Influence of Climate Change on the European Hazel (*Corylus avellana* L.) and Norway Maple (*Acer platanoides* L.) Phenology in Lithuania During the Period 1961-2010

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Abstract

The study was conducted at Vokė Branch of the Lithuanian Research Centre for Agriculture and Forestry employing the archival data of phenological observations in Lithuania during 1961-2010. The aim of the research was to estimate the influence of climate change on phenological phases of spring and autumn indicator plants (*Corylus avellana* L. and *Acer platanoides* L.) and the length of spring-summer period in Lithuania during 1961-2010.

In Lithuania, over the 50 years flowering time of spring season indicator European hazel (*Corylus avellana* L.), which starts on March 27 on average, exhibited higher variation (SD = 16.1) and earlier onset (-0.43 days per year) compared with the beginning of Norway maple leaf colouring. Larger scale of advance in 1981-1990 (-3.92 days per year) and 1991-2000 (-1.28 days per year) periods are associated with the increased average air temperature related to climate warming. Reliable correlations (p-value <0.01) between the dates of European hazel phenological phases and the average air temperatures of January–April were established. Norway maple (*Acer platanoides* L.) leaf colouring started on September 16 on average and just slightly varied during the entire study period (SD = 4.9). The influence of meteorological conditions on the beginning of Norway maple leaf colouring was very weak (r <0.3 in 72.5 % of cases). Variations of the beginning of spring season affected the length of spring-summer period. It was determined that the length of spring-summer period strongly correlated with the dates of the beginning of flowering of spring season indicator European hazel (R^2 0.8492, p-value <0.01).

Key words: climate change, phenology, indicator plants, spring-summer period, growing season.

Introduction

In recent decades, phenological studies have received much attention. This is related to global climate change and its influence on ecosystems. Variation in plant phenological phases, which naturally occurs year after year, is a sensitive and evidently visible indicator of climate change (Sparks et al. 2009). Over the past decade, scientists from various countries have presented abundant research results confirming very large variations in the dates of plant phenological phases and other phenological events (Bertin 2008, Menzel et al. 2006b, Menzel et al. 2011, Ibáñez et al. 2010, Sparks et al. 2011). Climate change causes much earlier onset of the phenological phases of spring plants. The assessment of the shifts of phenological phases of 20 deciduous and coniferous tree species in the northern part of Europe during 1971-2005 revealed that bud burst and flowering started on average 7 days earlier (Nordli et al. 2008). The data of research performed in the Baltic States also show large scale variations in phenological phases. During 1986-2000 on the territories of Latvia and Lithuania first phenological events of spring occurred on average 10-13 days earlier than in 1971-1985 (Kalvane et al. 2009). Investigations performed in Estonia show that in 1948-1999 more than 80 % of spring phenological phases began earlier, but in summer and autumn changes in phenological phases were slighter (Ahas and Aasa 2006).

In the zone of cool temperate climate the thermal factor is very important, because the development of plants in early spring usually depends on the temperature (Kulienė and Tomkus 1990). The analysis of climate change influence on plant phenology revealed that due to climate warming spring phenological events (such as leafing and flowering) in some cases occurred a few weeks earlier, but an average advance was 4-5 days °C^{-1} (Bertin 2008). The studies performed in Europe confirm differences in behavior between annual and perennial plants. The average temperature response of perennial plants was greater (-4.2 days °C^{-1}) than that of annual plants (-3.0 days °C^{-1}) (Estrella et al. 2009).

