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Influence of the thermal mode on seasonal phenological phenomena in Lithuania

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Data of a phenological research performed in 1961–2000 in Lithuania are summarized. Average many-year dates of the beginning of flowering of European hazel (*Corylus avellana* L.), European bird cherry (*Padus avium* Mill.), sweet mockorange (*Philadelphus coronarius* L.), small-leaved linden (*Tilia cordata* Mill.) and the colouring of Norway maple (*Acer platanoides* L.) leaves were determined. Alterations in the dates of phenophase occurrence of European hazel and sweet mockorange in relation to climate warming were evaluated. The research has shown that because of temperature impact and its larger fluctuations early in spring, the dates of the beginning of flowering for European hazel (*Corylus avellana* L.) are characterized by higher mean square deviation values (S = 16 days) than of other indicator plants such as European bird cherry, sweet mockorange, small-leaved linden (S = 6–9 days).

The thermal regime of February (r = –0.76 – (–0.84)) and March (r = –0.63 – (–0.79)) has a stronger impact upon annual fluctuations of the dates of the beginning of flowering of European hazel. The beginning of flowering of the summer indicator sweet mockorange depends upon the thermal regime of April (r = –0.56 – (–0.66)) and May (r = –0.38 – (–0.56)).

Key words: phenological periods, plants-indicators, climate, air temperature mode

INTRODUCTION

Since 1990, particular attention to phenological research is given worldwide. It is due to climate warming of the last decades and the response of plants and animals manifested in their development phases. Evidences of climate changes in the natural environment are abundant. They comprise the lengthening of the vegetation period, changed timing of plant phenophases and other less conspicuous changes in plant and animal communities (Menzel, 2000; Menzel, 2003; Ahas, 1999; Bradley et al., 1999; Harrington et al., 1999; Bogaert et al., 2002; Root et al., 2003). Recently, due to global climate warming, the tendency towards elongation of warm season of a year is observed. These changes occur because of a considerable warming of spring and winter seasons. Many-year observations (a period of 30 years) of the seasonal rhythm revealed that recently in northern Europe common birch (*Betula pendula* Roth.) sprouts leaves 5–10 days earlier and European bird cherry (*Padus avium* Mill.) starts flowering 10–15 days earlier (Минин, 2001).

At present, in temperate climate zones of Europe and North America the period when forest trees have leaves is by 8–10 days longer than at the beginning of the 20th century. In the last century, the dates of plant flowering phenophase in spring were gradually becoming earlier, and the dates of phenological phenomena in autumn exhibit a tendency to occur later, thus increasing the length of the plant growth season (Beaubien et al., 2000; Chmielewski et al., 2000; Defila, 2000; Menzel, 2000; Defila et al., 2001; Zhou et al., 2001). Nowadays, data of long-term observations of plant development are more and more often employed for evaluation of climate changes.

The aim of the current research was to determine the influence of climate warming on the seasonal development of plants and to identify the dependence of plant phenophase occurrence on thermal regime on the territory of Lithuania in the period 1961–2000.

METHODS

In Lithuania, phenological observations have been performed since 1959. In 1960–1970, the phenological network in Lithuania included more than 200 localities on the territory of the country. Presently, phenological observations are performed in 23 localities (density of a network 0.4 / 1000 km^2). The phenological network of Lithuania comprises the territory at 54^{0}10' and 56^{0}20'

North latitude and 21⁰48' and 26⁰33' East longitude. In the majority of the present phenological stations, observations have been carried out for more than 30 years.

To characterize the limits of phenological phases in Lithuania, the beginning of flowering of European hazel (*Corylus avellana* L.), bird-cherry (*Padus avium* L.), sweet mockorange (*Philadelphus coronarius* L.), small-leaved linden (*Tilia cordata* L.) and the colouring of Norway maple (*Acer platanoides* L.) leaves (Kulienė, Tomkus, 1990) were employed.

Phenocorrespondents performed phenological observations of these plants in the period 1961–2000 in 13 stations situated in different regions of Lithuania. L. Kulienė and J. Tomkus divided the territory of Lithuania into phenoclimatic regions differing in seasonal rhythm, air temperature and precipitation (Kulienė, Tomkus, 1990). Data of phonological observations from three phenoclimatic regions of Lithuania were chosen for a more detailed analysis. The phenoclimatic regions and stations of Lithuania:

1. The region of the West Žemaičiai Plain and the Central Lithuanian Plain: Šilutė, Jurbarkas, Dotnuva, Kaišiadorys, Lazdijai, Pasvalys, Biržai.
2. The region of the Žemaičiai Upland: Akmenė, Telšiai, Kelmė.
3. The Aukštaičiai region: Ukmergė, Širvintos, Trakų Vokė.

