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Temporal and spatial variability of the most important phenological phases of birch in the Czech Republic

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Abstract

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Phenology is the study of the times of recurring natural phenomena in plants and animals. The Czech Meteorological Service launched its phenological observations in 1940, with a whole data-providing network, including the archives from the year 1923. Today the Czech Hydrometeorological Institute (CHMI) operates with a network of phenological stations encompassing field crops, fruit trees and wild plants, according to the Methodical instructions number 2, 3, 10. There are also observed several very important allergenic species from which birch (*Betula verrucosa* Ehrh.) has been chosen for the subject of this case study – as one of the most frequent allergenic plants in Europe, including the Czech Republic. Its pollen grains are the most important allergen.

Observing phenological phases (flower buttons visible, beginning and end of flowering) is important for identification of the pollen season. At wild plant stations, there are observed these phenophases in *Betula verrucosa* Ehrh: sprouting, first leaves, full leaves, flower buttons visible, beginning and end of flowering, bud creation, lignification of sprouts, yellowing of leaves, defoliation and ripening of fruits.

Temporal and spatial variability in the chosen phenophases (sprouting, first leaves, full leaves, flower buttons visible, beginning and end of flowering) was explored with using statistical (basic statistical characteristics) and GIS methods for the periods 1992–2006 and 1992–2007 with respect to allergenic importance of the phenophases.

Temporal variability was monitored at the phenological stations Lednice (48°48' N, 16°48' E, 165 m asl) and Pernink (50°22' N, 12°47' E, 860 m asl), the spatial variability at 44 stations with MASL (mean above sea level) ranging from 155 m (Doksany – Polabská nížina) to 1102 m (Filipova Huť – Šumava). The results are presented in form of tables and maps. In this case study we observed the following shifts in phenophases (lowland in comparison with mountain): sprouting (22.6 days), first leaves (19.8 days), full leaves (21.6 days), flower buttons visible (26.5 days), beginning of flowering (27.2 days), end of flowering (25.4 days).

Keywords

pollen, birch, phenophase, flowering, allergy season, GIS, sprouting

Introduction

The broadleved tree *Betula verrucosa* Ehrh. by another name *Betula pendula* Roth. is the most widespread species of the *Betula* (birch) genus in Europe. The main reason of its expansion from southern Europe far northwards, and also to higher altitudes in the Alps Mts, is its modesty and resistance against severe climate. The remarkably white bark has probably a very important role in reflecting back a substantial portion of incident solar radiation. The white pigment from the birch bark contains betulin – triterpenic pentacyclic steroid alcohol having an anti-inflammatory effect. This seems to be the ground of adaptability for survival at places

with intensive and long-lasting sunshine. Birch tree is a quick growing species with low demands. It can reach a height of even 25 m and an age of 150 years. This tree is often introduced in restored regions or deforested territories. It's one of the typical pioneer tree species (expressing vigorous growth in youth, early fertility, short life), very active in colonisation of deserted land (abandoned fields, meadows, but above all places with bare soil and dumps). The birch can regenerate very well, especially in mineral soils (sandy and clayey soils) and every locality with sufficient supply of sunshine and at least minimum of moisture. Its seed production capability is high. The low weighing seeds can be wind-transported to long distances (up to 1 km from the parent tree), and therefore the birch invades free areas very easily. Together with pine, for example, birch trees build up the initial phase of forest ecosystems, but from the viewpoint of commercial forestry, there are mostly considered as mere weed. Birch wood is persistent, heating also in humid conditions, but low durable. The discussed species is very important in landscape engineering and it has a high aesthetical value. There have been grown several conspicuous, decorative forms of the species. For its resistance against unfavourable conditions, the birch is often used to create verdures in towns. *Betula verrucosa* is on one hand a decorative and useful species, but on the other, according to the pollen calendar it is a strong allergenic woody plant from March to May. We aimed our examinations especially at phenophases connected with pollen dispersal (flower buttons visible, beginning and end of flowering). The pollen dissemination in the atmosphere over these phenophases, represents a considerable stress for sensitive people. The normal size of pollen grain is 20–30 micrometers (it is about one third of human hair thickness). A number of specific proteins occurring on pollen grain surface can trigger an inadequate (exaggerated) response of the immune system (Fig. 1).

