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# Influence of cultivar and rootstock on phenological characteristics of plum

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**Abstract**. The influence of three clonal rootstocks (‘Pixy’, ‘Fereley’ and ‘St. Julien A’) together with seedlings of Myrobalan (control) on the phenological characteristics (flowering and harvest date) of the plum cultivars ‘Čačanska Rana’, ‘Čačanska Lepotica’ and ‘Čačanska Najbolja’ was studied in the Belgrade region (Serbia) over three years. The meteorological conditions during the study years were a source of variability in the results related to flowering time. The earliest start, full and end of flowering were recorded in the second experimental year, while the latest flowering phase occurred in the first. The rootstocks had no effect on flowering time, while the harvest date was 3–5 days later for the clonal rootstocks than for the seedling rootstock. Among the cultivars, the earliest harvest date was for the cultivar ‘Čačanska Rana’, which also required the fewest days from full bloom to harvest. The study presents the correlation matrix between the investigated indicators of phenological characteristics and air temperatures for the studied combinations of plum cultivars and rootstocks, which shows that the phenological characteristics (flowering and harvest date) are directly influenced by the meteorological conditions in the investigated years.

**Key words**: *Prunus domestica* L., cultivar, rootstock, flowering, harvest, correlation

## Introduction

The flowering period is one of the most critical phases in the annual cycle, as plum flowers are sensitive to low temperatures, especially to late-spring frosts. The generative organs of the plum are most sensitive to spring frost from full bloom until shortly after fruit set (Szabó, 2003). Flowering time is considered a quantitatively inherited trait that is influenced by the additive effect of genes (Hansche et al., 1975). However, in addition to the genetic influence, external environmental factors, also have an effect, particularly air temperature (Rodrigo & Herrero, 2002), especially in the last week of February (Liverani et al., 2010). In addition to air temperature, the progression of the different phenological phases also depends on other abiotic factors such as precipitation, relative humidity (Gradziel & Weinbaum, 1999), day length (Pudas et al., 2008), and soil water content (Szabó, 1997). The flowering time of plums is also influenced by air temperatures in winter and spring, as most European plum cultivars require a relatively high number of chilling units during winter (more than 1,000 hours) (Okie & Hancock, 2008). Another important factor for frost resistance is the differentiation stage of the buds at the time of frost, which has a direct effect on yield (Neumüller, 2011). It has been observed that plum cultivars differ in the frost resistance of their buds, even if the buds are at the same stage of development (Enache & Baciu, 2016). Cultivars with an earlier flowering period are more susceptible to late-spring frosts. Later flowering in plums can lead to higher productivity, especially in areas where late-spring frosts are common (Okie & Hancock, 2008). Flowering time is influenced by genetic and environmental factors, primarily air temperature, as cold weather lengthens flowering time, and warm weather shortens it.

Harvest date is a genotype-specific trait that is inherited quantitatively (Dirlewanger et al., 2004). Nergiz & Yildiz (1997) and Blažek & Pišteková (2009) found that the time of harvest is influenced by both genetic and environmental factors. Crisosto et al. (2007) emphasize that the time of harvest is an important factor for consumer acceptance of the fruit, as it influences fruit quality. Neumüller (2011) states that the harvest time of plums is directly related to their placement on the market and the formation of their selling price, with better prices being achieved at the beginning and end of the plum ripening season. This is supported by the fact that genotypes with very early to early or late to very late fruit ripening times are preferred.

This study aimed to determine the influence of cultivar and rootstock on the phenological characteristics of plums, and to determine the correlation between phenological parameters, which is one of the key factors for understanding the functioning of complex biological and physiological processes in the life cycle of the fruit tree.

## Materials and Methods

*Plant material*. The study was conducted in the plum orchard of the experimental station „Radmilovac" of the Faculty of Agriculture in Belgrade (Serbia). During the three years the influence of a seedling rootstock (Myrobalan as a control) and three clonal rootstocks ('Pixy', 'Fereley', and 'St. Julien A') on flowering and harvest date of three table plum cultivars ('Čačanska Rana', 'Čačanska Najbolja' and 'Čačanska Lepotica') was investigated. The orchard was planted in spring 2010. The planting distance between the rows was 4 m with different distances in the row depending on the rootstock vigour: 2.3 m for Myrobalan seedling, 2.0 m for 'Fereley' and 'St. Julien A' and 1.7 m for 'Pixy'. The training system is the spindle. The usual cultivation methods were used, including drip irrigation. Each variant (cultivar/rootstock) was represented by six trees (two replicates with three trees).

*Methods*. Flowering was recorded according to the recommendations of the International Working Group on Pollination: beginning of flowering – 10% open flowers, full flowering – 80% open flowers, end of flowering – 90% petal fall (Wertheim, 1996). The duration of flowering was determined by the number of days from the beginning to the end of flowering. The abundance of flowering was rated on a scale from 1 to 9 (1 – trees without flowers, 9 – abundant flowering). The time of maturity was taken as the date of commercial harvest.

*Statistical analysis*. The results for phenological traits (start, full, end of flowering, duration of flowering, time of harvest and number of days from full bloom to harvest) were statistically processed using Fisher's analysis of variance (ANOVA) model of a single factorial experiment, using the F-test for $R \leq 0.05$ and $R \leq 0.01$. The one-factorial analysis included the study of the individual influence of cultivar, rootstock and year, with the two remaining factors considered as replicates. The significance of the differences between the mean values was determined using the Duncan multiple range test at a significance level of 0.05. Data analysis was performed using the statistical software package IBM SPSS Statistics 20 (SPSS Inc., Chicago, IL, USA). The correlation analysis between individual phenological traits and air temperature was carried out using IBM SPSS Statistics 20 (SPSS Inc, Chicago, IL, USA).

