INFLUENCE OF SNOW COVER AND WINTER AIR TEMPERATURES ON FLOWERING OF EUROPEAN HAZEL (*Corylus avellana* (L.) IN NORTHERN CARPATHIANS

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Spring phenology of European hazel is evaluated on the background of changes in snow cover and air temperatures during winter period in the paper. Meteorological data and onsets of spring phenophases were recorded during years 1987 -2015 in Botanical garden of Technical University in Zvolen. Methodology of Slovak Hydrometeorological Institute in Bratislava (SHMI) was applied for observation of Phenological phases of European Hazel. Datasets of winter meteorological condition consist of number of days with snow cower, frost days, depth of snow cover and mean air minimal temperatures. Hazel sensitively responds to winter snow conditions. Most sensitive to the onset of flowering hazel influences snow depth in February as well as number of days with snow cower during winter. The onset of the flowering delays the low minimum air temperatures in February.

Key words: Snow, Air Temperature, European Hazel Phenology

INTRODUCTION

Phenological observations are one of the methods of studying changes in environmental conditions and their impact on original forest ecosystems. Increased attention is currently devoted to the response of woody species to global change. These are also manifested by the higher variability and occurrence of extremes of the main climatic elements, especially rainfall and air temperatures. Changes in climate conditions in the country, apart from temperature and humidity changes, can also result in significant changes in the composition and size of the original ecosystems. Thanks to the easy and reliable identification of phenological manifestations of woods, it is possible to assess changes in ecosystems and to anticipate the possibilities of their further development. Phenology as a bioindicator contributes to the knowledge of the laws of many biological processes such as seasonality of vegetation, the risk of late frost damage, and at the same time enables the determination of the dependencies of generative phenological phases from some meteorological elements, and in time areal forecast of the onset of flowering and pollen loads. European hazel (*Corylus avellana* L.) belong to woody plan of the original forest ecosystems in Slovakia. It is widely spread across Europe. Pollen grains cause frequent allergic symptoms. For proper diagnosis and the timing of preventive treatment for patients, the data on the onset of flowering are important. Consequently, increased attention was paid to the research of its generative organs also in other European countries (Kasprzyk, 2003, Črepinšek et al., 2011, Malkiewicz et al., 2016). The main reason of the study is to know the interrelationships between the course of the weather conditions (snow and air temperatures) and the flowering applicable for the areal forecast of this phenophase. Flowering is also frequently applied as a reliable bioindicator of changing climatic conditions on local level.

Phenological records thus become an important source of information in prognoses of further expansion and vitality of woody plants (Bagar and Nekovář 2006, Piotrowicz and Myszkowska 2006, Škvareninová 2009).

DATA AND METHODS

Phenology of European hazel was recorded in the period 1987-2015, on stands of original distribution in the Zvolen basin in Central Slovakia – Northern Carpathian. North and northwest exposures (81%) predominate on the site, with a lower percentage of southwestern and western exposure-oriented slopes. The altitude range varies from 290 to 377 meters above sea level. The site is characterized by an mean annual temperature of 8.2 ° C, annual rainfall 755 mm and 69 days with snow cover (Střelcová and Škvarenina 2007).

Phenological scale of Slovak Hydrometeorological Institute in Bratislava was applied for evaluation of flowering onset of European hazel (BBCH 60 - at least 10% male flowers pollenate). Onset of flowering was related to dates and day of the year respectively.

