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Trends in the Phenological Pattern of Hybrid Plane Trees (*Platanus × acerifolia* (Ait) (Wild)) in Sarajevo Ecological Conditions

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ABSTRACT

Phenological research of plant species is of great importance in the context of adaptation to climate change and changing environmental factors, especially in dynamic urban environments, such as the area of Sarajevo. This research aims to determine trends in the phenological pattern of hybrid plane trees in the area of Sarajevo so that recommendations can be made for the use of plane trees in greening urban and suburban areas since they largely depend on microclimatic conditions. In this paper, the authors researched the variability of leafing phenology of maple (*Platanus × acerifolia* (Ait) (Wild)) at six different localities in the area of Sarajevo. Observations were made in the spring of 2009, 2014, 2016, and 2020. Six phenological phases in the spring aspect of leaf development were monitored (0 - dormant buds, 1 - beginning of bud opening, 2 - open buds, 3 - leaf opening, 4 - young leaves, 5 - fully developed leaves). The results showed differences in the beginning and end of phenological phases by years and localities. Analysis of variance showed statistically significant differences in the duration of leaf development phases caused by the year of observation, locality, and the interaction of locality and year, which indicates the influence of seasonal climatic elements and micro-location conditions, as well as their interaction on the occurrence of phenophases. The results of this research can be used to recommend the use of plane trees in selected locations, with the selection of appropriate provenances and respect for phenological characteristics. Research needs to be continued and extended to leaf rejection research, which is particularly significant given the frequent heavy snowfall during the winter months in the investigated area.

Keywords: *Platanus x acerifolia*; urban greening; leafing phenology

INTRODUCTION

Due to the increased need for climate research caused by various changes, plants can be used as indicators because each climatic change reflects in their rhythm and development. Significant climate change has occurred worldwide, including a rise in temperatures (Iglesias et al. 2007).

Urban greenery has an important role in shaping cities and settlements through its aesthetic and environmental functions. Trees located in urban areas are exposed to various biotic and abiotic factors which affect their development (Vukičević 1996).

Phenology studies the functional dependence of the annual development of the plant world on climatic conditions. Changes in the continuity of flowering and foliage over the years, for some tree species, show that plants can respond to different climate changes and can adapt to different conditions. Urban spaces affect plants and their phenological processes differently. They create a special microclimate, and one of the main factors influencing the greenery in the city is the effect of heat islands. Heat islands are created due to the lack of green areas and a higher presence of asphalt surfaces. Therefore, it is important to conduct phenological research in urban parts of cities because their warmer conditions can help to assess the potential effects of climate change on plants, as stated by many authors (Luo et al. 2007, Mimet et al. 2009, Richardson et al. 2013, Orzechowska-Szajda et al. 2020). There has been a small number of previous research on plane trees in Sarajevo. Hukić et al. (2008) performed DNA analysis of plane trees in the lined walkways of the city of Sarajevo, and the expected polymorphism was not obtained.

This research aims to determine the phenological variability of plane trees (*Platanus x acerifolia*) in the area of Sarajevo. The results will be used in future planning of the use of *Platanus x acerifolia* in urban greenery to make optimal use of the different dynamics of phenological phases of leafing and thus flowering in different localities.

MATERIALS AND METHODS

Research Area

The field research of this paper included six localities in the Sarajevo area. In the very center of the city, plane trees were observed in the Mirza Delibašić and Davorin Popović Park, in At-mejdan Park (only for 2009, 2014 & 2016) and in a tree-lined avenue that stretches from Alipaša's Mosque to Ciglane. Trees were also observed in Meša Selimović Boulevard and at the beginning and the end of Velika Aleja. The locations are shown in Table 1.

At the sites of Velika Aleja - beginning and Velika Aleja - end, and in the memorial park Mirza Delibašić and Davorin Popović and At-mejdan Park, there are large, old plane trees planted during the Austro-Hungarian rule in Bosnia and Herzegovina. These trees are still of good vitality, although the plane trees in the parks are surrounded by buildings and are shaded most days. The sites in Velika Aleja are important because they are located near the protected area, Vrelo Bosne, and because of the old trees that adorn this natural oasis. The height of the trees reaches an enviable 40 m, and diameter at breast height (DBH) of most trees is more than 1 m. Trees are vital and have minor damage having in mind their age. Velika Aleja is located in the southwestern part of the Sarajevo Field, at the foot of the mountain Igman, and it is therefore exposed to low temperatures, frost, and shorter daylight.