Lengthening of warm period is observed worldwide for several decades already, especially in the northern hemisphere (Jeong et al. 2011). Due to climate changes the thermal growing season in the Greater Baltic Area starts 12 days earlier and ends 8 days later (Walther and Linderholm 2006). During the last decades of the 20th century, earliness of plant phenological phases in spring and lateness in autumn affected the prolongation of plant growing season in most European countries (Ahas and Aasa 2006, Jeong et al. 2011, Menzel et al. 2001, Menzel et al. 2008, Karlsen et al. 2007, Kalvane et al., 2009, Romanovskaja et al. 2009). This means that shifts in plant development phases mirror the direction of climate change, which in the 20th century shows the tendency towards warming. According to the forecasts of climatologists, changes of meteorological conditions and climate warming will continue in future. It is predicted that in the middle of the 21st century on the territory of Lithuania the average air temperature in winter will be by 1.2-1.3 °C higher than the current; average air temperature in summer will also increase (Bukantis and Rimkus 1996). Application of hydrological models suggest that from 2001 to 2090 average soil moisture at a 0-1000 mm layer will be reducing every thirty years (in 2001-2030 18%, in 2031-2060 24% and in 2061-2090 31.5%) (Stonevičius et al. 2008). Finnish and Swedish scientists predict that in northern Europe winter and late autumn would be characterized by the most significant warming (Räisänen et al. 2004). It is likely that in future the changed hydrothermal conditions will affect phenological phases of plants, duration of growing season and seasonal development of perennial plants (Galvonaitė et al. 2007, Veriankaitė et al. 2010). The expected changes can affect forest productivity (output), biodiversity and forest wellness conditions. Therefore, the climate change is assessed by scientists as a key environmental factor that will determine the future sustainability of forest ecosystems (Ozolinčius 2010).

The aim of the present study was to evaluate the impact of climate change on phenophases of spring and autumn indicator plants (*Corylus avellana* L., *Acer platanoides* L.) and on the length of spring-summer period in Lithuania during 1961–2010.

Materials and methods

In Lithuania, phenological observations have been performed since 1959. Presently, phenological observations are performed in 23 localities (density of a network – 0.4/1,000 km^2). The phenological network in Lithuania comprises the territory at 54°10' and 56°20' North latitude and 21°48' and 26°33' East longitude. According to the dependence of plant development upon climatic conditions, the territory of Lithuania is divided into 3 phenoclimatic regions: I – the region of the West Žemaičiai Plain and Central Lithuania's Plain, II – the region of the Žemaičiai Upland and III – the region of the Aukštaičiai (Kulienė and Tomkus 1990) (Figure 1).

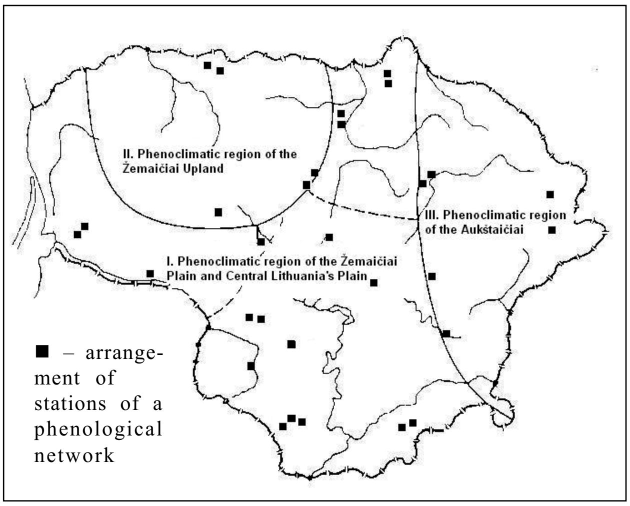

Figure 1. Phenological network and phenoclimatic regions of Lithuania

Archival data of phenological observations collected during 1961-2010 in Lithuania were used in this study. Phenological events were recorded in 5 stations Šilutė (55°35' N and 21°48' E), Akademija (55°40' N and 23°87' E), Trakų Vokė (54°63' N and 25°10' E), Papilė (56°15' N and 22°80' E), Keturvalakiai (54°55' N and 23°15' E), which represent all phenoclimatic regions. The choice of plants as season indicators was made based on the division of indicator plants commonly used in Europe; the most suitable for climate zone of Lithuania were chosen (Kulienė and Tomkus 1990). Plants used to characterize the limits of phenological phases in Lithuania were employed in the research, i.e. beginning of flowering (BBCH61) of European hazel (*Corylus avellana* L.) and colouring of leaves (BBCH92) of Norway maple (*Acer platanoides* L.). The phenological dates refer to the day of the year and phenological phases are in Bundesanstalt, Bundessortenamt and Chemical Industry (BBCH) codes (Meier 1997).