Dependence of flowering onset were evaluated on meteorological data as given below:

- DSC - number of days with snow cower
- SD - depth of snow cover (cm)
- SC ≥1 - number of days with snow cower ≥ 1 cm
- SC ≥5 - number of days with snow cower ≥ 5 cm
- SC ≥10 - number of days with snow cower ≥ 10 cm

<u>air temperature</u>

- T_{min} - mean minimal temperature (°C)
- FD - number of days with daily minimum temperature less than 0°C
- ID - number of days with daily maximum temperature less than 0°C

RESULTS AND DISCUSSION

Onset of flowering in Zvolen basin was recorded on the March 2 in average with the earliest date on the January 24th, 2014 and latest date on the April 1st, 1987. During 28 years of observation the statistically significant decreasing trend resulting in earlier onset of flowering by 8 days was recorded (Fig. 1). The date of flowering based on observations from years 1930 -1960 presented for Zvolen basin was estimate on the March 13th (Kurpelová, 1972).

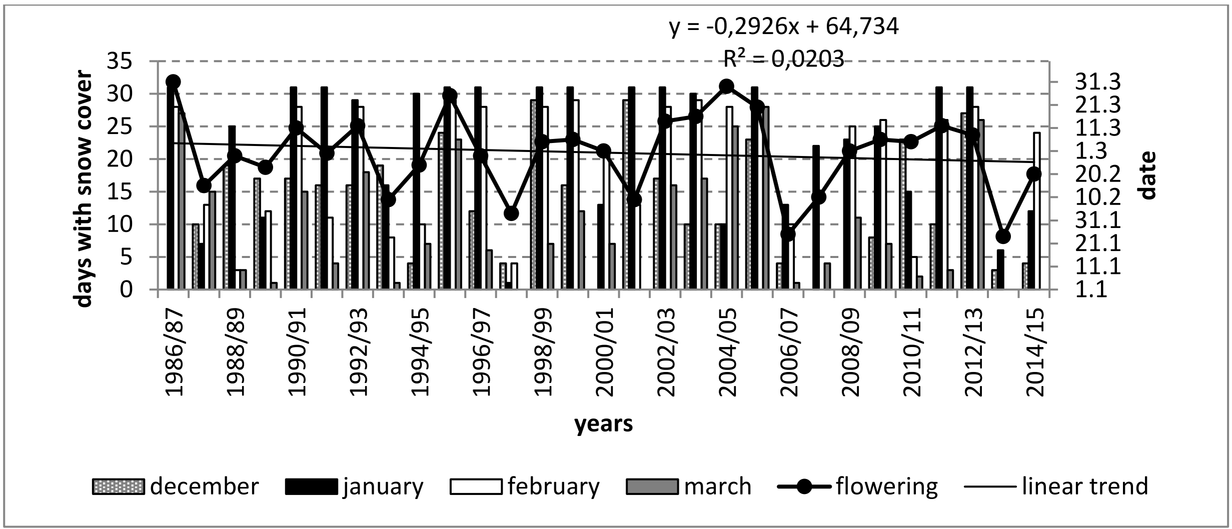

Figure 1. Dependence of European Hazel flowering on number of days with snow cover during period of years 1987–2015 in Zvolen basin

This comparison documents average shift of flowering onset by 11 days toward earlier date in conditions of changing climate. On the other side Bednářová and Merklová (2006) presented onset of European Hazel flowering during years 1991 – 2005 on the April 4th in Czech Republic. However, this significant delay by 33 days as compare with data from the North Carpathian is given by altitude of the stand (625 m) first. Kasprzyk (2003) found in years 1999 -2001 the flowering onset since the middle until the end of February for Rzeszów (SE Poland). Earlier onset of flowering in Rzeszów by about 2 – 3 weeks as compare with date can be caused by landscape character. Thermic inversion in hilly area of Zvolen Basin can significantly influence thermic time of European hazel. Except for it the different series of years used for Polish and Slovakian studies can significantly influence results

Duration of snow cover significantly influenced flowering date of European hazel (Fig. 1). Small number of days with snow cover (1-13 days) in years 1998, 2007 and 2014 in January to March accelerated onset of flowering. Persistent snow cover with higher number of days with snow cover (23-31 days) in 1987, 1996, 2005, 2006 delayed flowering to the last decade of March. Highly statistical significance was found (p<0,001) for winter months as well as for March (Fig. 2 and 3) (r=0,77). Different significances were found in relations among flowering dates and depths of snow cover (Tab. 1). According to results given in tab. 1 the depth of snow cover in February most significantly influence the flowering of European hazel (r = 0,701–0,778). Flowering is accelerated with falling snow depth.