Plane trees in Meša Selimović Boulevard and Alipašina Street are located along the roads and are constantly exposed to dust and exhaust gases. In Alipašina Street, among other factors, electrical and trolleybus installations obstruct the normal development of the canopy. The trees also have very little space for the development of the root system. The plane trees in Meša Selimović Boulevard and Alipašina Street were planted in 1997. The trees were donated from Spain. However, bad planting material (or unsuitable for the conditions of the locations) has resulted in poor vitality, and these trees are often damaged by snow (Beus 2009).

Methods

Observations of phenological phases of leafing were made in the spring periods of 2009, 2014, 2016, and 2020. First observation every year took place on February 20, when the buds are in the winter dormancy phase, to register the beginning of the bud swelling phase. The last date when all trees were in Phase 0 was taken as the beginning of the observation. The date when all the trees in an individual locality were in Phase 5 were recorded as the end of the observation. The length of the observation by years and localities is shown in Table 2.

Field data collection was performed visually. The change of six different phenological phases in individual trees was monitored: 0 - dormant buds, 1 - beginning of bud opening, 2 - open buds, 3 - opening the leaves, 4 - young leaves, and 5 - fully developed leaves (Figure 1).

Table 1. Localities and number of observed trees per locality.

No	Locality	Number of trees observed	Average height of trees (m)	Average DBH (cm)	Year of planting	Height of surrounding buildings
1.	Mirza and Davorin Park	15	30-40	>100	End of XIX ct.	Up to 10 floors
2.	Alipašina Street	30	15	25	1997	Up to 10 floors
3.	Meša Selimović Boulevard	30	15	25	1997	Up to 20 floors
4.	At-mejdan	14	30-40	>100	End of XIX ct.	Up to 10 floors
5.	Velika Aleja - beginning	30	30-40	>100	1892	No buildings
6.	Velika Aleja - end	30	30-40	>100	1892	No buildings

Table 2. Length of observation of phenological phases of plane trees’ leafing.

No	Locality	Number of observation days per year			
		2009	2014	2016	2020
1.	Mirza and Davorin Park	52	58	52	78
2.	Alipašina Street	41	77	89	69
3.	Meša Selimović Boulevard	39	61	78	61
4.	At-mejdan	50	69	83	-
5.	The beginning of Velika Aleja	42	48	74	92
6.	The end of Velika Aleja	41	42	91	80

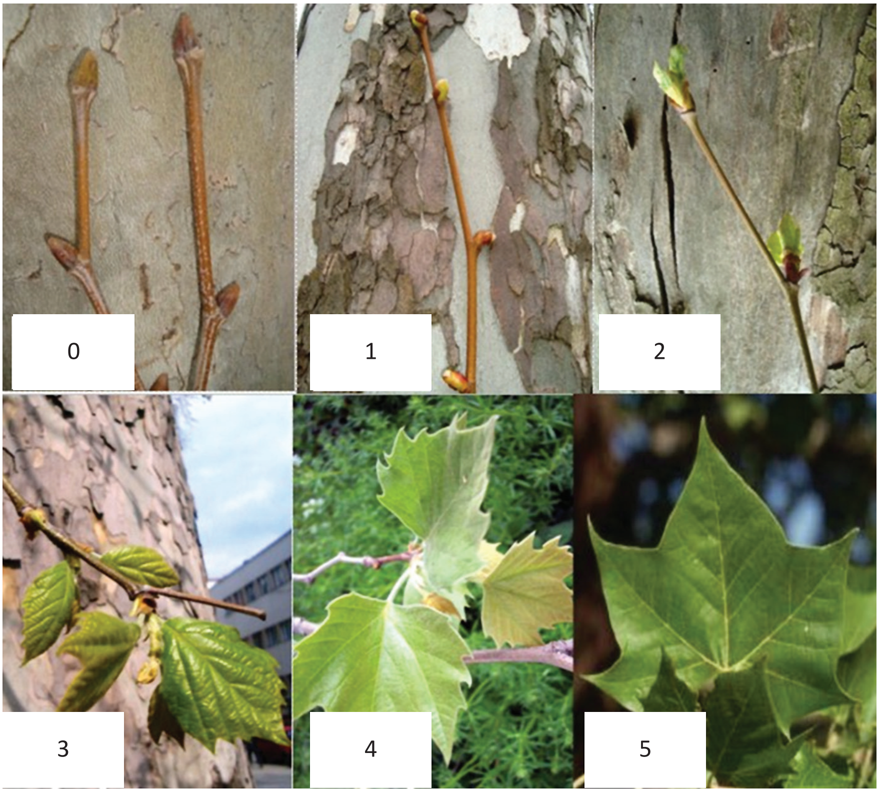

Figure 1. Observed phenological phases (Baručija 2015).

