Possibilities of application of phenological observations

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Abstract: This paper deals with the practical application of phenological data. Ways of using phenological data are presented in case studies (from the area – applied and landscape ecology – occurrence of allergens and soil erosion, agriculture and climatology) for the Czech Republic (Central Europe). Phenological data were obtained from direct observations of the Czech hydrometeorological institute. Data were evaluated for different long-term periods (from 1931 to 2012). Period of pollen occurrence for common hazel, goat willow, white birch and small-leaved lime is defined in this article. Pollen of analysed trees can appear in landscape as follows: common hazel from the 33rd day to the 118th day of the year, goat willow from the 61st day to the 125th of the year, white birch from the 96th day to the 138th day of the year and small-leaved lime from the 163rd day to the 215th day of the year. Spring barley, maize and sugar beet were evaluated in this paper. Analysed phenological data show great variability in individual year. The prolongation of growing season was found out for spring barley in locality Branišovice (South Moravia, the Czech Republic). Prolongation of the growing season can be caused climate change, varietal specifics, sowing and harvest dates, sowing density, more powerful and modern agricultural machinery etc. Length of the growing season is one of the main factors influencing the value of protective effect of vegetation (so called factor C). It has been found that the longer the crop on the plot is the lower the value of factor C.

Key Words: growing season, spring barley, pollen allergens, C factor, Czech Republic

INTRODUCTION

Term of the onset of phenological phases (for example emergence, heading, tillering, beginning of flowering etc.) and operations sowing and harvest are recorded in phenological observations. The phenological phase is an annual recurring, externally well recognizable, repeatedly occurring development of plant organs every year.

Data from phenological observations can be used in a number of disciplines but also in practice. We can mention three basic areas in which phenological data possible to use: a) Applied and landscape ecology, b) Agriculture and c) Climatology (on the basis case studies).

MATERIAL AND METHODS

The article is composed of case studies addressing the different areas of phenological data utilization. Different localities, crops and time periods were evaluated in individual case scales. The summarizing table is shown in Table 1.

These phenological phases were evaluated for field crops in this paper: emergence (EM), tillering (TI), the beginning of leaf sheath elongation (BLSE), first node (FN), second node (SN), swelling of the sheath of the last leaf (SSLL), heading (HE), milky ripeness (MR), yellow ripeness (YR) and full ripeness (FR). Phenological phases: beginning of flowering 10%, 50%, 100% (BF 10, 50, 100) and end of flowering (EF) were evaluated for tree species in pollen analysis.

Sowing (SD) and harvest (HA) were also evaluated which are monitored in phenological observation for field crops. Closer specification of individual phenological phases and term of sowing and harvest are given in Methodological prescription No. 2 – Instruction for the activity of phenological stations for field crops (Valter 1982).

Most of the territory of the Czech Republic falls according Köppen climate classification into the damp continental climate (Dfb). The average annual temperature is between 5.5 °C and 9 °C in the Czech Republic. The average annual rainfall is 686 mm (Tolasz 2007).

Calculation of the protective effect of vegetation (so called factor C) was performed on the grounds of Methodology – Protection of agricultural land from erosion (Janeček et al. 2012). The calculation of C factor was made on the basis of the formula %R × C and this value divided by 100 (Wischmeier and Smith 1978).

Table 1 Summarizing table of evaluated locality, period and crops

Area of use	Subcategories	Locality	Altitude (m a.s.l)	Analysed periods	Kind of plant
Applied and landscape ecology	Pollen allergens	Český Rudolec, Březina, Lednice,	540 450 165	1991–2012	common hazel, white birch, small-leaved lime, goat willow
	Soil erosion control	Tupesy, Sokolnice Strážnice Ivanovice na Hané Luhačovice Tečovice	240 255 177 220 329 260	1961–2012	sugar beet, maize, spring barley
Agriculture	-	Strážnice	177	1991–2010	spring barley
Climatology	-	Branišovice	180	1931–2012	spring barley

RESULTS AND DISCUSSION

a) Applied and landscape ecology

The first possible use of phenological data within applied and landscape ecology is the **monitoring of pollen allergens** in the landscape.

