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MONITORING THE SPRING PHENOLOGICAL STAGES IN A SPRUCE MONOCULTURE IN THE DRAHANSKÁ VRCHOVINA UPLAND IN 2005–2011

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Abstract

BEDNÁŘOVÁ, E., TRUPAROVÁ, S., MERKLOVÁ, L.: *Monitoring the spring phenological stages in a spruce monoculture in the Drahanská vrchovina upland in 2005–2011.* Acta univ. agric. et silvic. Mendel. Brun., 2012, LX, No. 6, pp. 15–20

The paper evaluates the onset and duration of spring vegetation phenological stages in a spruce monoculture of the third age class in relation to changing parameters of the environment in the region of the Drahanská vrchovina Upland. Temperature requirements of Norway spruce necessary for the onset particular phenological stages were evaluated on the basis of sums of effective temperatures > 5 °C. The period of 2005–2011 is processed in relation to long-term monitoring since 1991. Based on results obtained, there is considerable variability owing to changing climatic conditions in the onset of spring phenological stages in the course of monitored years. In recent years, the earlier onset of spring phenological stages occurs and their duration gets shorter. This phenomenon is caused by higher air temperatures in spring months. The statistical processing of results obtained demonstrated the high dependence of the onset of particular phenological stages on the temperature of air and soil. Particular factors affecting budbreak and foliation cannot be detached and thus, it is necessary to be evaluated as a complex of influences. Long-term phenological studies of forest trees can serve as the bioindicator of climatic changes.

Norway spruce (*Picea abies* /L./ Karst.), monoculture, phenological stages, weather, effective temperature, soil temperature, environment

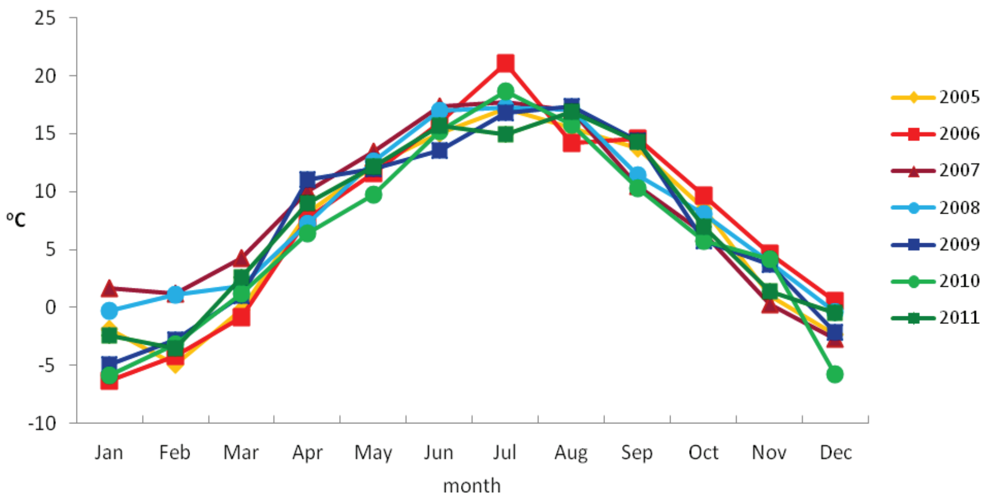
Phenological stages express biological limits. Within the limits demands of plants on conditions of the external environment are studied (Kurpelová, 1980; Bednářová, Merklová, 2007; Merklová, Bednářová, 2008). In addition to genetic factors, variability of the onset and duration of phenological stages of forest trees is considerably affected by meteorological factors. Phenological monitoring can characterize the growing season duration in studied regions. The phenology of forest trees can be used at the evaluation of the effect of actual conditions of the environment on the development of plant communities and thus to contribute to the discussed question of climatic changes and their impacts on the species composition and health conditions of forest ecosystems (Bednářová, Merklová, 2011). Climatic changes can result in the time shift of the onset of phenological stages and disturbances in their further development. Through the analysis of these manifestations it is possible to obtain information on the actual condition and development of all components of the environment, the climate character of the given area but also information on genetic manifestations of particular populations in the studied area (Škvareninová, 2009, 2010). The importance of phenological monitoring becomes evident in the knowledge of developmental relationships between phenological trends of populations and the development of climatic parameters as documented by some papers (Bauer, 2007; Škvareninová, Snopková, 2010). The effect of climatic changes on forest stands is a long-term phenomenon requiring multiyear monitoring. Forest trees as long-lived plants can be considered as bioindicators of climatic changes. Only long-term time series of phenological examinations, possibilities of comparing various localities on the Earth and the knowledge of temperature changes in the course of time are a condition for the successful use of phenology in problems of evaluating climatic changes (Koch *et al.*, 2005).