After monitoring the phenophases, the authors collected data on meteorological elements for the springs of 2009, 2014, 2016, and 2020. (Federalni hidrometeorološki zavod 2010, 2015, 2017, 2021).

Statistical Analysis

Data processing was done in Microsoft Office Excel 2016 and statistical program IBM SPSS 26.0 for Windows. Based on the collected data, the authors calculated the earliest and latest dates of the phases and the duration of phases by localities and years. Analysis of variance for the duration of phenophases was performed regarding the influence of locality, year of observation and interaction of locality and year. A multiple Duncan's test was also performed to determine the grouping of sites and years according to the common average lengths of phases.

RESULTS

Meteorological data for the months in which field research of plane tree phenology was conducted in the Sarajevo area (2nd-6th month) were collected from the report of the Federal Hydrometeorological Institute for 2009, 2014, 2016 and 2020 for Sarajevo (Federalni hidrometeorološki zavod 2010, 2015, 2017, 2021) and are shown in Table 3.

Table 3 shows that the meteorological elements in the research months were different by years. February had an average temperature ranging from 1.0ºC in 2009 to 7.8ºC in 2014. The amount of precipitation ranged from 19.9 $mm·m^{-2}$ in 2014 to 25.5 $mm·m^{-2}$ in 2020. March was the coldest on average in 2009, with an average temperature of 4.7ºC, and the warmest in 2014 with 8.1ºC. The lowest monthly amount of precipitation was recorded in 2020, 53.0 $mm·m^{-2}$, and the highest in 2016, 131.7 $mm·m^{-2}$. The average temperature in April ranged from 10.2ºC in 2014 to 12.9ºC in 2016, and the monthly amount of precipitation from 23.1 $mm·m^{-2}$ (2020) to 148.5 $mm·m^{-2}$ (2014). The average temperature in May ranged from 13.5ºC (2014) to 16.2ºC (2009), and the monthly amount of precipitation from 63.5 $mm·m^{-2}$ (2009) to 186.2 $mm·m^{-2}$ (2014). In June, average temperatures ranged from 17.5ºC (2014) to 19.5ºC (2016). The monthly amount of precipitation ranged from 92.1 $mm·m^{-2}$ (2020) to 154.5 $mm·m^{-2}$ (2009).

As stated in the materials and methods, observations were made for the first time each year on 20 February, when the buds were in the dormant phase, to register the beginning of the budding phase. The last date when all trees were in Phase 0 was recorded as the beginning of the phase. The date when all trees in an individual locality were in Phase 5 was recorded as the end of the phase. Durations of phases 0 and

Table 3. Basic meteorological data by years and months of observation.

Month	Year	Average temperature (°C)	Max temperature (°C)	Date	Min temperature (°C)	Date	Insolation (hours)	Monthly sum of precipitation (mm)	Max daily sum of precipitation (mm)	Date
II	2009	1.0	14.2	05	-11.6	23	76.5	53.7	15.9	19
	2014	7.8	19.8	16	-3.0	4	113.7	19.9	8.0	23
	2016	7.4	21.2	17	-5.7	6	80.7	87.0	17.6	26
	2020	5.0	21.6	17	-5.9	7	128.5	70.4	25.5	27
III	2009	4.7	20.0	30	-4.6	26	102.7	83.6	16.2	7 & 10
	2014	8.1	24.7	18	-0.7	12	169.5	67.3	24.1	6
	2016	6.1	24.0	31	-1.7	25	112.3	131.7	25.3	1
	2020	6.5	24.4	13	-4.8	24	141.2	53.0	17.8	4
IV	2009	12.1	23.4	1	3.5	15	181.7	61.3	17.1	4
	2014	10.2	24.3	8	-0.6	12	105.6	148.5	19.9	17
	2016	12.9	28.9	17	0.0	26	168.6	60.5	17.0	10
	2020	11.5	28.1	18	-5.0	2	239.0	23.1	7.6	22
V	2009	16.2	30.8	22	4.8	31	229.6	63.5	18.6	28
	2014	13.5	29.7	23	1.6	6	176.8	186.2	73.3	14
	2016	13.9	32.5	28	1.5	17	189.8	82.1	23.3	20
	2020	14.2	29.5	15	3.4	4	164.2	96.3	24.5	21
VI	2009	17.8	33.3	16	8.7	14	200.3	154.5	58.7	02
	2014	17.5	31.0	24	6.0	3	196.9	125.1	28.5	26
	2016	19.5	32.3	24	9.1	4	215.5	96.4	32.0	27
	2020	18.1	33.0	29	7.5	3	212.3	92.1	24.4	23