Material and methods

The CHMI operates with a phenological network of wild plants (Fig. 2.), following the concerned methodology (Český hydrometeorologický ústav, 1988). In birch, there are observed the following phenological phases: sprouting, first leaves (10, 50, 100%), full leaves, flower buttons visible, flowering (10, 50, 100%), end of flowering, formation of buds, yellowing of summer leaves, lignification of sprouts, discolouration (yellowing) of autumn leaves (10, 100%), defoliation (10, 100%), ripe fruits. We focus on the phenological phases associated with pollen production (flower buttons visible, flowering) and also on phenophases sprouting, first leaves (10%), full leaves (100%) and defoliation (10, 100%). At present, the birch is observed at 45 phenological stations.

We have subjected to basic statistic processing the data assembled over the period 1992–2007 at two stations situated at different altitudes. Birch is one of the most important allergenic species – that is why we also counted the number of days between the phenophases, especially between the phenophases flower buttons visible – beginning of flowering – end of flowering, which is very important for allergic sensitive person. For providing temporal and spatial pattern of phenophase entrance over the whole Czech Republic, the data have been converted to drawn maps (mean dates of phenophase entrance for period 1992–2006).

The detailed phenophase description represents instruction number 10 in the methodology (Český hydrometeorologický ústav, 1988). Patterns of phenophases are illustrated in the Phenological atlas (2004).

Description of the phenophase sprouting: the covering scales of the bud are partly opened. The tips of new leaves are visible at the bud tops. Only the terminal buds are observed. The date of the entrance of this phenophase is the first day when the number of

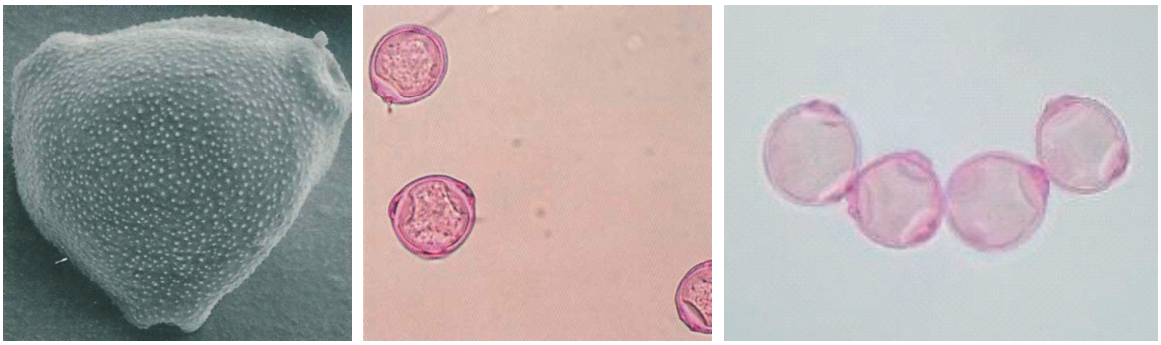

Fig. 1. Birch pollen grains

partly opened terminal buds is higher than 10 percent of the total.

Description of the phenophase first leaves: the whole leaf rib is just visible when examining the adaxial (upper) side of the leaf. The leaf blade is partly developed, but the precedent leaf folding in the bud is still recognisable.

Description of the phenophase full leaves: the leaf-blade is full opened; the whole leaf-stalk is distinctly visible. Form and size of the leaf are characteristic for mature leaf.

Description of the phenophase flower buttons visible: prolongation of catkins (male inflorescence) – the catkin is primarily rigid, with bractes pressed close one to other. Then the catkins most frequently release in the upper third, and bend downwards. In the flexural part, anthers protrude.

Description of the phenophase beginning of flowering: catkins are soft and already opened, anthers are full visible and some of them open and release pollen simultaneously. Entrance of this phenophase is associated with pollen release into the air.

Description of the phenophase end of flowering: the catkins are already empty, turn dark and dry, separate from the tree and fall on the ground.

The maps were processed with using geographic information systems (Application Clidata-GIS). As the input data, there were used the mean dates of phenophase entrance from the period 1992–2006. The maps use a horizontal resolution of 500 meters with reference to altitude (method of local linear regression between the measured or calculated value and the digital relief model). The regression coefficients were calculated for each station, based on the neighbouring stations and in accordance with the least squares method. The coefficients were subsequently interpolated into the space model, and the space distribution of the specific element was calculated by means of map algebra and linear equations.

In total, data from 44 stations with MASL (mean above sea level) ranging from 155 m (Doksany – Polabská nížina) to 1102 m (Filipova Huť – Šumava Mountains) were used for the maps creation. The stations Lednice (165 m) and Pernink (860 m) are described in details in the statistical results. The first station is situated in lowland, the second in mountains, the first in the south and the second in the north of the republic. Both stations have recorded complete time series, without interruption, for the period 1992–2007.

