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The influence of urban conditions on the phenology of some ornamental species

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Abstract. The differences between the phenology of plants in rural and urban areas are the subject of research all over the world. The aim of this study is to assess the impact of urban conditions and distance from the town center on the phenology of ornamental species: *Forsythia x intermedia; Mahonia aquifolium; Spiraea x vanhouttei; Albizia julibrissin; Syringa vulgaris; Chaenomeles japonica, Aesculus hippocastanum; Prunus cerasifera; Catalpa bignonioides; Tilia tomentosa*. The study assesed the date of average onset of individual phenological phases of some ornamental species, analyzing the variability of dates when bud-bursting, flowering and fruit-setting occur, in relation to the two areas analyzed, namely the town center and a neighboring area located 5 km from the town center. In order to compare the bud-bursting (09 BBCH), the first open flowers (60 BBCH), the end of flowering (69 BBCH) and the ripe fruit (89 BBCH), the F-Test Two - Sample for Variances test was used. The results show the variation of phenological phases from one species to another, from one area to another and the influence of urban environment on phenology, on vegetation season of the analyzed species, each phenological phase starting earlier in the town center compared to the neighboring area, 5 km away.

Key words: urban climate, phenological observations, ornamental species, BBCH-scale, green spaces.

Introduction

Phenology refers to the recurrent annual cycles of plant activity, such as the appearance of leaves in spring season and their fall in autumn. These cycles are driven by climate indices (Ma & Zhou 2011) and are therefore an important indicator of annual meteorological trends (Cosmulescu et al. 2010a,b). For example, in Europe it has been found that a spring temperature rise of 1°C has been associated with a 7-day advance of the growing season (Chmielewski & Rötzer 2001). Similar results have been reported in the eastern United States, where the vegetation season begins 4-6 days earlier since the mid-1960s (White et al. 2009, Li et al. 2016), in China, where the phenology of spring has advanced on average by 2.88 days per decade in response to the rising spring temperatures (Ma & Zhou 2011), in Romania where spring phenology is strongly influenced by temperature (Cosmulescu & Ionescu 2018). Therefore, phenology is one of the most obvious and easy to measure plant responses to climate changes. The impact of global warming and urbanization on vegetation phenology has been gradually recognized and accepted as a consensus. In China, Ding et al. (2020) found that spring phenology occurs 9.6 days earlier, while the autumn phenology 6.63 days later in urban areas, compared to rural areas. These results are in line with the results of previous research conducted in China (Zhou et al. 2016, Jeong et al. 2018). Rapid urbanization is accepted as an important factor leading to ecosystem change (Li et al. 2016). In particular, the increase in impermeable surfaces (roads, buildings, parking lots, etc.) has changed the process of energy exchange between the surface of the land and the atmosphere. These changes have intensified urban temperatures and contribute to the emergence of urban heat island (Zhou et al. 2014). Consequently, it has been widely observed that, due to the effect of urban heat island (UHI), plants in urban areas usually have an earlier spring phenology and a later autumn phenology than their rural counterparts (Li et al. 2016, Zhou et al. 2016, Jeong et al. 2018). There are numerous studies around the world that show the impact of urbanization and global climate changes on the environment. Urban conditions can significantly influence plant phenology by changing the hydrological regime or local climate (Buyantuyev & Wu 2012). Research on the island of urban heat and related issues is current and important especially as the percentage of the population living in urban areas is increasing and high temperatures can affect the thermal comfort and well-being of city inhabitants (Santamouris 2014). Cities are an important area of phenological research, as ecological conditions can help assess the potential effects of climate changes on plants (Luo et al. 2007, Cosmulescu et al. 2020). The aim of this study is to assess the impact of urban conditions and distance from the town center on the phenology of some ornamental species. The study assesed the average duration of individual phenological phases of some ornamental species, analyzing the variability of the dates when bud-bursting, flowering and fruit-setting occur, in relation to the two analyzed areas, respectively the town center (Z1) and a neighboring area (Z2), located at 5 km from the town center.