MATERIAL AND METHODS

Phenological stages in a pure spruce stand (the third age class) were studied on a research plot of the Institute of Forest Ecology, Mendel University in Brno. The research area is defined by coordinates 16° 41´30´´ E and 49° 26´31´´ N in the geographical unit of the Drahanská vrchovina Upland. Climatically, the area is classified as moderately warm and moderately humid with a long-term mean annual temperature 6.6 °C and 683 mm annual precipitation (composite authors 1992). Fig. 1 and Tab. I demonstrate precipitation and temperature characteristics of the locality. Phenological observations were carried out according to methods of the ČHMÚ (1987) /Czech Hydro-meteorological Institute/. Phenological stages were monitored at ten trees of Norway spruce (*Picea abies* /L./ Karst.) of the same provenance. During the spring season (April to June), phenological monitoring was carried out 3 times a week. Following phenological stages were observed: budbreak from 10%, foliation beginning from 10%, foliation beginning from 50%, foliation beginning from 100% and full foliation (100% unfolded leaf area). The day ordinal number from the beginning of a calendar year was assigned to the date of particular phenological stages. Air temperatures in the studied stand were monitored by means of the Datalogger Minikin T sensor placed on the lower margin of crowns. For monitoring the amount of precipitation the Climatronic rain gauge and datalogger MicroLog ER were installed in the open area. The soil temperature was measured by the MicroLog SP sensor at a depth of 20 cm.

RESULT AND DISCUSSION

The presented paper is related to a study, which is carried out at the studied locality since 1991 and results obtained have been already partly published



1: *Monthly averages of air temperature in the years 2005–2011*

I: *Total precipitation in the years 2005–2011*

Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	∑
2005	64.0	64.0	20.0	37.0	97.0	39.0	99.0	90.0	73.0	3.0	31.0	83.0	**700.0**
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**
2008	25.0	9.0	46.7	52.0	37.3	51.0	164.0	62.0	61.5	25.1	24.6	24.4	**582.7**
2009	14.0	39.1	87.4	8.1	43.7	84.3	193.8	30.7	16.3	49.8	41.1	47.8	**656.1**
2010	1.5	50.8	11.2	67.6	138.4	102.1	107.7	114.3	96.0	9.1	41.4	37.3	**777.5**
2011	12.4	9.7	36.1	36.6	74.0	54.0	125.0	65.0	39.0	35.0	1.0	17.0	**504.7**

(Bednářová, Kučera, 2002; Bednářová, Merklová, 2007; Bednářová, Merklová, 2011). The start and duration of particular phenological stages change according to the character of weather in particular years, which results from data obtained. The response of the onset and duration of phenological stages on the air temperature at Norway spruce (*Picea abies* /L./ Karst) has been evaluated by means of cumulative sums of effective temperatures.

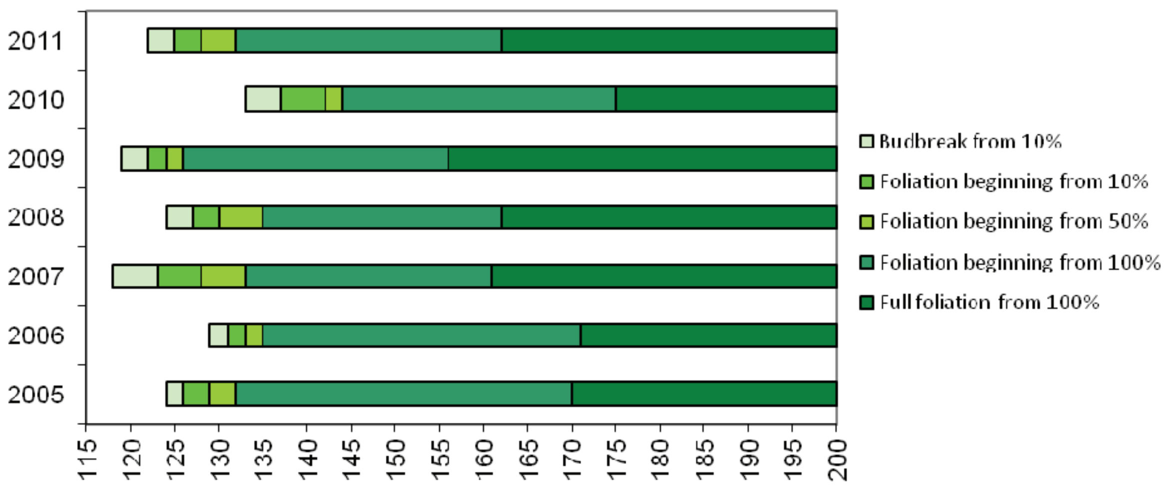
Response of phenological stages on the variability of weather

