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Phenological Observation in the Czech Republic – History and Present

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1. Introduction

Periodicity in the life of plants and animals is considered to be an indirect indicator for the periodicity in the climate. This is because plants and animals continuously respond to changing climatic influences. It is at the same time a supporting science for biogeography, ecology and phytocenology. Phenology is a branch of science which deals with the study of periodically recurring natural life cycles in the course of time, called phenological phases of plants and animals, as they relate to environmental conditions, particularly climate and weather. The base of the word phenology emanates from the Greek word fainó, which means "I reveal" (Krška, 2006). Dating from ancient times, the observation of the surrounding environment has been one of the basic features of everyday life, specific expressions in the acquired pieces of knowledge arise from weather proverbs e.g. "September brews the wine, in October we drink it". The weather proverbs had of course great importance even for peasants and other professions. Phenological observations, which are according to the kind of observed organisms divided into phytophenological and zoophenological. In climatology the basic time period is a year together with its months but the growth and subsequent development of plants and animals do not follow our calendar. Natural life cycles of organisms are determined, simply said, by internal (genetic) and external (climatological) conditions. And we divide the year into phenological periods according to the response of nature to the real course of the weather (Rožnovský & Havlíček, 1999). Phenology season onset in relation to synoptic situation studied Hájková & Kožnarová & Sulovská (2011). Agroclimatological classification is based on relation of plants to selected climatological characteristics as well as agroclimatological indicator of temperature, agroclimatological indicator of irrigation and agroclimatological indicator of hibernation (Žalud, 2010).

In this chapter we briefly describe history of phenological observations in the Czech Republic and phenological observations at present including concisely description of

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current methodology used at CHMI (Czech Hydrometeorological Institute) phenological stations. The Czech Hydrometeorological Institute cooperates with other European countries within the phenology research, very short description is provided. From all observed species we have chosen the Common Hazel as one of the most important pollen allergen. Phenological results in the Common Hazel were evaluated in the Czech Republic within the period 1991–2010 including climatological characteristics.

2. History of phenological observation in the Czech Republic

Phenological observations have a long tradition in Czech Lands. We can divide it into two parts – phenological observations executed in the last centuries and observation of phenological stages at present.

2.1 History of phenological observations in 18th and 19th century in Czech countries

The first Czech meteorologists J. Stepling, A. Strnad and M. A. David, whose activities are known from the second half of the 18th century and David's from the 19th century as well, devoted themselves to studying the influence of weather on the life of plants and animals. A. Strnad attached his remarks to regular measures, which he carried out at the Prague observatory from the 1st January, 1775 up to nearly the end of his life (23rd September, 1799). A number of these phenological observations is also attached to his paper "Meteorologischer Beytrag auf das Jahr 1792". A longer article, containing an economic survey of the year 1791, was published by Strnad in Mannheim Eefemeridas with the heading „Conditio anni generalis" (Seydl, 1954).

The Mannheim or Falc meteorological society (Societas meteorologica Palatina), was assigned on the 15th September 1780 as a "meteorological class" to the Academy of Sciences, which has been in existence in Mannheim since 1763, and worked till 1799. The society welcomed, apart from meteorological measurement, also notes on phenology and nosology, especially the reports on the blossoming and ripening of fruits of the most important cultural plants, on the results of haymaking, harvest and fruit harvest, both from the point of view of the quantity and quality, and the data on the diseases of plants and on damage caused by insects. And the reports on arrivals and departures of migrating birds, e.g. storks, swallows, nightingales and cuckoos were welcomed. The first phenological calendar in our literature was published by Med. Dr. Tadeáš Haenke in his longer paper „Blumenkalendar fűr Noumen in Jahre 1786". The author carried out in the years 1784 and 1785 a detailed observation on the earlier and later beginning of spring, on its course and the changes of plants during this time (Seydl, 1954).

The principles for regular and methodologically unified phenological observations in a station net were laid by the Swedish botanist Carl von Linné. He established the network of 18 stations in Sweden in the years 1752–1755. Professor ing. Dr. Octavianus Farský (Farský, 1942) said, that phenology of botany cultivated from the time of Linné has not only purely scientific (biological, phyto - a zoographical, ecological and climatological), but first of all practical importance. Regular phenological observations in the Czech countries were first introduced by the Patriotic – economic company, the successor of K. k. Ackerbau-Gesellschaft, based in 1769 as an order of the Empress Maria Teresia in Prague for the enhancement of agriculture. The following phenological elements were observed: the development of buds into leaves, the beginning of blossoming, the end of blossoming and maturation of seeds. Further, some animals e.g. bats, hamsters, badgers, snakes and lizards, frogs, which do not leave our countries and hibernate in winter, mainly their awakening in spring and the beginning of hibernation were observed. The Prague lawyer Karl Fritsch as a significant part of his work in the field of phenology. His first work on phenology was devoted to the influence of weather on vegetation. In the paper „Elemente zu einer Untersuchung űber den Einfluss der Witterung auf die Vegetation"Fritsch explained the link between the yearly amount of warmth and moisture to the most important phases of the development of a plant, he presents eight charts of meteorological data (e.g. gradual total of positive values of the air temperatures, the differences in gradual total of precipitation) (Seydl, 1954).

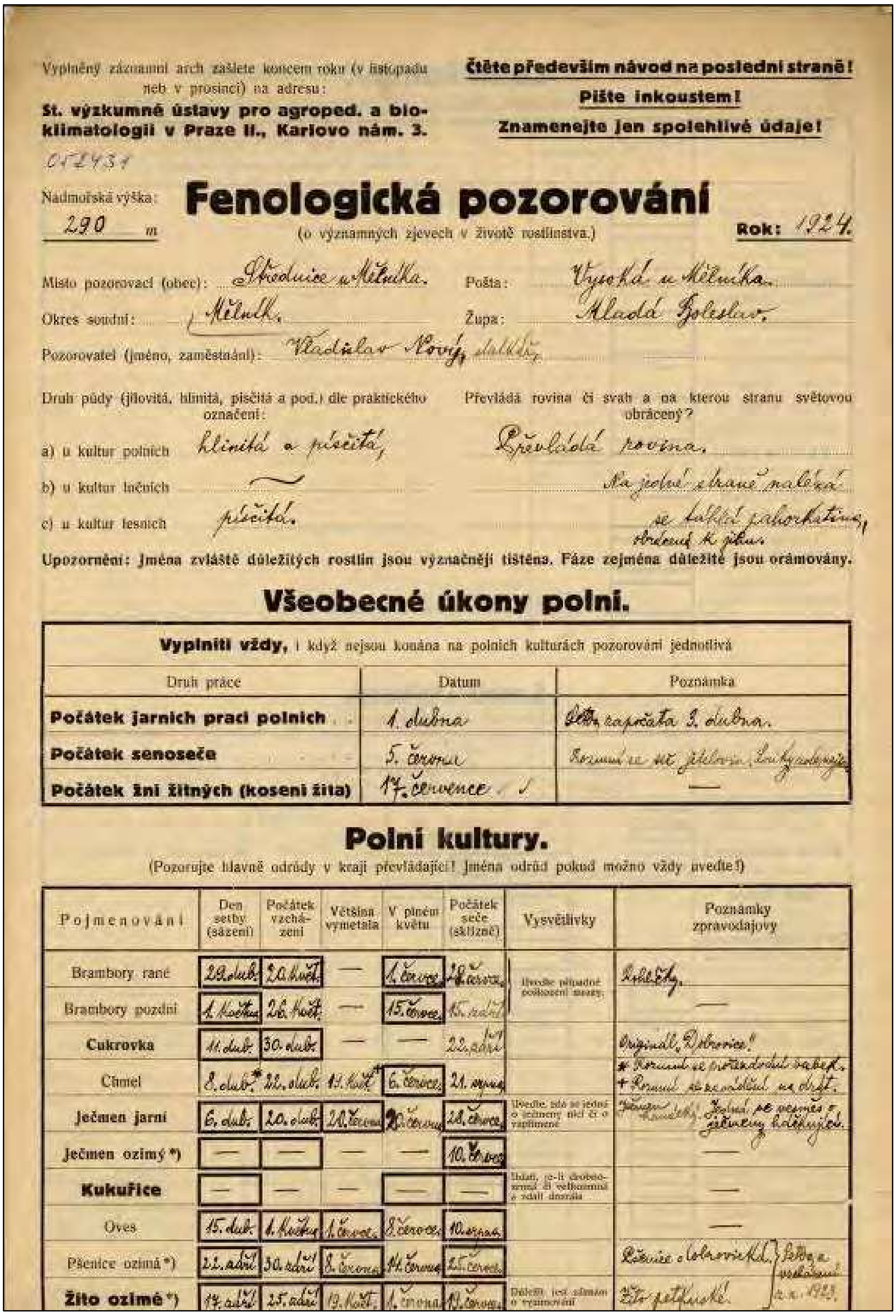
2.2 The first phenological observations in the Czech Republic in the 20th century

The state phenological service was organized in Moravia by the Department for soil science and agricultural meteorology of the Regional research office of agriculture in Brno. Prof. Ing. Dr. Václav Novák (1888–1967) set up in 1923 one of the first national phenological services in the world. The observation net was soon so extensive (with 650 observers involved in its activities), that it was unsustainable in the long term. The organization of phenological services was so sophisticated, several challenges in newspapers and professional press were published in order to acquire other observation sites, national schools and public corporations were asked for cooperation. The results of these observations were gradually processed in a long-term average of phenological phases, the so-called phenography. Coming out of these observations, phenological yearbooks were published, with map enclosures for the years 1923 and 1924 – and thus the principles of the beginning of the Czech phenography were laid. The material was processed together with professor Novák and professional officer ing. Josef Šimek. Phenological yearbooks were put together in the years 1927–1937 (Novák & Šimek, 1926).

In the year 1931 prof. ing. Dr. Bohuslav Polanský (1901–1983) jointed in by organizing phenological observations in the Moravian – Silesian country. In the year 1942 docent ing. Dr. Octavianus Farský, later professor at the School of agriculture in Brno, tried to introduce hunting – phenological observations in the area of the Bohemia and Moravia protectorate. He collectively described his hunting – phenological observations in the journal „Stráž myslivosti", no. 27, volume XIX (Farský, 1942).

As O. Farský stated, already in the last century the „Fysiokratická společnost", based on the impulse of the author, teacher and naturalist Dr Karel Slavomil Amerling (1807–1884), started to practise phenology and gained merit in the development of our applied natural sciences and progress in agriculture and forestry. In hunting – phenological observations, the following species of our commercial game were observed: feathered: *Scolopax rusticola L., Tetrao tetrix L., Tetrao urogallus L., Perdix perdix L., Phasianus colchicus L.* and furry: *Lepus europaeus Pall., Sus scrofa L., Ovis musimon Pall., Dama dama L., Cervus elaphus L., Capreolus capreolus L.* (Farský, 1942).

The phenological phases follow one after the other in a certain stable order; the first phenological calendar was published by the above mentioned T. Haenke. Arising from these long-term phenological observations, we can create the so called "Calendars of nature" for a certain place and its surrounding. We can also add a border data of the beginnings of these phases (the earliest and the latest, their amplitudes, phenoanomaly, the curve of phenodynamics) (Brablec, 1952).



Vyplněný záznamní arch zašlete koncem roku (v listopadu neb v prosinci) na adresu:
St. výzkumné ústavy pro agroped. a bioklimatologii v Praze II., Karlovo nám. 3.

Čtěte především návod na poslední straně!
Pište inkoustem!
Znamenejte jen spolehlivé údaje!

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Nadmořská výška: 290 m

Fenologická pozorování

(o významných zjevech v životě rostlinstva.)

Rok: 1924.

Místo pozorovací (obec): Střednice u Mělníka. Pošta: Vysoká u Mělníka.
Okres soudní: Mělník. Župa: Mladá Boleslav.
Pozorovatel (jméno, zaměstnání): Vladislav Nový, [illegible]

Druh půdy (jílovitá, hlinitá, písčitá a pod.) dle praktického označení:
a) u kultur polních: hlinitá a písčitá,
b) u kultur lučních: —
c) u kultur lesních: písčitá.

Převládá rovina či svah a na kterou stranu světovou obrácený? Převládá rovina. Na jedné straně naléhá se [illegible] pahorkatina, obrácená k jihu.

Upozornění: Jména zvláště důležitých rostlin jsou význačněji tištěna. Fáze zejména důležité jsou orámovány.

Všeobecné úkony polní.

Vyplniti vždy, i když nejsou konána na polních kulturách pozorování jednotlivá

Druh práce	Datum	Poznámka
Počátek jarních prací polních	1. dubna	[illegible] započata 3. dubna.
Počátek senoseče	5. června	[illegible]
Počátek žní žitných (kosení žita)	17. července	—

Polní kultury.

