at all levels (root, shoot, leaf). In our experiment we focussed on study of physiological changes occurring in leaves. Under water deficit, the parameter Ψ_w commonly drops significantly, and thus it is a proper parameter for monitoring the water condition in plants. The decrease of Ψ_w values with increasing dehydration has also been reported by Rose et al. (2009), with no significant differences in Ψ_w values confirmed between the provenance from the margin of the native range of beech (Poland) and the central provenance for the native distribution area of this species (Germany). Similarly, we did not confirm significant differences at the Ψ_w level among the Slovak provenances of beech with origin in the following areas: PV1 – wet climate of Slovakia, altitude 1,116 m a.s.l.; PV2 – medium wet climate of Slovakia, altitude 710 m a.s.l. and PV3 – dry climate of Slovakia, altitude 400 m a.s.l. The progressive impact of drought on 4-year-old seedlings was also investigated by Galle and Feller (2007), recording after 36 days of dehydration the minimum Ψ_w values about –2.7 MPa. In our experiments, parallel with Ψ_w decreasing with dehydration during the study period, we recorded also a decreasing trend in the osmotic potential of leaves (Ψ_s). The lowered values of Ψ_s in plants ensure to keep up the turgor and, consequently, the sufficient stomatal conductivity in leaves under low water potential (Nguyen-Queyrens and Bouchet-Lannat 2003). Tschaplinski et al. (1998) monitored the response of several forest woody plants (*Quercus prinus* L., *Quercus alba* L., *Acer rubrum* L., *Cornus florida* L., *Nyssa sylvatica* Marsh.) to three different regimes of rainfall penetration into the soil (drought, control, wet) in June–September. During this experiment, in the variant with reduced rainfall penetration (drought), Ψ_w and Ψ_s decreased. Towards the end of the experiment, the Ψ_s values were below –1.5 MPa in all the monitored woody plants; the most remarkable drop Ψ_s due to the stress influence was recorded in *Quercus prinus* L., with Ψ_s –1.94 MPa (in the understorey) to –1.96 MPa (in the main stand layer). The corresponding Ψ_w values ranged from –2.89 MPa (in the main stand layer) to –3.02 MPa (understorey). To measure osmotic potential is also important for assessment of osmotic adjustment. In our experiment we focussed on assessment of osmotic adjustment through enhanced accumulation of proline under significantly reduced osmotic potential of leaves. In the water regimen of plants, osmotic potential is exactly the component closely connected with proline accumulation in these plants. This correlation between proline and osmotic potential has also been found by Handa et al. (1986). These authors observed enhanced proline accumulation in a tomato cell suspension with a relatively low osmotic potential (–1.06 MPa to –1.5 MPa).

The amino-acid proline is a compatible solute generally recognised to perform in plant protection against stress in various effects: by contributing to osmotic adjustment, detoxifying reactive oxygen forms, stabilising membranes and natural structures of enzymes and proteins (Farooq et al., 2009). Proline is generally accumulated in plants stressed by osmosis, and it plays the key role in the control of osmosis and in the anti-oxidative protective mechanisms (Cha-um and Kirdmanee, 2009). The accumulation of free proline under stress conditions is enormously important for plant adaptation to stress (Molinari et al., 2007). An instant raise of proline in assimilation organs of wheat stressed by drought was observed by Tatar and Gevrek (2008), who recorded proline accumulation more than 13.7-fold compared to the normal conditions. A similar response – increased proline accumulation in chickpeas seedlings stressed by drought, ensuring apart from maintaining the cell turgor also preserving the structural integrity of membranes has also been confirmed by Najaphy et al. (2010). Proline accumulation in leaves of beech and spruce under drought stress was observed by Slugeňová et al. (2011) – beech and spruce. Slugeňová (2010) investigated the seedlings´ response to the process of controlled dehydration. Under significantly reduced water potential (below –2.0 MPa), she recorded enhanced proline accumulation in the two woody plants: 5.21-fold in beech and 5.7-fold in spruce. The presented facts give evidence that the capacity of accumulation of free proline in plants under stress is species-specific.

Under water deficit and enhanced accumulation of solutes, the osmotic potential of plant cells is reduced. This allows the water to enter the cells, and to ensure their appropriate turgor. This phenomenon is known as osmotic adjustment (*OA*) (Farooq et al., 2009). *OA* is an effective mechanism for retaining the turgor of tissues (Brestič and Olšovská, 2001) and also a mechanism enabling the plants to avoid adverse effects of drought. The leaves able to perform *OA* are able to keep up their turgor under lower water potential than the leaves in which no *OA* has occurred. For that reason, the plants can also use water fixed in soil with rather strong bonds (Slováková and Mistrík, 2007). This fact has also been supported with the soil water potential values measured in our experiment (Fig. 6), with especially low values recorded in the provenance PV2/S (710 m a.s.l., medium wet climate of Slovakia). The appropriately maintained turgor also helps to keep up the stomata open, enhancing in such a way the exchange process of CO_2. Despite the significantly enhanced proline accumulation observed with aggravating drought, the lowered Ψ_s values and significantly lower soil water potential values give evidence for *OA*. Nevertheless, this is only a hypothesis, as the parameters of gas exchange in leaves were not found sufficiently unchanged in the end of our experiment.

The slow synthesis of photosynthetic pigments and fast decomposition of these pigments also belong to the numerous effects of water deficit on plant organisms. The photosynthetic pigments are used as reliable markers for assessment of metabolic imbalance in photosynthetic and growth processes under drought conditions. Reduction of chlorophyll content – considered as a typical symptom of oxidation stress, may be the result of photo-oxidation of pigments and degradation of chlorophyll. The chlorophyll loss due to drought has been recognised to be the main cause of inactivation of photosynthesis (Anjum et al., 2011). The reduction of chlorophyll content due to drought is primarily caused by the damage to chloroplasts by active forms of oxygen (Mafakheri et al., 2010). The adverse effect of water deficit in beech seedlings subjected to the 55-day dehydration was manifested through the decrease in contents of *Chl a*, *Chl b* and the total chlorophyll *a* + *b* in comparison with the control seedlings. The drought, however, did not cause significant differences in contents of photosynthetic pigments between the provenances in the final phase of the experiment. Slugeňová (2010) published that the drought had a strong influence on contents of assimilation pigments – their reduction in beech and spruce seedlings. On the other hand, there was not detected significant influence of drought on the *Chl a/b* ratio in either of the studied woody plants (beech and spruce). Ditmarová et al. (2010) studying spruce exposed to strong water deficit (36-day dehydration) observed that the *Chl a/b* ratio was unchanged, while the particular *Chl a* and *Chl b* contents were noticeably reduced. The preserved *Chl a/b* ratio in dehydrated individuals of *Arbutus unedo* L. has been documented by Munné-Bosch and Penuelas (2004). The authors observed the total chlorophyll *a* + *b* reduction under severe drought representing 63% compared to moderate drought stress. No comparable reduction of *Chl a* + *b* was reached in our three provenances (PV1 – 26%, PV2 – 25%, PV3 – 41%). Gallé and Feller (2007) testing the influence of drought on 4-year-old beech seedlings obtained a reverse result – the ratio of chlorophylls *a* and *b* was raised due to the drought stress.

The water stress due to the 55 days of dehydration resulted in a decrease of chlorophyll *a* + *b* content in all seedlings. We also recorded lowered content of carotenoids (Car x + c) in both beech provenances. Similar findings under drought stress were obtained by Efeoğlu et al. (2009) with three cultivars of maize and by Munné-Bosch and Penuelas (2004) with individuals of *Arbutus unedo* L.

The study of stress physiology and competition ecology is essential for evaluation of the climatic and site limitations of European beech (Bolte et al., 2007). The provenance study focused on beech, its distribution and survival in drought has become truly needed in European context in the recent years. This is also evident based on the large number of works dealing with this issue (Fotelli et al., 2009; Rose et al., 2009; Robson et al., 2012). All the studies focussed on beech ecosystems suffering from water deficit agree in the finding that the provenances (ecotypes) of beech from southern or south-eastern parts of the beech native distribution range are tolerant to drought.

Conclusions

The physiological response to prolonged water deficit (as negative drought effect) was found expressive in most of the parameters (parameters of water deficit, ratio *Chl/Car*, proline accumulation) in the plants representing the provenance. This provenance is native to the optimum growth and ecological conditions of beech. Despite the PV2´s origin, our results showed a very sensitive response to drought only in this provenance. The provenances representing the marginal areas of beech distribution range (PV1 – wet climate of Slovakia, altitude 1,116 m a.s.l.; PV3 – dry climate of Slovakia, altitude 400 m a.s.l.) responded to adverse water regimen much less sensitively than PV2. Quantification of the differences among the studied provenances has revealed that the provenance PV3 was the most resistant against the drought because is originated from dry climate of Slovakia.

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Posúdenie vplyvu stresu zo sucha na vybrané biochemické a fyziologické charakteristiky listov bukových sadeníc rôznej proveniencie

Súhrn

V príspevku sú predložené výsledky štúdie reakcie sadeníc buka lesného (*Fagus sylvatica* L.) rozdielneho pôvodu na riadený proces dehydratácie. V rámci experimentu sme otestovali proveniencie PV1 (1 116 m n. m., vlhká klíma Slovenska), PV2 (710 m n. m., stredne vlhká klíma Slovenska) a PV3 (400 m n. m., suchá klíma Slovenska) na vybrané fyziologické a biochemické parametre. Jednotlivé proveniencie boli prezentované sadenicami vo veku 4 roky, pričom každá proveniencia obsahovala dva varianty: *kontrola* a *sucho*. Sadenice variant sucho boli po dobu 55 dní vyradené zo zálievky a miera ich dehydratácie bola monitorovaná prostredníctvom vodného potenciálu listov (Ψ_w) a osmotického potenciálu listov (Ψ_s). V závere experimentu sme zaznamenali zníženie hodnôt Ψ_w a Ψ_s zodpovedajúce veľmi silnému stresu. Ψ_w poklesol na hodnoty –2,37 MPa (PV1), –3,14 MPa (PV2) a –2,53 MPa (PV3). Hodnoty Ψ_s sa najvýraznejšie znížili vplyvom vodného deficitu u proveniencii PV2 (–2,54 MPa). Sucho na jednej strane spôsobilo významnú degradáciu asimilačných pigmentov (*Chl a, Chl b, Chl a + b, Chl/Car*) a na druhej strane zapríčinilo významne zvýšenú akumuláciu prolínu v listoch stresovaných sadeníc. Na základe pozorovaných zistení a reakcií sadeníc vystavených nepriaznivým vlhkostným podmienkam, možno spomedzi monitorovaných proveniencií považovať provenienciu PV2 za najcitlivejšiu na pretrvávajúci vodný deficit.

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Structural changes in the agricultural landscape and occurence of gene pool importance trees

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Abstract

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The content of this paper is assessment of the changes in the landscape structure in the cadastral area in Žirany as compared between 1869 and 2012. In the second part of this paper, the occurrence of gene pool trees identified within the cadastral area is presented.

Changes in the representation of landscape elements, their internal structure and surface-area spatial distribution of land is a reflection of property ownership relations, land use forms, especially forms of intensification in agriculture and socio-economic development of society. Landscape structure was evaluated from maps and field research of the current situation. The current landscape structure (CLS) in 2012 was evaluated using 9 groups and a total of 44 landscape elements. In assessing the historical landscape structure (HLS) from 1869, 8 groups and 19 basic landscape elements were used. The most significant changes in the secondary landscape structure between 1869 and 2012 were identified in the following elements in the compared time periods: a slight decrease in the portion of forest (from 42.83 to 40.76%), increase in the portion of non-forest woody vegetation (from 0.33 to 4.00%), reducing the share of agricultural used areas (from 44.16 to 37.86%), decrease of surface of grass-herb vegetation (from 10.17 to 5.99%) and increase of the built up areas (from 1.56 to 6.44%). A significant change is observed in the conversion of mosaic structure of narrow-band fields to large-block forms of agricultural land use. Attention was devoted on the spatial distribution of tree species and biodiversity in the group of non-forest woody vegetation (NFWV) during the mapping of the CLS features. In the formations of NFWV 6 species with important gene pool and above-standard biometry and age of trees have been identified with a total of 47 subjects within the land. These are the species: *Castanea sativa* Mill. (18 subjects) *Mespilus germanica* L. (1 subject), *Quercus cerris* L. (1 subject), *Q. dalechampii* Ten. (2 subjects), *Q. petraea* (Mattusch.) Liebl. (23 subjects), *Q. polycarpa* Shur. (2 subjects). Genetically significant trees were also localized by GPS.

Keywords
agricultural landscape, land use changes, rare trees, secondary landscape structure

Introduction

Landscape structure is a reflection and a result of long-term human activities on the nature components and depends on form and intensity of land use and its natural resources. The original (natural) landscape changes into a secondary landscape structure are as a result of human activity (Ružička and Ružičková, 1973). In this category we can identify a subset of historical landscape structures, in which landscape elements represent their existence and continuity for at least 50 years. Historical landscape structures (HLS) with links to important buildings of civilizations, transport systems and historical paths, but also on agricultural land use, for example terraced rice fields, vineyards, olive groves etc. are known in the world (Supuka et al., 2008). A complex description of the HLS of Slovakia and their categories according to forms of economic activity is mentioned by Huba et al. (1988).

Many publications are currently devoted to the study of the development of landscape structure changes over different compared periods. Pucherová (2004) presents the results of development and changes in landscape structure on example of five cadastral territories of Nitra region and compares the 2nd half of the 19th century (1863, 1879, 1892) to 2002. Categorization of historic landscape structures of agricultural land in Slovakia was published by Špulerová et al. (2011), according to the categories of crops and ground cover. Petrovič (2006) in his publication deals with development of the landscape in the area of dispersed settlements on the example of Pohronský Inovec and Tribeča. Hreško and Guldanová (2012) analysed changes in secondary landscape structure on the example of protected areas and Bihuňová and Štěpánková (2012) evaluated changes in land use from point of rural tourism development.

Atlas of cultural landscape was prepared in Italy, where the decisive factor is the differential land use forms, features and value of cultural and historic landscape components (Agnoletti, 2011). Štefunková et al. (2011) dealt with development changes, biodiversity and cultural and historical values of the vineyard landscape in the region of Malé Karpaty. Vine-growing segment of the cultural landscape in Nitrianske Hrnčiarovce cadastre, its development and values was published by Supuka et al. (2011).

In research of development and changes in landscape structure of studied area, biodiversity including cultural biodiversity and gene pool valuable trees is often inventoried. Supuka (2010) states that in the landscape of Slovakia, formations of non-forest woody vegetation represent an area of 60,000 ha, of which 6,000 ha are planted wind-breaks. There is 15 to 30 species of trees identified at wind-breaks, in many cases, gene pool very rare. Commemorative trees of point, group or alley character represent 466 sites in Slovakia and 167 species of gene pool rare trees. In Czech Republic in area of study, Olomouc region, 95 features of on-road tree alleys with high species diversity were mapped. These mainly have the gene pool value, as many natural landmarks (Esterka et al., 2010). Criteria for designating protected trees have been developed in the Slovak legislation as part of Law of nature and landscape protection (No. 543/2002 Z. z.) (Krištof, 1999). In the list there is listed 110 species of trees and for each species are defined minimal criteria of age (at least 100 years) and girth stem 130 cm above ground (for trees at least 150 cm). Trees represent an important landscape dominants, as well as significant historic and landscape-forming element (Kupka, 2010).

The aim of this paper is to evaluate the developmental changes in secondary landscape structure in the cadastral territory of Žirany compared in two time periods, and between 1869 and 2012. Emphasis is laid on elements of non-forest woody vegetation and preserved structures of crops (orchards, vineyards and forest remains), where gene pool rare tree species with potential for their conservation and cultural value were evaluated.

Material and methods

Within the mapping of the secondary landscape structure (SLS) we started from the publication of Ružička and Ružičková (1973). From the original classification of 6 groups of elements of SLS after the modification and refinement (Pucherová, 2004), we used 9-group-classification of landscape elements in the current landscape structure (CLS) (Table 1). The total number of evaluated landscape elements in CLS in the evaluated area was 44. The basis of this evaluation was the field mapping CLS, which was conducted in the days 17 August 2011, 27 September 2011 and 12 June 2012. When creating a digital model of CLS we used 4 map sheets of basic maps at scale 1:10,000, issued by the Office of geodesy, cartography and cadastre of the Slovak Republic, as a base. To refine the presence of the selected landscape elements we used orthophotos (Orthophotomap © Geodis Slovakia, ltd. 2003, aerial photo and digital orthophoto © Eurosense, ltd., 2003). Given that in 1869 the original map did not contain the group of technical elements, in the evaluation of the historical landscape structure (HLS) we used only the eight basic groups of 19 landscape features (Table 1). The HLS were processed on the basis of maps of 2nd military mapping in 1869. We created digital models of maps in two time periods in the SLS area of interest in GIS using ESRI ArcView 3.1 (Figs 1 and 2). These were used in assessing of the land use form changes in two time frames. In each time frame we evaluated the character, planar representation and share of individual landscape elements and their groups. Then both digital models on the level of individual groups of landscape elements were covered over each other. The result is a map of changes in the SLS in the cadastral territory Žirany between 1869 and 2012 (Fig. 3).

In mapping and assessment of elements of non-forest woody vegetation (NFWV), in addition to standard forms of mapping biodiversity of species of trees and their sociability in the spatial structure of NFWV, we paid attention especially to searching, identifying and assessing of old, oversized, and gene pool important species. The mapping was carried out according to modified method (Krištof, 1999) with the measurement values such as tree height, crown width, trunk circumference of 130 cm above the ground and estimated age, with the addition of value allocation in the country using GPS devices, Garmin type of e-Trex Legend C. During mapping, we focused on the elements of historic landscape structures, and active and abandoned vineyards and orchards outside urban settlements, solitary in the country, permanent grassland and pastures with the presence of trees, road alleys in the country.

Table 1. Area representation and proportion of landscape elements in the historical and current landscape structure of cadastral area Žirany

Group of landscape elements	**Landscape element of CLS**[1]	**CLS**[1]		**Landscape element of HLS**[2]	**HLS**[2]	
		ha	**%**		**ha**	**%**
Forest woody vegetation	Continuous deciduous forest	608.18	39.17	Forests	665.01	42.83
	Continuous mixed forest	15.77	1.01			
	Young trees	3.28	0.21			
	Continuous intersections	5.72	0.37			
Sum:		**632.95**	**40.76**		**665.01**	**42.83**
Non-forest woody vegetation	Woods	1.65	0.11	Line woody vegetation	2.09	0.14
	Groups of trees	1.69	0.11			
	Line woody vegetation	10.07	0.65			
	Alleys	1.20	0.08			
	Planes of bushes with trees	15.14	0.98			
	Riparian stand of water streams	11.05	0.71	Riparian stand of water streams	2.94	0.19
	Heaths	3.84	0.24			
	Overgrown shrub-tree in mosaics	17.43	1.12			
Sum:		**62.07**	**4.00**		**5.03**	**0.33**
Grasslands	Pastures	29.69	1.91	Pastures	29.96	1.93
	Meadow	33.41	2.15			
	Extensive grasslands of succession type with low proportion of trees	17.08	1.10			
	Extensive grasslands of succession type with high proportion of trees	11.06	0.71	Meadow	128.01	8.24
	Planes of rattan with low proportion of ground wood	1.82	0.12			
Sum:		**93.06**	**5.99**		**157.97**	**10.17**
Agricultural areas	Large-block arable land	478.42	30.81	Narrow-striped fields	625.81	40.30
	Narrow-striped fields	50.25	3.24	Mosaic structures – vineyards, narrow-striped fields, orchards, grasses	52.89	3.41
	Mosaic structures 1 – vineyards, narrow-striped fields, orchards	29.16	1.88			
	Mosaic structures 2 – vineyards, narrow-striped fields, orchards, grasses	5.71	0.37			
	Intense, large-scale orchards	18.04	1.16	Plantations of fruit trees	7.07	0.45
	Extensive, small-scale orchards	6.18	0.40			
Sum:		**587.76**	**37.86**		**685.77**	**44.16**

Table 1. Area representation and proportion of landscape elements in the historical and current landscape structure of cadastral area Žirany – continued

Group of landscape elements	**Landscape element of CLS[1]**	**CLS[1]**		**Landscape element of HLS[2]**	**HLS[2]**	
		ha	**%**		**ha**	**%**
Rocks and bedrock substrate	Natural rock formations	0.15	0.01	Natural rock formations	3.60	0.23
	Stone-pits	16.48	1.06			
Sum:		**16.63**	**1.07**		**3.60**	**0.23**
Water stream	Dry ditch storms, intermittent streams	0.07	0.01	Natural water streams	2.07	0.13
	Water streams regulation, drainage channels	1.34	0.09			
Sum:		**1.41**	**0.10**		**2.07**	**0.13**
Built up areas	Built-up areas of rural houses and individual residential buildings outside urban area	21.03	1.35	Residential houses	7.03	0.45
				Residential farm buildings outside urban area	0.57	0.04
	Gardens	65.26	4.20	Farms and gardens	7.27	0.47
	Churches and cemeteries	1.72	0.11	Churches and cemeteries	1.77	0.11
	Schools, playgrounds, administrative and civic equipment	3.01	0.20	Public squares	7.64	0.49
	Settlement vegetation	8.96	0.58			
Sum:		**99.98**	**6.44**		**24.28**	**1.56**
Technical elements	Industrial production areas	8.94	0.58		0.00	0.00
	Agricultural production areas, farms, agricultural stores, reinforced dung-yards	7.32	0.47			
	Illegal waste dumps, unused areas	0.36	0.02			
	Used building and technical objects in the open country, areas of water management	0.36	0.02			
	Reinforced and handling areas	2.79	0.18			
Sum:		**19.77**	**1.27**		**0.00**	**0.00**
Traffic elements	Important main roads	1.75	0.11	Paved roads	1.45	0.09
	Side roads	1.57	0.10			
	Other roads	6.67	0.43			
	Local reinforced communications	3.74	0.24	Other roads	7.57	0.49
	Local non-reinforced communications	8.59	0.55			
	Railway lines, stations and slopes along the railway line	16.07	1.03	Bridges	0.08	0.01
	Bridges	0.81	0.05			
Sum:		**39.20**	**2.51**		**9.10**	**0.59**
		1,552.83	**100.00**		**1,552.83**	**100.00**

1 – CLS, Current landscape structure; 2 – HLS, Historical landscape structure.