The station Lednice (48°48' N, 16°48' E, 165 m asl.) is situated in southern Moravia, the river basin Dyje, Lednice Castle Park. Birch trees are observed at the locality 1 (this station consists of 2 localities), vegetation unit – dispersed green vegetation, macro-relief – flat ground, geological substrate – clayey drift and combined soil, level of protection – the other categories of non-forest land. Birch locality conditions: micro-relief – flat ground, slope – up to 5 degrees, exposition – the phenological experiment is situated in the nearest parts of locality with given macro-relief, illumination of station – full illumination, humidity conditions – hygromesophyte, initial age – 40–60 years.

Station Pernink (50°22' N, 12°47' E, 860 m asl) is situated in the western part of the Krušné hory Mts, in the river basin Ohře. Birch trees are observed at the locality 1 (station has only one locality), vegetation unit – dispersed green vegetation, macro-relief – flat

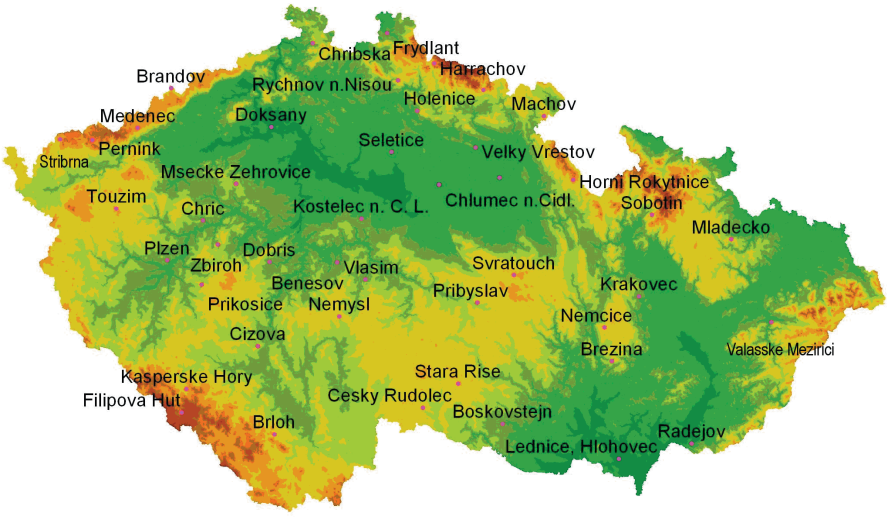

Fig. 2. Phenological network for wild plants

ground, geological substrate – plutonic rock, level of protection – the other categories of non-forest land. Birch locality conditions: micro-relief – flat ground, slope – up to 5 degrees, exposition – experiment is situated in the middle part of the locality with the given macro-relief, illumination of the station – full illumination, humidity conditions – mesophyte, initial age – 10–20 years.

Statistical results (stations Lednice and Pernink, period 1992–2007) in tables (Table 1–10), are given in form of Julian days.

Table 1. Phenophase – Sprouting *(statistical results)*

Station	Average	Standard deviation	Variance	Minimum	Maximum	Variation range	Average – median
Lednice	94.1	3.3	11.2	87 (28. 3.)	101 (11. 4.)	14	0.1
Pernink	116.7	6.4	41.0	102 (12. 4.)	127 (7. 5.)	25	–1.3

Table 2. Phenophase – First leaves *(statistical results)*

Station	Average	Standard deviation	Variance	Minimum	Maximum	Variation range	Average – median
Lednice	100.8	5.8	33.9	90 (31. 3.)	113 (23. 4.)	23	–0.2
Pernink	120.6	6.1	37.7	107 (17. 4.)	132 (12. 5.)	25	–0.4

Table 3. Phenophase – Full leaves *(statistical results)*

Station	Average	Standard deviation	Variance	Minimum	Maximum	Variation range	Average – median
Lednice	121.1	4.6	21.3	112 (22. 4.)	130 (10. 5.)	18	1.1
Pernink	142.7	7.7	60.0	129 (9. 5.)	161 (10. 6.)	32	1.7

Table 4. Phenophase – Flower buttons visible *(statistical results)*

Station	Average	Standard deviation	Variance	Minimum	Maximum	Variation range	Average – median
Lednice	94.2	4.4	19.2	90 (31. 3.)	105 (15. 4.)	15	2.2
Pernink	120.7	8.2	68.1	102 (12. 4.)	138 (18. 5.)	36	–0.3

Table 5. Phenophase – Beginning of flowering *(statistical results)*

Station	Average	Standard deviation	Variance	Minimum	Maximum	Variation range	Average – median
Lednice	97.9	4.3	18.9	93 (3. 4.)	107 (17. 4.)	14	1.9
Pernink	125.1	7.6	58.4	107 (17. 4.)	141 (21. 5.)	34	–0.9

