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Research Article

Spring phenology of some ornamental species, as an indicator of temperature increase in the urban climate area

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Abstract

The aim of this study is to provide information on the phenology of urban spring season, of some species of ornamental trees and shrubs, in the light of climate changes occurred over the recent decades. Ten species of ornamental shrubs and trees cultivated in two areas of a town located in southwestern Romania were studied. It was found that the spring season phenology of the studied species is dependent on the climatic year, in recording differences between the number of days from November 1 and the beginning of each spring phenophase, both from one species to another and from one climatic year to another, and also from one area to another; the spring phenology starting earlier in the urban area regardless of the species and the climatic year. Higher temperatures, rising from one year to another, are speeding-up the onset and development of spring phenology, regardless of species, and the urban climate through the effect of urban heat island leads to even earlier onset of spring phenophases and shortening of the growing season, so that by phenological differences existing within the species from one climatic year to another and from one climatic zone to another, spring season phenology can be considered an indicator of temperature rise.

Keywords: climate changes; rural climate; spring season phenology; temperature; urban climate

Introduction

Phenology, the time of biological reproductive events, recurring annually, provides a critical signal of climate variability and the effects of these climate changes on plants. Research conducted in recent decades has quantified the extent to which plant phenophases respond to local changes in temperature and rainfall, being specific to both location and species. The extent to which plants are affected by changes in temperature and rainfall, their ability to adapt, will ultimately determine the potential for ecological stability (Fitchett *et al.*, 2015). Phenological observations provide an excellent mechanism to study the impact of climate changes, because climate variables are causing variations in the phenophase calendar (Zhou *et al.*, 2016; Menzel *et al.* 2006; Cosmulescu and Ionescu, 2018; Cosmulescu *et al.*, 2019, 2020). Wohlfahrt *et al.* (2019) found a significant advance of phenophases in areas with higher degrees of urbanization. Meng *et al.* (2020) stated that

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cities are ideal natural laboratories for assessing the response of plant phenology to rising temperatures. The spring phenology of plants, i.e. the beginning of seasonal cycle of plant growth, is controlled by environmental factors (e.g. temperature, rainfall and light) (Shen *et al.*, 2016; Yang *et al.*, 2020). Numerous studies have suggested that spring phenology occurs earlier, along with increasing temperature in regions with temperate climate (Piao *et al.*, 2011; Buitenwerf *et al.*, 2015; Shen and Cao, 2015). Earlier spring phenology is able to ensure a higher gross primary crop (Richardson *et al.*, 2010), but it can also have a negative influence on ecosystem services (Keenan *et al.*, 2014). As a result, studying the response and sensitivity of spring vegetation phenology is highly important in designing the future scenarios under the pressure of climate change and other environmental changes. Urbanization causes the change of natural environment (especially rural areas around cities) in many respects, including the microclimate (Matei *et al.*, 2020; Tian *et al.*, 2020). The urbanization process has the effect of increasing the local air temperature causing an urban heat island (UHI) effect, prolonging the photoperiod by introducing artificial light and turning more soil into impermeable surfaces, which eliminates rainwater infiltration and natural recharging of groundwater and the result are environmental conditions for vegetation growth, which are significantly different, between rural and urban areas, which determines the rural-urban difference of spring plant phenology (Zipper *et al.*, 2016; Parece *et al.*, 2018). The aim of this study is to provide information about the spring phenology of some species of ornamental trees and shrubs, in light of climate changes occurred over recent decades, under urban environmental conditions.

