SNOW COVER AND ITS INFLUENCE ON THE BEGINNING OF FLOWERING OF SNOWDROP (GALANTHUS NIVALIS L.) AT THE INTERNATIONAL PHENOLOGICAL STATION (GPM) IN BANSKÁ BYSTRICA OVER THE PERIOD FROM 2003 TO 2017

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The contribution deals with the dependence of the beginning of flowering of snowdrop (Galanthus nivalis L.) from the number of days with the snow cover at the GPM station in Banská Bystrica over the period from 2003 to 2017. The snowdrop was found to have a relatively large variability of the onset days of the beginning of flowering (42 days). The earliest onset of this phenological phase was recorded on February 20 in 2014, when there was 10 days with a snow cover in Banská Bystrica. The latest onset was on April 3 in 2006, when there was 89 days with a snow cover in the winter season. From the observed onsets of the beginning of flowering over the given period, the downward trend has emerged, which means the shift of this phase into earlier terms. The regression model shows a statistically significant effect of the number of days with the snow cover in the winter season on the beginning of flowering of snowdrop. Following that, if the snow cover lasts 3 days longer in the winter season, the onset of the beginning of flowering of snowdrop (Galanthus nivalis L.) will be shifted one day later.

Keywords: phenological observations, beginning of flowering, snowdrop (Galanthus nivalis L.), Global phenological monitoring, regression analysis

INTRODUCTION

Galanthus nivalis (snowdrop) is a perennial, angiospermous, monocotyledonous herbaceous plant, from the *Amarylidaceae* family, which grows from a bulb. From the underground bulb, which is covered in brown scales, two daisy leaves and a stalk stalk grow. At the end of the stem is a single flower, which is composed of three outer and three inner petals. Outer white petals are protruding and have an elongated shape. From the flower after the flowering, a dry puffy fetus is formed, called three-celled capsule. The blossoming snowflake can resist even stronger frost. By releasing the accumulated energy from the substance exchange, snowdrop produces heat and heats up to ten degrees Celsius. Therefore they melt the surrounding snow and create the conditions for survival. But after flowering, the snowdrop will hide back into the ground.

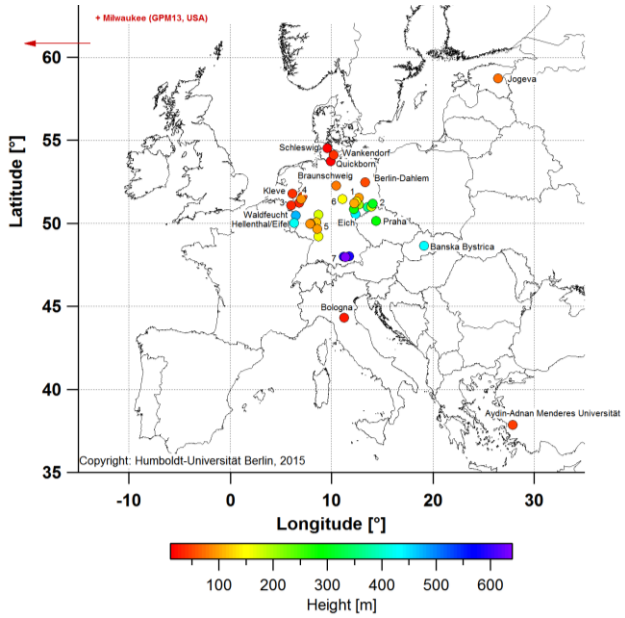

Figure 1. Network of GPM phenological stations (http://gpm.hu-berlin.de)

In Banská Bystrica, *Galanthus nivalis* was observed through the Global phenological monitoring (GPM) project. GPM is a network of phenological stations where fruit trees and ornamental shrubs are grown in one place. The coordinator of the stations is the Humbolt University in Berlin. Not all plant species can grow at any site (http://gpm.hu-berlin.de/gpm/faces/index.xhtml). Phenological stations are located near the meteorological station. The spatial distribution of the stations is shown on Fig. 1.

MATERIALS AND METHODS

The beginning of flowering of *Galanthus nivalis* is dependent on several factors. The aim of the paper was to analyse and evaluate the start of beginning of flowering of *Galanthus nivalis* with regard to the number of days with the snow cover and the average monthly air temperatures for the winter season in Banská Bystrica. For a more accurate analysis of the relationship between these meteorological indicators (snow cover and air temperature) and the onset of beginning of flowering of snowdrop we used a regression analysis.

