Temporal and spatial variability in allergy-triggering phenological phases of hazel and alder in Czechia

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Abstract

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Pollen grains of alder (*Alnus glutinosa*), hazel (*Corylus avellana*) and birch (*Betula verrucosa*) belong to the most important allergens not only in the Czech Republic but also in the whole Europe. Both alder and hazel pollen cross-react with birch pollen, and the allergenicity of the two species is moderate to high.The data on temporal and spatial variability in phenophases selected with respect to their allergenic effect (flower buttons visible, beginning and end of flowering) and compiled with using statistical and GIS methods during the period 1992–2007 were compared with the current year's outcomes of the Czech Hydrometeorological Institute phenological network. The resulting maps use a horizontal resolution of 500 meters, method Clidata – DEM, with dependence on altitude. Temporal variability was monitored in the phenological stations Lednice (48°48' N, 16°48' E, mean above sea level (MASL) 165 m) and Horní Rokytnice (50°11' N, 16°30' E, 743 m MASL), the spatial variability in 34 stations with MASL ranging from 155 m (Doksany – Polabská nížina) to 830 m (Měděnec – Krušné hory Mts). The results are presented in tables and maps. In this case study we observed the following shifts in phenophases (lowland in comparison with mountain): flower buttons visible (38.4 days), beginning of flowering 10% (21.8 days), and end of flowering (26.3 days). The results of average entrance of phenophase from this case study: flower buttons visible (Hazel – February 3 to February 22, Alder – February 7 to February 26), beginning of flowering 10% (Hazel – February 19 to March 20, Alder – February 22 to April 2), end of flowering (Hazel – March 9 to April 17, Alder – March 15 to May 13)

Keywords

Alder, flowering, GIS, hazel, phenophase, pollen, statistics

Introduction

The broadleaved tree alder (*Alnus glutinosa*) and shrub hazel (*Corylus avellana*) belong to the most widespread woody plants in Czechia and in other parts of Europe. The pollen of both are the most important allergens, namely due to cross-sensibilization among hazel, alder and birch. Phenology as the study of recurring vegetation cycles and their connection to climate plays a prominent role in forecast models system. The Czech Hydrometeorological Institute (CHMI) operates a network of phenological stations with wild plants. Volunteer observers register onset of phenophases according to the CHMI methodology instructions number 10. Alder and hazel are in observation programme, with a special focus on phenophases closely connected with pollen season (flower buttons visible, beginning and end of flowering). The data are stored in the Fenodata database (Oracle application). Phenological data are usually recorded at the phase start, expressed in form of the day of year.

Hazel is usually a 2 to 8 m-high shrub, in the Czechia it can be found on rich-in-aluminium soils. This woody plant is abundant from lowlands to foothills, rare in mountains (maximum 1,310 m asl). The pollen grain of hazel is usually oval, isopolar, the normal size is 18–35 micrometers. Alder is a broadleved tree or shrub the height of which can exceed 30 m. Alder trees grow in *Alnus* flood-plain forests, swamps, on clayey noncalcic soils, rich in aluminium. In Czechia, they can be found from lowlands to foothills, rarely in mountains (maximum 900 m asl) Nekovář (1993). An alder pollen grain is usually oval, isopolar, its normal size is 20–30 micrometers (Fig 1).

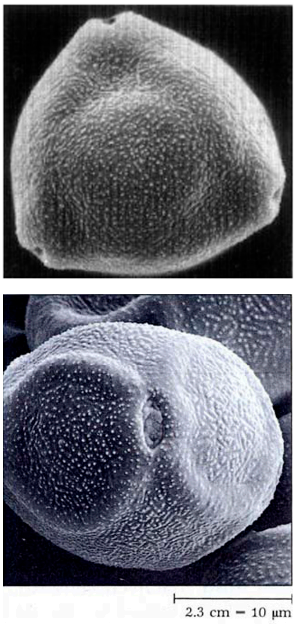

Fig 1. Hazel and alder pollen grains

There are several contributions about phenology and pollen season in hazel and alder in Europe. Remišová and Vinceová (2007), for example, present in their paper data on flowering of *Corylus avellana* in the Slovak Republic from 1987 to 2006. Škvareninová and Snopková (2007) studied phenological phases in *Alnus glutinosa* in relation to effective temperature values over the period of 1987–2006 in the Zvolen basin. Emberlin et al. (2007) reports about pollen season of *Alnus* spp. and *Corylus* spp. in the United Kingdom for period 1996–2005.

The aim of this case study was to monitor temporal and spatial variability in alder and hazel phenology in Czechia, and provide useful information for experts, general public, and especially for allergy-sensitive people. The results were processed by statistics and GIS methods in 1992–2007, as complete time series without interruption. Other species with allergy-triggering phenological phases belonging to CHMI phenological observation programme will be also studied in the future.

Material and methods

The Czech Hydrometeorological Institue (CHMI) operates with a phenological network of wild plants (Fig 2), following CHMI methodical instruction for phenological stations – wild plants number 10. In hazel and alder, 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. At present, hazel and alder are observed at 34 phenological stations. We focused on the phenological phases associated with pollen production (flower buttons visible, flowering).