(Pozorujte hlavně odrůdy v kraji převládající! Jména odrůd pokud možno vždy uveďte!)

Pojmenování	Den setby (sázení)	Počátek vzcházení	Většina vymetala	V plném květu	Počátek seče (sklizně)	Vysvětlivky	Poznámky zpravodajovy
Brambory rané	29. dub.	20. květ.	—	1. červen.	18. červen.	Uveďte případné poškození mrazy.	[illegible]
Brambory pozdní	1. května	26. květ.	—	15. červen.	15. září		—
Cukrovka	11. dub.	30. dub.	—	—	22. září		Original, Dobrovice!
Chmel	8. dub.*	22. dub.	19. květ.+	6. červen.	21. srpna		* Rozumí se prořezávání rašek. + Rozumí se [illegible] na drát.
Ječmen jarní	6. dub.	20. dub.	20. červen.	20. červen.	28. červen.	Uveďte, zda se jedná o ječmeny nicí či o vzpřímené	[illegible]
Ječmen ozimý *)	—	—	—	—	10. červen.		—
Kukuřice	—	—	—	—	—	Udejte, je-li drobnozrnná či velkozrnná a zdali dozrála	—
Oves	15. dub.	1. května	1. červen.	8. červen.	10. srpna		—
Pšenice ozimá *)	22. září	30. září	8. června	14. června	25. červen.		[illegible]
Žito ozimé *)	17. září	25. září	19. květ.	1. června	13. červen.	Důležitý jest záznam o vymetání	Žito petkuské. [illegible] v r. 1923.

Fig. 1. Report of phenological observations at station in Střednice, year 1924.

The operative of the Hydrometeorological institute Josef Brablec processed and published the calendar of nature for Plumlov in Moravia during the period 1926–1947 (Brablec, 1952), for Hodonín in Moravia during the period 1924–1949 and for Střednice at Mělník in Bohemia during the period 1923–1949 (Brablec, 1953). At the above mentioned station Střednice at Mělník, Vladimír Nový, a farmer, carried out some meteorological observations and noticed not only prescribed species of plant and field crops (Fig. 1), but he also recorded data about weeds and other plants and his records have been up to the present the only long-term observation rows at our disposal.

In 1939, all meteorological services in the area of protectorate Bohemia and Moravia were brought together and the Central meteorological institute for Bohemia and Moravia was established, from the year 1940, phenological observations were overtaken by the Czech meteorological service with the whole net (about 1 000 places) and the archive of data since 1923. From that time up to the present, the phenology makes up a part of the meteorological service, included in 1954 in the Hydrometeorological institute (Miháliková, 1983; Krška & Vlasák, 2008). Phenological observations were conducted according to the principles included in the Handbook for phenological observers from the year 1956 (Pifflová et al., 1956). It was determined for the observers of the institutes for general phenology, which served mainly the needs of agriculture production (Fig. 2).

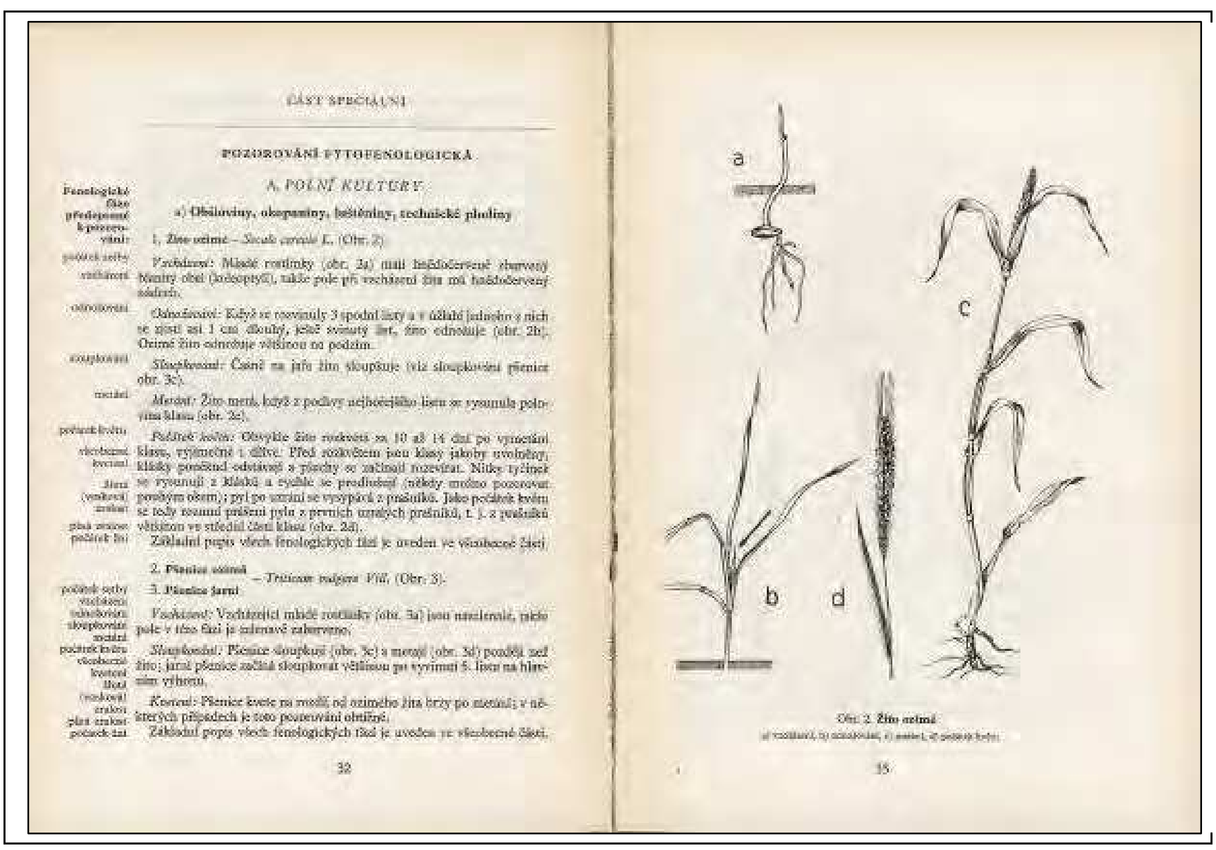


Fig. 2. Handbook for phenological observers (1956) – demonstration.

A constituent part of the handbook was also zoophenological observations. The following phenomena were observed e.g. the date of arrival, mass arrival, the first singing, herding and departure of thrushes, martins, quails, cuckoos, swifts, larks, starlings and swallows. With bee melliferous, the first flight and the first congeries of pollen were observed.

3. Phenological observation in the CHMI at present

A significant change in phenological observations came in the year 1983; observation sites were divided into stations observing field crops and fruit trees. Separate instructions for both types of stations were issued for observers. The transformation was finished in the year 1987 by issuing methodological instructions for the activities of phenological stations observing forest plants (from January 1st 1987). From January 1st 2005, Phenological atlas (Coufal et al., 2004) became an aid for observers in the net of the CHMI.

In the year 2004 a trial run of the database Oracle Phenodata started, for acquiring and storing phenological data (application pod Clidata in environment Oracle) and since 1st Jan. 2005 phenological data have been stored in this database up to the present. Older data were transferred to this database from environment Excel, where they had been stored till that time.

The present phenological net in the area of the Czech Republic is consisting of the three types of stations (forest plants, fruit trees, field crops). Voluntary observers monitor the beginnings of phenophases according to the methodological instructions of the CHMI (art. 2, 3 and 10 – in the year 2009 new, updated instructions for observers were issued), data are recorded in the phenological notepad and then transferred to current reports. The current reports are sent by post or in the electronic version to the branch offices of the CHMI, where the data are checked and transferred to application Oracle Phenodata by the phenologists of the branch offices of the institute. Current reports of field crops are sent once a week from 10th to 49th week of the year, reports on fruit trees 10 times a year and reports on forest plants 14 times a year.

3.1 Present methodology for phenological observations

Phenological observations are carried out at three types of stations – at field, fruit and forest stations (Fig. 3). The stations are selected with regard to that fact that their position should represent the respective area, it should not defy the local conditions in any way (e.g. clenched valley, frost basin, slopes with geographical polarity, places with atypical soil conditions), and at the same time it has to be close to a climatological station. The Czech phenological network consists of 79 field phenological stations, 34 fruit trees phenological stations and 49 wild plants phenological stations at present.

With field stations, such areas are chosen, which are in the given land register and used as arable land. Within these, selected parts of the overgrowth of the plant were then observed, where the plant was sown in the respective year, and the species of it are recorded. **With fruit stations**, such sections of the soil with cultivated fruit trees were chosen, where the plants are homogeneous in terms of the terrain, slope and its orientation, spacing etc. and at the same time they are uniformly cultivated, i.e. the same pruning, nutrition, cultivation and protection. In these areas 5 to 15 individuals are selected, which have identical biological features (the same species, variety, age, rootstock and shape) such individuals are then monitored until they perish or their health state is considered sufficiently representative. **In the case of forest station**, where plants are found in the surroundings, not standardized by the human, the rules are as follows: the locality has to be sufficiently far from any built-up area, outside the reach of urbanization, industrial, building, mining or agricultural activities;

it should contain just one type of botanical community and one type of macro relief, it should be rich in varieties, which means preferably mixed forests to cultural pine groves, or forest edges to their denser and poorer centres, and the plant should have optimal living conditions. In these localities such areas are chosen, which are homogenous from the ecological point of view. From these approximately five healthy individuals are chosen, in the case of shrubs 20–40 years old, in the case of trees 40–60 years old. Within each area, the location, elevation, exposition and slope, soil characteristics, irrigation or moisture conditions, in the case of forest stations also subsoil, botanical community, irradiation and the grade of legal protection are registered.

Fig. 3. Map of CHMI phenological station at present (situation in 2010).

The observer then carries out observations each lasting two days during the vegetation period, and outside the vegetation period once or twice a week. The vegetation period is defined at field stations from March to November, at fruit stations from April to October and at forest stations from March to October. The results of the observations are to be reported during the vegetation period at field stations every week, at fruit stations in the given terms from April to May each fortnight, from June to mid July once every three weeks, till the beginning of October once every six weeks and then at the beginning of December, at forest stations they should be handed in from March to June once a fortnight, from July to December always at the end of a month. Besides the data about the observed phenophases, the observer has to provide information concerning possible damage, both the damage caused by weather conditions, insects and fungi and other pathogenic agents, in the case of field crops also concerning the length of plants and the number of leaves and agro technological interventions carried out. If any of the station conditions in the observed area significantly change, (e.g. a change in cultivation, new building site nearby, the dehydration of the area), the observation there has to terminate.

At field station, 19 crops are observed: Winter and Spring Wheat (*Triticum vulgare*) - Fig. 4, Winter and Spring Barley (*Hordeum vulgare*), Winter Rye (*Secale cereale*), Oat (*Avena sativa*), Sugar Beet and Fodder Beet (*Beta vulgaris*), Potato (*Solanum tuberosum*), Mays (*Zea mays*), Broad Bean (*Vicia faba*), Field Pea (*Pisum sativum*), Green Bean (*Phaseolus vulgaris*), Cultivated Flax (*Linum usitatissumum*, Winter Rape (*Brasica napus*), Oppium Poppy (*Papaver somniferum*), Lucerne (*Medicago sativa*), Trifolium (*Trifolium pratense*) and Hops (*Humulus lupulus*). With these crops, the following phenophases are observed: 1) sowing, 2) emergence, 3) leaf bud burst, 4) first leaves, 5) tillering, 6) the beginning of leaf sheath elongation, 7) the beginning of stem elongation, 8) first node, 9) second node,10) swelling of the sheath of the last leaf, booting, 11) heading, 12) closing rows of the growth, 13) total closing of the growth, 14) beginning of the side shoots growth, 15) beginning of decortications, 16) inflorescence emergence, 17) beginning of flowering, 18) beginning of male flowers flowering, 19) beginning of female flower flowering, 20) full flowering, 21) end of flowering, 22) cone development, 23) green ripeness, 24) milky ripeness, 25) milky wax ripeness, 26) yellow ripeness, 27) full ripeness, 28) harvest ripeness, 29) dead tops, 30) harvest.

Fig. 4. Winter Wheat (*Triticum vulgare*) – full ripeness (Photo: Lenka Hájková).