We evaluated the timelines of observation of the beginning of flowering of snowdrop at the GPM phenological station near the meteorological station in Banská Bystrica in the period from 2003 to 2017. The evaluated data were complete and observed according to standard methodology. The beginning of flowering (BBCH60) is considered the day when the first flowers (10%) were completely formed on the observed individuals.

RESULTS

Winter is an annual season that begins in a temperate zone with a winter solstice and ends with a spring equinox. It has shortest days and lowest average air temperatures. In areas that are further away from the equator, snow often occurs in winter. Data from satellites that relate to total snow mass provide important information in monitoring climate change. Observations show that the amount of snow cover in the Northern Hemisphere is slowly declining. A similar trend was recorded at our meteorological station.

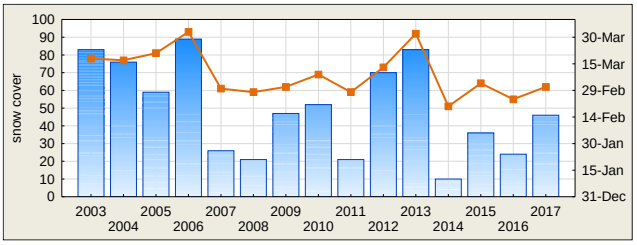

Figure 2. The onset of the beginning of flowering of Galanthus nivalis and the number of days with the snow cover (Dec-Mar) for the period from 2003 to 2017

The trend of the beginning of flowering of snowdrop during the reviewed years is declining, which means that the onset of the phenological phase has shifted to earlier dates. In the evaluated 15-year period, the average onset of this phenophase in Banská Bystrica was 10 March. The earliest onset of beginning of flowering of snowdrop was observed on February 20 in 2014, when only 10 days were recorded with snow cover through the winter season. The latest onset of this phenophase was on April 3 in 2006, when there was for up to 89 days with snow cover in Banská Bystrica (Fig.2).

In meteorology, as winter months are considered following months: December, January and February. The correlation analysis revealed that the number of days with snow cover during the winter period and the average temperature in February are relatively high correlated with the onset of the beginning of flowering of snowdrop. The high correlation coefficient exists also with the average air temperatures in March as well as the number of days with the snow cover for December-March. For a more accurate analysis of the relationship between these meteorological indicators (snow cover and air temperature) and the onset of beginning of flowering of snowdrop we used a regression analysis. We chose a model in which the number of days with a snow cover for December-March was the independent variable. The dependent variable was the date of the beginning of flowering of snowdrop replaced by the serial numbers of the day from the beginning of the year. The selected regression model has confirmed that the number of days with snow cover has a significant effect and is the cause of changes in the beginning of flowering of snowdrop (Tab. 1).

Table 1. Detailed results of regression analysis with estimation of the dependence of the beginning of flowering of snowdrop on the number of days with snow cover in December-March for the period from 2003 to 2017

	Regression Summary for Dependent Variable : flowering R= ,9246 R2= ,8550 Adjusted R2= ,8438 p<.000					
	b*	Std.Err. of b*	b	Std.Err. of b	t(13)	p-value
Intercept			46,6	2,88	16,15	0,000
snow cover	0,9246	0,11	0,5	0,05	8,75	0,000

It is clear from Table 1 that the estimation of the dependence of the beginning of flowering of snowdrop on the number of days with snow cover in winter is statistically significant. We also obtained a point estimation of the regression line, which illustrates the interdependence between these variables (Fig. 3).

The selected regression model explains up to 85.5% of the variability of the dependent variable and indicates that if the snow cover in winter period lasts 2 days longer than the measured average, the onset of the beginning of flowering of snowdrop will be shifted 1 day later.

