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Phenological research of climate changes in the north part of Lithuania by the phenological garden of Šiauliai University

Asta Klimienė[1] · Rimanta Vainorienė[1] · Ramutis Klimas[1]

Abstract Šiauliai University Botanical Garden is a member of the International Phenological Garden network since 2005. It is the only one botanical garden in the East Europe that participated in the programme. In 2015, 18 species were observed. For research, data of 14 plants was used. The aim of this study is to estimate the responsiveness of the species of plants of the phenological garden to annual and monthly precipitation and temperature of the air. The main variables in this investigation were growing season length and the beginning of the growing season. In the period 2006–2015, the lowest annual air temperature was in 2010 (6.0 °C), and the highest was in 2015 (8.9 °C). The lowest precipitation was in 2015 (37.3 mm), and the highest was in 2012 (63.5 mm). The leanest regression among growing length, average annual precipitation, and air temperature showed that statistically significant correlation between growing length and average annual air temperature was found for nine plants, between growing length and precipitation was found for three plants, and between growing length and both factors was found for one plant, *Salix smithiana*, only. Due to the short evaluating period (2007–2015), consistent regression of the length of the growing season could not be found. The growing length of *Betula pubescens* sequentially increased. The average growing season of 14 plants starts on April 27 (±3), but for *Corylus avellana*, it is on April 26 (±3). Longevity of the growing season was the most related with precipitation for *C. avellana* in summer, autumn, and winter and with air temperature, *Ribes alpinum* and *Salix acutifolia* in summer and in autumn.

✉ Asta Klimienė
astakl3g@gmail.com

[1] Šiauliai University, Vilniaus str. 88, LT-76285 Šiauliai, Lithuania

Introduction

Phenology is the study of periodic plant and animal life cycle events and how they are influenced by environmental changes, especially seasonal variations in temperature and precipitation driven by weather and climate (Chmielewski et al. 2013). Phenological observations are one of the most sensitive data in identifying how plants respond to climate conditions, and they are also used in the study of climate change and global warming (Chmielewski and Rötzer 2001). Phenology varies greatly over broad geographic gradients, according to climate zone and vegetation type, and substantial interannual variability at the start and end of the growing season, and thus growing season length, is observed as a result of year-to-year variability in weather. Phenology also varies within communities, and the phenology of individuals plays a key role in determining how ecosystems are structured and how they function (Cleland et al. 2007).

Unified methodology is very important for phenological investigations as well as for identification and monitoring of phenological stages of geographically widely distributed plants. The International Phenological Garden (IPG) network was established in 1959, for the purpose of collecting phenological data from sites across Europe (Chmielewski and Rötzer 2001). All gardens participating in the programme grow genetically identified plants. The observation network is coordinated by the scientists from Humboldt University in Berlin. The international observation programme is focused on possible impacts of climate change on forest ecosystems. Scientific aims are monitoring of environmental changes, climate-impact studies, development of phenological models,

calibration of remotely sensed data, and calculation of pheno-
logical maps (http://ipg.hu-berlin.de).

The seasonality of photosynthesis in winter-dormant/sum-
mer-active ecosystems is also phenological in nature, as are
the annual cycles of other ecosystem processes (Noormets
et al. 2010). In northern latitude regions such as Europe, tem-
perature is one of the main drivers regulating vegetation phe-
nological events. Thus, changes in temperature as a conse-
quence of global warming may lead to changes in the timing
of phenological events (Sobrino et al. 2011). Higher tempera-
tures in this time always led to an advanced leafing or
flowering of trees. Therefore, the recent temperature changes
are well reflected in the development of vegetation.
Phenological observations are a good indicator to evaluate
possible impacts of climate changes on the biosphere
(Chmielewski 2002). Currently, the main attention is paid to
assess climate changes and to research changing environment.
In the report of the Intergovernmental Panel on Climate
Change (IPCC), it is said that climate changes greatly influ-
ence all continents (IPCC 2014). The seasonal changes of the
plants and possible longevity of the growing season are related
with climate changes. In the region of Baltic countries, phe-
nological phases prolonged obviously during the last 30–
40 years.

The aim of this study is to estimate the responsiveness of
the species of plants of the phenological garden to annual and
monthly precipitation and temperature of the air. The main
variables in this investigation were growing season length
and the beginning of the growing season.