*Agroecological conditions*. The experimental plum orchard in which the studies were carried out is located at a latitude of 44°45'N and a longitude of 20°35'E. It is characterized by hilly terrain and an average altitude of about 110 m. The area where the plum orchard is located is characterized by a continental climate, with an average annual air temperature of 10.9 °C over 53 years (1951–2003). The average air temperature during the growing season (April-October) over these 53 years was 16.7 °C (Figure 1). The average annual temperature during the study period was 12.6 °C, and the average temperature during the growing season was 17.9 °C. The average annual temperature during the study period was 1.6 °C above the long-term average, while the average temperature during the growing season was 1.2 °C above the long-term average.

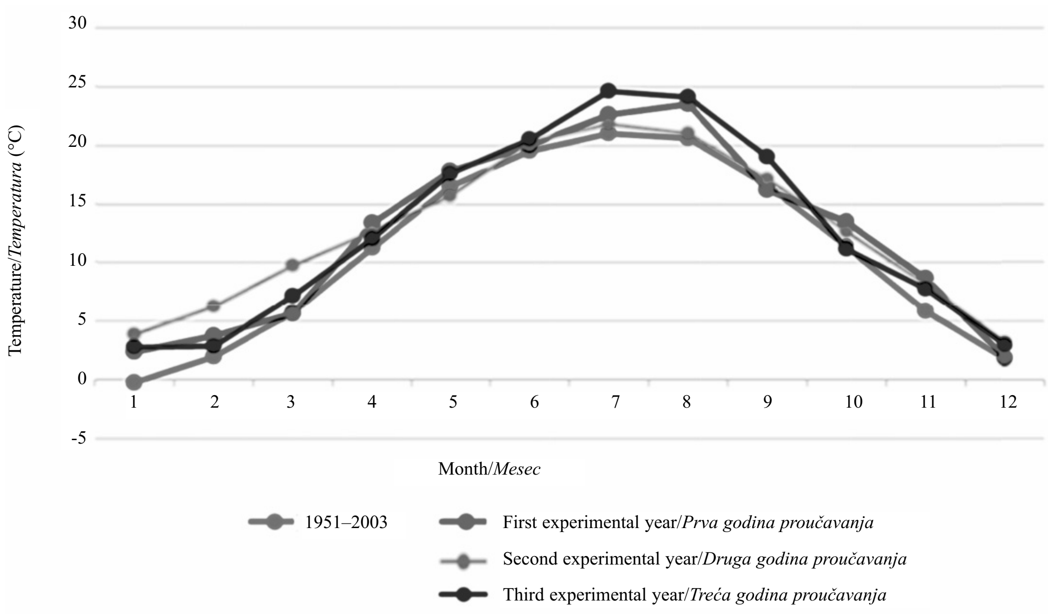


Figure 1. Average monthly air temperature, long-term average (1951–2003) and study period (first, second and third experimental year)
*Slika 1. Srednje mesečne temperature vazduha, višegodišnji prosek (1951–2003) i period proučavanja (prva, druga i treća godina proučavanja)*

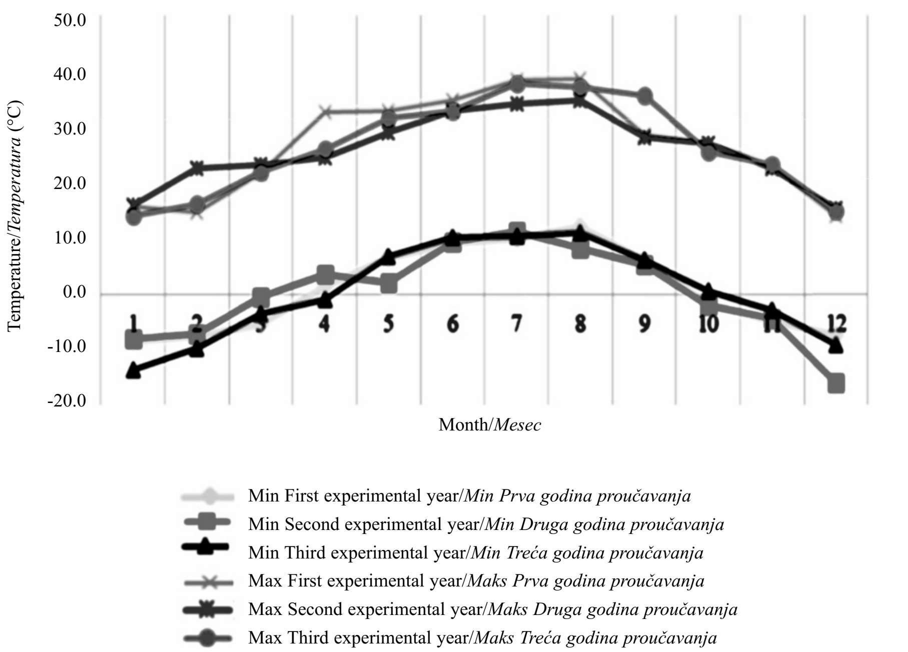


Figure 2. Absolute maximum and minimum air temperatures during the study period
*Slika 2. Apsolutne maksimalne i minimalne temperature vazduha u periodu proučavanja*

A comparison of the average annual air temperatures shows that the years included in the study were warmer than the long-term average, with first experimental year being slightly colder than second and third experimental year. The absolute minimum air temperature of -15.9 °C during the study period was measured in December of second experimental year (Figure 2). It is important to note that temperatures below -10 °C only occurred in December of second experimental year and January of third experimental year, when the plum trees were in the biological dormancy phase and were most resistant to winter frosts. However, in the study years, particularly in the first and the third, the trees were exposed to late spring frosts that occurred in March, although these temperatures did not cause any damage to the flower buds. The absolute maximum air temperature during the study period was 38.5 °C, and was measured in August of first experimental year (Figure 2). In this year, the maximum temperatures of the other summer months, namely June (34.7 °C) and July (38.2 °C), were also measured.