Length of the spring-summer period was described using the beginning of flowering of European hazel (BBCH61) and colouring of leaves of Norway maple (BBCH92); and the growing season was described using 2 phenological phases of silver birch (*Betula pendula* Roth): beginning of leafing (BBCH11) and the beginning of leaf colouring BBCH92. Climate data (monthly temperature and precipitation) for the years 1961-2010 were obtained from the Lithuanian Hydrometeorological Service. Meteorological stations were selected in locations close to the phenological stations (distance less than 50 km). For the study of time series the regression analysis and correlation analysis were used. Temporal trends of phenological dates were obtained as coefficients of linear regressions of phenological date (day of the year) versus year over the period of 1961-2010. A negative value of a trend hence indicates an earlier occurrence of the respective phase, whereas a positive value represents a delay.

Results

From 1961 to 2010 in Lithuania the dates of the onset of phenological phases of spring and autumn indicator plants (European hazel and Norway maple) varied unevenly. The average dates of the beginning of spring indicator European hazel flowering consistently advanced for a few decades in a row (1971-2000) and varied more (*SD* = 8.9-21.7) than the beginning of autumn indicator Norway maple leaf colouring (*SD* = 2.7-5.8) (Table 1). Shifting dates of phenological phases of spring and autumn indicator plants influenced changes in the length of spring-summer period. It was found that longer spring-summer period coincided with the decades when the average dates of phenological phases of spring indicator European hazel were earlier than the multi-annual average.

The dynamics of deviations of the beginning of indicator plants phenological phases and length of spring-summer period from the average multi-annual dates show the changes over the course of 50 years. In 1961–1985 the dates of the beginning of European hazel flowering were characterized by positive deviations, i.e. later onset of this phenological phase compared with the multi-annual average (Figure 2).

Table 1. Dates of the beginning of phenological phases of indicator plants and length of spring-summer period in Lithuania

Period	Beginning of *Corylus avellana* flowering		Beginning of *Acer platanoides* leaf colouring		Length of spring-summer period	
	Date	*SD*	Date	*SD*	Days	*SD*
1961-1970	06.04	12.5	17.09	5.5	164	11.4
1971-1980	31.03	8.9	17.09	2.7	170	10.0
1981-1990	26.03	21.7	13.09	5.8	172	19.5
1991-2000	19.03	14.0	14.09	5.2	180	13.1
2001-2010	22.03	16.1	17.09	4.2	179	14.7
1961-2010	27.03	16.1	16.09	4.9	173	14.7

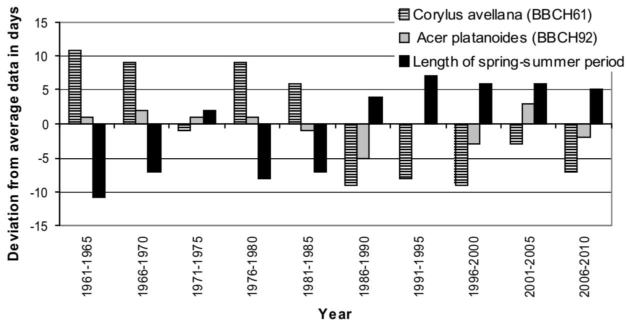

Figure 2. Deviations in dates from the multi-annual average of the beginning of *Corylus avellana* flowering and *Acer platanoides* leaf colouring and length of spring-summer period

Since 1985 deviations from multi-annual averages in the dates of phenological phases of spring indicator changed dramatically and became negative. While deviations from the multi-annual average in the date of phenological phase indicating the beginning of autumn (Norway maple leaf colouring) were small, but in the course of the last three decades the trend towards earlier onset of this phenological phase is observed. It should be noted that deviations from the multi-annual average in the length of spring-summer period were inversely proportional to deviations in the dates of the beginning of European hazel flowering. These results demonstrate that prolonged duration of the warm period is closely related to the changes during the spring season.

Trends and extent of the changes in dates of the onset of phenological phases of indicator plants and the length of spring-summer period are presented in Table 2. Negative regression coefficients confirm that during the last three decades the dates of phenological phases advanced but the extent of this advance differed regarding phenological phases of spring and autumn indicator plants. More pronounced trends in date shift were assessed for phenological phases beginning in spring. In the period 1981–1990, the beginning of European hazel flowering advanced particularly rapidly (by -3.92 days per year), but later the rate of advance somewhat decreased (Table 2). Due to considerable advance of spring season, in the course of that same decade the length of spring-summer period was increasing on a similar scale (by 3.38 days per year).

