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CHANGES IN PHENOLOGY OF SERBIAN PLUM VARIETIES UNDER AGROECOLOGICAL CONDITIONS OF THE CENTRAL BLAKAN MOUNTAIN REGION IN BULGARIA

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Abstract

For the period 2019-2022, the phenological manifestations were studied of the Serbian plum cultivars such as 'Čačanska rana', 'Čačanska najbolja', 'Čačanska lepotica', 'Čačanska rodna', and 'Valjevka' and their response to climatic factors such as temperature, rainfall, relative air humidity in RIMSA-Troyan. The trees are grown on light gray forest soil, under non-irrigated conditions, with tillage between the inter-row spacing. The phenophases were studied, such as the beginning of flowering, end of flowering, and fruit ripening periods. The earliest flowering began in 2019 for 'Čačanska rodna' cultivar (28.03.), and the latest flowering began on 6.04.2019 for 'Kyustendilska plum'. In the following years, spring temperatures delayed the vegetation onset and the beginning of flowering was around 07.04 for 'Čačanska lepotica', followed by 'Čačanska rodna' (10.04.) and 'Čačanska najbolja' (12.04). The latest end of flowering was reported on 7-8 May 2022 ('Valjevka' and 'Kyustendilska plum'). For the entire study period, the phase from flowering to harvest maturity was shortened. To obtain favorable conditions for growth and fruit-bearing in the Central Balkan Mountain region, the introduced Serbian cultivars require changes in cultivation technology and adaptation to changes in the global climate.

Key words*: climatic factors, phenology, plum cultivars.*

INTRODUCTION

Prunus domestica L. is one of the most frequently grown fruit growing species in Bulgaria because of its high ecological adaptation and the various directions for the use of the fruits. In 2022, plums and cherry plums had the largest share of the entire fruit production, followed by cherries and apples, with a relative share of 25%, 24%, and 21% respectively (https://www.mzh.government.bg/bg/statistika-i-analizi/izsledvane-rastenievadstvo/danni/).

'Stanley' variety is widely grown in orchards and, according to Agrostatistics Department, it occupied 73.4% of orchards in Bulgaria in 2019.

According to FAOSTAT (2022), Serbia ranks among the largest producers of plums in the world, taking third place after China and Romania, according to the production in 2022 (488,593 tons). As the development of the market is focused on the quality of fresh plum fruits, in recent years there has been a growing demand for fruits of larger size and good quality for fresh consumption (Tomić, 2022).

There is a need to expand the assortment and introduce plum varieties tolerant to *Plum pox virus,* with good economic qualities and different ripening periods, suitable both for fresh consumption and processing.

The monovarietal structure consisting of the 'Stanley' variety can be changed by introducing new plum genetic resources and creating new varieties that meet the latest requirements of producers and consumers (Bozhkova, 2013). Successful plum production requires well-adapted varieties to the specific growing conditions of the production area. Due to the interaction between the environment and the genotype, it is very important to evaluate in advance the agro-ecological conditions of the area and the pomological characteristics of the variety.

The leading place of autochthonous varieties in the structure of varieties is decreasing. It is slowly being taken by varieties with combined characteristics, such as 'Cačanska lepotica' and 'Čačanska rodna', as well as 'Stanley', which, despite its numerous shortcomings, is one of the

leading varieties in Serbian plantations (Tomić et al., 2019).

'Čačanska lepotica', 'Čačanska rodna', 'Čačanska najbolja', 'Valjevka', were introduced at the Research Institute for Fruit Growing of Pitesti in Romania (Butac, 2021). In 2018-2020, flowering and ripening periods, yield (kg/tree^{-1}), growth vigor, and susceptibility to *Plum pox virus* (PPV) were studied. For the Pitesti region, the flowering of the investigated cultivars took place in the first half of April, and the average ripening period varied from the beginning of July ('Boranka') to the end of August ('Mildora' and 'Čačanska Rodna'). 'Čačanska Lepotica', 'Čačanska Najbolja', 'Mildora', and 'Valerija' are reported as high-yielding varieties (over 15 kg tree^{-1} in the 5th year after planting). Most of the introduced Serbian varieties showed very good results in Romanian climatic conditions, but the most common was 'Čačanska Lepotica'.