Materials and methods

Lithuanian territory is in the middle of the latitude bar which is
characterized by the change of seasons. The natural seasonal
occurence is related with the changes of annual cold and warm
seasons. During the period of 2006–2015, there was gathered
and evaluated hydrometeorological data of Šiauliai District.
The meteorological data was received from the
Meteorological Department of Šiauliai City. Since 2007, phe-
nological data of plants has been gathered from the phenolog-
ical garden of Šiauliai University Botanical Garden (ŠUBG).
ŠUBG is located in the north part of Lithuania (55° 55′; 23°
16′ E). It is the only one botanical garden in the Baltic coun-
tries which participated in the international observation pro-
gramme. ŠUBG has joined the IPG network in 2005 (IPG No.
152). In that time, 14 plants were obtained from Humboldt
University (Germany) for observation. The observation
started in 2007. In 2008, five additional plants were received;
thus, the phenological garden was expanded. However, in
2013, after winter season, two vanished species were re-
downloaded. So in the 9-year period, the total was three re-
downloaded species, namely *Picea abies* (early), *Larix
decidua*, and *Populus tremula*. In 2015, in ŠUBG, 18 species
were grown and observed, from which two are varieties.
Plants of 12 families were grown there, 4 plant species belong
to *Pinopyta*, and 14 belong to *Magnoliophyta* divisions. ID
number is given for each plant species and variety. All inves-
tigated data is recorded in the international data basis. In the
data basis, eight phenological stages are now investigated

Table 1 List of evaluated plants in Šiauliai University Botanical Garden

No.	Identification no.	Species of the plant, origin	Arriving date	Investigated phenological phases	Taxonomy
1	111	*Larix decidua* Mill. (Germany)	2013	UL, BF, FF	*Pinaceae* Lindl.
2	121	*Picea abies* (L.) H.Karst. f. early (Germany)	2013	MS	*Pinaceae* Lindl.
3	122	*Picea abies* (L.) H.Karst. f. late (Germany)	2005	MS	*Pinaceae* Lindl.
4	131	*Pinus sylvestris* L. (N-Scandinavia)	2008	MS	*Pinaceae* Lindl.
5	211	*Betula pubescens* Ehrh. (Germany)	2005	UL, BF, FF, CL, FL	*Betulaceae* Gray
6	221	*Fagus sylvatica* L. (Germany)	2005	UL, CL, FL	*Fagaceae* Dumorf.
7	235	*Populus tremula* L. (Germany)	2008	UL, CL, FL	*Salicaceae* Mirb.
8	261	*Robinia pseudoacacia* (USA)	2008	UL, BF, FF, RF, CL	*Fabaceae* Lindl.
9	271	*Sorbus aucuparia* L. (Czech)	2005	UL, JS, BF, FF, RF, CL, FL	*Rosaceae* Juss.
10	281	*Tilia cordata* Mill. (Germany)	2008	UL, BF, FF, RF, CL, FL	*Tiliaceae* Juss.
11	311	*Ribes alpinum* L. (Austria)	2005	UL, BF, FF, RF, CL, FL	*Grossulariaceae* DC.
12	323	*Salix acutifolia* Willd. (Germany)	2005	UL, BF, FF, CL, FL	*Salicaceae* Mirb.
13	324	*Salix × smithiana* Willd. (Germany)	2005	UL, BF, FF, CL, FL	*Salicaceae* Mirb.
14	326	*Salix viminalis* L. (Germany)	2005	UL, BF, FF, CL, FL	*Salicaceae* Mirb.
15	331	*Sambucus nigra* L. (Germany)	2005	UL, BF, FF, RF, CL, FL	*Sambucaceae* Batsch ex Borkh.
16	411	*Corylus avellana* L.	2005	UL, BF, FF, RF, CL, FL	*Corylaceae* Mirb.
17	421	*Forsythia suspensa* (Thunb.) Vahl 'Fortunei'	2005	UL, BF, FF, CL, FL	*Oleaceae* Hoffmanns. et Link
18	431	*Syringa × chinensis* 'Red Rothomagensis'	2005	UL, BF, FF, CL, FL	*Oleaceae* Hoffmanns. et Link