Table 6. Phenophase – End of flowering *(statistical results)*

Station	Average	Standard deviation	Variance	Minimum	Maximum	Variation range	Average – median
Lednice	115.1	5.6	31.3	106 (16. 4.)	126 (6. 5.)	20	0.1
Pernink	140.5	9.0	80.6	122 (2. 5.)	158 (7. 6.)	36	–0.5

Table 7. Average number of days between phenophases *(difference between mean dates)*

Station	Beginning of flowering – flower buttons visible	End of flowering – beginning of flowering	End of flowering – flower buttons visible
Lednice	3.7	17.2	20.9
Pernink	4.4	15.4	19.8

Table 8. Beginning of flowering – flower buttons visible *(statistical results)*

Station	Average	Standard deviation	Variance	Variation range
Lednice	3.7	0.9	0.8	3.0
Pernink	4.4	2.1	4.4	6.0

Table 9. End of flowering – beginning of flowering *(statistical results)*

Station	Average	Standard deviation	Variance	Variation range
Lednice	17.2	4.0	15.7	15.0
Pernink	15.3	4.3	18.5	15.0

Table 10. End of flowering – flower buttons visible *(statistical results)*

Station	Average	Standard deviation	Variance	Variation range
Lednice	20.9	4.2	17.9	16.0
Pernink	19.7	4.9	24.3	18.0

Results

Phenophase: Sprouting

Phenophase entrance: In some localities, the first day of this phenophase is already dated in the period from March 30 to April 4; then, from April 5 to April 18, sprouting starts across the major part of the territory, and the latest entrance of this phenophase is in the mountain areas: from April 17 to April 22, in the highest situated mountain locations even after April 23 (Fig. 3).

Phenophase: First leaves

Phenophase entrance: over 85% of the Czech territory, the phenophase first leaves starts from April 10 to April 21, in the highest situated mountain areas (Krušné hory, Krkonoše, Orlické hory, Jeseníky, Beskydy and Šumava mountains) even after May 4 (Fig. 4).

Phenophase: Full leaves

Phenophase entrance: in lowlands and medium positions, birch is fully foliaged in average from April 29 to May 10, over 85% of the territory of the territory the fully is reached up to May 22. Only extreme mountain positions delay the beginning of this phase to May 23 and later (Fig. 5).

Phenophase: Flower buttons visible

Phenophase entrance: in lowlands and medium positions starts the phenophase flower buttons visible mostly from April 10 to April 20, but in the lowest and most-south situated localities it can be shifted before April 10 (it is the case of the Lednice station, where the mean date is shifted some days earlier, including year 2007). In medium situated areas, flower buttons become visible a few days later – from April 21 to April 25, in mountain positions from April 26 to April 30, and in the highest situated mountain positions starts this phenophase even later than on May 1 (Fig. 6).

Phenophase: Beginning of flowering

Phenophase entrance: for most of territory of the Czech Republic, the start is dated from April 13 to April 24

(at the southernmost located Lednice again few days earlier), at central and partly also at mountain positions from April 25 to May 6, in the highest situated mountain positions later than on May 7 (Fig. 7).

Phenophase: End of flowering

Phenophase entrance: *Betula verrucosa* first ends with blooming from April 25 to May 10 (across 75% of the territory), latest even after May 26 in the highest situated mountain locations (Fig. 8).

