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Results of a phenological study of the tree layer of a mixed stand in the region of the Drahanská vrchovina Upland

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ABSTRACT: The paper presents the results of phenological studies of Norway spruce (*Picea abies* [L.] Karst.), European beech (*Fagus sylvatica* L.) and European larch (*Larix decidua* Mill.) in a mixed stand in 2004 to 2007. The results show different onset and duration of phenological stages in the particular years. This broad range was important in spring phenological stages. High correlations were determined between the mean air temperature and the start of phenological stages in monitored species. The onset and duration of autumn phenological stages are affected not only by air temperature but also by air humidity. The annual variability in the onset and course of phenological stages in forest species showed that except genetic factors external conditions, particularly meteorological factors, affecting their onset and duration were also important. Relationships between the onset of phenological stages and changes in meteorological parameters were expressed by the sum of effective air temperatures exceeding 0 and 5°C. To evaluate the relationships by means of the sum of effective temperatures > 5°C, the stage of budbreak was most important in all studied species.

Keywords: phenology; effective temperature; vegetation period; climatic change

Phenological studies make it possible to understand regularities in the course of life manifestations of plants depending on external conditions of the environment. Thus, they are a valuable source of information on the onset and duration of growing seasons in various climatic regions. Phenology serves to monitor the time course of growth and phenological stages of plants in the given region.

In addition to genetic factors also external conditions particularly meteorological factors participate in the variability of the onset and duration of phenological stages in forest plants. The beginning of budbreak, leaf unfolding and flowering are usually possible when the air and soil temperature exceed a certain critical point characteristic of each stage of the plant life cycle (Larcher 1988; Bednářová, Kučera 2002).

The dependence of tree phenology on climatic signals is well established (Lechowicz, Takayoshi 1995; Kramer 1996). Temperature has been found to be the best environmental signal for the tree to use for the optimal timing of the onset of growth. For determining the onset of developmental stages, the concept of temperature sum has often been used (Häkkinen, Hari 1988; Kramer 1996, 2000; Diekmann 1996; Van Vliet et al. 2002). Temperature sum is the accumulated temperature above a certain threshold value from a certain starting date, calculated by the progressive addition of mean daily temperatures (Havlíček et al. 1986; Diekmann 1996; Bagar, Klimánek 1999; Bagar, Nekovář 2007). For the calculation of temperature sums, most commonly a threshold value is used which defines the beginning of the thermal growing season, usually 5°C. The temperature sum during the growing season is referred to as the effective temperature sum (Tuhkanen 1980; Havlíček et al. 1986; Lappalainen 1994; Diekmann 1996; Bagar, Klimánek 1999; Bagar, Nekovář 2007).

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Temperature sum models may not be equally accurate for all species. Early-flowering species and late-flowering species can be expected to differ in their responses, particularly in deciduous forests with their strong seasonal variation in light intensity. For spring geophytes direct solar radiation may play an important role for vegetative and generative development (Diekmann 1996; Merklová, Bednářová 2006).

The course of autumnal phenological stages depends again on the air temperature affecting the synthetic activity of plants. Nutrient and water reserves and particularly the effect of diurnal photoperiod (Larcher 1988) are other important factors. Due to weather the particular stages can be shifted and thus the further development of plants disturbed.

Depending on changes in weather in the given climatic conditions according to changes in phenological stages we can also evaluate trends in climate changes (Kramer 1996, 2000). Expected climatic changes and related negative factors can affect the course of basic living phenomena of plants (Kramer 2000, Luknárová 2002; Bednářová, Kučera 2002; Škvareninová et al. 2006). Due to warming changes in the development of forest trees and herbs can also occur. Phenological data are a certain expression of the climate character of a given region. Thus, they can contribute to assess the variability of weather and also to evaluate the impacts of potential climatic changes on forest ecosystems (Bednářová, Merklová 2007a). Acquired knowledge could be used in the habitat change of some species where their future evolution and reproduction under the influence of changed climate conditions will be ensured (Škvareninová 2005).

MATERIAL AND METHODS

Phenological observations of forest trees have been carried out on a research plot of the Institute of Forest Ecology, Mendel University of Agriculture and Forestry (MUAF) in Brno (Rájec – Němčice) since 1991. The present paper is aimed at the results of monitoring phenological phenomena of the tree layer of a young mixed stand in 2004 to 2007.

The research plot locality is situated on the north-eastern to eastern slope of the watershed ridge at an altitude of 625 m. The area is characterized by coordinates 16°41'30''E and 49°26'31''N in the geographical unit of the Drahanská vrchovina Upland. Climatically, the region is slightly warm and slightly humid with the long-term mean of annual temperatures 6.6°C and annual precipitation 683 mm (Kolektiv 1992). In the period 1990 to 2006, mean annual temperature 6.96°C and total precipitation 734 mm were measured. Figs. 3 and 4 characterize the actual situation of the locality from the aspect of precipitation and temperature.

The species composition of trees of the 27-year mixed stand is as follows: Norway spruce (*Picea abies* [L.] Karst.) 60%, European beech (*Fagus sylvatica* L.) 30%, European larch (*Larix decidua* Mill.) 10% and European birch (*Betula pendula* Roth) as an interspersed species. The shrub layer of the stand is represented by *Sambucus racemosa* L. and the herb layer by *Fragaria vesca* L., *Mercurialis perennis* L., *Vaccinium myrtillus* L., *Maianthemum bifolium* L. *Tussilago farfara* L. and *Petasites albus* (L.) Gaertn. occurring at the stand margin. For phenological observations, the modified methodology of the Czech Hydrometeorological Institute (ČHMÚ 1987) was used. Phenological observations are always carried out at 10 sample trees of the Norway spruce, European beech and European larch.