The time course of phenological stages in a spruce monoculture is evident in Fig. 2. A phenological stage of the budbreak beginning occurred on average the 124th day from the calendar year beginning in 2005 to 2011, i.e. one to two days earlier compared to a long-term average (1991 to 2011). A stage the start of foliation from 10% was determined for the evaluated period the 127th day, which is 2 days earlier compared to the long-term average. The beginning of foliation from 50% was on average (2005–2011) the 130th day, i.e. 3 days earlier compared to a long-term average. A phenological stage the beginning of foliation from 100% occurred in 2005 to 2011 the 134th day from the year beginning and in the long–term average the 137th day. A phenological stage of the full foliation (100% unfolded leaf area) occurred the 165th day from the beginning of the calendar year. Monitoring spring vegetation stages in a spruce monoculture showed that during the 21-year period their onset and duration differed depending on climatic parameters of particular years. Among the onsets of phenological stages in monitored years there was a considerable range. At the phenological stage of budbreak, the range took 15 days, at the phenological stage of the beginning of foliation from 10% 16 days, at the start of foliation stage from 50% 18 days and at the start of foliation stage from 100% 17 days. The widest interval was noted at the stage of full foliation, namely 27 days.

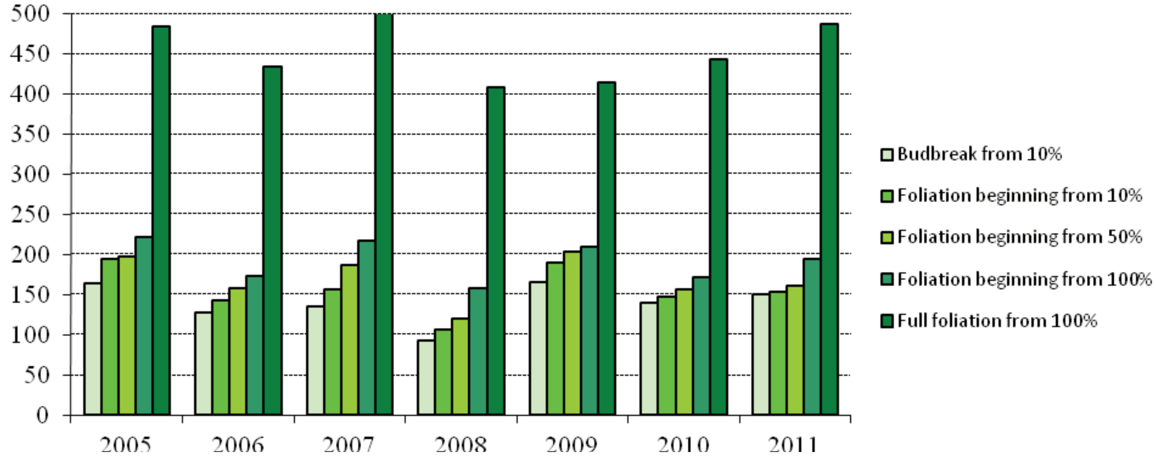
When comparing results obtained from a former season (Bednářová, Kučera, 2002; Bednářová, Merklová, 2011), we can see that in recent years, the earlier onset of spring phenological stage occurs. Results presented consist also with data of other authors who mention that in resent years, the earlier onset of phenological data occurs particularly in the spring season (Škvareninová, 2009; Bagar, Nekovář, 2007; Možný, Nekovář, 2007). Measured data prove that the variability of onset and the duration of phenological stages at forest trees are considerably affected by meteorological factors. As a result of higher temperatures the earlier onset of phenological stages occurs as well as shortening their duration, extending the growing season till the late autumn at the expense of the rest season. These findings correspond also to results of other authors (Menzel *et al.*, 2003; Seidel, 2005; Sparks, 2006).