Table 4. Dates of the first and last occurrences of phenophases by years and localities.

Locality	Year	Phase 0	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5
Park Mirza Delibašić and Davorin Popović	2009	27/3-7/4	30/3-19/4	7/4-9/5	19/4-15/5	9/5-18/5	15/5-30/5
	2014	21/3-27/3	24/.-17/4	14/4-20/4	20/4-5/5	5/5-30/5	17/5-30/5
	2016	27/3-1/4	29/3-29/4	20/4-29/4	29/4-27/5	23/5-6/6	23/5-10/6
	2020	18/3-18/4	18/3-24/4	11/4-29/4	18/4-9/5	4/5-4/6	17/5-4/6
Alipašina Street	2009	27/3-2/4	30/3-13/4	2/4-23/4	7/4-4/5	15/4-6/5	4/5-30/5
	2014	4/3-15/3	7/3-14.4	2/4-20/4	17/4-17/5	26/4-20/5	5/5-30/5
	2016	6/3-20/3	15/3-12/4	30/3-4/5	2/4-9/5	29/4-3/6	17/4-10/6
	2020	18/3-11/4	18/3-18/4	11/4-24/4	18/4-4/5	24/4-25/5	13/5-25/5
Meša Selimović Boulevard	2009	27/3-5/4	30/3-13/4	5/4-19/4	13/4-25/4	19/4-6/5	4/5-30/5
	2014	21/3-27/3	24/3-14/4	2/4-17/4	14/4-11/5	25/4-20/5	14/5-30/5
	2016	17/3-28/3	24/3-13/4	28/3-26/4	2/4-13/5	20/4-3/6	3/5-10/6
	2020	18/3-5/4	18/3-5/4	11/4-24/4	11/4-24/4	18/4-24/4	13/5-17/5
At-mejdan	2009	2/4-9/4	5/4-29/4	9/4-6/5	29/4-15/5	9/5-21/5	18/5-30/5
	2014	10/2-24/3	21/3-20/4	14/4-26/4	26/4-20/5	17/5-26/5	26/5-30/5
	2016	19/3-24/3	26/3-24/4	20/4-6/5	2/5-28/5	22/5-10/6	1/6-10/6
	2020	-	-	-	-	-	-
The beginning of Velika Aleja	2009	9/4-19/4	11/4-2/5	19/4-6/5	2/5-18/5	12/5-21/5	18/5-30/5
	2014	2/4-11/4	5/4-20/4	17/4-5/5	29/4-14/5	8/5-20/5	17/5-30/5
	2016	2/4-17/4	9/4-29/4	17/4-12/5	23/4-30/5	12/5-5/6	17/5-10/5
	2020	18/3-24/4	11/4-29/4	24/4-29/4	24/4-17/5	13/5-7/6	29/5-16/6
The end of Velika Aleja	2009	11/4-19/4	13/4-25/4	19/4-6/5	4/5-15/5	12/5-21/5	21/5-30/5
	2014	8/4-14/4	11/4-29/4	23/4-5/5	29/4-14/5	8/5-20/5	17/5-30/5
	2016	5/3-17/3	12/4-2/5	26/4-22/5	6/5-23/5	17/5-3/6	23/5-10/6
	2020	18/3-24/4	11/4-29/4	24/4-29/4	29/4-17/5	13/5-4/6	25/5-4/6