During the spring season (April to June), phenological observations are carried out three times a week. In the summer and autumn season, the observations are carried out once a week. The ordinal number of a day from the beginning of the calendar year was assigned to the date of particular phenophases.

The following phenological stages of forest trees are evaluated in the paper: budbreak from 10%, the beginning of foliage from 10%, the beginning of foliage from 50%, the beginning of foliage from 100%, quite unfolded leaf area (full foliage 100%), leaf yellowing 10%, leaf yellowing 100% and leaf fall from 100%. The stage of flowering was not monitored because these species (if not subject to a stress factor) begin to yield only at older age. The onset of the particular phenological stages was determined as to a day when at least 50% of the monitored species reached the given stage. A day when the mean daily air temperature reached a higher temperature than 5°C for the period of three days (Havlíček et al. 1986) was determined as the beginning of the large growing season. Sums of mean daily air temperatures with threshold values 0°C and 5°C (TS 0°C and TS 5°C) were calculated for each of the phenological stages.

In studied stands, sensors were installed to measure air temperatures (Datalogger Minikin T), namely at the lower limit of tree crowns at a height of 4 m. These measurements of selected characteristics have been carried out at the locality since 2005. A measuring device of the EMS Brno Co. (Environmental Measuring System, Brno) was used. The methodology and installation of the device were described in detail by Kučera (2003, 2005). At a distance of 500 m from the assessed stand, the amount of precipitation, air temperature and radiation were monitored in the open area.

To evaluate phenological data for the characterized period, arithmetic mean, maximum and minimum value, variation range and standard deviation were calculated. Relationships were calculated between selected spring phenological stages and air temperatures in the period before the onset of the phenological stage.

RESULTS AND DISCUSSION

The aim of the paper was to evaluate phenological stages of a tree layer in a mixed stand in relation to the sum of effective temperatures before the onset of the monitored stage in the area of the Drahanská vrchovina Upland for the period 2004–2007.

The onset and duration of phenological stages of plants are effected by a complex of external factors (air temperature, soil temperature, global radiation, moisture conditions, site quality) together with the inner periodicity (or genetic properties) (Bednářová, Kučera 2002). Temperature requirements are different in each of the monitored species. This fact serves as a basis for different onset and duration of phenological stages in selected tree species. Responses of monitored tree species to air temperature were evaluated on the basis of cumulative sums of effective temperatures > 5°C as compared with the sum of temperatures > 0°C. A temperature above 5°C is important for the budbreak of the temperate zone species. These findings are evident from the processed results of temperature sums of mean daily temperatures, which are decisive for the onset of phenological stages (Figs. 2 to 9).

Results of the time course of phenological stages of monitored species of a mixed stand throughout the growing season 2004–2007 are demonstrated in Fig. 1.

The response of phenological stages to variability of weather in the particular monitored species

Norway spruce

Compared to all monitored species the spruce responded least to the variability of weather in the particular years (Fig. 1). The onset of budbreak in Norway spruce occurred on average the 125th day in the period 2004 to 2007 at the sum of temperatures above 5°C (TS5 = 157°C) and at the sum of temperatures above 0°C (TS0 = 416°C). First, the stage of budbreak in spruce began the 121st day at the sum of temperatures above 5°C amounting to 172.7°C and at the sum of temperatures above 0°C amounting to 525°C (2007) and at the latest the 128th day in 2005 at the sum of temperatures above 5°C 179.6°C and at the sum of temperatures above 0°C 442°C.