Effective air temperatures on the onset and duration of phenological stages

Larcher (2003) mentions that for the budbreak of trees of a temperate zone, a daily temperature > 5 °C is important. The sum of effective temperatures preceding the respective stage is a decisive characteristic for the evaluation of the budbreak start and the onset of other phenological stages. Determined sums of effective temperatures in particular years for the onset of monitored phenological stages are evident from Fig. 3. For the studied season 2005 to 2011, the sum of effective temperatures for the budbreak beginning was on average TS5 = 139.4 °C. The start of foliation from 10% was conditioned by a sum TS5 = 155.8 °C. The sum of effective temperatures TS5 = 169.3 °C preceded the beginning of foliation from 50%. The start of foliation from 100% occurred at the sum of effective temperatures TS5 = 192.5 °C. The phenological stage of full foliation occurred on average (2005–2011) at TS5 = 453.2 °C.



2: *Onset end duration of vegetative phenological stages in a spruce monoculture*



3: *Sums of air temperature over 5 °C from phenological stages at Norway spruce in the years 2005–2011*

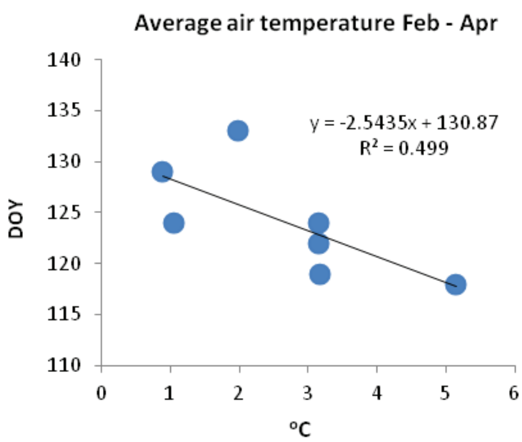
Determined dependences correspond also to results of other authors (Bednářová, Kučera, 2002; Merklová, Bednářová, 2008; Škvareninová, Snopková, 2010; Bednářová, Merklová, 2011). The high correlation of the onset of spring phenological stages at Norway spruce with air temperatures in February to May was mentioned by Luknárová (2001), Braslavská, Kamenský (1999). Above all, spring phenological stages are affected by air temperatures during the early spring. The previous long-term monitoring proved that, in this region, the humidity regime during spring months was sufficient for the start of vegetation. The sum of temperatures activating the start of phenological stages is decisive for the onset of the stages. Monitoring the phenological and growth processes of trees in this region prove in the long term that physiological processes in trees occur only at air temperatures > 5 °C and, therefore, it is suitable to consider the sum of cumulative temperatures TS 5 °C at this locality. Results obtained show that in recent years, the onset of spring phenological stages occurs earlier at the higher sum of effective temperatures and shorter duration of particular stages.

Effects of soil temperatures on the budbreak and start of foliation

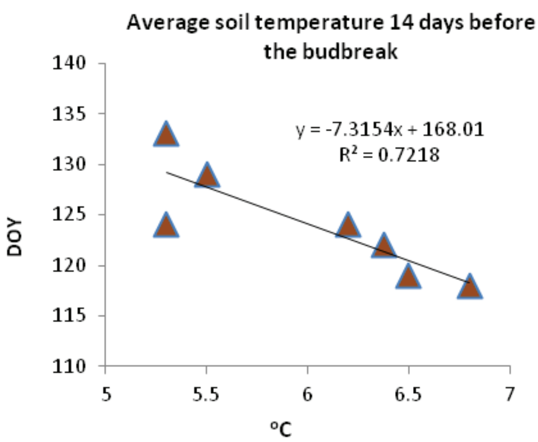
The start of budbreak and foliation is affected not only by air temperatures but also by soil temperatures because these two values are interrelated. Lavander *et al.* (1973), Timis and Woral (1974) and Bednářová, Kučera (2002) mention that soil temperatures show a considerable role in the phenology of budbreak. Particular factors affecting budbreak and the start of foliation cannot be detached and it is necessary to be evaluated as the whole complex of factors. To determine the rate of dependence of these two microclimatic factors in the studied stand linear regression was carried out between the air temperature and soil temperature (Fig. 4 and Fig. 5).