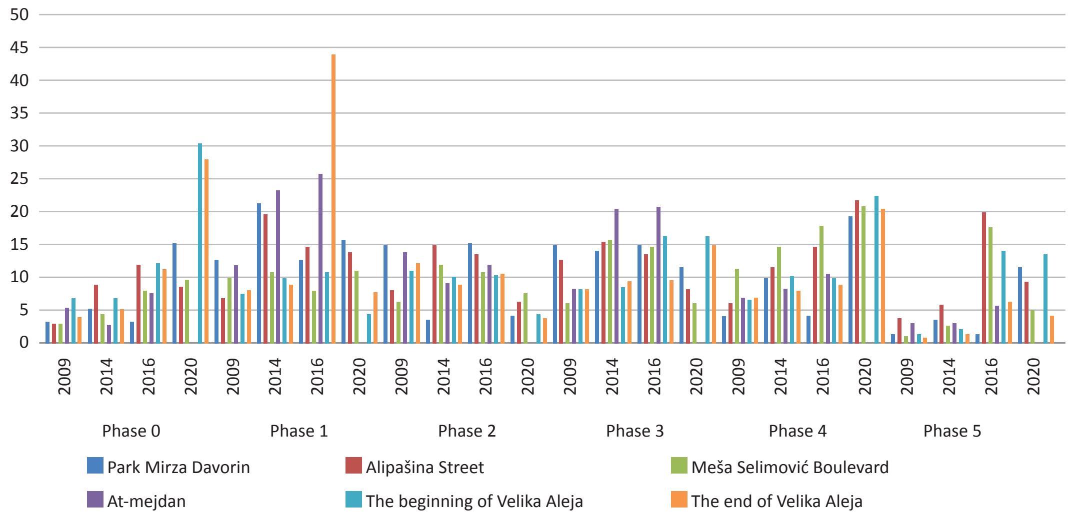

Figure 2. Duration of phases (in days) per localities and years.

5 were not complete because we did not observe autumn of the previous year and the following autumn (when trees entered Phase 0).

The length of observations by years and localities is given in Table 2. According to the duration of the observation period, which lasted 39 days at shortest and 94 days at longest, it can be concluded that the phases were of different lengths, i.e., started earlier/later depending on the location and annual, i.e., seasonal climate.

The dates of the first and last occurrences of the phases by years and localities are shown in Table 4. Phase 1 (beginning of bud opening) occurred at earliest on March 7, 2014. at the site of Alipašina Street, and at latest at the end of the Velika Aleja in 2009 (April 13).

The authors calculated the average durations of leafing phases per localities and years. Duration of phases per localities and years is shown in Figure 2.

The dormant buds phase (incomplete, from the last date when all the trees on the site were in that phase until the first appearance of Phase 1) of all observed years and localities lasted the shortest in 2016 on the site of Mirza Delibašić and Davorin Popović Park, and the longest in 2020 on the beginning of Velika Aleja. The bud swelling phase lasted the shortest in 2020 on the beginning of Velika Aleja (5 days) and the longest in 2016 on the end of Velika Aleja (44 days). The phase of open buds lasted the shortest in 2014 in the Mirza Delibašić and Davorin Popović Park (4 days) and the longest at the same location in 2016 (15 days). The phase of opening of leaves lasted the shortest in 2020 in Meša Selimović Boulevard (6 days), and the longest in 2016 in At-mejdan Park (21 days). The phase of young leaves lasted the shortest (4 days) at the Mirza and Davorin Park site in 2016 and the longest (23 days) in 2020 on the beginning of Velika Aleja. The phase of open leaves (incomplete, from the first appearance of this phase to the date when all trees on the observed site were in this phase) lasted the shortest in 2009 on the end of Velika Aleja (1 day), and the longest in 2016 in Alipašina Street.

Tests of between-subjects effects table (Table 5) for the duration of phenological phases of leafing showed statistically significant differences caused by year, locality, and interaction of the effects of the year of observation and locality (Fizr.>Ftab., Sig.<0.005).

As the results showed statistically significant differences in the duration of phases by years and localities, a multiple Duncan's test was performed for this trait to determine whether individual years/localities were grouped according to average values.

Duncan's test results by year showed no grouping for phases 0, 1, and 4. For Phase 2, 2009 and 2014, formed one group. For Phase 3, 2009 and 2020 formed one group, and for Phase 5, 2016 and 2020 formed one group.