Fig. 1 Monthly precipitation in different seasons in 2007–2015 in Šiauliai District. Months of **a** winter, **b** spring, **c** summer, and **d** autumn
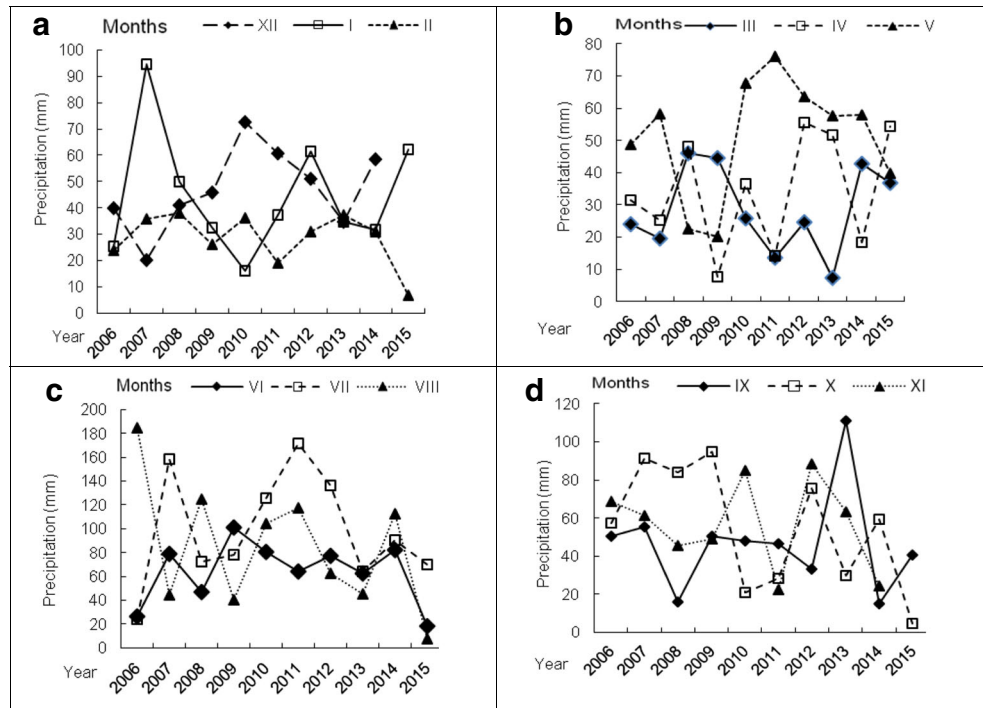

(Table 1). Thus, by the network requirements, the following phenological phases are observed: beginning of leaf unfolding (UL), may shoot (MS), St. John's sprout (JS), beginning of flowering (BF), general flowering (FF), first ripe fruits (RF), autumn colouring (CL), and leaf fall (LF).

For research, data of 14 plants growing in the phenological garden of ŠUBG was used (Table 1). The other four plants were too young and did not have all stages needed for the investigation. For evaluation, the length of growing and start of the growing season were observed and compared by annual precipitation and annual air temperature using correlation and leanest regression coeficients.

ŠUBG phenological garden is founded on the smooth relief. The plants were planted by the requirements and

Fig. 2 Monthly air temperature in different seasons in 2007–2015 in Šiauliai District. Months of **a** winter, **b** spring, **c** summer, and **d** autumn
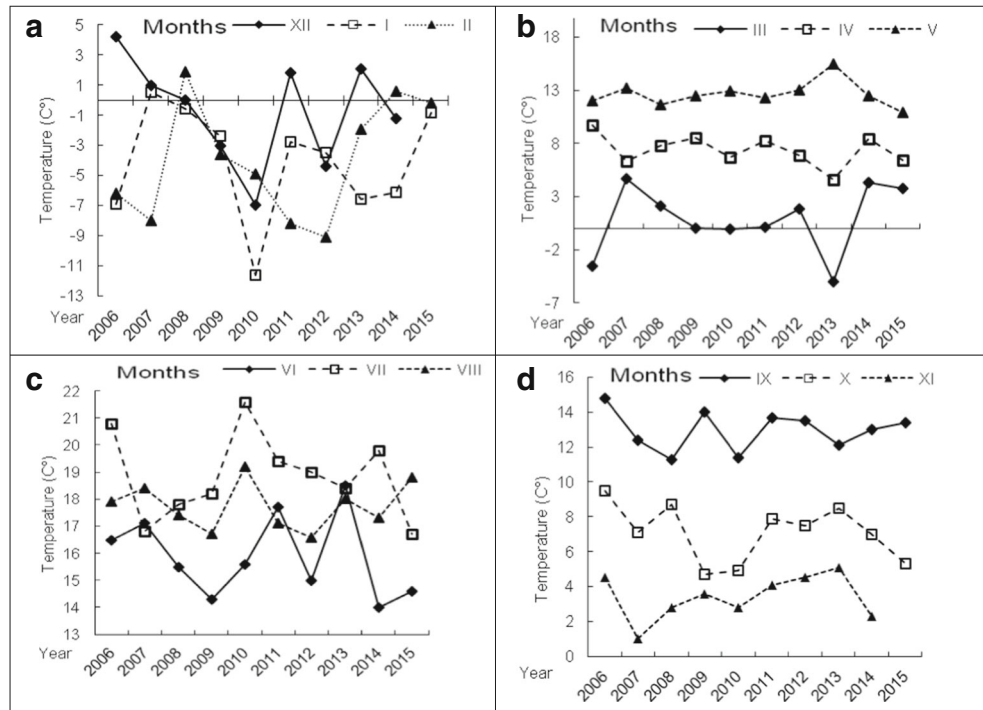
methodology with the distance of 5–6 m. Currently, in the phenological garden, 12 plant species are fully observed, since the other five do not attain generative maturity; these are, namely, *Fagus sylvatica*, *P. tremula*, *Tilia cordata*, *P. abies*, and *R. alpinum* which are observed to flower abundantly but do not ripe fruits. The condition of 15 plants is good, but three plants are satisfactory only. *Sorbus aucuparia* and *Sambucus nigra* grow slowly yet ripe poorly. *Salix acutifolia* has some branches to dry off every year.

