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Intraseasonal stem circumference oscilations: their connection to weather course

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Abstract
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The diameter (circumference, radial) growth of trees is primarily connected with activity of secondary lateral meristematic tissues – cambium and phellogen. Their activity is linked with the basic physiological processes running in trees, the influence of which can be either direct or indirect. This process is also influenced by climate and weather fluctuations. At the same time, the tree stem with its tissues (bark, phloem, xylem) serves as a water reservoir for transpiration, and the short-time oscilations in the stem magnitude reflect the water balance and water potential of these tissues. The study ran in the vegetation period 2006. We measured short-time stem circumference changes on 1 beech and 3 spruce individuals in a primeval spruce forest in locality Predná Poľana (1360 m asl). In this contribution we deal mainly with inter-daily circumference changes and their connection to the seasonal weather course. A strong weather signal, affecting the circumference changes, was observed both on spruce and beech.

Key words
circumference changes, growth, spruce, beech, climatic signal

Introduction

The circumference (diameter, radial) growth of trees is primarily connected with activity of secondary lateral meristematic tissues-cambium and phellogen. According to Požgaj et al. (1997) wood creation is much more intensive than the creation of phloem. The sensitivity of tree ring formation to external factors has provided a background for new wood science branches – dendrochronology and dendroclimatology (Fritts (1976), Cook and Kairiukstis (1990)). Kozlowski et al. (1991) and Larcher (2001) suggest that activity of these meristematic tissues is linked with the basic physiological processes running in trees, the influence of which can be either direct or indirect – through metabolites and hormonal growth stimulators. This process is also linked with climate and weather fluctuations. There exist several works dealing with diameter growth, its seasonal trends and relation to physiological processes, climate factors, weather fluctuations and tree health status. (eg. Deslauriers et al. (2003), Ďurský and Mozoľová (2001), Ježík and Vоško (2002), Knott (2004), Kramer (1982), Tardif et al. (2001), Tatarinov and Čermák (1999), Zweifel et al. (2000)). Short-time (over a day or a few days) fluctuations in woody plant circumference is also strongly influenced by water balance of the woody plant. In this case, the tree stem with its tissues (bark, phloem, xylem) serves as a water reservoir for transpiration, and deviation in the stem diameter (caused by shrinkage and swelling) reflect the water balance and water potential of these tissues as mention eg Offenthaller et al. (2001), Zweifel and Häsler (2001), Zweifel et al. (2001, 2006). The study ran in the vegetation period 2006. We measured short-time stem circumference changes on 1 beech and 3 spruce individuals in a primeval spruce forest in locality Predná Poľana. Here, in conditions of Slovakia, beech reaches its upper distribution limit and spruce is on its own altitudinal vegetation zone. In this contribution we deal mainly with inter-daily circumference changes and their connection to the seasonal weather course. To detect this linkage, we applied mainly modified methods widely used in dendrochronology and dendroclimatology.

Material and methods

Examined experimental material was acquired from the research site located on the Predná Poľana (PP) (48°37' N, 19°27' E, 1360 m asl) during the growing season 2006. The site is a part of the Poľana Biospheric reserve and the Zadná Poľana Nature reserve. The research plot is situated near the top of a south-west oriented slope with an inclination 5–25°.

The parent rock material is volcanic (andesite), the soil type has been classified as a Dystric Cambisol.

The studied forest stand belongs to the seventh forest altitudinal vegetation zone, the group of forest types Sorbeto–Piceetum, Acereto-Piceetum. The dominant tree species is spruce (*Picea abies*, (L.)) (93%) mixed with beech (*Fagus sylvatica*, (L.)) (4%) and European rowan (*Sorbus aucuparia*, (L.)). It is an uneven-aged primeval forest with spruce stands having up to 150–190 years and reaching an average height of 25 m. The stand structure is mosaic, clump, highly differentiated in thickness and height, the stocking value is about 0.6. In conditions of Slovakia the beech trees growing in this locality reach the upper distribution limit. Their growth forms are either shrubs suppressed under the main spruce layer or trees, mainly on sites where the main spruce layer is more opened. We measured stem circumference in three spruce and one beech individuals. The selected spruce trees were 19.0–21.5 m high and 26–39 cm in dbh. Their age was estimated (wood cores) between 85–100 years. The selected beech was a tree-formed individual, 14.5 m high and 25 cm in dbh. The age of tree-formed beech trees estimated from wood cores varied between 55–80 years.

The area belongs to cold mountain climate type, with mean annual temperature ranging from 3.5–4.0 °C and mean annual precipitation total reaching 900–1,100 mm over the last decade. For better comparison of seasonal climate with the long-term average, we used climatic data from the station of the Slovak Hydrometeorological Institute (SHI) Sliač. The meteorological station Sliač is situated in Zvolen basin, 23 km west from the PP, at 315 m asl.

The values of meteorological variables were measured at a meteorological station belonging the Slovak Hydro-meteorological Institute, situated at an altitude of 1260 m asl, by the mountain hotel Poľana, at about a 500 m distance from the studied forest stand. The information about the monthly temperatures and precipitation amounts was provided by the SHI.