The average daily air temperatures during the flowering period (Figure 3) varied considerably in the individual years of the study. In the first year of study, the average daily air temperatures showed an increasing trend from the beginning to the end of the flowering period and were in the optimal range for pollination and fertilization for plums (Figure 3a). From the results shown in Figure 3b, it can be concluded that in second experimental year lower air temperatures were recorded during the flowering phase, especially from the third to the fifth day, when the average daily temperatures were below 10 °C. In third experimental year, average daily air temperatures remained stable during the first five days, showing a gradual increase, while on the sixth and seventh days, slightly lower values were recorded compared to the average value observed during the flowering period that year (Figure

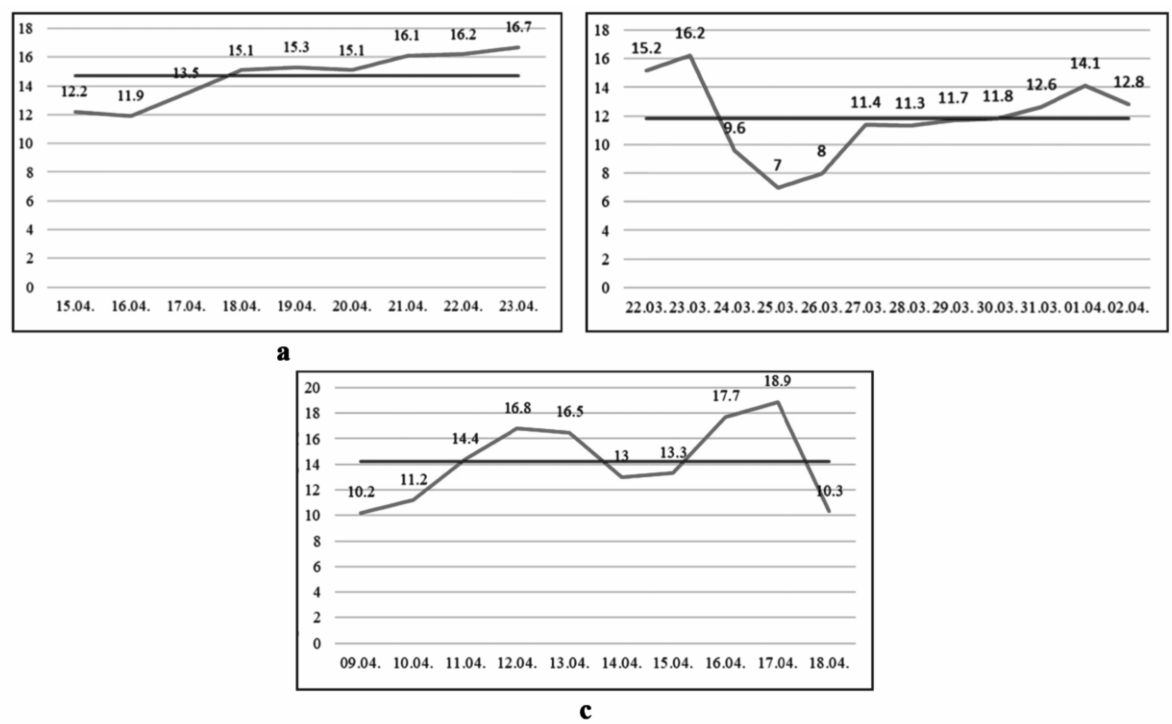


Figure 3. Dynamics (red line) of mean daily air temperatures during the flowering phase for the first (a), second (b), and third (c) year of study. The blue line in each graph represents the average value of the mean daily air temperatures during the flowering period

*Slika 3. Dinamika kretanja (crvena linija) srednjih dnevnih temperatura vazduha tokom fenofaza cvetanja za prvu (a), drugu (b) i treću (c) godinu ispitivanja. Plava linija unutar svakog pojedinačnog grafikona predstavlja prosečnu vrednost srednjih dnevnih temperatura vazduha za vreme trajanja cvetanja*

3c). The average value of mean daily air temperatures during the flowering period was 14.7 °C in the first, 11.8 °C in the second, and 14.2 °C in the third experimental year. This is of particular importance as the fluctuations in these values, as well as their differences between years, have a significant impact on the dynamics and progression of flowering.

## Results

The results of the start, full and end of flowering are shown in Table 1, with differences depending on the cultivar/rootstock combinations and the year of research.