Materials and Methods

The research area was set-up in the town of Găești, located in the S-W of Dâmbovița County, Muntenia, Romania, at 44°50’ northern latitude, 25°19’ eastern longitude and 190.62 m altitude. From this area, six species of ornamental shrubs (*Forsythia intermedia; Mahonia aquifolium; Spiraea vanhouttei; Syringa vulgaris; Chaenomeles japonica, Albizia julibrissin*) and four ornamental trees (*Aesculus hippocastanum; Prunus cerasifera; Catalpa bignonioides*, *Tillia tomentosa*) were chosen for study, in two areas: the town center (Z1) and a neighbouring area (Z2), located 5 km from the town center. For the analysis of the temperature factor, the climatic data recorded by the National Meteorological Institute for Găești Meteorological Station were used. Data recorded over 50 years were processed and two time periods were used for analysis and comparison: 1970-1995 and 1995-2020. The phenophases of the vegetation season, from the start of vegetation until the end of flowering, were recorded using BBCH-scale (Table 1), used by other researchers for various plant species (Stratópoulos *et al.*, 2019; Cosmulescu and Scrieciu, 2019; Cosmulescu *et al.*, 2020), through observations on leafing and flowering over the years 2018-2019, 2019-2020 and 2020-2021 at an interval of 2-4 days, calculating the number of days from November 1 at different phenophases.

Table 1. Description of spring phenophases recorded in ornamental species based on the BBCH code

No. of phenological phase	Phenological phase	BBCH Code	Description of BBCH Code
F0	Bud bursting	09	Visible green leaves
F1	Leaf occurrence/development	19	The first visible whole leaves
F3	Elongation of stem or growth of rosette, development of shoots	39	The shoots reached 90% of final length
F5	Inflorescence occurrence	59	Separation of floral buds
F6	Flowering	60	The first flowers have opened
	Full flowering	65	At least 50% of flowers are open, the first petals fall
	End of flowering	69	The end of flowering: all petals have fallen

Results and Discussion

Regarding the analysis of temperature

The effects of climate change on seasonal activity in terrestrial ecosystems are significant and well documented. Temperature is the main factor of many plants' development processes and, in many cases, higher temperatures have been shown to accelerate plant development and lead to the earlier transition to the next ontogenetic stage (Badeck *et al.*, 2004). An analysis of the temperature parameter was made in Găești area, over two reference intervals (1970-1995 and 1995-2020). The variation of the average annual temperatures over the two analysed time intervals (1970-1995 and 1995-2020), of the annual average of the maximum and minimum temperatures in the analysed intervals for Găești area is presented in Table 2. The average temperature over the 1970-1995 interval is 10.15 °C, the lowest average temperature (9.20 °C) being recorded in 1976, and the highest (11.74 °C) in 1994. The average temperature over the period 1995-2020 was higher, respectively 11.10 °C with the lowest average temperature of the range (9.58 °C) recorded in 1997 and the highest average temperature (12.36 °C) recorded in 2014. The average annual maximum temperatures over the period 1970-1995 was 16.19 °C and over the period 1995-2020 it was 17.11 °C, while the average annual minimum temperatures were 5.19 °C over 1970-1995 and 5.83 °C over 1995-2020.

Table 2. Variation of average annual temperatures over the analysed time intervals in Găești area, South-West Romania

Descriptive statistics	Mean temperature (°C)		Maximum temperature (°C)		Minimum temperature (°C)	
Time interval	1970-1995	1995-2020	1970-1995	1995-2020	1970-1995	1995-2020
Mean	10.15	11.10	16.19	17.11	5.19	5.83
Standard deviation	0.62	0.67	0.87	0.88	0.58	0.49
Minimum	9.20	9,58	14.82	15.60	3.88	4,75
Maximum	11.74	12.36	18.13	19.09	6.58	6.55
CV%	6.11	6.04	5.37	5.14	11.23	8.43