Assessment of the influence of average temperatures and precipitation amount on the dates of the beginning of phenological phases of indicator plants

Table 2. Slopes of the linear regressions (days per year) of the beginning of phenological phases and length of spring-summer period during 1961-2010

Period	Beginning of *Corylus avellana* flowering	Beginning of *Acer platanoides* leaf colouring	Length of spring-summer period
1961-1970	1.0	0.66	-0.27
1971-1980	1.21	0.11	-1.15
1981-1990	-3.92	-0.54	3.38
1991-2000	-1.28	-0.79	0.47
2001-2010	-0.13	-0.47	-0.32
1961-2010	-0.43	-0.05	0.38

in all cases revealed statistically significant (p-value < 0.01) correlation between the dates of phenological phase of European hazel and average temperatures of January – April (Table 3). Negative correlation coefficients indicate that advanced dates of this phenological phase were due to increased temperature and precipitation amount. However, the dependences on precipitation amount were much weaker.

Correlations determined between dates of the beginning of autumn indicator Norway maple leaf colouring and meteorological parameters were weak, when $r > \pm 0.3$ (27.5% of all cases) or very weak, when $r < \pm 0.3$ (72.5% of all cases) (Table 4). Increases in temperature and precipitation amount produced uneven effect on the beginning of Norway maple leaf colouring. The results of the study show that higher temperature in August and September slightly delayed the beginning of Norway maple leaf colouring. The beginning of this phenological phase was slightly earlier as a result of increased precipitation amount in July.

The season favourable for plant growth begins in early spring (with the onset of European hazel flowering) and lasts until early autumn (up to the beginning of Norway maple leaf colouring). The plant growing season, which is defined by phenological phases of silver birch, is on average 42 days shorter than the spring-summer period (Table 5).

Growing season in Lithuania starts 39 days later than the spring. However both seasons end almost simultaneously. Strong and moderate statistically significant correlations between the beginning, end and length of spring-summer period and growing season suggest similar trends regarding the changes of these seasons. Therefore, changes in only spring-summer period, which is longer, were assessed. It was found that the length of spring-summer period strongly correlated with dates of the beginning of spring indicator European hazel flowering (R^2 0.8492; p-values < 0.01) (Figure 3 A).

These results confirmed that longer spring-summer period is due to an earlier onset of spring, while delayed beginning of autumn was of no significance.

Table 3. Correlation coefficients (r) between dates of the beginning of Corylus avellana phenological phases and temperature (T) and precipitation (P)

Station	Meteorological parameter	Correlation coefficients (r) between dates of phenological phases and temperature (T) and precipitation (P)			
		January	February	March	April
Trakų Vokė	T	-0.60**	-0.74**	-0.78**	-0.36**
	P	-0.02	-0.49**	-0.12**	-0.09**
Akademija	T	-0.52**	-0.73**	-0.70**	-0.29**
	P	0.09**	-0.09**	-0.20**	-0.06
Šilutė	T	-0.56**	-0.77**	-0.73**	-0.41**
	P	0.24**	-0.31**	-0.06	-0.04
Papilė	T	-0.44**	-0.45**	-0.56**	-0.19**
	P	-0.20**	-0.12**	-0.34**	0.14**
Keturvalakiai	T	-0.45**	-0.82**	-0.70**	-0.39**
	P	0.25**	-0.48**	-0.14**	-0.07*

* – statistically significant correlation coefficients with p-values < 0.05
** – statistically significant correlation coefficients with p-values < 0.01

Table 4. Correlation coefficients (r) between dates of the beginning of *Acer platanoides* phenological phases and temperature (T) and precipitation (P)

Station	Meteorological parameter	Correlation coefficients (r) between dates of phenological phases and temperature (T) and precipitation (P)			
		July	August	September	October
Trakų Vokė	T	-0.09*	0.24**	0.33**	-0.21**
	P	-0.30**	-0.22**	0.03	0.34**
Akademija	T	0.07	0.14**	0.28**	-0.05
	P	0.37**	0.01	-0.23**	0.24**
Šilutė	T	0.03	0.34**	0.36**	-0.29**
	P	-0.35**	-0.19**	0.03	0.36**
Papilė	T	0.23**	0.17**	0.07*	-0.16**
	P	-0.27**	0.01	0.02	0.10**
Keturvalakiai	T	0.23**	0.29**	0.25**	-0.36**
	P	-0.30**	-0.28**	0.32**	0.26**