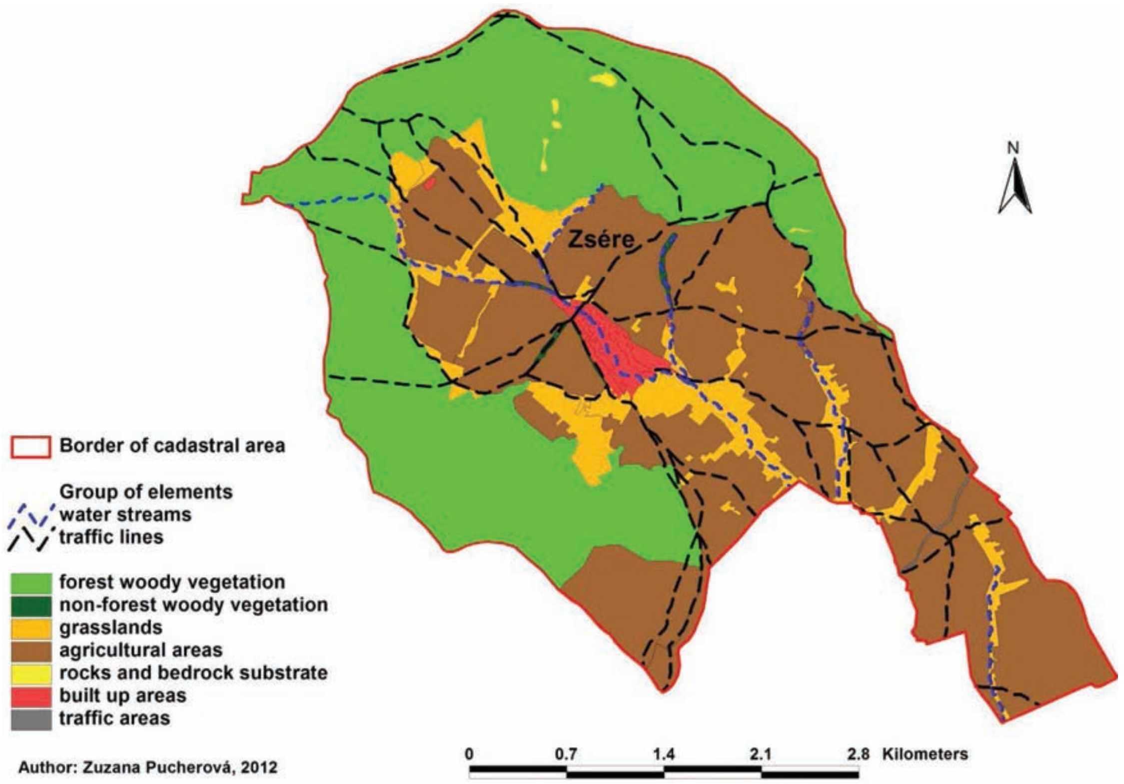

Fig. 1. Historical landscape structure of cadastral area Žirany in 1869.

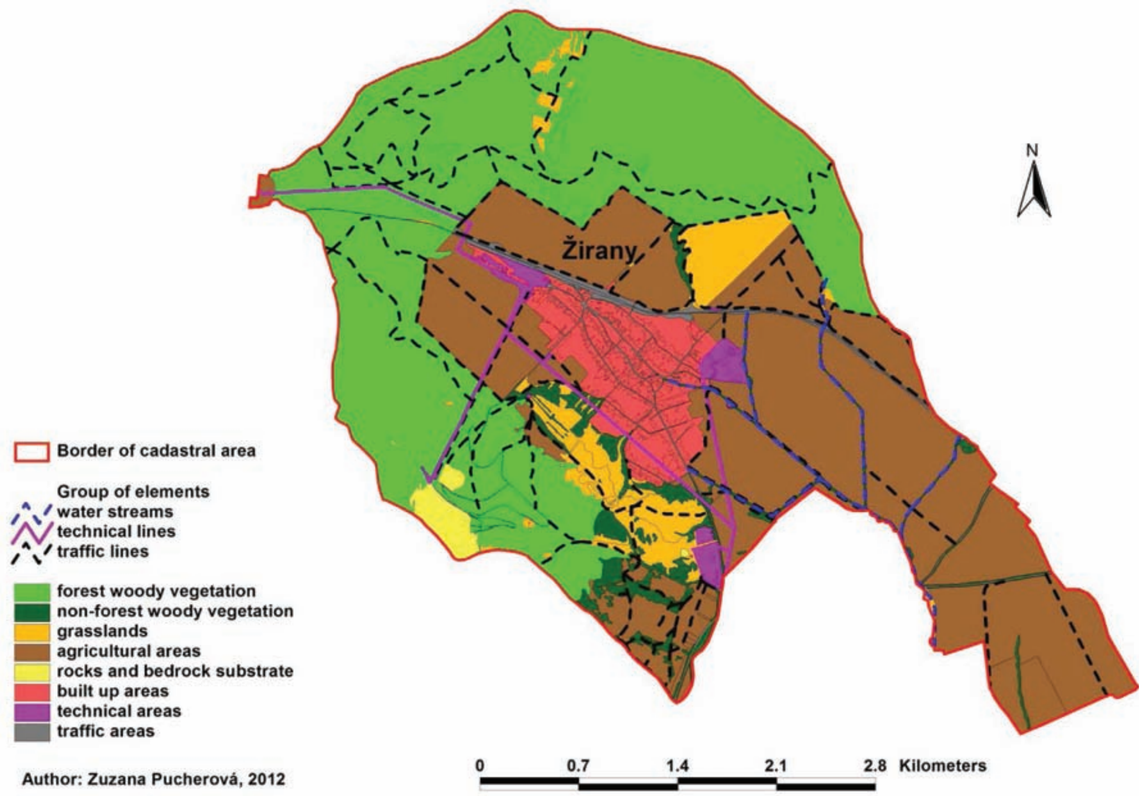

Fig. 2. Current landscape structure of cadastral area Žirany in 2012.

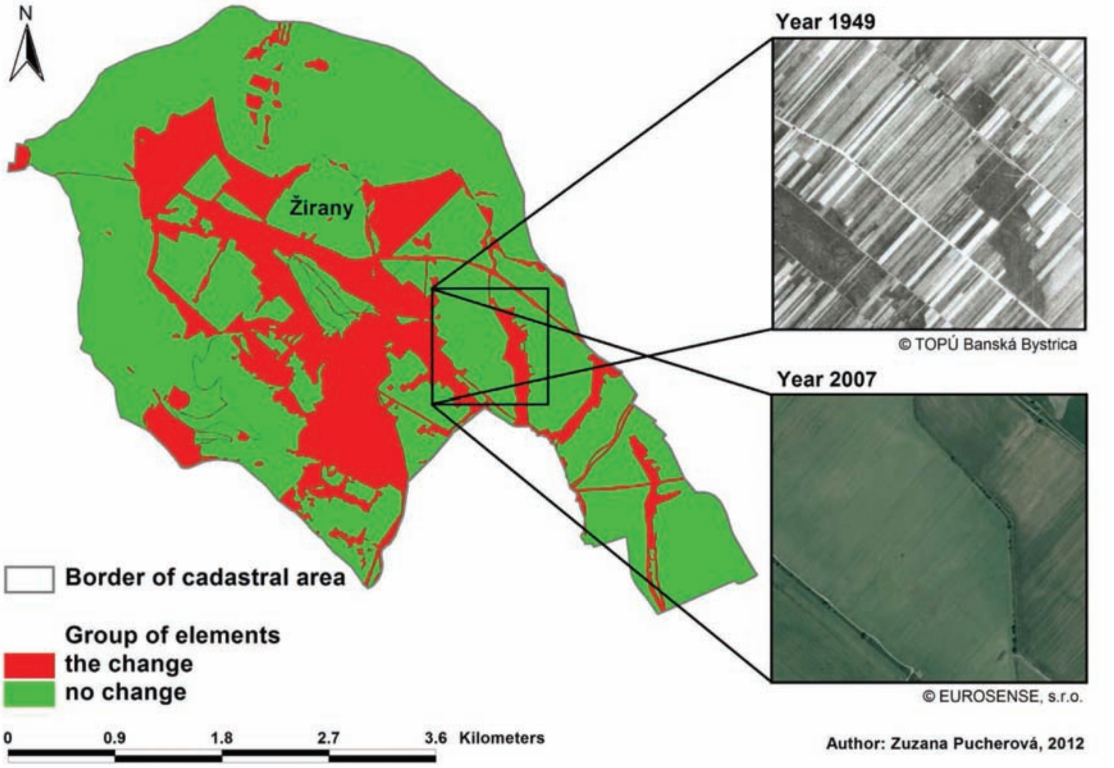

Fig. 3. Changes of secondary landscape structure of cadastral area Žirany since 1869 to 2012 and comparison of land use form changes since 1949 to 2007 at aerial photos.

Results

Of the total cadastral territory of Žirany (1,552.83 ha), landscape elements of forest woody vegetation (665.01 ha, 42.83%) and agricultural areas (685.77 ha, 44.16%) have the most representation in the HLS. Continuous forests line the south-western, northern and south-eastern part of the land in a shape of horseshoe. In the middle of this area are narrow-band fields that line the rivers along the meadows and pastures (157.97 ha, 10.17%) and cut off the large areas of narrow-striped fields. Landscape features of the other groups were represented at HLS only slightly (Table 1), even a group of technical elements is not located in evaluated area in HLS. A group of agricultural crops had form of complementary areas with mosaic structures of vineyards, narrow-band fields, fruit trees and orchards, crops and grass fields. These occur in the southern part of the land in continuous contact with the forest and form the basis of the current mosaic structure with a number of woody plants of gene pool importance.

Like in the HLS also in the CLS, landscape elements of the forest woody vegetation (632.95 ha, 40.76%) and agricultural areas (587.76 ha, 37.86%) are predominant. Built up elements are in an area of 99.98 ha (6.44%), thus we can conclude the growth of urban areas within the historical development. The occurrence of elements of NFWV (62.07 ha, 4.00%) plays an important role in the CLS, particularly in terms of eco stabilizing features in agricultural landscapes. Other elements of CLS occupy smaller areas (Table 1).

In the formations of NFWV 6 species with important gene pool and above-standard biometry and age of trees have been identified with a total of 47 subjects within the land (Table 2). These are the species: *Castanea sativa* Mill. (18 subjects) *Mespilus germanica* L. (1 subject), *Quercus cerris* L. (1 subject), *Q. dalechampii* Ten. (2 subjects), *Q. petraea* (Mattusch.) Liebl. (23 subjects), *Q. polycarpa* Shur. (2 subjects). The trees in the category of fruit species have been identified in particular areas of landscape elements belonging to the historic landscape structures such as abandoned or extensively managed orchards and vineyards. Native species of the genus *Quercus* sp. were identified in areas of extensive and abandoned grassland and permanent pasture. Measured biometric values (Table 2), as well as allocation of cadastral area (Fig. 4) are important data of gene pool significance and also as potential for protection of elements in the cultural landscape. The values of the identified individual chestnut trees with 700 cm girth stem of 1.3 m above the ground and an estimated age of 450 years are remarkable. In the category of species of *Quercus* sp. are valuable rare species occurrences *Q. polycarpa* Shur. and *Q. dalechampii* Ten., as well as their biometric values and reached estimated age of 250 years. *Q. petraea* (Mattusch.) Liebl. represents the most valuable individual gene pool importance of data as 400 cm girth and estimated age of 300 years. Identified oversized trees have a particular historical, cultural and gene pool values. Implementation of the chestnut culture in this land is probably related to nearby locations in chestnut grove Jelenec (Gýmeš), where according to literature were the first planting carried out in the 13th century.

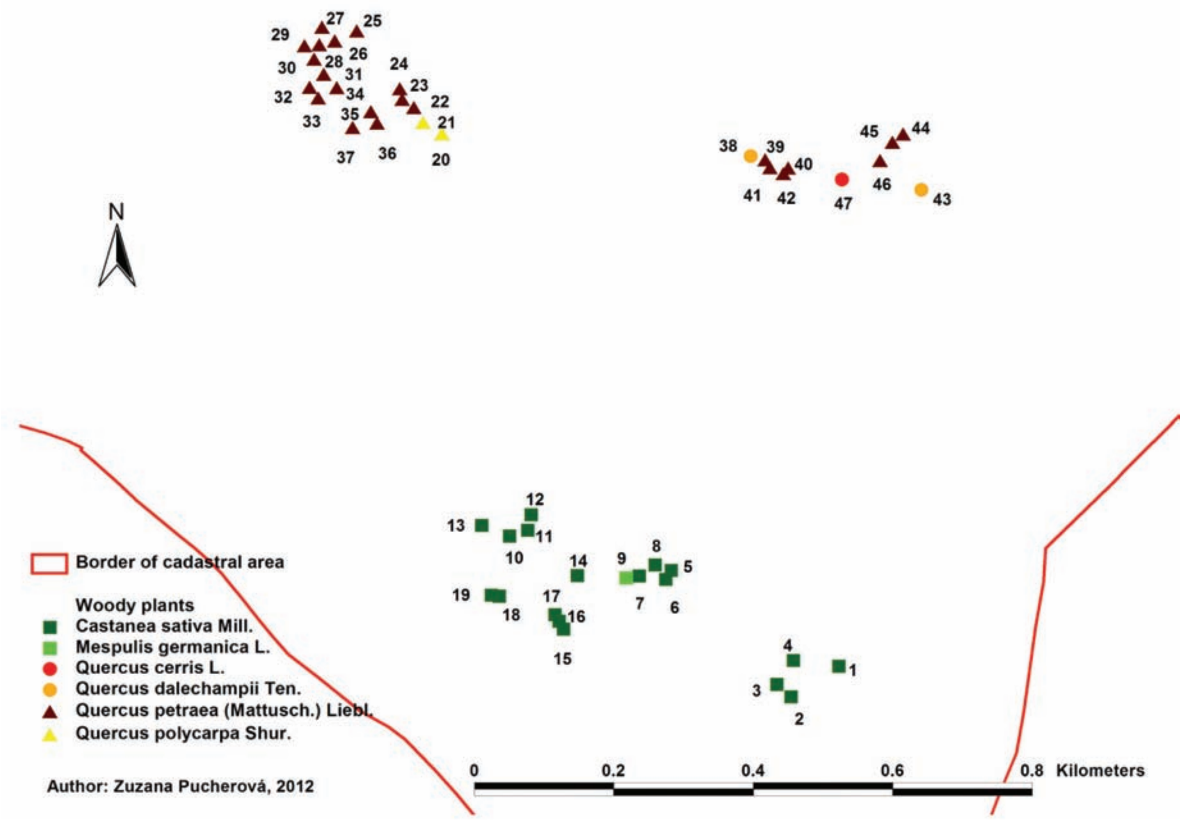

Fig. 4. Location of specifically and genetically significant trees in cadastral area Žirany.

Table 2. Description and parameters of rare tree species occurring in cadastral area of Žirany

S. n.	Species Latin name	Girth stem $h_{1,3}$ [cm]	Height [m]	Crown width [m]	Estimated age [years]	Position		Altitude [m]
1	*Castanea sativa* Mill.	330	18	7	300	N 48°36.338´	E 018°18.186´	270
2	*Castanea sativa* Mill.	300	20	12	300	N 48°36.292´	E 018°18.108´	279
3	*Castanea sativa* Mill.	310	18	9	300	N 48°36.289´	E 018°18.084´	280
4	*Castanea sativa* Mill.	330	20	10	350	N 48°36.323´	E 018°18.094´	271
5	*Castanea sativa* Mill.	270	22	8	300	N 48°36.360´	E 018°17.863´	296
6	*Castanea sativa* Mill.	350	16	8	350	N 48°36.357´	E 018°17.860´	296
7	*Castanea sativa* Mill.	220	16	9	300	N 48°36.364´	E 018°17.834´	299
8	*Castanea sativa* Mill..	280	14	11	300	N 48°36.368´	E 018°17.819´	301
9	*Mespulis germanica* L.	shrubby sprout shape	6	6	100	N 48°36.361´	E 018°17.806´	300

Table 2. Description and parameters of rare tree species occurring in cadastral area of Žirany – continued