Table 1. Phenological characteristics of plum cultivar/rootstock combinations
*Tabela 1. Fenološke osobine proučavanih kombinacija sorta/podloga šljive*

| | | Flowering/*Cvetanje* | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Beginning/*Početak* | | | | Full/*Puno* | | | | End/*Kraj* | | | |
| Factor/*Faktor* | | 1st | 2nd | 3rd | Mx | 1st | 2nd | 3rd | Mx | 1st | 2nd | 3rd | Mx |
| Interaction cultivar × rootstock/*Interakcija sorta × podloga* | | | | | | | | | | | | | |
| ‘Č. Rana’/‘St. Julien A’ | | 107† | 82 | 100 | 96 | 108 | 85 | 102 | 98 | 114 | 92 | 108 | 105 |
| ‘Č. Rana’/‘Pixy’ | | 107 | 81 | 100 | 96 | 108 | 84 | 102 | 98 | 114 | 92 | 108 | 105 |
| ‘Č. Rana’/‘Fereley’ | | 107 | 82 | 99 | 96 | 108 | 85 | 101 | 98 | 114 | 92 | 108 | 105 |
| ‘Č. Rana’/Myrobalan | | 107 | 82 | 100 | 96 | 108 | 85 | 102 | 98 | 114 | 93 | 108 | 105 |
| ‘Č. Lepotica’/‘St. Julien A’ | | 106 | 83 | 102 | 97 | 108 | 86 | 104 | 99 | 114 | 92 | 109 | 105 |
| ‘Č. Lepotica’/‘Pixy’ | | 106 | 82 | 102 | 97 | 108 | 85 | 104 | 99 | 114 | 92 | 109 | 105 |
| ‘Č. Lepotica’/‘Fereley’ | | 106 | 83 | 102 | 97 | 108 | 86 | 104 | 99 | 114 | 92 | 109 | 105 |
| ‘Č. Lepotica’/Myrobalan | | 106 | 83 | 102 | 97 | 108 | 86 | 104 | 99 | 114 | 92 | 109 | 105 |
| ‘Č. Najbolja’/‘St. Julien A’ | | 105 | 83 | 102 | 97 | 108 | 86 | 104 | 99 | 113 | 93 | 109 | 105 |
| ‘Č. Najbolja’/‘Pixy’ | | 105 | 83 | 102 | 97 | 108 | 86 | 104 | 99 | 113 | 93 | 109 | 105 |
| ‘Č. Najbolja’/‘Fereley’ | | 106 | 83 | 102 | 97 | 108 | 86 | 104 | 99 | 114 | 93 | 109 | 105 |
| ‘Č. Najbolja’/Myrobalan | | 106 | 83 | 102 | 97 | 108 | 86 | 104 | 99 | 114 | 93 | 109 | 105 |
| | ‘St. Julien A’ | 106 | 83 | 101 | 97 | 108 | 86 | 103 | 99 | 114 | 92 | 109 | 105 |
| Rootstock | ‘Pixy’ | 106 | 82 | 101 | 96 | 108 | 85 | 103 | 99 | 114 | 92 | 109 | 105 |
| *Podloga* | ‘Fereley’ | 106 | 83 | 101 | 97 | 108 | 86 | 103 | 99 | 114 | 92 | 109 | 105 |
| | Myrobalan | 106 | 83 | 101 | 97 | 108 | 86 | 103 | 99 | 114 | 93 | 109 | 105 |
| Cultivar | ‘Č. Rana’ | 107 | 82 | 100 | 96 | 108 | 85 | 102 | 98 | 114 | 92 | 109 | 105 |
| *Sorta* | ‘Č. Lepotica’ | 106 | 83 | 102 | 97 | 108 | 86 | 104 | 99 | 114 | 92 | 109 | 105 |
| | ‘Č. Najbolja’ | 106 | 83 | 102 | 97 | 108 | 86 | 104 | 99 | 114 | 93 | 109 | 105 |
| Year/*Godina* | | $106^{a*}$ | $83^{c}$ | $101^{b}$ | 97 | $108^{a}$ | $86^{c}$ | $103^{b}$ | 99 | $114^{a}$ | $92^{c}$ | $109^{b}$ | 105 |
| ANOVA | Rootstock *Podloga* | n.s. *n.z.* | | | | n.s. *n.z.* | | | | n.s. *n.z.* | | | |
| | Cultivar *Sorta* | n.s. *n.z.* | | | | n.s. *n.z.* | | | | n.s. *n.z.* | | | |
| | Year *Godina* | ** | | | | ** | | | | ** | | | |

†Number of days since January 1/ *Broj dana od 1. januara;*
*Mean values following the same letter within a column for each factor are not significantly different according to the Duncan multiple range test ($P \leq 0.05$) / *Srednje vrednosti praćene istim slovom u kolonama za svaki faktor se ne razlikuju značajno premaDuncanovom testu višestrukih intervala ($P \leq 0,05$);*
**Very significant differences for $p \leq 0.01$ / *Veoma značajne razlike za $P \leq 0,01$;* n.s. – not significant / *n.z. – nije značajno.*

The earliest flowering of all cultivar/rootstock combinations was recorded in the second year of the trial, while the latest dates were recorded in the first experimental year. The sub-phases full flowering and end of flowering occurred earliest in the second and latest in the first experimental year. It is interesting to note that the first and the third experimental years can be regarded as years with explosive flowering, in which 80% of the flowers opened within a short period of time. The analysis of variance showed that year as a factor significantly influences the variability of the timing of full bloom. The average start of flowering for all cultivar/rootstock combinations and all years was April 7, full bloom was on April 9, and the end of flowering was on April 15. The average start of flowering for the cultivar 'Čačanska Rana' was April 6, one day earlier than for the cultivars 'Čačanska Lepotica' and 'Čačanska Najbolja'. A similar dynamic was observed for the rootstocks. In the trees on the 'Pixy' rootstock flowering began on average on April 6, while in the trees on the other three rootstocks it began one day later (on April 7). In the cultivars 'Čačanska Lepotica' and 'Čačanska Najbolja', full bloom occurred on April 9, one day later than in the cultivar 'Čačanska Rana'. On the other hand, no differences were found in the average time of full bloom of the rootstocks studied. The average time of the end of flowering was the same for all tested cultivars and rootstocks (April 15). The results of the analysis of variance in relation to all partial phases of flowering show that the differences between the rootstocks and between the cultivars were not statistically significant. In contrast, the meteorological conditions in the individual study years influenced the average dates of all flowering sub-phases.