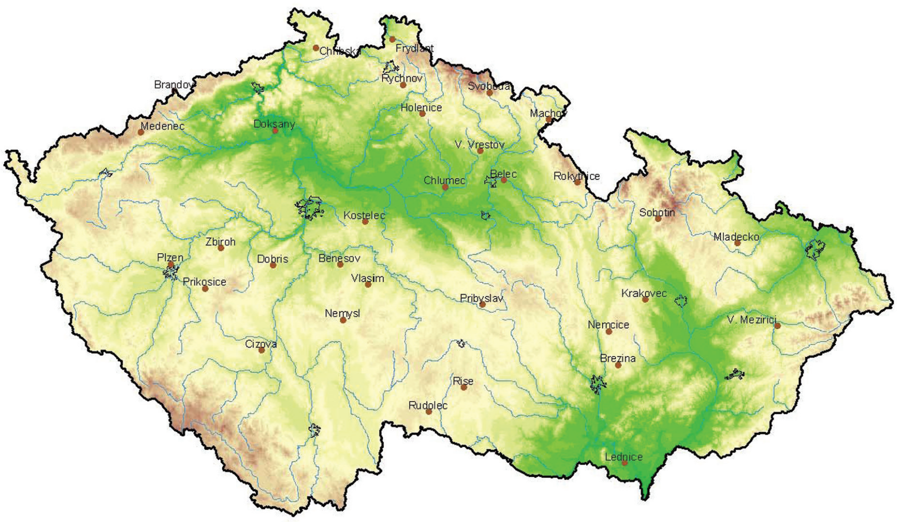

Fig 2. Phenological network for wild plants (stations observing hazel and alder)

We have subjected to basic statistic processing the data assembled over the period 1992–2007 at two stations situated at different altitudes. Hazel and alder are the most important allergenic species, cross-reacting with birch. Allergy sensitive persons can profit from information about flowering, hence we have also counted the number of days between the phenophases *flower buttons visible – beginning of flowering – end of flowering*. Hazel and alder belong to the first-blooming allergenic species. The assembled data have been processed to maps (mean dates of phenophase entrance for period 1992–2007) – temporal and spatial pattern of phenophase entrance over the whole Czechia.

The detailed phenophase description represents instruction number 10 in the methodology (Czech Hydrometeorological Institute, 1987). Patterns of phenophases are in the Phenological atlas, Coufal et al. (2004).

From statistical characteristics we chose these parameters: average value, standard deviation, variance, minimum, maximum, variation range, average – median.

The maps were processed with using geographic information systems (Application Clidata – GIS). As the input data, we used the mean dates of phenophase entrance from the period 1992–2007. 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, with using the data from neighbouring stations, by the least squares method. The distance between two neighbouring phenological stations at similar conditions was 40 km. The coefficients were subsequently interpolated into the spatial model, and the spatial distribution of the specific element was calculated by using tools of map algebra and linear equations, Hájková and Nekovář (2006), Tolasz et al (2007).

In total, data from 34 stations with MASL (mean above sea level) ranging from 155 m (Doksany – Polabská nížina, lowland) to 830 m (Měděnec – Krušné hory, Mts) were used for creating the maps. The stations Lednice (165 m) and Horní Rokytnice (743 m) are described in details in the statistical results. The first station is situated in a lowland, the second in mountains, the first one is in the South and the second one on the North-east 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 the Southern Moravia, in the river basin of the Dyje River, Castle Park Lednice. Hazel and alder trees are observed at the site 1 (this station consists of 2 sites), vegetation unit – dispersed green vegetation, macrorelief – flat ground, geological substrate – clayey drift and combined soil, level of protection – the other categories of non-forest land. Hazel and alder site conditions: micro-relief – flat ground, slope – up to 5 degrees, illumination of site – full illumination, water conditions – hygromesophyte, initial age: 20–40 years. The station Horní Rokytnice (50°11' N, 16°30' E, 743 m asl) is situated in the Orlické hory Mts, in the river basin of Divoká Orlice. Alder trees are observed at the site 2 (this station comprises 7 sites), vegetation unit – mountain pine grove, macrorelief – plateau, geological substrate – crystallic slate, level of protection – protected provincial area. Alder site conditions: micro-relief – rampart, slope – up to 5 degrees, illumination of site – full illumination, humidity conditions – mesophyte, initial age – 20–40 years.

Hazel trees are observed at the site 4, vegetation unit – damp meadow and wetland, macrorelief – plateau, geological substrate – crystalline slate, level of protection – protected provincial area. Hazel site conditions: micro-relief – flat-ground, slope – up to 5 degrees, illumination of site – full illumination, humidity conditions – hydrohygrophyte, initial age – 20–40 years.

Statistical results for hazel and alder (station Lednice and Horní Rokytnice, period 1992–2007) in the tables (Tables 1–14), are given in form of the day of year.

Table 1. Phenophase – Flower buttons visible, *Corylus avellana* (statistical results)

Station	Average	Standard deviation	Variance	Minimum	Maximum	Variation range	Average – median
Lednice	42.1	21.7	470.6	10 (10.1.)	79 (20.3.)	69	–2.9
H. Rokytnice	79.2	17.2	295.6	46 (15.2.)	108 (18.4.)	62	1.2

Table 2. Phenophase – Flower buttons visible, *Alnus glutinosa* (statistical results)

Station	Average	Standard deviation	Variance	Minimum	Maximum	Variation range	Average – median
Lednice	46.2	20.4	415.2	18 (18.1.)	84 (25.3.)	66	1.7
H. Rokytnice	84.6	14.8	218.1	61 (2.3.)	110 (20.4.)	49	1.6