From May 31 up to the end of September (September 28) or October (October 26) we carried out parallel measurements of temperature and relative humidity of air, intensity of global radiation and daily precipitation totals. The scanning ran continually, at 10 min intervals. The data were stored into the memory of a digital measuring MINICUBE 32 central (EMS Brno, Cz). In the first days of August, the equipment measuring global radiation intensity was damaged, and therefore the data about global radiation could not be used in analysis of influence of meteorological variables on changes in the stem circumference. Soil temperature and soil water potential (plaster bricks) were measured at a depth of 0.3 m, and the values were stored into the memory of a MICROLOG central (EMS Brno, Cz) in situ in the studied forest stand.

The changes in stem circumference were measured with an automatic band dendrometer – Dendrometer increment sensor DR 22 (EMS Brno, Cz). Circumferential band was made from stainless steel 12 mm wide and 0.2 mm thick, with a small thermal expansion – contraction factor. The data were therefore not corrected for thermal expansion. The tension strength of dendrometers was 10–15 N. The dendrometers were installed at 2.5 m above ground. The measured circumference data were stored at 10 min intervals into the data-loggers. We performed our circumference measurements from May 13, 2006 to October 26, 2006. For comparison with climatic data we used a segment from May 31.

For our analysis, we used daily average circumference values and climatic data. Because no growth occurs until the end of May, to ease comparison, May 31 was arbitrarily set to the zero value for all band dendrometers.

The circumference increments (CI) were calculated using the difference between mean values of two successive days. The obtained values of CI were filtered through "low-pass" and "high-pass" digital filters. It was done for the purpose of studying the variance at particular frequencies related to different processes running in tree stems. These filters are based on moving averages weights presented in Fritts (1976). They are reciprocal filters, designed to pass variance at opposite extremes of the frequency spectrum. Thus we obtained a "low-frequency" and "high frequency" signal.

For detailed climatic response analysis we used a segment from June 5 to September 28 (116 days). We analysed the values of CI and their corresponding signals in relation to the photoperiod (DL – day length) and to the daily values of climatic variables (SP – soil water potential, ST – soil temperature, AT – air temperature, AH – relative air humidity, PR – precipitation) their one-day delay (L1 – lag 1 day before the current day) and some longer-period averages (or in case of precipitation sums) values (4d – preceding four days for all climatic variables, 14d, 28d, 35d – preceding 14, 28, and 35 days for air temperature and precipitation). In total, we used 22 independent variables. Due to high values of correlations between independent variables, we used partially modified (without autocorrelation but including photoperiod) method of "response function analysis", detailed described in Fritts et al. (1971), Fritts (1976), Cook and Kairiukstis (1990), which has found an extensive use in area of dendroclimatology. Predictor variables were transformed into a new set of orthogonal or uncorrelated variables called principal components or eigenvectors and then standardized. Thus we obtained the factor scores matrix. We used 17 standardized eigenvectors, which represented 99.9% of original variability, as predictors in stepwise multiple-regression analysis. Further, we only used significant ($P < 0.05$) partial multiple regression coefficients for model construction, and insignificant regression coefficients were provided with a value of zero. Then the regression coefficients of eigenvectors were mathematically transformed (using eigenvectors amplitude matrix) into a new set of coefficients corresponding to the original set of variables. In a similar way, the standard errors of regression coefficients were transformed and the statistical significance of transformed regression coefficients of original climatic variables was calculated.

Results

Fig. 1 illustrates the climate history in the locality Predná Poľana across the individual months 2006. In summary, the year 2006 was characterised by a cold winter with high accumulated snow cover. The examined locality had a coherent 40–50 cm thick snow cover in forest even towards the end of April (April 29, 2006), and patches of this cover were present even at the installation of the dendrometers (May 13, 2006). Evidently the highest temperature was recorded in July, with the values in Sliač exceeding the long time average by 3.6 °C. Then there followed August-average in temperature and a sunny autumn period with temperature above the average. As for the precipitation totals, the period from January to April was normal. The most abundant precipitation total was recorded in June, followed by August. The autumn period up to the end of year can be characterised as warm and deficient in precipitation. The total precipitation amount over the growing season (April–September) was 642 mm at a mean temperature of 10.7 °C. The summer total (June–August) was 397 mm at an average temperature of 13.5 °C.

Fig. 2 (a, b, c) illustrates the course of daily climate variables: water potential of soil, length of astronomic day, mean daily values of air and soil temperature, mean daily relative air humidity, and daily precipitation totals over the growing season 2006 – during the measurements of stem circumference. In context of influence of weather on changes in stem circumference, it is necessary to keep in mind some anomalies in the weather history, especially the cold first decade of June, the highest daily precipitation totals recorded from June 27 to June 28 with occurrence of torrent rains (52 and 54 mm over some tens of minutes). The last decade period of July was very warm as a result of penetration of very warm air from west. In this air, lines of instability arose several times, associated with storms. Towards the end of the first decade of August, an occlusive front was progressing from west towards the interior of the continent. In the following days, central Europe was under influence of an extensive area of low atmospheric pressure. The associated frontal system was influencing the weather with frequent precipitation. At the end of the second decade of August, warm south-western airflow was dominant. The third decade, after a cold front transition, there dominated cold weather up to the end of the month.