Figure 1 lists the average terms for the occurrence of white birch, common hazel, small-leaved lime and goat willow. The average time of flowering is evaluated in these trees also. Pollen of common hazel is one of the earliest allergens scattering in the air. Common hazel flowering on average thus: at locality Lednice from the 60th day to the 81rd day of the year, at locality Březina from the 80th day to the 95th day of the year and at locality Český Rudolec from the 67th day to the 93rd day of the year. Pollen of goat willow is another allergen occurring in the landscape which appears at locality Březina from the 88th day to the 111th day of the year and at locality Český Rudolec from the 84th day to the 103rd day of the year. Pollen grains of white birch are other allergen that appears in air. Pollens of white birch are among the most aggressive allergens. White birch has on average the shortest flowering time from analysed tree species (from 9 days to 14 days). White birch flowering at the analysed localities on average thus: from the 102nd day to the 116th day of the year in Lednice, from the 120th day to the 129th day of the year in Březina and from the 115th day to the 125th day of the year in Český Rudolec. Pollen of small-leaved lime appears at the latest of the analysed the trees species. It flowering from the 178th day to the 198th day of the year at locality Březina and from the 186th day to the 200th day of the year at locality Český Rudolec.

The occurrence of allergens was determined on the basis of measured phenological data for individual years. Figure 2 was created from the terms of the earliest date of flowering and the latest date of end of flowering. Pollen grains of common hazel appear in nature first from the 33rd day to the 118th day of the year. Pollen of goat willow is the second in line of analysed allergens. Goat willow blooms in term from the 61st day to the 125th of the year. Pollen of white birch may occur from the 96th day to the 138th day of the year. Small-leaved lime flowering as the last of the analysed plants. It was flowering from the 163rd day to the 215th day of the year (Figure 2).

Anti-erosion protection of soil is the second possibility of using phenological data in applied and landscape ecology. Protective effect of vegetation (so called C factor) enters into calculation of value of long-term soil loss from a given plot (Wischmeier and Smith 1978). The C factor depends on vegetation cover and agronomic management. Soil cover plays an important role for soil protection from the erosion (Boardman and Poesen 2006).

Figure 1 Average values of occurrence of pollen allergens from selected tree species