Table 3. Phenophase – Beginning of flowering 10%, *Corylus avellana* (statistical results)

Station	Average	Standard deviation	Variance	Minimum	Maximum	Variation range	Average – median
Lednice	54.9	21.0	443.1	12 (12.1.)	87 (28.3.)	75	6,9
H. Rokytnice	85.4	14.7	216.0	59 (28.2.)	111 (21.4.)	52	–1,1

Table 4. Phenophase – Beginning of flowering 10%, *Alnus glutinos*a (statistical results)

Station	Average	Standard deviation	Variance	Minimum	Maximum	Variation range	Average – median
Lednice	64.5	15.9	252.8	37 (6.2.)	90 (31.3.)	53	1.5
H. Rokytnice	86.3	15.2	230.7	60 (1.3.)	112 (22.4.)	52	0.3

Table 5. Phenophase – Beginning of flowering 50%, *Corylus avellana* (statistical results)

Station	Average	Standard deviation	Variance	Minimum	Maximum	Variation range	Average – median
Lednice	60.1	21.3	454.0	16 (16.1.)	94 (4.4.)	78	7.1
H. Rokytnice	89.1	15.1	227.7	61 (2.3.)	114 (24.4.)	53	–0,9

Table 6. Phenophase – Beginning of flowering 50%, *Alnus glutinosa* (statistical results)

Station	Average	Standard deviation	Variance	Minimum	Maximum	Variation range	Average – median
Lednice	69.1	15.8	248.4	43 (12.2.)	96 (6.4.)	53	2.1
H. Rokytnice	92.2	15.9	254.1	61 (2.3.)	113 (23.4.)	52	–1.3

Table 7. Phenophase – Beginning of flowering 100%, *Corylus avellana* (statistical results)

Station	Average	Standard deviation	Variance	Minimum	Maximum	Variation range	Average – median
Lednice	68.1	21.5	464.0	25 (25.1.)	101 (11.4.)	76	4.6
H. Rokytnice	97.1	12.4	154.3	74 (15.3.)	115 (25.4.)	41	0.1

Table 8. Phenophase – Beginning of flowering 100%, *Alnus glutinosa* (statistical results)

Station	Average	Standard deviation	Variance	Minimum	Maximum	Variation range	Average – median
Lednice	75.7	15.4	235.6	55 (24.2.)	101 (11.4.)	46	0.7
H. Rokytnice	101.2	11.4	130.5	77 (18.3.)	115 (25.4.)	38	–5.8

Table 9. Phenophase – End of flowering, *Corylus avellana* (statistical results)

Station	Average	Standard deviation	Variance	Minimum	Maximum	Variation range	Average – median
Lednice	79.9	21.3	453.6	33 (2.2.)	108 (18.4.)	75	0.4
H. Rokytnice	104.8	12.7	162.0	77 (18.3.)	120 (30.4.)	43.0	–3.2

Table 10. Phenophase – End of flowering, *Alnus glutinosa* (statistical results)

Station	Average	Standard deviation	Variance	Minimum	Maximum	Variation range	Average – median
Lednice	81.6	15.2	231.7	60 (1.3.)	106 (16.4.)	46	2.6
H. Rokytnice	107.9	10.6	111.5	81 (22.3.)	119 (29.4.)	38	–3.1

Table 11. Average number of days between phenophases, *Corylus avellana*

Station	Flower buttons visible – beginning of flowering	Beginning of flowering – end of flowering	Flower buttons visible – end of flowering
Lednice	12.8	25.0	37.8
H. Rokytnice	6.2	19.4	25.6

Table 12. Average number of days between phenophases, *Alnus glutinosa*

Station	Flower buttons visible – beginning of flowering	Beginning of flowering – end of flowering	Flower buttons visible – end of flowering
Lednice	18.3	17.1	35.4
H. Rokytnice	1.7	21.6	23.3

Table 13. Beginning of flowering – end of flowering, *Corylus avellana* (statistical results)

Station	Average	Standard deviation	Variance	Variation range
Lednice	25.0	9.7	94.7	36
H. Rokytnice	15.8	7.6	57.2	24

Table 14. Beginning of flowering – end of flowering, *Alnus glutinosa* (statistical results)

Station	Average	Standard deviation	Variance	Variation range
Lednice	16.8	3.7	14.0	15
H. Rokytnice	18.6	9.1	82.8	28

Results

Phenophase: Flower buttons visible

Phenophase entrance: in lowlands and at medium altitudes started the phenophase *flower buttons visible* in hazel already from February 3 to February 22; in alder from February 7 to February 26. Interval of mean dates of phenophase entrance was smaller in hazel than in alder. Phenophase entrance: in the highest situated mountain positions from March 15 to March 24 in hazel; from the end of March to the mid-April in alder.