Szabó & Nyéki, (1996) studied 63 European plum varieties on 6 sites of different specifics between 1982 and 1989. It was found that the development and duration of flowering were mainly influenced by air temperature. An average daily temperature below 10°C results in a stigma viability period of 3 to 5 days versus 1 to 2 days when it is above 13°C. Anthers open slowly below 14°C and rapidly above 20°C. Plum varieties are divided into 3 groups according to the duration of flowering: short (less than 8 days), medium (8 to 11 days) and long (more than 11 days). According to the period of flowering, 5 groups were formed: early, medium-early, medium, medium-late, and late. The flowering periods of varieties in the same group or adjacent groups overlap to a large extent.

Phenological changes are one of the most striking manifestations of global climate warming. The extent to which plants are affected by changes in temperature and rainfall, their inherent adaptive capacity determines their production potential, the ecological stability of ecosystems, and food security (Cosmulescu, 2023)

In general, it is observed that the main response to climate change is expressed in the length of the vegetation period, the earlier onset of spring phenophases, and the delay of autumn ones. The impact of long-term climate change on cherry and apple development was identified as differences in flowering period and compared in ten regions of Central Europe. Early flowering was found in all regions for the period 1951-1995 (Roetzer et al., 2000). When investigating the impact of environmental factors on the phenology of fruit orchard species, decisions can be made regarding the location of varieties in different growing areas, depending on local environmental conditions (Cosmulescu et al., 2008). The analysis of the species response to the climate shows a linear dependence (correlations) of the phenophases with the early spring climatic conditions. A warming trend was also found, especially for November and January (Cosmulescu, 2023).

The duration of the flowering period is a characteristic that is influenced by climatic and genetic factors. The impact of the meteorological factor manifests itself in different years, thus causing in the same variety a different duration of time between the beginning and end of flowering. In general, the earlier flowering develops, the shorter its duration (Cosmulescu et al., 2010).

Chmielewski et al. 2003 showed that a 1°C increase in average air temperature between February and April caused an early start of vegetation and flowering of fruit trees by about 5 days.

The objective of the present study is to show a phenological calendar for 2019-2022 and the behavior of Serbian varieties to the changes in the climatic conditions of the Central Balkan Mountain region in Bulgaria.

MATERIALS AND METHODS

The study was conducted in the period 2019-2022 on the territory of RIMSA in Troyan (42°53′N 24°43′E, altitude 420 m). The plum varieties, such as 'Čačanska rana', 'Čačanska najbolja', 'Čačanska lepotica', 'Čačanska rodna', 'Valjevka', 'Stanley', 'Kyustendilska' plum were studied.

The trees are grafted on a cherry plum rootstock, in a period of full fruit bearing. They are grown on light gray forest soil, under non-irrigated conditions, with tillage between the inter-row spacing, at a planting scheme of 5 x 4 m.

The phenological manifestations were studied by monitoring the climatic factors such as

temperature, rainfall, and relative air humidity, based on data from a stationary meteorological station on the territory of RIMSA.

Flowering phenophase was studied by observing and recording the flowering onset (10% open flowers), full bloom (80% open flowers), and end of flowering (90% petal fall) and determined according to Wertheim (1996). The period of physiological maturity is determined based on the number of days from full flowering to harvest.

The tree yield (kg) was analyzed. The standard error section was added as a statistical data processing, and regression equations were derived, using Analysis Tools Microsoft Excel.

RESULTS AND DISCUSSIONS

Climate

Average daily temperatures at the beginning of March were extremely low in 2022 (0.5°C). It was higher in 2019 (8.0°C) and 2020 (8.9°C). For each subsequent year in 2021 (3.6°C) and in 2022 it became lower (0.5°C) (Table 1). In 2019 and 2020, the average monthly temperatures was about 6.8-7.8°C, but in 2021 it was 3.3-3.9°C, and in 2022 it was from 0.5°C at the beginning of the month to 8.7°C at the end. April for the first 2 years was cooler, and in the second ten-day period temperatures reached 8-11°C, but in 2021 it gradually increase from 6.3 to 7.3 °C and at the end of April it reached 11.3°C, which did not repeat in 2022. Then high temperatures were observed at the beginning of April (11.1°C), with a decrease to 7.2°C in the middle of the month and warming to 13.5°C at the end of April (Table 1).