The investigation data were processed using statistical package Statistica for Windows version 8.0 (StatSoft, Inc. Tulsa, OK, USA) and according to the basic guide to the statistical analysis of biological data by Tucker (2003). The difference was considered statistically significant when $P < 0.05$.

Results

The length of the growing season usually depends on annual air temperature and precipitation. The values and linear trend of means of annual precipitation and air temperature in four seasons are presented in Figs. 1 and 2. The average temperature in winter in 2006 distinguished by the annual temperature since December 2006 was 4.2 °C, and in January 2007, it was 0.5 °C. Mostly (in the years 2006, 2007, 2008, and 2013), the annual temperature was positive. The coldest temperature registered was in winter 2010 (January −10 °C, February −4.9 °C, December −7 °C). The warmest was in July 2010, 21.6 °C.

Fig. 3. The length of the growing season measured for different plants ▶ between 2007 and 2015. *Red line* indicates trend line, calculated with the least squares methods with the R^2 shown at the bottom of each graph
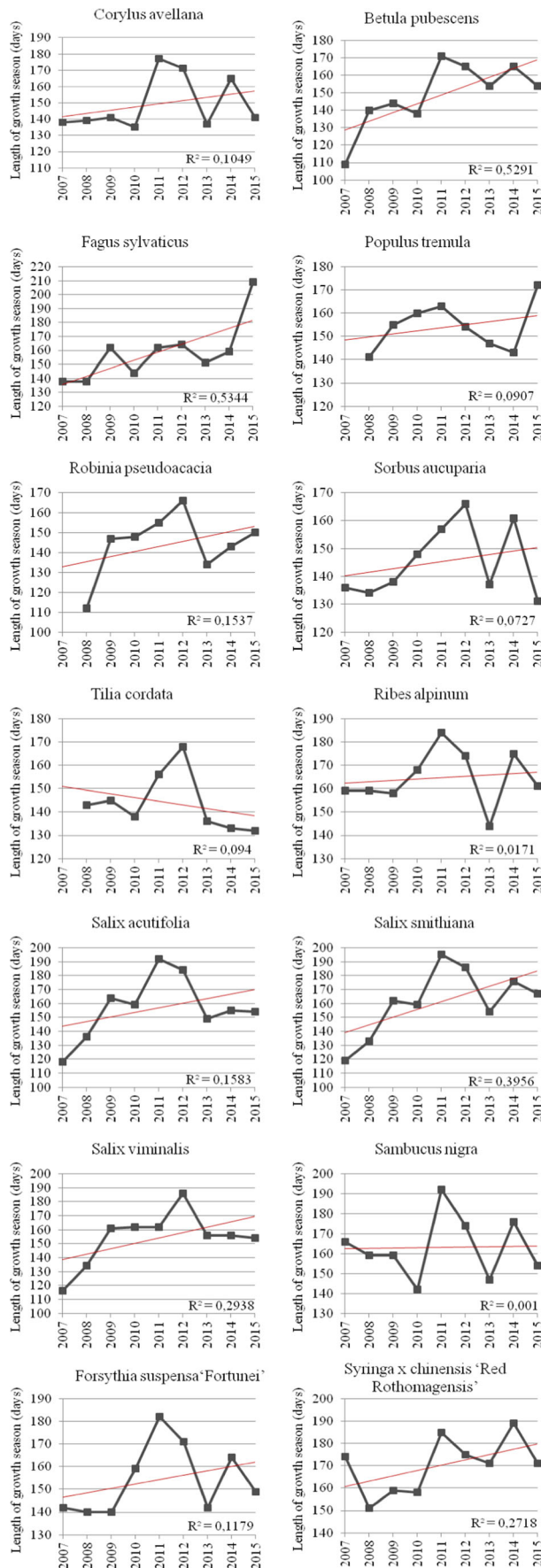
Thus, the lowest annual air temperature was in 2010 (6.0 °C) (Table 2), and the highest was in 2008 (8.0 °C) and in 2015 (7.9 °C). The lowest precipitation was in 2015 (36.3 mm), and the highest was in 2012 (63.5 mm). In the 9-year period, the greatest variety and extreme fluctuation of precipitation were in July (107.5 mm), August (73.4 mm), January (28.9 mm), and February (28.9 mm). The greatest variety of the average air temperature was in January and February (accordingly −3.8 and 3.7 °C), July (18.3 °C), and August (17.7 °C). The biggest variations and temperature differences were in March (from min. −5 °C to max. 4.7 °C) and December (from min. 2.1 °C to max. −7 °C).