Measuring values of soil water potential reflecting the strength of bonds between soil and water enabled us to assess soil water accessibility. In spite of the fact that the studied period was in precipitation below the reference long-term mean, we did not record a significant moisture deficit in summer months (June, July, August, Fig. 2a), thanks to frequent occurrence of storms in studied area.

Relative air humidity strongly varied between the days. In summary, the lowest values of air humidity were recorded in July.

After the cold first decade of June, the mean daily air temperature has exceeded a value of 10 °C, and the soil temperature a value of 5 °C. Up to the end of September, the soil temperature did not sink below this limit. The air temperature manifested a steep increase in the second half of June when we also for the first time recorded continual increasing stem perimeters (Fig. 2d) both in spruce (demonstrated on spruce No. 10) and in beech. The beginning of this process can be dated exactly between 16. and 20. June for spruce, and between 20. and 24. June for beech. In case of spruce, the increase was very steep while beech started slowly and manifested a conspicuous acceleration after June 25. The arrows in Fig. 2d point out some notable changes (slowing down) in rate of stem perimeter growth that are easy to identify optically. Comparing these changes with the course of mean air temperature, we can see their correlation with remarkable decreases at the beginning of July (below 13 °C for three days), and similarly on July 15, 16 and 17 (on 16 even under 10 °C). In August, the temperature sunk below 13 °C from 2. to 16., and for four days it kept under 10 °C. After August 7, we did not recorded a remarkable increase in perimeter in spruce trees, with exception of cases when a preliminary decrease in perimeter (caused by shrinkage) was followed by precipitation event. On August 7, spruce reached 97% of its maximum circumference. On August 14, beech reached 93% of its maximum circumference. On September 1, spruce reached 100% and beech 99% of their maximum circumferences.

On Fig. 3 (a, b, c) we can see that course of daily growth curves and course of monthly increment and growth curves of individual spruce trees were synchronised and different from curves for beech. The spruce trees created major parts of their increments already during the last two weeks of June (from 49 to 53%), in July from 34 to 35% and in August from 12 to 17%. In September, the perimeters were diminished by 7 to 8% of the annual increment, and then followed an increase in October, again. By the end of July, there had been created from 83 to 88% of the annual increment, with maximum (100%) recorded towards the end of August. On the other hand, the beech tree created only 14% of its annual increment in June. The highest proportion, up to 60% was created in July, in August it was 24%. Summarising, by the end of July it had been created 74% and by the end of August 99% of the total annual increment.

Fig. 4a illustrates the course of daily increments in spruce (s10) and beech (b2) trees over the time period that we subjected to a thorough analysis in context with climatic variables. We can see that the increment values varied substantially between the days, and in case of spruce we also recorded conspicuous drops into negative values indicating diminishing stem circumference between the individual days. This phenomenon was especially evident after the termination of major circumference growth, after the mentioned August 7.

The increment time series can be treated similar to image or sound signal with a certain frequency. Consequently, the increment signals of individual trees were processed using the method of digital filtering following the works by Fritts (1976) and Cook and Kairiukstis (1990). In such a way, we obtained a low-frequency (LF) and high-frequency (HF) signal presented in Fig. 4b. Summarising the values for individual days, we obtained growth curves for both low and high frequencies (Fig. 4c). Comparing these curves with the measured growth curves we can see that the low-frequency signal very well corresponds to the growth process of the trees. On the other hand, the high-frequency signal does not indicate a growth trend. Consequently, it corresponds to the reversible day-to-day changes. Re-examining the Fig 4b we find that the growth process expressed with the low-frequency signal was different in spruce and beech, according to the facts just mentioned in the analysis of the growth curves.

The obtained multiple-regression relations between the increments, their frequencies and individual eigenvectors or principal components of the independent climatic variables were explanatory for major part of the variability. In case of spruce we could explain through these relations from 76 to 80% of increment variability, in beech it was possible to explain 67%. The highest proportion of the explained variability was obtained with the low-frequency signal: from 93 to 95% for spruce trees and 89% for beech. In case of the high-frequency signal, the share of explained variability was lowest: 43–48% in spruce and 28% in beech. The

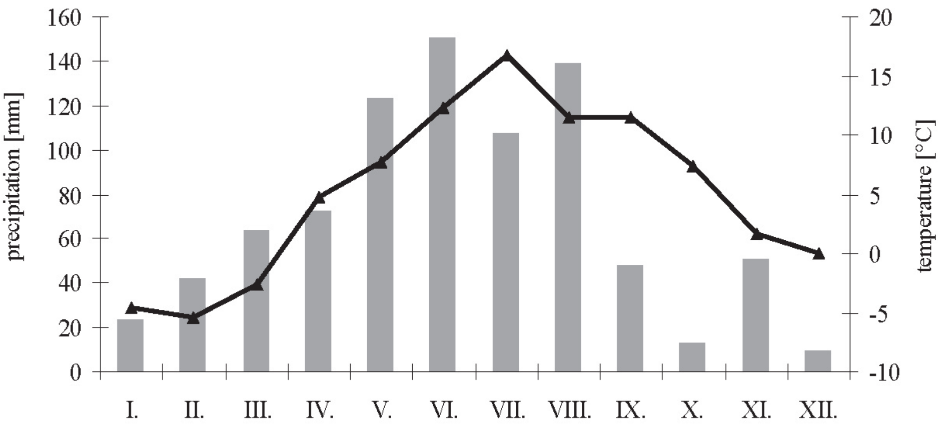

Fig. 1. Mean monthly temperatures (line) and precipitation totals (bars) at Predná Poľana in 2006

climate signal alone (without influence of photoperiod) represented in spruce increment from 65 to 69%, in beech 66% of variability. In case of low frequencies, the climate signal in spruce represented from 62 to

