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THE INFLUENCE OF TEMPERATURE ON PHENOLOGY OF ORNAMENTAL WOODY SPECIES IN URBAN ENVIRONMENT

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Abstract

The main aim of this paper is to establish how urban environment conditions do influence the development of shrub ornamental plants in terms of their phenology. Spring season phenology of six species of ornamental shrubs and four of trees from an urban area of Muntenia, Romania, was analyzed under the influence of temperature. The analyses were made using correlations and the cold hours accumulated by species were calculated until the flowering bud breaking. The results obtained show that temperature significantly influences the onset of spring phenological phases and their duration. The research will be going on focusing on changes that occur in phenology of species from one year to another, under the influence of variable climatic conditions from year to year, in order to highlight the effect of climate changes on urban phenology.

***Key words**: phenology, temperature, phenophase duration, global thermic balance, cold hours.*

INTRODUCTION

Climate lays conditions on the living environment of world life, being a major factor in the development and spread of vegetation. During a season, depending on occurring phenophase, different environmental factors can affect the triggering and evolution of the plant growth. Among many environmental factors that affect the development and implicitly of plant phenology, temperature is probably the most important in the case of the budding, budding and flowering in the temperate climate (Glover, 2007; Tooke & Battey, 2010; Heide, 2011; Cosmulescu et al., 2010a, Birsanu & Cosmulescu, 2017; Cosmulescu & Calusaru, 2020).

The second factor affecting the phenophases is the photoperiod, which has implications especially for flowering. Glover (2007) considers that flowering is more important during the day, then temperature and less water stress. This is explained by the fact that there is an optimal time for flowering, which differs in each species, depending on numerous factors and formed as a result of a selection process (Thomas & Vince-Prue, 1997; Glover, 2007).

The city is a complex phenomenon whose physical dimension can change the local climate. The shape and manner of layout of the buildings, the materials from which they are made, the degree of waterproofing of soil, the characteristics and dimensions of paved surfaces in the squares and on streets are elements that affect the city climate.

The most well-known climatic phenomenon generated by geometry and "consistency" of urban environment is the island of urban heat. The phenomenon especially affects the air temperature and urban surfaces in the urban climate compared to the surrounding areas (Gartland, 2012; Costache & Rădutoiu, 2007). The most well-known effect of the urban heat island on the development of plants is the onset of some phenophases, especially in spring season (Lakatos & Gulyás, 2003; Cosmulescu et al., 2010b; Cosmulescu & Gruia, 2016; Costache & Radutoiu, 2006).

The impact of some environmental factors on phenophases has led to the development of urban phenology. The researchers believe that the effects generated by urban heat island especially on temperatures, offer the possibility to study the impact of climate change on plants development. This is because current temperatures in urban areas are considered representative of what will happen in the future and in rural areas (Neil & Wu, 2006; Jochner & Menzel, 2015). It can be said that temperature plays the most important role in weeding, as demonstrated by testing several phenological models (Fu et al., 2012).

Sparks & Menzel (2002) present phenology as the ideal way to demonstrate the effects of global warming on the living world. Phenological changes are a large part of all evidence that species respond to climate change (Walther et al., 2002). Due to the comprehensive biological record, plants have become a model group in detecting the impact of climate change, including the impact on phenology (Stefanescu et al., 2003; Dell et al., 2005; Menzel et al., 2006).

However, understanding and predicting these changes remains rather a challenge. In the context of climate change but also of challenges related to pollution in urban environment, ornamental vegetation is one of the factors that can improve the environmental quality but also the ornamental quality of urban spaces and can provide an environment for a quality life for the citizens of cities (Radutoiu & Stefanescu, 2017).

The main aim of this paper is to establish how urban environment conditions influence the development of ornamental plants through their phenology. Phenological data applied in landscaping could lead to optimization of expenses with the maintenance of green areas, to the avoidance of some choices of dendrological-floricultural material that is unsuitable to the place and purpose, and to obtaining of urban green spaces of quality and more diverse, with reduced efforts expenses. The choice of shrub and tree species as the subject of the research was due to the fact that they are vital elements in the composition of green spaces.

MATERIALS AND METHODS

The research area, Găești town, is located in South-West of Dîmbovița County, Muntenia, Romania, at $44^0 50'$ north latitude, $25^0 19'$ east longitude and 190.62 m altitude. Located at the contact between the Romanian Plain and Cândești Piedmont, between the valleys of Argeș and Potopu rivers, it has a temperate continental climate of transition characterized by hot, dry summers and winters with average temperatures below 0^0C. From this area, 6 species of ornamental shrubs were selected for the study (*Forsythia x intermedia, Mahonia aquifolium, Spiraea x vanhouttei, Albizia julibrissin, Syringa vulgaris, Chaenomeles japonica*) and 4 ornamental trees (*Aesculus hippocastanum, Prunus cerasifera, Catalpa* sp.*,* *Tilia* sp.). Phenophases of the spring season, from the beginning of vegetation period until the end of flowering were recorded using BBCH-scales by observations on leafing and flowering in 2018-2019, at an interval of 2-4 days, calculating the number of days between different phenophases.