At **fruit tree stations** the following 15 plants are observed: Apple (*Malus domestica*) – Fig. 5, European Pear (*Pyrus communis*), Prunus (*Prunus domestica & P. insititia*), Wild Cherry (*Cerasus avium*), Sour Cherry (*Cerasus vulgaris*), Apricot (*Armeniaca vulgaris*), Peach (*Persica vulgaris*), Red Current (*Ribes rubrum*), Black Current (*Ribes nigrum*), Gooseberry (*Grossularia uva-crispa*), Common Walnut (*Juglans regia*), Common Hazel (*Corylus avellana*), and Vine (*Vitis vinifera*). The following phenophases in the respective plants are observed: 1) beginning of blooding, 2) leaf bud burst, 3) flower bud burst, 4) mixed bud burst, 5) first leaves, 6) inflorescence emergence, 7) beginning of flowering, 8) beginning of flowering (male flowers), 9) beginning of flowering (female flowers), 10) full flowering, 11) beginning of petal fall, 12) end of flowering, 13) bud creation, 14) end of shoots elongation, 15) bunches begin to hang, 16) softening of berries, 17) harvest ripeness, 18) harvest, 19) end of leaf fall.

Fig. 5. Apple – variety Champion (*Malus domestica)* – flowering (Photo: Lenka Hájková).

Fig. 6. Blackthorn (*Prunus spinosa*) – flowering (Photo: Lenka Hájková).

At wild plants stations are 24 species of wood plants and 21 species of herbs observed. Among the wood plants are: Norway Spruce (*Picea excelsa*), European Larch (*Larix decidua*), Scotch Pine (*Pinus sylvestris*, Scrub Pine (*Pinus mugo subsp*. *Mughus*), Wild Cherry (*Cerasus avium*), Blackthorn (*Prunus spinosa*) – Fig. 6, Rowan *(Sorbus aucuparia),* Midland Hawthorn *(Crataegus oxyacantha),* Robinia *(Robinia pseudoacacia),* European Hornbeam *(Carpinus* *betulus),* Common Hazel *(Corylus avellana),* Silver Birch *(Betula pendula),* Common Alder *(Alnus glutinosa),* Grey Alder *(Alnus incana),* European Beech *(Fagus sylvatica),* Pedunculate Oak *(Quercus robur),* Goat Willow *(Salix caprea),* Harewood *(Acer pseudoplatanus),* Norway Maple *(Acer platanoides),* Lime Tree *(Tilia cordata),* European Dogwood *(Cornus sanguinea),* Cornelian Cherry *(Cornus mas),* Black Elder *(Sambucus nigra)* and Racemic Elder *(Sambucus racemosa).*

Observed herbs are as follows: Marsh Marigold *(Caltha palustris),* Wood Anemone *(Anemone nemorosa)* – Fig. 7, Hepatica *(Hepatica nobilis),* Meadow Buttercup *(Ranunculus acris),* Wild Strawberry *(Fragaria vesca),* Trefoil *(Trifolium repens),* Perforate St. John's-wort *(Hypericum perforatum),* Rosebay Willowherb *(Chamerion angustifolium),* Heath *(Calluna vulgaris),* Bilberry *(Vaccinium myrtillus),* White Dead Nettle *(Lamium album),* Ox-eye Daisy *(Chrysanthemum leucanthemum),* Coltsfoot *(Tussilago farfara),* Butterbur *(Petasites hybridus),* White Butterbur *(Petasites albus),* Colchium *(Colchicum autumnale),* Lily of the Valley *(Convallaria majalis),* Common Snowdrop *(Galanthus nivalis),* Cocks Foot *(Dactylis glomerata),* Meadow Foxtail *(Alopecurus pratensis)* and Reed *(Phragmites australis).* The following phenophases are observed in these plants: 1) bud burst, 2) first leaves, 3) fully leaved, 4) inflorescence emergence, 5) beginning of flowering, 6) end of flowering, 7) bud creation, 8) first fruit visible, 9) St. John's sprouts, 10) pulpy sprouts begin to lignifying, 11) leaves colouring, 12) leaves fall, 13) fruit ripeness, 14) haymaking and second haymaking.

Fig. 7. Wood Anemone (*Anemone nemorosa*) – flowering (Photo: Lenka Hájková).

4. The Czech phenology and Europe

The Czech Hydrometeorological Institute is involved in the international cooperation in phenological observations in the project called **IPG – International Phenological Garden** since the end of 1990s. Since the half of the 20th century, the network of international phenological gardens has been working, supervised by the Humboldt University in Berlin.

The network contains more than 70 stations, in the Czech Republic there are 3 stations: at the observatory in Doksany (50°28' N, 14°10' E, 158 m asl, IPG–No. 85), in the arboretums of forestry schools in Kostelec nad Černými lesy (50°00' N, 14°52' E, 345 m asl, IPG–No. 86) and Křtiny at Brno (49°19' N, 16°45' E, 475 m asl, IPG–No. 87). The administrator of IPG delivered the observed trees from the nursery for trees in Ahrensburg at Hamburg for free, the biological material is thus genetically identical. The removal and planting is ensured by the operator. The observation is not paid, after the end of each calendar year, a report is sent to the administrator, who processes the results, prepares a yearbook and sends it for free to all the stations of the network (Nekovář et al., 2008). The main idea of the IPG was to standardise the conditions for observation – to use unified regulations for observations realized in similar surroundings only for professionals and thus on clone plants coming from one nursery. The aim of the project IPG is to study the presupposed impacts of changes in the climate on forest plants.

Fig. 8. 3-D model of phenological station in Doksany.

The International Phenological Garden in Doksany was set up in the year 2000 on the premises of the CHMI observatory, thanks to the Humboldt University in Berlin, which provided forest plants for free. The IPG is situated about 50 km of Prague, in the Ústí region. Its elevation is 158 m above sea level, its average yearly air temperature is 8.5 ° C and the average amount of precipitation is 450 mm. The IPG in Doksany was established as a first in the framework of the entire Czech Republic. In total, 9 phenological phases in 19 plants are observed. The wood plants have been placed in an area of the observatory in Doksany in such a manner, that they will either impede each other in the future, or influence the phenological measuring. The IPG is situated in a representative place, which is not influenced by local microclimatic conditions. The situation of the IPG is apparent in Fig. 8, which has been created by means of a 3D model, showing the garden in spring, summer, autumn and winter. Phenological observations in forest growth can be very demanding especially in difficult to access terrain. In recent years, an effort has been gathering strength, to use automatic monitoring with the help of phenological cameras and satellites. A greater objectification and an increase in the precision of phenological observations is thus to be expected.

Fig. 9. Foliage within the year – Common Hazel (*Corylus avellana*) (Photo: Martin Možný).

In September 2006, in the CHMI, a piloting project of an all-year-long monitoring of phenological phases by a digital camera was commenced, within the framework of the phenological garden (IPG) in Doksany. Figure 9 shows an example of the phenological development taken in automatic regime. A digital camera Canon PowerShot S3 IS was used, it was positioned in a closed container with a sight, its interior heated by the heating foil and it was attached to a swivel stand.

In Europe, the international cooperation in phenological observation and the analyses of data by the use of programme COST is greatly intensifying (**European Cooperation in Scientific and Technological Research**). The CHMI was a member of COST 725 (**Establishing a European Phenological Data Platform for Climatological Applications)** and COST ES603 (Assessment of production, release, distribution, health impact of allergenic pollen in Europe).

In the year 2010, the project PEP 725 (Pan European Phenology DB) was commenced. It was another step in the continuation and enlargement of the European phenological database for scientific purposes, education and research. Project PEP 725 is proposed to run until 2014 with the presumption of prolongation at a later date.

Further cooperation was initiated by the activities of the **Joint Research Centre (JRC)** of the European Committee in the town of Ispra in Italy. **The European Agrophenological Net (EAgPN)** was established, which will provide "country truth" for calibration of satellite snaps and for calculation of the quantity and quality of the harvest of cereals, corn, rape and sunflower. Since the end of the 90s, the University of Waningen initiated the **European Phenological Net (EPN)**, which is the creation of purpose-built websites, informing about national nets, general number of stations, plants and phases (Nekovář & Rožnovský, 2006).

5. "A case study - phenology observations of Common Hazel (*Corylus avellana*) in Czechia"

5.1 Climatological characteristics of the Czech Republic during the period 1991–2010

The country's natural and environment is characterized by a moderate, humid climate and four alternating seasons. Its vegetation is determined by the merging of the Hercynian and Carpathian forest areas and the warm Pannonian steppe. The overall character of the landscape reflects vertical variation in the georelief.

The climate is generally favourable and has rather maritime character. Despite the small surface area of the country, the climate is highly varied. The elongated shape of the territory results in a slight increase in continentality as one moves east (Tolasz et al, 2007).

The maps (Fig. 10–12) introduce the average values of the selected climatic elements (air temperature, atmospheric precipitation, duration of sunshine) in the Czech Republic during the period from 1991–2010 in the warm half of the year, i.e. from April to September.

Air temperature, sunshine and precipitation are closely connected with growth of plants. The average values of air temperature ranges between 10 and 16 °C (the maximum values are in the South Moravia and Polabská Lowland), the sunshine duration oscillates between 1,050 and 1,350 hours (in the part of south and North Moravia show the maximum values) and the precipitation totals are between 300 and 650 mm (the highest values are in the mountain areas of Krkonoše, Jeseníky, Beskydy and Šumava Mts.).

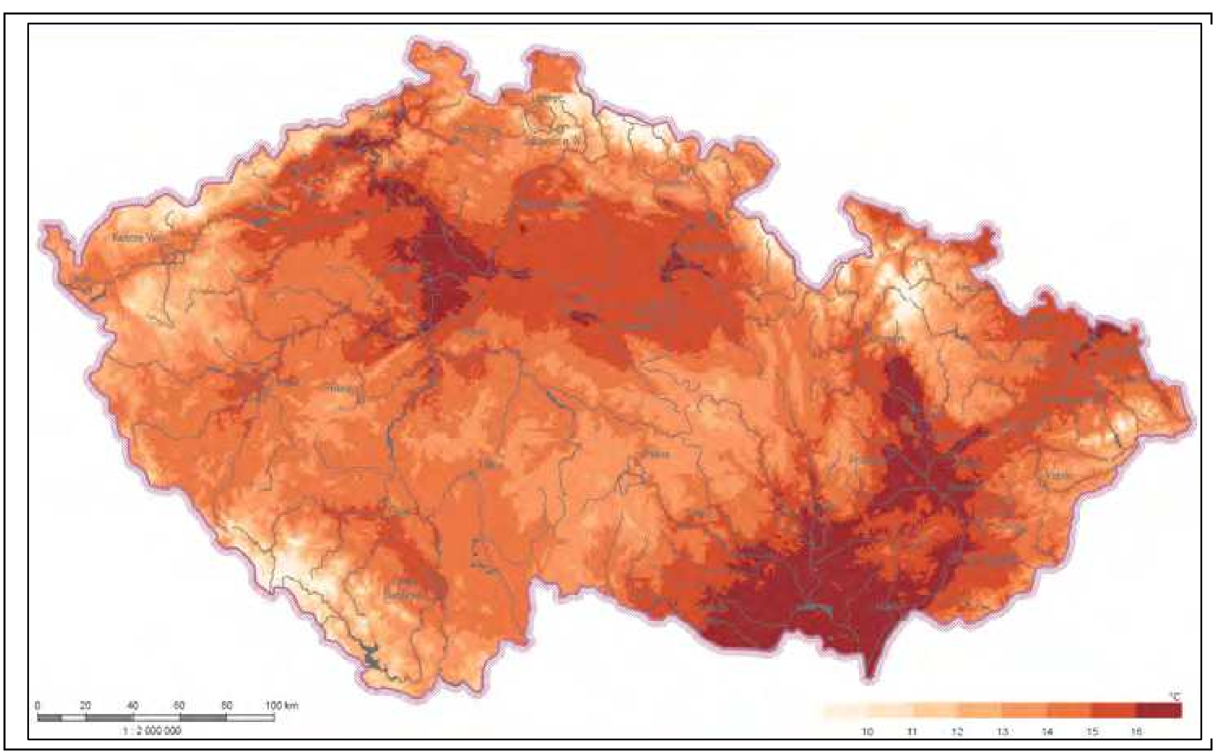


Fig. 10. Average air temperature in warm half-year (April–September).