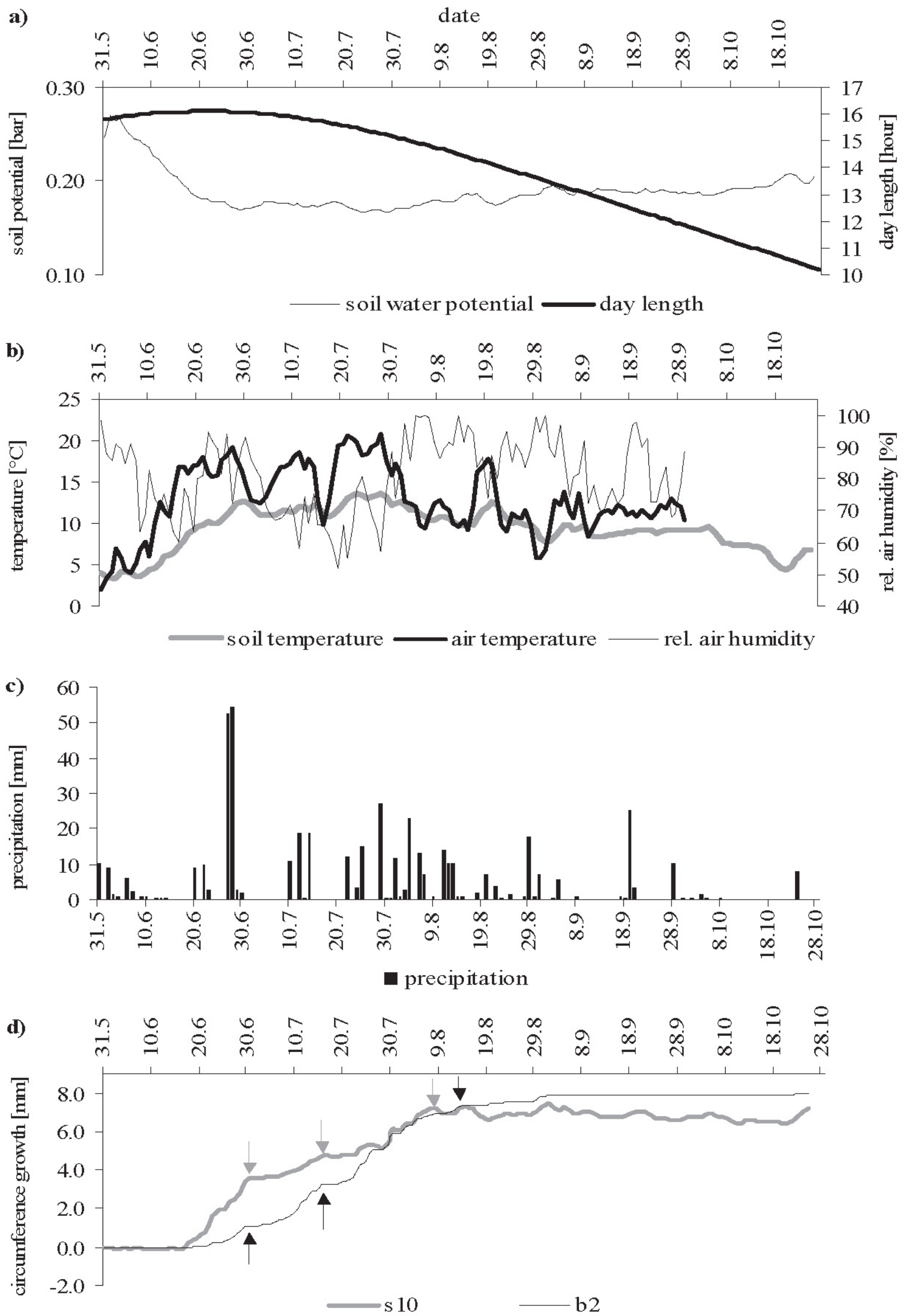

Fig. 2. Seasonal course of mean daily soil water potential and day lengt (**a**), soil temperature, air temperature and relative air humidity (**b**), precipitation (**c**) and circumference growth (**d**) of spruce (s10) and beech (b2) individuals

70% in beech up to 83%. In case of high frequencies was the influence of photoperiod insignificant and the climate signal represented from 43 to 47% of the total variability for spruce trees and 28 % for beech.

The influence of individual factors is illustrated in Fig. 5a, b, c. Noticeable are primarily the highest values of regression coefficients-having the strongest influence on the analysed signals. The responses of all the examined spruce trees were very similar. As for the increment itself (Fig. 5a), spruce responded in positive way, especially to the day length, relative air humidity in the given day, precipitation in the preceding day and mean air temperature over the preceding 4 days. The response was negative in case of air humidity over the preceding four days. The temperature over the last 14 days influenced the increment creation less strongly and in positive way, similar to the precipitation in the given day and in the preceding four days. In case of beech, the influence of photoperiod was found considerably weaker. The most positive was the influence of temperature and especially precipitation in the preceding day, temperature in the preceding four and fourteen days and, different from spruce, also the mean temperature over the preceding 28 and 35 days. Similar to spruce, the increment was negatively influenced by air humidity in the preceding four days.