Individual plants were analysed by dependency of monthly average of precipitation and air temperature and length of the growing season (Table 2). *F. sylvatica* (138 days ± 3), *P. tremula* (141 days ± 3), *Robinia pseudoacacia* (112 days ± 3), *Forsythia suspensa* 'Fortunei' (140 days ± 3), and *Syringa × chinensis* 'Red Rothomagensis' (141 days ± 3) had the shortest length of the growing season in 2008. In Lithuania, all these plants start growing in the middle of spring and usually flower in May, except for *P. tremula*; this plant is local and flowers early, in April–May (Table 6). *Corylus avellana* (177 days ± 3), *Betula pubescens* (171 days ± 3), *P. tremula* (163 days ± 3), *R. alpinum* (184 days ± 3), *S. acutifolia* (192 days ± 3), *Salix smithiana* (195 days ± 3),

Table 2 Annual length of the growing season, precipitation, and air temperature in Šiauliai District

Plants	Years									Regression of the length of growing/ precipitation	Regression of the length of growing/°C
	2007	2008	2009	2010	2011	2012	2013	2014	2015		
	Average air temperature, °C										
	7.5	8.0	7.0	6.0	7.6	6.7	7.4	7.7	7.9		
	Average precipitation, mm										
	61.9	52.9	49.2	59.9	55.9	63.5	49.9	51.9	36.2		
	Length of vegetation										
Corylus avellana	138	139	141	135	177	171	137	165	141	0.56	−0.62*
Betula pubescens	109	140	144	138	171	165	154	165	154	0.12	2.62
Fagus sylvatica	138	138	162	144	162	164	151	159	209	−1.84*	14.45
Populus tremula	–	141	155	160	163	154	147	143	172	−0.42*	2.28
Robinia pseudoacacia	–	112	147	148	155	166	134	143	150	0.50	−4.25*
Sorbus aucuparia	136	134	138	148	157	166	137	161	131	0.87	−6.43*
Tilia cordata	–	143	145	138	156	168	136	133	132	1.06	−4.65*
Ribes alpinum	159	159	158	168	184	174	144	175	161	0.51	−1.97*
Salix acutifolia	118	136	164	159	192	184	149	155	154	0.19	−6.10*
Salix smithiana	119	133	162	159	195	186	154	176	167	−0.24*	−2.27*
Salix viminalis	116	134	161	162	162	186	156	156	154	0.07	−7.59*
Sambucus nigra	166	159	159	142	192	174	147	176	154	0.52	2.15
Forsythia suspensa 'Fortunei'	142	140	140	159	182	171	142	164	149	0.66	−3.58*
Syringa × chinensis 'Red Rothomagensis'	174	151	159	158	185	175	171	189	171	0.10	2.58

*$P < 0.01$

Corylus avellana

Betula pubescens

Fagus sylvaticus

Populus tremula

Robinia pseudoacacia

Sorbus aucuparia

Tilia cordata

Ribes alpinum

Salix acutifolia

Salix smithiana

Salix viminalis

Sambucus nigra

Forsythia suspensa 'Fortunei'

Syringa x chinensis 'Red Rothomagensis'

S. nigra (192 days ± 3), and *F. suspensa* 'Fortunei' (182 days ± 3) had the longest growing length in 2011 (Table 2, Fig. 3). The leanest regression among growing length, average annual precipitation, and average annual air temperature showed that statistically significant correlation between growing length and average annual air temperature was found for nine plants, between growing length and precipitation was found for three plants, and between growing length and both factors was found for one plant, *S. smithiana*, only. Thus, the tendency that annual air temperature makes more influence for plants than annual precipitation may be noticed (Table 2, Fig. 3).

