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

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Abstract

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

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

Key words

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

Introduction

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

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

Data and methods

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

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

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

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

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

Table 1. Continued

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

Results and discussion

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

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

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

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

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

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

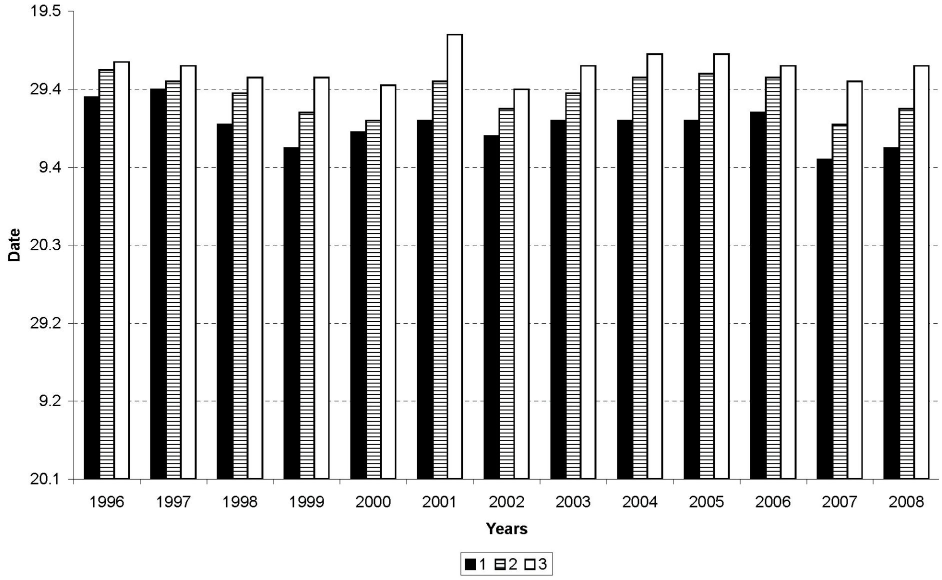

Fig. 1. The mean beginnings of the bud burst stage in the altitudinal groups during the period of 1996–2008.

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

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

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

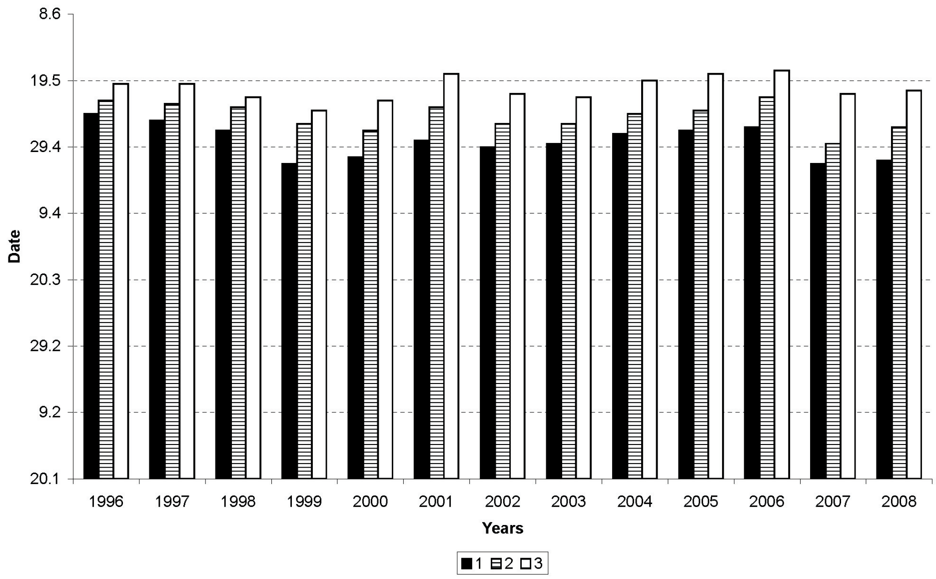

Fig. 2. The mean beginnings of the first May sprouts stage in the observed altitudinal groups during the period of 1996–2008.