In the low-frequency signal, the influence of photoperiod increased, and in spruce it was the dominant factor influencing the signal strength. The second most important factor with positive influence was temperature in the preceding four and also fourteen days. The positive influence of precipitation in the given day, preceding day and in preceding four days was weaker and rather uniform, as well as temperature in the given and the preceding day. In case of beech, the dominant factor was positive influence of temperature in the preceding 4, 14, 28 and 35 days. The influence of temperature was also found positive in the given and the preceding day. The influence of photoperiod was similar. Unlike in spruce, influence of long term temperature was found

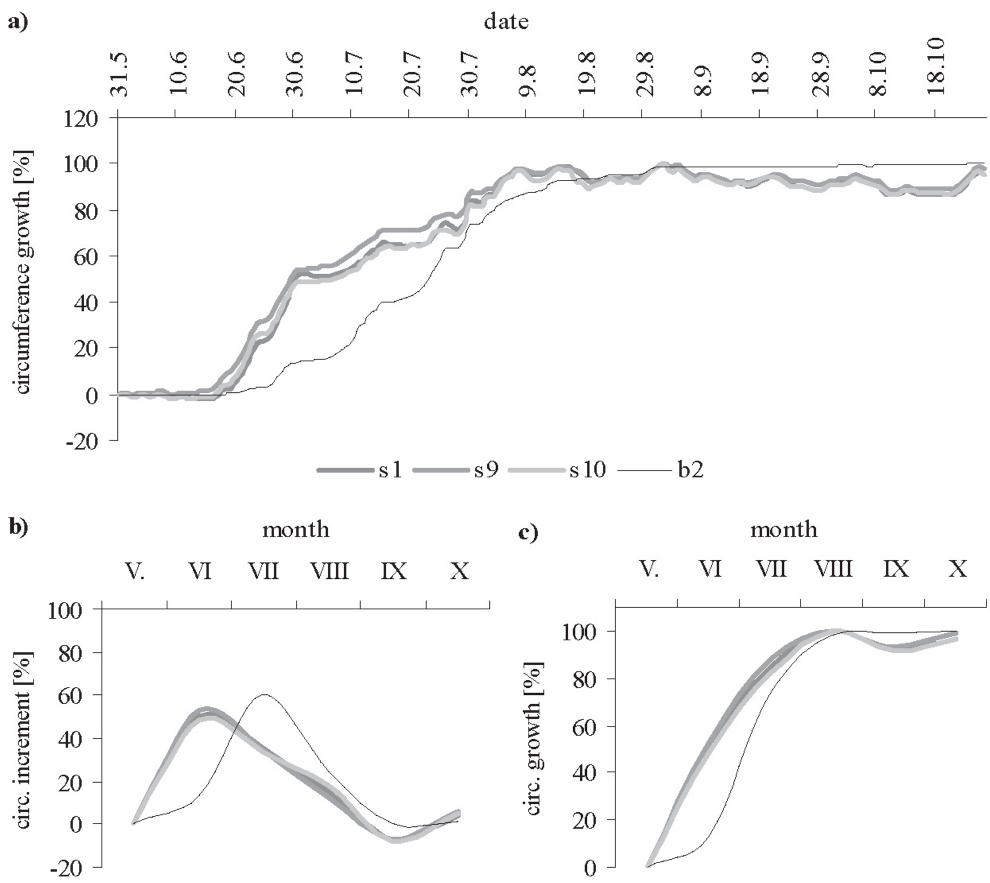

Fig. 3. Relative seasonal growth curves of measured trees (**a**) and their relative monthly increment (**b**) and growth (**c**) curves

positive. The most remarkable negative relation was recorded for air humidity in the preceding four days.

In case of high-frequency signal, the influence of photoperiod was negligible. For spruce, influence