* – statistically significant correlation coefficients with p-values < 0.05
** – statistically significant correlation coefficients with p-values < 0.01

Table 5. Differences and dependence of spring-summer period and the start, end and length of the growing season

Difference in	Days	*SD*	Correlation coefficients (r)
Start	39	12.6	0.70**
End	4	5.9	0.63**
Length	42	13.2	0.61**

** – statistically significant correlation coefficients with p-values < 0.01

Discussion and conclusions

The territory of Lithuania is situated in the zone of temperate climate, characterized by seasonality. The beginning of flowering of some perennial plants coincides with the season's change; in phenological studies therefore they are selected as indicators for inves-

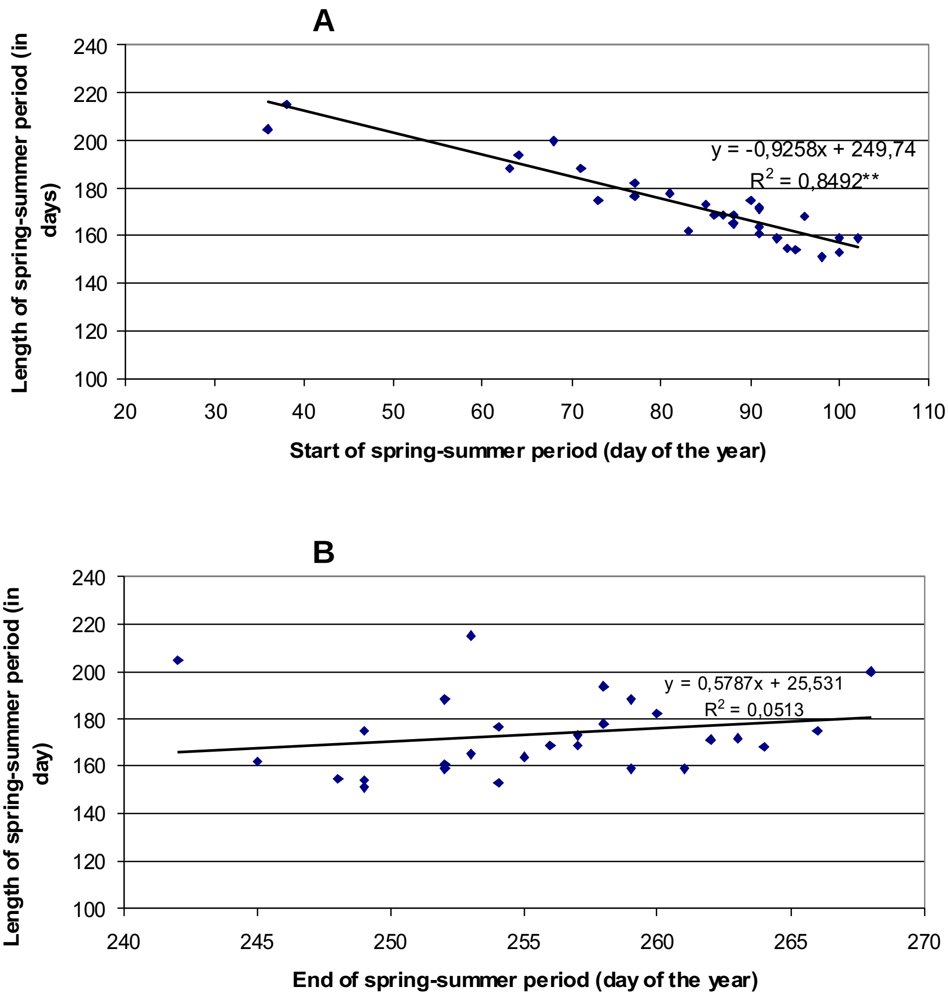

Figure 3. The dependence between the length of spring-summer period and its beginning (A) and end (B)