Data of climate evaluation is very important in the beginning of the growing season, which differs for individual plants (Figs. 1 and 2). Possible correlation of annual air temperature and precipitation may also be noted (Table 3). Due to the short evaluating period (2007–2015), consistent regression of the length of the growing season could not be found. But the tendency may be observed that for the number of plants, high consistency was related with air temperature. The growing length of *B. pubescens* sequentially increased in the 9-year period. The tendency of sequent increasing was indicated to the *Salix* genus plants, *R. pseudoacacia*, and *F. sylvatica*. *C. avellana*, and *S. nigra* plants were recorded to have especially high fluctuations of growing length.

The influence of precipitation content and air temperature during all four seasons (spring, summer, autumn, and winter) to the length of the growing season and start of the season was estimated in this study as well. It was found that the length of the growing season was statistically significantly linked with the precipitation in spring and the result was valid for six plants (Table 3). The length of growing was linked with air temperature in spring for three plants only. But precipitation in

autumn had significant influence for ten plants and air temperature (in summer) for nine plants. The highest rates of leanest regression was in comparison with precipitation, namely for *R. pseudoacacia* in spring and summer. *R. pseudoacacia* had the highest rates by the annual temperature in summer, autumn, and winter seasons as well (respectively $R = -15.39$, $R = -24.33$, and $R = -9.18$, $P < 0.001$). The weakest regression was for *B. pubescens* precipitation in summer ($R = -0.03$, $P < 0.05$), *S. aucuparia* precipitation in spring ($R = 0.01$, $P < 0.05$), and *Salix viminalis* precipitation in summer ($R = -0.01$, $P < 0.001$). The weakest correlation coefficient was found between annual air temperature and growing season to *S. viminalis* ($r = -0.03$, $P < 0.001$) and *S. smithiana* ($r = -0.13$, $P < 0.001$) (Table 3). *R. pseudoacacia* and *S. viminalis* are introduced species in Lithuania and do not grow naturally (Table 6). *B. pubescens*, *S. aucuparia*, and *S. smithiana* are local species. The negative but highest and statistically significant regression was found between the length of growing and air temperature to *S. nigra* in summer and autumn seasons (respectively $R = -35.15$ and $R = -44.85$, $P < 0.001$) (Table 3).

By the data of the phenological garden (Table 4), *C. avellana*, *Salix* genus, *R. alpinum*, and *F. suspensa* 'Fortunei' flowered the earliest. For *C. avellana*, the greatest influence to longevity of the growing season had precipitation in summer, autumn, and winter (Table 5) (respectively $r = 0.19$, $P < 0.001$; $r = -0.47$, $P < 0.001$; and $r = -0.74$, $P < 0.01$) and air temperature in summer ($r = -3.73$, $P < 0.001$) and autumn ($r = -8.71$, $P < 0.01$).

Data about the links among BF stages (start of the growing season), average seasonal precipitation, and average seasonal air temperature was not calculated for *P. tremula*, *F. sylvatica*, and *T. cordata* because of the too short period of investigation.

Table 3 Links among begining of the growing season (UL-BF stages), average seasonal precipitation, and average seasonal air temperature

Plant	R precipitation/ spring	R precipitation/ summer	R precipitation/ autumn	R precipitation/ winter	R °C/ spring	R °C/ summer	R °C/ autumn	R °C/ winter
Corylus avellana	0.34	0.19**	−0.47**	−0.74**	6.26	−3.73**	−8.71**	1.10
Betula pubescens	−0.12**	0.03*	−0.16**	−0.17**	1.06	−0.71**	1.72	0.67
Robinia pseudoacacia	2.62**	−4.25**	−0.76**	2.33	8.20	−15.39**	−24.33**	−9.18**
Sorbus aucuparia	0.01*	−0.08**	−0.20**	−0.16**	4.93	−5.67**	−1.78**	1.104
Ribes alpinum	−0.22	−0.09**	−0.27**	−0.10**	5.57	−2.11**	−7.24**	1.71
Salix acutifolia	0.03	0.06**	−0.06**	−0.02**	−0.83**	−1.19**	4.96	0.58
Salix smithiana	0.06**	0.11	−0.01	0.20	0.12	−0.13**	3.32	−0.60**
Salix viminalis	0.22**	−0.01**	−0.08**	−0.29	−2.63**	0.08	5.24	−0.03**
Sambucus nigra	0.81**	−0.60**	−1.60**	−2.40**	12.65	−35.15**	−44.85**	2.54
Forsythia suspensa 'Fortunei'	−0.81**	−0.08**	0.26**	0.09**	−3.06**	9.02	6.93	1.19
Syringa × chinensis 'Red Rothomagensis'	−0.09**	−0.01**	−0.12**	1.02**	10.64	−5.61**	−7.14**	1.78