The results of the Duncan's test for the phase duration by localities are shown in Table 6.

Duncan's test for Phase 0 (dormant buds) showed grouping into four groups. The beginning of Velika Aleja and the end of Velika Aleja formed separate groups with a longer average length, and the other four sites are divided into two groups that overlap. For Phase 1, bud swelling, Duncan's test showed grouping in five groups: Mirza and Davorin Park and the end of Velika Aleja formed one group, all other localities were not grouped. At-mejdan had the highest average value. For Phase 2, Alipašina Street and At-Mejdan were in one group, with higher average values of the phase duration, while all other localities were in the other group. For Phase 3 according to Duncan's test, At-mejdan site was in a separate group, with the highest average value, one group consisted of Meša Selimović Boulevard and the end of Velika Aleja, and the other group included the beginning of Velika Aleja, Alipašina Street and Mirza and Davorin Park. For Phase 4 Duncan's test showed grouping into 4 groups, Meša Selimović Boulevard was in a separate group with the longest average duration of the phase, while other localities were put into 3 groups. For Phase 5, Alipašina Street was in a separate group with the highest average duration, while other localities were divided into two groups.

Table 5. Tests of between-subjects effects for duration of phenological phases of leafing.

Phase	Source	Type III Sum of Squares	df	Mean Square	F	Sig.
0	Corrected Model	37110.700[a]	23	1613.509	62.714	0.000
	Intercept	51032.279	1	51032.279	1983.530	0.000
	Year of observation	14701.267	3	4900.422	190.470	0.000
	Locality	5632.288	6	938.715	36.486	0.000
	Year * Locality	9252.666	14	660.905	25.688	0.000
	Error	15179.528	590	25.728		
	Total	116604.000	614			
	Corrected Total	52290.228	613			
1	Corrected Model	43803.746[a]	23	1904.511	65.855	0.000
	Intercept	100552.565	1	100552.565	3476.973	0.000
	Year of observation	7483.963	3	2494.654	86.262	0.000
	Locality	8363.725	6	1393.954	48.201	0.000
	Year * Locality	25306.284	14	1807.592	62.504	0.000
	Error	17062.548	590	28.920		
	Total	167512.000	614			
	Corrected Total	60866.293	613			
2	Corrected Model	7391.858[a]	23	321.385	24.640	0.000
	Intercept	47077.617	1	47077.617	3609.286	0.000
	Year of observation	3194.972	3	1064.991	81.649	0.000
	Locality	318.033	6	53.005	4.064	0.001
	Year * Locality	3154.921	14	225.352	17.277	0.000
	Error	7695.647	590	13.043		
	Total	69838.000	614			
	Corrected Total	15087.505	613			
3	Corrected Model	11362.591[a]	23	494.026	23.201	0.000
	Intercept	74603.371	1	74603.371	3503.616	0.000
	Year of observation	2155.243	3	718.414	33.739	0.000
	Locality	2769.884	6	461.647	21.680	0.000
	Year * Locality	5624.909	14	401.779	18.869	0.000
	Error	12563.018	590	21.293		
	Total	110100.000	614			
	Corrected Total	23925.609	613			
4	Corrected Model	23214.267[a]	23	1009.316	50.445	0.000
	Intercept	84269.950	1	84269.950	4211.795	0.000
	Year of observation	13486.883	3	4495.628	224.691	0.000
	Locality	2853.380	6	475.563	23.769	0.000
	Year * Locality	1692.933	14	120.924	6.044	0.000
	Error	11804.771	590	20.008		
	Total	141375.000	614			
	Corrected Total	35019.037	613			
5	Corrected Model	31924.850[a]	23	1388.037	66.930	0.000
	Intercept	32550.464	1	32550.464	1569.548	0.000
	Year of observation	7232.896	3	2410.965	116.254	0.000
	Locality	11420.093	6	1903.349	91.777	0.000
	Year * Locality	5468.057	14	390.576	18.833	0.000
	Error	12235.862	590	20.739		
	Total	78369.000	614			
	Corrected Total	44160.712	613			

Table 6. Grouping of sites for the duration of phases according to the Duncan's test.