** – statistically significant correlation coefficients with *p*-values < 0.01

tigations of seasonal changes. In the vegetation zone of the country, which is dominated by mixed forests, the beginning of European hazel flowering indicates the onset of spring; it is one of the earliest flowering plants. It has been revealed that in the period 1961-2010 in Lithuania the dates of the beginning of European hazel flowering were very inconsistent and characterized by particularly high levels of variation. The years 1981-1990 were characterized by particularly evident annual changes in the dates of phenological phases of European hazel. Exceptional changes in natural environment during that decade are represented by larger average standard deviation (*SD* = 21.7) in the dates of the beginning of European hazel flowering compared with this parameter of other decades (Table 1). The onset of autumn coincides with the beginning of Norway maple leaf colouring. The dates of the beginning of this phenological phase varied less. Variation in the dates of phenological phases of the same plants tested in other geographical latitudes differed, but was also high. In western Poland, situated south of Lithuania, in 1977-2007 European hazel flowered a month earlier than in Lithuania (56.5 days from the start of the year), and the mean standard deviation (*SD*) was 24.9. Meanwhile, the dates of leaf colouring in autumn varied considerably less (*SD* = 10.0-12.5) (Sparks et al. 2011). In Latvia, situated at higher latitudes, variation in the dates of the beginning of European hazel flowering in 1971-2000 reached 18.8-27.1 %, and variation in the dates of the beginning of Norway maple leaf colouring – 2.0-4.3 % (Kalvane et al. 2009). This means that early spring was characterized by more pronounced changes in natural environment, because the weather fluctuations in spring are particularly intense and more contrasting than in autumn. The results obtained in Germany after analysis of the phases of 35 different plants during 1951-2002 confirmed that the dates of early phenological events, i.e. occurring in spring, were more changeable than of later occurring phases (Menzel et al. 2006a). Studies performed in various European countries, situated between the northern and middle latitudes, revealed very significant and reliable changes in the dates of phenological phases during 1971-2000. According to these studies in 78 % of all cases leaf unfolding, flowering and fruit ripening started earlier (Menzel et al. 2006b).

Meteorological conditions are very important for plant development, but the increased ambient temperature is extremely significant for phenological phases. U.S. scientists who used special cameras for field experiments reported that an increase in ambient temperature by +2°C resulted in 4-9 days earlier bud burst and leaf appearance of forest plants (*Liquidambar styraciflua, Quercus rubra, Populus grandidentata, Betula alleghaniensis*), and the temperature increase by +4 °C caused an advance of 6–14 days (Gunderson et al. 2011). According to A. Menzel (2003), leaf unfolding and flowering of different plant species in spring and summer strongly correlated with temperature of the previous month (R^2 between 0.65 and 0.85). In our study strong correlations (r between -0.70 and -0.82; p-value < 0.01) were determined between the average temperature of February and March and the dates of phenological phases of spring season indicator (European hazel) in almost all areas, except for Papilė (r =-0.45 – -0.56; p-value <0.01) (Table 3). Papilė is situated in northern Lithuania and belongs to the phenoclimatic region of Žemaičiai highlands. Highlands cover most of the area of this phenoclimatic region, and it mostly determines the hydrothermal regime (compared with the Lithuanian average, the spring is coldest here and the precipitation amount is lower) and the related seasonal development of plants (Kulienė and Tomkus 1990). It should be mentioned that the average temperature of January also influenced the beginning of phenological phases as moderate correlations were established (r = -0.45 – -0.60; p-value <0.01). However, precipitation amount had no decisive impact on the dates of the beginning of European hazel flowering because the established correlations were very weak and in some cases statistically unreliable. A certain trend has been revealed: the precipitation amount of February affected the dates of the beginning of European hazel flowering in southeastern (Trakų Vokė) and southwestern (Keturvalakiai, Šilutė) parts of the country where light, water permeable and quickly drying soils prevail.

Average temperature and precipitation amount in Lithuania were less important for the onset of autumn than for the spring season. The dates of the beginning of Norway maple leaf colouring weakly correlated with average temperatures of August and September (Table 4). Weak positive correlation coefficients indicate the trend towards the delay of phenological phase in case of warmer period lasting till October. And contrary, due to warmer October the Norway maple leaf colouring showed the trend of earlier occurrence. The increased precipitation amount in mid-summer caused earlier onset of this phenological phase. Rainy summers therefore resulted in earlier beginning of phenological autumn.

Our study shows that the temperature regime of a few months preceding the onset of phenological phases had a greater impact than the precipitation amount, but only for the shifts of the dates of spring indicator phenological phases. Thus, the increase of the average temperature during the cold period, characteristic of the final decades of the last century, preconditioned earlier onset of spring. Data on the deviations from the multi-annual average confirm a distinct advance in the dates of phenological phases and longer spring-summer period during 1985-2010 (Figure 2).