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

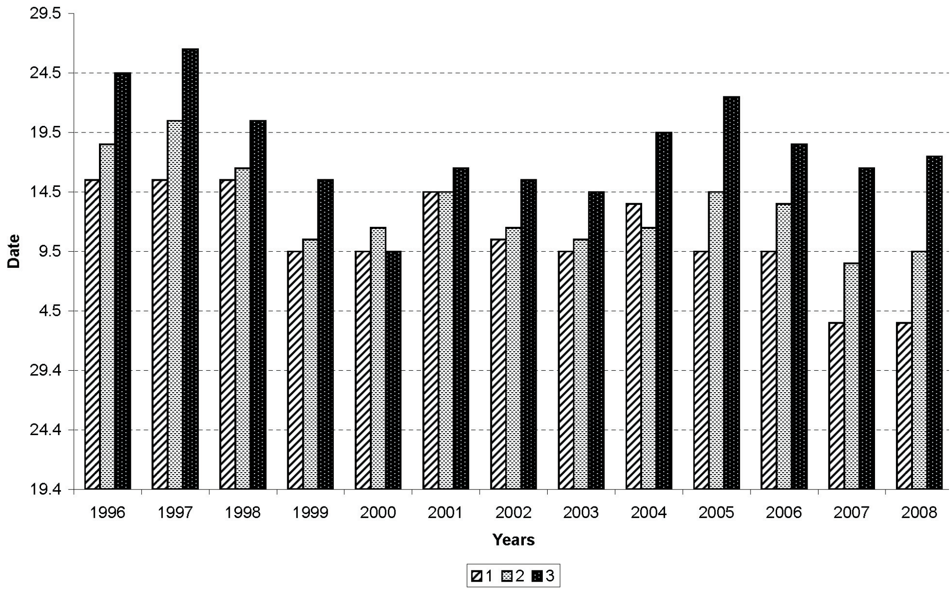

Fig. 3. The mean beginnings of the male flowers lasting stage in the altitudinal groups during the period of 1996–2008.

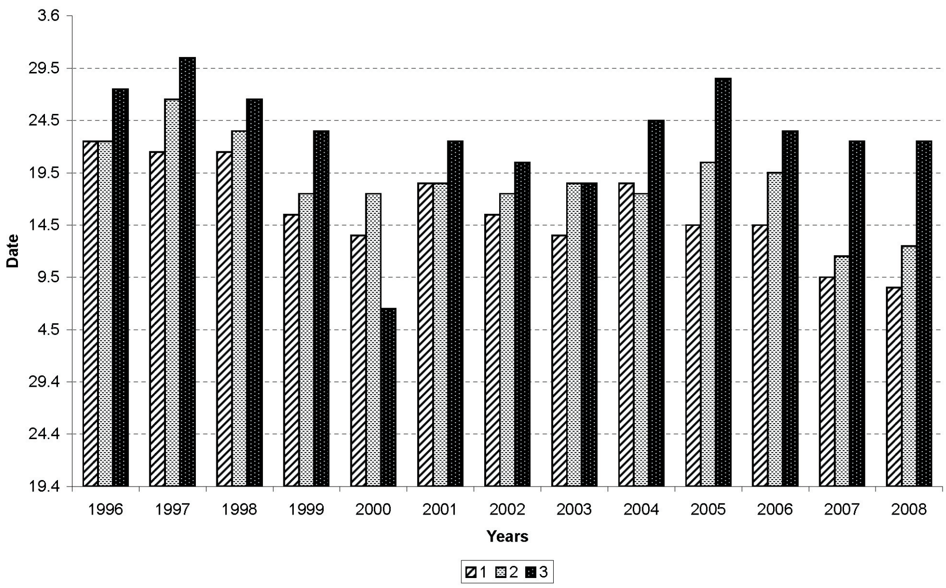

Fig. 4. The mean beginnings of the general flowering stage in the altitudinal groups during the period of 1996–2008.

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

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

+ earling beginning; – later beginning.