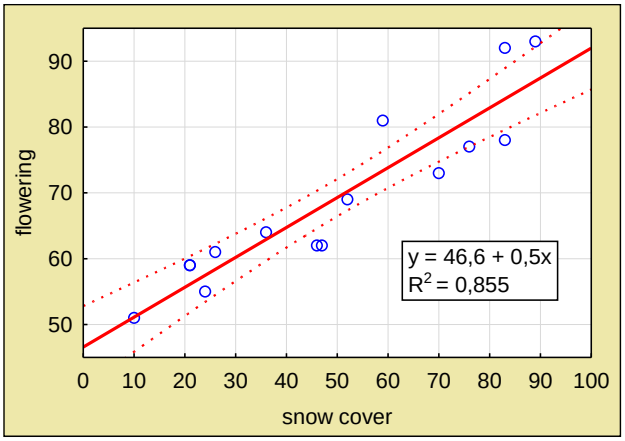

Figure 2. Regression line illustrating dependence of the beginning of flowering of snowdrop on number of days with snow cover in December-March for the period from 2003 to 2017

Figure 4 illustrates the average February and March air temperatures measured at the meteorological station in Banská Bystrica for the reviewed period. Since the average temperatures of these two months highly correlate with the onset of the beginning of flowering of snowdrop, we can also consider the model that describes the relationships between these variables as statistically significant.

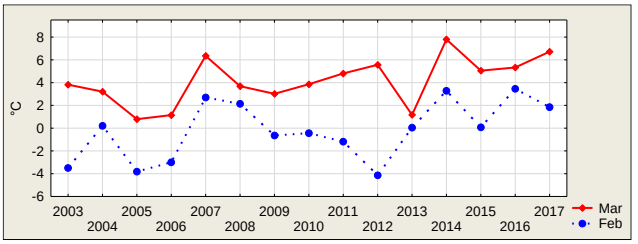

Figure 3. The course of average air temperature in the period from 2003 to 2017

In this model, the independent variables were the average monthly air temperatures for the months of February and March. The dependent variable was again the serial number of days from the beginning of the year, which replaced the dates of the beginning of flowering of snowdrop. Through this regression model, we have found that from these two months only March air temperature conditions have statistically significant influence on the onset of beginning of flowering of snowdrop. February temperature ratios proved to be statistically insignificant (Tab. 2).

Table 1. Results of regression dependence of the beginning of flowering of snowdrop on average air temperatures in February and March for the period from 2003 to 2017

	Regression Summary for Dependent Variable: flowering R= ,8440 R2= ,7123 Adjusted R2= ,6643 p<.001					
	b*	Std.Err. of b*	b	Std.Err. of b	t(12)	p-value
Intercept			85	5,28	16,04	0,000
°C (Febr)	-0,3173	0,19	-1,6	0,94	-1,69	0,117
°C (Mar)	-0,6224	0,19	-3,8	1,16	-3,31	0,006

In the case of step regression, the average temperature in February will be excluded, thus reducing the proportion of the explained variability (Tab. 3). From the selected regression model, it follows that increase of the average March air temperature by 1 °C results in a shift of the beginning of flowering of snowdrop by 5 days to earlier dates.

Table 2. Results of regression dependence of the beginning of flowering of snowdrop on average air temperatures in March for the period from 2003 to 2017

	Regression Summary for Dependent Variable: flowering R= ,8025 R2= ,6440 Adjusted R2= ,6166 p<.000					
	b*	Std.Err. of b*	b	Std.Err. of b	t(13)	p-value
Intercept			90	4,71	19,04	0,000
°C (Mar)	-0,8025	0,17	-5	1,02	-4,85	0,000

The obtained results correspond to the findings of national and international European research. Similar shift of the beginning of flowering of snowdrop to earlier dates was also found by Hajkova et al. (2011). Similar observations of the shift in phenological phases can be observed by other plants and woods. For example, Zverko et al. (2016) also found the shift of the spring phenological phases by the selected woody plants to earlier terms. Similarly, Pálešová et al. (2011) and Škvareninová (2016) found a significant correlation between the spring phenological phases and the average air temperature by selected woody plants.

CONCLUSION

The onset of the beginning of flowering of snowdrop with respect to external factors correlates best with the air temperature in February and March and the number of days with snow cover during the winter period. Regression analysis has shown that these factors have a significant impact on the onset of this phenophase and thus explain the greatest proportion of variability. The remaining variability of the beginning of flowering can be explained by other factors, e.g. precipitation sums, condition of the bulb, orientation of the habitat, terrain shape, soil type, etc. Phenological observations are an important part of climatological monitoring. Their results help in the examination and assessment of natural conditions and their peculiarities in various regions of Slovakia.

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