Phase	Locality	Subset				
		1	2	3	4	5
0	At-mejdan	5.36				
	Meša Selimović Boulevard	6.57	6.57			
	Park Mirza Davorin	6.85	6.85			
	Alipašina Street		8.19			
	The end of Velika Aleja			12.28		
	The beginning of Velika Aleja				14.15	
	Sig.	0.113	0.082	1.000	1.000	1.000
1	The beginning of Velika Aleja	8.17				
	Meša Selimović Boulevard		10.10			
	Alipašina Street			13.88		
	Park Mirza Davorin				15.75	
	The end of Velika Aleja				17.27	
	At-mejdan					20.50
	Sig.	1.000	0.644	1.000	0.106	1.000
2	The end of Velika Aleja		8.98			
	The beginning of Velika Aleja		9.06			
	Meša Selimović Boulevard		9.27			
	Park Mirza Davorin		9.55			
	Alipašina Street			10.85		
	At-mejdan			11.55		
	Sig.	1.000	0.412	0.269		
3	The end of Velika Aleja		10.67			
	Meša Selimović Boulevard		10.78			
	The beginning of Velika Aleja			12.42		
	Alipašina Street			12.63		
	Park Mirza Davorin			13.90		
	At-mejdan				16.82	
	Sig.	1.000	0.893	0.083	1.000	
4	At-mejdan	8.64				
	Park Mirza Davorin	9.48				
	The end of Velika Aleja		11.04			
	The beginning of Velika Aleja		12.38	12.38		
	Alipašina Street			13.67		
	Meša Selimović Boulevard				16.28	
	Sig.	0.277	0.085	0.100	1.000	1.000
5	The end of Velika Aleja	3.29				
	At-mejdan	3.95				
	Park Mirza Davorin	4.47				
	Meša Selimović Boulevard		6.74			
	The beginning of Velika Aleja		7.82			
	Alipašina Street			9.78		
	Sig.	0.163	0.176	1.000	1.000	

DISCUSSION

According to the beginnings of individual phases by years and localities (shown in Table 4), Alipašina Street and Meša Selimović Boulevard stand out with the earliest beginnings. Phase 1 started at earliest in Alipašina Street in 2014 (March 7), and Phase 2 in 2016 in Meša Selimović Boulevard (March 28). Phase 3 started at earliest in 2016 (April 2) at the locations of Alipašina Street and Meša Selimović Boulevard, and Phase 4 at Meša Selimović Boulevard (April 18). Phase 5 started at earliest in 2016 in Alipašina Street (April 17).

The latest start of Phase 1 occurred in 2009 on the end of Velika Aleja (April 13), Phase 2 at the same location in 2016 (April 26), Phase 3 on the end of Velika Aleja in 2016 (May 6), Phase 4 in 2016 at the location At-mejdan (22.5.) and Phase 5 at At-mejdan in 2016 (1.6.).

The year 2016 had the earliest beginnings of phases in some locations, and the latest beginnings of phases in other locations, which confirmed the influence of the micro-location and seasonal climate on the leafing phenology of plane trees.

Analysis of variance in this research showed statistically significant differences by localities, years, and according to the interaction of localities x years. Statistically significant differences by localities were obtained by Velić (2010), Baručija (2015), Drndo (2016).

Duncan's test showed different groupings per years and phases.

These results are important for understanding adaptation and response of plane trees to microclimatic conditions and changing seasonal climate. As a scientific discipline, phenology deals with the measurement and analysis of seasonal physiological processes and their relationship to the environment. The phenology of forest trees is important for discovering the enduring link between climate change and the physiological activity of trees (Ballian and Kajba, 2010). As phenology is temperature-dependent, accelerated climate change requires that monitoring of the impact of these changes on plants is carried out more frequently (Piao et al. 2019). As stated by Ducci et al. (2012), phenology is an important aspect of adaptation. Phenology traits are conditioned by several biological and environmental factors necessary for launching the processes, but they are also under strong genetic control (Ducci et al. 2012).

Phenological research in urban areas is important because warmer conditions of these areas can help to assess the potential effects of climate change on plants, as stated by many authors (Luo et al. 2007, Mimet et al. 2009, Richardson et al. 2013, Orzechowska-Szajda et al. 2020). Wohlfahrt et al. (2019) investigated changes in plant phenology caused by urbanization using publicly available pan-European data sets for 1981-2010 period. The authors found a significant advancement in leaf development, flowering and fruiting phenological phases, as well as higher air temperatures with higher degrees of urbanization.