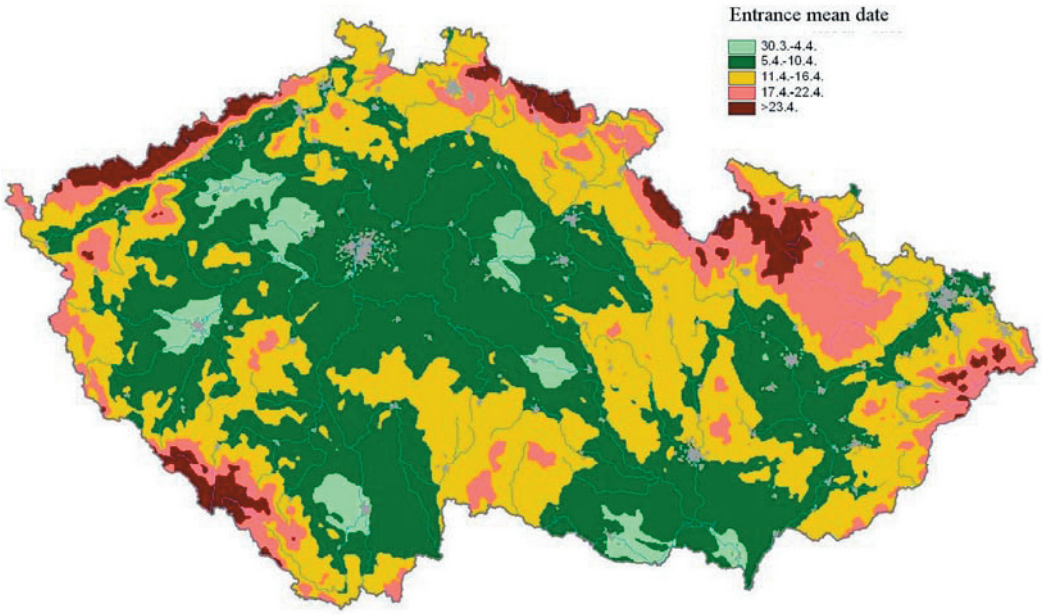

Fig. 3. Phenophase – sprouting, the mean dates for period 1992–2006

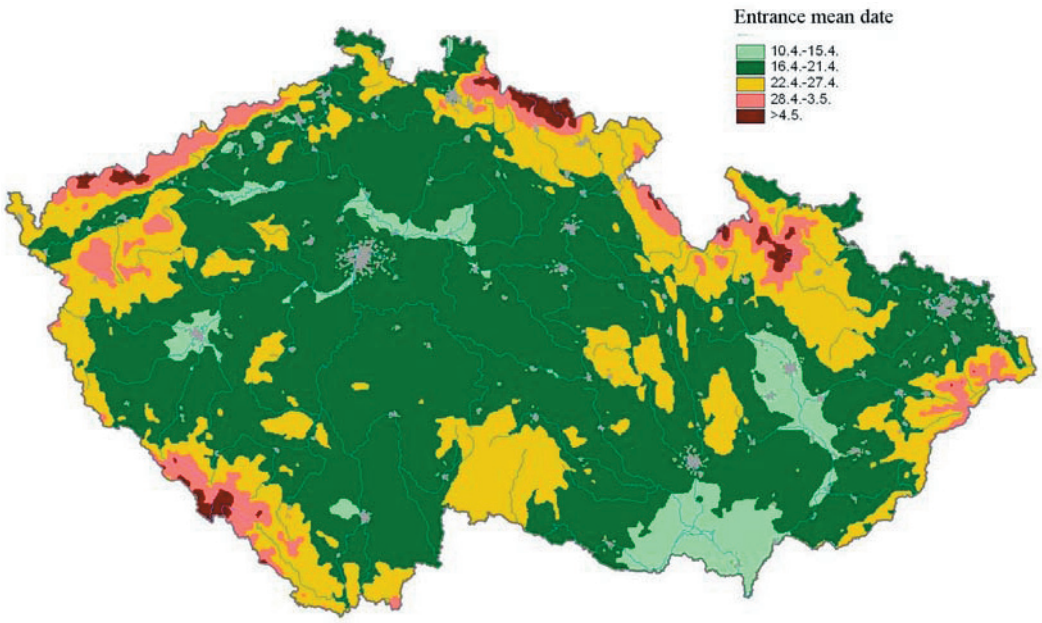

Fig. 4. Phenophase – first leaves (10%), the mean dates for period 1992–2006

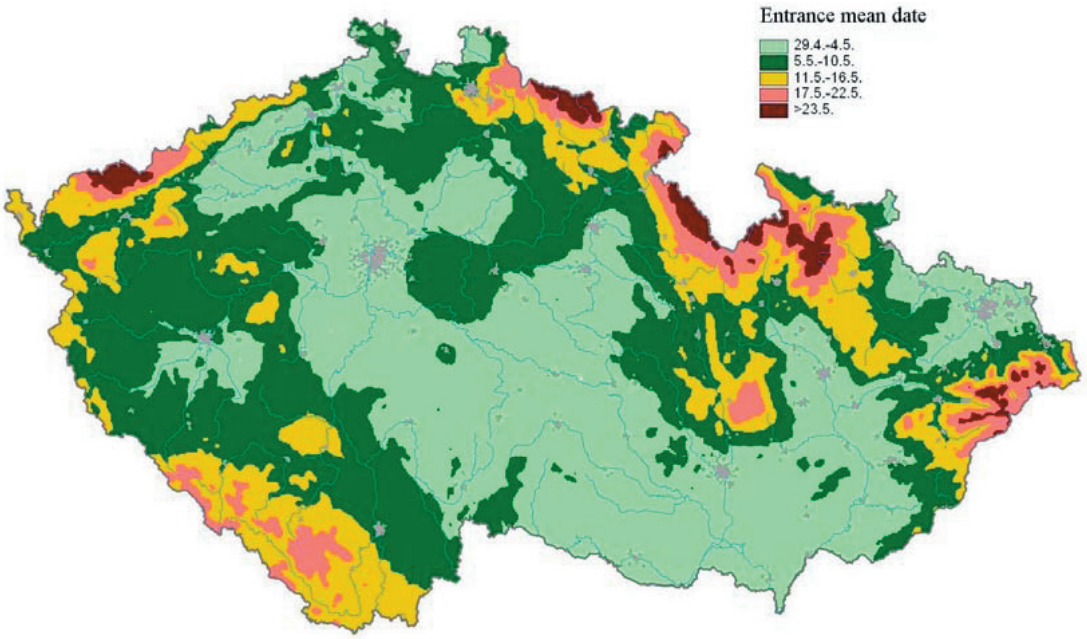

Fig. 5. Phenophase – full leaves, the mean dates for period 1992–2006

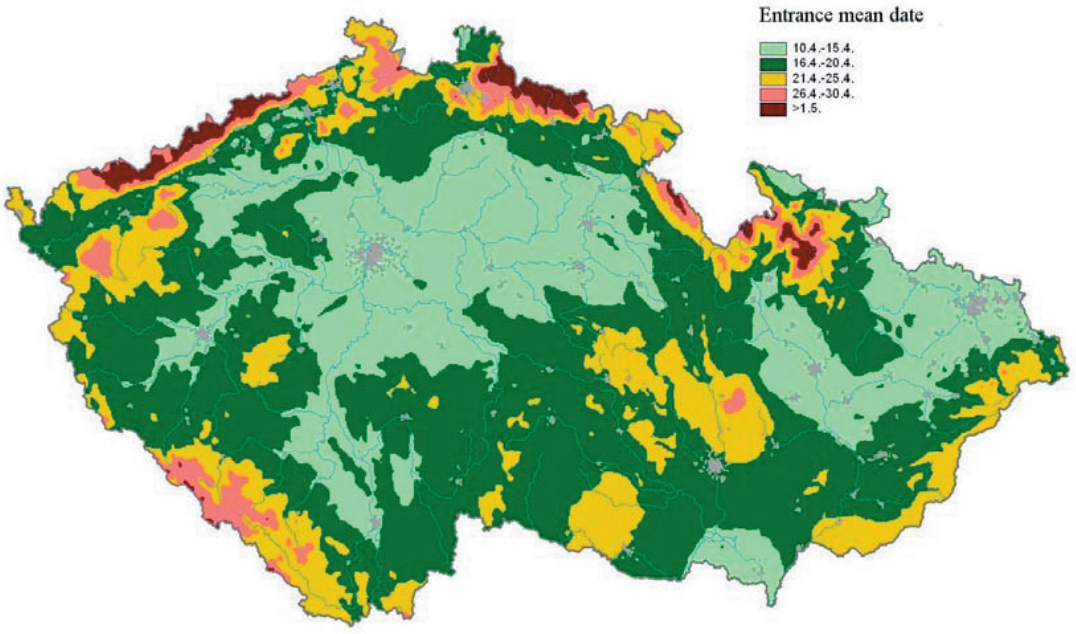

Fig. 6. Phenophase – flower buttons visible, the mean dates for period 1992–2006

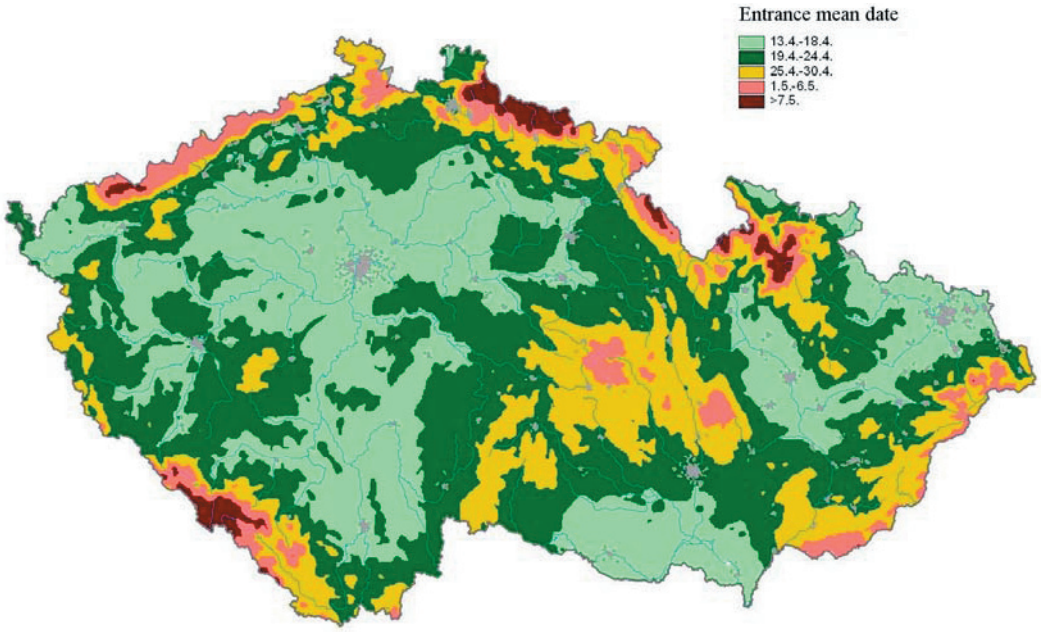

Fig. 7. Phenophase – beginning of flowering (10%), the mean dates for period 1992–2006

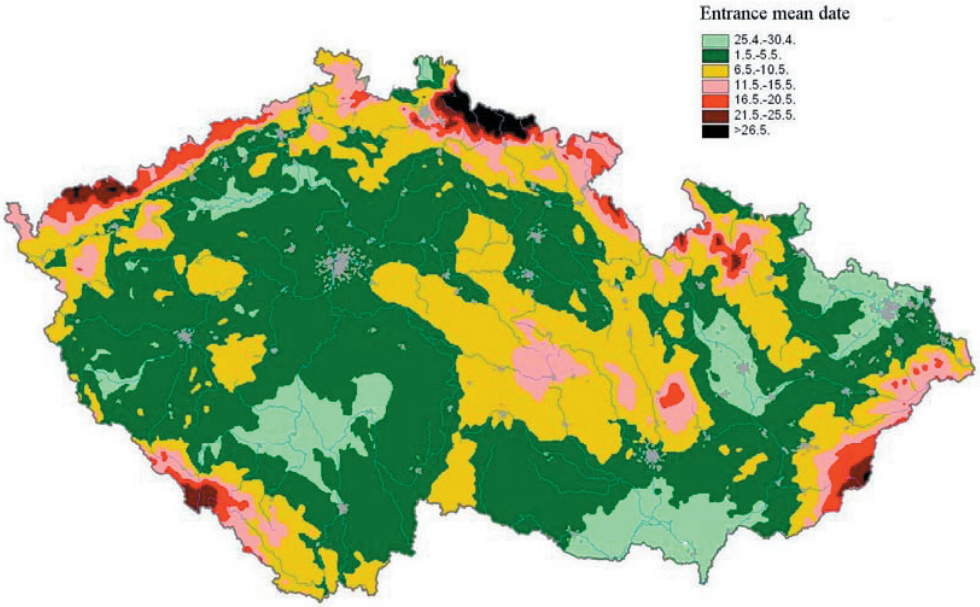

Fig. 8. Phenophase – end of flowering, the mean dates for period 1992–2006

Discussion

The two stations (lowland and mountain) were chosen for a detailed statistical processing of data on phenophases´ entrance. The station Lednice is situated in a lowland of the southern Moravia, the station Pernink is in the north-western part of the Czech Republic. The beginning and duration of phenological