Material and Methods

The research area, Găeşti town, is located in the Southwest of Dâmbovița County, Muntenia, Romania (44°43′10″N 25°19′11″E and 190.62 m altitude). Located at the contact between the Romanian Plain and the Cândeşti Piedmont, between the valleys of Argeş and Potopu rivers, it has a temperate continental climate of transition characterized by hot summers, droughts and winters with average temperatures below 0^0C. From this area, 10 species of ornamental shrubs: *Forsythia x intermedia*; *Mahonia aquifolium*; *Spiraea x vanhouttei*; *Albizia julibrissin*; *Syringa vulgaris*; *Chaenomeles japonica, Aesculus hippocastanum*; *Prunus cerasifera*; *Catalpa bignonioides*; *Tilia tomentosa*, were chosen for study, in two areas: the town center Z1; 44°71′81″23N, 25°32′03″48E) and a neighboring area (Z2; 44°72′02″26N, 25°29′96″E), located 5 km from the town center. Ten

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

No. of Phonological phase	Phenological phase	BBCH code	Description of BBCH code
F0	Bud-bursting	09	Visible green leaves
F1	Occurrence/Development of leaves	19	The first whole visible leaves
F3	Elongation of stem or growth of the rosette, development of shoots	39	Shoots attained 90% of final length
F5	Occrrence of inflorescence	59	Separation of floral buds
F6	Flowering	60	First open flowers
	Full flowering*	65	At least 50% of flowers are open, the first petals are falling
	The end of flowering*	69	The end of flowering: all the petals are fallen
F7	Fruits development	71	Ovary growth, young fruit
F8	Strengthening or ripening of fruits and seeds	89	Mature fruit

plants of each species were analysed in each location, over two years (2018-2019 and 2019-2020). The phenophases of the growing season, from the start of vegetation until the end of flowering and fruit-setting were recorded using BBCH-scale (Table 1), also used by other researchers for various plant species (Finn et al. 2007, Babálová et al. 2018, Cosmulescu & Scrieciu 2019, Cosmulescu et al. 2020), through observations on leafing, flowering and fruit-setting, at an interval of 2-4 days, by calculating the number of days from November 1 for different phenophases. In order to outline the variation of some phenological phases from one area to another and implicitly the influence of urban environment on the phenology of the analyzed species, the F-Test Two-Sample for Variance test was used.

Results

This study assesses the impact of urban environment on the spring and autumn phenology, addressing the phenology of 10 plant species analyzed in two study areas, the town center and a neighboring area. Table 2 presents the date of the average onset of spring and autumn phenological phases in 10 species, in days and depending on the distance from the center. In *Forsythia intermedia* the bud-bursting (09 BBCH) occurred at 123 days from November 1 in the town center (Z1) and one day later, respectively at 124 days from November 1 in the analyzed neighboring area (Z2). The first whole leaves (19 BBCH) became visible at 114 days from November 1 in the town center and at 115 in the surrounding area, full flowering (65 BBCH) occurred at 126 and 127 days, respectively, from November 1 and the beginning of leaf fall (93 BBCH) at 344 and 346 days respectively from November 1. In *Mahonia aquifolium* the bud-bursting (09 BBCH), the first visible green leaves (19 BBCH), shoots at 90% of the final length (39 BBCH), the appearance of inflorescence (59 BBCH), the end of flowering (69 BBCH), the young fruit (71 BBCH) and ripe fruit (89 BBCH) are phenophases that occurred two days earlier in the town center compared to the surrounding area located 5 km and full flowering (65 BBCH) occurred 3 days earlier in the town center than in the surrounding area. In *Spiraea vanhouttei* the BBCH 93 and BBCH 97 occurred 1 day earlier in the town center, BBCH 09, 19, 39, 60, 71, 89 with two days earlier, BBCH 69 with 3 days earlier in the town center, and BBCH 59 with 7 days earlier in the town center than in the neighboring area. In *Syringa vulgaris* most phenophases (09.19, 39, 60,65,69,71,89 BBCH) also started two days earlier in the town center. The appearance of inflorescence (59 BBCH) started 3 days earlier in the town center and all the leaves fell 1 day later in the neighboring area compared to the town center. In *Albizia julibrissin* most phenological phases had a 2-day earlier onset in the town center, except for 19 BBCH and 39 BBCH which occurred 3 days earlier in the town center and 89 BBCH (fruit ripening) which occurred 4 days later in the surrounding area. And in *Tillia tomentosa* the onset of phenological phases occurred earlier in the town center and later in the surrounding area. Phenophases 09, 19, 39, 60, 65, 69, 71, 93, 97 occurred two days earlier, phenophase 89 three days and stage 59 with 1 day earlier. Stages 09, 19, 39, 59, 65, 69, 89, 97 occurred 2 days earlier in the town center at *Aesculus hippocastanum*, 71 and 93 with 1 day earlier and BBCH 60 with 3 days earlier. BBCH 19 in *Aesculus hippocastanum* occurred at 154-156 days from November 1, BBCH 89 occurred at 249-251 days from November 1, BBCH 93 at 351-352 days, and BBCH 97 at 370-372 days. The high difference between the number of days until the beginning of a phase is due to the day of November 1, taken as a benchmark, in our study, for calculating the number of days until the beginning of a phenological phase. In *Catalpa* sp. 1 day later the BBCH 65, 71, 93 and 97 occurred in the surrounding area, 2 days later the BBCH 19, 39, 59, 60, 69 and the BBCH 0989 with 3 days later. In *Prunus* the BBCH 09,19, 93 AND 97 occurred 1 day earlier in the town center, the BBCH 39, 59, 60, 69 and 89 with two days earlier, the BBCH 65 with 3 days earlier and BBCH 71 with 5 days earlier. In *Chaenomeles* the BBCH 09, 39, 59, 60 and 65 occured 1 day earlier in the town center compared to the surrounding area, the BBCH 19, 69, 71, 93 and 97 occurred 2 days earlier, while fruit ripening (BBCH 89) occurred with 6 days earlier. Phenological spring season begins with *Chaenomeles* for which the bud-bursting occurred at 87 days from November 1, in the town center, and 88 days in the surrounding area, followed by *Mahonia aquifolium*, then followed by *Prunus*. Most days from November 1 at the beginning of bud-bursting passed in *Albizia julibrissin* (188 days in the town center and 190 days in the surrounding area) and in *Catalpa sp*. (184 days in the town center and 187 days in the surrounding area). In order to highlight the variation of some phenological phases from one area to another and implicitly the influence of urban environment on the phenology of the analyzed species, the F-Test Two-Sample for Variances test was used and the obtained results are presented in Table 3.