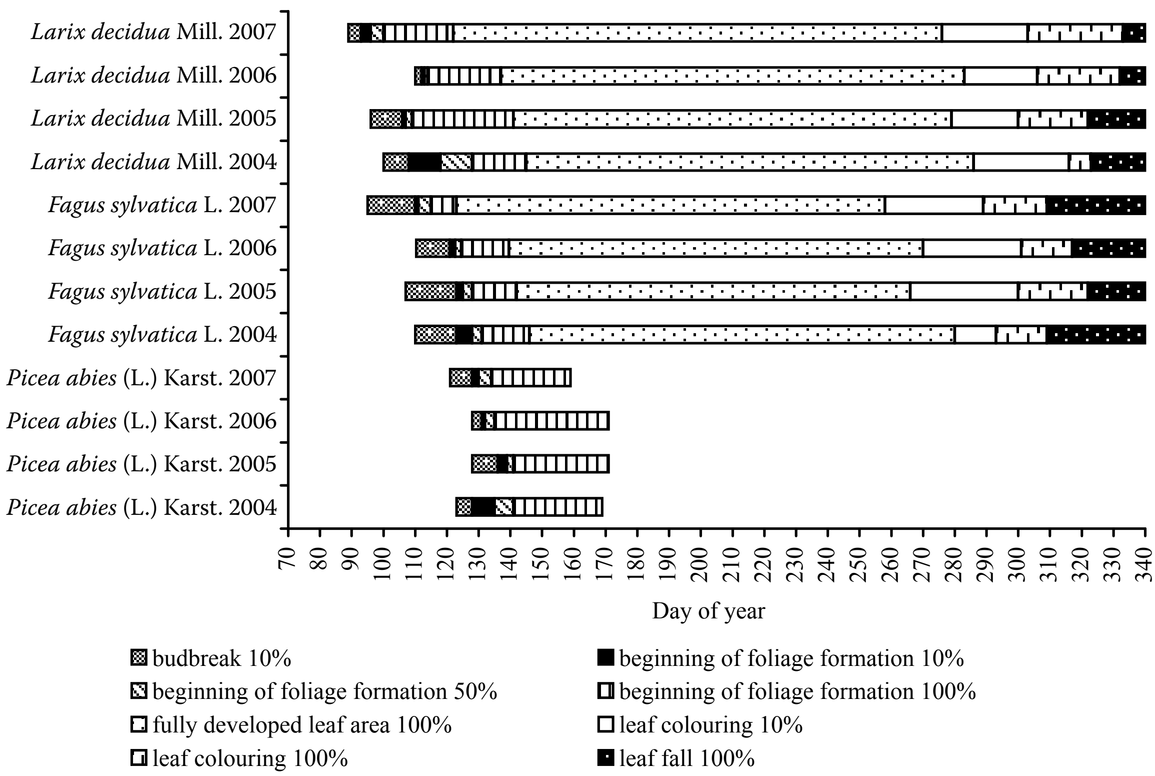

Fig. 1. The course of phenological stages of the tree species of a mixed stand in 2004–2007

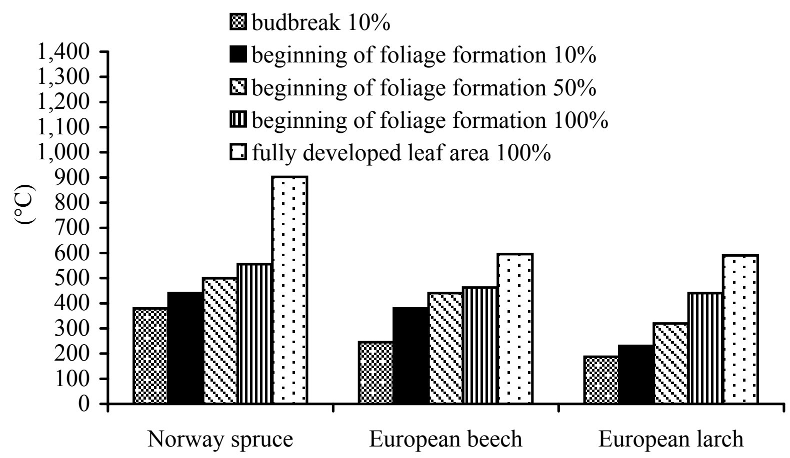

Fig. 2. Temperature sums above 0°C – spring, summer 2004

The onset of foliage in spruce began between the 128th day (2004 – TS5 = 181°C, TS0 = 440°C, 2007 – TS5 = 205.4°C, TS0 = 593°C) and the 136th day (2005 – TS = 199.7°C, TS0 = 501°C).

Full 100% foliage occurred in 2007, viz. the 159th day, i.e. 12 days earlier than in the previous year, at the sum of effective temperatures 493.7°C and the sum of temperatures above 0°C 1,036°C. In 2005, full foliage occurred the 171st day at the sum of temperatures above 5°C 511.6°C and at TS0°C = 87°C (Figs. 2 to 9). A mean value for the budbreak of spruce on the 16-year average was the 122nd day, for the beginning of foliage the 128th day and for 100% full foliage the 162nd day (Bednářová, Kučera 2002; Bednářová, Merklová 2007a). The most frequent budbreak for the 16-year period was in 2007.

European beech

On the basis of 4-year results, the mean time of budbreak (10%) of beech was determined in a mixed stand, viz. the 106th day. In 2007, beech began to develop buds as early as on the 95th day (TS5°C = 35.2, TS0°C = 259). Results obtained for the 16-year period (Bednářová, Merklová 2007b,c) show the onset of the stage in the range between the 84th day at the minimum sum of effective temperatures 10.9°C (year 1994) and the 120th day affected by the sum of temperatures 135.6°C (year 1991).

The beginning of foliage (from 10%) was in 2007 already on the 110th day at the sum of temperatures above 5°C 102°C and at the sum of temperatures above 0°C 400°C. In previous years, the stage ranged between the 121st (2006 – TS5 = 96°C, TS0 = 249°C) and the 123rd day (2004, TS5 = 145°C, TS0 = 380°C, 2005, TS5 = 152°C, TS0 = 389°C). For the period of 16 years, the mean value of the stage was the 114th day (TS5 = 80.1°C). Full 100% foliation occurred first during the last 4 years the 123rd day at the sum of temperatures above 5°C–175°C, TS0 = 537°C (2007) and at the latest the 146th day (TS5 = 249.4°C, TS0 = 596°C) in 2004 (Figs. 2 to 9). In 1991–2006, this phenological stage occurred between the 127th day at the sum of temperatures 330.8°C (2000) and the 163rd day at the sum of temperatures 161.6°C in 1991.

The period of the photosynthetic activity of a leaf area is terminated by the autumn phenological stage (autumn yellowing of leaves). According to