Phenological observations were carried out by S. Nacevičius' methods for phenological supervision (Nacevičius, 1975) in each district of Lithuania on a typical local relief, ground and vegetation on the area 3–4 km in diameter (in parks, woods or nearby sites where plants grow in natural conditions). Observations were carried out every day early in spring and later on each second day (summer and autumn). The beginning of a phenophase was fixed when the stage of development reached 25% of flowers or leaves of the plants (Baronienė, Romanovskaja, 2005).

The data were statistically processed: the average date, standard error (Sx), and mean square deviation (±S) were calculated. Statistical dependence of the date of phenophase occurrence in the study plants on air temperature was determined applying the correlation and regression methods (Доспехов, 1973).

RESULTS AND DISCUSSION

The territory of Lithuania lies in the zone of middle latitudes and is characterised by seasonal changes. The beginning of flowering of some perennial plants coincides with seasonal changes, therefore, these plants are suitable indicators for investigation of these changes. For example, in our latitude the beginning of the phenological spring season coincides with the beginning of flowering of European hazel (*Corylus avellana* L.). Research data of the four last decades revealed rather significant fluctuations in the dates of the beginning of flowering of European hazel, predetermined by the impact of climate warming. On the territory of Lithuania, the flowering of European hazel begins on March 28 on an average (Table 1).

In comparison with the plants-indicators of other phenological phases, the beginning of flowering of European hazel is very inconsistent and characterised by a high variation (coefficient of variation 18.4%). The impact of climate warming upon plants flowering later in spring and summer is not so strong. For example, annual fluctuations of the beginning of flowering of sweet mockorange (*Philadelphus coronarius* L.), which is an indicator of phenological summer, were considerably smaller than the dates of the beginning of flowering of European hazel; deviations from the mean were only ± 3. The beginning of the phenological autumn season is indicated by the colouring of Norway maple (*Acer platanoides* L.) leaves. On the territory of Lithuania it starts on September 15 on average. In the course of 40 years, the date of this phenophase has not been characterised by strong fluctuations (deviation from the mean only ±2 days). Meanwhile in some years, the deviation in the dates of the beginning of flowering of European hazel was on average 8 days and reached over 40 days from the many-year average (Romanovskaja, 2004; Baronienė, Romanovskaja, 2005).

Data of the long-term phenological observations in Lithuania show that fluctuations in the dates of pheno-

Table 1. **Dates of the beginning of phenophases of plants-indicators in Lithuania (average date 1961–2000)**

Plant and phenophase	Period	Average date	Standard error of the mean (Sx)	Square deviation of the mean (S)	Coefficient of variation (V) %
Flowering of	1961–1980	April 03	7	11	11.9
Corylus avellana	1961–2000	March 28	8	16	18.4
Flowering of	1961–1980	May 12	4	5	4.2
Padus avium	1961–2000	May 10	4	7	5.8
Flowering of	1961–1980	June 13	3	5	2.9
Philadelphus coronarius	1961–2000	June 11	3	6	3.7
Flowering of	1961–1980	July 09	5	7	3.6
Tilia cordata	1961–2000	July 06	4	9	4.7
Acer platanoides	1961–1980	Sept. 17	3	4	1.6
leaf yellowing	1961–2000	Sept. 15	2	5	2.0