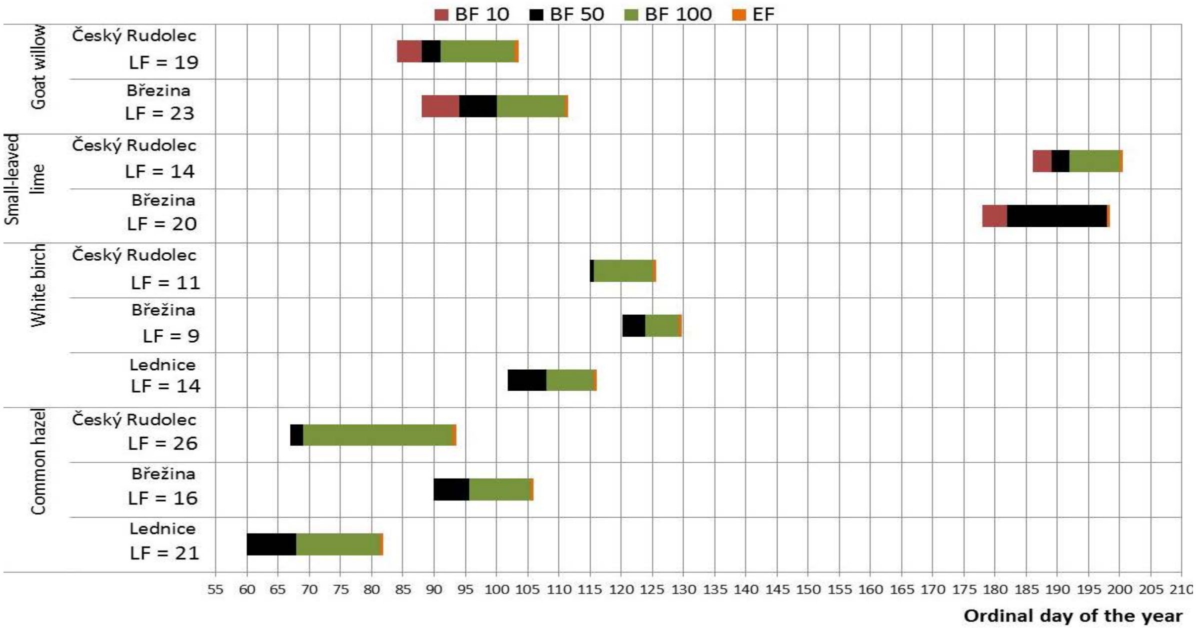
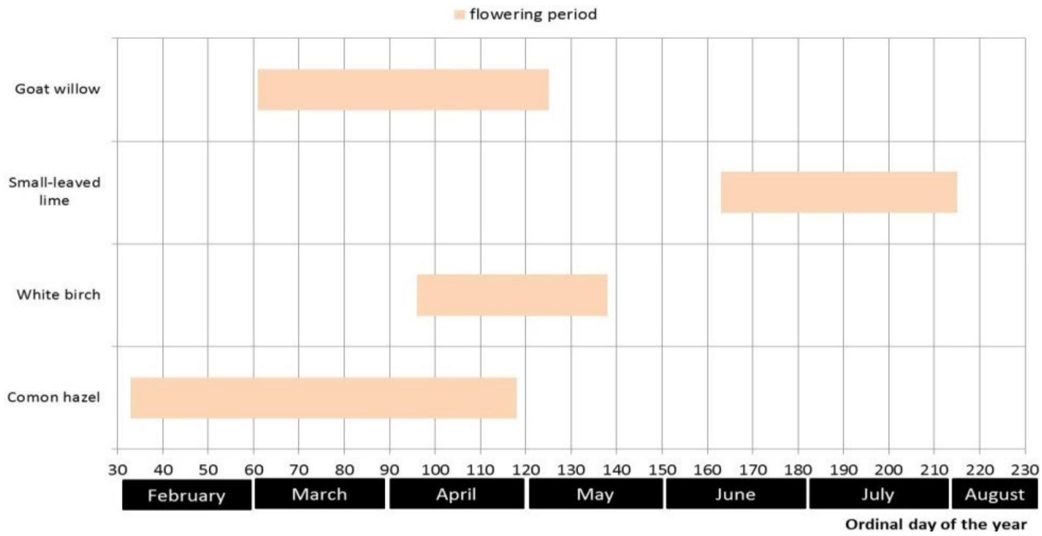


Figure 2 Demarcation of the occurrence of allergens of common hazel, goat willow, white birch and small-leaved lime



Dates of sowing and harvest (data from phenological observations) were used for calculation values of C factor. The largest percentage difference between values of C factors was found out in the spring barley at locality Luhačovice (Table 2). Lower value of C factor was found out for a long growing season. The main reason for the lower value of C factor in long growing season is that the crop protects the surface of the soil longer. The same result was found out in other contributions (Stehnova and Stredova 2016).

Date of sowing is another important factor that affects the value of C factor. The sooner the spring barley is sowed, the value of C factor is lower. The sowing and emergency of plants are characterized as a crisis period due to soil erosion. In this period the soil is insufficiently protected by vegetation and could happen the big loss of soil. Erosion dangerous period of plants (sowing, emergence) had to occur in period when erosion dangerous rains don´t occur. Erosion dangerous rains appear from April to October (with different probability).