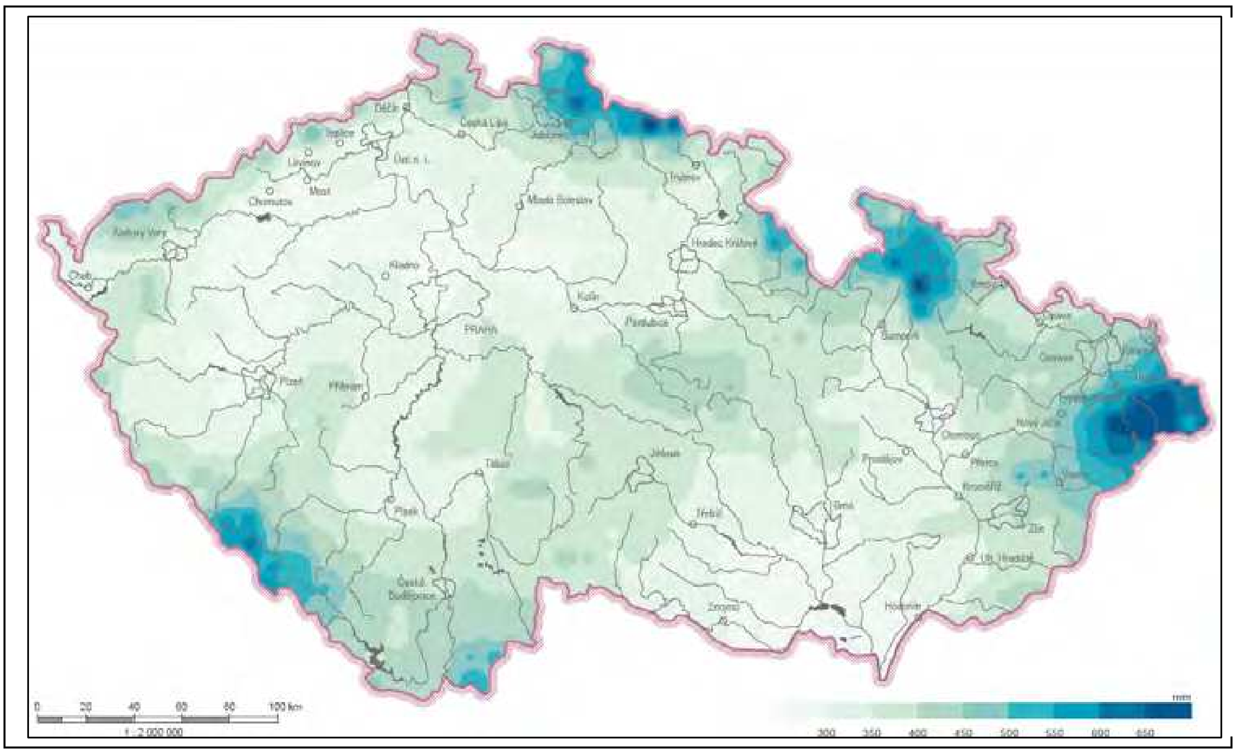


Fig. 11. Average precipitation total in warm half-year (April–September).

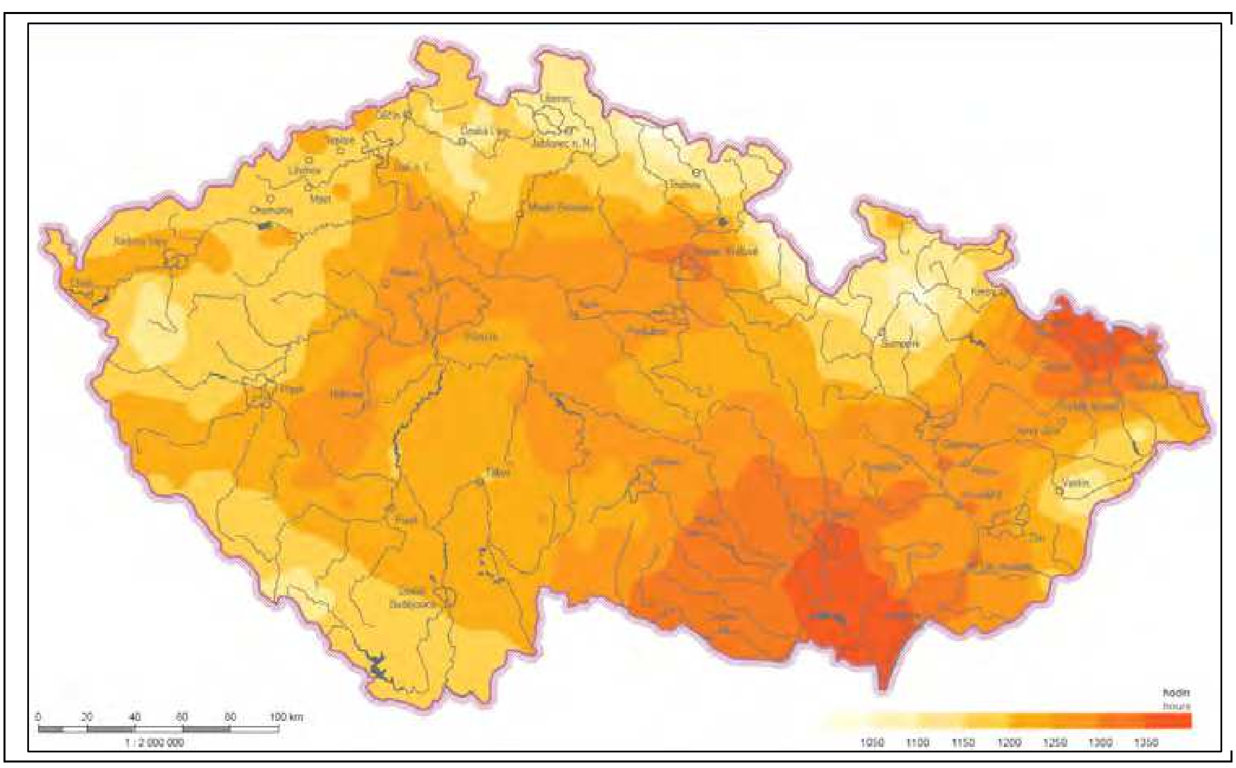


Fig. 12. Average total of sunshine duration in warm half-year (April–September).

5.2 Botanical description and occurrence of the Common Hazel in the Czech Republic

Common Hazel – *Corylus avellana* is a medium sized spherical shrub 2 to 8 m high, with straight branches with diameter of 30 cm. The bark is smooth, brown-gray. The young twigs are densely hairy. The buds are sessile, glabrous, oval, and bluntly spiky. They have simple, rounded leaves with double–serrated margins, shortly petiolated, 7 to 12 cm long, on the face sparsely and densely hairy on the back. The roots are mainly spreaded on the surface. The male flowers are arranged in pendant catkins, 10 cm long. The new unblooming catkins occur on the shrubs in mid of summer. Small female flowers are sessile to twig, unobtrusive, similar to buds. They grow usually in pairs, and are completely enclosed in support scales, which protrude from red stigmas. The plant is monoecious. The Hazel flowers as early as 8–10 years, however, it becomes, that pistil's flowers are damaged by frost, and it does not produce fruit annually. The fruit is a nut surrounded by an involucres (husk) which partly to fully encloses the nut, it called „punčoška". Shell (pericarp) is cinnamon brown. The Hazel can be found as undergrowth in light forest, in forest edges, as a part of shrubs in the surrounding of water, in the clear-cut areas and bounds, it is often planted. It reaches ages of 60–80 years. Taxonomy classification is mentioned in Table 1.

Order	*Fagales*
Family	*Corylaceae*
Genus	*Corylus*
Species	*Corylus avellana* L.

Table 1. Taxonomy subsumption.

The Hazel has no special moisture requirements and grows even in the areas of poor rainfall. It is modest in demands on soil, hates peat and muddy soil. It is resistant to climate, it is a thermophilic tree species in our country that searches often thermally favourable position with the southern exposure.

It expanded in the Termophyticum and the Mesophyticum scattered to abundantly (Hejný & Slavík et al., 2003), rarely in the Oreophyticum. The Hazel is very abundant at some localities, particularly in the upper hill country belt to submontane belt of southwest Bohemia and part of south Bohemia (here is rich in shrub forest floor, but it also creates extensive separate bushes formation). In the lowland belt to the submontane belt, exceptionally above the cirques (max.: Hrubý Jeseník Mts., Velká kotlina, 1,310 m asl; Krkonoše Mts., Schlusterova zahrádka, 1,100 m asl).

In forestry is considered for weed tree species, are grown mainly large–bed cultivars for the nuts. Nuts have a high content of protein, fats and vitamins B. Pressed oil is used in parfumery and painting. Hazel rods are used in basket making. Hazel is the first grazing for bees due to early flowering period. Infusions of the leaves are used in folk medicine (skin rashes and intestinal illnesses treatment). Dried leaves were used during the war as a tobacco substitutes.

5.3 The Common Hazel as an allergen

Pollen grains of Hazel are triangular, flat, about a size of 20 up to 27 μm in diameter with three porous apertures, smooth and unsticky (Fig. 13). The production of pollen is plentiful, if species does not grow in the shrub floor and is overshadowed (Rybníček et al., 1997).

Fig. 13. Common Hazel (*Corylus avellana*) – pollen (Photo: Lenka Hájková).

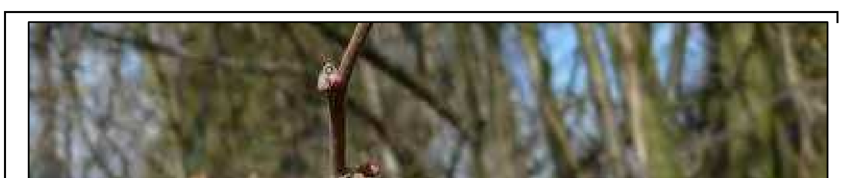


Fig. 14. Common Hazel (*Corylus avellana*) – flowering (Photo: Jana Škvareninová)

Pollen is transmitted by wind very well. Pollen grains of the Hazel contain at least allergen Cor a 1 (Špičák, Panzner et al., 2004). The Hazel belongs among moderately significant to very important pollen allergens. Primarily it reacts across with pollen botanically related species (birch – hornbeam – alder), (beech – oak).

The flowering of the Common Hazel (Fig. 14) lasts on average 22–23 days in the selected elevation zones, standard deviation ranges between 2.3 and 5.3 days. Common Hazel begins to flower on average between 24th February and 24th March. The probability of the beginning of flowering between 12th March and 21st March is 19 %, between 2nd and 11th March 16 % and between 21st and 29th February 16 %. The earliest beginning of flowering was recorded on 12th January 1994 (Lednice), the latest onset was registered on 12th April 2006 (Měděnec).

5.4 Analysis of phenological data in the Common Hazel

Within the framework of phenological observations and according to the methodology of the CHMI, the following phenophases of the Common Hazel are observed: the bud burst (10 %), the first leaves (10, 50, 100 %), the fully leaved (100 %), the inflorescence emergence (10 %), the beginning of flowering (10, 50, 100 %), the end of flowering (100 %), the bud creation (10 %), the first fruit visible (10 %), the herb sprouts begin to lignifying (10 %), the leaves colouring (10, 100 %), the leaves fall (10, 100 %), the fully ripe (10, 50, 100 %). The size of the crop has also been recorded. The Common Hazel is in the network of CHMI phenological stations (wild plants) observed at stations at elevations from 155 m (Doksany) to 830 m (Měděnec). The observed areas are located at stations on plains or on moderate slopes (slope up to 10°), at very bright stands. Typical moisture conditions are mainly hygromezophytic and mezophytic.

The phenological data of the selected plants were evaluated in the environment Excel, but especially a space analysis in the environment of geographical information systems was carried out. For the depiction of maps, the method Clidata-DEM was used with a horizontal differentiation of 500 m and of regressive semi-diameter 40 km. This method is based on local linear regression between the measured value (average data of the onsets of the selected phenophases in the period 1991–2010) and a digital model relief. For each station, regressive coefficients from the nearest stations by means of the method of the smallest squares were calculated, which were later consequently interpolated in the space distribution, and by means of map algebra, and a straight line equation, a space distribution of the given phenophase was acquired. The maps are processed from the observed data from the phenological stations; in the area above the boundaries of the present occurrence the map expresses potentially possible values. Termopluviograms were constructed according Kožnarová et al. (1997), some results of termophenopluviograms have already been published with Apple, Pear, Apricot, Morello and Walnut (Kožnarová & Sulovská & Hájková, 2011).