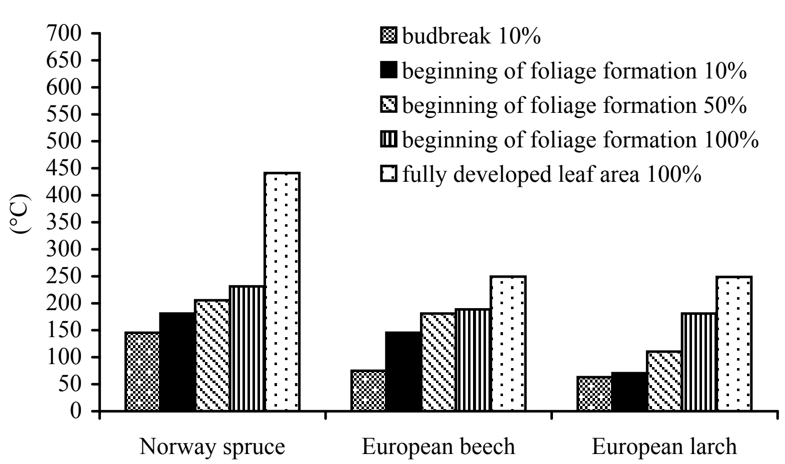

Fig. 3. Temperature sums above 5°C – spring, summer 2004

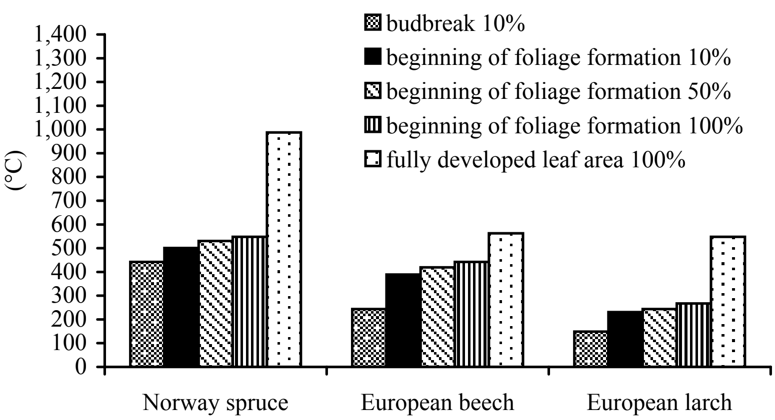

Fig. 4. Temperature sums above 0°C – spring, summer 2005

the results of many authors, this stage starts at the beginning of September under our conditions, leaf fall at the end of September until the beginning of October and total leaf fall occurs usually in November (Štefančík 1995).

In the monitored mixed stand, a period between the beginning of yellowing and 100% yellowing in beech lasted for 27 days on average. The most frequent yellowing of leaves 10% in beech (the onset of autumn yellowing) for the period 2004–2007 occurred the 258th day (TS5 = 1,601.7°C, TS0 = 2,639°C) and at the latest the 280th day (TS5 = 1,543.6°C, TS0 = 2,560°C). An interval for this stage was 22 days. On average, the onset of the stage of the beginning of autumn leaf yellowing occurred the 269th day (TS5 = 1,580.3°C, TS0 = 2,555.8°C). The phenological stage of 100% leaf yellowing occurred first the 289th day from the beginning of the year (TS5 = 1,745°C, TS0 = 2,935°C) and at the latest the 301st day (TS5 = 1,788.8°C, TS0 = 2,835.4°C). On average, this stage occurred the 296th day (TS5 = 1,704.6°C, TS0 = 2,893°C). During the last four years leaf fall 100% occurred the 314th day on average (TS5 = 1,732°C, TS0 = 2,893°C). This finding is also consistent with data of other authors. Chalupa (1969) reported that in the years when minimum temperatures did not fall below 0°C and soil moisture was sufficient, a great deal of leaves fell also in the first decade of November. In some years, the smaller part of leaves remains on trees until December. In the beech stand evaluated for the 16-year period, the latest leaf fall was noted the 332nd day with the sum of temperatures above 5°C 2,340.5°C. First, 100% leaf fall occurred the 305th day (TS5 = 1,308.1°C) (Bednářová, Merklová 2007b). A number of authors related the onset of autumn phenological stages with the previous marked fall of temperatures and with the period of the occurrence of frequent rainfalls (Haspelová-Horvátovičová 1995; Priwitzer, Minďáš 1998; Škvarenina et al. 2006).

European larch

The budbreak of larch in the stand was noted first the 89th day in 2007 at the sum of temperatures above 5°C 24.1°C and at the sum of temperatures above 0°C 220.1°C. This stage occurred at the latest in 2006, viz. the 110th day (TS5 = 29.8°C, TS0 = 131.8°C).

In the period 2004–2007, the mean temperature for this stage was the 99th day, which is an interesting finding if we compare these results with the