phases are influenced by many factors (air temperature, soil temperature, water conditions, position of locality, sunshine duration) together with genetic equipment of the plants. The dependence on altitude and also on aspect is documented in the results. The dating of phenophase entrance is in average earlier in lowlands: the sprouting about 22.6 days earlier, the first leaves about 19.8 days earlier, the full leaves about 21.6 days earlier, the flower buttons visible about 26.5 days earlier, the beginning of flowering about 27.2 days earlier and the end of flowering about 25.4 days earlier. Also for the period 1982–1999, it appears that spring came earlier and the growing season was longer in lowland regions of Fennoscandia, and along most part of the Norway coast (Hogda et al., 2001). Values of variance and also variation range are wider for higher altitudes. The highest variance was determined for the phenophase flower buttons visible (probably for the short time interval of distinguish this phenophase) and the end of flowering. The earliest and the latest phenophase entrance show a wide variance in years 1992–2007. The variation range was found expressively higher (nearly two times) at the mountain station Pernink than in lowland (the flower buttons visible 36 days, the beginning of flowering 34 days and the end of flowering 36 days). Deviation average – median, expressing whether lower or higher values are more important than the median, is in the case of lowland station mostly positive – so it means, that later phenophase entrance is more important. For the mountain station, the contrary was found. In case of phenophases connected with pollen season (the flower buttons visible, the beginning of flowering, the end of flowering), all average – median deviations are positive, by contrast to the mountain station when they were found negative. The pollen season is in average longer in lowland than in mountains. The average number of days between flower buttons visible and beginning of flowering is in its turn higher at the mountain station.