The average duration of flowering was 8.3 days, with variations of 7–11 days depending on the year (Table 2).

The cultivar 'Čačanska Lepotica' grafted on the rootstocks 'St. Julien A', 'Fereley', and Myrobalan had the shortest average flowering duration of 8 days. The cultivar 'Čačanska Rana' on the rootstocks 'Pixy', 'Fereley' and Myrobalan had the longest average duration of flowering of 8.7 days. The duration of flowering of the cultivar/rootstock combinations in the first experimental year was between 7 and 8 days. In the second year, flowering lasted between 9 and 11 days, while in the third year it was between 7 and 9 days. The shortest average flowering duration of eight days was observed in the cultivar 'Čačanska Lepotica', while it was 8.3 and 8.7 days in the cultivars 'Čačanska Najbolja' and 'Čačanska Rana', respectively. The longest average duration of flowering was observed in trees on the clonal rootstock 'Fereley' and it was 8.7 days. The other rootstocks achieved the same average values for this parameter (8.3). The second year was characterized by the longest average flowering duration (9.9), followed by the first year (7.7), while the shortest duration was observed in the last year with an average of 7.4 days. The variability of the results in terms of average flowering duration was caused by the influence of the year, i.e. meteorological conditions, while the influence of cultivar and rootstock was not statistically significant.

The ripening period of cultivar/rootstock combinations ranged from the beginning of July to the beginning of the second decade of August, which corresponds to an average period of 38 days. The earliest harvest date was recorded in the last year of the study (July 4) for the combination 'Čačanska Rana'/Myrobalan, and the latest in the first experimental year for the combination 'Čačanska Najbolja'/'St. Julien A' (August 11). The same combinations also had the earliest and latest average harvest dates for all three years of the study (Table 2). The cultivar 'Čačanska Rana' had the earliest harvest date (July 8 on average), slightly later was the cultivar 'Čačanska Lepotica' (July 26), while the latest harvest date was for the cultivar 'Čačanska Najbolja' (August 7). The seedling rootstock Myrobalan caused the fruits of the grafted cultivars to ripen three to five days earlier than those of the cultivars grafted on clonal rootstocks. On average, the harvest date was the same for all cultivars and rootstocks in the second and third year of the study (July 24), while it was one day later in 2013 (July 25). The analysis of variance showed that, in addition to the significant influence of the cultivar on the average harvest date, the rootstock and meteorological factors had no influence on this parameter in the years studied.

The shortest number of days from full bloom to harvest date was recorded in the first year for the combination 'Čačanska Rana'/'Pixy' (81 days), the longest for the combination 'Čačanska Najbolja'/'Pixy' in the second year (134 days). On average for all combinations, the value of this parameter was 99 days in

Table 2. Duration of flowering, harvest date and number of days from full bloom to harvest of plum cultivar/rootstock combinations
*Tabela 2. Trajanje cvetanja, vreme sazrevanja i broj dana od punog cvetanja do berbe proučavanih kombinacija sorta/podloga šljive*