*$P < 0.05$

**$P < 0.001$

Table 4 Average of start of the growing season of plants phenologically investigated in ŠUBG

Means	Corylus avellana	Betula pubescens	Robinia pseudoacacia	Sorbus aucuparia	Ribes alpinum	Salix acutifolia	Salix smithiana	Salix viminalis	Sambucus nigra	Forsythia suspensa, 'Fortunei'	Syringa × chinensis, 'Red Rothomagensis'
UL											
Average	IV.26	IV.7	V.13	IV.28	IV.07	IV.4	IV.22	IV.23	IV.10	IV.27	IV.21
S±	3	3	3	3	3	3	3	3	3	3	3
Min.	IV.17	IV.14	V.02	IV.14	III.20	IV.4	IV.09	IV.14	III.20	IV.19	III.28
Max.	V.06	V.06	V.27	V.06	IV.26	V.07	V.06	V.06	V.05	V.06	V.06
BF											
Average	IV.04	V.02	VI.08	V.23	IV.26	IV.1	IV.08	IV.13	VI.19	IV.21	V.22
S±	3	3	3	3	3	3	3	3	3	3	3
Min.	III.09	IV.3	V.30	V.21	IV.19	III.0	III.25	IV.01	VI.06	IV.13	V.19
Max.	IV.23	V.09	VI.15	V.30	V.07	IV.5	IV.20	IV.29	VII.2	V.07	V.27

R. pseudoacacia and *S. nigra*, both flowering early in the summer, are significantly correlated by precipitation in all four seasons and by annual air temperature in summer and autumn (respectively $r = -15.39$ and $r = -35.15$, $P < 0.001$). Thus, air temperature rather than precipitation is more influential for the separate plants in different seasons. But statistically significant correlation and regression of annual air temperature and annual precipitation and the start of the growing season (Table 6) was found only for *S. aucuparia* ($P = 0.036$) and *S. × chinensis* 'Red Rothomagensis' ($P = 0.017$).

Discussion

Various studies show that phenology is not only a good bioindicator for temperature changes in general but also mirrors them quantitatively. Average phenological trends across the countries systematically vary with temperature changes of the same country (Menzel et al. 2006). The average length of the growing season in Europe (EGS–BGS) lasts 188 days and depends highly on the mean annual air temperature. The regression equation indicates that 1 °C increase in mean air temperature is associated with an extension of the growing season by about 5 days. The shortest duration was observed in North Scandinavia with only 139 days (4.5 months) and 172 days (5.5 months) (Rötzer and Chmielewski 2001). According to many year research data, it is evident that since 1989, the mean daily air temperature of February and March has considerably increased (Romanovskaja and Baksiene 2007). While evaluating air temperature in northern Lithuania, it was found that winter season was more exclusive during the 9-year period: air temperature in December, January, and February varied from −10 to 4.2 °C. A big variety of air temperature was also observed in the first months of astronomical spring, especially in March (−5 to 4.7 °C).

The length of the growing season is an important measure in forestry, agriculture, and horticulture. On average, the beginning of the growing season in Europe starts on April 23 (Rötzer and Chmielewski 2001; Chmielewski 2002). In the Lithuanian latitude, the beginning of the phenological spring season coincides with the beginning of flowering of European hazel (*C. avellana*) (Romanovskaja and Baksiene 2007) and *P. tremula* and the *Salix* genus (Table 6). 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. In Lithuania, European hazel starts to flower on March 28 on average. In contrast with this data, in Šiauliai (northern part of Lithuania), flowering of *C. avellana* starts on April 26 (±3 days), while all 14 plants that were observed in the study start flowering on April 27 (±3 days; according to the data of the last 9 years). Also, for the comparison of the flowering seasonality and start of season of the plants in Lithuania and in

Table 5 Correlation and regression coeficients of the start of the growing season, annual precipitation, and air temperature

Means	Start of the growing season and annual precipitation	Reliability (P)	Start of the growing season and annual air temperature	Reliability (P)
Sorbus aucuparia				
Correlation coeficient	0.013	0.974	0.700	0.036*
Regression coefficient	0.013		4.932	
Syringa × chinensis 'Red Rothomagensis'				
Correlation coeficient	−0.048	0.903	0.764	0.017*
Regression coefficient	−0.092		10.644	
All plants (*n* = 14)				
Correlation coeficient	−0.038	0.728	0.111	0.310
Regression coefficient	−0.181		3.586	

*Marked values are statistically significant, $P < 0.05$

ŠUBG phenological garden, the annual flowering time in country is presented in Table 6.