S. n.	Species Latin name	Girth stem $h_{1,3}$ [cm]	Height [m]	Crown width [m]	Estimated age [years]	Position		Altitude [m]
10	*Castanea sativa* Mill.	700	24	16	450	N 48°36.412´	E 018°17.798´	307
11	*Castanea sativa* Mill.	280	20	12	300	N 48°36.430´	E 018°17.819´	305
12	*Castanea sativa* Mill.	420	22	14	350	N 48°36.445´	E 018°17.815´	305
13	*Castanea sativa* Mill.	380	18	12	350	N 48°36.423´	E 018°17.743´	301
14	*Castanea sativa* Mill.	290	18	14	300	N 48°36.371´	E 018°17.644´	322
15	*Castanea sativa* Mill.	340	16	12	300	N 48°36.279´	E 018°17.613´	331
16	*Castanea sativa* Mill.	310	13	10	300	N 48°36.286´	E 018°17.606´	332
17	*Castanea sativa* Mill.	250	15	9	300	N 48°36.292´	E 018°17.600´	331
18	*Castanea sativa* Mill.	510	24	18	400	N 48°36.314´	E 018°17.495´	334
19	*Castanea sativa* Mill.	530	24	18	400	N 48°36.314´	E 018°17.480´	344
20	*Quercus polycarpa* Shur.	260	22	12	250	N 48°36.975´	E 018°17.335´	329
21	*Quercus polycarpa* Shur.	220	16	13	250	N 48°36.999´	E 018°17.280´	339
22	*Quercus petraea* (Mattusch.) Liebl..	310	18	18	250	N 48°36.995´	E 018°17.274´	338
23	*Quercus petraea* (Mattusch.) Liebl.	320	18	18	250	N 48°37.004´	E 018°17.252´	336
24	*Quercus petraea* (Mattusch.) Liebl.	310	24	18	250	N 48°37.025´	E 018°17.246´	335
25	*Quercus petraea* (Mattusch.) Liebl.	310	24	18	250	N 48°37.091´	E 018°17.152´	330
26	*Quercus petraea* (Mattusch.) Liebl..	390	24	18	300	N 48°37.074´	E 018°17.093´	334
27	*Quercus petraea* (Mattusch.) Liebl..	400	22	17	300	N 48°37.082´	E 018°17.089´	335
28	*Quercus petraea* (Mattusch.) Liebl.	260	18	12	250	N 48°37.069´	E 018°17.078´	341
29	*Quercus petraea* (Mattusch.) Liebl.	280	24	20	250	N 48°37.064´	E 018°17.051´	349
30	*Quercus petraea* (Mattusch.) Liebl..	280	18	16	250	N 48°37.054´	E 018°17.073´	348
31	*Quercus petraea* (Mattusch.) Liebl.	330	26	17	300	N 48°37.032´	E 018°17.095´	348
32	*Quercus petraea* (Mattusch.) Liebl..	290	25	15	300	N 48°37.023´	E 018°17.075´	341
33	*Quercus petraea* (Mattusch.) Liebl.	270	18	14	250	N 48°36.995´	E 018°17.111´	346
34	*Quercus petraea* (Mattusch.) Liebl.	370	16	12	300	N 48°36.999´	E 018°17.148´	342
35	*Quercus petraea* (Mattusch.) Liebl.	310	20	16	300	N 48°36.989´	E 018°17.207´	346
36	*Quercus petraea* (Mattusch.) Liebl.	260	17	15	250	N 48°36.976´	E 018°17.212´	339
37	*Quercus petraea* (Mattusch.) Liebl.	290	20	12	250	N 48°36.967´	E 018°17.162´	348
38	*Quercus dalechampii* Ten.	220	16	14	150	N 48°36.971´	E 018°17.945´	296
39	*Quercus petraea* (Mattusch.) Liebl.	170	10	7	100	N 48°36.971´	E 018°17.977´	281
40	*Quercus petraea* (Mattusch.) Liebl.	190	10	10	150	N 48°36.963´	E 018°17.988´	282
41	*Quercus petraea* (Mattusch.) Liebl.	240	12	14	200	N 48°36.957´	E 018°17.974´	281
42	*Quercus petraea* (Mattusch.) Liebl.	230	12	12	200	N 48°36.962´	E 018°17.987´	281
43	*Quercus dalechampii* Ten.	310	13	11	250	N 48°36.947´	E 018°18.269´	244
44	*Quercus petraea* (Mattusch.) Liebl.	390	22	16	300	N 48°37.008´	E 018°18.227´	247
45	*Quercus petraea* (Mattusch.) Liebl.	320	20	12	300	N 48°37.003´	E 018°18.205´	241
46	*Quercus petraea* (Mattusch.) Liebl.	270	16	15	250	N 48°36.969´	E 018°18.174´	251
47	*Quercus cerris* L.	240	12	12	200	N 48°36.952´	E 018°18.109´	271

Discussion

The total cadastral area of the village is the same (1,552.83 ha) in two time periods (1869 and 2012). Based on the evaluation of SLS, we can conclude that the area was evaluated in the course of historical development, not only used by man, but also directly influenced by anthropogenic activity. Two basic features of the landscape: forest woody vegetation and agricultural areas are the most significant elements in both landscape structures (HLS, CLS). From mutual comparison of HLS and CLS in cadastral area of Žirany a few changes results within each group of landscape features. Some of landscape elements of the SLS in the studied area between 1869 and 2012 were replaced by other groups. By mutual comparison of maps HLS and

CLS we can not only identify these changes (Fig. 3), but also quantify them through their mapping results of SLS. The surfaces with a change in their landscape elements occupy 450.86 ha (29.03%) of the total cadastral area. Modified areas are mainly located in the close vicinity with the urbanised area of village. The changes occurred at the expense of narrow-striped of arable land, crops and grass plots. Technical elements that are represented by industrial and agricultural technical areas were added to the CLS. Vice-versa, areas with constant group of landscape elements represent 1,101.97 ha (70.97%). They are particularly remote areas of continuous forest in south-western, northern and south-eastern part of the cadastral area and southeast corner of the cadastral area with agricultural land. At Fig. 3 cut-out segment of Žirany cadastre and comparison of land use form changes since 1949 to 2007 can also be seen. Aerial photos show changes from mosaic to large-scale agriculture structure.

Species of the genus *Quercus* sp. are among long-living trees with frequent occurrence of oversized individuals, together with other species they form the basic compositional element in the historic parks in the world, as well as in Slovakia, or in nature reservations, for example Kašivárová (Benčať, 1984; Kubišta, 2006; Feriancová and Štěpánková, 2006). In terms of species composition, all four species of the genus *Quercus* were identified in the phytogeographical zone Tribeč. They are also mapped in the cadastral area of Žirany. In detail research and mapping of oaks in Slovakia (Požgaj and Horváthová, 1986), *Quercus dalechampii* Ten. and *Q. polycarpa* Shur. were identified in the cadastral area of Nitrianske Hrnčiarovce and Kostoľany pod Tribečom, but the authors do not mention them in the cadastral area of Žirany. Our identification, including biometric data can be considered as original and important gene pool.

Castanea sativa Mill. is considered to be an old culture pulp in Slovakia with early introduction in the 13th century, first in the territory of so called Forgáč estate around the castle Gýmeš (Jelenec), which is a neighbour territory with cadastral area of Žirany (Benčať, 1984). In terms of gene pool values, occurrence of old and oversized individuals Benčať and Lindtner (1968) listed three largest individual chestnuts in Slovakia (1) – Častá, vineyards, $d_{1,3}$ = 231 cm, age 400–500 years, (2) – Častá, oak forest, $d_{1,3}$ = 189 cm, age 300–350 years, (3) – Častá, Lindtnerova garden, $d_{1,3}$ = 182 cm, age 250–300 years. In 1999, I personally identified (Supuka, not published) sweet chestnut tree *(Castanea sativa)* Mill. in area of Hodruša Hamre, Pazmányiho farmstead, the girth stem in $h_{1,3}$ = 720 cm, crown width from 17 to 21 m, 18 m height, age 350–400 years. The largest identified sweet chestnut tree in the land Žirany with its values (girth stem in $h_{1,3}$ = 700 cm, 24 m height, crown width from 16 to 18 m, age about 450 years) is a unique, historic and genetically very valuable tree in the study area.

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Zmeny v štruktúre poľnohospodársky využívanej krajiny a výskyt genofondovo významných stromov

Súhrn

Obsahom príspevku je zhodnotenie zmien v krajinnej štruktúre na území katastra Žirany v komparovaných rokoch 1869 a 2012. V druhej časti príspevku je prezentovaný výskyt genofondovo významných stromov identifikovaných na území katastra.

Zmeny v zastúpení krajinných prvkov, ich vnútorná štruktúra a plošno-priestorová distribúcia na území katastra je odrazom vlastníckych pomerov, foriem využívania zeme, intenzifikačných foriem najmä v poľnohospodárstve a socio-ekonomického rozvoja spoločnosti. Krajinná štruktúra bola zhodnotená z mapových podkladov a terénnym výskumom súčasného stavu. Súčasná krajinná štruktúra v roku 2012 bola hodnotená použitím 9-tich skupín a s celkovým počtom 44 krajinných prvkov, v roku 1869 bolo použitých 8 základných skupín a 19 krajinných prvkov. Najvýznamnejšie zmeny v druhotnej krajinnej štruktúre v rokoch 1869 a 2012 boli identifikované v nasledovných prvkoch v porovnávaných časových horizontoch: mierne zníženie podielu lesa (z 42,83 na 40,76 %), zvýšenie podielu nelesnej drevinovej vegetácie (z 0,33 na 4,00 %), zníženie podielu poľnohospodársky využívaných plôch (z 44,16 na 37,86 %), pokles plôch trávobylinných porastov (z 10,17 na 5,99 %) a zvýšenie skupiny sídelných prvkov (z 1,56 na 6,44 %). Významná zmena je zistená v premene mozaikovej štruktúry úzkopásových polí na veľkoblokové formy poľnohospodárskeho využívania krajiny.

Pri mapovaní prvkov súčasnej krajinnej štruktúry dôraz bol položený na priestorovú distribúciu a biodiverzitu drevín v skupine nelesnej drevinovej vegetácie (NDV).

Vo formáciách NDV bolo na území katastra identifikovaných spolu 6 druhov genofondovo významných, biometricky a vekovo nadštandardných drevín s celkovým počtom 47 jedincov. Sú to druhy: *Castanea sativa* Mill. (18 jedincov), *Mespilus germanica* L. (1 jedinec), *Quercus cerris* L. (1 jedinec), *Q. dalechampii* Ten. (2 jedince), *Q. petraea* (Mattusch.) Liebl. (23 jedincov), *Q. polycarpa* Shur. (2 jedince). Genofondovo významné dreviny boli tiež lokalizované pomocou GPS.

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Time and spatial trends in the brown bear *Ursus arctos* population in Slovakia (1900–2010)

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Abstract

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This work discusses several factors underlying changes in distribution of brown bears in Slovakia. Our evaluation was carried out based on historical records, map documents, and data from the bear census in Slovakia (2002–2010), and it was performed with using GIS tools. We concluded that: i) bears preferred well forested localities with colder climate at higher altitudes and that the influence of altitude was significantly stronger than the impact of forest cover density, ii) bear occurrence and relative density gradually decreased with decreasing altitude, iii) in the long term aspect, the most noticeable fluctuation occurred in medium altitudes from 400–1,100 m a.s.l. (SD > 10%), the highest stability was observed from 1,500 m a.s.l. (SD < 2%), and absence or very rare occurrence (less than 5%) was recorded below 300 m a.s.l, iv) unregulated interventions affected spatial distribution of brown bears across Slovakia in long term perspective. We presume, that evaluating of the data come from bear census in particular game grounds by using of spatial analysis will be possible to use as one of the indicator of the state of the population in Slovakia and for formulation of management of the brown bear.

Keywords

altitude, Carpathians, density, historical records, management, spatial analysis

Introduction

The relation between the man and the nature was critical in the period of intensive development of pasturage and sheep breeding connected with the so called Walachian colonisation of the territory of today Slovakia. The general leitmotiv was intensive killing and hunting bears in all possible ways (shooting, catching in soil traps, iron chains, nooses). Eradication of wild game was ordered according to the hunting regulations ordered by the emperor Joseph II, and each kill of a bear was rewarded (Čajka, 1986). The most noticeable drop in the brown bear population in Slovakia probably occurred in the midst of the 19th century. The abolition of servitude (1848) and shifting the urbarium to the ownership of the former retainers were incentives for the people to fight against wild animals that endangered these people's proprieties. From 1857, there exist records about 99 bears killed only in the regions of Šariš and Zemplín (Eastern Slovakia), the number of the total kills for the rest of the country (97 individuals) seems incomplete (Molnár et al., 1984). This massive decline was probably caused by using strychnine for poisoning wolves (Blattný, 1965 cit. in Jamnický, 1993), with a „side effect" of death also to a large number of bears Kavuljak (1930 cit. in Jamnický, 1993). Then the kills in the regions of Zemplín and Šariš were negligible (Jamnický, 1993), incomparable with 1857 (Molnár et al., 1984). This allows us to suppose that the Slovak bear population was divided into the East-Carpathian and West-Carpathian at that time (Straka et al., 2011, 2012). Figure 1 displays maps of bear distribution in Slovakia during the period from 18/19th century to the year 2010.

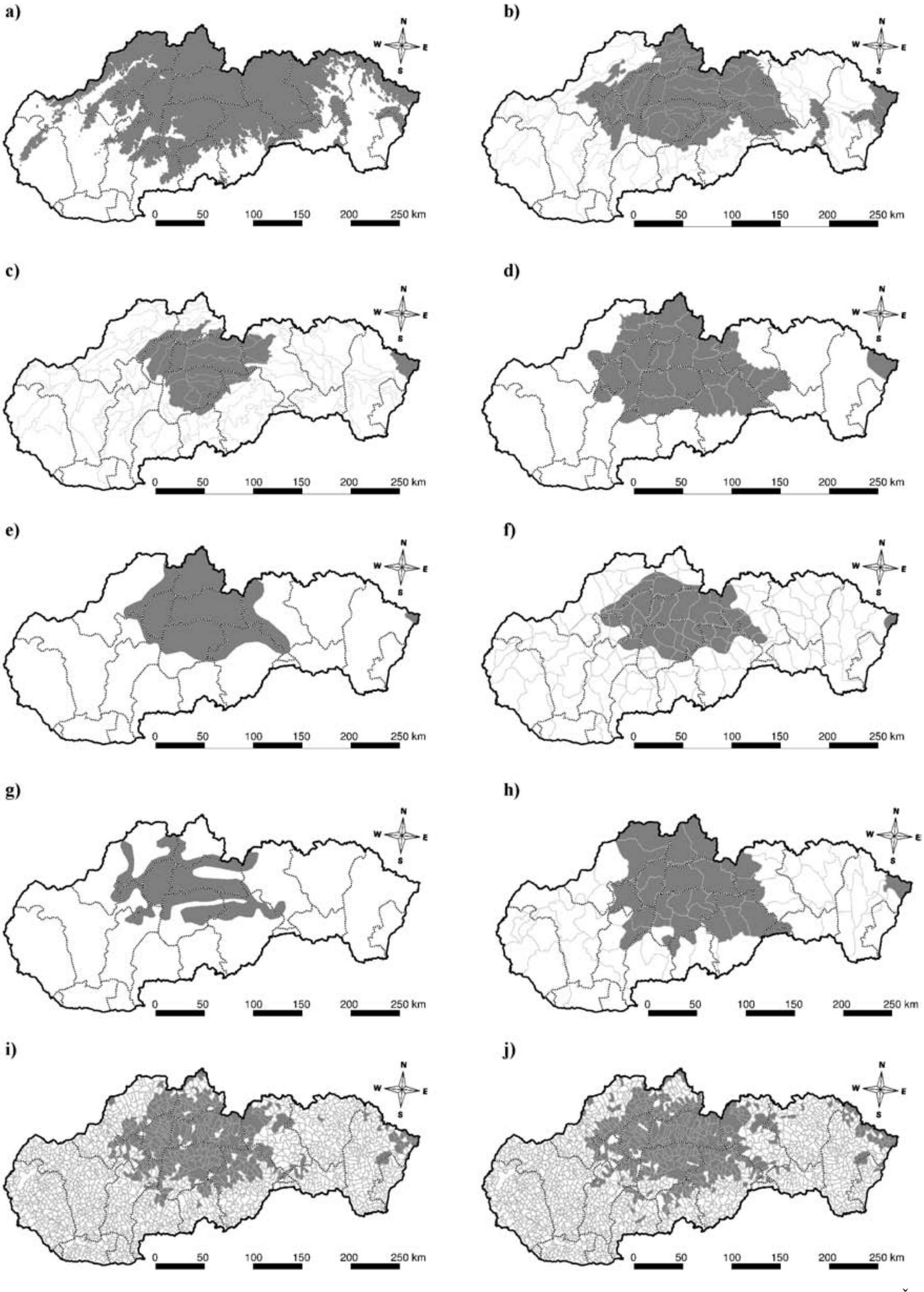

Fig. 1. Maps of bear distribution in Slovakia. a) 18/19th century (hypothesis); b) 19/20th century (Molnár et al., 1984, Štofík et al., 2010); c) WWI.–WWII. (Feriancová, 1955), d) 1953 (Feriancová, 1955); e) 1968 (Škultéty, 1970); f) 1972 (Hell and Sládek, 1974); g) 1977 (Sabadoš and Šimiak, 1981); h) 1980–1991 (Hell and Sabadoš, 1993); i) 2002 (©NFC SR, 2011); j) 2010 (©NFC SR, 2011).

The re-joining was probably hindered by the Act article XX/1883 on the game management allowing everybody to kill bears occurring on the land in their ownership. The act was valid for everyone, not only for the hunters, all around the year, so that were not any reasons to keep the kills in secret. This act was valid until the end of the WWII. By the Decree of the regional President No. 127, 203/14-1932 the bear has been given status of the over-the-year protection. This decree came in force on September 1 1932. However, the regional President was forced by hunters to issue a new regulation No. 208, 647/14-1932 allowing a subject to kill bears on the land in their ownership also in the case when the hunting right had been rented (Škultéty, 1970).

By the year 1932, the reduction of bear population was such dramatic that this required to accept legislative measures to keep the population in Slovakia viable. In this period, the number of brown bears in Slovakia was only several tens (Feriancová, 1955; Škultéty 1970; Janík et al. 1986; Hell and Sabadoš, 1993).

From 1958 to the earliest 80s, the game managers were focussing at killing old large individuals, especially males. During 1980s, there was initiated administrative regulation of killing large males. While in 1980–1982 was the average weight of killed indi-

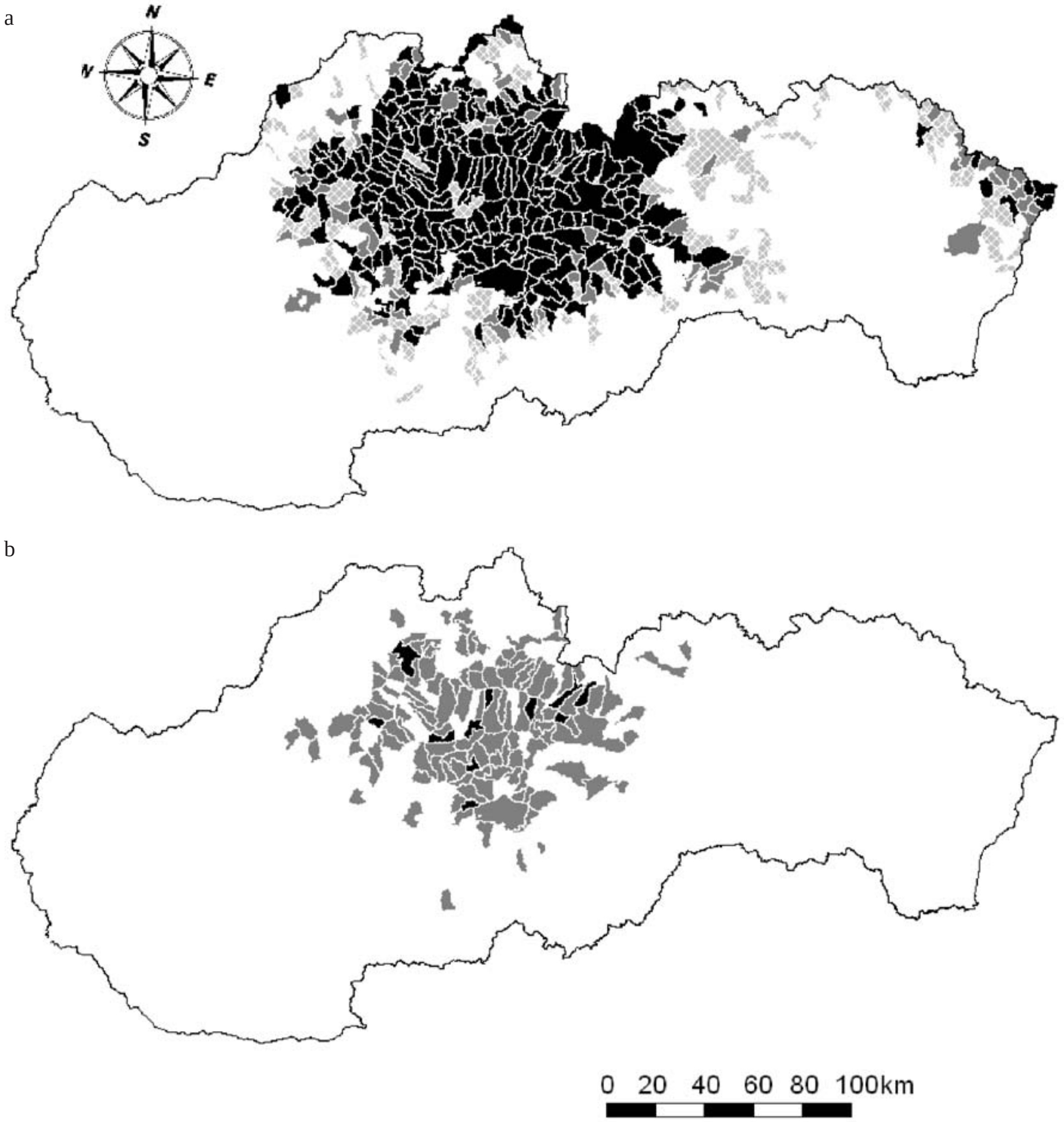

Fig. 2. State and management of the brown bear population in Slovakia (2002–2010). a) Occurrence stability S%: ■ = 100%, ▩ = 67%, ▨ = 33%, b) kill rate: ■ < 0.1 ps km^{-2}, ▩ > 0.1 ps km^{-2}.

viduals 142.5 kg, in years 1989–1991 it was only 101.8 kg (Hell and Slamečka, 1999). Since 1972 Sabadoš and Šimiak (1981) report that in 1972 was started also control of the stocks, which may have considerably influenced the distribution of brown bear in this period. Contrarily Hell et al. (1983) recommended an increase in kill from 5% to 8% of the existing stock. Hell et al. consider this value biologically acceptable, not endangering the game stocks. Today the bear kill rate is controlled only in smaller individuals, up to 100 kg, or with the front paw wide less than 12 cm (Adamec, 2007). State and management of the brown bear population in Slovakia (2002–2010) is presented in Fig. 2.