| Factor *Faktor* | | Duration of flowering (days) *Trajanje cvetanja (dani)* | | | | Harvest date *Vreme sazrevanja* | | | | No DFBH *BDPCB* | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1st | 2nd | 3rd | Mx | 1st | 2nd | 3rd | Mx | 1st | 2nd | 3rd | Mx |
| Interaction cultivar × rootstock/*Interakcija sorta × podloga* | | | | | | | | | | | | | |
| ‘Č. Rana’/‘St. Julien A’ | | 7 | 10 | 8 | 8.3 | 193 | 189 | 189 | 190 | 85 | 104 | 87 | 92 |
| ‘Č. Rana’/‘Pixy’ | | 7 | 11 | 8 | 8.7 | 189 | 190 | 191 | 190 | 81 | 106 | 89 | 92 |
| ‘Č. Rana’/‘Fereley’ | | 7 | 10 | 9 | 8.7 | 191 | 188 | 187 | 189 | 83 | 103 | 86 | 91 |
| ‘Č. Rana’/Myrobalan | | 7 | 11 | 8 | 8.7 | 190 | 186 | 185 | 187 | 82 | 101 | 83 | 89 |
| ‘Č. Lepotica’/‘St. Julien A’ | | 8 | 9 | 7 | 8.0 | 213 | 210 | 209 | 211 | 105 | 124 | 105 | 112 |
| ‘Č. Lepotica’/‘Pixy’ | | 8 | 10 | 7 | 8.3 | 205 | 207 | 206 | 206 | 97 | 122 | 102 | 107 |
| ‘Č. Lepotica’/‘Fereley’ | | 8 | 9 | 7 | 8.0 | 211 | 208 | 207 | 209 | 103 | 122 | 103 | 110 |
| ‘Č. Lepotica’/Myrobalan | | 8 | 9 | 7 | 8.0 | 207 | 204 | 202 | 204 | 99 | 118 | 98 | 105 |
| ‘Č. Najbolja’/‘St. Julien A’ | | 8 | 10 | 7 | 8.3 | 223 | 219 | 221 | 221 | 115 | 133 | 117 | 122 |
| ‘Č. Najbolja’/‘Pixy’ | | 8 | 10 | 7 | 8.3 | 217 | 220 | 222 | 220 | 109 | 134 | 118 | 121 |
| ‘Č. Najbolja’/‘Fereley’ | | 8 | 10 | 7 | 8.3 | 219 | 217 | 220 | 219 | 111 | 131 | 116 | 120 |
| ‘Č. Najbolja’/Myrobalan | | 8 | 10 | 7 | 8.3 | 221 | 216 | 218 | 218 | 113 | 130 | 114 | 119 |
| | ‘St. Julien A’ | 7.7 | 9.7 | 7.3 | 8.3 | 210 | 206 | 206 | 207 | 102 | 120 | 103 | 108 |
| Rootstock | ‘Pixy’ | 7.7 | 10.3 | 7.3 | 8.3 | 204 | 207 | 206 | 206 | 96 | 122 | 103 | 107 |
| *Podloga* | ‘Fereley’ | 7.7 | 9.7 | 7.7 | 8.7 | 207 | 204 | 205 | 205 | 99 | 118 | 102 | 106 |
| | Myrobalan | 7.7 | 10.0 | 7.3 | 8.3 | 203 | 202 | 202 | 202 | 95 | 116 | 99 | 103 |
| | ‘Č. Rana’ | 7.0 | 10.5 | 8.3 | 8.7 | 191 | 188 | 188 | 189b | 83 | 103 | 86 | 91c |
| Cultivar | ‘Č. Lepotica’ | 8.0 | 9.3 | 7.0 | 8.0 | 209 | 207 | 206 | 207a | 101 | 121 | 102 | 108b |
| *Sorta* | ‘Č. Najbolja’ | 8.0 | 10.0 | 7.0 | 8.3 | 220 | 218 | 220 | 219a | 112 | 132 | 116 | 120a |
| Year / Godina | | $7.7^{b*}$ | $9.9^{a}$ | $7.4^{c}$ | 8.3 | 206 | 205 | 205 | 205 | $98^{b}$ | $119^{a}$ | $102^{b}$ | 106 |
| | Rootstock *Podloga* | | n.s. *n.z.* | | | | n.s. *n.z.* | | | | n.s. *n.z.* | | |
| ANOVA | Cultivar *Sorta* | | n.s. *n.z.* | | | | ** | | | | ** | | |
| | Year *Godina* | | ** | | | | n.s. *n.z.* | | | | ** | | |

*Mean values following the same letter within a column for each cultivar are not significantly different according to the Duncan multiple range test ($p \leq 0.05$) / *Srednje vrednosti praćene istim slovom u kolonama za svaki faktor se ne razlikuju značajno premaDuncanovom testu višestrukih intervala (p ≤ 0,05);*
No DFBH – number of days from full bloom to harvest / *BDPCB–broj dana od punog cvetanja do berbe;*
**Very significant differences for $p \leq 0.01$ / *Veoma značajne razlike za p ≤ 0.01*; n.s. – not significant / *n.z. – nije značajno.*

the first, 119 days in the second and 102 days in the last year of the study. On average, across cultivars and study years, the shortest number of days from full bloom to harvest date was recorded for trees grafted on Myrobalan rootstock (103 days), and the longest for trees grafted on ‘St. Julien A’ rootstock (108 days). The average number of days from full bloom to harvest date showed the following decreasing trend for all cultivars: ‘Čačanska Najbolja’ (120 days) > ‘Čačanska Lepotica’ (108 days) > ‘Čačanska Rana’ (91 days). The meteorological conditions in the study years and the cultivars had a significant influence on the variability of the number of days from full bloom to the harvest date, while the influence of the rootstock was not statistically significant.

The results presented in Table 3 show the correlations between the number of days from January 1 to full flowering, the duration of flowering, the number of days from January 1 to the harvest date, the number of days from full flowering to the harvest date, the

Table 3. Correlation matrix between the studied indicators of phenological traits and air temperature in plum cultivar/rootstock combinations
*Tabela 3. Korelacioni matriks među ispitivanim pokazateljima fenoloških osobina i temperatura vazduha između proučavanih kombinacija sorta/podloga šljive*

| Characteristics /*Osobina* | DF/*DC* | HD/*VP* | No DFFH/*BDPCB* | TFF/*TPC* | TFP/*TFC* | TFFH/*TPCB* |
|---|---|---|---|---|---|---|
| FF/PC | -0.87** | 0.11 | -0.55** | -0.99** | 0.98** | 0.90** |
| DF/DC | 1 | -0.14 | 0.34 | 0.83** | -0.82** | -0.83** |
| HD/VP | | 1 | 0.77** | 0.00 | -0.05 | 0.50** |
| NoDFFH/BDPCB | | | 1 | 0.63** | -0.67** | -0.15 |
| TFF/TPC | | | | 1 | -0.99** | -0.84** |
| TFP/TFC | | | | | 1 | 0.82** |
| TFFH/TPCB | | | | | | 1 |

FF – number of days from January 1 to full bloom; DF – duration of flowering (days); HD – number of days from January 1 to harvest; No DFFH – number of days from full bloom to harvest; TFF – average daily temperature from January 1 to full bloom; TFP – mean daily temperature during the flowering phase; TFFH – mean daily temperature from full bloom to harvest / *PC – broj dana od 1. januara do punog cvetanja; DC – trajanje cvetanja u danima; VB – broj dana od 1. januara do berbe; BDPCB – broj dana od punog cvetanja do berbe; TPC – srednja dnevna temperatura od 1. januara do punog cvetanja; TFC – srednja dnevna temperatura u toku fenofaze cvetanja; TPCB – srednja dnevna temperatura od punog cvetanja do berbe;*

*Correlation coefficients are statistically significant for R ≤ 0.05 based on t-test / *Koeficijenti korelacije su statistički značajni za R ≤ 0,05 na osnovu t-testa;*

**Correlation coefficients are statistically significant for R ≤ 0.01 based on t-test / *Koeficijenti korelacije su statistički značajni za R ≤ 0,01 na osnovu t-testa.*

average daily temperature from January 1 to full flowering, the average daily temperature during the flowering phenophase, and the average daily temperature from full flowering to harvest.