Table 2. Mean start date and standard deviation (SD) of occurrence of individual phenological phases depending on distance from the town centre [in days].

Species/BBCH code	ZONE	09	19	39	59	60	65	69	71	89	93	97
Forsythia intermedia	Z1	123*±4.24	114±11.31	118±14.14	119.5±14.84	121±14.14	126.5±12.02	164.5±20.50	-	-	344±19.79	363±24.01
	Z2	124±4.24	115.5±10.60	119.5±13.43	121±14.14	122±14.14	127.5±12.02	166.5±20.50	-	-	346±19.79	365.5±23.33
Mahonia aquifolium	Z1	107.5±6.36	117.5±0.70	125±5.65	130.5±9.19	137±11.31	160±14.14	189.5±3.53	199±2.82	216±1.41	-	-
	Z2	109.5±6.36	119.5±0.70	127±5.65	132±9.89	138.5±12.02	163±12.72	191.5±3.53	201.5±2.12	218±1.41	-	-
Spiraea vanhouttei	Z1	139±9.89	153±25.45	157.5±24.74	165±16.97	173±8.48	184±16.97	216.5±0.70	220±1.41	227.5±0.70	345±12.72	369±22.62
	Z2	141±9.89	155±25.45	159.5±16.97	172±24.04	175±8.48	186±16.97	219.5±0.70	222±1.41	229.5±0.70	346.5±13.43	370.5±23.33
Syringa vulgaris	Z1	141±7.07	150±7.07	160±15.55	165.5±9.19	168±7.07	175±0.60	203±2.82	205.5±3.53	230.5±0.70	341±18.38	368±24.04
	Z2	143±7.07	152±7.07	162±15.55	168±9.89	170.5±7.77	177.5±0.70	205±2.82	207.5±3.53	232±1.41	342±18.38	369.5±24.74
Albizia julibrissin	Z1	188±8.48	197.5±7.77	210.5±6.36	230.5±4.94	237±5.65	247.5±4.94	312±7.97	322.5±4.94	342±8.89	348.5±20.50	369±22.62
	Z2	190±8.40	200±7.07	213±5.65	232.5±4.94	239±5.63	249.5±4.94	314.5±7.77	324.5±4.94	346.5±13.43	350.5±21.92	371±21.21
Tillia tomentosa	Z1	143±2.82	174±4.24	184±2.82	188±5.65	209.5±4.94	218.5±2.12	239.5±4.94	247.5±6.36	262±1.41	348.5±21.92	365.5±27.57
	Z2	145±2.82	176.5±3.53	186±2.82	189.5±4.94	211.5±4.94	220.5±2.12	241.5±4.94	249.5±6.36	265±2.82	350.5±23.33	367.5±26.16
Aesculus hippocastanum	Z1	154.5±12.02	161±16.97	166.5±14.84	180±11.31	188.5±12.02	196.5±12.02	225.5±16.26	235±15.55	249±21.21	351.5±21.92	370.5±21.92
	Z2	156±12.72	163.5±17.67	168.5±14.84	182±11.31	191±12.72	198.5±12.02	227±15.55	236.5±14.84	251±21.21	352.5±21.92	372.5±20.50
Catalpa bignonioides	Z1	184.5±19.09	189±14.14	203±9.89	211±2.82	223±5.65	226±4.24	240.5±4.94	250±1.41	298.5±53.03	347.5±21.92	370±21.21
	Z2	187±16.97	191±12.72	205.5±7.77	213±14.14	225±7.07	227.5±4.94	242±5.65	251.5±2.12	300±53.74	348.5±21.92	371±21.21
Prunus cerasifera	Z1	117.5±3.53	120.5±0.70	131.5±0.70	138.5±0.70	141.5±3.53	150.5±0.70	163.5±3.53	186±14.14	249.5±3.53	360±1.41	393±0.60
	Z2	118.5±3.53	121.5±0.70	133.5±0.70	140±1.41	143±4.24	153±2.82	165.5±2.12	188.5±14.84	254±0.60	361.5±2.12	394.5±0.70
Chaenomeles japonica	Z1	87±42.42	121.5±4.94	128.5±9.19	131±11.31	134±12.72	181±36.76	202.5±38.89	217.5±31.81	299.5±19.50	247.5±3.53	278.5±3.53
	Z2	88±42.42	123±5.65	129.5±9.19	132±11.31	135±12.72	182±36.76	204.5±37.47	219±31.11	305.5±30.5	249.5±3.53	280±2.82