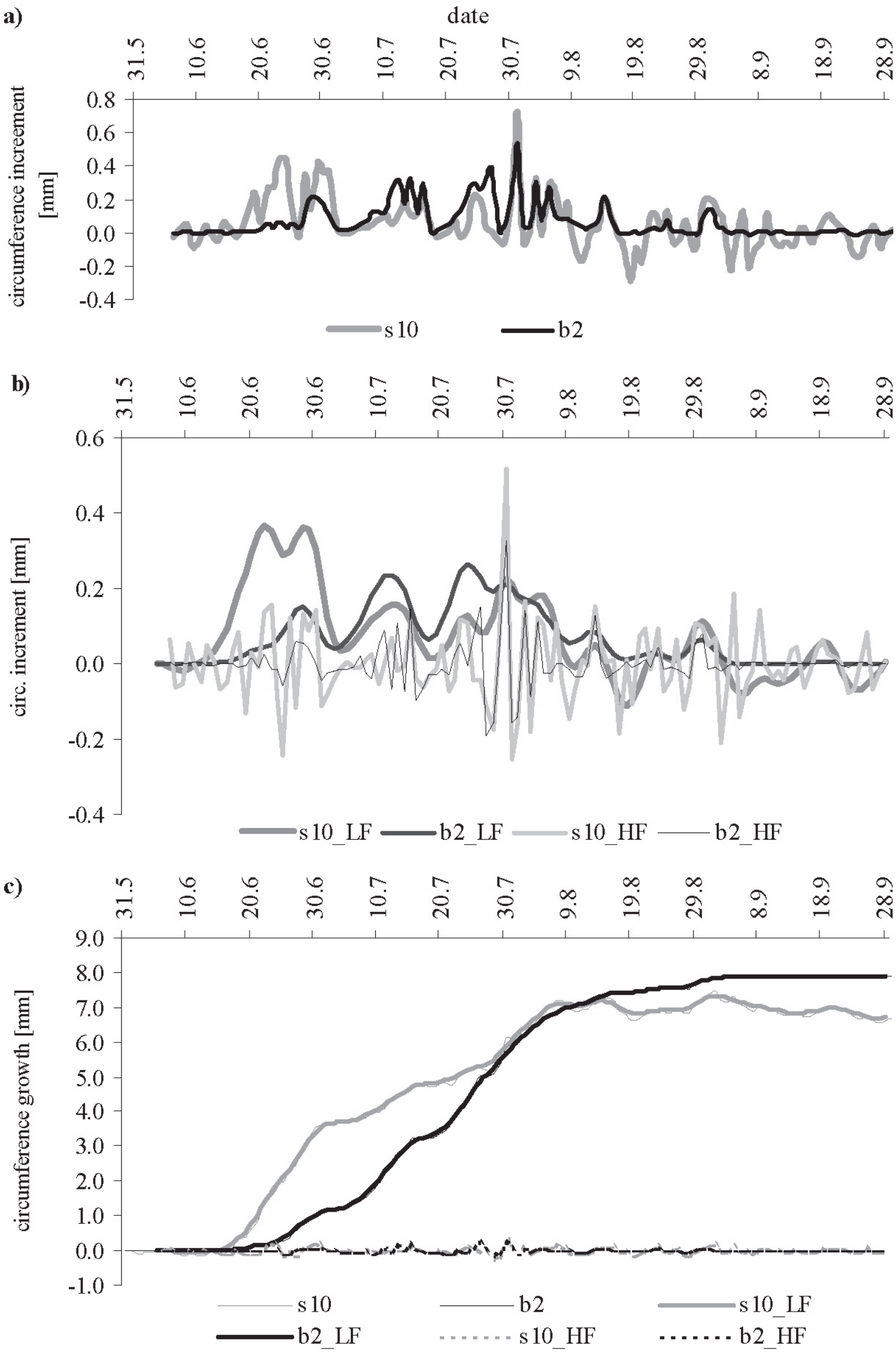

Fig. 4. Seasonal daily increment curves of spruce (s10) and beech (b2) individuals (**a**), their low (LF) and high-frequency (HF) components (**b**) and corresponding increment, low-frequency and high-frequency growth curves (**c**)

of air humidity in the given day and precipitation in the preceding day were found equally high significant. Influence of air humidity over the previous four days was found negative and weaker. In beech, the most important factor was precipitation in the preceding day. Influence of air humidity in the given day and negative influence of humidity in the preceding four days were substantially weaker than in spruce.