In place of a phenological observation station, which climatological stations lack in most cases, so-called technical rows for necessary methodological elements for geographical coordinates of phenological stations were assessed for the calculation of complementing meteorological characteristics. The methodology for the calculation was as follows: before the individual calculation of technical rows, the entrance data from climatological stations of the CHMI were carefully checked from the point of view of their quality using the software ProClimDB (Štěpánek, 2009). The methodology of the error detection in calculation combines several procedures e.g. comparison of differences between neighbouring stations, comparison with the expected value calculated by means of geostatistical methods and so on, the result of this combination is that it is easy to automate. After the error correction, the rows were homogenised by the use of several statistical tests, different reference rows, iteration testing-assessment-correction of nonhomogenities. The correction of nonhomogenities was carried out directly in the daily data (more e.g. in Štěpánek et.al, 2009). For each station, the missing values from the period 1991–2010 were further completed by means of geostatistical methods. And with the use of these homogenised and completed station rows, new technical rows in selected points were finally calculated (in relation to the position of the original stations). The calculation of technical rows itself arises from the methodology IDW, whereby the applied data of the neighbouring stations are at first standardised for elevation of the point at which we calculate a new row (Štěpánek et.al, 2011) and then a new value by means of weighted average is calculated. The adjustment of parameters for the calculation differs for each meteorological element. The results of the onsets of phenological phases of plant species of the corresponding phenological station in the given year were associated with technical rows for geographical coordinates of phenological stations in the period 1991–2010 for further processing. And such prepared data were used for calculating meteorological characteristics according to the following procedure: pentad air temperature was calculated as the average air temperature for five consecutive days before the day of the onset of the selected phenophase in the given year. The sum of the air temperatures, the total of sunshine duration and the number of days with precipitation total of at least 1 mm during the selected phenophase intervals were calculated during the entire mentioned interval (so they include the day of the phenophase onset). The accumulated temperatures are processed as sums of average daily air temperatures in the given phenophase interval (ºD e.g. DD), the duration of sunshine as a total of daily amounts of sunshine in the phenophase interval (hour) and the number of days with precipitation total of 1 mm or more comes out of daily precipitation totals in the selected days of the phenophase interval corresponding to the selected criterion.

5.5 Temporal and spatial variation in Common Hazel phenology

Temporal and spatial variation of phenophase onsets in Common Hazel is very different in given year. Fig. 15 and 16 show annual deviations of phenophase onsets (the bud burst, the inflorescence emergence, the beginning and the end of flowering, the leaves fall) of Common Hazel from the average within the twenty year period 1991–2010.

The years 2007, 2008, 1998, 2002, 1994 and 1995 had earlier onset with hazel, the years 2006, 1996, 2005 and 2010 were recorded later phenological phases onsets. The highest negative deviations, i.e. an earlier phenophase onsets, were as follows: the sprouting –9 days (2007), the inflorescence emergence –28 days (2007), the beginning of flowering –28 days (2007), the end of flowering –23 days (2007) and the leaves fall –7 days (1994). The highest positive deviations, i. e. later phenophase onsets, were with the sprouting +12 days (2006), the inlorescence emergence +28 days (2006), the beginning of flowering +29 days (1996), the end of flowering +25 days (2006) and the leaves fall +11 days (2001). The differences in the deviations with the inflorescence emergence, beginning and end of flowering are almost one month.

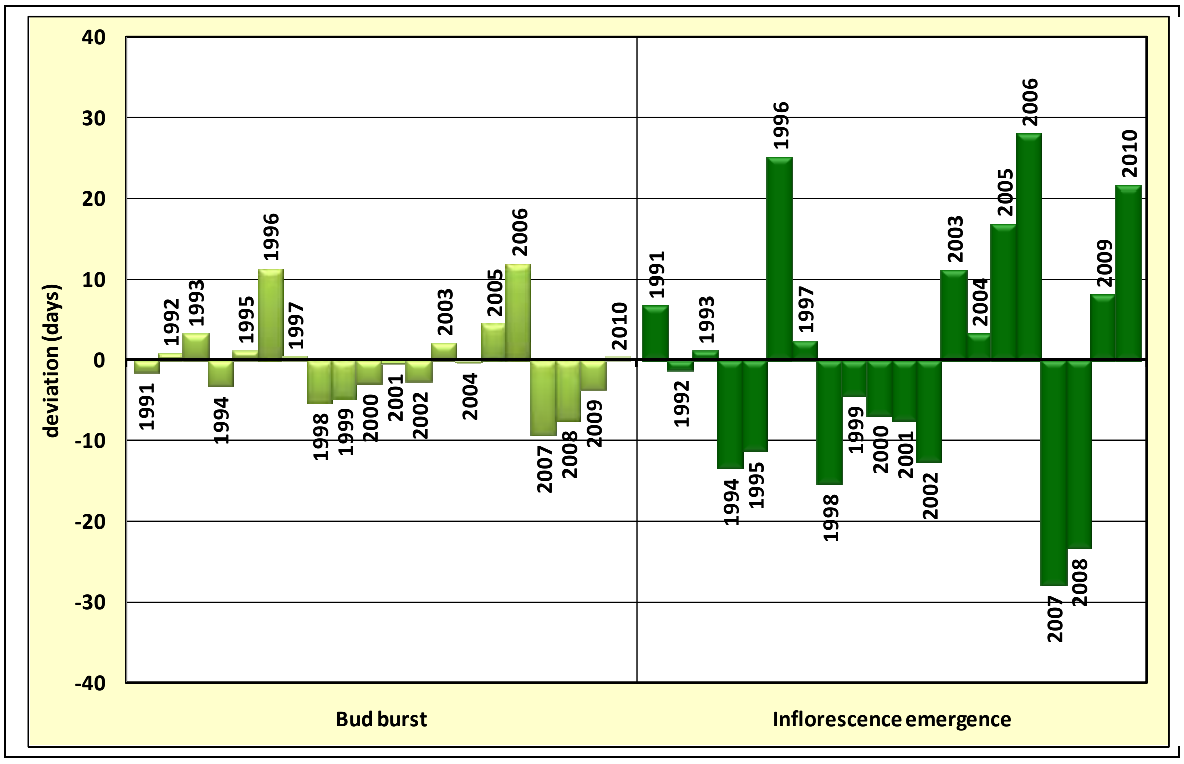


Fig. 15. Annual deviations of phenophase onsets (bud burst, inflorescence emergence) of Common Hazel (*Corylus avellana*) from the long term average 1991–2010.

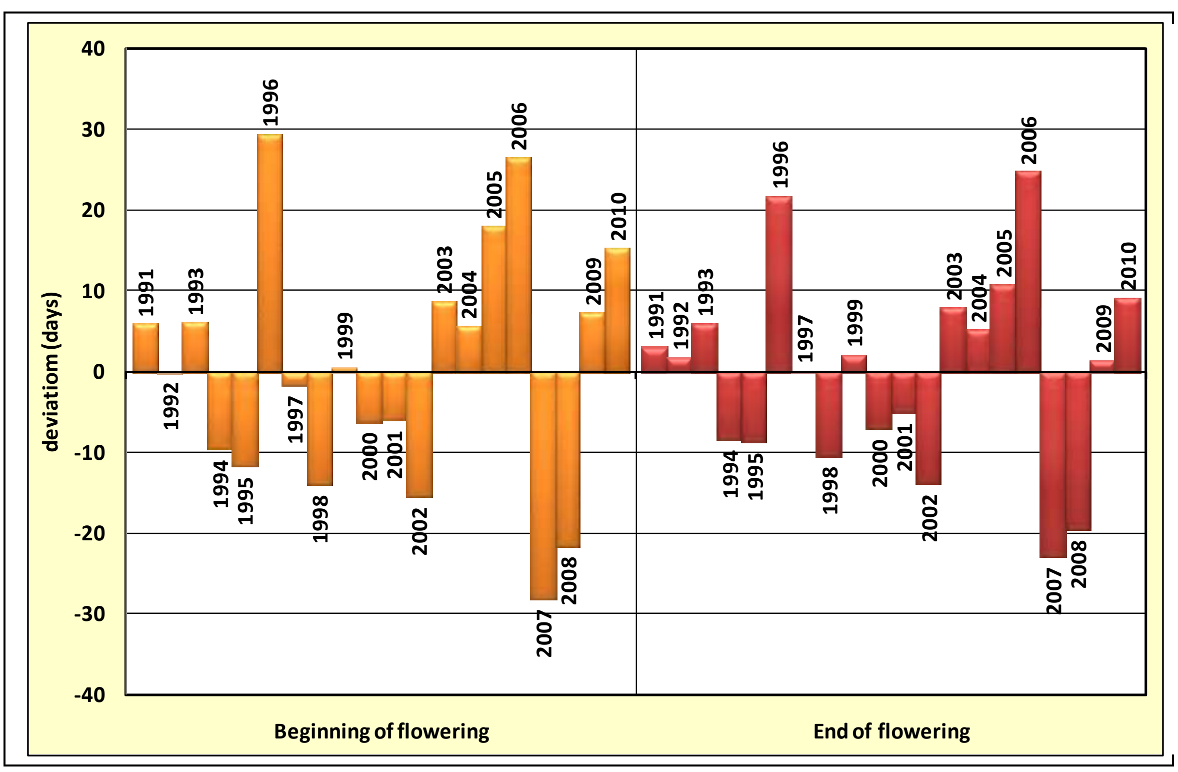
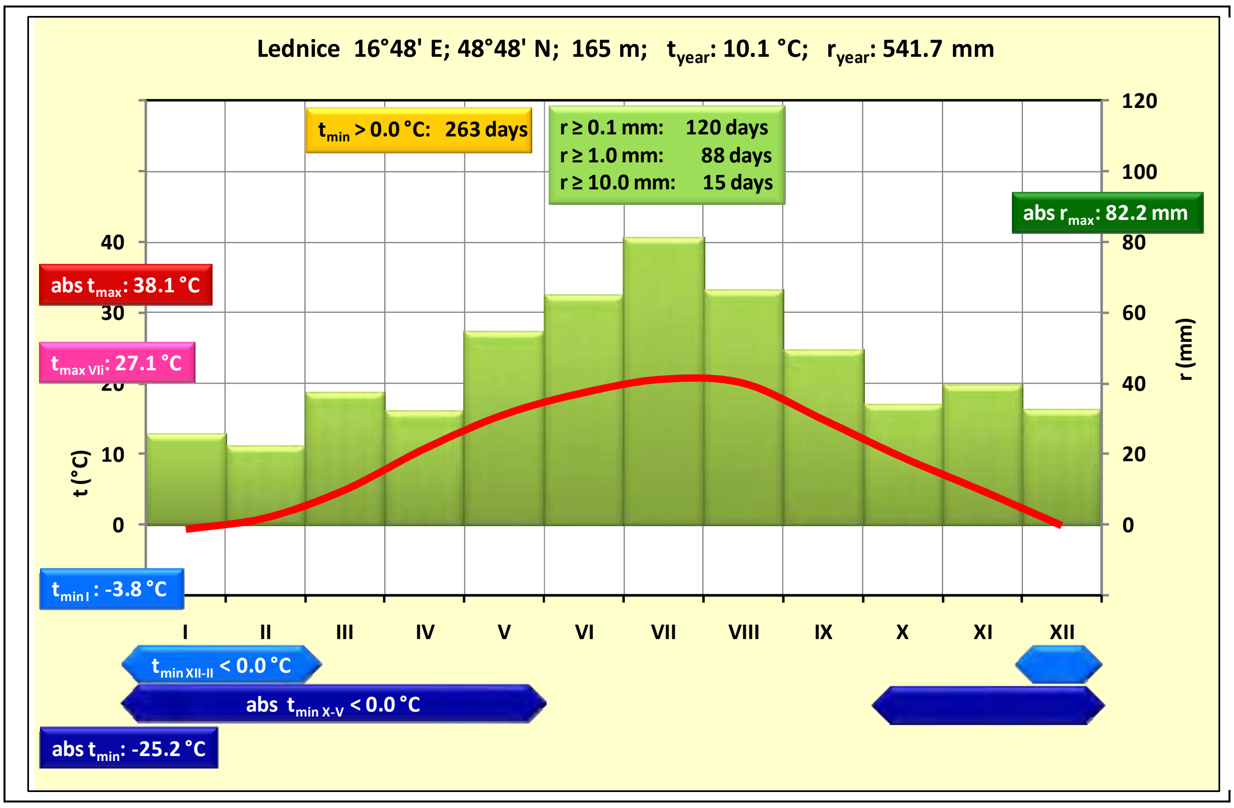


Fig. 16. Annual deviations of phenophase onsets (beginning of flowering, end of flowering) of Common Hazel (*Corylus avellana*) from the long term average 1991–2010.



t = average monthly air temperature (°C); r = average monthly total precipitation (mm); t_{year} = average year air temperature (°C); r_{year} = average year total precipitation (mm); abs t_{max} = absolute maximum of air temperature; $t_{max\ VII}$ = average monthly maximum of air temperature of the warmest month; $t_{min\ I}$ = average monthly minimum of air temperature of the coldest month; abs t_{min} = absolute minimum of air temperature; $t_{min\ XII\text{-}II}$ < 0.0 °C = months with average minimum of air temperature < 0.0 °C; abs $t_{min\ IX\text{-}VI}$ < 0.0 °C = months with absolute minimum of air temperature < 0.0 °C; t_{min} > 0.0 °C = average count of days with air temperature > 0.0 °C; abs r_{max} = absolute maximum of daily total precipitation; r ≥ 0.1 mm= average count of days with total precipitation ≥ 0.1 mm; r ≥ 1.0 mm = average count of days with total precipitation ≥ 1.0 mm; r ≥ 10.0 mm = average count of days with total precipitation ≥ 10.0 mm.