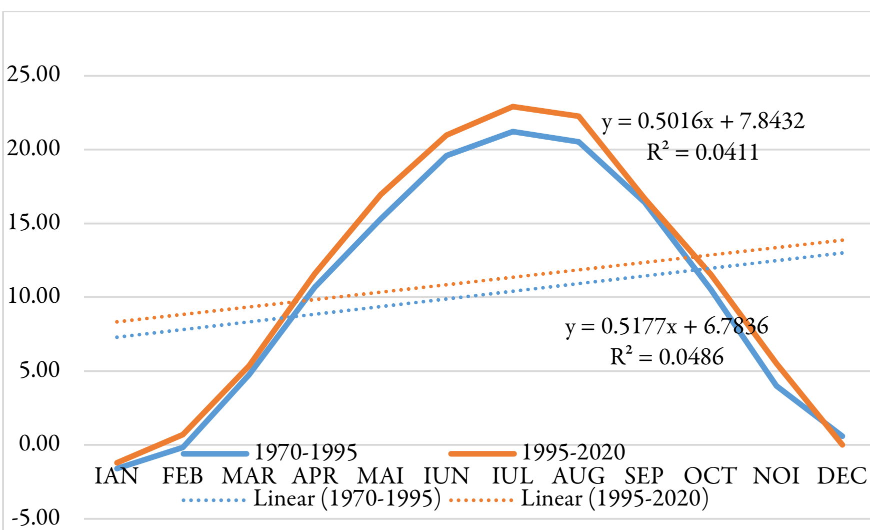

Figure 1. Evolution of monthly average temperatures over the analysed time intervals

The increase of average daily air temperature generally leads to a reduction of the growing duration and earlier bud bursting. It is considered that, among the countless environmental factors that affect the development and implicitly the phenology of plant, temperature is probably the most important in the case of bud bursting, leafing and flowering in temperate climates (Tooke and Battey, 2010; Heide, 2011; Polgar and Primack, 2011).

According to the climatic data (Figure 1) there is a tendency to increase the average monthly temperature, following the model of a linear line whose equation is $y = 0.5177x + 6.7836$ for the interval 1970-1995 and $y = 0.5177x + 6.7836$, for the period 1995-2020. Over the analysed periods, the temperature increased continuously, the trend being linear and the confidence interval was ± 0.5°C. This trend of increasing temperature is supported by many researchers (Della Marta *et al.*, 2007; Cosmulescu *et al.*, 2010 a, b; Cosmulescu *et al.*, 2015; Cosmulescu and Gruia, 2016; Cosmulescu and Ionescu, 2018).

Regarding the analysis of spring phenology by species, climatic year and area

The time of phenological stages varies depending on species, on age and on the local climate within a species. In recent years, the difference between spring vegetation phenology between towns and surrounding areas has been used to quantify the effects of urbanization on spring vegetation phenology (Li *et al.*, 2016; Zhou *et al.*, 2016; Yao *et al.*, 2017). In the present study the difference between spring phenology of urban vegetation, from two different areas, depending on the species of ornamental shrubs and depending on the climatic year are summarized in Table 3.

Table 3. The starting date of spring phenological phases depending on species of ornamental shrubs and climatic year [in days]