IUCN (2001) classifies the brown bear *Ursus arctos* as a low endangered animal – dependent on protection. According to the Act on Nature and Landscape Protection (No. 543/2002) and Decree of the Ministry of the Environment (No. 24/2003), forcing EU directives on habitats and birds, the brown bear is a species with a high protection priority of European importance. The paragraph § 35 (No. 543/2002) defines the brown bear as a protected animal, but it allows to ask for an exception (according to § 40 and § 56).

The number of brown bear population in Slovakia has been questioned by a range of authors the results of whom we use in this work. Our aim was to use spatial data on brown bear distribution in Slovakia and to analyse the factors affecting in long-term but also short-term aspect this bear population in this country.

Material and methods

In this work we used: a) the layers of forests, districts and contour lines of SR – CVM 50 (Continuous digital vector map of Slovakia), background the Base maps of the Slovak Republic, scale 1 : 50,000, b) layer of map sets of Slovakia 1 : 5,000 (©Institute of Geodesy, Cartography and GIS), c) layer of hunting associations in Slovakia (©NFC SR – National Forest Centre Slovak Republic, 2002), d) data on shoots (mortality and similar.) from 1900–2010 (Molnár et al., 1984; Jamnický, 1993; Feriancová, 1955; Finďo et al., 2007; Sabadoš and Šimiak, 1981; Hell and Sládek, 1974, Hell et al., 1983; Hell and Slamečka, 1999; Kassa, 1998, 2001, 2002, 2006a, 2006b, 2007; Adamec, 2007; Štofik, 2010; ©NFC SR, 2011), e) data on damage to bee hives and agricultural facilities in Poland 1999–2010 (Sergiel et al., 2012), f) data on damage to bee hives and game management facilities in Slovakia in 1999–2006 (Hell et al., 2007), 2002–2010 (©NFC SR, 2011), g) generated historical data on bear distribution in Slovakia at the turn of the 19th/20th century Molnár et al. (1984), Štofík et al. (2010), h) generated historical data on bear distribution in Slovakia between WWI and WWII (Feriancová, 1955), i) map of bear distribution in Slovakia in 1953 (Feriancová, 1955), j) map of bear distribution in Slovakia in 1968 (Škultéty, 1970), k) map of bear distribution in Slovakia in 1972 (Hell and Sládek 1974), l) map of bear distribution in Slovakia in 1977 (Sabadoš and Šimiak, 1981), m) map of bear distribution in Slovakia in 1982 (Janík et al., 1984), n) map of forest enterprises with bear kill records from 1980–1991 (Hell and Sabadoš, 1993), o) data on spring game stocks (SGS), kills and damage caused by bears in individual hunting grounds in Slovakia from 2002 to 2010 (©NFC SR, 2011), p) data on number of inhabitants in individual districts of Slovakia to 31. 12. 2010 (©Statistical Office SR 2011).

The data were processed in the following steps:

i) Identification of the brown bear distribution in Slovakia from the data on hunting and occurrence of brown bears in the individual geomorphological units (Miklóš ed., 2002) at the turn of the19/20 centuries (Molnár et al., 1984; Štofík et al., 2010), between the WW I and WW II (Feriancová, 1955) and coupling these data with the layers of geomorphological units in Slovakia in the GIS environment (Miklóš (ed.), 2002).

ii) Identification of brown bear distribution from map sources: 1953 (Feriancová, 1955), 1967 (Škultéty, 1970), 1972 (Hell and Sládek, 1974), 1977 (Sabadoš and Šimiak, 1981), 1980–1991 (Hell and Sabadoš, 1993) and vectorised in GIS by visual interpretation (Olah et al., 2005, 2006).

iii) Identification of bear distribution and density (estimate) by coupling the data on spring game stock (SGS) reported by game associations in years 2002–2010 (©NFC SR, 2011) with the layer of game associations (©NFC SR, 2002). The layer for game grounds comprised 1,915 polygons, of which 91 which were not used within the spatial analysis of hunting grounds (non-hunting or closed areas). The reporting duty to assess the annual reports on the spring game stock (to March 31) is implied by the Act No. 540/2001 Z. z. on the national statistics. The hunting rights in the rented game grounds are provided for ca. 36,581 members of game associations and clubs (Dugovič, 2010), participating together with employees of state and military grounds in the game census.

iv) Creation of layers of uniformly dispersed area units – quadrates (segments 10 × 10 km and 5 × 5 km) in overlap with Slovakia.

v) Relative forest cover calculated in the GIS programme CVM 50 for individual game grounds and segments of map grid (2 × 2.5 km) and standard layers (Step iv).

vi) Digital terrain model (raster 500 × 500 m) created in GIS programme Grass 6.1 on the background of contour lines from SVM 50, and then derived a map of hypsometric zones (scaled by 100 m a.s.l.).

vii) Overlapping the data on human population and the layer of districts.

viii) Evaluation of long-term changes in bear area distribution (Steps i, ii, iii).

ix) Relative values were calculated by overlapping the layer of the evaluated time periods (Steps i, ii, iii) and the layer of hypsometric zones (Steps i, ii, iii vs. vi).

x) In GIS programme (period 2002–2010), there were compared the data on distribution, density (Step iii) and stability (S%: no occurrence = 0%, 3 and less years = 33%, 4 to 6 years = 67%, 7 and more years = 100%) of bear occurrence related to forest cover (Step v), altitude (Step vi) and human population density (Step iii vs. v vs. vii vs. viii) within game grounds (Step i) and uniformly distributed plots (Step iv, map grid 1 : 5,000). There were analysed segments covering the relevant area by +95%.

xi) The data from published works and the data assembled in this research used for assessment of numbers of bears extinct from the population (hunted or dead naturally) in years 1900–2010 (Molnár et al., 1984, Jamnický, 1993; Feriancová 1955; Finďo et al., 2007; Halák, 1993; Sabadoš and Šimiak 1981; Hell et al., 1983; Hell and Slamečka, 1999; Kassa, 1998, 2001, 2002, 2006a, 2006b, 2007; Adamec, 2007; Štofík, 2010; ©NFC SR, 2011).

xii) Comparing the data on damage with the changes in dispersal. Spatial analysis of hunting bears in Slovakia in years 2002–2010 (©NFC SR, 2011) performed in frame of game grounds.

Results and discussion

Hunting rate (killing rate and natural mortality)

Based on the records on bear kills in Slovakia (Molnár et al., 1984; Jamnický, 1993; Feriancová, 1955; Finďo et al., 2007; Halák, 1993; Sabadoš and Šimiak, 1981; Hell et al., 1983; Hell and Slamečka, 1999; Kassa, 1998, 2001, 2002, 2006a, 2006b, 2007; Adamec, 2007; Štofík, 2010; ©NFC SR, 2011), there were evaluated changes in number of the killed (naturally dead) bears from the year 1900 to the year 2010. The data from the beginning of the 20th century are only incomplete (Fig. 3).

By the year 1932, the number of brown bear individuals in Slovakia had been reduced to several tens (Feriancová, 1955; Škultéty, 1970; Janík et al., 1986; Hell and Sabadoš, 1993), which was also responded by reduction of the occurrence area of this species (Figs 1, 3). By regulation of the regional President No. 127, 203/14-1932 valid since September 1, 1932 the brown bear was being protected round the year (Škultéty, 1970), which was probably responded by its penetration into territories without any occurrence recorded before (Feriancová, 1955; Figs 1, 3).

From 1958 the earliest 80th, the hunters were focussing on shooting old large animals, mainly males (Hell and Slamečka, 1999), which probably affected reduction of the brown bear range in Slovakia (Figs 1, 3). In the 1980s, there was initiated control of the kill rate of large males, and this was responded by extension of the range and density of the brown bear in Slovakia (Hell and Slamečka, 1999). The map of kill

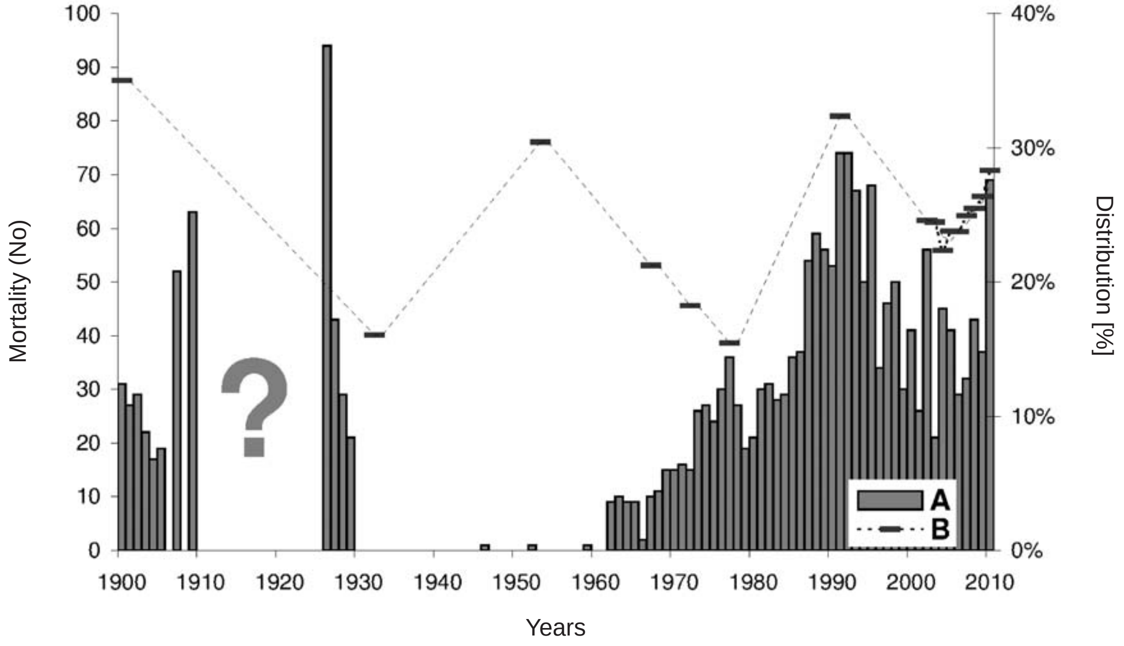

Fig. 3. Mortality of bears and changes in their distribution in Slovakia. A) Kill rate and mortality of bears in Slovakia [No]; B) Distribution of bears in Slovakia [%].

rate in 1991 (for individual forest enterprises) covering a relatively long time period (1980–1991) has excluded from analysis areas of the supposed overlapping of the East-Carpathian and West-Carpathian population (Hell and Sabadoš, 1993).

Selective control of killing individuals weighing up to 100 kg, with the width of the front paw up to 12 cm (Kassa, 2001; Adamec, 2007) was probably responded by penetrating brown bears in areas in which the species did not occur in formerly (Figs 2, 6).

Altitude

During the period 2002–2010, the bears showed preferences for higher situated localities (Table 1), which means colder climate (Lapin et al., 2000) and more days with snow cover (Šťastný 1988).

The bear population density was higher in the area with more stabile presence and at higher altitudes (Fig. 4), with lower human population density and denser forest cover (Table 1). Comparing the changes in spatial distribution patterns (2002–2010), there was detected significant influence of altitude on occurrence stability and density (Table 1).

From the long-term viewpoint, the largest fluctuations in dispersal were found in medium altitudes ranging 400–1,100 m a.s.l. (SD < 10%); the lowest in high mountains from 1,500 m a.s.l. and more (SD < 2%). Absence or only minimum occurrence (mean < 5%) was recorded in game grounds situated up to 300 m a.s.l. (Fig. 5).

The brown bear occurrence did not show significant differences in bear occurrence dependent on altitude. In higher situated localities, the bears receded between the WWI and WWII and in the 1970-s after unregulated hunting (Fig. 6).

Today, the confines of brown bear occurrence are shifted lower compared to the former data (Fig. 6), and there also exist hibernation records from lower situated localities in the Eastern Carpathians (Štofík and Saniga, 2012).

Forest

The bear occurrence was more stabile in game grounds (Table 1) with denser relative forest cover than in other game grounds, however, with significant differences only detected at altitudes showing positive effects on bear occurrence and density (Table 1). The forest cover in the regions of the Tatra Mts since 1855 (Olah et al., 2005) and in the region of the Eastern Carpathians Mts (Olah et al., 2006) is significantly increasing, which we suppose also in other regions, and this fact may be reflected in bear occurrence in lower situated localities.

Probably several times increased human population (Dubcová et al., 2008), changes to landscape infrastructure and patchy character of forest cover accounted for the discontinuity between the East and

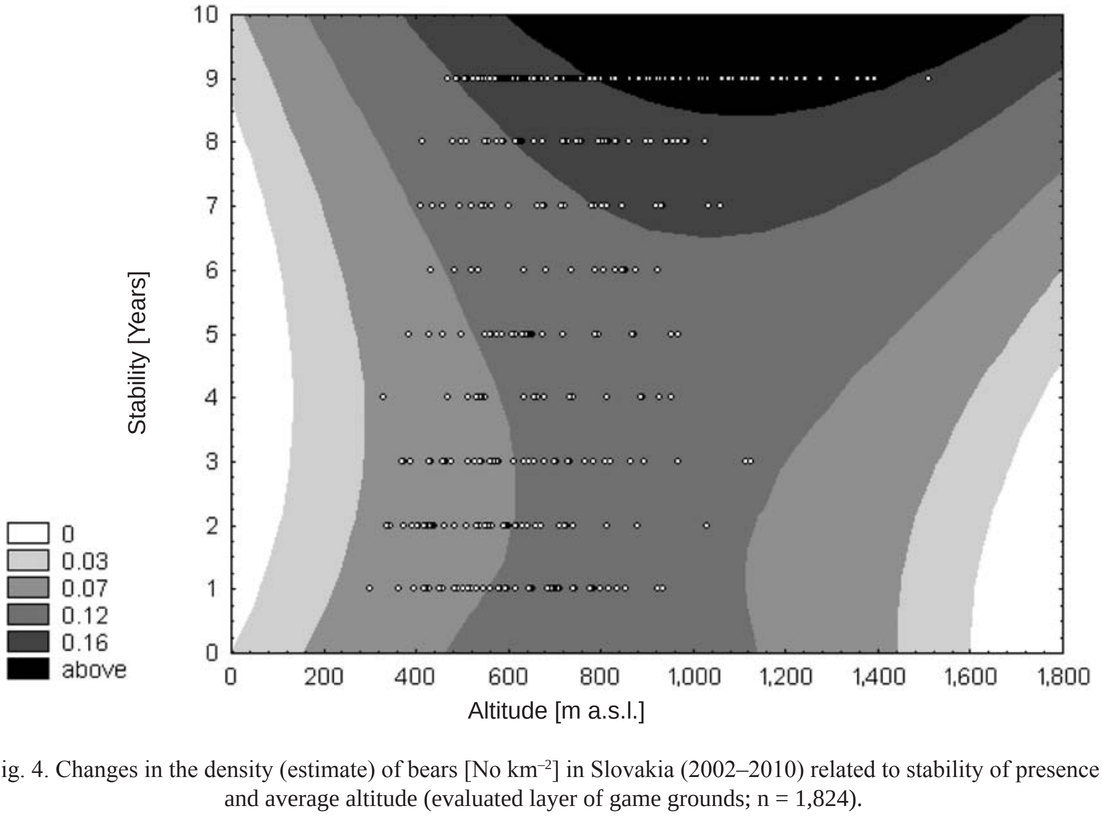

Fig. 4. Changes in the density (estimate) of bears [No km^{-2}] in Slovakia (2002–2010) related to stability of presence and average altitude (evaluated layer of game grounds; n = 1,824).

Table 1. Stability of bears [S%] in Slovakia (2002–2010) related to selected attributes

S%	Evaluated attributes	Game grounds
0%	No	1,371
	Altitude: average / SD [m a.s.l.]	340 / 163
	Forest cover: average / SD [%]	28% / 28%
	Density of human population: average / SD [No km^{-2}]	127 / 126
33%	No	123
	Altitude: average / SD [m a.s.l.]	608 / 167
	Forest cover: average / SD [%]	56% / 21%
	Density of bears (SGS estimate): average / SD [No km^{-2}]	0.07 / 0.08
	Density of human population: average / SD [No km^{-2}]	88 / 61
67%	No.	67
	Altitude: average / SD [m a.s.l.]	672 / 157
	Forest cover: average / SD [%]	60% / 20%
	Density of bears (SGS estimate): average / SD [No km^{-2}]	0.09 / 0.06
	Density of human population: average / SD [No km^{-2}]	87 / 64
100%	No.	263
	Altitude: average / SD [m a.s.l.]	806 / 203
	Forest cover: average / SD [%]	60% / 19%
	Density of bears (SGS estimate): average / SD [No km^{-2}]	0.15 / 0.09
	Density of human population: average / SD [No km^{-2}]	96 / 45
Slovakia	No.	1,824
	Segment area: average / SD [km^2]	26.54 / 21.00
	Altitude: average / SD [m a.s.l.]	438 / 244
	Forest cover: average / SD [%]	36% / 29%
	Density of bears (SGS estimate): average / SD [No km^{-2}]	0.12 / 0.09
	Density of human population: average / SD [No km^{-2}]	119 / 113

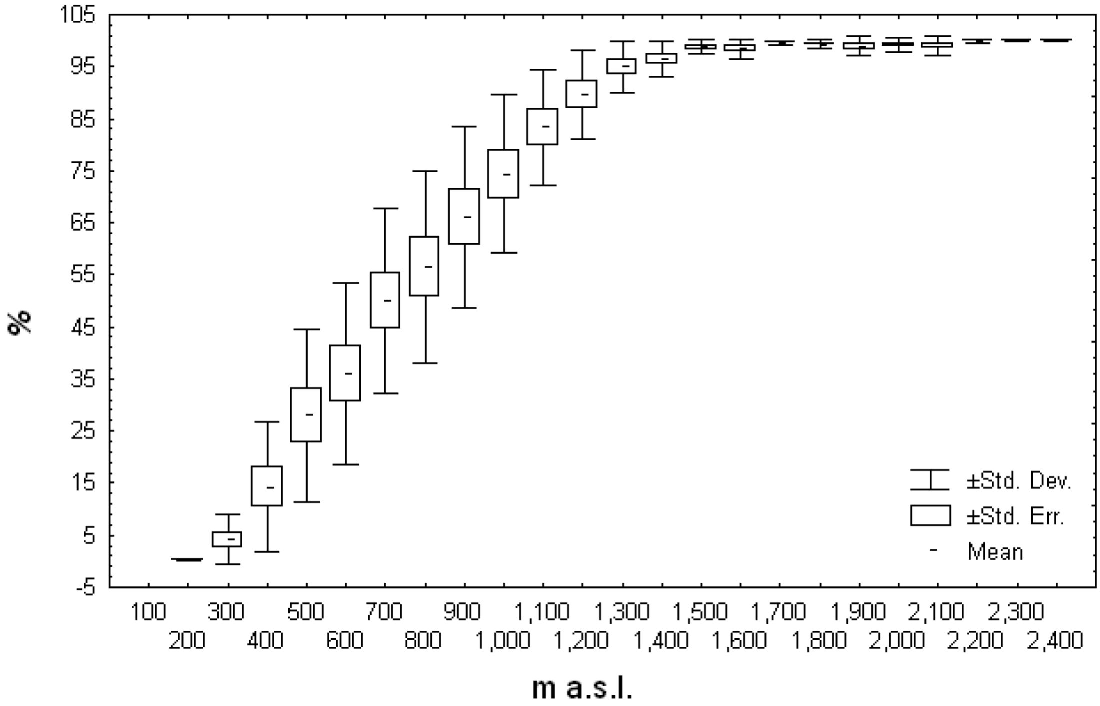

Fig. 5 Analysis of long-term changes in the distribution of bears related to relative values of hypsometric zones of altitude in Slovakia. Data sources from: 1900 cca, 1932 cca, 1953, 1968, 1972, 1977, 1980–1991, 2002 and 2010.