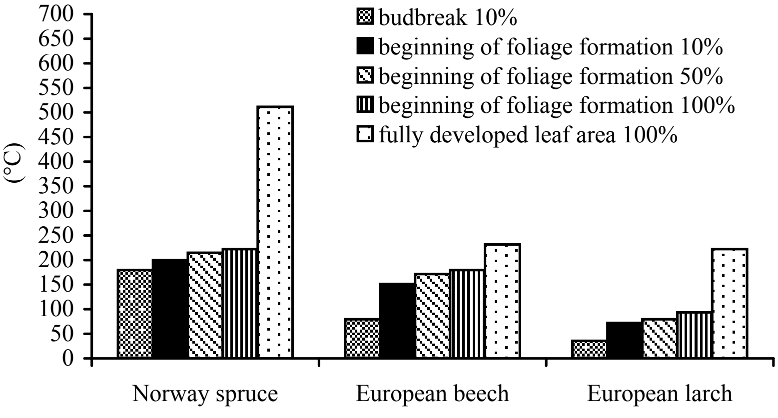

Fig. 5. Temperature sums above 5°C – spring, summer 2005

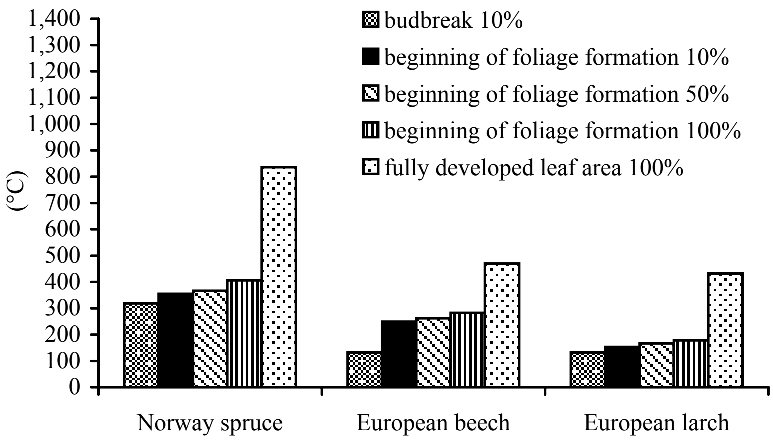

Fig. 6. Temperature sums above 0°C – spring, summer 2006

long-term monitoring of larch in the Drahanská vrchovina Upland (Bednářová, Merklová 2006), when the same mean value was determined for budbreak in the period 1991–2005. From the aspect of the particular years, the variability of the onset of phenological stages of larch is markedly dependent on external conditions, namely air temperature. The beginning of foliage from 10% was on average on the 110th day during the 15-year period, variation range 23 days. The mean sum of effective temperatures for this phenological stage was 67.3°C. In 2006, this stage was noted the 112th day (at TS5 = 41.1°C, TS0 = 153.1°C). In 2007, on the other hand, this stage occurred already the 93rd day (at TS5 = 32.2°C, TS0 = 248.3°C) and in 2004, this stage occurred the 108th day at TS5 = 70.6°C and TS0 = 231°C. In 2005, it occurred the 106th day at TS5 = 72.2°C, TS0 = 231.2°C. The beginning of 100% foliage was on average on the 121st day during the 15-year period, a range for the monitored period was 29 days, the mean value of cumulative effective temperatures was 124.0°C. In 2007, this stage occurred already the 100th day (TS5 = 42°C, TS0 = 289.5°C), in 2006, the 114th day (TS5 = 56.2°C, TS0 = 178.2°C), in 2005, the 109th day (TS5 = 93.5°C, TS0 = 267.5°C) and in 2004, the 128th day (TS5 = 181°C, TS0 = 440.3°C).

In the course of the last 4 years, the stage of full 100% foliage occurred always more frequently in larch. In 2004, this stage occurred the 145th day (TS5 = 248.8°C, TS0 = 590.2°C), in 2005, it occurred the 141st day (TS5 = 222.3°C, TS0 = 548.2°C), in 2006, it occurred the 137th day (TS5 = 199.5°C, TS0 = 431.9°C). In 2007, it occurred already the 122nd day (TS5 = 173.8°C, TS0 = 531.3°C) (Figs. 2 to 9). The earlier beginning of this stage can be explained by the fast onset of high spring temperatures in 2006 and by very mild winter and extraordinarily warm spring in 2007.

The beginning of leaf (needle) yellowing from 10% occurred on average the 281st day during the last 4 years at the sum of temperatures above 5°C 1,657°C and at the sum of temperatures above 0°C 2,694.1°C. The results of Chalupa (1969), Kramer (1996), Larcher (1988, 2003) documented that the beginning of needle yellowing in larch was in mid-October, which also corresponds with our long-term results. The 100% yellowing of leaves (needles) occurred on average the 306th day during the period

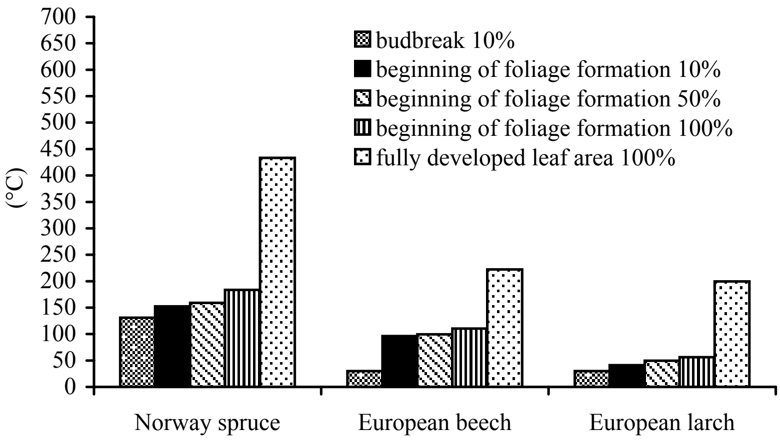

Fig. 7. Temperature sums above 5°C – spring, summer 2006

Table 1. Mean monthly precipitation in 2004–2007

Year/month	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	Σ
2004	83.0	68.3	70.7	48.0	63.6	118.1	78.7	69.6	63.4	58.9	93.1	29.1	844.5
2005	34.5	64.0	53.1	38.8	97.0	38.7	113.7	117.4	126.3	2.0	37.4	75.7	798.6
2006	35.0	51.0	71.0	79.0	64.3	71.4	17.5	200.7	4.3	21.1	30.5	10.7	656.5
2007	43.9	37.8	65.8	1.0	48.5	65.5	115.3	34.5	116.6	38.4	37.1	17.3	621.8

2004 to 2007 (TS5 = 1,727.8°C, TS0 = 2,874°C), i.e. 5 days later than the long-term 16-year mean (Bednářová, Merklová 2006). A period between the beginning of yellowing and 100% yellowing lasted 25 days in larch.

The phenological stage of 100% leaf fall occurred on average the 328th day during the last 4 years at the sum of temperatures above 5°C 1,741°C and at the sum of temperatures above 0°C 2,931.6°C. A mean value for 100% needle fall for a long-term 15-year mean was the 322nd day with an interval of only 15 days. The mean sum of effective temperatures for this stage was 1,863.9°C. The interval of the minimum and maximum of cumulative effective air temperatures from the beginning of budbreak until the 100% needle fall ranged from 1,301.4°C to 2,336.5°C (Bednářová, Merklová 2006).