The analysis of the correlation between the number of days from January 1 to full bloom and the duration of flowering shows a highly significant negative correlation (r = -0.87**) (Table 3). The cultivar/rootstock combinations studied with a higher number of days from January 1 to full bloom (i.e. later flowering) had a shorter flowering duration. This phenomenon can be explained by the influence of air temperatures from January 1 to full bloom, which led to a later flowering date in the first and the third experimental year, but also to a shorter flowering duration. In second experimental year, the opposite was the case: the flowering phase began earlier and lasted longer. This observation is also confirmed by a very strong negative correlation between the number of days from January 1 to full bloom and the average daily temperature from January 1 to full bloom (r = -0.99**). The correlation coefficient indicates that the earlier time of full bloom in the plum cultivars and rootstocks is due to the higher average temperatures from January 1 to full bloom. The correlation coefficient between the number of days from January 1 to full bloom and the number of days from full bloom to harvest date was r = -0.55**. A lower number of days from January 1 to full bloom resulted in the studied cultivar/rootstock combinations having a higher number of days for fruit development from full bloom to harvest. This phenomenon is related to the air temperatures before and after full bloom. The results show a negative correlation between the average daily temperatures from January 1 to full bloom and the average daily temperatures from full bloom to harvest date (r = -0.84**). The number of days from January 1 to full bloom was highly significantly correlated with the average daily temperature during the flowering period (r = 0.98**), and with the average daily temperature from full bloom to the harvest date (r = 0.90**). The duration of flowering was strongly positively correlated with the average daily temperature from January 1 to full bloom (r = 0.83**), but strongly negatively correlated with the average daily temperature during the flowering time (r = -0.82**) and the average daily temperature from full bloom to harvest (r = -0.83**). Based on the results of the correlation analysis presented, a high and statistically significant correlation coefficient was found between the number of days from January 1 to harvest and the number of days from full bloom to harvest (r = 0.77**). The cultivars and rootstocks studied had longer fruit development in the years with earlier flowering. An example of this is the second year of the study, in which flowering started significantly earlier compared to the first and the third, but lasted an average of 119 days from full bloom to the harvest date. The number of days for fruit development from flowering to harvest in the first and third year of the study was 99 and 102 days, respectively. The number of days from full bloom to harvest was strongly positively correlated with the average daily temperature from January 1 to full bloom (r = 0.63**) and strongly negatively correlated with the average daily temperature during the flowering (r = -0.67**). Very high negative correlation coefficients were found between the average daily air temperature from January 1 to full bloom and the average daily temperature during flowering (r = -0.99**) as well as the average daily temperature from full bloom to harvest (r = -0.84**). In the years with higher temperatures before flowering (the second year), the temperatures during the flowering phase and fruit development were lower. On the other hand, the first and third experimental year were characterized by slightly lower temperatures from 1 January to full bloom, but significantly higher temperatures during flowering and the period from flowering to fruit harvest. Finally, a very high positive correlation coefficient (r = 0.82**) was found between the average daily temperature during flowering and the average daily temperature from full bloom to harvest.

## Discussion

In addition to the genetic basis of the cultivar, the start and duration of flowering depend on the temperature or the sum of active temperatures after the dormancy period has ended. According to Galán et al. (2001), air temperature is one of the most significant factors influencing flowering, as well as all other phenological phases. Also, Bonofiglio et al. (2008) state that the biological cycle is greatly influenced by air temperature. The variation in flowering time depending on the year is consistent with the results of other authors (Blažek & Pištěková, 2009; Koskela et al., 2010). The results of our study regarding flowering time in the first and third year were within the time interval found by various authors (Dragoyski et al., 2010; Glišić et al., 2011; Milošević & Milošević, 2011; Milatović, 2019). The influence of rootstock on the flowering time of grafted cultivars was not observed, which confirms the results of previous studies (Sosna & Licznar-Małańczuk, 2012). Our results agree with those of Milatović (2019), who reported that the average flowering duration of European plum cultivars in the Belgrade region is nine days, with annual fluctuations ranging from 7 to 11 days.

The harvest date of plums is directly related to their market placement and the formation of their selling price. An important fact is that harvesting the fruit at the appropriate moment affects the quality of the fruit, its shelf life, and transportability, as well as the overall yield. Our results on the ripening time of the cultivar 'Čačanska Lepotica' agree with those of other authors (Mratinić et al., 2006; Dragoyski et al., 2010; Glišić et al., 2011; Milošević & Milošević, 2011). Under the conditions of the Belgrade region, the fruits of the cultivar 'Čačanska Lepotica' ripened earlier, compared to the results of Blažek et al. (2004) and Blažek & Šecová (2013) for the agroecological conditions of the Czech Republic, Butac et al. (2012) for the conditions in Romania, and Minev & Stoyanova (2012) in the conditions of Bulgaria. The harvest date of the cultivar 'Čačanska Najbolja' determined in our study was slightly earlier compared to the results of other authors (Blažek et al., 2004; Mratinić et al., 2006; Dragoyski et al., 2010; Milošević & Milošević, 2011; Minev & Stoyanova, 2012). The fruits of the cultivar 'Čačanska Rana' had an earlier harvest date under the agroecological conditions of the Belgrade-Danube region than under the agroecological conditions of the Czech Republic (Blažek & Šecová, 2013), and Poland (Markuszewski & Kopytowski, 2013).