Fig. 17. Climagram of Lednice.

For detailed analyse of phenological phases were used two stations Lednice (165 m asl) and Přibyslav (533 m asl). The average duration of growing season in Lednice station is 231 days, in Přibyslav station it is 223 days. The length of growing season or more precisely the growth of plants and phenological phases onsets are closely connected with climate, mainly temperature influences the course of phenological stages. Figures 17 and 18 present climatological conditions at stations in Lednice and Přibyslav by means of climagram. The climagram provides overall climatological description of specified station. In the climagram are described the course of main climatological elements (air temperature - average, minimum, maximum; precipitation total; number of days with precipitation total ≥ 0.1; 1.0; 10.0 mm). These climatological characteristics were evaluated in the same period as phenological phase's onsets (1991–2010) to show the climatological conditions of the Common Hazel in the selected stations. The stations are situated at different conditions – Lednice station is situated in Dyje lowland at elevation of 165 m and Přibyslav station is situated in „Českomoravská vysočina" at elevation of 530 m. The air temperature has the principal influence on phenological phase onset. The onsets of phenological phases in

Přibyslav station are delayed – it is correlated with the course of average monthly air temperature. The average year air temperature in Přibyslav is 7.4 °C; in Lednice it is 10.1 °C, also the occurrence of absolute minimum temperature < 0 °C is higher at station in Přibyslav within months IX–XII and I–VI; in Lednice station is the occurrence of days with absolute minimum temperature < 0 °C minor just during months X–XII and I–V. On other side the number of days with t_{min} > 0.0 °C is higher at station in Lednice (263 days). The absolute minimum temperature is lower in Přibyslav station (-26.4 °C). Even though the precipitation total has not so important influence on phenological stages onsets, the climagram includes it to present the whole climatological conditions. The annual precipitation total is naturally higher at station in Přibyslav (693.8 mm) in comparison with Lednice station (541.7 mm). Number of days with precipitation total above 0.1mm; 1.0 mm and 10.0 mm is also higher in Přibyslav station.

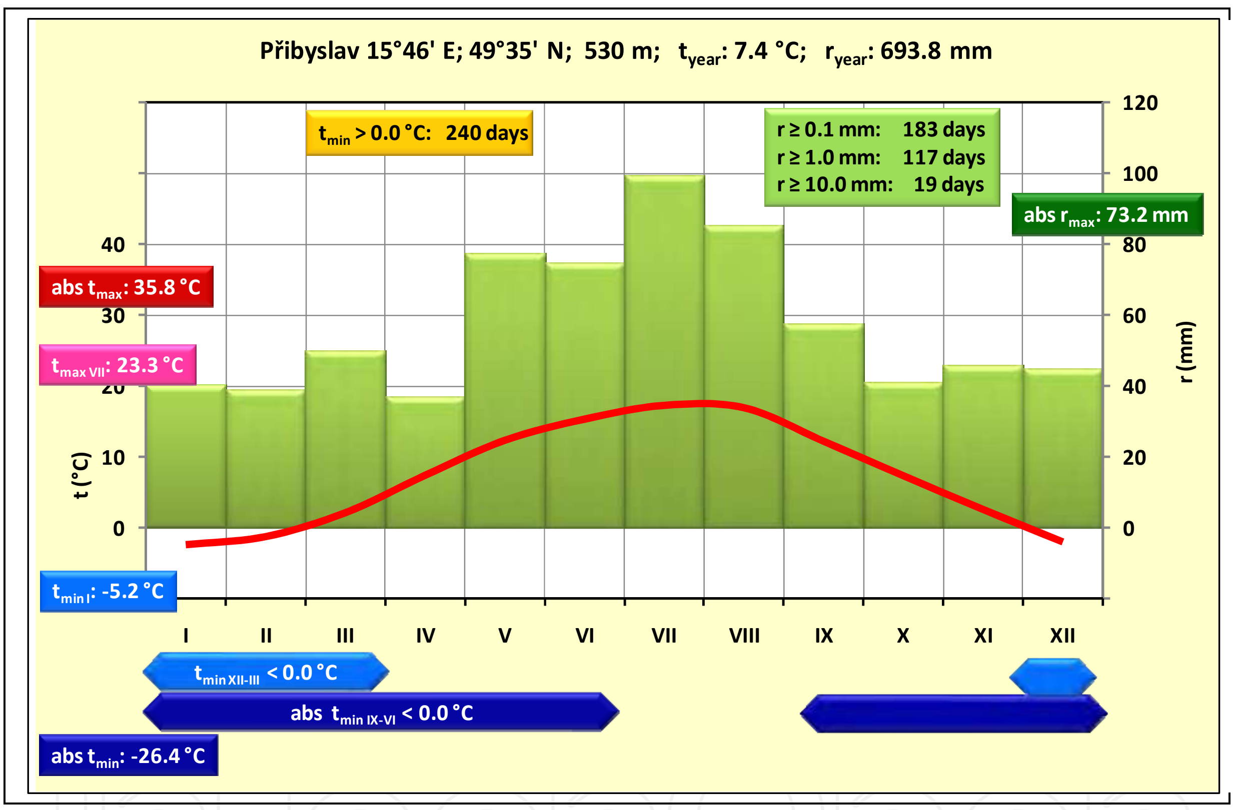


Fig. 18. Climagram of Přibyslav.

Duration of the flowering at stations in Lednice and Přibyslav illustrates Fig 19. Each year is very variable and the time of flowering is different in Lednice and Přibyslav station. The average time of flowering at station in Lednice is 23 days; at station in Přibyslav is 19 days. The shortest duration of flowering was in station at Lednice 6 days (2010), in Přibyslav station it was 7 days (1994). On the other hand the longest duration of flowering was recorded in the year 1997 (45 days) in Lednice station; in Přibyslav station the longest duration of flowering was in the year 2008 (37 days). The extreme duration of flowering was not recorded in the same year at both stations. The average onset of the beginning of flowering within the whole Czech Republic starts on 6th March, the average onset of the end of flowering begins on 28th March. The average duration of flowering is 22 days.

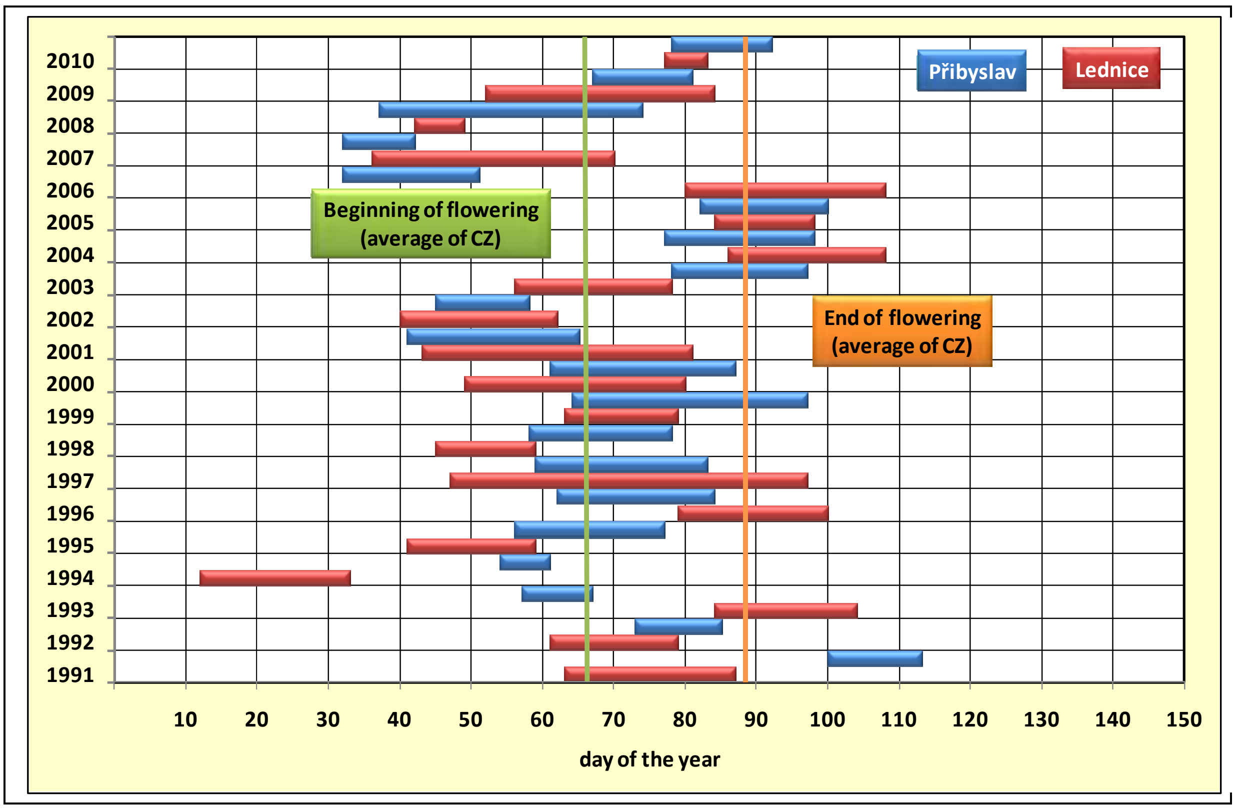


Fig. 19. Average time of flowering of Common Hazel (*Corylus avellana*).

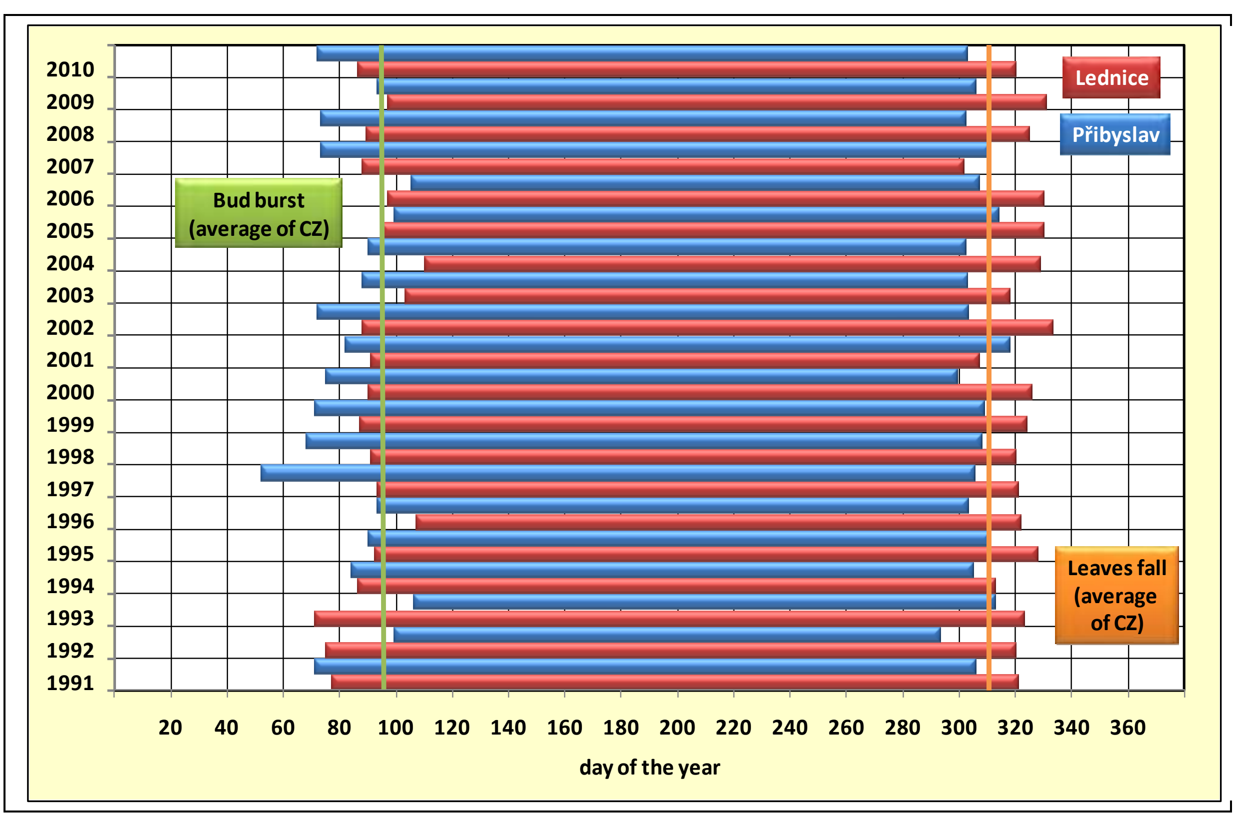


Fig. 20. Average time of growing season (bud burst–leaves fall) of Common Hazel (*Corylus avellana*).