Table 2 Values of C factor for extreme years at selected locality

Crop	Phenological station	Length of the growing season	Year	Data from phenological observations		Value of C factor	Percentage difference
				Sowing	Harvest		
Sugar beet	Tupesy	192	1970	21 March	28 September	0.3408	28.9%
		134	1974	5 May	15 September	0.4793	
	Sokolnice	199	1974	14 March	28 September	0.3317	24.6%
		157	1981	30 April	3 October	0.4397	
Maize	Strážnice	193	2010	23 April	1 November	0.4679	12.5%
		113	1992	16 April	7 August	0.4714	
	Ivanovice na Hané	154	2007	2 April	3 September	0.4294	32.1%
		97	1994	2 June	7 September	0.6315	
Spring barley	Luhačovice	154	1983	18 April	25 July	0.2535	43.5%
		98	1974	5. March	6 August	0.1433	
	Tečovice	154	1974	22 February	25 July	0.1930	24.1%
		95	1964	14 April	18 August	0.2126	

b) Agriculture

A detailed analysis of phenological data is also useful in agricultural practice for example in the application of plant protection products, in yield and growth models, in optimizing irrigation, pathogen prediction, agrometeorological modelling etc. It is clear from graph (Figure 3) that individually years show great variability. Roetzer et al. (2000) states that phenological manifestations of plants are closely related to seasonal weather conditions. This may be a reason for the large variability of phenological data at the analysed localities. Variability of phenological phases and climatic conditions can have a significant effect also on seed quality.

Earliest sowing was performed in year 2007 (the 54th day of the year) and in year 1997 (the 66th day of the year). In these years the longest growing season was found out (144 days). The shortest growing season was found out in years 1996 (115 days) and 2008 (114 days).

c) Climatology

However, phenology is most commonly associated with climate change. Phenology is often referred to as the auxiliary science of climatology. Above all due to the close relationship between phenological data and climatic conditions of the external environment (Sobíšek 1993). We need long-term phenological observations for a climatic analysis that can be used to study climate change.

The average values of phenological phases and average term of sowing and harvest were rated for three long periods (Figure 4). It was found out that the growing season (GS) was prolonged (GS is understood as an interval between sowing and harvest). Šiška and Takáč (2008) state that GS will be extended about 21 days by 2020 and about one month by year 2050. However, long-term changes in field crop phenology may not be due to only climatic changes but may also be influenced by varietal specifics, better farming techniques, sowing density, sowing and harvest timing, microclimate conditions etc.

A positive relationship between plant development and temperature has been demonstrated in Germany i.e. increasing air temperature causes a shortening in the phenological phase (Estrella et al. 2007). This trend was also found at locality Branišovice. Trend of shortening the interval between the phenological phases was detected at the phenophasis emergence and heading. Phenological analysis with use linear trend analysis for apricot (Velkopavlovická variety) shows that phenological phases beginning of flowering occurs earlier about 2 days in every decades (Chuchma et al. 2016). The earlier date of sowing was found out also in this locality. Prolongation of interval between sowing and emergence was found. The earlier sowing affects the following phenological stages. This "measure" is sometimes considered adaptive measures to adapt to climate change (Rezaei et al. 2017).

Figure 3 Detailed analysis of phenological data for spring barley at locality Strážnice