To highlight the influence of temperature on phenology, climate data from Tîrgoviște Meteorological Station, 27 km from the research area, were used. The global thermal balance resulting from the summation of average daily temperature over the time interval was calculated. With this help can be highlighted the amounts of temperature degrees until the triggering of a certain phenophase, or in other words allowing to appreciate what amount of degrees is needed for a particular species to go through a certain phenophase (for flowering, for ripening fruit, etc.).

The accumulated cold hours from November 1 until flowering bud burst were calculated according to the method used by Cosmulescu & Ionescu (2018). The relationships between temperature and phenology were investigated using correlations.

RESULTS AND DISCUSSIONS

Phenological changes are the clearest manifestations of climate warming. Understanding long-term trends, as well as the mechanisms underlying divergent responses, is an essential part of managing and mitigating the effects of climate changes through phenology. From a phenological point of view, the main reaction to these changes is considered to be the increase of vegetation season length (Robeson, 2002), respectively, an earlier occurrence of spring phenophases and a delay of autumn ones.

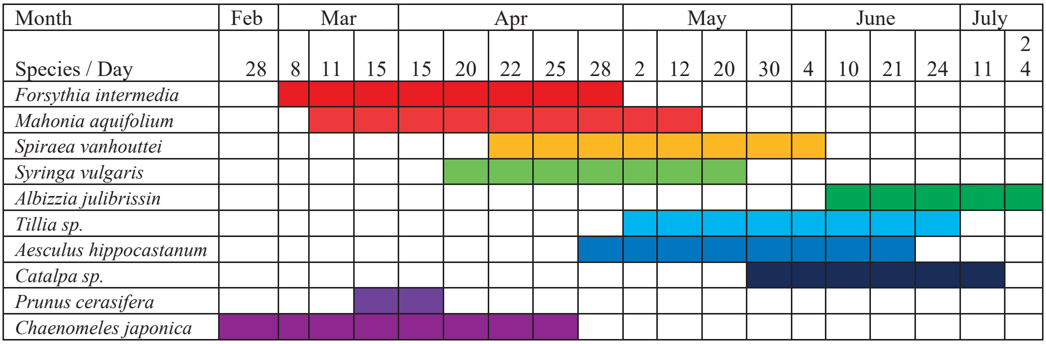
Chart 1 presents the phenogram of spring phenology, respectively, bud-breaking and flowering of the 10 species under study. The moment of blossoming bud-breaking varies considerably. The earliest blossoming bud-breaking occurred in *Chaenomeles* (February 28) while the latest in *A. julibrissin* (June 10). The timing of phenological stages (phenophases) varies according to species, age, local climate and many biotic and abiotic conditions (Denny et al., 2014; White et al., 1997). The shortest duration from bud-breaking to the end of blossoming was in *P. cerasifera* (March 15 - April 15).

Table 1 shows the duration, in days, of different phenophasesfor the 10 species. The fewest days from November 1 to vegetative bud-breaking (107 days) passed in *M. aquifolium*, while the highest number of days (176 days) in *A. julibrissin*. The number of days from 1 November to blossoming bud-breaking was 128 days in *Forsythia intermedia* and 211 in *Catalpa* sp. From blossoming bud-breaking to flowering, the time duration was between 2 days in *Tillia* sp. and *S. vulgaris* and 15 days in *Catalpa* sp. The duration of flowering phenophase was between 9 days in *S. vanhouthei* and 53 days in *Tillia* sp. and *Chaenomeles*. In literature there are many studies related to phenology. Defila & Clot (2001), reported a growth trend of vegetation season period by 13.3-day in chestnut (*Aesculus hippocastanum*). Also, analyzing 100 species, Abu-Asab et al. (2001) found in 89 of them a significant trend towards occurrence of the first flowering by 2.4 days earlier.

The same authors demonstrate the higher variability of spring phenophases, compared to the autumn ones, similarly to the results presented by Roetzer et al. (2000). The time and duration of flowering phenophase are influenced by temperature (Birsanu Ionescu & Cosmulescu, 2017; Cosmulescu et al., 2015). Pálešová & Snopková (2010) in central Slovakia confirmed that higher temperatures recorded in the last decades have a significant influence on spring phenophases development. Thus, the higher air temperature in the spring months triggers the onset of spring phenological phases.