The onset of both spring-summer period and growing season coincides with plant phenological phases of early spring, while their endings – with the beginning of tree leaf colouring. The growing season, which lasts from the beginning of silver birch leafing till the beginning of its leaf colouring, is more frequently analyzed in phenological studies. Limits of the growing season in spring and autumn are more closely related to the average temperatures exceeding 10°C. It is essential for the agricultural crop vegetation. Awakening of wild plants in spring characterized by tree sap flow, European hazel or grey alder (*Alnus incana* Moench.) flowering, start when the temperature rises to +5°C. When tree leaves start colouring in autumn, the average daily air temperature is already lower than +10°C (Kulienė and Tomkus 1990). Plant growth and development depend on temperature, so at a temperature <+10°C the season of active plant growth ceases. Our studies show that the spring-summer period ends only 4 days later than the growing season, i.e. these seasons end almost simultaneously (Table 5). A strong negative correlation has been established between dates of the onset of spring-summer period and its length (R^2 = 0.8492) (Figure 3 A). Meanwhile, the length of spring-summer period did not correlate with its closing date (R^2 = -0.0513) (Figure 3 B). These results suggest that changes in phenological events of spring more significantly influenced the duration of spring-summer period. In spring, when warm period follows the cold, phenological processes are more intensive than in autumn, when the warm period is replaced by the cold. Therefore, the dates of the occurrence of phenological phases in autumn vary considerably less. It suggests that the earlier does spring start, the longer is the growing season favourable for the development of perennial plants, regardless of whether autumn starts earlier or slightly later.

During 1961-2010 the warm season in Lithuania was becoming longer by +0.38 days year $^{-1}$ (Table 2). Thus, the spring-summer season in recent decades has become on average 8-16 days longer (Table 1). In Germany, first phenological phases occurring in spring became from -0.18 to -0.23 days year $^{-1}$ earlier, and the succeeding onset of perennial trees' leafing occurred from -0.16 to -0.08 days year $^{-1}$ earlier. Phenological changes in autumn, however, were smaller and were manifested by the delay of phenological phases (delayed by + 0.03 to +0.10 days year $^{-1}$ on average) (Menzel et al. 2001). R. Ahas (2000) assessed that in Estonia the plant growing season lengthened, but the duration of separate seasons was different. For example, the length of spring reduced while that of summer and autumn – slightly increased. H. W. Linderholm (2006) states that over the last five decades the growing season lengthened by 10-20 days, and the earlier beginning of the growing season is very noticeable.

Changes in the dates of phenological phases of indicator plants reflect fluctuations of meteorological conditions, especially of the second half of the last century. It has been significantly influenced by global climate warming. According to the IPCC (2007) data, the average temperature on our planet has risen by 0.74°C over the last 100 years; the period of 1995-2006 was the warmest since 1850. In addition, during 1956-2005 the average temperature has been increasing faster (0.10–0.16°C per decade). This affected climatic conditions in both Europe and Lithuania. In Lithuania, the average annual temperature in 1991-2003 increased from 6.2 to 7.0°C (Galvonaitė et al. 2007). The territory of Lithuania is the zone of western transfer. Here, same as in the entire Baltic Sea region, the hydrothermal regime is mainly conditioned by the processes in the Atlantic Ocean, which are characterized by the North Atlantic Oscillation (NAO) index. In the Baltic Sea region changes in phenological phenomena have been primarily related to the changes of the NAO index during winter months (Ahas and Aasa 2006). In Estonia, high correlation coefficients (> -0.5) were determined between the plant (*Tusilago farfara* L., *Betula pendula* Roth., *Syringa vulgaris* L.) phenological phases and the NAO index for December-March and January-March (Aasa et al. 2004). During 1965-2005 earlier onset of tree phenological phases in spring was more pronounced in western Norway than in other regions of the country. It was found that earlier bud burst of the same trees in this region was induced by the processes taking place during January and February in the Atlantic Ocean (Nordli et al. 2008). Plant responses to continent-wide climate changes are obvious. If the NAO index in winter is positive, the strengthened westerly winds carry relatively warm air masses into the major part of Europe. In Lithuania and Latvia, earlier dates of phenological phases of spring and summer plants, which had become more frequent after 1980, coincided with positive NAO index values (Kalvane et al. 2009). Thus, the climate change in Lithuanian is a part of global climate changes.