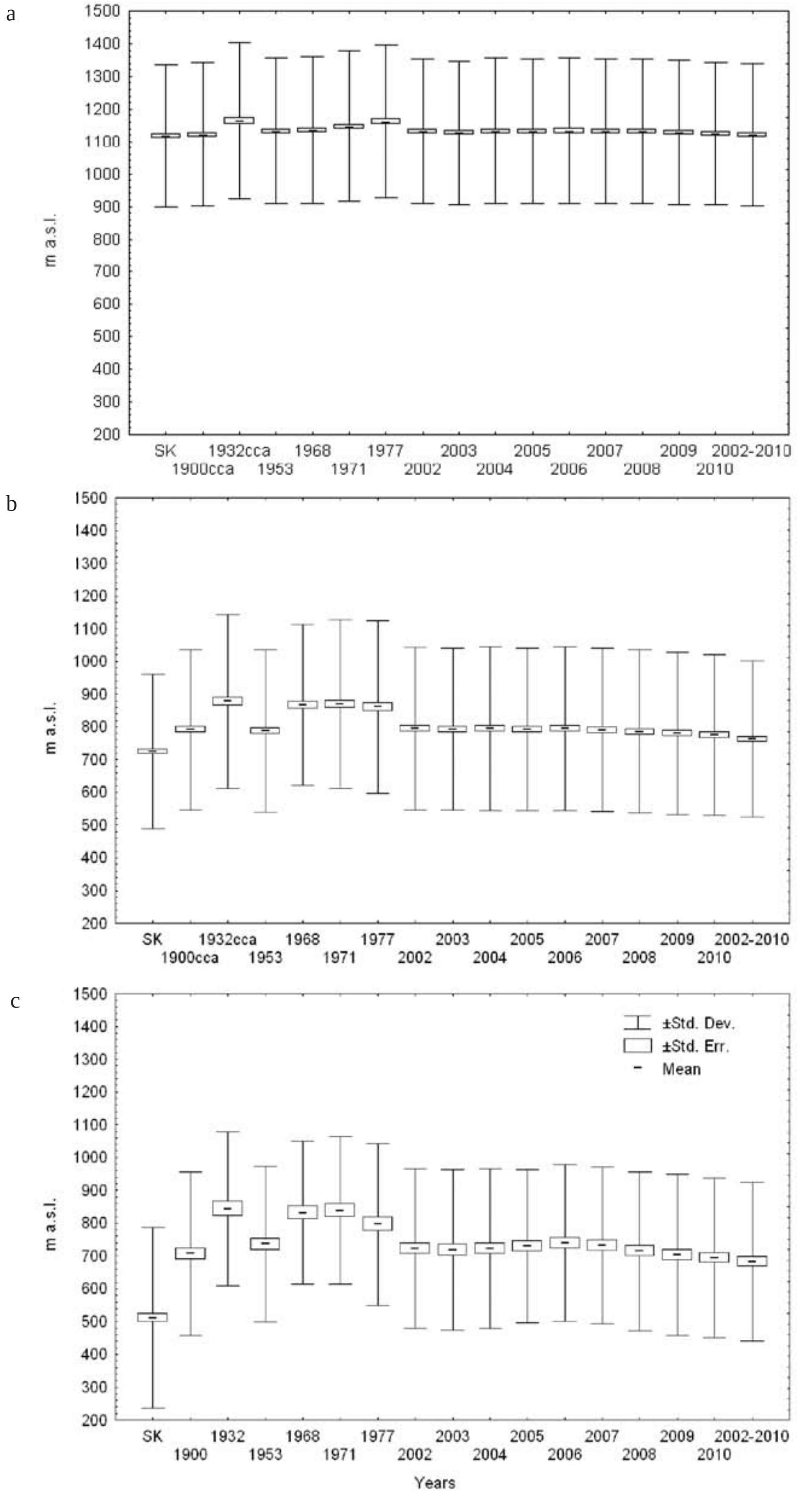

Fig. 6. The presence of bears in relation to average altitude in different evaluated layers of segments in Slovakia (1900–2010) (evaluated segments of the territory of Slovakia covered +95%): a) evaluated layer of segments 2 × 2.5 km; b) evaluated layer of segments 5 × 5 km; c) evaluated layer of segments 10 × 10 km.

West Carpathian populations of brown bear in Slovakia (Straka et al., 2011, 2012). Some link between these two populations seems to follow from a genetic analysis carried out in Polish Carpathians (Śmietana et al., 2012), the results, however, could be influenced due to re-introduction of 8 synanthropic individuals from the Western Carpathians into the Eastern Slovakia (Štofík et al., 2010).

Long-term changes in range

The data on brown bear occurrence (Fig. 1b) at the turn of the 19th and 20th century have been probably underestimated (Molnár et al., 1984, Štofík et al., 2010), as there exist records on several bear kills at the western boundary with the Czech Republic, dated into the 19th century, and a report on bear occurrence observed in 1908 (Bartošová, 2002). The map of brown bear dispersal from the period between WWI and WWII (Feriancová, 1955, Fig. 1c) illustrating districts with reoccurrence of brown bear may a bit over-estimate the dispersal of the bear population in the given period.

The first map (Fig. 1d) illustrating the dispersal of bears across the territory of Slovakia is dated from 1953 (Feriancová, 1955). The material for the map creation was collected in form of questionnaires submitted by Commissioners for forests to the directors of individual forest districts. The map evaluated the bear distribution according to individual districts (Feriancová, 1955). The map from 1968 (Fig. 1e) was compiled with the data on spring stock of brown bear in individual forest enterprises (Škultéty, 1970), the attached map, however, was prepared for units smaller than forest enterprises. In the earliest 1970s, Sládek carried out a mapping evaluation of bear dispersal in Slovakia (Hell and Sládek, 1974) based on the data reported from forest enterprises (Fig. 1f). Also this map seems elaborated for units smaller than forest enterprises.

Kalina et al. (1980) inform about the reduction of forest enterprises (state forest enterprises) in the former ČSSR to 113 in 1978 from 278 in 1945 (with a minimum area of 23,000 ha). So we may suppose that the evaluation according to forest enterprises might result in over-estimation of data about spatial distribution, and therefore, they have been attached map sets providing more details on bear dispersal. In year 1977 Sabadoš and Šimiak (1981) processed the data supplied in questionnaires and statistic records of bear stocks in forest enterprises (Fig. 1g).

The map that was used for the analyses was not elaborated for individual forest enterprises, and it may be supposed that also the attached map was prepared from units smaller than forest enterprises. We also must make remark that Sabadoš and Šimiak (1981) didn't depict presence of the bears in the area of Eastern Carphatians on the map from 1977 in spite of confirmed data of presence of brown bear from that period (Štofík et al., 2010). The brown bear distribution in year 1982 was documented in the work Janík et al. (1984). Despite the link between the East Carpathian and West Carpathian population evident in the map, the authors conclude that the ecological conditions in the area of the Ondavská vrchovina Mts are not suitable for brown bear permanent sites. Such sites are possible only with preserved migration corridors along the state boundary with Poland.

Due to these discrepancies between the text and the map, the map was excluded from spatial evaluation. The bear dispersal in 1991 was evaluated based on the data on bear kills in years 1980–1991 (Hell and Sabadoš, 1993, Fig. 1h). The map base was created for forest enterprises representing bigger area units and longer time periods in comparison with the other map bases – which may results in bigger errors loading spatial analyses.

From the long-term point of view we may suppose that while the bear population was severely affected by unregulated hunting, the occurrence in high-situated localities was continual even under the strongest hunting pressure.

Short-term changes in range and density

More detailed data concerning changes in the bear range are available from the period 2002–2010, recorded in spring game census in game grounds (n = 1,824; mean 27 km^2; SD 21.13 km^2). This evaluation did not include areas outside the game grounds (Koreň et al., 2011). In the short-term aspect, the population was found expanding into lower situated localities (Fig. 6), with more stable occurrence in higher altitudes with rare human presence and also significantly denser bear population (Fig. 4). The effects of disturbance of bears on their time and spatial distribution and animals avoiding areas with possible disturbance were discussed in several works (Nellemann et al., 2007; Rode et al., 2006.).

The bear stocks are rising also in the surrounding countries: Ukraine (Delehan et al., 2011), and Poland (Jakubiec, 2001); increasing numbers have also been reported from Slovakia (Štofík et al., 2010; Rigg and Adamec, 2007). As well as the area of distribution (Śmietana et al. 2012) also in eastern part of Polish Carpathians is increasing.

Damage

Unlike in the neighbour Poland, there have not been recorded evident changes in damage to beehives since 2006, nevertheless, with exception of a moderate increase in 2010. On the other hand, a more distinct damage increase has been evident since 2007 on hunting facilities (Fig. 7), probably due to strengthening (Rigg and Adamec, 2007) and extension of the bear population (Fig. 3). Beginning with 2006, we observe brown bears retreating into localities at low altitudes and with sufficient forest cover (Table 1). The increase in damage to bee hives (Poland – Sergiel et al., 2011) and hunting facilities (Slovak Republic – ©NFC SR, 2011), may be to some extent explained by roof game feeding – and so also indirect feeding of bears.

Recently there has been also evidence that another big omnivore – wild boar increased its population (Geisser and Reyer, 2004, 2005; Bieber and Ruf 2005; Taschalidis and Hadjisterkotis, 2008; Keuling et al., 2010) thanks to supplementary feeding (Geisser and Reyer, 2004). To avoid this trend, it is recommended either to stop supplementary feeding and reduce, in such a way, the negative impact of game management (Bieber and Ruf, 2005), or to use hunting as an alternative for preventing damage to the agricultural crops (Geisser and Reyer, 2004).

Conclusions

In long-term aspect, the brown bear distribution in Slovakia was responded sensitively by unregulated shooting. The reduction of brown bear stock is primarily evident on receding in higher situated colder localities. In short-term aspect, we can observe more stable, denser population at higher altitudes in colder climatic regions. The restricted allowable hunting rates and easy accessible sources of anthropogenic food are factors promoting the increase of bear population in Slovakia.

We are conscious of the fact that the data from the historical maps are only attempt to the most exact depiction of the presence of bear at that time and the data processed from the spring census are only approximate, not corresponding to the factual stocks of this animal. Therefore we propose the spatial analysis within the game grounds as a suitable supplementary method to the data processed from the spring census, data about presence and data about bear mothers with cubs, all together to use for formulation of management of the brown bear in Slovakia.

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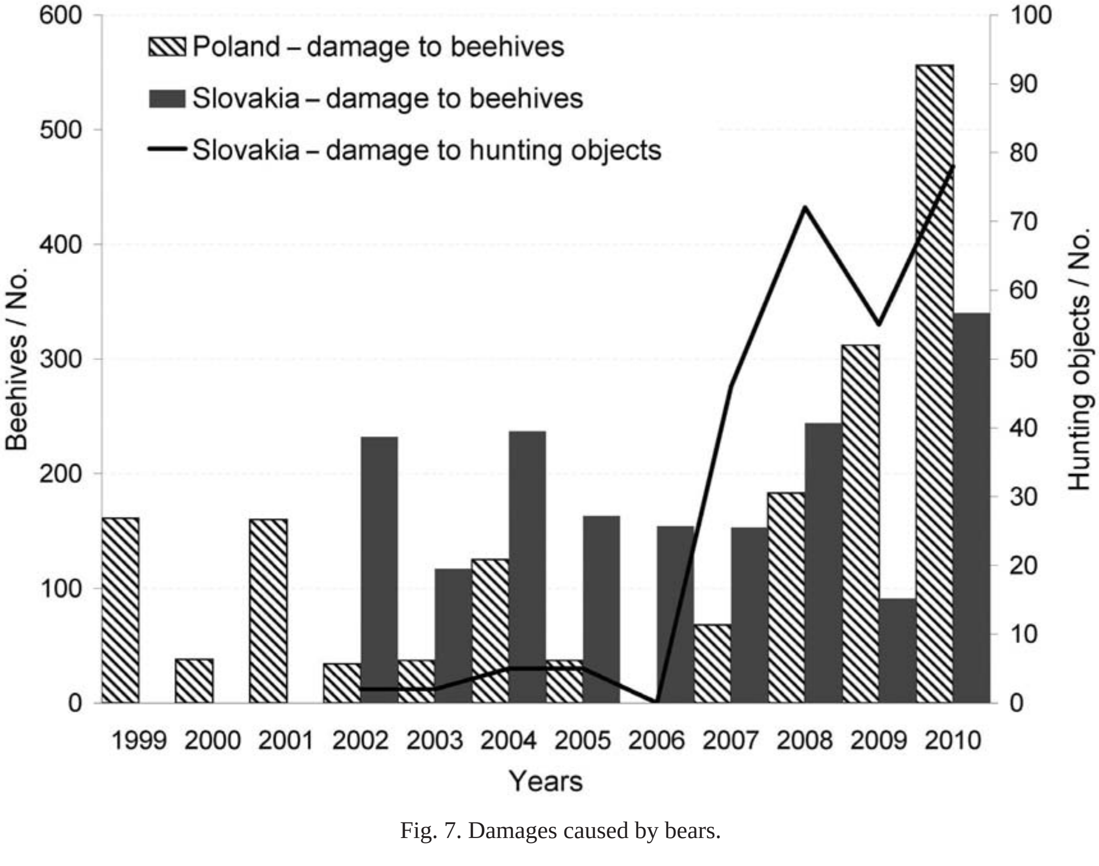

Fig. 7. Damages caused by bears.

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Časopriestorové zmeny populácie medveďa hnedého *Ursus arctos* na Slovensku (1900 – 2010)

Súhrn

V tejto práci, na základe historických údajov, mapových podkladov a údajov o medveďoch v rámci JKS (jarné kmeňové stavy) – sčítania zveri na Slovensku (2002 – 2010), za pomoci GIS programov vyhodnocujeme vybrané faktory ovplyvňujúce zmeny v rozšírení medveďov na Slovensku. Vyhodnocujeme, že: i) medvede preferujú chladnejšie oblasti, vyšších nadmorských výšok s dostatočnou pokrývkou lesa, pričom výraznejšie vplýva na výskyt medveďov nadmorská výška ako pokryvnosť lesa, ii) so znižujúcou sa nadmorskou výškou postupne klesá frekvencia výskytu a relatívna hustota medveďov, iii) dlhodobo k najvýraznejším výkyvom v rozšírení dochádza v stredných nadmorských výškach 400 – 1 100 m n. m. (SD > 10 %), k najmenším od 1 500 m n. m. (SD < 2 %) a žiadny, alebo minimálny výskyt (do 5 %) bol zaznamenaný do 300 m n. m., iv) neregulované zásahy v dlhodobom horizonte ovplyvňovali priestorovú distribúciu medveďov na území Slovenska.

I keď mapové údaje z minulosti boli len pokusom o čo najpresnejšie znázornenie rozšírenia medveďov (ich spoľahlivosť je sporná) a údaje z jarného sčítania zveri v rámci poľovných revírov pravdepodobne nevystihujú skutočný stav populácie (absolútne hodnoty), predpokladáme, že priestorové analýzy z jarného sčítania zveri po prípadnom doplnení o výskytové údaje a údaje o vodiacich medvediciach môžu prispieť (ako jeden z indikátorov) k skvalitneniu manažmentu medveďov na Slovensku.

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Soil moisture condition in a spruce ecosystem after applying wood ash on the soil surface

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Abstract

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We examined the effects of wood ash applied on soil surface in a spruce ecosystem on the course of soil moisture content, available water reserves and soil water conductivity in the upper 20 cm soil layer. The study was carried out in the growing seasons 2011 and 2012, on three parallel plots: a plot supplied with wood ash at an amount of 5 t ha^{-1} in spring, a plot supplied with the wood ash in the same amount in autumn, and a non-treated control plot. In the layer with the highest occurrence of sucking roots, we analysed two hydro-pedological cycles: the prevailing semi-uvidic interval defined with the limits of maximum capillary capacity (MCC) and the point of diminished availability (PDA), and the semi-arid interval defined with the hydrolomits PDA and wilting point (WP) in the growing season 2011 in summer. The soil moisture content and hydraulic conductivity (with several exceptions due to micro-differences in soil properties) were higher on plots supplied with the wood ash.

Keywords

available water, forest ecosystem, hydrolimits, soil moisture content, wood ash

Introduction

Changes to ecological conditions in the natural environment are responded by changes in specified units of the system atmosphere – forest ecosystem – aeration zone. Today we are experiencing extreme rainfall events with alternating periods of considerable precipitation deficit and episodes showing extreme precipitation totals. As the result, the water regimen of soils is changing, mostly due to increase in temperature and evapotranspiration and due to reduced precipitation totals. In soils, these changes most significantly affect the superficial layers and the zone with the highest occurrence of active roots in which, apart from water intake, transport and storage, also the content of nutrients for plants in soil solutions is decisive (Bublinec et al., 2006). In this context, spruce ecosystems appear as the most critically endangered by drought. Growing mostly on acid soils poor in mineral nutrients, spruce trees also suffer from notably fluctuating nutrients availability – possible to overcome with a suitable fertiliser (Bublinec, 1994; Bublinec and Machava, 2009; Bublinec and Voško, 1987). A promising option seems to be wood ash applied on soil surface or incorporated into upper soil layers after clear cutting or natural disturbances. The wood ash provides a reserve of nutrients removed from the forest environment by wood harvesting (Bublinec et al., 2005). Thanks to its structure, mimicking clayey materials, the wood ash can serve as a medium enhancing the soil water retention capacity, enabling to increase the soil water storage capacity.

This work analyses the moisture content in surface soil layers in a spruce ecosystem supplied with wood ash. This substance, apart from delivering elements necessary for plant nutrition and controlling soil physical properties, should also improve the plants´ resistance against drought and frost (Otepka and Tóthová, 2011). The problem is solved also with the aim to increase the efficiency of soil physical and hydric performance. The study of wood ash effects on water regimen in soils was conducted within the project of EU structural funds ITMS 262202 20016 “Wood ash use in forest management” and the project APVV-0580-10 “Transformation, transport and distribution of materials in the surface horizon of forest soils”.

Material and methods

The research plots are situated in the forested area of the Veporské vrchy and Stolické vrchy Mts, forest management unit Hriňová, in an 80-year-old spruce ecosystem, compartment 138 B, area 3.59 ha. The local climate is moderately warm and wet; the average temperature in July is 16 °C, the annual precipitation sum is 800 mm. In this locality (Table 1) we chose three monitoring plots, each 20 × 20 m in size. The soils on plots are clayey-sandy to sandy-clayey, moderately moist to moist. Wood ash was applied in an amount of 5 t ha^{-1} throughout plot S in spring 2010, and throughout plot A in autumn 2010. Plot K was left without ash as a control.

Soil moisture content was measured gravimetrically, at intervals of ten days, to the depth of 80 cm, with each measurement repeated 3–5 times. The detailed description of the sample analysis and hydro-limits setting is in our papers published formerly (Tužinský, 2004, 2007). The water storage and soil water characteristics were assessed according to Kutílek (1966, 1978). The results of the analyses were evaluated by the one-way analysis of variance and the Duncan’s test in the Statistica package (Sokal and Rohlf, 1995).

Results

Soil moisture content and available water reserves in the growing season 2011

The rainfall sum over the growing season 2011 was 400 mm. Deficit in rainfall were April (17 mm), August (23 mm) and September (10 mm). The highest amount of precipitation had fallen in July (215 mm), from which more than 70% was in the second half of the month. Fairly favourable was also June (93 mm), mainly due to uniform precipitation pattern over this month (Fig. 1).

Table 1. Research site Hriňová

Tree species	Stocking density	Canopy density	Age	GFT^{o}	Soil type	Exposure, altitude
Spruce 100%	0.8	85–90	80	*Fagetum typicum*	Cambisol Typical	NNE 825

^{o} – typological unit.