The same trend was observed in Suffolk, UK (Sparks et al., 2006) and in Europe (Ahas et al., 2002). Each fruit tree species has a specific requirement regarding the cold which refers to the hours accumulated below the cooling temperature threshold, hours that are important for leaving the dormant state. The maximal biological effect of an hour of cold is obtained, according to the specialized literature, between 0 and 7°C. The cold requirement is the result of long-term climate adaptation of tree genotypes in different regions. Instead, it limits the climatic distribution of genotypes of fruit trees in temperate areas (Sherman & Beckman, 2003). The need for cold is the main factor that determines the flowering time (Egea et al., 2003; Ruiz et al., 2007), which is an important agronomic feature for seeds and fruits development in species of fruit trees in temperate areas. Fan et al. (2010) report in *Prunus* genus a need for cold hours between 320 and 1049 hours in 2008, and between 294 and 970 hours in 2009, in genotypes analyzed within the Southern Fruit and Tree Nut Research Laboratory (Byron, GA, USA).

Chart 1. Phenogram of blossoming bud-breaking - the end of flowering



Month	Feb	Mar			Apr					May				June				July	
Species / Day	28	8	11	15	15	20	22	25	28	2	12	20	30	4	10	21	24	11	24
Forsythia intermedia		■	■	■	■	■	■	■	■										
Mahonia aquifolium			■	■	■	■	■	■	■	■	■								
Spiraea vanhouttei							■	■	■	■	■	■	■	■					
Syringa vulgaris						■	■	■	■	■	■	■							
Albizzia julibrissin															■	■	■	■	■
Tillia sp.										■	■	■	■	■	■	■	■		
Aesculus hippocastanum									■	■	■	■	■	■	■	■			
Catalpa sp.													■	■	■	■	■	■	
Prunus cerasifera				■	■														
Chaenomeles japonica	■	■	■	■	■	■	■	■											

Table 1. Duration(days) of different vegetation phenophases

Species/Phenophases	1 November-vegetative bud-breaking	1 November-blossoming bud-breaking	Bud-breaking - flowering	Beginning-end of flowering
Forsythia intermedia	112	128	3	50
Mahonia aquifolium	107	131	8	26
Spiraea vanhouttei	135	173	3	9
Syringa vulgaris	135	171	2	28
Albizzia julibrissin	176	222	6	40
Tillia sp.	112	183	2	53
Aesculus hippocastanum	152	179	6	50
Catalpa sp.	138	211	15	39
Prunus cerasifera	117	132	7	29
Chaenomeles japonica	112	120	5	53

The number of cold hours accumulated by the 10 species from November 1 to blossoming bud-breaking (Table 2) varies between 1632 hours in *Chaenomeles*, 1680 in *F. intermedia* and *M. aquifolium*, respectively, 1704 hours in the rest of the species, although they live under the same climatic conditions. The results are in accordance with the literature that states that each species has a certain requirement regarding the cold and only after accumulating the necessary cold hours it leaves the dormant state (Cosmulescu & Birsanu, 2018). Vegetation phenophases are influenced and are triggered when a certain amount of temperature is accumulated. The timing of flowering phenophase depends on the cultivar's requirements for heat. Citadin et al. (2001) consider that the requirement for heat is another factor that determines the bud-breaking and flowering of temperate species.

Table 2. Hours of cold accumulated from November 1 to blossoming bud-breaking

Species / Phenophases	Date of blossoming bud-breaking	Days of cold	Hours of cold
Forsythia intermedia	08 March	70	1680
Mahonia aquifolium	11 March	70	1680
Spiraea vanhouttei	22 April	71	1704
Syringa vulgaris	20 April	71	1704
Albizzia julibrissin	10 June	71	1704
Tillia sp.	02 May	71	1704
Aesculus hippocastanum	28 April	71	1704
Catalpa sp.	30 May	71	1704
Prunus cerasifera	12 March	71	1704
Chaenomeles japonica	28 February	68	1632

Table 3 presents the average temperature of flowering period and the global thermal balance in analyzed species. The average temperature during the flowering period ranged from 9.69^{0}C in *Prunus* to 22.85^{0}C in *Catalpa* sp. The sum of average temperature degrees from January 1 at the beginning of flowering phenophase ranged from 153^{0}C in *Chaenomeles* to 1601^{0}C in *Alizzia*. The findings of Zverko et al. (2014) indicate that the increase of temperature has a significant influence on the earlier occurrence of spring phenological phases in the species analyzed in the Boky Nature Reserve of Slovakia (*Crataegus monogyna*, *Corrylus avellana*, *Prunus spinosa*, *Cornus mas*). Long-term systematic monitoring of phenophases offers the possibility to estimate changes in the onset or the end of phenophases, which allows to evaluating the influence of climate changes on nature. Several variables involved in spring phenology are modified in urban areas. Air temperature appears to be the main climatic factor in plant phenology (Roetzer et al., 2000; Defila & Clot, 2001; Menzel et al., 2006; Defila & Jeanneret, 2007; Luo et al., 2007). Mimet et al. (2009) found an early onset of flowering in the town, confirming the previous results from European cities (Roetzer et al., 2000) and from China (Lu et al., 2006). Mimet et al. (2009) combined experimental and observational methodology to provide a better and deeper view on climatic habitat in an urban context, and it shows that the town influences the phenology of plants by reducing daily temperature variation and by increasing minimum temperature.