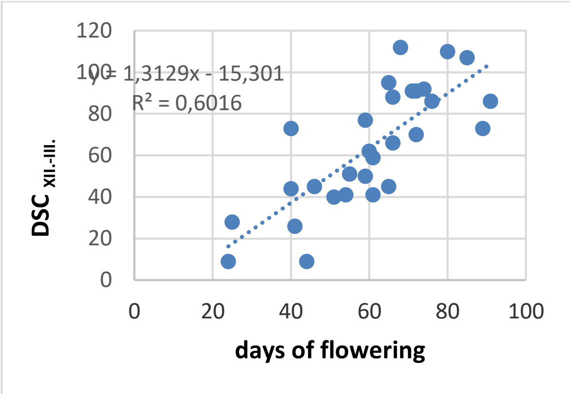

Figure 2. Dependence of European Hazel flowering on number of days with snow cover in December-March ($DSC_{XII-III}$)

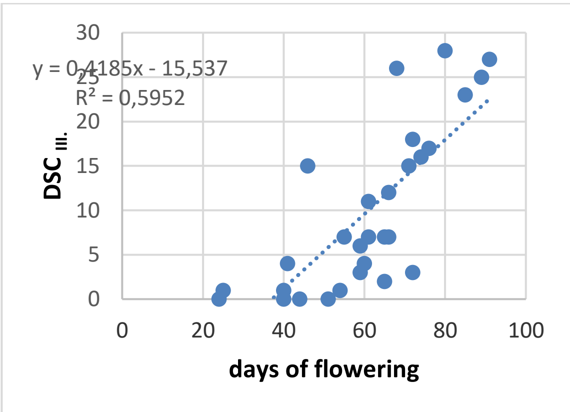

Figure 3. Dependence of European Hazel flowering on number of days with snow cover in March

Table 1. Statistical characteristics depth of snow cover and flowering (*Corylus avellana* L.) in winter months (r – correlation coefficient, *p<0,001)

snow depth	R				
	XII.-III.	XII.	I.	II.	III.
total	*0,744	0,341	0,428	*0,778	0,643
1 cm	*0,747	0,386	0,489	*0,740	0,664
5 cm	*0,699	0,335	0,445	*0,736	0,657
10 cm	0,667	0,362	0,345	*0,701	0,609

The air temperature dominantly influences European hazel flowering. The hazel flowers on the March 2nd in average in Zvolen basin. As a highly significant indicator of flowering onset (r=0,91) was found mean of 2 months temperatures in January-February (Fig. 4). Highly significant relation (r=0,89) between flowering and minimum air temperature was found in February too (Fig. 5). Acceleration of phenophase onset was observed on southward oriented slopes. This knowledge was found in Poland too (Puc and Kasprzyk, 2013).

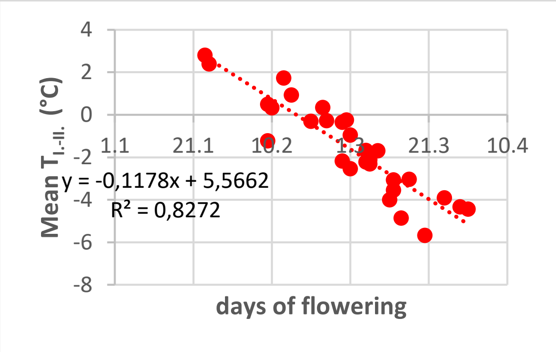

Figure 4. Dependence of European Hazel flowering on mean air temperatures in January-February