Species/BBCH Code	Year	09		19		39		59		60		65		69	
		Z1	Z2	Z1	Z2	Z1	Z2	Z1	Z2	Z1	Z2	Z1	Z2	Z1	Z2
Forsythia intermedia	2019	120	121	122	123	128	129	130	131	131	132	135	136	179	181
	2020	126	127	106	108	108	110	109	111	111	112	118	119	150	152
	2021	136	138	138	140	144	146	145	147	146	148	150	152	189	191
	Mean	127.33	128.67	122	123.67	126.67	128.33	128	129	129.33	130.67	134.33	135.67	172.67	174.67
	SD	8.08	8.62	16	16.01	18.03	18	18.08	18.03	17.56	18.03	16.01	16.50	20.26	20.26
Mahonia aquifolium	2019	112	114	118	120	129	131	137	139	145	147	170	172	192	194
	2020	103	105	117	119	121	123	124	125	129	130	150	154	187	189
	2021	131	133	135	137	145	148	158	160	159	161	166	168	196	198
	Mean	115.33	117.33	123.33	125.33	131.67	134	139.67	141.33	144.33	146	162	164.67	191.67	193.67
	SD	14.29	14.29	10.16	10.16	12.22	12.77	17.16	17.62	15.01	15.52	10.58	9.45	4.51	4.51
Spiraea vanhouttei	2019	146	148	171	173	175	177	177	189	179	181	196	198	216	220
	2020	132	134	135	137	140	142	153	155	167	169	172	174	217	219
	2021	130	132	133	137	150	153	179	181	187	189	195	197	215	217
	Mean	136	138	146.33	149	155	157.33	169.67	175	177.67	179.67	187.67	189.67	216	218.67
	SD	8.72	8.72	21.39	20.78	18.03	17.90	14.47	17.78	10.07	10.07	13.58	13.58	1.21	1.53
Syringa vulgaris	2019	146	148	155	157	171	173	172	175	173	176	175	178	201	203
	2020	136	138	145	147	149	151	159	161	163	165	175	177	205	207
	2021	140	142	141	143	144	146	171	172	185	187	189	191	226	228
	Mean	140.67	142.67	147	149	154.67	156.67	167.33	169.33	173.67	176	179.67	182	210.67	212.67
	SD	5.03	5.03	7.21	7.21	14.36	14.36	7.23	7.37	11.01	11	8.08	7.81	13.43	13.43
Albizia julibrissin	2019	182	184	192	195	206	209	227	229	233	235	244	246	307	309
	2020	194	196	203	205	215	217	234	236	241	243	251	253	317	320
	2021	196	199	198	199	208	210	-	-	-	-	-	-	-	-
	Mean	190.67	193	197.67	199.67	209.67	212	230.5	232.5	237	239	247.5	249.5	312	314.5
	SD	7.57	7.94	3.18	5.03	4.73	4.36	4.95	4.95	5.66	5.66	4.95	4.95	7.07	7.78
Chaenomeles japonica	2019	115	117	125	127	135	136	139	140	143	144	155	156	175	178
	2020	117	118	118	119	122	123	123	124	125	126	207	208	230	231
	2021	113	116	121	123	130	132	125	127	131	133	155	158	-	-
	Mean	115	117	121.33	123	129	130.33	129	130.33	133	134.33	172.33	174	202.5	204.5
	SD	2	1	3.51	4	6.56	6.66	8.72	8.50	9.17	9.07	30.02	29.46	38.89	37.47