*Values represent the mean of two years (2019 şi 2020)

Table 3. Variation of the average date of occurrence of phenological phases depending on the area (F-Test Two-Sample for Variances) (in days)

	09		60		69		89	
	Z1	Z2	Z1	Z2	Z1	Z2	Z1	Z2
	Variable 1	*Variable 2*	*Variable 1*	*Variable 2*	*Variable 1*	*Variable 2*	*Variable 1*	*Variable 2*
Mean	138.5	140.2	173.25	175.05	215.7	217.75	263.8333	266.8333
Variance	1015.944	1039.122	1634.014	1663.303	1880.011	1887.236	1716.5	1794.063
Observations	10	10	10	10	10	10	9	9
df	9	9	9	9	9	9	8	8
F	0.977695		0.982391		0.996172		0.956767	
P(F<=f) one-tail	0.486873		0.489661		0.497767		0.475846	
F Critical one-tail	0.314575		0.314575		0.314575		0.290858	

Discussion

Urbanization and anthropogenic activities affect the regional climate and ecosystems. Under the increase of urbanization level and associated with the growth of urban population in the near future, the understanding of urbanization impact on terrestrial ecosystems is important for predicting future environmental changes. Jeong et al. (2019) stated that, regardless of the species, the urban environment has significant relationships with spring phenology and significantly negative relationships with autumn phenology, respectively the urban environment causes early onset of spring phenology (of up to 13 days) and delaying of leaf colouring (of up to 15 days). According to the data obtained (Table 2) it can be seen that in the urban area each phenological phase had an earlier onset in *Forsythia intermedia*. Cosmulescu et al. (2020) reported a number of 112 and 128 days, respectively, from November 1 to vegetative and floriferous bud-bursting, respectively, in Forsythia intermedia. In *Mahonia aquifolium* the spring phenophases occurred earlier in the town center (Table 2) which agrees with those specified by Prevéy et al. (2020): phenological models developed by indicates that the flowering and ripening of fruit in *Mahonia aquifolium* will advance by an average of 25 days by the middle of the 21st century, and 36 days by the end of the 21st century. Phenophases also took place 1 to 7 days earlier in *Spiraea vanhouttei* in the town center comparatively to the neighboring area. Toma & Zaharia (2014) analyzed the phenological stages in *Spiraea vanhouttei* to provide information that can be used to improve the management and maintenance of urban green spaces due to the extensive data that can be collected worldwide, especially in Europe, using the same coding method of phenological information, the BBCH codes. Also *Syringa vulgaris* behaved similarly to other species, spring phenophases were triggered earlier in the town center than in the outskirts. The same behaviour was also recorded in *Albizia julibrissin, Tillia tomentosa*, *Aesculus hippocastanum, Catalpa* sp. and *Prunus* sp. Rosemartin et al. (2015) compiled a data set from 1956 to 2014 on leafing and flowering of *Syringa vulgaris* in the United States. Babálová et al. (2018) stated that the change in the onset of phenophases in southwestern and central Slovakia, showing that in *Tilia* the flowering (60 BBCH) occurs earlier by 2.4 to 6 days depending on temperature. Weryszko-Chmielewska et al. (2019) studied the response of *Tillia* sp. from the urban and forest environment over the period 2001–2018 and showed that in 2018, when there was a significant increase in temperature above the average of the 17-year study period, flowering and the end of flowering clearly accelerated, in *Tillia* sp. The moment of phenological phases in *Tillia sp*. occurred earlier in urban areas compared to natural habitat conditions by 7-15 days in the study conducted by Kolyasnikova & Vlasov (2017). The number of days from November 1 until the onset of spring phenophases in the studied species was similar to that reported by other authors. Orzechowska-Szajda et al. (2020) showed that BBCH 