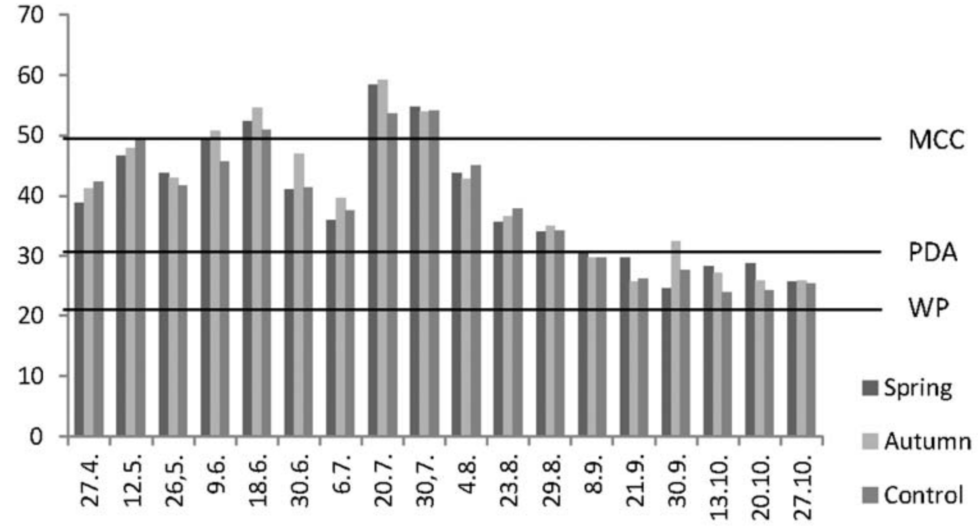

Fig. 1. Water storage [mm] in the growing season 2011.

In terms of hydrological limits, the moisture content in surface soil layers on the monitoring plots at the beginning of the growing season was between the point of maximum capillary capacity point (MCC) and point of diminished availability (PDA). The capillary pores were saturated with water in the first two ten-day periods of June, evidently due to long-lasting precipitation. At that time, the soil water occurred also in form of capillary free water. Maximum soil moisture values were recorded in the second and the third ten-day period of June when the 161 mm monthly total resulted in a soil moisture increase above the lower MCC limit. In August, deficient in rainfall, there followed the most distinct decrease in moisture content (by 21% vol.) and transformation of free water to immobile water. Then, until the end of the growing period, the soil moisture fluctuations on the plots were damped considerably, with the values fluctuating between the point of diminished availability and the wilting point (WP), the water being capillary fixed.

The data describing water available for plants (Fig. 2) distinguish two phases within the growing season: the first from the end of April to the first ten-day period of August, interrupted with only a short episode at the beginning of June, with sufficient amount of water susceptible by plants (>20 mm) in the upper 20 cm soil layer. Any other time, the soil water reserves available for plants were not sufficient: from the second ten-day period of September on plots with ash scattered in spring and on the control plot maintaining within the bottom third of this interval.

Soil moisture content and available water reserves in the growing season 2012

The total rainfall in the growing season 2012 was 363 mm. Compared with the growing season 2011, in 2012 were recorded higher precipitation totals at the beginning and at the end of the growing season, and the precipitation pattern over the whole period was more uniform. Like in 2011, the major part fell in June and July (219 mm), in July 2012 it was by 80 mm less than in July 2011.

The graphical representation of soil moisture content by means of hydrolimits (Fig. 3) shows that the fluctuation range of soil moisture content was relatively small, with the values mostly within the limits MCC and PDA. In spring, soil moisture content on plots treated with ash (plots S and A) varied close to the upper hydrolimit PDA, with prevailing mobile capillary water. In the other days of the growing season, the water storage on these plots maintained within the lower third of the range PDA–MCC, with water reduced to immobile capillary water. The reserves of plant-accessible water (Fig. 4) on monitoring plots varied like in the growing season 2012, from sufficient until the first ten-day period of June followed by insufficient until the end of the growing season. The most dramatic drop in water reserves occurred already in the second ten-day period of June (a drop of 14 mm in less than ten days), the maximum of 20 mm on the plot supplied with ash in autumn. Such a moisture reduction was a surprise, because of 90 mm precipitation fallen on the plots in 11 rainy days in the first and second ten-day periods of June. Similar situation with water reserves was in August. The total rainfall in this month was 135 mm fallen in 20 days, however, the water reserves maintained below the lower limit of sufficient storage, with exception of the last days of the second ten-day period.

Analysis of soil moisture condition on parallel plots

The analysis of moistening, duration of moistening and moisture stratification within the surface soil layers by

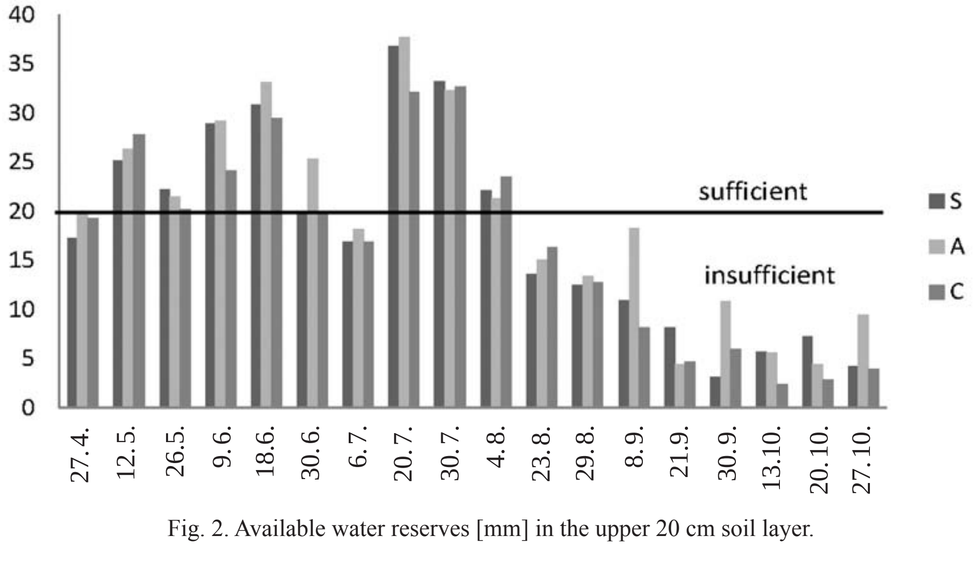

Fig. 2. Available water reserves [mm] in the upper 20 cm soil layer.

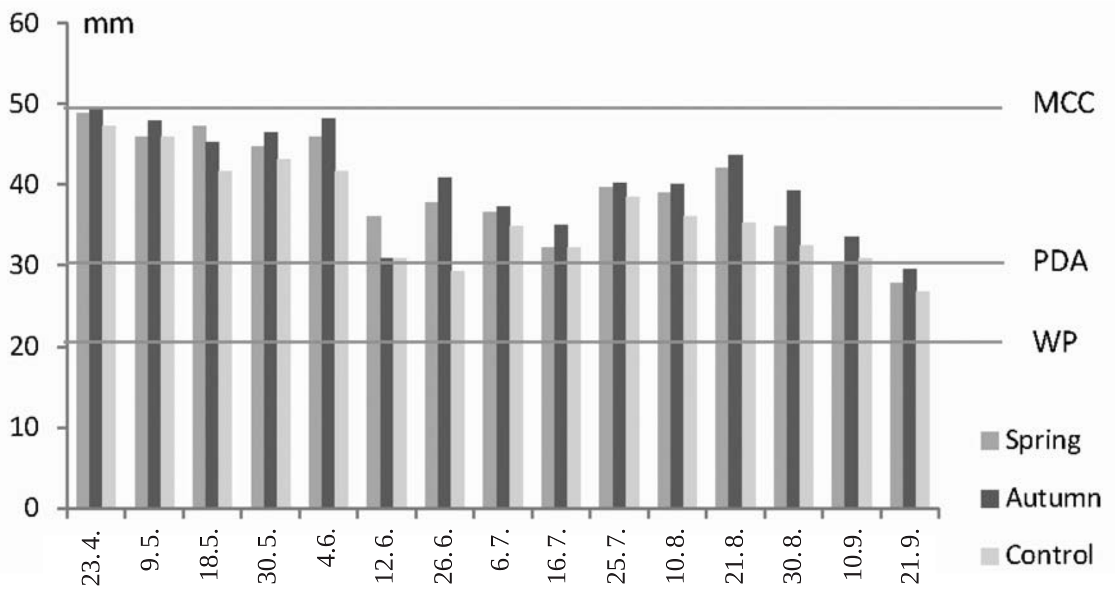

Fig. 3. Water storage [mm] in the growing season 2012.

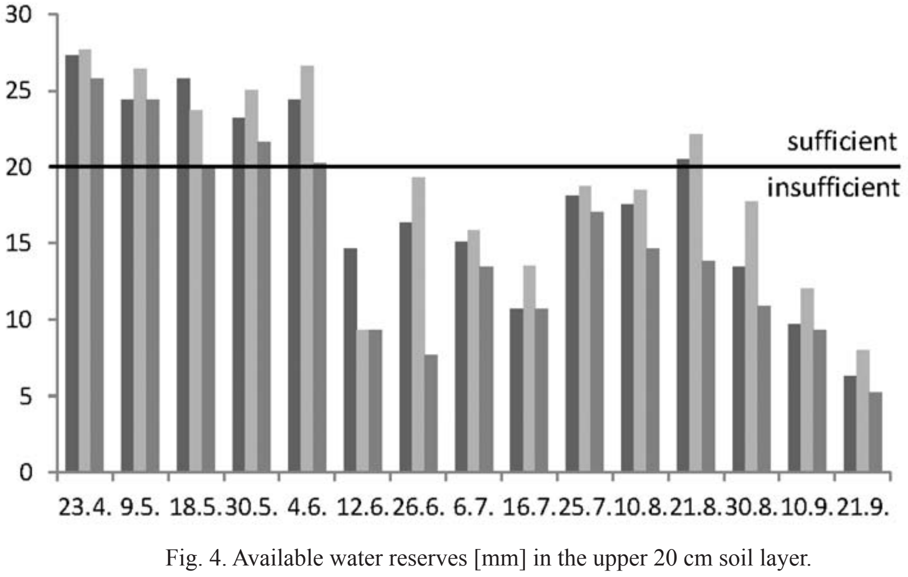

Fig. 4. Available water reserves [mm] in the upper 20 cm soil layer.

means of hydrolimits has resulted in detection of two hydro-pedological cycles on the monitoring plots during the study seasons. The dominant was semiuvidic interval defined with the limits MCC and PDA; in the summer months, it was the semi-arid interval with the limits PDA and WP. The occurrence of intervals correlated with the intensity and time course of precipitation totals. In the growing season 2011, the MCC–PDA interval persisted for 4 months, in the season 2012, it covered all the season except the final days of September.

Soil moisture content values in the two growing seasons were determined on all three plots in the second half of July, with small exceptions in the same days. The maximum values were: 58.3% vol. on the plot supplied with ash in spring, 59.2% on the plot supplied with ash in autumn, and 54.1% on the control plot. Expressed in terms of hydrolimits, they represented from 106 to 116% MCC. The minimum values were from 24% vol. (control plot) to 26% vol. (plot with ash applied in autumn), representing from 48 to 52% of the MCC. The average soil moisture content on the control plot was 37.8% vol., on the plot treated with ash in spring 38.9% vol., on the plot treated with ash in autumn 39.9% vol., being from 78–80% MCC.

Evaluating the reserves of plant-accessible water, we recorded the following highest soil water reserves: 37.6 mm on plot supplied with ash in autumn, 36.8 mm on plot supplied with ash in spring, and 32.6 mm on control plot. All these values correspond to sufficient reserves of accessible water.

Especially worth to notice are long periods of lacking accessible water: in the growing season 2011 from the second ten-day period of August, in 2012 already from the first days of the second ten-day period of June. The accessible soil water reserves in the studied growing season varied within: 2.4–32.6 mm on the control plot, 3.1–37.6 mm on plot treated with wood ash in spring, and 4.4–37.6 mm on plot treated with wood ash in autumn.

The results of statistical analysis did not detected statistically significant differences in accessible water storage among the parallel plots in both growing seasons, the extreme values, however, measured on the individual plots, point at positive influence of wood ash application on increase in accessible water reserves. In this case, the statistical differences might be superimposed with extreme character of precipitation events in the studied seasons and also inadequate due to relative short measurement period (two years are not enough for declaring unequivocal conclusions about positive trends in soil amelioration – concerning its hydraulic, retention, textural and structural properties).

However, it is necessary to note that the soil water reserves (with small exceptions) were more abundant on plots treated with wood ash. Considered are to be also other soil properties significantly affecting the soil water retention capacity, such as the original soil texture and structure, humus content, initial moisture content (hydrophobicity), vegetation cover, stand canopy and others.

Discussion

In context of development and utilisation of renewable energy sources sensu the legislation and strategic documents of the SR and EU (Ilavský and Bublinec, 2005), wood ash, as a potential energy source of domestic origin is also characterised, thanks to its qualitative features, as an alternative source of nutrients. In forest management, it becomes considered especially for moderation of forest soils acidification and supply of basic nutrients (Otepka and Tóthová, 2011). The use of sources improving the plants´ resistance, especially against drought, is well-reasoned mainly in case of spruce ecosystems, the most endangered in case of low or insufficient reserves of accessible water. Very important is also the issue of controlling the soil physical properties, such as soil texture and structure (retention or retardation). The hitherto obtained results in research on water regimen in soils in ecosystems with dominant spruce suggest that also in this natural environment, the water reserves across the physiological soil profile are gradually reduced (Tužinský, 2002, 2004, 2011). The results of our research covering two growing seasons 2011 and 2012 are preliminary, possible to summarise in the following way:

- Under relatively equal atmospheric precipitation sums, more favourable moisture conditions and more equilibrated moisture history in surface soil layers in spring 2012 may be explained by more abundant water reserves from winter snow and abundant rainfall in April on all study plots.
- Inspecting the differences in soil moisture content among the plots (S, A, and C) we can see that the water reserves on plots spread with wood ash were higher, so the ash was contributing to retention and retardation of water reserves by affecting humus formation (increasing the humus proportion) and by affecting physical properties of organic and inorganic compartment of the soil.
- Intervals defined with extreme soil moisture values and fluctuations of available water reserves on plots supplied with ash are more favourable for plants than on the untreated control plot; the results of statistical analysis, however, did not disclose statistically significant differences among the variants in the two growing seasons.
- Positive effects of ash application may also be expected in case of water accumulation in the cover soil horizons, infiltration and percolation into deeper soil layers – which would drive the water supply into the most dried-out surface layers by capillary action from deeper situated, wetter soil layers.

Acknowledgements

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Vlhkostné pomery po aplikácii drevného popola v smrekovom ekosystéme na povrch pôdy

Súhrn

Predkladaná práca sa zaoberá hodnotením vplyvu povrchovej aplikácie drevného popola vo vegetačných obdobiach rokov 2011 a 2012 na priebeh vlhkosti pôdy, zásoby využiteľnej vody (ZV) a vodivosť pôdy v povrchovej 20 cm vrstve. Za týmto účelom boli pripravené tri varianty aplikácie drevného popola: kontrolná plocha bez aplikácie drevného popola, plocha s jarnou aplikáciou drevného popola v množstve 5 t ha^{-1} a plocha s jesennou aplikáciou drevného popola v množstve 5 t ha^{-1}. Vo vrstve pôdy s najvyšším výskytom sacích koreňov (0–20 cm) boli analyzované dva hydropedologické cykly, dominantný semiuvidický interval s vlhkosťou pôdy medzi hydrolimitmi maximálna kapilárna kapacita (MKK) a bod zníženej dostupnosti (BZD) a vo vegetačnom období roka 2011 v letných mesiacoch semiaridný interval s vlhkosťou pôdy medzi hydrolimitmi BZD a bod vädnutia (BV). Nebezpečenstvo z ohrozenia suchom vyplýva pre smrekové porasty z nedostatočnej zásoby využiteľnej vody, do oblasti ktorej sa znížila vlhkosť pôdy v roku 2011 v druhej polovici vegetačného obdobia, v letných mesiacoch pri minimálnych zásobách až do spodnej tretiny variačného rozpätia, v roku 2012 už na začiatku 2. dekády júna s trvaním do konca vegetačného obdobia.

Vlhkosť pôdy a jej hydraulická vodivosť (až na malé výnimky spôsobené mikrorozdielmi vlastností pôdy) bola vyššia na plochách s aplikáciou drevného popola.

Výsledky štatistickej analýzy nepreukázali štatistickú významnosť v rozdieloch zásob využiteľnej vody medzi jednotlivými variantmi aplikácie počas oboch vegetačných období, napriek tomu intervaly extrémnych hodnôt z jednotlivých experimentálnych plôch poukazujú na pozitívny vplyv aplikácie drevného popola na zvýšenie zásob využiteľnej vody. Štatistické rozdiely mohli byť v tomto prípade zahladené extrémnym charakterom zrážkových situácií v sledovaných vegetačných obdobiach a tiež relatívne krátkym časovým úsekom merania, nakoľko dva roky predstavujú v tomto smere krátky čas na výrazné preukázanie pozitívneho trendu zlepšovania vlastností pôdy (hydraulických, retenčných, textúrnych ako aj štruktúrnych).

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Short communication

Ascomycetes and their anamorphs associated with shoots of silver birch (*Betula pendula*) growing in the urban greenery of Nitra in Slovak Republic

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Abstract

Hečková, Z., Adamčíková, K., Strelková, M., Rózová, Z. 2013. Ascomycetes and their anamorphs associated with shoots of silver birch (*Betula pendula*) growing in the urban greenery of Nitra in Slovak Republic. *Folia oecol.*, 40: 137–140.

Microfungi of silver birch (*Betula pendula*) were studied in urban greenery of Nitra. Samples were collected in November 2011 and April 2012. In this investigation were used incubations of fresh material in moist chambers and the conventional photomicroscopy for morphological descriptions. During the study of the mycoflora of birch shoots seven anamorph species of Ascomycetes were recorded on the collected samples. Fungus found on shoots was *Disculina betulina*. *Discula betulae*, *Alternaria alternata* and *Fusarium* sp. were the other fungi recorded on leaves. *Prosthemium betulinum*, *Myxocyclus polycystis* and *Phoma* sp. were found on wood and bark. Disease symptoms and some distinctive morphological features are described in this work.

Key words

Betula pendula, Discula betulae, Disculina betulina, Prosthemium betulinum

Introduction

Betula pendula Roth is autochthonous species in Slovakia. This Euro-Siberian species has a very wide climatic tolerance. *B. pendula* is a frequently planted tree in parks and other urban areas in Slovakia. Among broad-leaved trees, birch is regarded as tolerant to effects of industrial pollution (Ernst et al., 1998). It is highly adaptable to degraded environment but is commonly infested by microfungi and thus, is frequently the object of mycological studies. Recent studies have demonstrated damage caused by fungi to *Betula* ssp. in Slovakia (Juhásová et al., 2003; Bernadovičová, 2008; Pastirčáková and Pastirčák, 2010). A number of fungal species associated with *Betula pendula* has also been recorded in other countries including woodlands in Scotland (Green and MacAskill, 2007; De Silva et al., 2008), Estonia (Hanso and Drenkhan, 2010), urban greenery and woodlands in Czech Republic (Gregorová et al., 2006). The objective of this study was to identify the microscopic fungi associated with the shoots of *B. pendula* in different types of urban greenery in Nitra town.

Materials and methods

Once in November 2011 and once in April 2012, dead and also live shoots and leaves were collected from 30 individuals of *Betula pendula* at 4 sites (Klokočina, Chrenová, city Park and city Centre) in Nitra.

All fungi were determined from fresh plant material. Samples were placed in Petri dishes containing filter-paper moistened in distilled water and incubated at room temperature for 24 hours before being examined. Microscopic fungi were identified to the genus level, and the species level where possible, based on morphological characteristics under an Olympus BX 51 light microscope. Measurements were made through the medium of QuickPhotomicro 2.2 programme, and the morphometric values were compared with previously published data for the taxa (Hanso and Drenkhan, 2010; Green and Castlebury, 2007; Pastirčáková and Pastirčák, 2010; Hantula et al., 1998; Ellis and Ellis, 1997).

Results and discussion

Anamorph: ***Disculina betulina*** (Sacc.) Höhn. The teleomorph state is *Ophiovalsa betulae* (Tul. & C. Tul.) Petrak. It is pathogenic fungus on wood and bark. *D. betulina* was recorded at each site. Conidia were aseptate, hyaline, long and curved (falcate). Values of characters measured on spores of *D. betulina* on *Betula* reported on examined material are 41–64 × 6–3 µm (mean 53 × 4 µm). Characters measured on spores from Estonia are 29.4–58.6 × 5.6–2.7 µm (Hanso and Drenkhan, 2010).