From the analysis of the results on the number of days from November 1 to the beginning of different spring phenophases, differences are found both depending on the analysed shrub species and depending on the area and climate. If in *Forsytia intermedia* species the bud bursting (09) occurred at 120 days after November 1 in 2019, at 126 days in 2020 and at 136 days in 2021 in the town center (Z1), in the neighbouring area (Z2) it occurred 1-2 days later, in all three years. In *M. aquifolium*, the difference between budding (09) in Z1 zone and Z2 was two days and the number of days from November 1 to bud bursting was different depending on the climatic year, being between 103 days (2020) and 131 days (2021) in the city center and between 105 (2020) and 133 (2021) in the neighbouring area Z2. *In Spiraea vanhoutei*, the difference from one year to another between the number of days from November 1 to budding (09) is between 2 and 16 days, and from one area to another is 2 days. In *S. vulgaris* the difference from one climatic zone to another is also 2 days and the difference from one climatic year to another is between 4 and 10 days. In *A. julibrissin*, the differences from one climatic zone to another, regarding the number of days from November 1 to bud bursting (09) were 1-3 days and from one climatic year to another between 2 and 14 days. Also, in *C. japonica* there were differences of 1-3 days from one climatic zone to another, and 2-4 days from one year to another. Badeck *et al.* (2004) consider that early budding and flowering in temperate zones are an effect of climate change associated with rising temperatures, and Tian *et al.* (2020) showed that spring phenology begins earlier in urban areas than in surrounding areas due to rising city temperatures. With regard to flowering (60), there were also differences between the number of days from November 1 at the beginning of this phenophase, both depending on climatic year and species but also depending on climatic zone. In 2019, the differences from one area to another were 1 day in *C. japonica*, *F. intermedia*, 2 days in *M. aquifolium, S. vanhouttei* and 3 days in *S. vulgaris*. In 2020, the differences from one area to another were 1 day in *F. intermedia, M. aquifolium, C. japonica*, 2 days in *S. vanhouttei and S. vulgaris*. In 2021 these differences were 2 days in all species of ornamental shrubs analyzed. The results obtained are in line with those stated by Parece and Campbell (2018), namely that microclimatic variations produce intra-urban differences in vegetation phenophases. The end of flowering (69) recorded differences from one area to another, differences that were between 2 days in *F. intermedia, M. aquifolium* and *S. vulgaris* and 4 days in *S. vanhouttei*, in 2019, between 1 day in *C. japonica* and 2 days for the other species of ornamental shrubs in 2020 and 2 days in 2021 for all species analyzed. It can be seen that, regardless of species and regardless of climatic year, the beginning of each spring phenophase occurs earlier in the urban area compared to the neighbouring area. Other studies too have showed differences between rural-urban phenology: on average 15 days (Li *et al.*, 2016), 3.56 days (Gervais *et al.*, 2017). Yang *et al.* (2020) showed that the beginning of vegetation season (SOS) in urban areas occurred 7.4 days earlier than in rural areas, the end of vegetation season (EOS) in urban areas occurred 5 days later than in rural areas, and in urban areas the phenology was also influenced by the type of vegetation and the different level of urbanization. It can also be seen that, regardless of climatic zone, bud bursting (09) begins at the earliest in *C. japonica* and *M. aquifolium* and at the latest in *S. vulgaris* and *S. vanhouttei*, the beginning of flowering (60) begins at earlier in *F. intermedia* and later in *S. vanhouttei*, and flowering ends (69) earlier in *C. japonica* in 2019 and later in *A. julibrissin*, regardless of climatic year. From the appearance of inflorescence (59) to the end of flowering (69), on average, a different number of days pass depending on the area (urban climate zone - neighbouring area): 44.67 - 45.67 days in *F. intermedia*, 52 - 53 days in *M. aquifolium*, 43.34 - 44 days in *S. vulgaris*, 46.33 - 43.67 days in *S. vanhouttei*, 73.50 - 74.17 days in *C. japonica*, which shows that the duration of flowering phenophase is shorter in the urban climate zone, compared to the neighbouring zone. The spring phenology of four ornamental trees was also analyzed, depending on the climatic year and the climatic zone, and the results obtained are presented in Table 4. It can be seen that there are differences from one species to another, from one climatic year to another, and also from one climatic zone to another. In 2019 the bud bursting (09) occurred earlier in the urban area by 1 day in *P. cerasifera*, by 2 days in *A. hippocastanum* and *T. tomentosa* and by 4 days in *C. bignonioides* , in 2020 it occurred earlier by 1 day in all species of ornamental trees analyzed, and in 2021 it occurred 2 days earlier in the urban area in all species analyzed except for *P. cerasifera* in which bud bursting occurred 3 days earlier. Flowering (60) registered an earlier onset in the urban area compared to the rural one and depending on the climatic year with 2-3 days earlier in A. *hippocastanum*, 1-3 days earlier in *C. bignonioides*, 1-2 days earlier in *P. cerasifera* and 2 days earlier in *T. tomentosa*. There are also differences in flowering (60) and from one climatic year to another, depending on the species: in *A. hippocastanum* differences between 6 and 17 days in Z1, and between 6 and 18 days in Z2; in *T. tomentosa* differences between 7 and 16 days; in *C. bignonioides* between 12-20 days in Z1, and between 11 and 21 days in Z2; in *P. cerasifera* differences of 5-6 days in Z1 and 6-7 days in Z2.

Table 4. The starting date of spring phenological phases depending on ornamental tree species and climatic year [in days]