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

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

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

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

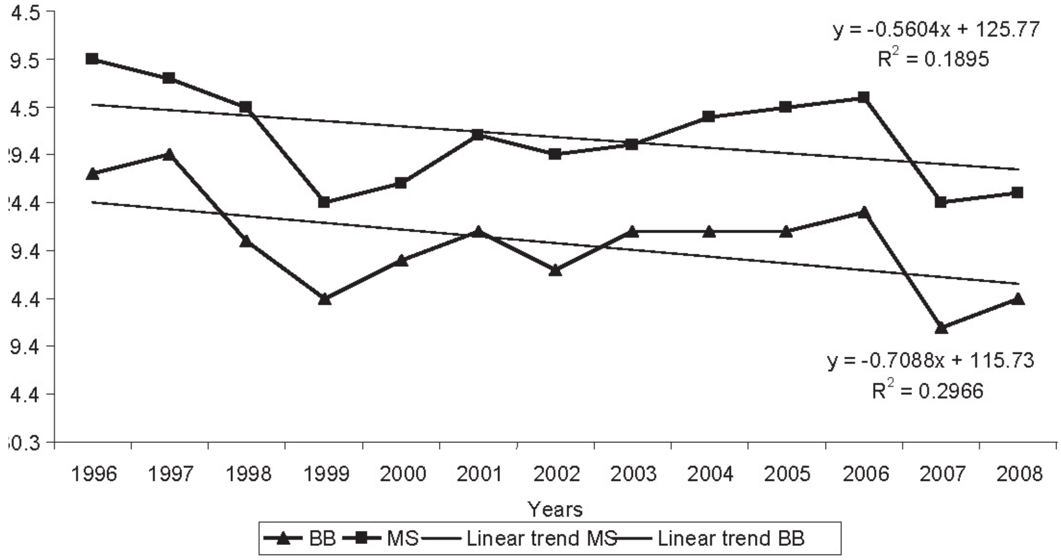

Fig. 5. The average starts of vegetative phenostages in particular years and their trends of development during the period of 1996–2008 in the 1st altitudinal group.

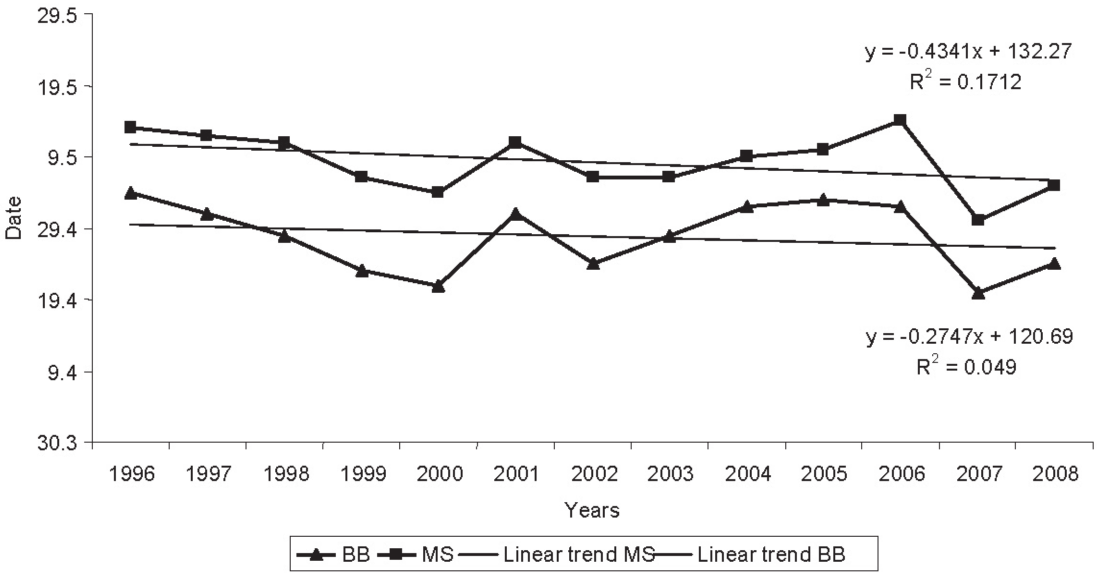

Fig. 6. The average starts of vegetative phenostages in particular years and their trends of development during the period of 1996–2008 in the 2nd altitudinal group.