The influence of air temperature on the flowering phase is supported by the results of the correlation analysis, which revealed a highly significant negative correlation between the time of full bloom and the duration of flowering (r = -0.87**). In the years with an earlier time of full bloom, the flowering phase lasted longer, which was particularly characteristic of the second year of the study, in which flowering lasted the longest (9.9 days on average). In contrast, in the first and the third experimental year, when flowering occurred later, the flowering duration was two and three days shorter respectively compared to second experimental year. The analysis of the flowering time and the average daily air temperatures before flowering in the study years shows that higher average temperatures from January 1 to flowering in the second experimental year (6.8 °C) led to an earlier flowering time in that season. Conversely, lower average air temperatures from January 1 to full bloom in 2013 and 2015 (5.0 °C and 5.3 °C, respectively) led to later flowering in these years by 22 and 17 days, respectively. This is confirmed by the correlation coefficient between the time of full bloom and the average daily temperatures from January 1 to flowering, which was negative and highly significant (r = -0.99**). The correlation between the time of full bloom and the average daily air temperatures during the flowering period showed a highly significant dependence between these two parameters (r = 0.98**). Compared to the second year, the flowering date was significantly later in the first and third years of the study, and higher average daily air temperatures were also measured during the flowering period in these years.

In addition, a very high negative correlation coefficient (r = -0.82**) was found between the duration of flowering and the average daily temperature during the entire flowering phase. Higher average daily air temperatures during the flowering period in the first (15.2 °C) and third (14.4 °C) experimental year led to a shorter flowering duration of the plum (7.7 and 7.4 days, respectively). In the second year, on the other hand, more days were required from the start of flowering to the end of flowering (10 days) as the average daily air temperatures were lower during this period (11.4 °C). The influence of air temperatures on flowering duration in the years under investigation is clearly shown by the reciprocal positive correlation between flowering duration and air temperatures from January 1 to the time of full bloom (r = 0.83**). The years with a shorter flowering duration (first and third experimental year) were also characterized by lower air temperatures before flowering. In addition to flowering, air temperatures have a significant influence on the phenological phases of fruit growth and development, leading to fruit ripening. It is important to note that all three phases of fruit development are longer in colder weather and shorter in warmer weather. This is confirmed by the statistically significant correlation coefficient (r = 0.50**) between the harvest date and the average daily temperature from full bloom to harvest. In our research, higher temperatures in the first and third year of the study (19.7 °C and 19.4 °C, respectively) led to faster growth and development of the fruit, and thus to an earlier harvest. In contrast, the average temperature in the second experimental year was lower (17.1 °C), meaning that more days were required for the fruit to reach physiological ripeness. All this underlines the fact that meteorological conditions, especially air temperatures, are one of the most important factors that control and determine the course of flowering and ripening of plums (Florea et al., 2020). Due to climate change, in particular an earlier flowering period, the adaptation of fruit crops in temperate zones will be jeopardized in the future (Drkenda et al., 2018).

## Conclusion

Phenological phases such as flowering and ripening were influenced by the genotype of the cultivar, as well as by the agro-ecological and growing conditions. The rootstock had no influence on the flowering time of the grafted plum varieties. The only factor that caused significant differences in flowering time was the year. The meteorological conditions, especially the air temperature, had a significant influence on the dynamics of the flowering phase. The influence of rootstock and meteorological factors on the ripening time of the studied varieties was not significant, while the differences in ripening time between the cultivars were significant.

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## Uticaj sorte i podloge na fenološke karakteristike šljive

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## Rezime

U radu je prikazan uticaj tri vegetativne podloge (Piksi, Ferlej i Julijanka A) i jedne generativne podloge (sejanac džanarika kao kontrola) na fenološke osobine (cvetanje i vreme zrenja) sorti šljive Čačanska rana, Čačanska lepotica i Čačanska najbolja u uslovima Beograda (Srbija) tokom tri godine. Meteorološki uslovi tokom godina istraživanja bili su izvor varijabilnosti u rezultatima koji se odnose na vreme cvetanja. Najraniji datum početka, punog i kraja cvetanja zabeležen je u drugoj godini proučavanja, dok je najkasnija faza cvetanja bila u prvoj godini proučavanja. Podloge nisu imale uticaj na vreme cvetanja, dok je datum zrenja na vegetativnim podlogama bio za 3–5 dana kasnije u odnosu na sejanac džanarike. Među sortama, najraniji datum berbe bio je kod sorte Čačanska rana, kojoj je bio potreban i najmanji broj dana od punog cvetanja do berbe. U radu je prikazan korelacioni matriks među ispitivanih pokazatelja fenoloških osobina i temperatura vazduha za proučavane kombinacije sorta/podloga šljive, koji pokazuje da su fenološke osobine (cvetanje i vreme zrenja) bili pod direktnim uticajem meteoroloških faktora u godinama proučavanja.

**Ključne reči**: *Prunus domestica* L., sorta, podloga, cvetanje, berba, korelacija