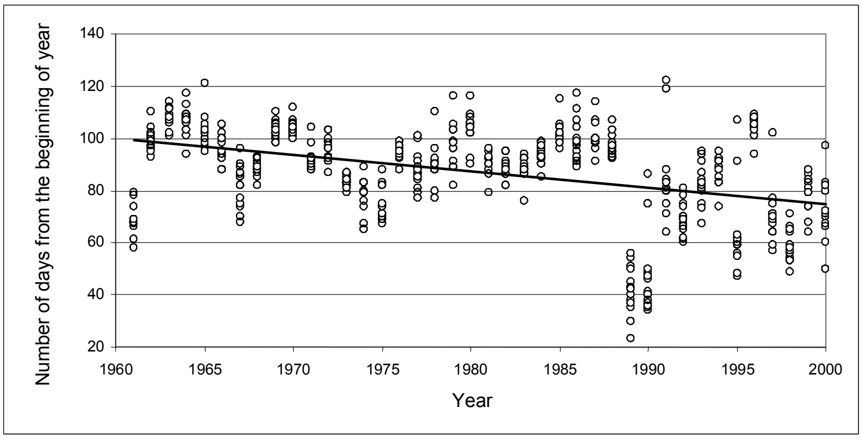

Fig. 1. Trend of the beginning of flowering of *Corylus avellana* in 13 sites of Lithuania in 1961–2000

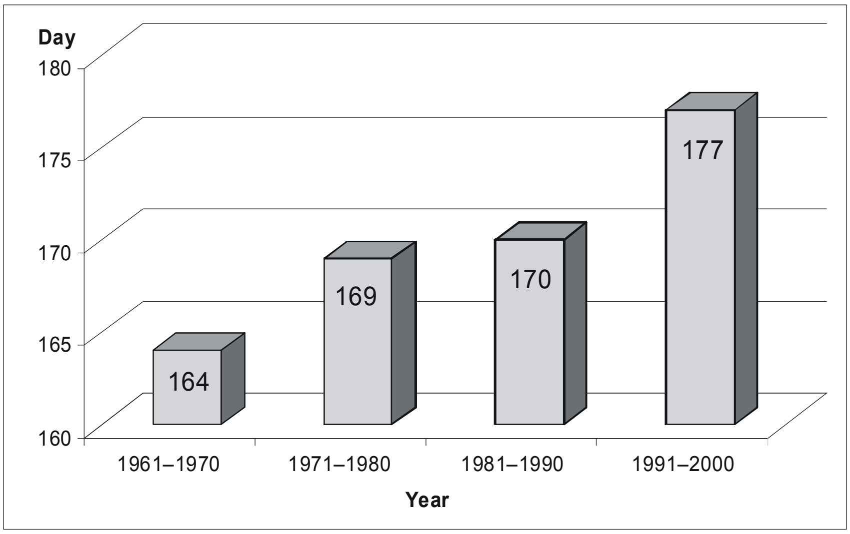

Fig. 2. Fluctuations in the duration of plant growth season in Lithuania in 1961–2000

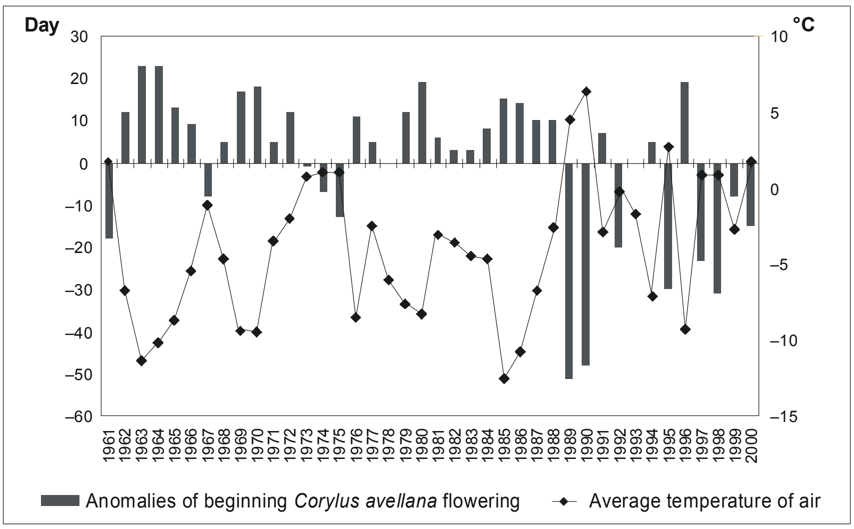

Fig. 3. Deviations of dates from the many-year average of the beginning of flowering of European hazel depending on average daily air temperature of February and March in Trakų Vokė, Dotnuva and Šilutė in 1961–2000

phases of plants-indicators are particularly large in early spring when the weather changes frequently. It is confirmed by a comparison of the mean square deviation (S) values. For instance, the mean square deviation of the dates of the beginning of flowering for European hazel reached 16 days from the average while for other indicator plants only 5–7 days (Table 1). Besides, it was noted that during the first three decades of investigations (1961–1990) the flowering of European hazel frequently started later and during the last decade earlier than on average (Fig. 1). It is clearly demonstrated by the trend of annual dates of the beginning of flowering of European hazel in various locations of Lithuania (Fig. 1).