In 2022, the average monthly temperature in March was 3.2 (°C), and in February was 3.8 (°C). This difference completely determines the changes that affected the phenological development in 2022. The cooler temperature in March (from 8.03 to 13.03, and on 19.03 and 20.03 with negative daily mean values) delayed the flowering processes.

The smallest amounts of rainfall were reported in May (28.8 mm) and July (35.0 mm). The total amount of rainfall for the 2022 vegetation was 361.6 mm (Figure 1). For comparison, the vegetation amount of rainfall in 2021 was 285.4 mm, as this was the lowest recorded vegetation rainfall amount for the last twenty years.

In 2020 and 2021, there was evenly distributed rainfall for each ten days of the spring months. It was about 10 mm in 2020, and about 20 mm in 2021. In 2022, at the beginning of March with 0.5°C, there were 15.4 mm, at the end of the month there was no rainfall, and in April the total amount was 50 mm.

All these factors have an impact on the phenophases of plum varieties in the conditions of the Troyan region.

Table 1. Climatic factors for 10-day periods in March and April

	March			April		
2019	**1-10**	**10-20**	**21-31**	**1-10**	**10-20**	**21-30**
Relative humidity (%)	61.0	69.0	62.0	68.0	79.0	70.0
Rainfall (mm)	1.6	14.3	0.6	50.4	45.1	11.4
Temperature (°C)	8.0	7.9	6.8	9.8	8.1	12.0
2020						
Relative humidity (%)	72.9	69.2	77.6	70.7	66.4	69.0
Rainfall (mm)	39.0	5.6	8.8	10.6	9.2	4.6
Temperature (°C)	8.9	7.2	5.3	5.9	11.3	11.1
2021						
Relative humidity (%)	69.1	83.1	75.2	72.7	75.1	73.3
Rainfall (mm)	5.1	20.0	22.6	26.0	20.6	10.4
Temperature (°C)	3.6	3.3	3.9	6.3	7.3	11.3
2022						
Relative humidity (%)	82.5	68.4	56.5	66.3	60.1	76.6
Rainfall (mm)	15.4	7.0	0.0	45.8	40.4	9.6
Temperature (°C)	0.5	-0.1	8.7	11.1	7.2	13.5

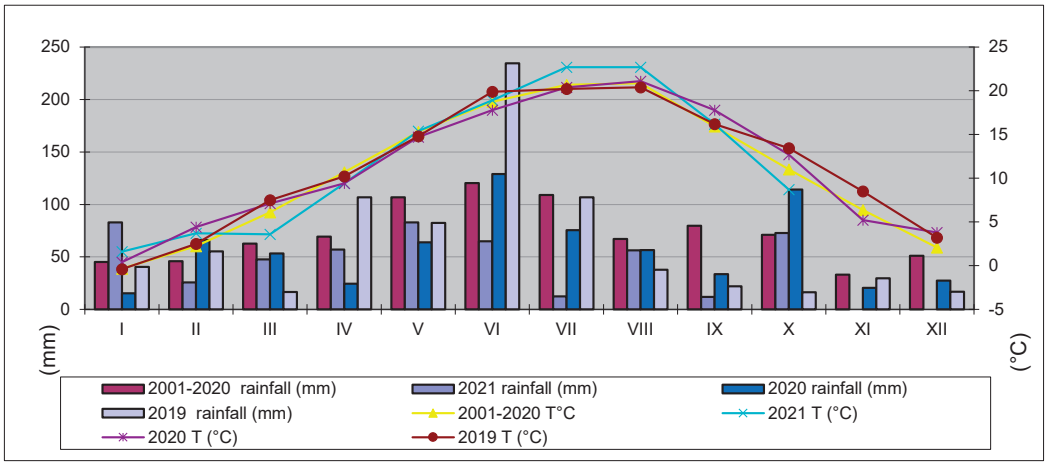

Figure 1. Average monthly temperatures and total rainfall amounts (2019-2022) and 30-year base period (1988-2017)

Changes in climatic factors are in the direction of global warming. In the period January - May, the changes in the course of temperatures and during the phases vegetation onset were provoked, but then the development of the plant stopped and the flowering phenophase was delayed.