Table 3. Average temperature in flowering period and global thermal balance (BTG) for flowering phenophase

Species	Beginning of flowering	End of flowering	Average t in flowering period (˚C)	BTG (˚C) for flowering phenophase
Forsythia intermedia	10 March	28 April	10.31	222
Mahonia aquifolium	18 March	12 May	11.45	301
Spiraea vanhouttei	24 April	04 June	16.81	657
Syringa vulgaris	21 April	20 May	15.03	623
Albizzia julibrissin	15 June	24 July	22.50	1601
Tillia sp.	03 May	24 June	19.51	796
Aesculus hippocastanum	03.May	21 June	19.24	796
Catalpa sp.	13 June	11 July	22.85	1556
Prunus cerasifera	15 March	15 April	9.69	259
Chaenomeles japonica	04 March	25 April	9.92	153

Table 4 shows the maximum, minimum and average temperatures over 2018-2019 in Găești area, and Table 5 shows the correlations between the temperature factor and duration of different spring phenophases. Positive correlations were calculated between the average temperature of flowering period and the number of days from November 1 to blossoming bud-breaking (r = 0.98), the average temperature in flowering period and the number of days from November 1 to vegetative bud-breaking (r = 0.74), the average temperature in the flowering period and the number of days from bud-breaking to flowering (r = 0.31), between the global thermal balance and the number of days from 1 November to blossoming bud-breaking (r = 0.97), in vegetative bud-breaking (r = 0.79), between the global thermal balance and the number of days from bud-breaking to flowering (r = 0.46), between the maximum temperature of the November-July period and the number of days from bud-breaking to flowering (r = 0.57), between the average temperature and the number of days from bud-breaking to flowering (r = 0.60). And the duration of flowering phenophase is influenced by maximum, minimum and average temperatures of November - July period (r = 0.44; r = 0.42; r = 0.44).

Table 4. Minimum, average and maximum temperature over period November 2018 - July 2019 in Găești town area

Month	Maximum temperature	Minimum temperature	Average temperature
November	8.13	2.4	5.17
December	3.07	-2.8	0.17
January	1.63	-4.43	-1.4
February	9.07	-1.18	3.86
March	16.33	2.47	9.2
April	16.6	5.83	11.23
May	22.63	11.37	16.9
June	28.97	17.9	22.87
July	28.67	16.67	22.13
Average	**15.01**	**5.36**	**10.01**

Table 5. Correlations existing between different phenophases

	No of days from November 1 - vegetative bud-breaking	No of days from November 1 – blossoming bud-breaking	No of days bud-breaking - flowering	No of days beginning – end of flowering	Hours of cold	Average t in flowering period (˚C)	BTG (˚C) for flowering phenophase
No of days from November 1–vegetative bud-breaking	1						
No of days from November 1 –blossoming bud-breaking	0.80	1					
No of days bud-breaking – flowering	0.16	0.28	1				
No of days beginning – end of flowering	-0.07	-0.02	-0.02	1			
Hours of cold	-0.07	-0.02	-0.02	1	1		
Average t in flowering period (˚C)	0.74	0.98	0.31	0.07	0.07	1	
BTG (˚C) for flowering phenophase	0.79	0.97	0.46	0.03	0.03	0.94	1
T MAX November – July	0.24	0.33	0.57	0.44	0.44	0.33	0.40
T MIN November – July	0.06	0.17	0.63	0.42	0.42	0.20	0.27
T MED November – July	0.16	0.26	0.60	0.44	0.44	0.28	0.35

CONCLUSIONS

This case study shows that temperature significantly influences the onset of spring phenological phases, their duration. The results regarding the cold hours do confirm that each species has a certain requirement regarding the cold and only after accumulating the necessary cold hours it leaves the dormant state, having in view that the 10 species analyzed, although they live under the same climatic conditions, they needed a variable number of hours of cold to trigger bud-breaking. The research will continue focused on the aspect of changes that occur in phenology of species from year to year, under the influence of variable climatic conditions from year to year in order to highlight the effect of climate changes on urban phenology.

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