Similar fluctuations in the dates of phenological phenomena were noted in the whole Europe. For example, recently the sprouting of leaves in Europe begins 6.3 days earlier on average; colouring of leaves is later by 4.5 days (Menzel, 2000). Such substantial fluctuations in the dates of spring phenological phenomena could have determined changes in the duration of plant growth period. A period between the beginning of phenological spring (beginning of flowering of European hazel) and of phenological autumn (beginning of colouring of Norway maple leaves) is called the plant growth season (Kulienė, Tomkus, 1990; Menzel, 2000; Tucker et al., 2001). A research performed in Lithuania shows that the duration of the plant growth season by 59–91% depends upon its beginning in spring, i.e. upon the dates of the beginning of flowering of European hazel (correlation coefficient r = –0.77 – (–0.96)). The obtained results show that the earlier phenological spring starts the longer is the plant growth season.

The data of our long-term observations show that the duration of the plant growth period in 1991–2000 increased by 13 days on an average versus the period 1961–1970 (Fig. 2).

According to Menzel (2000), since 1960 the plant growth period in Europe has increased by 10.8 days on an average. A research performed in Estonia also revealed that the plant growth period became longer, but the duration of separate phenological seasons differed (Ahas, 2000), i.e. the phenological spring shortened, while the phenological summer and autumn slightly lengthened.

Fluctuations of the dates of phenological phenomena, especially in spring, mostly depend on the changes of temperature regime. Evaluation of data of phenological observations throughout four decades and their comparison with climatic indices has shown that the earlier flowering of European hazel is related with the higher mean temperatures of February–March (Fig. 3).

According to many-year research data, it is evident that since 1989 the mean daily air temperature of February and March has considerably increased. These temperature changes could determine the higher frequency of negative anomalies of European hazel.

Dependence of the beginning of flowering of European hazel upon thermal regime has been also confirmed by statistical data analysis.

In three investigation localities, a strong correlation was determined between the date of the beginning of flowering of European hazel and the mean air temperature of February – r = –0.76 – (–0.84) (Table 2).

The correlation coefficients calculated with the mean temperature of March also showed a strong correlation in Trakų Vokė and Dotnuva and a medium correlation in Šilutė. A less influence on the date of the beginning of flowering of European hazel is exerted by the mean temperature of January because the determined correlations were weak. It demonstrates that the beginning of flowering of European hazel is predetermined by the temperature regime prevailing two months prior to the occurrence of a phenophase. The date of the beginning of flowering of sweet mockorange (starts flowering on June 11 on an average) depends upon the average temperature in April and May. The statistical indices show that the temperature of April has a stronger influence on the flowering of sweet mockorange in all three localities. Contrary to the early spring indicator, between the indicator of summer and average daily air temperature only medium correlations were revealed (Table 3).

Table 2. **Relationship between the beginning of flowering of *Corylus avellana* and the average temperatures of January–March in Lithuania (data of 40 years of meteorological and phenological observations)**

Station	Correlation (r) between dates of beginning of flowering of *Corylus avellana* and average temperature of month		
	January	February	March
Trakų Vokė 25⁰10'E 54⁰63'N	–0.61** n = 40	–0.81** n = 40	–0.79** n = 40
Dotnuva 23⁰87'E 55⁰40'N	–0.49** n = 40	–0.84** n = 39	–0.71** n = 40
Šilutė 21⁰48'E 55⁰35'N	–0.43** n = 39	–0.76** n = 39	–0.63** n = 40

** Correlation significant at 99% probability level.
n – number of correlation pairs.

Table 3. **Relationship between the beginning of flowering of *Philadelphus coronarius* and the average temperatures of January–May in Lithuania (data of 40 years of meteorological and phenological observations)**

Station	Correlation between dates of the beginning of flowering of *Philadelphus coronarius* and average temperature of month				
	January	February	March	April	May
Trakų Vokė	–0.37*	–0.39*	–0.45**	–0.56**	–0.55**
25°10'E 54°63'N	n = 40	n = 40	n = 40	n = 40	n = 40
Dotnuva	–0.47*	–0.33*	–0.47**	–0.62**	–0.38*
23°87'E 55°40'N	n = 40	n = 39	n = 40	n = 37	n = 39
Šilutė	–0.39*	–0.48**	–0.51**	–0.66**	–0.56**
21°48'E 55°35'N	n = 39	n = 39	n = 40	n = 37	n = 38

* Correlation significant at 95% probability level.
** Correlation significant at 99% probability level.
n – number of correlation pairs.