Dendroclimatologic studies help to evaluate the influence of climate change on sustainability of forest ecosystems. For example, the annual rings of trees are sensitive indicators of climatic factors of the growing season. Thus, environmental conditions affect the tree growth and their radial increment. In Lithuania, studies performed by A. Vitas (2002) showed that high temperature in spring (April, May) and abundant precipitation in summer (May-July) positively influenced the radial increment of Norway spruce (*Picea abies* (L.) Karst.). A. Šimatonytė (2010) has studied possible changes in the radial increment of Scots pine (*Pinus sylvestris* L.) due to climate warming; according to the obtained results, over the next 30 years the radial increment rates would be quite slow: from +0001 to 0004 mm per year.

Summarizing our study, we conclude that over the past five decades in Lithuania variations in plant phenological phases have been very conspicuous and particularly evident since the 1981-1990 decade. Variation and earlier occurrence of phenological phases of spring indicator European hazel were more pronounced than phenological phases of autumn indicator Norway maple. Variations in phenological phases of these indicators were mirrored in change of the length of spring-summer period. Lengthening of warm period of a year depended on the earlier onset of spring. It should be noted that during the early spring plant development is determined by temperature fluctuations. Exceptionally strong correlations were determined between average dates of the occurrence of phenological phases of spring indicator and average temperature of a few preceding months.

Changing environmental conditions may in future affect the phenological phases of forest plants. Modeling of the impact of climate change on plant phenological phases in Lithuania suggests that during the 21st century the dates of the beginning of European hazel and silver birch flowering will change most remarkably (Veriankaitė et al. 2010). Therefore, climate warming may in future affect not only phenological phases of perennial plants but also the sustainability of forest ecosystems.

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ВЛИЯНИЕ ИЗМЕНЕНИЯ КЛИМАТА НА ФЕНОЛОГИЮ ЛЕЩИНЫ ОБЫКНОВЕННОЙ (*CORYLUS AVELLANA* L.) И КЛЕНА ОСТРОЛИСТНОГО (*ACER PLATANOIDES* L.) В ЛИТВЕ В ТЕЧЕНИЕ ПЕРИОДА 1961-2010 Г.Г.

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Резюме

Исследования проведены в Вокеском филиале Литовского центра аграрных и лесных наук, используя архивные данные фенологических наблюдений, проведенных в Литве в период 1961-2010 г.г. Цель исследований - оценить влияние изменения климата на фенологические фазы растений - индикаторов начала весны (*Corylus avellana* L.) и осени (*Acer platanoides* L.) и продолжительность весенне–летнего периода в Литве в течение 1961-2010 г.г.

В течение 50-летнего периода начало цветения лещины обыкновенной (*Corylus avellana* L.), средние многолетние сроки наступления данной фенологической фазы в Литве приходятся на конец марта - 27 марта, проявлялось с большим отклонением (s = 16,1) и более раним наступлением фазы (по -0,43 дня в год), нежели начало пожелтения листьев клёна остролистного. Более раннее наступление фазы начала цветения лещины обыкновенной наблюдалось в течение периодов 1981-1990 г.г. (по -3,92 дня в год) и 1991-2000 г.г. (по -1,28 дня в год) в связи с потеплением климата и повышением средней температуры. Статистически достоверная корреляционная связь (p<0,01) установлена между датами наступления фенологической фазы лещины обыкновенной и средними месячными температурами с января по апрель. Дата начала пожелтения листьев клёна остролистного (которое приходится в среднем на 16 сентября) мало изменялась (s = 4,9) в течение всего периода наблюдений. Влияние метеорологических условий на начало пожелтения листьев клёна остролистного было незначительным (в 72,5% случаев r < 0,3). Изменения дат наступления фенологических фаз в начале весны имели большое влияние на продолжительность весенне – летнего периода. Было определено, что продолжительность весенне – летнего периода сильно коррелировала с датами начала цветения индикатора весны лещины обыкновенной (R^2 0,8492; p<0,01).

Ключевые слова: изменение климата, растения индикаторы, весенне – летний период, вегетационный период.