Anamorph: ***Discula betulae*** (Westend.) Mennycook, commonly known by the illegitimate name *Discula betulina* (J. Kickx f.) Arx. – syn. *Gloeosporidium betulinum* J. Kickx f.. *D. betulae* is common foliar pathogen of birch in Europe (Green and Castleburry, 2007; Adamska, 2005; Bojarczuk and Przybyl, 2005). Currently, little is known about the life cycle of *D. betulae* (Sinclair and Lyon, 2005). Green and Castlebury (2007) in their research tested the hypothesis that *D. betulae* is the anamorph of *Gnomonia intermedia*, which was confirmed by the results from the ITS sequencing. *D. betulae* is regarded as a leaf disease causing leaf spots that can lead to premature defoliation (Sinclair and Lyon, 2005). *D. betulae* was found on three sites (Chrenová, city Centre and city Park). *D. betulae* forms dark lesions with dark margins on leaves. Conidia were aseptate, hyaline and ovoid. Values of characters measured on spores of *D. betulae* on *Betula* reported from examined material are 5–9 × 3–2 µm (mean 7 × 2 µm). Characters measured on spores from woodlands in Scotland are 4–8 × 1.5–2.5 µm (mean 6 × 2 µm) (Green and Castlebury, 2007).

Anamorph: ***Prosthemium betulinum*** Kunze. Species in this family (Pleomassariaceae) are saprotrophs on woody substrate, but generally their hosts are restricted (Pastirčáková and Pastirčák, 2010). The teleomorph state *Pleomassaria siparia* was not recorded on detached samples. Conidiomata of *P. betulinum*, immersed in the bark tissue, were found on detached birch twigs. Conidiophores were filiform, unbranched, hyaline, septate. Conidia brown, staurosporous, branched, with 2–3 main arms and 1–3 smaller arms. Main arms brown, with 3–5 transverse septa, with hyaline to pale brown apical cell. Smaller arms hyaline to pale brown, continuous or 1–3 septate (Fig. 1). This fungus was determined only at city Centre site. Values of characters measured on spores of *P. betulinum* on *Betula* reported from examined material are 33–49 × 19–13 µm (mean 40.5 × 15.5 µm). Characters measured on spores form other parts of Slovakia (e.g. Hlohovec, Šurany) are 37–47.5 × 15–11.5 µm (mean 41.5 × 14 µm) (Pastirčáková and Pastirčák, 2010), values recorded in Finland are 37–54 × 20–14 µm (Hantula et al., 1998) and in Estonia are 20–48.2 × 20.1–10.2 µm (mean 37.5 × 15.5 µm) (Hanso and Drenkhan, 2010).

Fig. 1. *Prosthemium betulinum* conidia.

Anamorph: ***Myxocyclus polycystis*** (Berk. & Broome) Sacc. This species was found on dead twigs. Pustules are depressed, elevating the cuticles slightly. Conidiophores are very pale brown to hyaline, septate, with slime coating. Conidia are large, smoky brown, clavate, oblong-elliptic, multilocular, with 7–8 transverse septa, at first taken with peduncles oozing out and forming black mass, clothed with gelatinous sheath (Fig. 2). This fungus was reported only at city Centre site. Values of characters measured on spores of *M. polycystis* on *Betula* reported from examined material are 59–69 × 25–18 µm (mean 63 × 22.5 µm). Characters measured on spores form other parts of Slovakia are 40–75 × 18.5–14.5 µm (mean 59.5 × 17) (Pastirčáková and Pastirčák, 2010), following Ellis and Ellis (1997) the values of conidia are 45–65 × 25–20 µm.

Fig. 2. *Myxocyclus polycystis* conidia.

Anamorph: ***Alternaria alternata*** (Fr.) Keissl., syn. *Alternaria tenuis* Fries. A sexual state has not yet been reported. *A. alternata* produces black lesions on young leaves, twigs and fruits, lesions may expand due to the production of a toxin, often resulting in leaf drop and twig dieback (Peres and Timmer, 2006). Conidiophores and conidia are brown. Conidia form long, branching chains, ovoid, obclavate, verruculose, with or without apical beak, 39–62 × 19–11 µm large, with three to eight transverse septa, in the lower part each portion has one or two longitudinal septa (Fig. 3). *A. alternata* is cosmopolitan species.

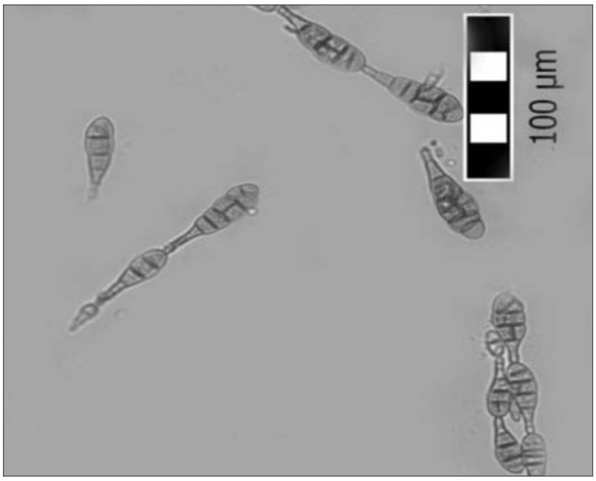

Fig. 3. *Alternaria alternata* conidia.

Anamorph: ***Phoma* sp.** Sacc. The genus is poorly understood, and generally considered to be a taxonomically difficult group of mitosporic fungi. Species of this genus are mainly known as plant pathogens (Crous et al., 2009). *Phoma* sp. occurred on leaves. Conidia were hyaline, single-celled, ellipsoid 11–6× 6–3 µm large (mean 9 × 4 µm).

Anamorph: ***Fusarium* sp.** Link. This genus contains a number of species. Many species of *Fusarium* cause cankers and dieback of trees and shrubs (Adamčíková et al., 2011; Sinclair and Lyon, 2005). Many fusaria are conidial states of *Nectria* and other hypocreaceous fungi (Ellis and Ellis, 1997). Conidia were hyaline, septate, curved and fusiform.

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Askomycéty a ich anamofné štádiá vyskytujúce sa na výhonkoch brezy previsnutej (*Betula pendula*) rastúcej v urbanizovanom prostredí mesta Nitra na Slovensku

Súhrn

Práca bola zameraná na štúdium druhovej diverzity mikroskopických húb, ktoré sa vyskytujú na breze previsnutej rastúcej v urbanizovanom prostredí mesta Nitra. Rastlinný materiál bol zbieraný v novembri 2011 a apríli 2012. Príspevok prezentuje askomycéty a ich anamorfné štádiá zistené z rastlinného materiálu po inkubácii vo vlhkých komôrkach. Počas výskumu boli použité konvenčné fotograficko-mikroskopické metódy pre stanovenie morfologických popisov. Zo vzoriek boli mikroskopicky identifikované huby *Disculina betulina* (Sacc.) Höhn, *Discula betulae* (Westend.) Mennycook, *Alternaria alternata* (Fr.) Keissl a *Fusarium* sp. Link na listoch a *Prosthemium betulinum* Kunze, *Myxocyclus polycystis* (Berk. & Broome) Sacc a *Phoma* sp. Sacc. na dreve a na kôre.

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Short communication

Role of representative woody plants in the spatial composition of dendrological gardens

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Abstract

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A more thorough exploration and deeper knowledge of the overseas colonies brought along the discovery and import to the European continent of several new plant species. Planting exotic species in the Hungarian parks became a wave of fashion in the last third of the 19th century. Landscape architecture also calls these landscape gardens of special plant collections dendrological gardens. Apart from the value of the individual specimens, these woody plants also had a great role in the spatial composition of the entire garden. These plants of diverse appearance endowed a part or the whole of the garden with a unique character, as the outcome of preliminary planning. Below I highlight different planning methods developed on the basis of using different representative, mostly exotic woody plants. Traces of these methods can still be discerned today even in badly neglected gardens. Knowledge of the criteria of planning and the typical use of plants can provide indispensable clues to the reconstruction of gardens.

Keywords

dendrological garden, garden design, historical garden

Introduction

In dendrological gardens the use of extraneous and indigenous plants and their spatial layout produce a peculiar atmosphere of the garden sight. As is known, the garden designers of 19th century and early 20th century Hungarian mansions and country houses had a special penchant for ever newer species of trees to create esthetic and tasteful compositions.

Raymund Rapaics uses the phrase dendrological garden to designate a distinct period of landscape gardens (Rapaics, 1940). It is important to know that dendrological gardens are mainly defined by the esthetic qualities of woody plants. These qualities derive from the complex arrangement of solitary and clustered plants. The plant composition of diverse groups and solitary items determine the spatial layout and overall impression of the garden. Thanks to the increasing amount of diverse foreign woody plants over the 19th century and the outcome of plant breeding efforts landscape architects and the garden owners themselves achieved more and more spectacular sights.

In the effort to explore all Hungarian dendrological gardens and define their number, at first I screened the available databases of existing parks, historical gardens (*Central European historic garden database*). This appears to be the most complete collection, including all smaller and greater Hungarian gardens. It lists 1,550

Hungarian gardens and parks in most different states of repair today. The major filtering was carried out with the help of the internet and some comprehensive publications. Lots of picture postcards, aerial photos, satellite pictures, photos and historical accounts available on the Internet helped my work. The published sources (e.g. Mészöly et al., 1984; Rapaics, 1940; Somkuthy and Tóth, 2000; Galavics, 1999) offered sufficient information on the historical background of the gardens.

Below I have examined and analyzed the landscape architectural use of woody plants typical of the dendrological phase of landscape gardens in the still extant Hungarian gardens.

Material and methods

For any discussion of the theme it is indispensable to clarify the concept of "dendrological garden". For me as a landscape architect, a dendrological garden is a garden architectural work in which a special spatial composition can clearly be discerned and in which there are valuable old and/or extraordinary tree species. Another characteristic feature is that they were created in the plant collection phase of late landscape gardens. This feature basically differentiates a dendrological garden from an arboretum, thus when a garden is created from a collection of new plants, it is an arboretum and not a dendrological garden. Dendrological gardens constitute a subset of arboretums created by the designing principles, esthetic and space compositional rules of concrete garden historical periods. Accents or contrasts with plants, as well as the reinforcement of certain parts of the gardens, e.g. the background or the borders, acquired immense significance in these gardens.

It was not always unambiguous or successful to pick out the dendrological gardens with the above method (see Introduction). In several cases it was unavoidable to personally explore the venue, for earlier photos and descriptions failed to give information of the real situation. Only a visit to the actual place could decide whether it still existed as a dendrological garden or only the historical sources registered a once flourishing garden in the place.

I have examined the features of plant composition (collecting the old characteristic tree species, examining the planting method of woody plants) in the screened list. The field experiences of the so-far visited gardens – some one third of the narrow list – are presented here with a few venues picked out that deserve special attention on account of the conscious, designed layout of trees and spatial compositions.

Results and discussion

Several gardens in Hungary still preserve the memory of former dendrological gardens. Many of them perished or were badly damaged during the tempestuous years after World War II. Out of the mentioned 1,550, I estimate at between 80 and 100 the number of dendrological gardens in which the one-time originally planted tree species can still be found. They are, however, mostly in distressing condition. Only few are well maintained, tended and flourishing. These include Vácrátót, the former park of the Vigyázó family's country house (today Hungary's largest botanic garden), as well as Cégénydányád, Szarvas, Alcsútdoboz, Erdőtelek, Kámon, Szabadkígyós, Lengyel, Martonvásár, Zirc. A larger group includes less well maintained gardens that still have valuable vegetation determining their character, e.g. Iharosberény, Baktalórántháza, Sopronhorpács, Szombathely-Bogát, Somogyvár, Szeleste, Vép, Zsennye, Tóalmás. In some cases the „new" function put a stamp on the park and caused lasting damage. One is the park of the Nagyrécse country house, today the garden of a school and local library. Though the original plant stock provides information of the former park, the spatial structure of the park has wholly vanished. The installation of the utilities of the district primary school and kindergarten completely transformed and deformed the garden for good.

The periods of dendrological gardens are often determined on the basis of the most characteristic, "fashionable" plants (e.g. plane (*Platanus × acerifolia* (Aiton) Willd.), conifers, Turkish hazelnut (*Corylus colurna* (L.)) (Rapaics, 1940; Kósa, 2000; Schmidt, 2003). It is still conspicuous that in some Hungarian counties conifers were very popular, the most frequent and characteristic of them being giant sequoia (*Sequoiadendron giganteum* (Lindl.)) found in nearly all dendrological gardens of Somogy, Vas and Zala counties, most of them aged about 150–180 years (Fig. 1). These spectacular trees are usually planted close to the mansion or country house. In these counties, first of all Zala and Vas, the more humid mountainous climate and the acid reaction of the soil are favourable conditions for planting and developing evergreens. Other conifers with a decisive role in the spatial composition of gardens are *Pseudotsuga menziesii* (Mirb.) Franco, *Cedrus atlantica* (Endl.) Manetti ex Carrière, *Pinus strobus* (L.), *Pinus nigra* (J. F. Arnold), *Pinus sylvestris* (L.), *Larix decidua* (Mill.) and members of the *Abies* genus. One of the finest and largest Douglas fir is in Segesd, in the northern, rear part of the park. At Bárdudvarnok the surviving vegetation includes two old and fine Atlas Cedar specimens close to the mansion, in the front and back gardens. Quite a lot of eastern white pine can be found in the gardens, mainly planted in groups, first of all in the shrubbery or wooded areas. Old specimens can be found at Csurgó, Szarvas, Zirc and Cégénydányád, among other places. Coniferous plants, first of all members of the *Pinus* family, mainly larches, thujas and false cypress (*Chamaecyparis*) plants were favoured in smaller or larger groups, sometimes in circles fairly removed from the country house. In this way the evergreens had a role to attract attention and orientate the glance. Larches – whether alone or in groups – are not so frequent as background or remote spectacle, but their intriguing veil-like habit turns them into a relieving counterpoint or subtle decoration against compact masses of trees. They are planted in groups of three in the parks of the Bezerédi-Széchenyi mansion at Rum and the Inkey country house at Iharos. Larches were usually not applied close to buildings.

Fig. 1. Aged giant sequoia in the park of Bárdudvarnok (Photo Author).

Planting deciduous trees in clusters was also typical. One of the most popular ornamental plants of the age was plane used 1) as lines of trees to designate axes and routes (e.g. at Acsád), 2) in clusters of trees, 3) as borders (e.g. to demarcate the pleasure ground) in the park of the country house at Tóalmás (Fig. 2) and to mark out the immediate surroundings of the house, 4) as a solitary tree, at accentuated points like the ramification or convergence of roads (Sárvár country house park, Arboretum of Alcsútdoboz). Sometimes it was used to organize large grass plots (Vácrátót, Margaret Island). As for deciduous trees, I have found considerable amounts of *Ginkgo biloba* (L.), *Liriodendron tulipifera* (L.), *Catalpa bignonioides* (Walter), *Quercus rubra* (L.) and various kinds of maple (*Acer*). Ginkgo is just as characteristic among deciduous trees as is giant sequoia among conifers. There are specimens aged 120–200 years at Acsád, Keszthely, Gernyeszeg (today: Gorneşti, Romania), Dég, Szabadkígyós, Somogyvár and Somogysárd next to the mansions (Fig. 3). It was used as a compositional element of clearings or lawns at Szarvas and Sellye and probably it was also applied at Sárvár and Somogyzsitfa. Owing to the crammed vegetation or changed functions at the mentioned places only guesses can be made about the one-time space-organizing role of these plants. Tree species with large leaves such as tulip-tree and Southern Catalpa were usually planted along access roads or to mark out large lawns outside the country house by placing individual specimens at salient points. Large tulip-trees can be found at Iharosberény, Körmend and Ivánc. Finally, mention must also be made of two tree species and a shrub species. One is the genus of beech trees with *Fagus sylvatica* L. cv. Atropunicea or purple beech, and *Fagus sylvatica* L. cv. Pendula or weeping beech, the other is the cypress oak (*Quercus robur* L. f. fastigiata). The basic species are indigenous in Hungary, but the mentioned kinds enjoyed greater popularity in dendrological gardens. The cypress oak of fine columnal habit is found from Sárvár to Gernyeszeg (e.g. Keszthely, Surd, Tura, Szarvas) at many places, either to articulate clearings or grassy surfaces, or as a distant sights,

Fig. 2. Plane trees as borders in the park of the country house at Tóalmás (Photo Author).

Fig. 3. Placement of a Ginkgo next to the mansion of Gernyeszeg (Gorneşti) (Photo Author).

sometimes as a single feature. The members of the *Fagus* genus were almost always close to the mansions, dominating free open spaces of varying size.

Among shrubs I would only mention the Magnolia species found in many Hungarian gardens (e.g. Csurgó, Segesd, Bályok (today: Balc, Romania)). They were customarily planted in representative gardens connected directly to the country houses. A favoured location was along the roads leading to the house or like solitary markers on either side of the road, constituting a symbolic gate.

The above discussion was reduced to the compositional role of the most characteristic and typical plants in dendrological gardens. It can be concluded that the one-time landscape architectural principles can still be detected even amidst the worst conditions of neglect. The plant stock of the gardens is senescent and defective; the state of the few gardens handled with professional competence provides no excuse for leaning back contentedly – quite to the contrary! Failure to access several gardens prevented me from assessing and analyzing their plant compositions. This situation requires the sounding of the alarm: the aging plant stocks and consequently the gardens themselves are doomed to perishing unless further assessment, treatment, rejuvenation and maintenance begin urgently.

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Kompozičná úloha drevín so zvláštnym habitom v dendrologických záhradách

Súhrn

Dôkladnejší výskum a spoznanie zámorských kolónií umožnili objavenie a dovoz mnohých nových rastlinných druhov na európsky kontinent. V Maďarsku sa objavili prvé jedince zvláštnych a unikátnych druhov rastlín v niektorých väčších parkoch už na začiatku 19. storočia. Móda vysadzovania exotov sa najviac rozšírila až v poslednej tretine 19. storočia. Pre tieto parky, vybudované v neskorom prírodno-krajinárskom (anglickom) slohu, zároveň zbierkového charakteru, používa krajinná architektúra označenie dendrologické záhrady. Tieto parky sú charakteristické nielen výskytom unikátnych drevín, ale aj ich harmonickým zapojením do priestorovej kompozície parku. Dreviny sa tak stávajú súčasťou celku, plnia kompozičnú úlohu, čo zvyšuje ich hodnotu. Rastliny s neobvyklým vzhľadom, dovtedy v našom podnebí nezvyčajné, vysadené ako výsledok vedomého plánovania, dávajú tak jedinečný charakter ucelenej časti parku alebo dokonca celému parku. Niektoré rastliny sa z dôvodu ich obľúbenosti stali v tomto období dokonca charakteristickými hlavnými rastlinami viacerých dendrologických záhrad. Používanie určitých rastlín v kompozícii týchto záhrad bolo často typické pre určitú oblasť a obdobie. Tieto rastliny sú v záhradnom obraze často dodnes badateľné, stali sa odtlačkami daného obdobia.

V mojom výskume chcem poukázať na postupy navrhovania záhrad, v ktorých zohralo prvoradú úlohu použitie exotických drevín so zvláštnym habitom, a ktorých vplyv môžeme dodnes rozoznať v parkovej kompozícii (aj v prípade zanedbaného parku). To je dôležité preto, lebo znalosť pôvodných plánovacích hľadísk a charakteristického spôsobu používania rastlín môže byť určujúcim východiskom pre prípadnú záhradnú rekonštrukciu. Púhou obnovou terénu a parkových prvkov, bez obnovy pôvodných rastlín, nie je možné reprodukovať náladu, estetický ani priestorový zážitok bývalého parku.

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Survey paper

Principles of long-term sustainable forest development implemented as the background for ecological forest management

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Abstract

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Forests are supposed to meet the requirements not only of the today developing society but also of next generations living a one or two hundred years after us. Being threatened by a range of harmful agents, including the global climate change, and providing manifold public benefits, the forests need global management driven in nature-close, ecological ways. The issues of long-term validity, permanency and ecological orientation of forest development can be successfully resolved only by consistent implementation of the following basic principles of forest management: principle of sustainable development, stabilisation, ecologisation, optimisation and economization.

Keywords

ecological forest management, sustainable forest development,

Introduction

In the recent days, little time and effort have been committed to deliberate the general trends in the Slovak forest management. The issue, however, is critically important in context of the present crisis. Are not the economic pressures pushing our forests towards the total crash? Where is the line allowable to recede? The assets are: our land, our nature, our health, our national wealth: The answer to these questions is to us, the foresters. We are responsible for our forests.