The duration of growing season (bud burst–leaves fall) at both stations demonstrates Fig. 20. The average duration of growing season at station in Lednice is 231 days, at station in Přibyslav 223 days. The average onset of the bud burst of the Common Hazel within the whole Czech Republic begins on 7th April; the average onset of the leaves fall is on 5th November. The shortest duration of growing season was 213 days (2007) and the longest duration of growing season was 252 days (1993) in Lednice station. At station in Přibyslav was the shortest duration of vegetation season was recorded in the year 1992 with 194 days, the longest duration of vegetation season was recorded in the year 1997 with 253 days.

The phenotermopluviogram on Fig. 21 represents relations between air temperature and precipitation total in period of flowering on location Lednice and Přibyslav. The longest period of Common Hazel on location Lednice was 50 days (1997), with sum of temperature (∑t) 255.7 DD and precipitation total (∑r) 43.4 mm, on location Přibyslav 37 days (2008), ∑t = 75.5 DD and ∑r = 49.6 mm. The shortest interval of flowering was in location Lednice 6 days (2010); ∑t = 56.7 DD and ∑r = 0 mm, and in Přibyslav 7 days (1994), ∑t = 26.5 DD and ∑r = 9.8 mm. Long-term mean of Lednice ∑t = 119.1 DD; ∑r = 25.0 mm; duration of flowering = 23 days. Long-term mean of Přibyslav ∑t = 35.1 DD; ∑r = 30.1 mm; duration of flowering = 19 days.

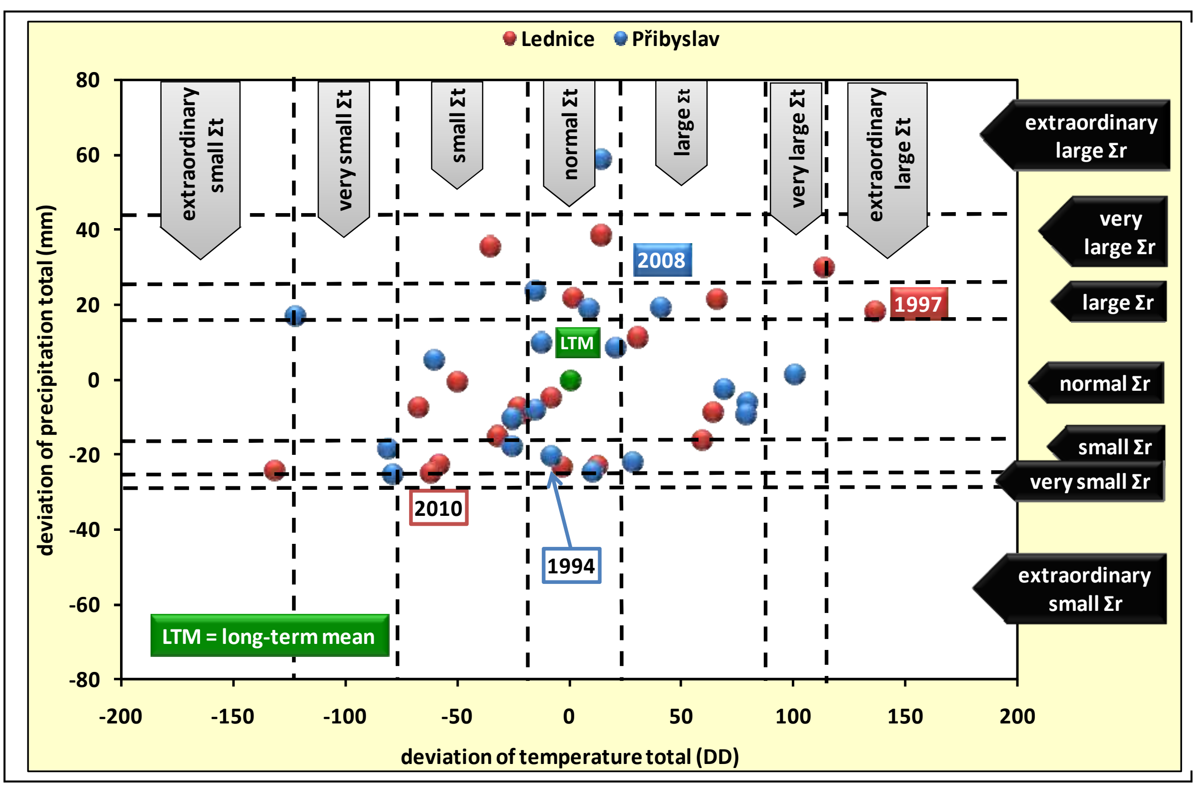


Fig. 21. Phenotermopluviogram of flowering of Common Hazel (*Corylus avellana*).

In Tables 2–5 some statistic results (average, median, 25% quartile, 75 % quartile, standard deviation and variation coefficient) of selected phenophase are enunciated. The variation coefficient presents the balance of time interval, it means a ratio of standard deviation and average. In the Common Hazel were chosen subsequent phenophase stages: the bud burst

(BBCH 07), the beginning of flowering (BBCH 61), the end of flowering (BBCH 69) and the leaves fall (BBCH 97). From the results is apparent the dependence on elevation. Table 6 presents the pentad air temperature to phenophase onset at elevation zones.

Statistical characteristic	Elevation (m)				
	≤ 200	201–400	401–600	601–800	≥ 801
Average	4. IV.	8. IV.	14. IV.	20. IV.	27. IV.
Median	31. III.	2. IV.	9. IV.	19. IV.	25. IV.
25 % quartile	27. III.	27. III.	1. IV.	13. IV.	20. IV.
75 % quartile	4. IV.	9. IV.	16. IV.	27. IV.	29. IV.
Standard deviation	8.9	6.5	8.9	10.3	6.3
Variation coeff. (s_x %)	9.47	6.63	8.56	9.36	5.38

Table 2. Statistical characteristics of bud burst (BBCH 07).

Statistical characteristic	Elevation (m)				
	≤ 200	201–400	401–600	601–800	≥ 801
Average	24. II.	28. II.	7. III.	15. III.	24. III.
Median	23. II.	1. III.	9. III.	22. III.	22. III.
25 % quartile	12. II.	13. II.	21. II.	6. III.	13. III.
75 % quartile	9. III.	15. III.	21. III.	31. III.	3. IV.
Standard deviation	11.2	10.0	11.2	8.8	8.7
Variation coeff. (s_x %)	20.36	16.95	16.96	11.89	10.48

Table 3. Statistical characteristics of beginning of flowering 10 % (BBCH 61).

Statistical characteristic	Elevation (m)				
	≤ 200	201–400	401–600	601–800	≥ 801
Average	18. III.	23. III.	30. III.	7. IV.	15. IV.
Median	22. III.	22. III.	2. IV.	5. IV.	20. IV.
25 % quartile	7. III.	10. IV.	19. III.	17. III.	18. IV.
75 % quartile	30. III.	4. IV.	13. IV.	17. IV.	25. IV.
Standard deviation	10.6	6.2	9.2	10.7	11.4
Variation coeff. (s_x %)	13.77	7.56	10.34	11.03	10.86

Table 4. Statistical characteristics of end of flowering (BBCH 69).

Statistical characteristic	Elevation (m)				
	≤ 200	201–400	401–600	601–800	≥ 801
Average	15. XI.	12. XI.	8. XI.	4. XI.	29. X.
Median	17. XI.	4. XI.	5. XI.	31. X.	18. XI.
25 % quartile	10. XI.	29. X.	30. X.	27. X.	16. XI.
75 % quartile	24. XI.	10. XI.	12. XI.	6. XI.	25. XI.
Standard deviation	14.0	11.1	10.2	10.5	11.6
Variation coeff. (s_x %)	4.39	3.51	3.27	3.41	3.84

Table 5. Statistical characteristics of leaves fall (BBCH 97).

Elevation (m)	Bud burst (BBCH 07)	Beginning of flowering (BBCH 61)	End of flowering (BBCH 69)	Leaves fall (BBCH 97)
≤ 200	5.8	3.1	5.2	6.3
201 až 400	5.9	3.0	4.9	5.9
401 až 600	6.0	2.6	4.7	4.5
601 až 800	6.6	2.8	4.6	3.5
≥ 801	6.8	2.8	4.8	1.5

Table 6. Pentad air temperature (°C) to phenophase onset.

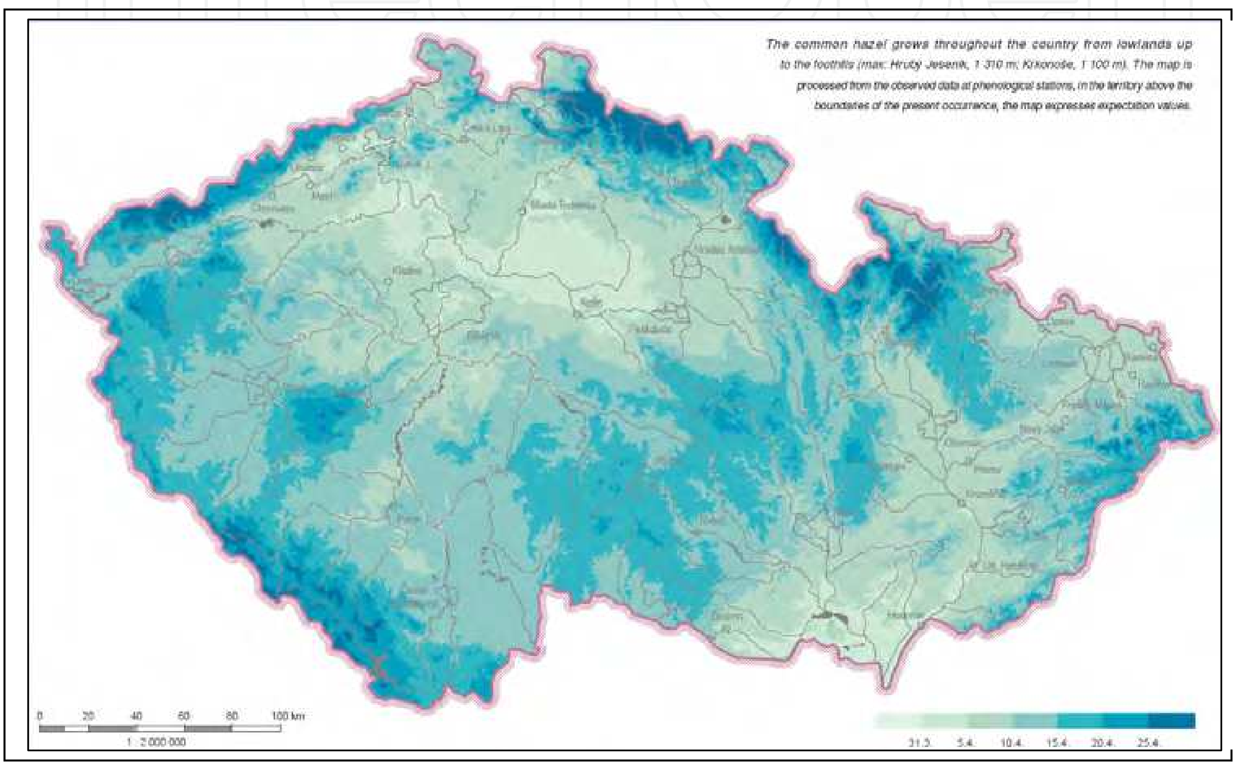


Fig. 22. The average date of bud burst of Common Hazel (BBCH 07).

The average date of selected phenological phase's onsets within the period 1991–2010 show figures 22–25. The onset of the bud burst of the Common Hazel begins between 31st March (lowlands) and 25th April (mountain areas), the beginning of flowering starts between 24th February (south Moravia, Polabská lowland) and 26th March (Krušné hory Mts., Šumava Mts., Krkonoše Mts., Jeseníky Mts., Beskydy Mts.), the end of flowering occurs between 16th March and 20th April and the leaves fall comes between 2nd November (the highest mountain elevations) and 14th November (Polabská Lowland, South Moravia).