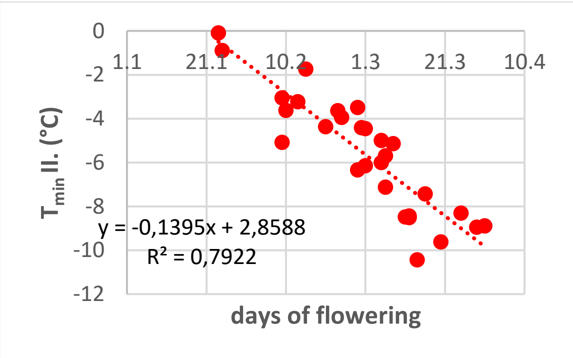

Figure 5. Dependence of European Hazel flowering on mean air temperatures in February

Shallowed rooted European hazel belongs to first flowering woody plants in spring season and warming of soil cover and can evoke flowering even at the end of winter period. Therefore, the influence of days with minimum and maximum air temperatures respectively on flowering of hazel were tested. Significant dependence of flowering onset on both number of days with minimum and maximum air temperature respectively in period January-February was found (r=0,773-0,821). Decreasing number of these days especially in warm winters accelerate the flowering (Fig. 6 and7).

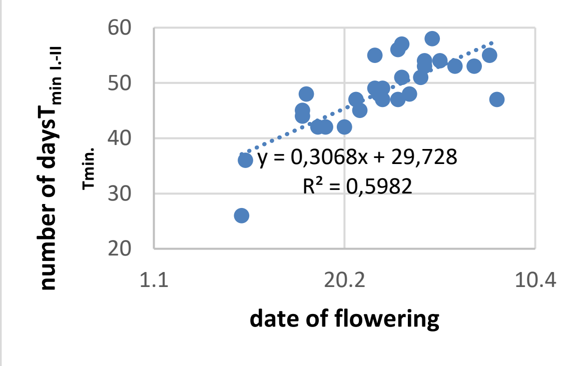

Figure 6. Dependence of European Hazel flowering on number of days with air minimum temperatures less than 0°C in period January – February

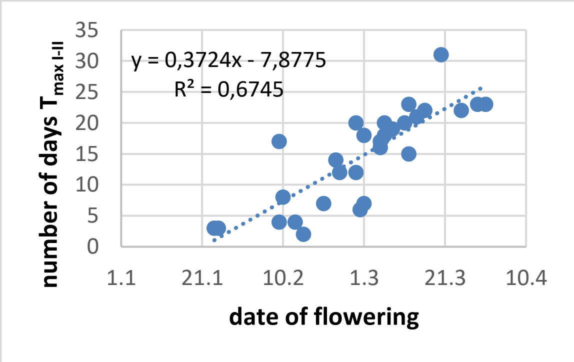

Figure 7. Dependence of European Hazel flowering on number of days with air maximum temperatures less than 0°C in period January – February ($T_{max\ I-II}$)

CONCLUSION

The onset of flowering depending on the snow and temperature conditions in the years 1987-2015 was monitored and evaluated in the Zvolen area - North Carpathian, Slovakia. Phenophase onset was found on March 2 in average. This data provides important information for patients diagnosed with pollen allergies.
The occurrence of snow cover significantly affects the flowering onset. We have found that the effect of the permanent snow cover in the months of January-March has shifted this onset to the last decade of March. Small number of days with snow cover resulted in flowering onset at the end of January.
Depth of snow significantly influences the date of flowering, most in February. Flowering is accelerated with falling snow depth.
We also found the significant dependence of the flowering onset on the number of days with both the minimum and maximum air temperatures less than 0°C in January-February. A frequent and long-lasting series of such days shifts the phenophase from the beginning to the middle of March. Flowering most affected February's minimum air temperatures.
The European hazel, as one of the first flowering woody plant with its phenological activity provides valuable information that can be applied in allergology, but also as

a bio-indicator of climate change in Northern Carpathian of Slovakia.

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