It is evident that the onset and the course of particular phenological stages were very variable being subject to the effect of temperature changes, particularly in the spring season. In 2006, low temperatures with the long-term snow cover were registered until April. Therefore, the onset of the stage of budbreak and the beginning of foliage in monitored species slightly fell behind compared to previous years.

Effects of temperature on the onset and duration of the stage of budbreak and the beginning of foliage became evident in all monitored species most markedly. Because of a rapid increase in temperatures in May 2006, the duration of the stage of the beginning of foliage was considerably shortened and full foliage occurred earlier in that year. 2007 was a very extreme year from the aspect of the early onset of spring vegetative phenological stages in all monitored species. In that year, a marked shift was noted in the onset of particular stages as compared to previous years.

To characterize the onset of monitored phenological stages sums of effective temperatures above 5°C and 0°C were evaluated (Figs. 2 to 9).

It turned out that in 2006 and 2007 the spring phenological stages occurred at lower effective temperatures than in previous years and, on the other hand, the autumn phenological stages started at higher effective temperatures. The results obtained signalize warming in autumn months at the monitored locality. If we compare the monitored period 2004 to 2007 with the long-term 16-year mean there is an evident trend of increasing temperatures particularly in the large growing season (Figs. 10 and 11).

Mean monthly air temperatures in the large growing season were lower on the ten-year mean in the period 1991 to 2000 than in the period 2001 to 2007. The most marked differences are in spring months (Fig. 11), which is also evident from the onset and duration of phenological stages. It is possible to characterize the year 1991 as an extreme year with late onsets of phenological stages and the year 1994 as the warmest year. In the second monitored stage,

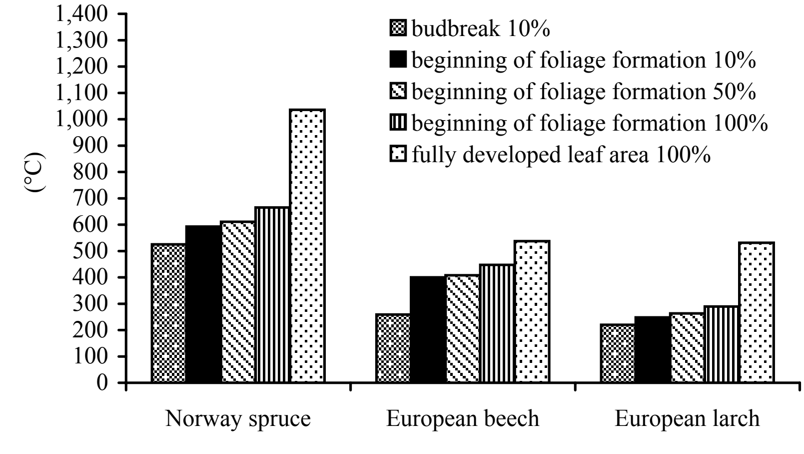

Fig. 8. Temperature sums above 0°C – spring, summer 2007

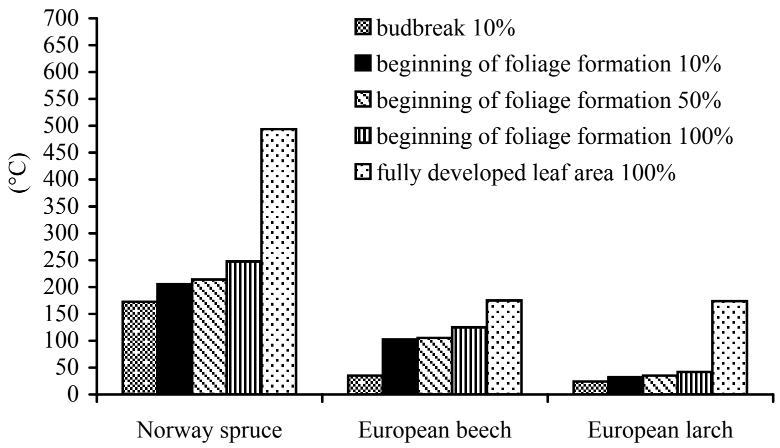

Fig. 9. Temperature sums above 5°C – spring, summer 2007

2000 can be considered as the warmest year and 2007 is characterized by very mild winter and high temperatures in the spring season. The autumn phenological stages were affected not only by temperatures but also by air humidity. The favourable precipitation situation in August and September 2005, 2007 and in August 2006 (Table 1) and higher temperatures during September and October compared to the previous year resulted in a longer period from the beginning to the end of leaf yellowing and leaf fall.

Warmer autumns would lead to earlier fruit ripening but delayed leaf senescence. Autumn plant events also tend to be more difficult to define and are subject to sudden individual weather events such as a single frost or high winds. Available data suggest a delay in autumn events in recent years (Sparks, Menzel 2002).