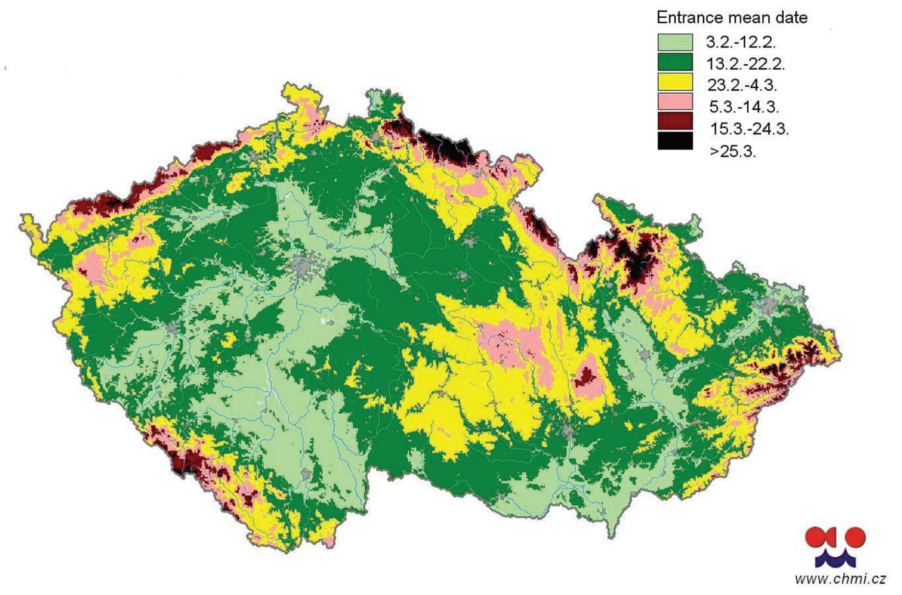

Fig 3. Phenophase – flower buttons visible, mean dates for period 1992–2007, *Corylus avellana*

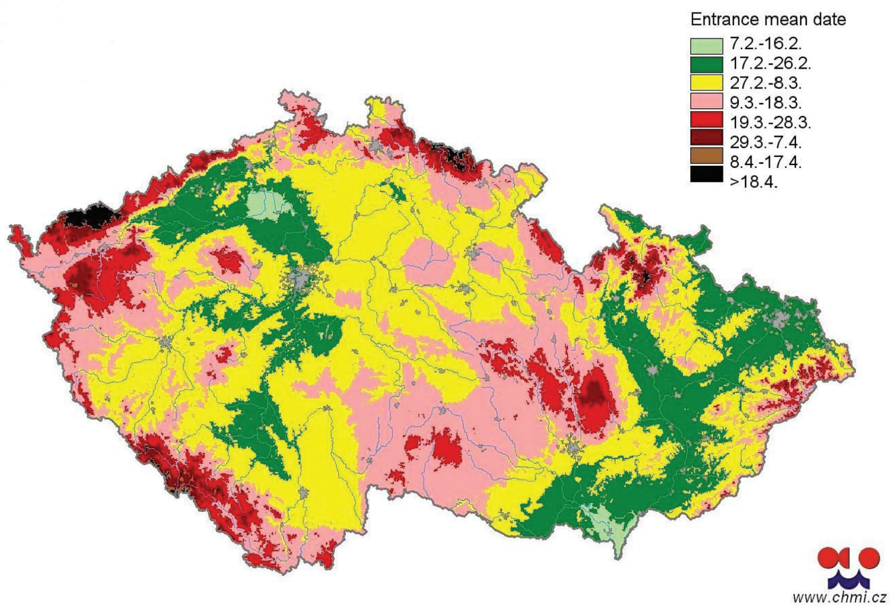

Fig 4. Phenophase – flower buttons visible, the mean dates for period 1992–2007, *Alnus glutinosa*

Phenophase: Beginning of flowering 10%

Phenophase entrance: across the major part of the Czech Republic started the phenophase *beginning of flowering 10%* in hazel from February 19 to March 20; in alder from February 22 to April 2. In the highest situated mountain positions it started at latest on March 31 in hazel, and on April 23 in alder.

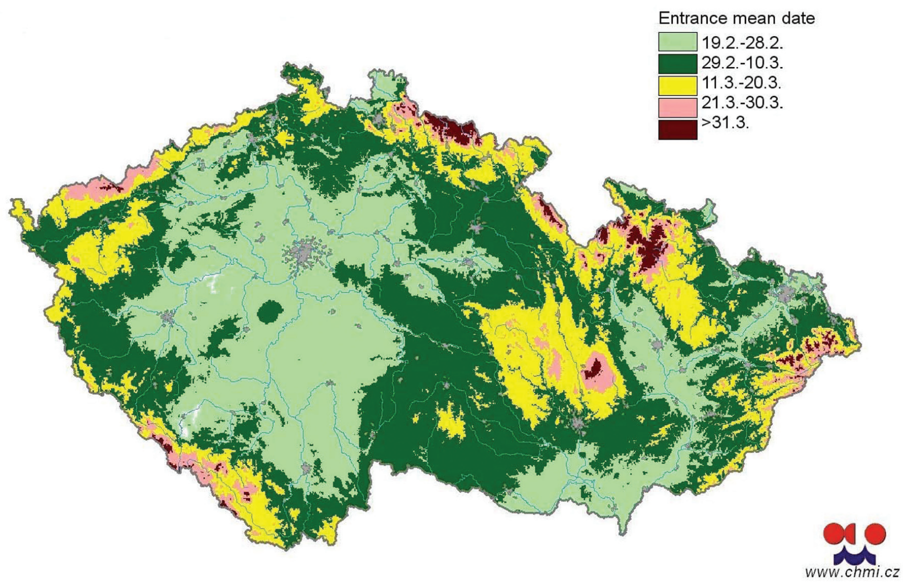

Fig 5. Phenophase – beginning of flowering 10%, the mean dates for period 1992–2007, *Corylus avellana*