Various studies show that the first stage of the growing season, the flowering, and a stage of first leaves correlate significantly with the air temperature of the previous month (Menzel 2003; Romanovskaja and Baksiene 2009; Kalvane et al. 2009). However, this study revealed that the start of the growing season, flowering, and leafing had statisticaly significant correlations with precipitation in March ($r = −0.6$, $P < 0.001$) and with air temperature in February ($r = −0.8$, $P < 0.0025$) and November ($r = −0.6$, $P < 0.001$).

Sparks et al.'s (2011) study revealed a highly significant correlation between the phenophase and the year and the phenophase and the temperature ($r = −0.6$, $P < 0.001$). In ŠUBG, statistically significant regression between the phenophase of the year and air temperature during the 9-year period was not found but only for two plants (*S. aucuparia* and *S. × chinensis* 'Red Rothomagensis').

Botanical gardens can offer many advantages in studies of phenology and climate impacts (Donaldson 2009; Primack and Miller-Rushing 2009; Sparks et al. 2011). There is typically a stability in both staffing and methods that results in continuity of recording protocols and a longevity that can rarely be achieved when records are made by individuals (Fitter and Fitter 2002). Phenological recording may often involve the same specimen in a relatively small area and thus eliminate some of the noise associated with phenological records made in the wild over large areas. Their compact area also makes interspecies comparisons more valid since environmental conditions will be much more similar. Many botanical gardens have their own meteorological station enhancing the value of the plant records that have been made. Botanical garden archives offer additional possibilities (Miller-Rushing and Primack 2008; Donaldson 2009; Primack and Miller-Rushing 2009; Sparks et al. 2011), though Šiauliai

Table 6. Flowering time of trees and scrubs in Lithuania (Navasaitis 2008)

No.	Name of plant	Flowering time	Species location
1	*Corylus avellana*	Spring/March–April	Local
2	*Betula pubescens*	Spring/May (early)	Local
3	*Fagus sylvatica*	Spring/May	Introduced
4	*Populus tremula*	Spring/April–May	Local
5	*Robinia pseudoacacia*	Summer(early)/June	Introduced
6	*Sorbus aucuparia*	Spring-summer/May–June	Local
7	*Tilia cordata*	Summer/June–July	Local
8	*Ribes alpinum*	Spring/May	Introduced
9	*Salix acutifolia*	Spring/April	Local
10	*Salix smithiana*	Spring/April	Introduced
11	*Salix viminalis*	Spring/April	Local
12	*Sambucus nigra*	Spring/summer/May–June	Introduced
13	*Forsythia suspensa* 'Fortunei'	Spring/May	Introduced
14	*Syringa × chinensis* 'Red Rothomagensis'	Spring/May	Introduced

Botanical Garden is the only one from Eastern Europe that participated in the IP network.

Conclusions

1. In the period 2006–2015, the lowest annual air temperature was in 2010 (6.0 °C), and the highest was in 2008 (8.0 °C) and in 2015 (7.9 °C). The lowest precipitation was in 2015 (36.3 mm), and the highest was in 2012 (63.5 mm). The biggest variations and temperature differences were in March (from min. −5 °C to max. 4.7 °C) and December (from min. 2.1 °C to max. −7 °C).

2. The leanest regression among growing length, average annual precipitation, and average annual air temperature showed that statistically significant correlation between growing length and average annual air temperature was found for nine plants, between growing length and precipitation was found for three plants, and between growing length and both factors was found for one plant, *S. smithiana*, only. The tendency is that annual air temperature makes more influence for plants than annual precipitation.

3. Due to the short evaluating period (2007–2015), consistent regression of the length of the growing season could not be found. But the tendency may be observed that for the number plants, high consistency was related with air temperature. The growing length of *B. pubescens* sequentially increased in the 9-year period. The tendency of sequent increasing was indicated to the *Salix* genus plants, *R. pseudoacacia*, and *F. sylvatica*. *C. avellana* and *S. nigra* plants were recorded to have especially high fluctuations of growing length.

4. The growing season of 14 plants starts on average on April 27 (±3), but for *C. avellana*, it is on April 26 (±3) during the 9-year period.

5. Longevity of the growing season was the most related with precipitation for *C. avellana* in summer, autumn, and winter, and with air temperature, it was for *R. alpinum* and *S. acutifolia* in summer and in autumn.

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