19 occurred at 119-124 days, BBCH 89 occurred at 240-245 days, BBCH 93 occurred at 261-264 days and BBCH 97 at 311-317 days, depending on the distance from town center. The results obtained by Roetzer et al. (2000) in the analysis of phenology in *Prunus* and *Forsythia intermedia* indicate that, despite regional differences, in almost all cases, the species bloomed earlier in urbanized areas than in the corresponding rural areas. Early onset in urban areas was about 4 days earlier for pre-spring phenophases and about 2 days for spring phenophases. It can be seen that, regardless of the species, regardless of the phenological phase, the urban environment accelerates the beginning of phenological phases, shortening the vegetation season. The results obtained by Orzechowska-Szajda et al. (2020) based on the average time of appearance of phenological phases in *Aesculus hippocastanum* showed that the onset of vegetation was observed earlier in the town center than on its outskirts. The analysis F-Test Two-Sample for Variances (Table 3) indicates that for all four phenological phases analyzed, namely bud-bursting, first open flowers, the end of flowering and ripe fruit, the statistical value of F is higher than Fcrit, so the null hypothesis that the two variables, ie the two analyzed areas would have equal variances, it is rejected, so the variances of the two analyzed areas are unequal, which shows that there are variations of the average data of phenological phases analyzed in the 10 species depending on the study area, Z1 (town center) and Z2 (outer area). It can also be seen that the variance is higher in the bordering area, as the number of days from November 1 at the beginning of a phenological phase is higher in the bordering area compared to the town center area, where the heat island effect causes the early start of phenological phases, ie implicitly the reduction of vegetation season. The value of P is higher than the specified alpha level of 0.05, ie the probability of obtaining an F higher than a critical F is at least 0.47, which strengthens the rejection of the null hypothesis that the variances of the two variables would be equal.

Conclusions

It can be seen that the urban environment accelerates the onset of phenological phases. The order in which the analyzed species start in vegetation is maintained from one year to another, a characteristic determined by the need for cold hours, respectively heat, for each species.

References

Babálová, D., Škvareninová, J., Fazekaš, J., Vyskot, I. (2018): The dynamics of the phenological development of four woody species in south-west and central Slovakia. Sustainability 10(5): 1497.

Buyantuyev, A., Wu, J. (2012): Urbanization diversifies land surface phenology in arid environments: Interactions among vegetation, climatic variation, and land use pattern in the Phoenix metropolitan region, USA. Landscape and Urban Planning 105(1-2): 149-159.

Chmielewski, F. M., Rötzer, T. (2001): Response of tree phenology to climate change across Europe. Agricultural and Forest Meteorology 108: 101-112.

Cosmulescu, S., Baciu, A., Botu, M., Achim, G.H. (2010a): Environmental factors' influence on walnut flowering. Acta Horticulturae 861: 83-88.

Cosmulescu, S., Baciu, A., Cichi, M., Gruia, M. (2010b): The effect of climate changes on phenological phases in plum tree (*Prunus domestica* L.) in South-Western Romania. South-Western Journal of Horticulture, Biology and Environment 1(1): 9-20.

Cosmulescu, S., Ionescu, M.B. (2018): Phenological calendar in some walnut genotypes grown in Romania and its correlations with air temperature. International Journal of Biometeorology 62(11): 2007-2013.

Cosmulescu, S., Scrieciu, F. (2019): Development of vegetation stages in medlar genotypes (*Mespilus germanica* L.) coded and described according to the BBCH scale. Biharean Biologist 14: 116-119.