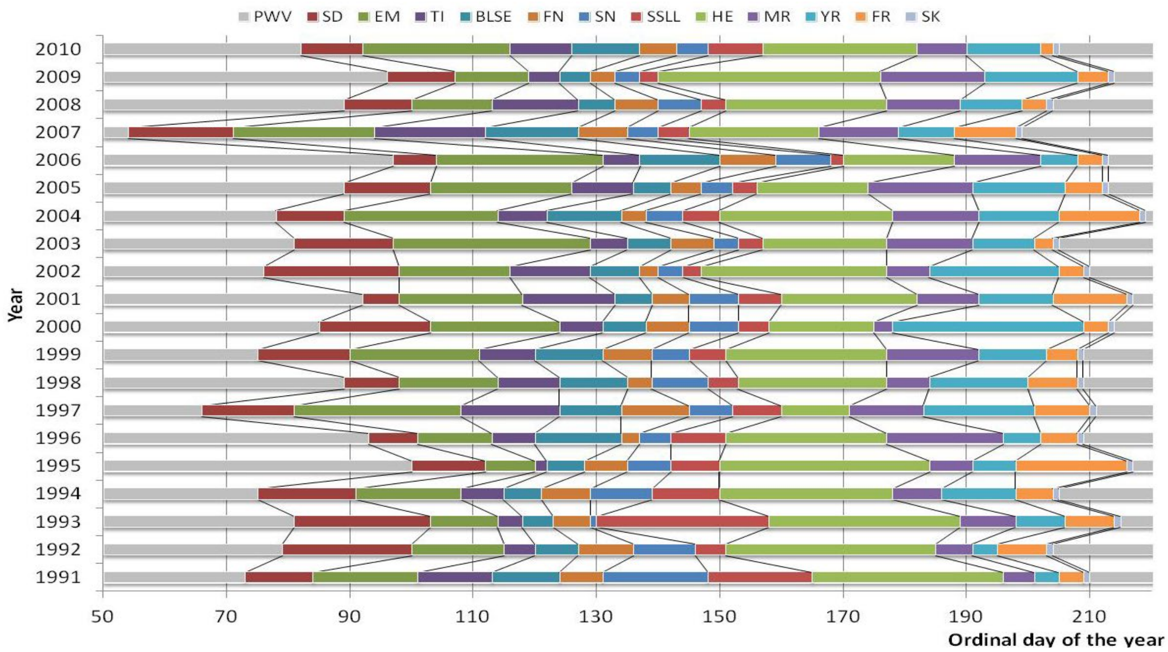
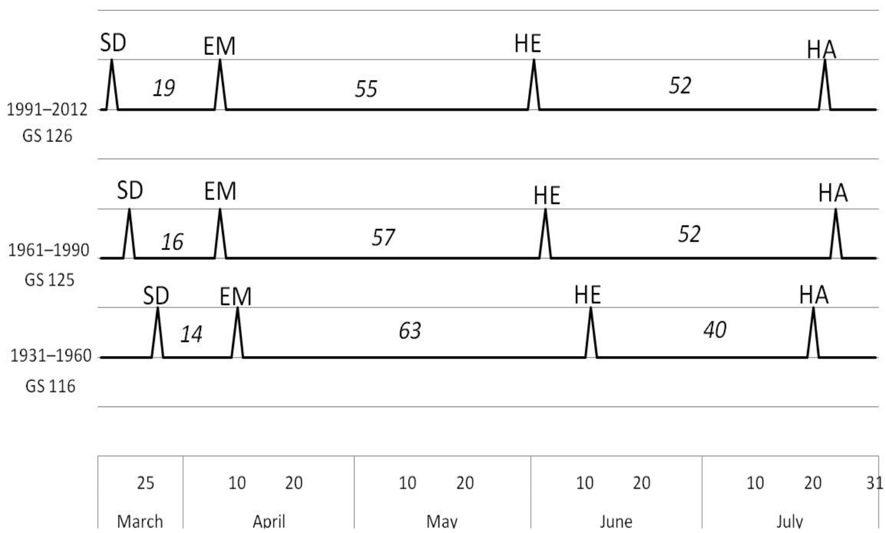


Figure 4 Analysis of long-term values of average terms onset of phenological phases and sowing and harvest of spring barley at Branišovice locality



CONCLUSION

Phenological data are a valuable data source. Their use is possible within many scientific disciplines but also in agricultural practice. The article provides examples of the use of these data in several case studies.

Analysed phenological data show great variability in individual year. The Prolongation of growing season was found for spring barley also. The shortening of interval between phenological phases (emergence and heading) was found out in spring barley. Climate change can cause cased the prolongation of the growing season but it is important to consider other possible factors that may affect the length of the growing season for example varietal specifics, sowing and harvest dates, sowing density, more powerful and modern agricultural machinery etc.

Dates of sowing and harvest were used in calculating the protective effect of vegetation (C factor) also. Length of the growing season is one of the main factors influencing the value of factor C. It has been found out that the longer the crop on the plot is the lower the value of factor C. Phenological data were also used for monitoring pollen allergens. It was found out that allergens appear in the following order common hazel, goat willow, white birch and small-leaved lime.

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