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

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

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

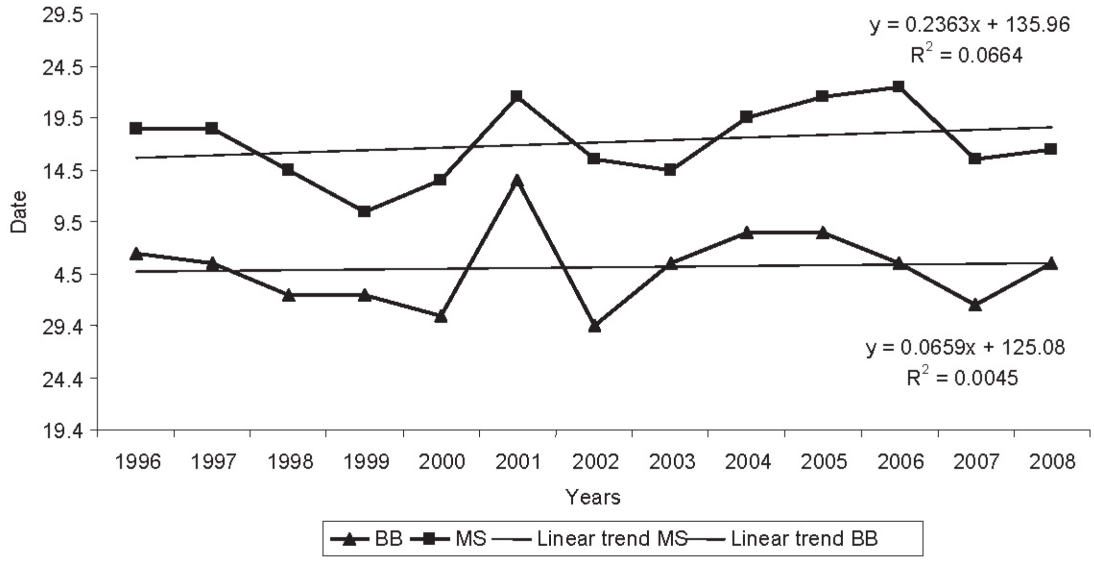

Fig. 7. The average starts of vegetative phenostages in particular years and their trends of development during the period of 1996–2008 in the 3rd altitudinal group.

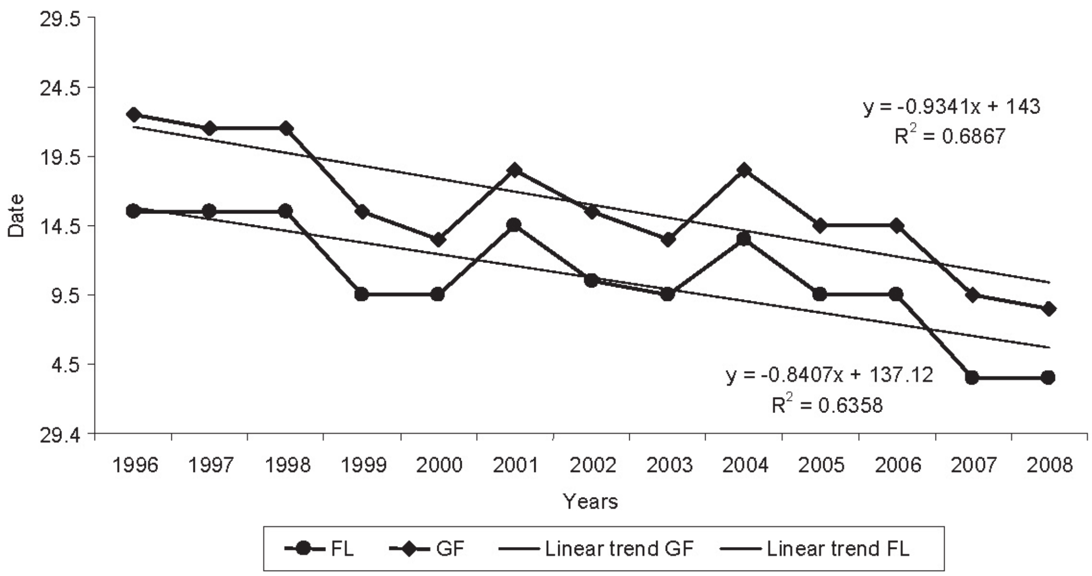

Fig. 8. The average starts of generative phenostages in particular years and their trends of development during the period of 1996–2008 in the 1st altitudinal group.