Cosmulescu, S., Stanciu Buican, A., Ionescu, M. (2020): The influence of temperature on phenology of ornamental woody species in urban environment. Scientific Papers Series B, Horticulture 64(1): 61-67.

Ding, H., Xu, L., Elmore, A.J., Shi, Y. (2020): Vegetation phenology influenced by rapid urbanization of the Yangtze Delta Region. Remote Sensing 12: 1783.

Finn, G.A., Straszewski, A.E., Peterson, V. (2007): A general growth stage key for describing trees and woody plants. Annals of Applied Biology 151: 127-131.

Jeong, S.J., Park, H., Ho, C.H., Kim, J. (2019): Impact of urbanization on spring and autumn phenology of deciduous trees in the Seoul Capital Area, South Korea. International Journal of Biometeorology 63(5): 627-637.

Jeong, S.J., Park, H., Ho, C.H., Kim, J. (2018): Impact of urbanization on spring and autumn phenology of deciduous trees in the Seoul Capital Area, South Korea. International Journal of Biometeorology 63: 627-637.

Kolyasnikova, N. L., Vlasov, I. N. (2017): Phenological studies of *Tilia cordata* (Mill.) in the city of Perm and its surroundings. Perm Agrarian Journal 17(1): 83-88.

Li, X., Zhou, Y., Asrar, G.R., Mao, J., Li, X., Li, W. (2016): Response of vegetation phenology to urbanization in the conterminous United States. Global Change Biology 23: 2818-2830.

Luo, Z., Sun, O.J., Ge, Q., Xu, W., Zheng, J. (2007): Phenological responses of plants to climate change in an urban environment. Ecological Research 22: 507-514.

Ma, T., Zhou, C. (2011): Climate-associated changes in spring plant phenology in China. International Journal of Biometeorology 56: 269-275.

Orzechowska-Szajda, I.D., Sobolewski, R.K., Lewandowska, J., Kowalska, P., Kalbarczyk, R. (2020): The influence of urban conditions on the phenology of *Aesculus hippocastanum* L. using the example of Wroclaw (Poland). Forests 11(12): 1261.

Prevéy, J.S., Parker, L.E., Harrington, C.A. (2020): Projected impacts of climate change on the range and phenology of three culturally-important shrub species. PloS One 15(5): e0232537.

Roetzer, T., Wittenzeller, M., Haeckel, H., Nekovar, J. (2000): Phenology in central Europe–differences and trends of spring phenophases in urban and rural areas. International Journal of Biometeorology 44(2): 60-66.

Rosemartin, A.H., Denny, E.G., Weltzin, J.F., Marsh, R.L., Wilson, B.E., Mehdipoor, H., Schwartz, M.D. (2015): Lilac and honeysuckle phenology data 1956–2014. Scientific Data 2(1): 1-8.

Santamouris, M. (2014): Cooling the cities - A review of reflective and green roof mitigation technologies to fight heat island and improve comfort in urban environments. Solar Energy 103: 682–703.

Toma, R., Zaharia, D. (2014): Phenological stages of Spiraea× vanhouttei according to BBCH code. Lucrări Ştiinţifice, Universitatea de Ştiinţe Agricole Şi Medicină Veterinară" Ion Ionescu de la Brad" Iaşi, Seria Horticultură, 57(1): 199-204.

Weryszko-Chmielewska, E., Piotrowska-Weryszko, K., Dąbrowska, A. (2019): Response of *Tilia sp*. L. to climate warming in urban conditions. Phenological and aerobiological studies. Urban Forestry & Urban Greening 43: 126369.

White, M., De Beurs, K.M., Didan, K., Inouye, D.W., Richardson, A.D., Jensen, O.P., O'Keefe, J., Zhang, G., Nemani, R.R., Van Leeuwen, W.J.D. (2009): Intercomparison, interpretation, and assessment of spring phenology in North America estimated from remote sensing for 1982–2006. Global Change Biology 15: 2335–2359.

Zhou, D., Zhao, S., Liu, S., Zhang, L. (2014): Spatiotemporal trends of terrestrial vegetation activity along the urban development intensity gradient in China's 32 major cities. Science of the Total Environment 488-489: 136-145.

Zhou, D., Zhao, S., Zhang, L., Liu, S. (2016): Remotely sensed assessment of urbanization effects on vegetation phenology in China's 32 major cities. Remote Sensing of Environment 176: 272–281.