According to a research performed in Germany, sprouting of leaves of various plant species and flowering in spring and summer strongly correlate with the temperature of the previous month (R^2 between 0.65 and 0.85) (Menzel, 2003).

Fluctuations in the development phases of plants, a longer plant growth season and a shorter cold season represent the trends of the general climate warming. Tendencies of climate warming are also reported from other countries of West and North Europe (Ahas, 1999; Defila, 2000; Defila et al., 2001). Therefore, the changing climate of Lithuania is part of the global climate changing. Researchers of Finland and Sweden forecast that in future in the northern part of Europe winter and late autumn would be considerably warmer (Räisänen et al., 2004). Further fluctuations in the dates of plant phenophases due to climate changes and the extent of lengthening of the plant growth periods would be possible to define only after several decades of phonological observations and data analysis.

CONCLUSIONS

1. The research data show that because of temperature impact and its larger fluctuations during early spring, the dates of the beginning of flowering of European hazel (*Corylus avellana* L.) are characterized by higher mean square deviation values (S = 16 days) than the related dates of other indicators – European bird cherry, sweet mockorange, small-leaved linden, the mean square deviation S = 6–9 days.

2. The flowering of European hazel (*Corylus avellana* L.) in Lithuania begins on March 28 on an average. The temperature regime of February (r^2 = 58–71%) and March (r^2 = 39–62%) exerts a stronger impact on the annual fluctuations of the beginning of flowering of European hazel, i.e. the date of European hazel flowering significantly correlates with the average temperatures of February (r = –0.76 – (–0.84)) and March (r = –0.63 – (–0.79)).

The beginning of flowering of a summer indicator, sweet mockorange, stronger depends on the thermal regime of April (r = –0.56 – (–0.66)) and May (r = –0.38 – (–0.56)).

3. During the period 1961–2000, due to climate warming the duration of plant growth season in Lithuania increased by 13 days on an average.

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TERMINIO REŽIMO ĮTAKA SEZONINIAMS FENOLOGINIAMS REIŠKINIAMS LIETUVOS TERITORIJOJE

Santrauka
Straipsnyje apibendrinti 1961–2000 m. Lietuvoje atliktų fenologinių stebėjimų duomenys. Buvo nustatytos fenologinių sezonų augalų indikatorių – paprastojo lazdyno (*Corylus avellana* L.), paprastosios ievos (*Padus avium* Mill.), darželinio jazmino (*Philadelphus coronarius* L.), mažalapės liepos (*Tilia cordata* Mill.) ir paprastojo klevo (*Acer platanoides* L.) fenofazių pasireiškimo daugiametės vidutinės datos. Buvo įvertinti paprastojo lazdyno ir darželinio jazmino žydėjimo fenofazės pasireiškimo datų pokyčiai, susiję su klimato šiltėjimu. Nustatyta, kad dėl temperatūros įtakos ir jos didesnių pokyčių ankstyvojo pavasario laikotarpiu paprastojo lazdyno (*Corylus avellana* L.) pražydimo datos pasireiškia didesne kasmetine kaita (S = 16 d.), nei kitų sezonų indikatorių – paprastosios ievos, darželinio jazmino, mažalapės liepos (S = 6–9 d.). Didesnę įtaką paprastojo lazdyno žydėjimo pradžios datų kasmetinei kaitai turi vasario (r = –0,76 – (–0,84)) ir kovo (r = –0,63 – (–0,79)) terminis režimas. Vasaros sezono pradžios indikatoriaus darželinio jazmino žydėjimo pradžia priklauso nuo balandžio (r = –0,56 – (–0,66)) ir gegužės (r = –0,38 – (–0,56)) terminio režimo.

Raktažodžiai: fenologiniai periodai, augalai indikatoriai, klimatas, oro temperatūros režimas