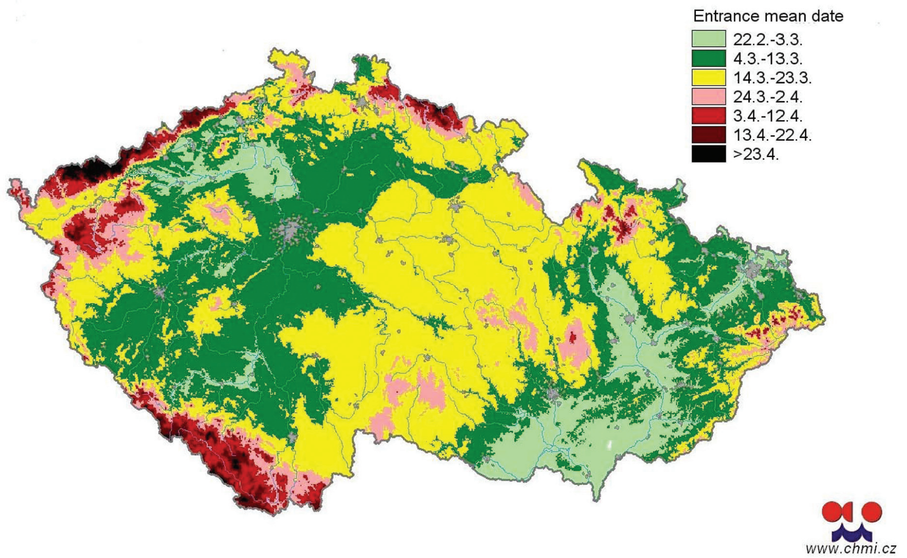

Fig 6. Phenophase – beginning of flowering 10%, the mean dates for period 1992–2007, *Alnus glutinosa*

Phenophase: Beginning of flowering 50%

Phenophase entrance: across the major part of the Czech Republic, the phenophase *beginning of flowering 50%* starts from February 24 to April 4 in hazel and from February 27 to April 27 in alder.

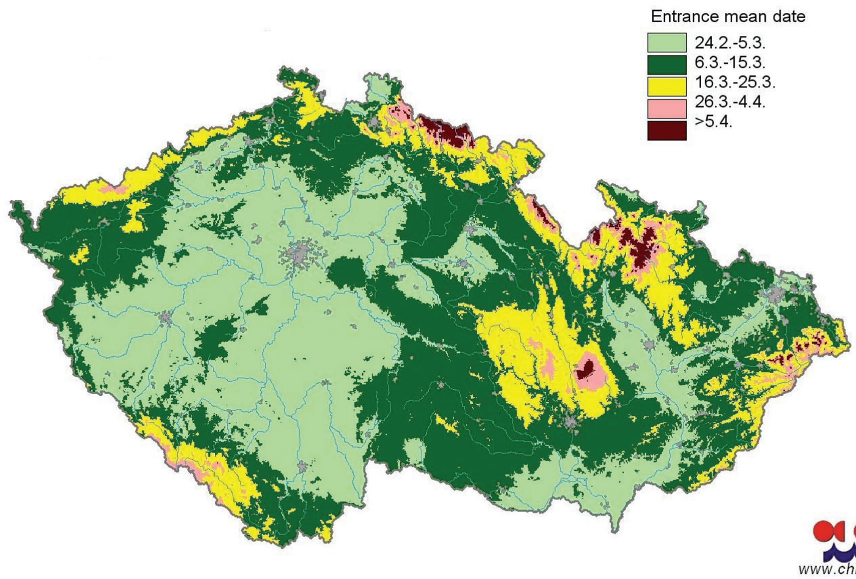

Fig 7. Phenophase – beginning of flowering 50%, the mean dates for period 1992–2007, *Corylus avellana*

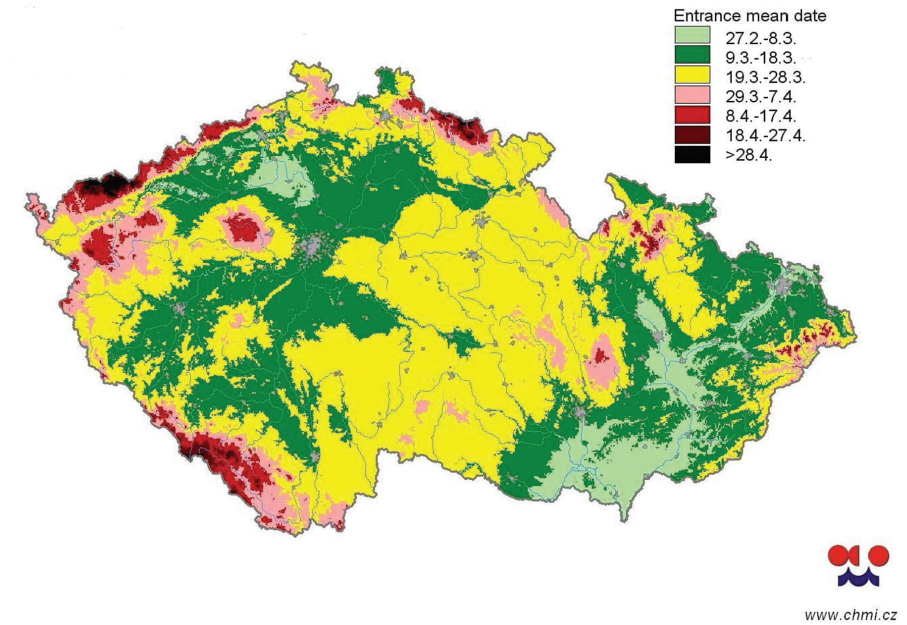

Fig 8. Phenophase – beginning of flowering 50%, the mean dates for period 1992–2007, *Alnus glutinosa*

Phenophase: Beginning of flowering 100%

Phenophase entrance: across the major part of the Czech Republic started the phenophase *beginning of flowering 100%* in hazel from February 28 to April 8; in alder from March 4 to May 2. In the highest situated mountain positions, the start could shift at latest on April 9 in hazel; in alder at latest on May 3.