The earliest flowering began in 2019, as the average temperatures of 10-12°C in the first ten days of April (Table 1) caused the beginning of flowering. The earliest flowering began in 2019 for 'Čačanska rodna' variety (28.03.) on the 88th day, followed by 'Čačanska lepotica' on the 89th day, as the latest flowering began for 'Kyustendilska plum' on 6.04.2019 (96th day) (Figure 2).

In the following two years, the spring temperatures in the third ten days of March and the first ten days of April were below 6°C, which delayed the beginning of flowering compared to 2019. In 2020, the beginning was reported on 07.04 for 'Čačanska lepotica' (98th day), followed by 'Čačanska rodna' (100th day) and 'Čačanska rana' (101th day).

In 2021, the beginning of flowering was delayed by the low temperatures (from 4 to 11°C), but flowering started even later in 2022 because in March there were negative temperature values and abundant rainfall amount (40-45 mm). A favorable period for the beginning of flowering was the last ten days of April when temperatures permanently exceeded 10°C (Table 1).

In general, for the period of the study, the trend of a gradual delay of the beginning of flowering is outlined. 'Čačanska lepotica', which is the earliest flowering variety, began flowering on the 89th calendar day in 2019, in the following years on the 98th; 105th; and 115th, the difference from the first to the last year is 17 days. The 'Stanley' variety began its flowering phase on the 94th day in 2019, respectively 102nd day (2020); 104th day (2021), and 115th day (2022), with a delay of 21 days.

The duration of the full bloom phase (80% open flowers) was from 10 to 18 days in 2019 and 2021, as it was shorter in 2020 and 2022 (10 to 15 days). Milatovic et al. (2018) determined that the average duration of flowering for all varieties was from 7.8 days in 2015 to 11.5 days in 2016, as the most abundant flowering was reported for the 'Valerija' variety (as well as for the control 'Čačanska lepotica').

The moment of overlapping of full blossoming of the 7 varieties in the present study is 6 to 10 days, in all years, which gives us reason to recommend using them in the same plantation, to favor cross-pollination.

The latest end of the flowering period was reported on 7-8 May 2022 ('Valjevka' and 'Kyustendilska plum' varieties).

The annual delay of the onset of flowering reduces the risks of late spring frosts in the area.

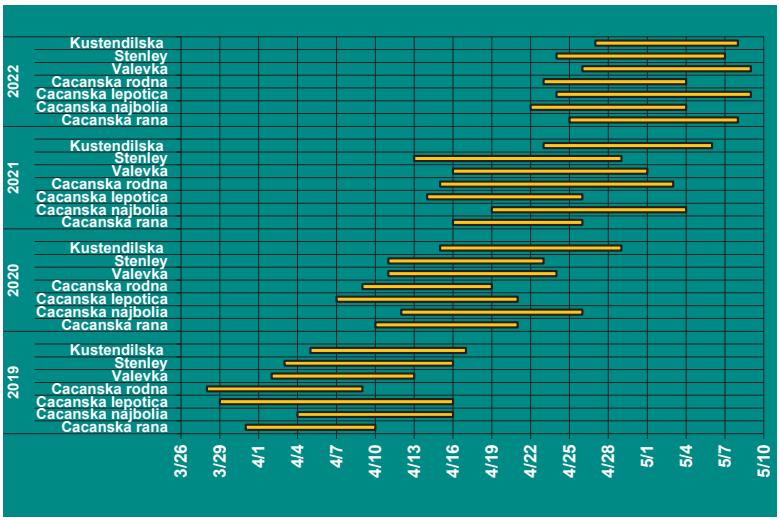

Figure 2. Flowering phenology of plum varieties

The sequence of the ripening period is the same, as a genetic trait of the varieties, but the annual global warming of the climate accelerates the onset of the ripening period.