Species/BBCH Code	Year	09		19		39		59		60		65		69	
		Z1	Z2	Z1	Z2	Z1	Z2	Z1	Z2	Z1	Z2	Z1	Z2	Z1	Z2
Aesculus hippocastanum	2019	163	165	173	176	177	179	188	190	197	200	205	207	237	238
	2020	146	147	149	151	156	158	172	174	180	182	188	190	214	216
	2021	160	162	162	164	167	169	174	176	186	188	206	209	239	241
	Mean	156,33	158	161,33	163,66	166,67	168,67	178	180	187	190	199,67	202	230	232,67
	SD	9,07	9,64	12,01	12,50	10,50	10,50	8,72	8,71	8,62	9,17	10,12	10,44	13,89	13,65
Tillia tomentosa	2019	145	147	171	174	182	184	184	186	206	208	217	219	236	238
	2020	141	143	177	179	186	188	192	193	213	215	220	222	243	245
	2021	164	166	166	168	183	185	195	197	222	224	232	234	-	-
	Mean	150	152	171,33	173,67	183,67	185,67	190,33	192	213,67	215,67	223	225	239,5	241,5
	SD	12,29	12,29	5,50	5,50	2,08	2,08	5,68	5,57	8,02	8,02	7,93	7,94	4,95	4,95
Catalpa bignonioides	2019	171	175	179	182	196	200	209	212	227	230	229	231	244	246
	2020	198	199	199	200	210	211	213	214	219	220	223	224	237	238
	2021	176	178	185	187	182	184	183	185	207	209	211	214	-	-
	Mean	181,67	184	187,67	189,66	196	198,33	201,67	203,67	217,67	219,67	221	223	240,5	243
	SD	14,36	13,07	10,26	9,29	14	13,58	16,29	16,20	10,07	10,50	9,17	8,54	4,95	5,66
Prunus cerasifera	2019	120	121	121	122	132	134	138	139	139	140	150	151	166	167
	2020	115	116	120	121	131	133	139	141	144	146	151	155	161	164
	2021	122	125	137	139	145	148	142	144	145	147	156	157	-	-
	Mean	119	120.67	126	127.33	136	138.33	139.67	141.33	142.67	144.33	152.33	154.33	163.5	165.5
	SD	3.61	4.51	9.54	10.12	7.81	8.39	2.08	2.52	3.21	3.79	3.21	3.05	3.54	2.12

The number of days from November 1 at the end of flowering (69) differed from year to year by a maximum of 15 days in *A. hippocastanum*, by 7 days in *C. bignonioides*, by 7 days in *T. tomentosa* and by 5 days in *P. cerasifera*, but also from one climatic zone to another, starting 1-2 days earlier in the urban area in *A. hippocastanum* and *C. bignonioides* and with 1-3 days earlier in *P. cerasifera*. It can also be seen that, regardless of the climatic zone and the climatic year, spring phenophases begin at the earliest in *P. cerasifera* and at the latest in *C. bignonioides*, and from the appearance of the inflorescence (59) until the end of flowering (69) in average there are 52 days in *A. hippocastanum*, 49.17 days in *T. tomentosa*, 38.83 days in *C. bignonioides* and 23.83 days in *P. cerasifera*, in the urban climate zone and on average 52.67 days in *A. hippocastanum*, 49.50 days in *T. tomentosa*, 39.33 days in *C. bignonioides* and 24.17 days in *P. cerasifera*, in the neighbouring area. From bud bursting (09) to the end of flowering (69), the average flow is 73.67 days in *A. hippocastanum*, 89.5 in *T. tomentosa*, 58.83 days in *C. bignonioides* and 44.5 days in *P. cerasifera*, in the urban climate zone and on average 74.67 days in *A. hippocastanum*, 90 days in *T. tomentosa*, 59 days in *C. bignonioides* and 44.85 days in *P. cerasifera*, in the surrounding area. It is found that the number of days from bud bursting until the end of flowering is lower in the urban climate zone by at least 1 day compared to the neighbouring area.

Conclusions

The spring phenology of species of ornamental shrubs and trees is depending on the climatic year, in recording differences between the number of days from November 1 and the beginning of each spring phenophase, both from one species to another and from one climatic year to another, but also from one climatic zone to another, the spring phenology, starting earlier in the urban climate zone regardless of the species and the climatic year. Higher temperatures, rising from one year to another, are speeding-up the onset and development of spring phenology, regardless of species, and the urban climate through the effect of the island of urban heat leads to earlier onset of spring phenophases and shortening the growing season, so that due to phenological differences existing within the species from one climatic year to another and from one climatic zone to another, spring phenology can be considered an indicator of temperature increase.

Authors' Contributions

Conceptualization: SC; Investigation: ABS; Methodology: SC, ABS, MI; Writing - original draft: ABS, MI; Writing - review and editing: SC. All authors read and approved the final manuscript.

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Conflict of Interests

The authors declare that there are no conflicts of interest related to this article.

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