Conclusions

Phenological observations allow us to recognise the life cycle of plants in dependence on outside conditions, and they give us valuable information about duration of vegetation season in different climatic regions. This case study manifests the dependence of seasonal events in the examined birch species on altitude and aspect of the locality. The temporal variability of date of the first occurrence of phenophase in its annual cycle is considerable, and it depends on climatic conditions, locality and weather conditions in the current year. Duration of snow cover and variability of weather have influence on timing the phenophase entrance in mountain areas. We have compared the values of variance of average monthly air temperatures (December, January, February) between meteorological stations situated in comparable conditions as phenological stations (phenological station Pernink, 860 m asl – meteorological station Měděnec, 828 m asl; phenological station Lednice, 165 m asl – meteorological station Lednice, 176 m asl). For the studied period 1992–2007, there was found bigger variance for values obtained at the mountain station, what indirectly confirms the results of statistical processing of phenophases-related observation data. It is recommended to address the next case study to phenophase entrance in connection with air temperature, precipitation, sunshine duration and synoptic situation with the aim to enable forecasting the following phenophase entrance (especially flower buttons visible and beginning of flowering) in the current year. For example, Karlsson et al. (2003) found that a temperature increase of 1 °C causes bud burst in mountain birch to occur 3–8 days earlier, with the strongest influence in the elevated northern Sweden. The research will be extended with a detailed analysis performed at other phenological stations localised at different altitudes and having different topography and for other allergenic plants observed within the CHMI phenological network. We will compare our results with other European phenological networks – *Betula verrucosa*, especially the phenophases connected first leaves and flowering, is also observed in other countries – for example Slovakia, Finland, Germany, Norway, Poland (Nekovář, 1993). The results presented in this case study provide a basic outline of the temporal patterns of phenophase entrance in *Betula verrucosa* in the Czech Republic over the recent years, and also statistic comparison of localities situated at considerably different altitudes.

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Časová a prostorová variabilita nejvýznamnějších fenologických fáz břízy v Česku

Souhrn

V uvedené práci byly zpracovávány nástupy vybraných fenofází (rašení, první listy (10 %), plné olistění, butonizace, počátek a konec kvetení) u břízy bradavičnaté. Výsledky jsou uvedeny jak ve formě statistických tabulek se statistickými charakteristikami průměr, směrodatná odchylka, rozptyl, nejranější a nejpozdější datum nástupu, variační rozpětí (u dvou vybraných stanic – nížinné a horské za období 1992–2007), tak ve formě map za využití

geografických informačních systémů (aplikace Clidata – GIS s horizontálním rozlišením 500 m a se závislostí na nadmořské výšce) z celkem 44 fenologických stanic. Jako vstupní data byla použita průměrná data nástupů zvolených fenofází za období 1992–2006.

Vzhledem k tomu, že bříza bradavičnatá je velmi významný alergen, zaměřili jsme se v práci rovněž na statistické zhodnocení počtu dní mezi nástupy alergologicky významných fenofází, výsledky jsou rovněž uvedeny v tabulkové podobě.

Ve výsledcích srovnání nástupu fenofází v odlišných podmínkách byla prokázána závislost nástupu fenofází na nadmořské výšce i na poloze, vzhledem k orientaci ke světovým stranám.

Časová variabilita nástupu fenofází je velmi velká a závisí na klimatických podmínkách dané lokality a na průběhu počasí v daném roce. V horských polohách má na časový nástup fenofází vliv délka trvání sněhové pokrývky a variabilita počasí. V budoucnosti je vhodné věnovat se dalšímu studiu nástupu fenofází ve spojení s teplotou vzduchu, sumou srážek, slunečním svitem a synoptickými situacemi pro možnost prognózy nástupu fenofáze (zejména butonizace a počátku kvetení) v aktuálním roce. Výzkum rozšířit o další detailní rozbor fenologických stanic v jiných polohách a nadmořských výškách a další alergologicky významné rostlinné druhy sledované ve fenologické síti stanic ČHMÚ. Uvedené výsledky poskytují čtenáři základní představu o vývoji nástupu vybraných fenofází u břízy bradavičnaté v Česku v posledních letech a statistické porovnání lokalit s výrazně odlišnou nadmořskou výškou.

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