In the mid-eighteen century, only 6% of Slovak forest stands were older than 60 years that means suitable for some use, due to devastation by extensive mining and metallurgy. This state of art forced implementation of a system of long-term planning coping with the essential ecological rules driving the forest growth and development. Planning is a tool enabling to control the management in such a way as to bring benefits for the owner and the society.

The primary factor of correct forest management is the law of long forest growth period. The life cycles of individual forest woody plants cover 200–500 years; in the biological-economic context, this period has been reduced to 100 years. The main task for forest management, implied by the long-term character of forest management process, is to guarantee permanent forest development in such a way as to guarantee fulfilling the main forest functions in accordance with the social needs also 100–200 years later. The requirements for long-term planning in forest management and final forest management plans directly follow from the fact that this system, applied in Slovak forests for the last 200 years, has survived two world wars, five revolutions and a spectre of political regimes. It is true, however, that this planning was subjected to certain pressures under each serious transformation (Authors‘ collective, 2006).

At present, the forest management begins intruded with alien, business-related “novelties” neglecting the limits set by ecological laws ruling the forest life. The independent national organisations performing long-term planning for the recent 100 years (recently the Lesoprojekt) have been transferred to private owners. Business aims are taking more and more priority: maximum profits (increasing allowable cuts), expenses limited to minimum (neglected protection, prevention, silviculture ...) and implementing the principle of short-term economic return (cuts shifted to lower age categories).

Among the social interests, the highest-rated have become the business and its paradigm – enhancing the competition success in achieving the maximum benefits. Nevertheless, the long-term forest growth and development are ecological affairs, not possible to comply with commercial-economic requests. It has been a hard labour to hamper the activities leading to the privatisation of national forests. These hidden interests can be averted only by the general public mention: “We will not disclaim our forests!“ (Konôpka et al., 2010).

The private forests mostly did not allow formation of a genuine proprietary „family relation“. It was not possible due to the geo-strategic position of Slovakia. We always served as a “cordon sanitaire” between the West and East, and this role was connected with fatal combat losses. Today, the dominant is interest for wood harvesting as a source of income. The public benefits of forests are out of interest, as these cannot be expressed in money.

The most serious issue in meeting the requirements of long-term sustainable forest development is the total allowable cut. The long-term perspective seems reaching beyond the mental capacities of many persons. The forests have become over-burdened. The primary cause is natural disturbances and certain liberty due to implementing the concept of nature-close silviculture, more intensive tending included. The second reason is the delayed legislation, not reflecting the essential changes to the forest condition.

The efforts of Slovak forestry over the recent 50 years (despite stresses) have resulted in an especially favourable condition of Slovak forests today. The stands entering the regeneration phase, that means the phase of biological-commercial maturity, exceed the target arrangement. Most of cutting variables in the effective regulation do not regard the principle of sustainable production, as they neglect the fact that by 40 years, mature stands will be lacking and the allowable cuts will be strongly limited. There is an urgent need for updating the allowable cut indicators – to prevent excessive cuts today and steep decrease in allowable cuts in the future. The improvement measures are ready for use.

The best guaranty of objective planning of long and short-term forest development in forest management can be provided at the national level.

The society acknowledges forest management only in terms of wood production. The non-wood-producing forest functions are understood as automatic externalities. We agree that the role of wood production in Slovakia is very important, as wood is our most valuable raw material, produced, moreover, under especially favourable conditions. This material can be obtained with minimum costs, by applying large-size clear cuts, associated naturally, with negative effects and unsatisfactory serving the non-production functions. For the man, however, these functions have several times higher value than the wood production. To serve these function optimally, the forests must be managed intentionally for this purpose. They must create a sound natural environment, providing permanent protection against a range of harmful factors, damping flood waves, consolidating skidding areas, preventing soil erosion, guaranteeing equilibrium in the landscape, storing carbon, entrapping airborne pollutants, and similar. The urgent priority of these tasks is also evident from the program of ecological landscape revitalisation, lowering flood risks included. These roles can be only served by forests whose structure is not very diverse from the structure of natural forests: close-to-the-nature forest. This forest type, characterised with a high degree of biotic diversity, can only be attained by applying close-to-the-nature management, understood, at the present level of knowledge and management possibilities, as ecologically oriented forest management. This is the idea declared by the Slovak forestry since the beginning of forestry university studies in Slovakia (Forest Institute at the Mining Academy in Banská Štiavnica established in 1808). However, to manage forests in this way is a more complex task, demanding more efforts and higher costs (Greguš, 2010).

The idea about covering all the costs necessary for a hundred-year protection and growing of forests and even about guaranteeing their non-wood-production functions (ecosystem services) with the money obtained for the harvested wood is a mistake. Unlike in the common business, the wood price is not created based on the costs required but determined by the free market according to the demands and supply. This trend is evident from Germany where the German Constitutional Court in 1990 ratified a decision declaring that the public and national forests have to serve environmental purposes and increasing wood production. Without the support the forest management is enjoying abroad, the forest management in Slovakia will finish in condition not possible to treat economically. Apart from this fact, endangered natural environment (also forests) starts to be a ethical problem also at the spiritual level.

Forest management in Slovakia should be redirected to ecological goals, not only for serving public-benefit functions. The primary request follows from the literally catastrophic health condition of our forests. More than ¾ cuts are forced due to harmful agents. A great share is to the global factors causing forest decomposition, disturbances in the management goals, problems in the aims, increasing demands on efforts and costs in the management context (Machava et al., 2008).

Declaring that the forests have been well-equipped to manage these problems by themselves is erroneous, irresponsible and criminal. The present forests are the result of a two-hundred-year management, and they have not yet developed capacities necessary to cope with modern harmful factors.

The issue of long-term and sustainable forest development can be met appropriately only through meticulous applying of generally accepted basic principles of forest management, as in the past, these principles originated namely with the purpose to ensure positive forest development into the far future.

Basic principles of long-term and sustainable development of forests

The basic principles are the leading concepts controlling in decisive extent the whole process of forest management; underlining, at the same time, primarily the future aspect. Our forestry, in concert with the central European knowledge, has derived these principles from the long-term historic experience approved with the new scientific knowledge. They address equally the public-benefit functions as well as the wood production aspect.

The principle of sustainable development

The essential presupposition for sustainable forest development is long-perspective planning. This requirement is natural due to the very long period of forest growth, while the forest growth is ecologically complex and permanently endangered. The result of this planning – forest management plan provides guaranty for improvements and systemic orientation of forests towards the delineated aims. Forest management protects forests from implementing of short-perspective commercial interests which would represent danger for providing public benefits and lead to forest exploitation by cutting (Bavlšík et al., 2010).

The short-term planning includes also monitoring (checking) of whether and to what extent the forest development and its management show a progress or a decline. It is a common interest of the whole society to control the sustainable development in this way in all forests in Slovakia, at least at ten-year intervals. A well-reasoned requirement is to ensure the continuity with the hitherto obtained developmental parameters.

The principle of sustainable development concerns all forest management activities. The requirements of the today generation must not be beyond the limits following from the justified demands of the next generations.

In accordance with the principle of sustainable development are all the measures supporting ecological laws ruling the forest dynamics, protective measures against harmful factors and the measures applied in ecological silviculture.

The principle of sustainable development requires a unique, forest management-specific of stand lay-out organisation system. All the stands (trees) determined for cutting must have their replaces, corresponding in quality and quantity. To meet this requirement is imperative for ensuring permanent, continual and well-balanced meeting of all forest functions, primarily the production (Greguš, 1976).

The today Slovak forestry works with the system of ten-year age classes seeming the best-suited for most of our forests. The system of diameter classes defined in the selection system is too complex, not applicable in the common practice. For the future, the system of growth degrees (after adjustment) seems promising. It is necessary to approve the final definition of the naturalness degrees (hemerobia – similarity measure with natural forests), necessary first of all for the purpose-oriented management ways.

For the system of age classes in the understory management system and the system of diameter classes in the selection system, there have already been determined the target layouts obligatory to follow in regeneration cutting with the aim to ensure continuity in performing forest functions.

The system of age classes is recommend to follow as obligatory also in the future, at least in relation to the average stand age (considering the fact that forest stands are getting uniform in age in context of ecological management) until a new, consistent supplementary system of stands intended for cutting has been created.

The principle of stabillisation

In the recent time, there has been a turn-over in forest management priorities due to effects of harmful factors. There arise urgent needs to remove the existing damage, extend protective measures and perform all interventions with focussing on strengthening the forest stability. On the edge of interest is improving the forest stands resistance against singular attacks by abiotic factors (especially wind and snow...). Apart from this static stability; there is highly required also ecological stability (homeostasis), ensuring stand resistance against influences by biotic factors and their capability to restore their original state. A special care is needed for the most serious bark beetle calamity. The just mentioned auto-regulation-oriented „doing nothing“ is indisputably contra-productive. The threatening climate change must not been neglected (Konôpka, 1999).

We may hope that the impaired forest stability would be handled with progressive and extensive implementation of ecological forest management concepts in accord with the principle of ecologisation. This process will require a long time.

The principle of ecologisation

Ecologisation means permanently extended knowledge concerning natural mechanisms driving forest ecosystems, and meticulous implementation of these laws in forestry practice. There are necessary to promote, as much as possible, processes of self-regeneration (natural regeneration), self-control (self-thinning, self-regulated changes in tree social status, competitions ...) and self-dependence (resistance against attacks by harmful agents). There has been generally accepted that the more diverse natural biocoenoses manifest more resistance (exceptions are possible) that less diverse communities. Nature-close forests should manifest a high degree of biotic diversity: patchiness (aprox. in size of regenerated segment), a mix of site-native and resistant species, diverse architecture and age. This idea depends on a range of technological, economic, organisation and other conditions it carried out (Bublinec, 2000).

This concept is in the best accord with the selection management system, in our „large-area“ practice, however, playing a role of an exception. More background for the ecological management implementation is provided in the understorey system. This system cannot be understood exclusively as a tool for obtaining regeneration and removal of parent stand, it also means improving quality of the upper stand layer, promoting increase in this layer and orientation towards ecological forest management (Bublinec and Gregor, 2002).

Extraordinary complexity associated with implementation of ecological principles in management of forest ecosystems requires a many-year experience and knowledge concerning the local conditions. And continual stand-check is records. Very helpful would be model stands for monitoring the ecological responses to specific interventions. Naturally, such an effective systemic approach is not possible with shifting effective foresters here and there according to the results of the recent selections in the country (forest management separation from politics).

The principle of optimisation

The principle of optimisation for providing public benefits and serving wood production functions is also a management purpose. The maximum obligate effect is possible to achieve only with especially high costs. The public interest is, however, serving function in an optimum way which can only be accomplished by appropriate management. But this is not easy, as at least 90% of the results obtained in forests are determined by the nature.

Optimum serving the public-benefit functions requires more complex approach (orientation on ecological forest growing, biotic diversity).

As for the production, appropriate management may ensure the natural maximum corresponding to the current forest state. It requires, however, focusing the overall concept of long-term planning and realisation in this way, regarding the rules governing increment creation. Woody plants have the highest increment creation rate at an age of 30–50 years, later, their growth decelerates. The final maximum production is obtained by timing the regeneration cuts in periods when the current increment creation is the same as the average of the former ones. This is the period of cutting maturity (well-known intercept of culmination of the total average and the total running increment in the value). After this point, each annual increase is lower than the average; so there occur increment losses. The forests switch from their role of wood producers to the role of goods for sale. This fact is the issue point for determining the cutting priorities. There is verified the axiom about the allowable cut equal to the increment created. There is an evident need for prohibition of cutting forests (trees) in stage of fast increment creation and maintaining stands in stage of slow increment creation (increment losses). The cutting itself should be implemented in accord with the generally used management approaches, taking in consideration also other principles.

The tending interventions regard the primary goals of stability, quality or increment creation set up based on considering the local conditions and requirements.

The principle of economization

The saving principle is the generalised principle how to rule the management in such a way as to meet the established goals as precisely as possible, with maximum profits and minimum costs.

In accordance with the rules of the current general economy, forest management also should seek economic independence. However, as we have just mentioned, the public-profit functions of the forests are accessible free and the wood costs are not as high as to compensate the many-year investments into the whole silvicultural process. The basic idea is that the community has to acknowledge that the public-profit activities mean ecological services and as such, they deserve appropriate financial rewards. The national strategy should support the restoration of national wood industry meeting the needs of Slovak forests and producing final products with corresponding competition values.

We mention here the three expenses-saving ways characteristic for forest management:

- o Minimum demands on human work – by using as many as possible self-controlling, self-restoring and self-protecting properties of forest ecosystems

- Preventive measures applied to protect against harmful factors effects
- Early elimination of pests in their initial stages.

Moral aspects in forestry

The zeitgeist of the modern time with selfish demands for inappropriately high living standard makes all the wheels rushing downwards a self-destructive spiral of hedonistic consumption, without any respect for the genuine social well-being. A healthy, good-looking and rationally managed forest is indisputably a valuable social good. The management approach for such a forest cannot be backed up with the idea of financial profit but it should seek forest development proposals.

Forest management comprises copying with extensive forest complexes, difficult accessible areas, long lasting, almost impossible-to-cover growth processes, diverse natural conditions and extraordinary climatic turbulences. Despite the comprehensive management system is at disposal, the freedom in decision is considerable. This freedom will even increase if the directives of forest management loss their effectiveness in context of effects caused by harmful agents. These complex activities are very far from easy to control. Under these circumstances, many things depend on the personal qualities of individual foresters, their education level, experience, discipline and goodwill to act in accordance with general ethical rules and with ethical rules valid in forestry.

Forestry ethics is the personal conviction about correctness of acting for profit of positive forest development and the sense for responsibility to serve the duties required by the community and by the forest owner. The forestry ethics may be appreciated as the most powerful asset for permanent and sustainable forest development. Neither the existing legislation nor financial stimuli can serve for this purpose satisfactorily. Their frequent products are foresters as „shock-working plan compliers “. To act in accordance with forestry ethics is not an easy matter. Forestry operations are heading many difficulties under conditions very far from optimum. We may only suppose that the major part of foresters has a good-will to use each possibility for implementing the forestry ethical rules as these people had decided for their forestry study motivated by their love for forests and by their will to devote to this love all their professional life. Such a motivation is essential. Personal conviction is an extraordinary effective tool, overco-ming really big barriers. Let’s enjoy our work in forests, let’s enjoy the results achieved in forest stands.

Despite that the forestry ethics is a long-used and generally recognised term, its rules have not been worded exactly yet. That is why we would like to propose here a possible wording. Naturally, agreement will be needed in more detail. This design is only an incentive.

We propose to define these principles in wording of accepted basic principles of long-term sustainable development of forests. As these ideas are oriented to forest improvement, it should be correct to acknowledge them as ethical standards.

The principle of sustainable development indisputably requires cyclic long-term planning, ensuring forest development for the future. The final management plan needs to be prepared in cooperation with the local manager responsible for its implementation.

Permanent performing all the forest functions will be ensured by designing and implementation of a special system of spatial arrangement (lay-out) in which the stands (trees) indented for cutting will have their standby parallels in all age classes.

Interventions in forest stands are carried out in compliance with principles of forest development sustainability then and only then they regard forest protection or seek a close-to-nature forest.

The principle of forest stabilisation requires permanent monitoring of health condition of forest stands and occurrence of pests in these stands. No delay is allowed for applying protective measures against pests and negative agents or for damage restoration.

This principle requires permanent and multifaceted improvement of forest stability (resistance) and preventive measures against effects of harmful agents. The backing-up idea for ensuring forest stability is the requirement for forest management oriented on ecological aspects.

The principles of ecologisation mean acting in concert with the perfect nature’s innate autoregulation processes ruling forest ecosystems – the processes we have already got familiar with. Promotion of biotic diversity has a significant role. Gathering experience from the given locality is a necessary prerequisite for assisting in the natural development of young and medium-old forest growth phases; in implementing principles of natural forest regeneration and in lifelong resistance against harmful agents.

Ecologisation is taken in concern especially in understorey cutting, exceptionally in selection cutting. Needed to mention is also permanent upgrading of one’s knowledge level (self-education).

The principle of optimisation of public-profit functions is best-complied with the selection cutting method. In most stands, however, one must manage with understorey methods, especially if small-area shelterwood regeneration is in question.

Optimum and, naturally, maximum production can be achieved by literal implementing the rules for appropriate using the regularities in increment creation in tended and in naturally regenerated forest stands. In regeneration process, the cutting intensity is primarily controlled by requirements for natural regeneration; it is necessary, however, to increase the cutting intensity with increasing cutting maturity. Stands at high maturity degrees need is reconstruction by artificial regeneration.

Allowable cuts must be derived in such a way as not to decrease the forest increment creation rate and not to exceed the cut reserves. Cuts beyond allowable amounts mean serious violation of principles of optimisation and permanent production.

To observe *the principle of economization* is a self-evident and generally valid obligation in area of public benefits equally as in area of wood production. In forest management, the highest priority is not to revenues but to meeting the tasks set for forest development. Maximum gains under minimum costs are only of secondary importance under compliance with these tasks.

A specific feature of forest management associated with economization is the effort to reduce the share of human work by using auto-regulation properties of forest ecosystems.

It is evident that forestry ethics is in accordance with the responsibility to act with provisions of Law, to respect the principles of the Ethical Codex of Forests of the Slovak Republic, S.E., as well as to maintain the laws the Lord gave to the mankind almost thousand years ago – the commandments of Decalogue.

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Uplatňovanie zásad dlhodobého a trvalého rozvoja lesov ako základ ich ekologického obhospodarovania

Súhrn

Lesné hospodárstvo nemožno riadiť podľa zásad krátkodobej ekonomiky (zvyšovanie výnosov, úspora nákladov, skracovanie návratnosti). Cieľom obhospodarovania lesov musí byť ich zveľaďovanie a nie zisk. Veď les je naša krajina, naša príroda, naše zdravie a naše národné bohatstvo. Musí sa riadiť zásadami dlhodobosti, lebo jeho úlohou je zabezpečiť, aby lesy plnili všetky potreby rozvíjajúcej sa spoločnosti aj o 100 či 200 rokov.

Ohrozenie našich lesov radom škodlivých činiteľov, vrátane globálnych klimatických zmien a úloha poskytovať veľavýznamné verejnoprospešné funkcie si vynucujú smerovať celé obhospodarovanie lesov na prírode blízke, teda ekologické hospodárenie.

Nastolenú problematiku dlhodobosti, trvalosti a ekologickej orientácie rozvoja lesov možno správne riešiť len dôsledným uplatňovaním základných princípov lesného hospodárstva. Tieto princípy sú vedúcimi koncepciami, ktoré rozhodujúcim spôsobom usmerňujú celý proces obhospodarovania lesov. Konkrétne tvoria tento systém princípov:

a) *Princíp trvalosti (trvalej udržateľnosti) rozvoja* si vynucuje, vzhľadom na dlhodobosť lesa a lesného hospodárstva, aj dlhodobosť plánovania. Kľúčovou podmienkou jeho fungovania, v podrastovom ekológii blízkom hospodárskom spôsobe, je vytvorenie špecifickej sústavy usporiadania porastov. Za všetky porasty určené na ťažbu musia byť v rastovom rade k dispozícii vhodné náhradné porasty. Vo výberkovom spôsobe je náhradnosť viazaná na hrúbku stromov.

b) *Princíp stabilizácie* vyžaduje prednostne sa sústrediť na posilňovanie odolnosti lesov, realizovať preventívne opatrenia a odstraňovať vzniknuté škody.

c) *Princíp ekologizácie* je založený na prehlbovaní poznávania prírodných zákonitostí v lesných ekosystémoch a ich maximálne možnom uplatňovaní v lesníckej praxi.

d) *Princíp optimalizácie* verejnoprospešných funkcií a produkcie je aj účelom hospodárenia. Optimálna produkcia (prirodzené maximum) sa dosiahne ťažbou orientovanou podľa zákonitostí prírastku. Intenzita ťažby musí stúpať so zvyšujúcim sa stupňom rubnej zrelosti, teda v súlade s narastajúcimi prírastkovými stratami.

e) *Princíp hospodárnosti* je zásada riadiť hospodárenie tak, aby sa zámery stanovených úloh splnili čo najdôkladnejšie, pritom podľa možnosti s maximálnym prínosom a pri minimálnych nákladoch.

Práca vyúsťuje do návrhu textácie zásad lesníckej morálky.

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Chronicle

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In the name of long-year colleagues, we wish Doc. Juhásová strong health, family happiness, job satisfaction and much success in research.

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