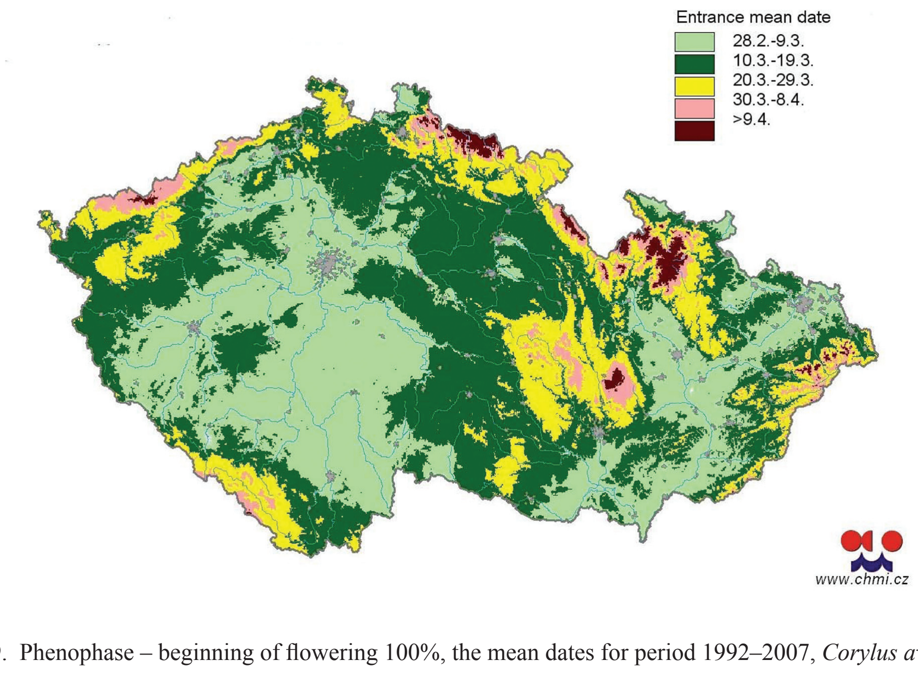

Fig 9. Phenophase – beginning of flowering 100%, the mean dates for period 1992–2007, *Corylus avellana*

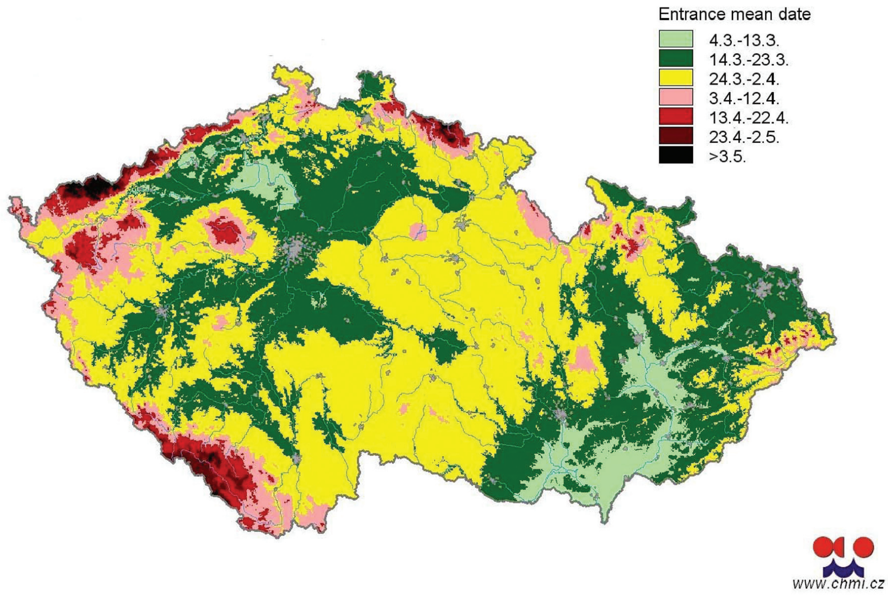

Fig 10. Phenophase – beginning of flowering 100%, the mean dates for period 1992–2007, *Alnus glutinosa*

Phenophase: End of flowering

Phenophase entrance: across the major part of the Czech Republic started the phenophase *end of flowering* in hazel from March 9 to April 17; in alder from March 15 to May 13; in the highest situated mountain positions, the start could be shifted at latest on April 18 in hazel; and on May 14 in alder.