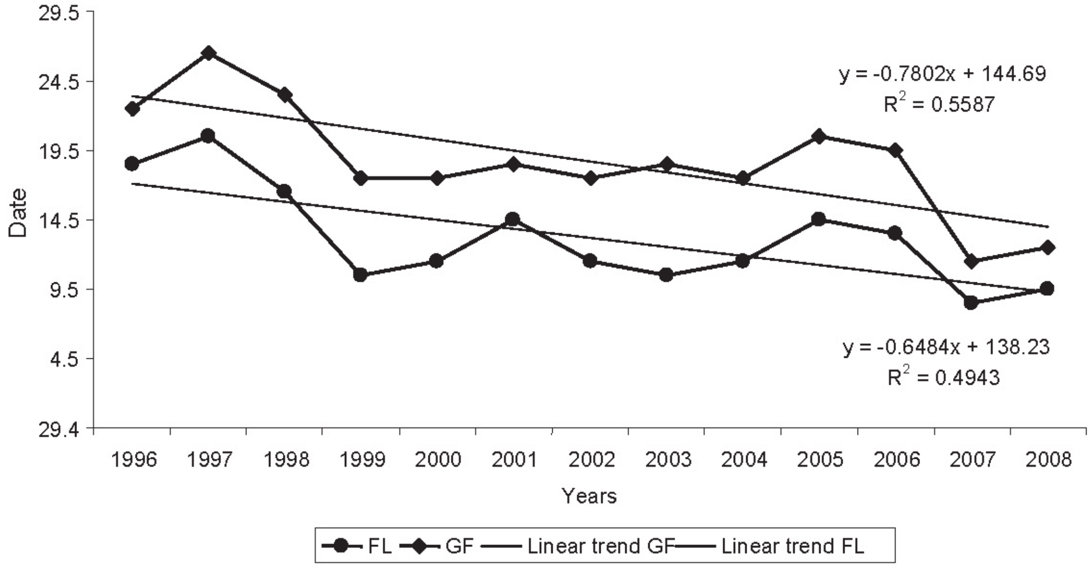

Fig. 9. The average starts of generative phenostages in particular years and their trends of development during the period of 1996–2008 in the 2nd altitudinal group.

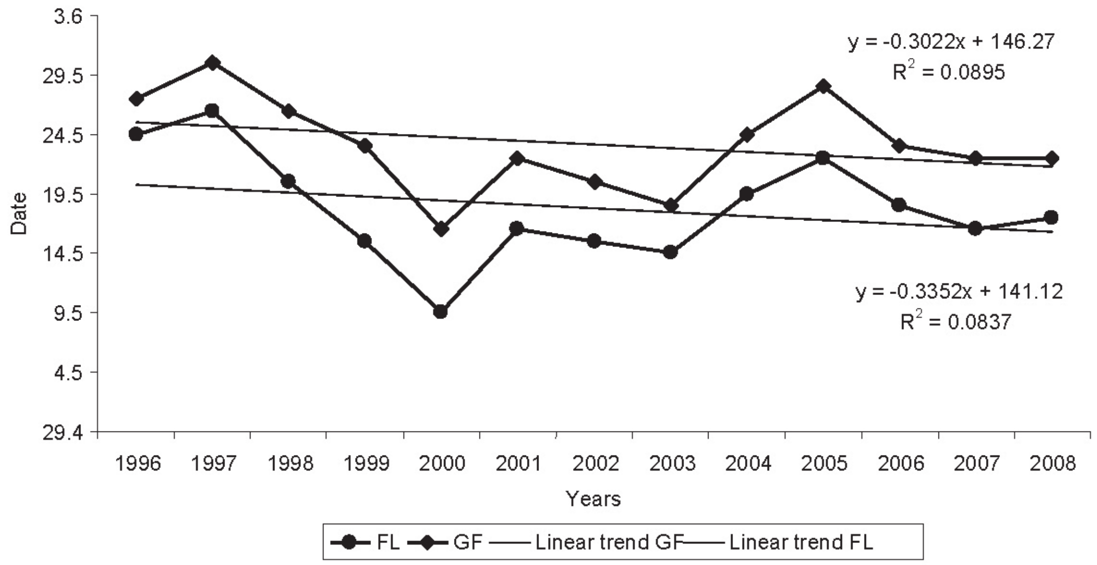

Fig. 10. The average starts of generative phenostages in particular years and their trends of development during the period of 1996–2008 in the 3rd altitudinal group.

Conclusions

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

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

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

Acknowledgement

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

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

Súhrn

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

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

Received December 4, 2009
Accepted July 22, 2010