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 × acerifolia; urban greening; leafing phenology

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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 × acerifolia; urban greening; leafing phenology

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**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 greeneries have an important role in shaping cities and settlements through their 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 greeneries 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).

| 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                  |

| No | Locality                  | Number of observation days per year |
|----|---------------------------|-------------------------------------|
| 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                       |
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 1.0°C in 2009 to 7.8°C 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 4.7°C, and the warmest in 2014 with 8.1°C. 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 10.2°C in 2014 to 12.9°C in 2016, and the 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 May ranged from 13.5°C (2014) to 16.2°C (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 17.5°C (2014) to 19.5°C (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

Figure 1. Observed phenological phases (Baručija 2015).
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             | 63.5                             | 18.6                             | 28   |
|       | 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        | 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     |
| Delibašić and Davorin Popović | 2014 | 21/3-27/3      | 24/1-7/4      | 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     |
| 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     |
| Mesić 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     | 15/4-30/5     |
|                   | 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      |
| 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      |
| The beginning of Velika Aleja | 2020 | -             | -             | -             | -             | -             | -             |
| 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      |
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 (Fzr. > 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* | 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 | 25.728 | 0.000 |
|       | Total | 116604.000 | 614 |          |       |      |
|       | Corrected Total | 52290.228 | 613 |          |       |      |
| 1     | Corrected Model | 43803.746* | 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 | 28.920 | 0.000 |
|       | Total | 167512.000 | 614 |          |       |      |
|       | Corrected Total | 60866.293 | 613 |          |       |      |
| 2     | Corrected Model | 7391.858* | 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 | 13.043 | 0.000 |
|       | Total | 69838.000 | 614 |          |       |      |
|       | Corrected Total | 15087.505 | 613 |          |       |      |
| 3     | Corrected Model | 11362.591* | 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 | 21.293 | 0.000 |
|       | Total | 110100.000 | 614 |          |       |      |
|       | Corrected Total | 23925.609 | 613 |          |       |      |
| 4     | Corrected Model | 23214.267* | 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 | 20.008 | 0.000 |
|       | Total | 141375.000 | 614 |          |       |      |
|       | Corrected Total | 35019.037 | 613 |          |       |      |
| 5     | Corrected Model | 31924.850* | 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 | 20.739 | 0.000 |
|       | Total | 78369.000 | 614 |          |       |      |
|       | Corrected Total | 44160.712 | 613 |          |       |      |
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.).

**DISCUSSION**

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

| Phase | Locality subset | 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 | 0.113 | 0.082 | 1.000 | 1.000 | 1.000 |
| 1     | At-mejdan       | 20.50 |        |        |        |        |
|       | Meša Selimović Boulevard | 10.10 |        |        |        |        |
|       | Alipašina Street | 13.88 |        |        |        |        |
|       | Park Mirza Davorin | 15.75 |        |        |        |        |
|       | The end of Velika Aleja | 17.27 | 1.000 | 0.644 | 1.000 | 0.106 | 1.000 |
| 2     | At-mejdan       | 1.000 |        |        |        |        |
|       | Meša Selimović Boulevard | 9.06 |        |        |        |        |
|       | Park Mirza Davorin | 9.27 |        |        |        |        |
|       | Alipašina Street | 9.55 |        |        |        |        |
|       | The end of Velika Aleja | 10.85 | 1.000 | 0.412 | 1.000 | 2.069 |
| 3     | At-mejdan       | 1.000 |        |        |        |        |
|       | Meša Selimović Boulevard | 10.78 |        |        |        |        |
|       | Park Mirza Davorin | 12.42 |        |        |        |        |
|       | Alipašina Street | 12.63 |        |        |        |        |
|       | The beginning of Velika Aleja | 13.90 | 1.000 | 0.093 | 0.083 | 1.000 |
|       | Meša Selimović Boulevard | 16.82 | 1.000 | 0.085 | 0.083 | 1.000 |
| 4     | At-mejdan       | 8.64  |        |        |        |        |
|       | Park Mirza Davorin | 9.48 |        |        |        |        |
|       | The end of Velika Aleja | 11.04 | 1.000 | 0.093 | 0.083 | 1.000 |
|       | Meša Selimović Boulevard | 12.38 |        |        |        |        |
|       | Alipašina Street | 12.38 |        |        |        |        |
|       | The beginning of Velika Aleja | 13.67 | 1.000 | 0.093 | 0.083 | 1.000 |
|       | Meša Selimović Boulevard | 16.28 | 1.000 | 0.085 | 0.083 | 1.000 |
| 5     | At-mejdan       | 3.29  |        |        |        |        |
|       | Park Mirza Davorin | 3.95 |        |        |        |        |
|       | The end of Velika Aleja | 4.47 | 1.000 | 0.093 | 0.083 | 1.000 |
| 6     | Meša Selimović Boulevard | 7.82 |        |        |        |        |
|       | Alipašina Street | 9.78  |        |        |        |        |
|       | The beginning of Velika Aleja | 12.78 | 1.000 | 0.093 | 0.083 | 1.000 |

Sig.
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 al. (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 Wroclaw, 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
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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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The authors declare no conflict of interest.

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