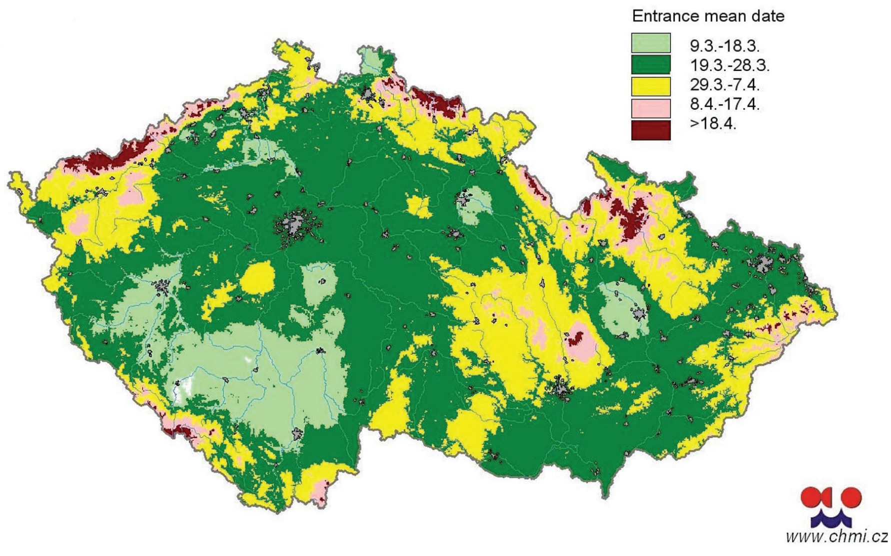

Fig 11. Phenophase – end of flowering, the mean dates for period 1992–2007, *Corylus avellana*

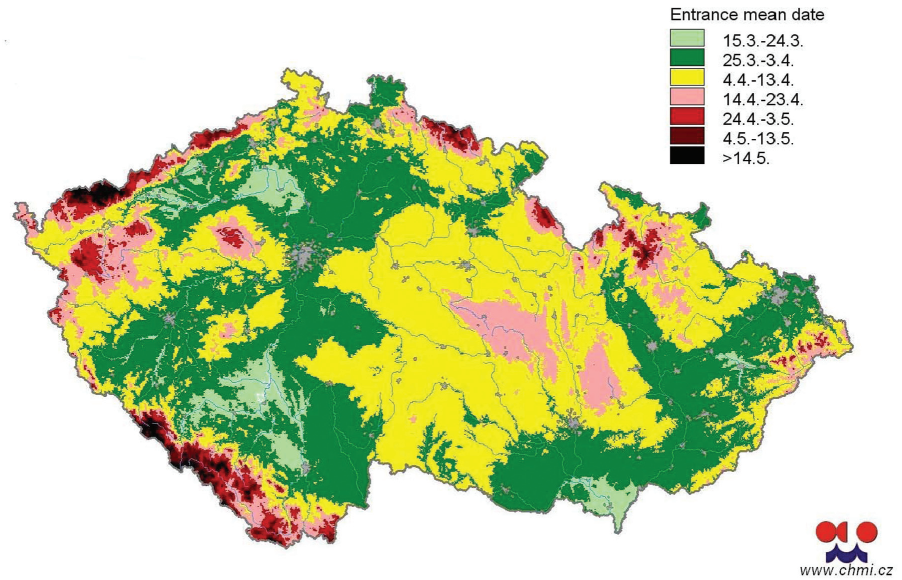

Fig 12. Phenophase – end of flowering, the mean dates for period 1992–2007, *Alnus glutinosa*

Discussion

The entrance of individual phenophases in hazel and alder was studied based on the data provided by two selected phenological stations (lowland and mountain) and subjected to detailed statistical processing. The station Lednice is situated in a lowland in the southern Moravia; the station Horní Rokytnice is in the North-east of the Czech Republic (Orlické hory Mts). The beginning and duration of phenological phases are influenced by multiple environmental factors (air temperature, soil temperature, water conditions, position of locality, sunshine duration) together with genetic equipment of the plants – similar results were obtained for birch Hájková et al. (2007). Comparison of phenophase entrance in different conditions was made on dependence on altitude and aspect. The timing of phenophase entrance in *Corylus avellana* was in average earlier in lowlands: the flower buttons visible by 37.1 days earlier, the beginning of flowering 10% by 30.5 days earlier, the end of flowering by 24.9 days earlier. The dating of phenophase entrance in *Alnus glutinosa* was on average also earlier in lowlands: the flower buttons visible by 38.4 days earlier, the beginning of flowering 10% by 21.8 days earlier, the end of flowering by 26.3 days earlier. Values of variance and also variation range were bigger in lower altitudes. *Corylus avellana* is the earliest allergen, the earliest phenophase entrance over the period 1992–2007 was found out on January 10th (flower buttons visible) and on January 12th (beginning of flowering). For *Alnus glutinosa*, the second earliest alergen, the earliest phenophase entrance was recorded on January 18 (flower buttons visible) and on February 6 (beginning of flowering). Both extremes were recorded at the Lednice station. There was a large gap between the earliest and latest phenophase entrance (column *minimum* and *maximum* in tables) during the period 1992–2007. The variation range was found expressively higher at the lowland station Lednice than in the mountains. Difference between the average and median (a value expressing whether lower or higher values are more important than the median or not) was in most cases positive – it means, that the later phenophase entrance was more important**.** The pollen season (period between beginning of flowering – end of flowering) in hazel was on average 25 days in lowlands and 15.8 days in mountains. The pollen season in alder was on average 16.8 in lowlands and 18.6 in mountains. The average number of days between flower buttons visible and end of flowering (the period, which is very important for allergy sensitive persons) in hazel was 41.6 days at Lednice station and 22.6 days at Horní Rokytnice station. The average number of days between flower buttons visible and end of flowering in alder was 38.2 at Lednice station and 23 days at Horní Rokytnice station.