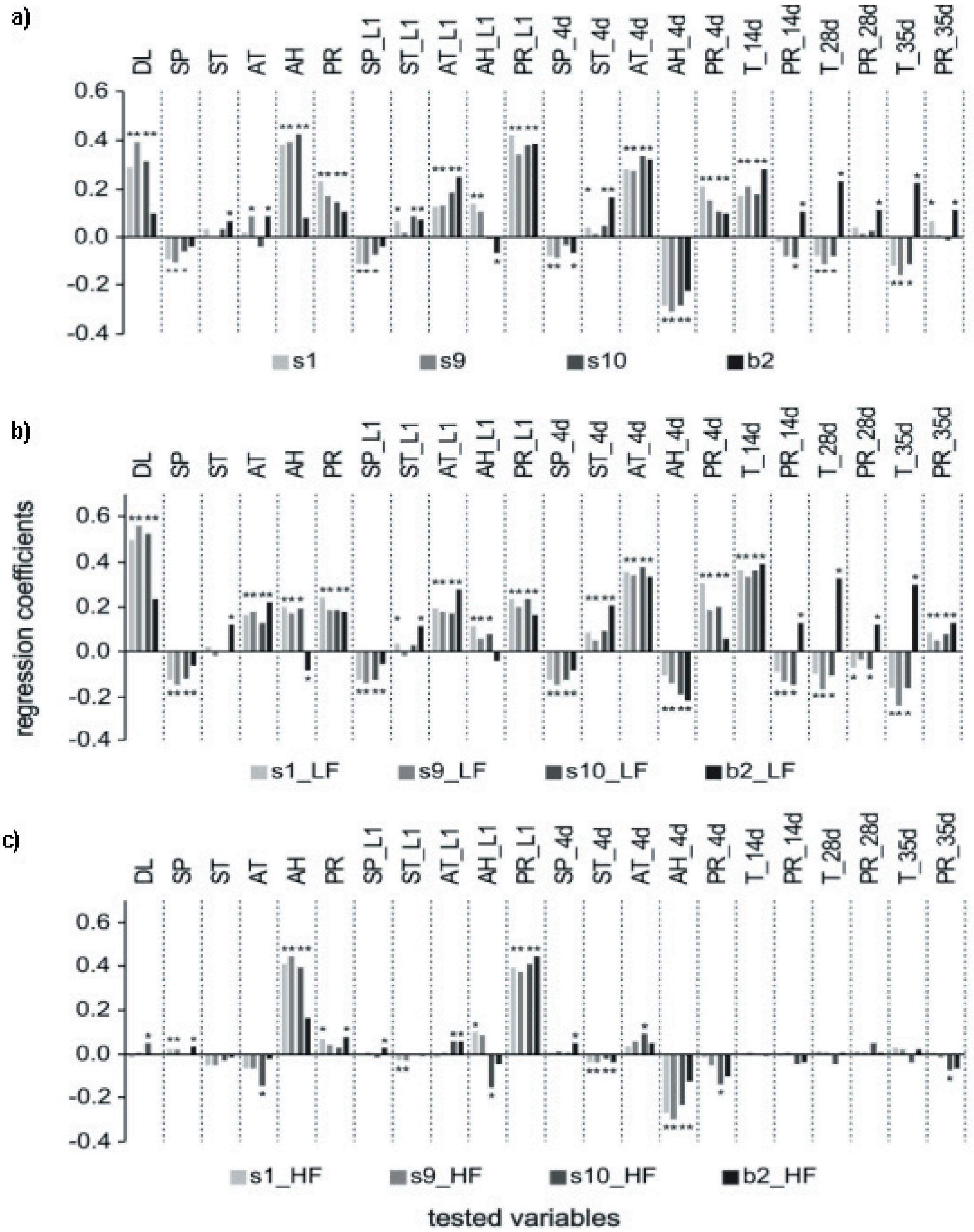

Fig. 5. Results of response function analysis (standardized regression coefficients) between measured increments (**a**) their low-frequency signals (**b**), high-frequency signals (**c**) and tested independent variables, where: DL – day length, SP – soil water potential, ST– soil temperature, AT (T) – air temperature, AH – relative air humidity, PR – precipitation, L1 means previous day, 4d – previous 4 days, and 14d, 28d, 35d – previous 14, 28 and 35days.
***** – marked statistically significant coefficients at P < 0.05

Discussion

In connection with seasonal dynamics of diameter growth in woody plants is commonly recognised that the onset of growth is primarily dependent on temperature, and the growth process is stopped in dependence on the day length. It seems to be evident because towards the end of August and in the first days of September, most woody plants in temperate zone stop their diameter increment creation (Šmelko et al. (1992)). In our case, both the beginning and sudden damping of the growth process, first of all the low-frequency signal, were distinctly synchronised with temperature. The important role of temperature in launching and keeping active performance of cambium and in production of xylem and phloem has also been confirmed by Gričar et al. (2006). Miller (in Šmelko et al. (1992)) reports 5.0 °C as a threshold value impeding growth in spruce, larch and mountain pine. Rossi et al. (2006a) suggest for a threshold value of air temperature necessary for spruce xylogenesis an interval of 6.5–10.0 °C and soil temperature between 3.0–7.5 °C. In our case, after the cold first ten-day period of June, the mean air temperature exceeded the limit of 8 °C for the first time on June 11, and the soil temperature was for the first time over 5 °C on June 12. The onset of growth started expressly after June 16 in spruce and after June 20 in beech following an abrupt rise of temperatures.

Our results also confirm strong influence of photoperiod on increment creation, especially in the studied spruce trees in which the major part of increment was being created over the short fortnight period in June following a temperature increase. The considerable influence of photoperiod on increment has also been confirmed by Rossi et al. (2006b), observing conifers in a cold environment and having found out that the maximum growth performance was synchronised with the day length. On the other hand, the growth performance of the studied beech reached its maximum in the second and the third decade of July and in the first days of August, because the species has at the locality the upper limit of its range and, evidently, requires bigger amounts of accumulated heat and necessary supply of assimilates. The increment dynamics in beech was in accord with the results obtained by Ježík et al. (2007), who found based on the data recorded with mechanical dendrometers installed on the same plot in growing seasons 2003–2005, that the beech increment was mostly dependent on temperature and reached its maximum mainly in July. Following the extreme hot period May-June 2003, the beech trees had created considerable high increments already by the end of June. In case of substantially colder weather in the year 2004, the increment created in June was significantly lower and it showed a steep peak, together with the temperature between August 5 and 19.

Kamlerová and Schejbalová (2006), performing their observations at 620 m asl, found that the increment creation in spruce started in the first half of May and reached its peak in July, after June exceedingly above-average in temperature and in precipitation. Krammer (1982) measured beech trees in the region of Lower Saxony (Germany, 500 m asl). He found out that the diameter increment creation started towards the end of April to the mid-May and finished about the end of August. Some fluctuations in diameter values, however, were observed up to the end of October. The highest increment rate was created in June and July. At the site with high precipitation, the fortnight increments were influenced heavily by the amount of global radiation and air temperature. Ďurský and Mozoľová (2001) studied diameter creation in trees close to our experimental site PP (5 km apart), at 850 m asl. The diameter increment of spruce and beech started to create since the mid-May and was finished towards the beginning or end of September. Knott (2004) found in a stand in the Czech Republic (460 m asl), that during the humid vegetation period 2001, precipitation and mainly temperatures showed positive effects on weekly diameter increment in fir and beech.