Table 2. Correlations between the onset of the stage of flowering in monitored tree species and mean air temperature in 2004 to 2007

	Correlation coefficient	R^2
Norway spruce	–0.9611	0.714
European beech	–0.8453	0.923
European larch	–0.7984	0.637

Statistical characteristics – the dependence of the onset of phenological stages on the sum of effective temperatures

Statistical processing showed the highest variability in Norway spruce and European beech in

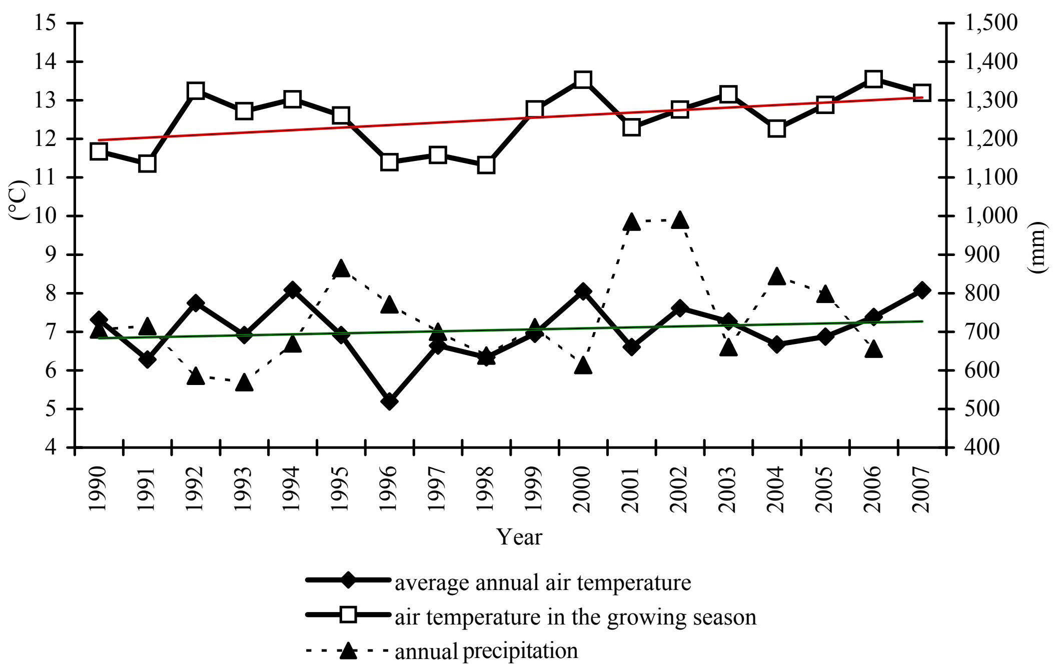

Fig. 10. Average annual air temperatures and annual precipitation in 1990–2007

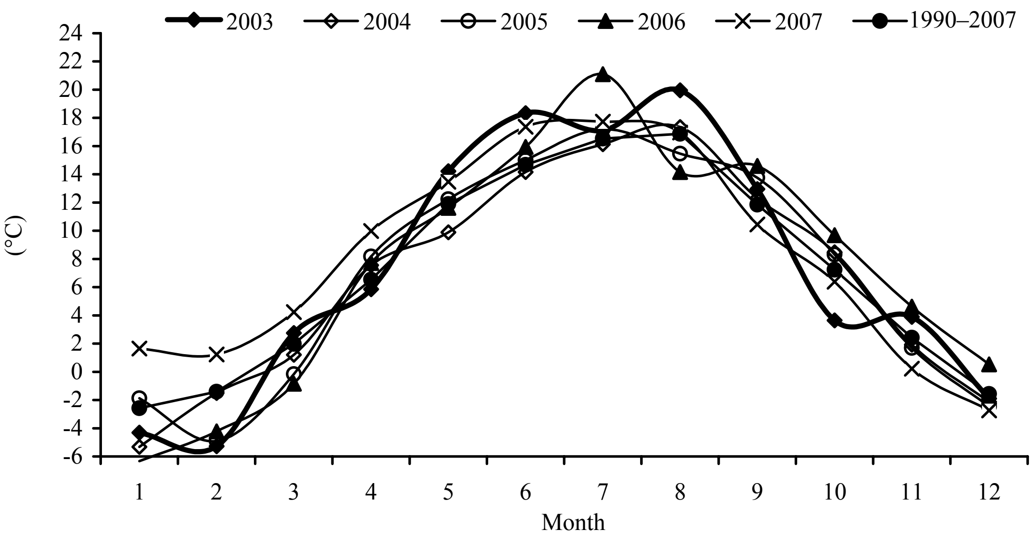

Fig. 11. Mean monthly temperatures in 2003–2007

the phenological stage of full 100% foliage. In European larch, it was the stage of the beginning of 100% foliage. On the contrary, the lowest variability was observed in the stage of 100% leaf yellowing in deciduous species and 10% budbreak in spruce. To evaluate the relations by means of the sums of effective temperatures above 5°C the stage of budbreak was most important of all monitored stages. Differences in the onset of phenological stages of the Norway spruce budbreak and of the beginning of foliage in European beech and European larch in a mixed stand in 2004 to 2007 are given in Fig. 12. Phenological stages copy the course of weather in the particular years. The most marked effect of air temperature on the onset of phenological stages was recorded in 2007, when high temperatures in the winter and early spring season started the development of plants very early.

A close relationship between the onset of phenological stages and air temperature in a period before the onset of monitored stages is demonstrated by calculated negative correlation coefficients (Table 2 and Fig. 13). The dependence of budbreak on air temperature became evident most markedly in tree species. In all monitored species, correlation coefficients were statistically significant ($\alpha > 0.001$). Determined correlations correspond with the results of other authors. Braslavská and Kamenský (1999) and Luknárová (2001) reported the highest correlation of the onset of the phenological stage of budbreak in spruce with air temperature in February to May. They also evaluated the beginning of flowering in Norway spruce and found the highest correlation between flowering and air temperature in March to May. Škvareninová (2003) evaluated the phenological observations of forest tree species of the Zvolen upland and mentioned the earlier onset of phenological stages by 9 days. Schieber (2006) also stated that the trend of the average onset of leafing showed a shift to earlier dates by about three days. Sparks and Menzel (2002), Sparks et al. (2006) reported a high correlation between air temperature