Conclusions

Phenological observations allow us to recognise the life cycle of plants in dependence on external 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 hazel and alder species on altitude and aspect of the locality. The temporal variability of timing 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. For the studied period 1992–2007, there was found bigger variance for values obtained at the mountain station, which indirectly confirms the results of statistical processing of phenophases-related observation data. For example, Emberlin et al. (2006) found that pollen seasons in *Alnus* spp. and *Corylus* spp. have changed in the Worcester area over the last 10 years, becoming longer and more severe in the recent years, but long term trends cannot be discerned based on this relatively small data set (Emberlin et al., 2006). Although the analyses are based on the Worcester data, the results can have a wider application, and they also can be used for other regions. The results of this study are also consistent with previous works declaring that the temperature is the main factor affecting the phenology of early flowering trees.

The mean date of beginning of flowering in European hazel in Slovakia is considered March 15 (evaluated period 1987–2006) (Remišová and Vinceová, 2007), for the Czech Republic we obtained February 19 to March 20 (evaluated period 1992–2007).

The analysis of the flowering data variability in hazel and alder in the Slovak Republic suggests their association with the air temperature variability towards the end of winter (Luknárová and Braslavská, 1999). Consequently, the next case study should address phenophase entrance in relation to air temperature, precipitation, sun hours and synoptic situation – with the aim to forecast the following phenophase entrance (especially flower buttons visible and beginning of flowering) in the current year. The results presented in this case study provide a basic outline of the temporal patterns of phenophases entrance in *Alnus glutinosa* and *Corylus avellana* in the Czechia over the recent years, and also statistical comparison between localities situated at noticeably different altitudes.

References

Aas, G., Riedmiller, A. 1997. *Stromy. Kapesní atlas* [Trees. Pocket atlas]. Praha: Slovart. 255 p.

Coufal, L., Houška, V., Reischlager, J.D., Valter, J., Vráblík, T. 2004. *Fenologický atlas* [Phenological atlas]. Praha: ČHMÚ. 263 p.

Český hydrometeorologický ústav 1987. *Návod pro činnost fenologických stanic – lesní rostliny* [Methodical instructions for phenological stations – forest plants]. Metodický předpis č. 10. Praha: ČHMÚ. 111 p., 18 appendices.

Emberlin, J. et al. 2006. Changes in the pollen seasons of the early flowering trees Alnus spp. and Corylus spp. in Worcester, United Kingdom, 1996–2005. *Int. J. Biometeorol*., 51: 181–191.

Hájková, L., Nekovář, J. 2006. GIS evaluation of selected generative phenophases for allergology purposes. *Geophys. Res. Abstr.*, 8: 01590.

Hájková, L., Sedláček, V., Nekovář, J. 2007. Temporal and spatial variability of the most important phenological phases of birch in the Czech republic. *Folia oecol.*, 34: 86–96.

Luknárová, V., Braslavská, O. 1999. Flowering variability of the most important spring producers of allergenic pollen in Slovakia. *Meteorol. Čas*., 2 (2): 21–28.

Nekovář, J. 1993. Phenology of forest plants in selected European countries. *Meteorol. Zpr*., 46 (1): p. 21–26.

Nekovář, J. et al. 2007. *Česká fenologická databáze pro klimatologické aplikace = Czech phenology database for climatological applications*. Praha: Český hydrometeorologický ústav. 124 p.

Remišová, V., Vinceová, A. 2007. Flowering of European hazel (Coryllus avellana L.) in Slovak Republic in the period 1987–2006. In *Klima lesa: sborník referátů z mezinárodní vědecké konference Křtiny 11.–12. 4. 2007.* Praha: Česká bioklimatologická společnost, 2007, p. 31.

Škvareninová, J., Snopková, Z. 2007. Assessment of phenological phases of common alder (Alnus glutinosa (L.) Gaertn.) in relation to effective temperature during period of 1987 – 2006 in Zvolen basin. In *Klima lesa: sborník referátů z mezinárodní vědecké konference Křtiny 11.–12. 4. 2007.* Praha: Česká bioklimatologická společnost, 2007, p. 39.

Tolasz, R. et al. 2007. *Atlas podnebí Česka = Climate atlas of Czechia*. Praha, Olomouc: Český hydrometeorologický ústav. 255 p.

Časová a prostorová variabilita alergologicky významných fenologických fáz lísky a olše v Česku

Souhrn

V uvedené práci byly zpracovávány nástupy alergologicky významných fenofází (butonizace, počátek a konec kvetení) u lísky obecné a olše lepkavé. 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 34 fenologických stanic. Jako vstupní data byla použita průměrná data nástupů zvolených fenofází za období 1992–2007.

Vzhledem k tomu, že líska a olše jsou velmi významnými alergeny (po bříze bradavičnaté), 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 těchto druhů rozšířit o další detailní rozbor fenologických stanic v jiných polohách a nadmořských výškách a zároveň o další alergologicky významné rostlinné druhy sledované ve fenologické síti stanic ČHMÚ. Uvedené výsledky poskytují čtenáři základní představu o vývoji nástupu alergologicky významných fenofází u lísky obecné a olše lepkavé v Česku v posledních letech a statistické porovnání lokalit s výrazně odlišnou nadmořskou výškou.

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