The Common Hazel reveals a great variability of different phenophase onset in the observed period 1991 to 2010. The phenological phases were most accelerated in the year 2007; on the contrary the onsets were most delayed in the year 2006.

The vertical phenological gradient (it means gradient of average date of phenological stage onset) for selected phenological stages are subsequent: for the bud burst 2 days/100 m of elevation, for the beginning of flowering is 3 days/100 m of elevation, for the end of flowering is 3 days/100 m of elevation and for the leaves fall 2 days/100 m of elevation.

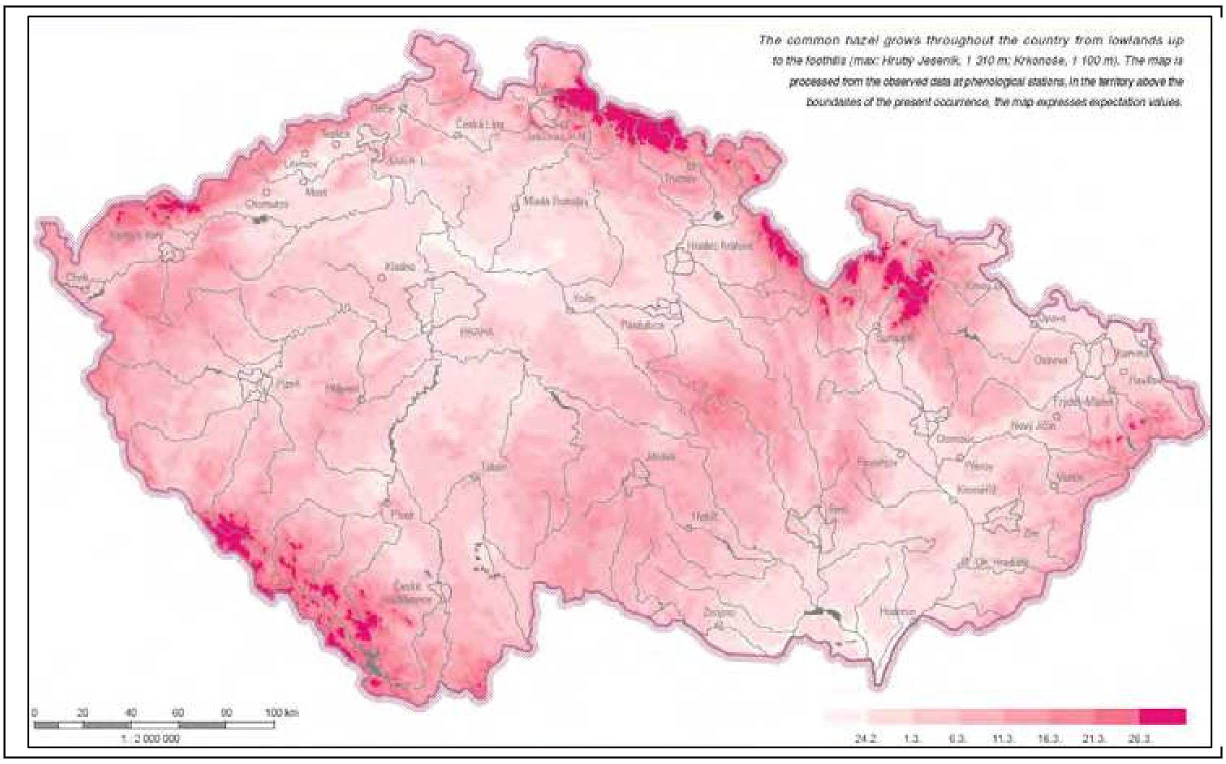


Fig. 23. Average date of beginning of flowering of Common Hazel (BBCH 61).

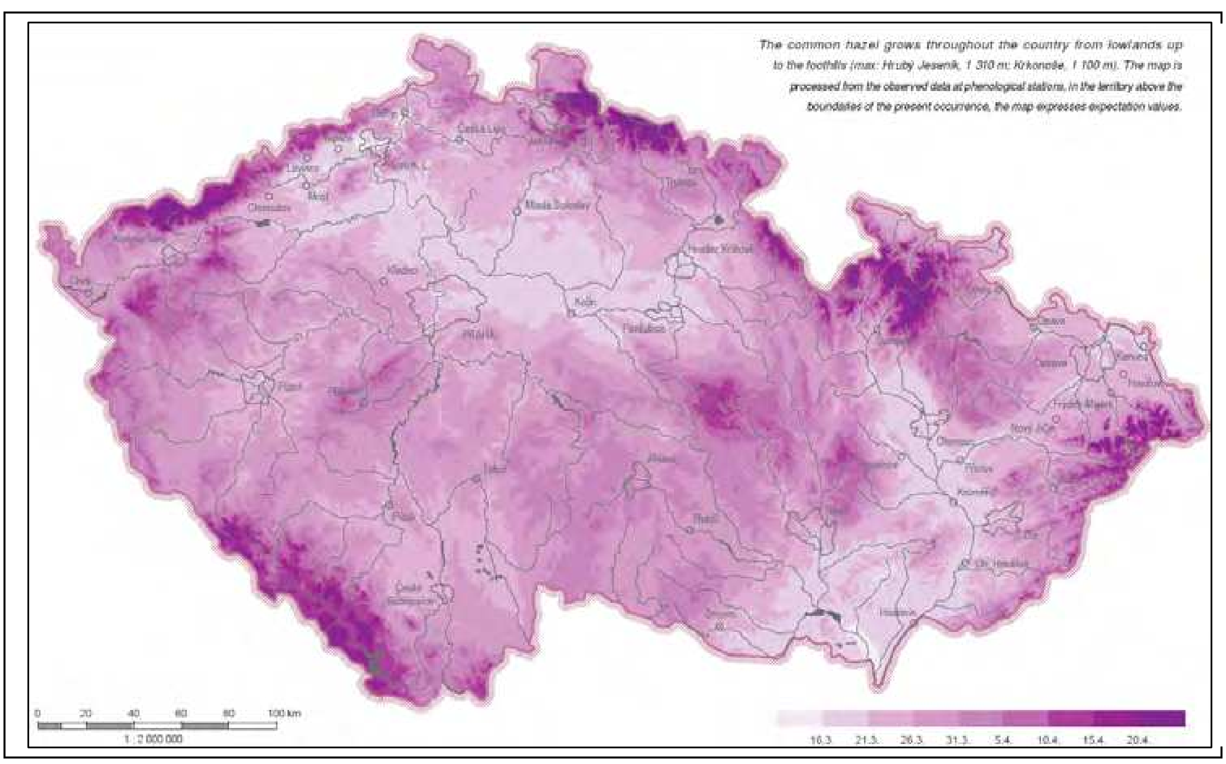


Fig. 24. Average date of end of flowering of Common Hazel (BBCH 69).

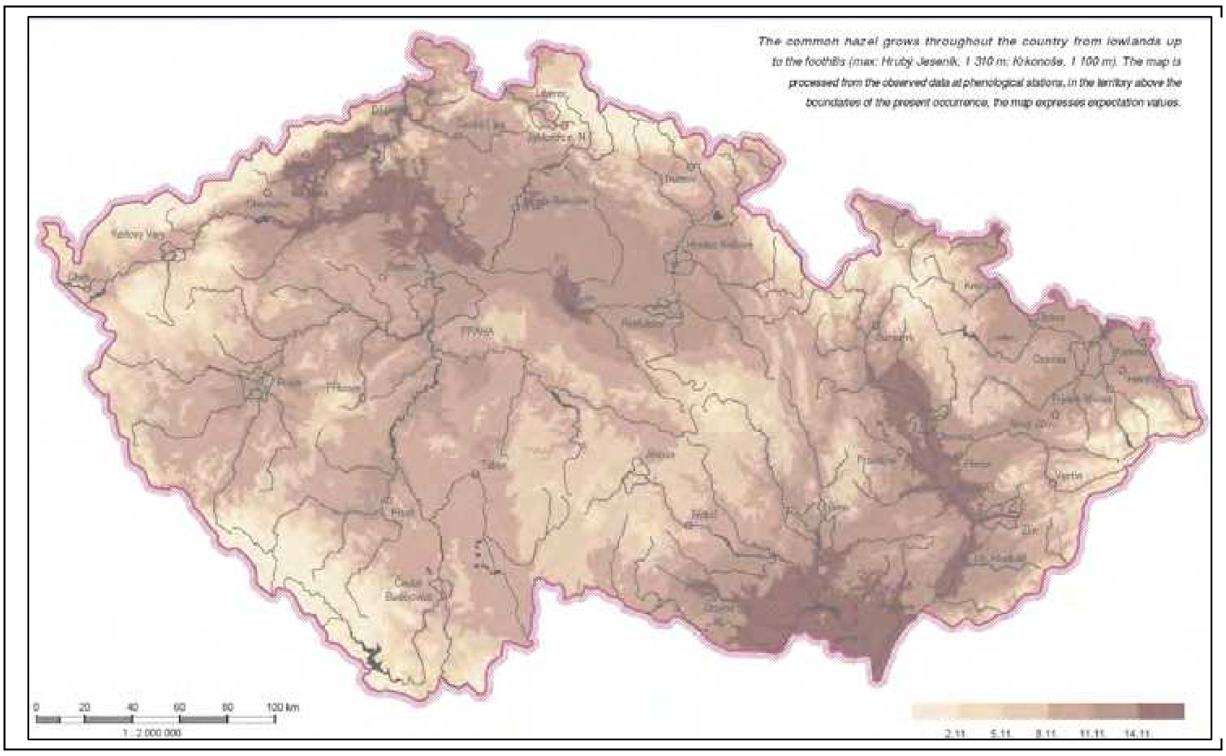


Fig. 25. Average date of leaves fall of Common Hazel (BBCH 97).

The Common Hazel begins to sprout on average between 4th and 27th April, the beginning of flowering comes between 24th February and 24th March, the end of flowering starts between 18th March and 15th April and the leaves fall is between 29th October and 15th November at elevation zones. The period between the bud burst and leaves fall takes from 185 and 225 days on average with the sum of air temperatures from 2,277 to 3,261 °D, the duration of sunshine 1,286–1,366 hours, precipitation total from 430 to 460 mm and 63.5 till 67.8 days with precipitation total of at least 1 mm.

6. Summary

Phenological observations in the Czech Republic have a long tradition; the beginning of phenological research began already in the 18th century. The Hydrometeorological Institute assumed existing phenological data in 1954 and phenological network within the Hydrometeorological Institute has been developed according the own methodology (Pifflová et al., 1956). There were some changes in the methodology of phenological observation till present, nowadays is the phenological network divided into three types of stations (field crops, fruit trees, forest plants). Data are stored in database FENODATA including historical records. The Czech Republic cooperates with other European countries within the phenology research (e.g. IPG, COST 725, COST ES603 and PEP725). From all observed species in the CHMI phenological network was processed detailed evaluation of phenological results in the Common Hazel within the period 1991–2010. The Common Hazel is very important pollen allergen; the time of flowering appears between 24th February and 24th March and lasts 22–23 days on average. The vegetation period takes 185–225 days (bud burst–leaves fall) on average. The

phenophase onsets are closely connected with climate, detailed analysis is shown in climagrams and phenotermopluviogram.

7. Acknowledgement

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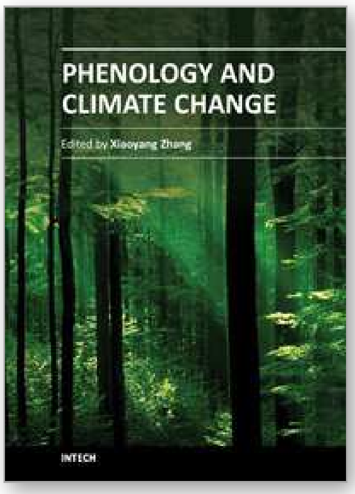

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Phenology, a study of animal and plant life cycle, is one of the most obvious and direct phenomena on our planet. The timing of phenological events provides vital information for climate change investigation, natural resource management, carbon sequence analysis, and crop and forest growth monitoring. This book summarizes recent progresses in the understanding of seasonal variation in animals and plants and its correlations to climate variables. With the contributions of phenological scientists worldwide, this book is subdivided into sixteen chapters and sorted in four parts: animal life cycle, plant seasonality, phenology in fruit plants, and remote sensing phenology. The chapters of this book offer a broad overview of phenology observations and climate impacts. Hopefully this book will stimulate further developments in relation to phenology monitoring, modeling and predicting.