Roetzer et el. (2000) researched effects of urbanization degree on flowering phenology on four species (*Galanthus nivalis*, *Forsythia* sp., *Prunus avium* and *Malus domestica*) in ten central European regions (Hamburg, Berlin, Cologne, Frankfurt, Munich, Prague, Vienna, Zurich, Basel and Chur). The results indicated that, despite regional differences, in nearly all cases, the studied species flowered earlier in urbanised areas than in the corresponding rural areas.

Jia et al. (2021) explored urbanization imprint on land surface phenology in 343 Chinese cities. They considered the urbanization intensity gradient ranging from 0% to 100%. The results showed that the growing season started on average 8.6 days earlier, and ended 1.3 days later in urban core areas (with urbanization intensity above 50%) relative to their rural counterparts (urbanization intensity lower than 1%).

Mimet et al. (2009) researched phenology of *Platanus acerifolia* and *Prunus cerasus* in relation to meteorological elements in the urban area (the city of Rennes, France). Their results showed the existence of both a climatic gradient and a developmental gradient corresponding to the type of urbanisation in the city. The town influenced plant phenology by reducing the diurnal temperature range and by increasing the minimum temperature as one approaches the town centre (Mimet et al. 2009). Increasing temperature can cause earlier occurrence of the phenological phases. It corresponds to the results of this research where all leafing phases in all observed years occurred later on the beginning and end of Velika Aleja, which are more distant from the city center, than in other localities, closer to the city center. Mimet et al. (2009) also confirmed the influence of ground cover type (plants or buildings) on the development of phenological phases (Mimet et al. 2009).

Mimet et al. (2009) found that the pre-flowering phases are best correlated with the mean of the minimum air temperature for the 15-day period before the observation, whereas flowering appears to be more dependent on the mean of the daily diurnal temperature range for the 8 days preceding the observation.

Orzechowska-Szajda et al. (2020) confirmed the extension of the period of vegetation in the city center in relation to its peripheries in research of phenology of *Aesculus hyppocastanum* carried out in 2017 in Wrocław, Poland. In the same research (Orzechowska-Szajda et al. 2020) the authors found that trees growing in road lanes entered the vegetation period later and defoliated faster, which confirms the negative impact of street conditions on the development of trees in urban space. Plane trees take a special place in green areas in Sarajevo, both because of their number and their visual dominance over many other species. During the war from 1992 to 1995, urban greenery in Sarajevo suffered heavy losses, according to Hadžidervišagić (2011). Plane trees are a very desirable species in our parks, and in planting them it is necessary to choose the best material, considering the origin of planting material and its phenological characteristics. According to Beus (2009), the introduction of inappropriate plane trees in Sarajevo (donated from Spain and France) often caused damage due to large amounts of snow.

CONCLUSIONS

When planning the greening of urban areas, special attention should be paid to the phenological characteristics of the species, hybrid, clone, and genotype and its interaction with environmental factors. Sometimes even minimal differences in some environmental factors can cause different reactions at the beginning of certain phenological phases.

One of the very important species for our urban areas is the plane tree, a tree of imposing appearance at any time of the year. Some of the trees observed in this study are over 100 years old, which implicates that the species is adapted to urban conditions.

The research results showed that the beginnings of plane tree leafing phases in Sarajevo were different both by years and by localities. It is not possible to say when the vegetation period begins. This points to the conclusion that the leafing of plane trees depends on the annual/seasonal climate, as well as on the microclimatic conditions of the locality, and certainly on the climate changes that cause differences in the seasonal climate.

Analysis of variance showed statistically significant differences caused by the years of observation (2009, 2014, 2016, and 2020), which shows that the influence of seasonal climate on plane tree leafing is significant. Analysis of variance showed statistically significant differences caused by observation sites, which proves that the influence of microclimatic conditions on the leafing of plane trees is significant.

In the observation areas, the plane tree has proven to be a species suitable for tree lines and its planting in parks. In that sense, it should continue to be used, considering the results of phenological observations and adaptation to microclimatic conditions. It is necessary to continue research on the phenology of leafing and undertake research on the phenology of flowering and leaf rejection to make recommendations for the use of this species on a particular locality.

Author Contributions

DB and MMH conceived and designed the research, DB carried out the field observations, MMH and DB processed the data and performed the statistical analysis, MMH and DB wrote the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

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