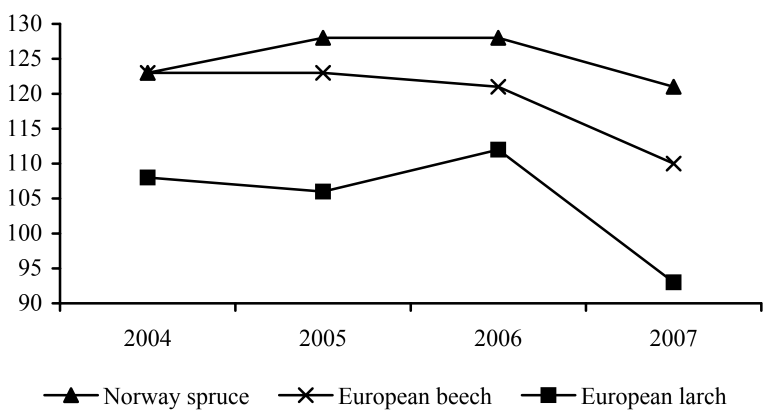

Fig. 12. Differences in the onset of phenological stages of budbreak in Norway spruce and of the beginning of foligae in European beech and European larch in a mixed stand in 2004–2007

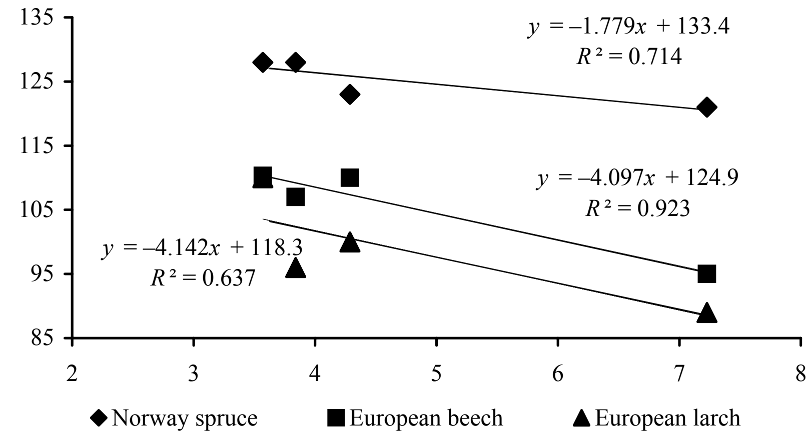

Fig. 13. Dependence between the onset of phenological stages and air temperatures

in spring months (March, April) and phenological stages of foliage and flowering of plant species and always more frequent onset of phenological stages due to increasing temperatures.

CONCLUSION

The paper evaluates the results of phenological monitoring of the tree layer in a mixed stand in the region of the Drahanská vrchovina Upland in 2004–2007. The onset and duration of particular phenological stages are described in monitored tree species in a 4-year period depending on effective temperatures at a threshold temperature of 0 and 5°C and a comparison for the 16-year period of monitoring in the given region is presented. Although growth and developmental processes are conditioned particularly genetically, a considerable role is also played by temperature and humidity together with site properties. The dates of the onset and course of particular phenological stages differed in the monitored stand depending on temperature conditions in the particular years. Particularly spring phenological stages were affected by air temperature during early spring.

The previous long-term monitoring proved that the moisture regime in spring months was sufficient in the region. The sum of temperatures activating the beginning of vegetation and the onset of the particular phenological stages are decisive. To evaluate the temperature demands of monitored species the cumulative sum of temperatures according to a threshold value T5°C and T0°C was used. The long-term monitoring of phenology and photosynthetic processes of trees in the region shows that physiological processes in trees take place only at a temperature above 5°C. Therefore, it is more suitable to take into account the sum of cumulative temperatures TS 5°C in the region.

The results obtained show that earlier onsets of phenological stages occur at lower effective temperatures in the monitored area. The effect of temperature was most important for the onset of spring phenological stages in European larch. High correlations were noted with air temperature 2 months before the onset of the stage of budbreak in forest trees. Owing to high temperatures in the autumn months the growing season is extended while the period of dormancy is shortened, which has a very important impact on forest trees. The extension of the growing season during a long time period can induce disturbances of physiological processes in forest trees and subsequently also their decline particularly in the species occurring at allochthonous sites.

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Výsledky fenologického sledování stromového patra smíšeného porostu v oblasti Drahanská vrchovina

ABSTRAKT: V práci jsou uvedeny výsledky sledování fenologie u smrku ztepilého (*Picea abies* [L.] Karst.), buku lesního (*Fagus sylvatica* L.) a modřínu opadavého (*Larix decidua* Mill.) ve smíšeném porostu v letech 2004 až 2007. Získané výsledky ukázaly rozdílný nástup a trvání fenologických fází v jednotlivých letech. Široké rozpětí bylo významné u jarních fenofází. Byly zjištěny vysoké korelace mezi průměrnou teplotou vzduchu a nástupem fenologických fází u sledovaných dřevin. Nástup a trvání podzimních fenologických fází jsou ovlivňovány nejen teplotou, ale i vlhkostí. Roční variabilita v nástupu a průběhu fenologických fází u lesních dřevin ukázala, že kromě genetických faktorů jsou také důležité vnější podmínky, zejména meteorologické faktory ovlivňující jejich nástup a trvání. Vztahy mezi nástupem fenologických fází a změnami meteorologických parametrů byly vyjádřeny sumou efektivních teplot vzduchu vyšší než 0 a 5 °C. Při vyhodnocení závislostí pomocí sum efektivních teplot nad 5 °C byla nejvýznamnější u všech sledovaných dřevin fáze rašení.

Klíčová slova: fenologie; efektivní teploty; vegetační období; klimatické změny

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