While in conditions of colder climate is the diameter growth of trees mostly influenced by temperature, in lower altitudes, especially in summer, precipitation turns more important. Ježík et al. (2007) recorded expressive shrinkage of beech stems measured at fortnight intervals in the extremely hot and dry summer 2003 on the plot situated in the 3rd forest altitudinal vegetation zone. The highest proportion of increment was in the case of 2003 created in May, in other years in June, followed by July. The similar effect of shrinking was observed by Zweifel et al. (2006) in oak, pine and spruce trees during the extreme drought in the year 2003 in the central valley in Switzerland.

Shrinkage and subsequent swelling of tree stems are not possible to distinguish fully from the growth process based on the measurements carried out with dendrometers. This phenomenon has also been pointed out by eg Krammer (1982), Zweifel et al. (2006), and it is also well-known from the observations of daily diameter dynamics (Deslauriers et al. (2003), Goldhamer and Fereres (2004), Herzog et al. (1995), Offenthaller et al. (2001), Ortuño et al. (2006), Tardif et al. (2001), Zweifel et al. (2001), Zweifel and Häsler (2001)). We observed shrinking of stems, mainly of spruce after cessation of growth after August 7.

In our approach, we filtered the original signal for obtaining its low-frequency and high-frequency component. The second is very close connected with reversible changes especially. It showed strongly positive responses to the precipitation in the preceding day and in case of spruce also to the changes in air humidity (rise in air humidity comparing to previous 4 days). As for moisture conditions, the low-frequency signal responded less positively to precipitation in the preceding day. The influence of air humidity variability on spruce trees was less less strong as for high-frequencies, too. It manifested closer correlation with the precipitation in the current day, with longer precipitation history and mainly for spruce with soil water potential.

Conclusions

In summary we can conclude, that we found a strong climatic signal in inter-daily circumference increment of spruce and beech in 2006 at the studied locality.

The circumference increment of spruce trees primarily associated with their cambium activity (low-frequency signal) was in the growing season 2006 mostly influenced by photoperiod, followed by mean air temperature over the preceding four and fourteen days. In case of reversible changes (high-frequency signal), there were primarily changes in air humidity and precipitation amount in the preceding day.

In case of beech, for the low-frequency signal, determining factors were mean temperatures, over the preceding four, fourteen, as well as 28 and 35 days. For the given, for beech extreme, locality, this fact points out necessity of temperature accumulation and evidently also accumulation of sufficient amounts of assimilates necessary for the cambium performance. The decisive factor in the high-frequency signal was influence of precipitation amount in the preceding day. Influence of changes in air humidity was less strong than that observed in spruce.

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Sezónne kolísanie obvodu kmeňov: ich spojitosť s priebehom počasia

Súhrn

Počas vegetačnej sezóny 2006 sme pomocou automatických dendrometrov zaznamenávali krátkodobé zmeny obvodu troch smrekov a jedného buka v prírodnom horskom lese v lokalite Predná Poľana. Podrobne sme analyzovali zmeny obvodu kmeňov medzi jednotlivými dňami, ktoré súvisia predovšetkým so sezónnym rastom (aktivita sekundárnych meristematických pletív) drevín ako aj ich vodnou bilanciou, a ich spojitosť s priebehom počasia. Po dlhej zime a chladnej prvej dekáde júna sme zaznamenali počiatok rastu kmeňov smrekov koncom druhej júnovej dekády, jeho následnú prudkú akceleráciu a vyvrcholenie v tretej júnovej dekáde. Rastový proces buka začínal mierne v tretej júnovej dekáde a vrcholil až v tretej júlovej dekáde. Do konca augusta sa vytvoril celý sezónny prírastok, pri jedincoch smreka prakticky už do konca prvej augustovej dekády. Použitím analýzy „response function“ sme zistili existenciu silného klimatického signálu ovplyvňujúceho zmeny obvodu kmeňov smrekov aj buka, ktorý bol rôzny pri jednotlivých frekvenčných komponentoch prírastkovej krivky. Pri jedincoch smreka, ktoré reagovali veľmi podobne, nízkofrekvenčná zložka prírastkovej krivky (ktorá súvisela predovšetkým s rastom stromov) závisela pozitívne hlavne od fotoperiódy a teploty počas predchádzajúcich 4 a 14-tich dní. Pri buku bola nízkofrekvenčná zložka prírastkovej krivky ovplyvnená najmä teplotou a jej akumuláciou za dlhšie obdobie (až 35 dní). Vplyv zrážok bol u obidvoch drevín slabší a prevažne pozitívny. Vysokofrekvenčnú zložku prírastkovej krivky (reverzibilné zoschýnanie a napúčanie) ovplyvňovali u obidvoch drevín najmä zrážkové pomery predchádzajúceho dňa a pri smrekoch silne aj zmeny vo vlhkosti vzduchu.

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