CONCLUSIONS

It follows that in recent years, the earlier onset of spring phenological stages occurs and shortening



4: *Budbreak as a function of average air temperature*



5: *Budbreak as a function of soil temperature* the length of their duration owing to higher air temperatures in spring months. A phenological stage of the start of budbreak began in the evaluated season (2005–2011) on average the 124th day from the year beginning, i.e. earlier as compared to the long-term monitoring (1991–2011). A stage of the start of foliation from 10% began 3 days earlier compared to the long-term average. As well as the beginning of foliation from 50% was noted 3 days earlier. Also a stage of the start of foliation from 100% was noted 3 days earlier as compared to a long-term average. Measured data prove that the variability of the onset and duration of phenological stages of forest trees are considerably affected by changing climatic conditions. Temperature requirements of particular tree species at the beginning of particular phenological stages are best expressed by sums of effective temperatures. The lowest determined sum of effective temperatures (2005–2011) when the budbreak occurred was TS5 = 92.6 °C. The highest measured sum (in 2009) for budbreak was TS5 = 166.0 °C. The beginning of foliation from 10% was conditioned by a minimum temperature 106.6 °C. The highest sum for this stage was 157.0 °C. For the beginning of foliation from 50%, the sum of effective temperatures 120.6 °C was sufficient. The measured maximum for this stage was 204.0 °C. The start of foliation from 100% occurred already at the sum of temperatures 158.6 °C. A maximum measured value (in 2009) for this stage was TS5 = 210.0 °C. A phenological stage of the fully unfolded leaf area occurred at the lowest sum of effective temperatures 408.0 °C and the highest sum at this stage was TS5 = 502.0 °C. Correlation coefficients show significant dependence of the onset of spring phenological stages on the foregoing air and soil temperature. Long-term phenological monitoring can serve as a reliable bioindicator of climatic changes. In recent years, above-average air temperatures were repeatedly measured at lower precipitation totals in autumn months. This phenomenon results in lengthening the growing season to late autumn at the expense of a rest period. Repeated shortening the dormancy can negatively affect the health condition of stands occurring particularly at allochthonous sites. Long-term phenological studies in relation to monitoring parameters of the environment can serve as reliable bioindicators of climatic changes.

SUMMARY

The presented study evaluates monitoring spring growing stages of Norway spruce (*Picea abies* /L./ Karst.) in a spruce monoculture of the third age class in the region of the Drahanská vrchovina Upland in relation to changing parameters of the environment. The study is part of a long-term monitoring at this locality. Temperature requirements of Norway spruce for the onset of particular phenological stages were evaluated on the basis of sums of effective air temperatures. The paper includes the period of 2005 to 2011 and compares it with evaluated results obtained during the 21-year period of monitoring. The onset and duration of monitored phenological stages differed in particular years depending on the course of weather. The response of phenological stages on the variability of weather is evident from the given range of the beginning of particular phenological stages during the period 1999 to 2011. The start of budbreak occurred in this period within 15 days, the beginning of foliation from 10% within 16 days, the beginning of foliation from 50% 18 days and the beginning of foliation from 100% 17 days. The widest range was detected at the phenological stage of full foliation (totally unfolded leaf area), namely 27 days. Results obtained prove that in recent years, the earlier onset of spring phenological stages occurs and the length of their duration shortens. These findings correspond to data on changing parameters of the environment, which are related to warming and lower precipitation totals in this region. Statistical processing proved the high dependence of the onset of spring phenological stages on air and soil temperatures in a time period before the beginning of a monitored phenological stage ($R^2 = 0.499$ for air average air temperature from February to April and $R^2 = 0.722$ for average soil temperature 14 days before budbreak). Therefore, the temperature of soil shows an indispensable role for the beginning of spring phenological stages. These two parameters of the environment cannot be detached because high dependences on them have been statistically demonstrated. At present, phenological monitoring becomes an important bioindicator of changes in the environment conditions.

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