'Čačanska rana' variety ripened first on July 15/20, followed by 'Čačanska lepotica' (August 5/6/10) in each subsequent year (Figure 3).

In 2019, the earliest ripening process was observed on the 199th day for 'Čačanska rana', and in 2020 on the 197th day. In the next 2 years, it was delayed and the variety ripened on the 201st day (2021) and the 203rd day (2022).

'Čačanska lepotica', in the first and second years, reached harvest maturity on the 217th/219th day, and in the following 2 years on the 222nd day. This indicates an approach to the ripening deadline and a shortening of the phenophase period from flowering to ripening over the years due to climate change, to higher summer temperatures and more severe droughts in the summer months, during the period of fruit ripening.

The latest ripening variety is the 'Kyustendilska plum'. An extremely significant shortening of the period of harvest maturity was observed. Except for the second year, its fruits ripened on 13.09 in 2019 (256th day), on 12.09. 2021 (255th day) and on 8.09.2022 (251st day) (Figure 3).

Because of the drought in late summer and autumn, trees do not normally stock up with nutrients for the period of forced dormancy, and accordingly, in each subsequent year, harvesting will require higher agrotechnical care and technological security, such as tillage, feeding, and irrigation.

Premature fruit ripening is a factor in alternation in fruit bearing. High autumn temperature and lack of rainfall (Figure1) slowed down and almost stopped the outflow of nutrients, plant storage was weaker and led to exhaustion, and the risk of frost in winter was a prerequisite for the alternation in fruit-bearing, since the differentiation of fruit buds (15.08-15.09) could not flow in the right direction.

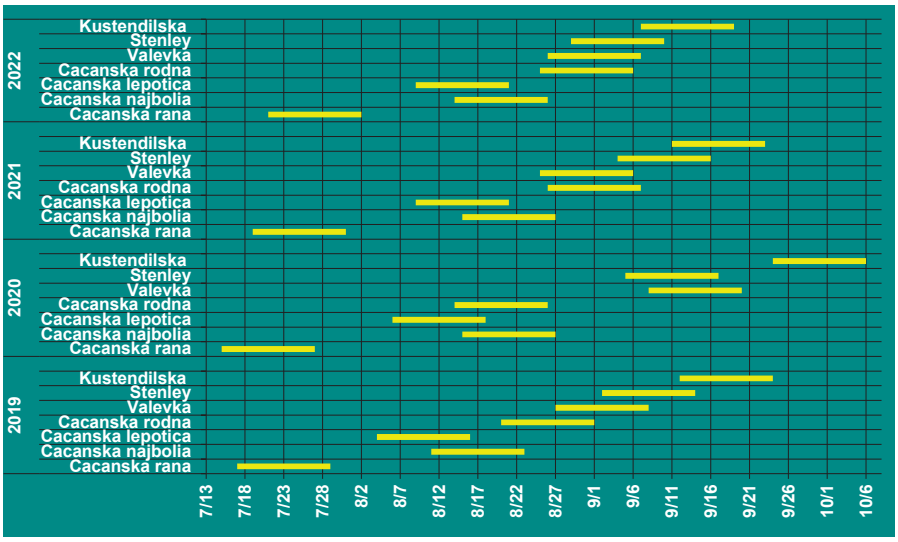

Figure 3. Ripening period of plum varieties

The measures that can compensate for these negatives to respond to the physiology of the tree are watering, and nutrient supply (more often with smaller doses of fertilizers), but this requires changes in cultivation technologies in mountain fruit growing. In the previous practice, irrigation was not applied, but in order to ensure fruit production with regular and high yields of quality fruit, it will be necessary. And on the other hand, changes in market requirements will also require an intensification of production technologies.

The difference between years with the earliest and latest fruit ripening according to Milatovic et al. (2018), varies from 7 to 15 days. The flowering and ripening periods of plum varieties in the Belgrade region is earlier compared to the Czech Republic, Central Bulgaria, and Northern Montenegro. These differences can be explained by the different environmental conditions between the studied regions.

Yields are directly dependent on the normal course of the phenological phases of the plants and the appropriate climatic conditions for fruit size and ripening (Figure 1 annual climate). In 2019, yields varied from 20 to 40 kg, according to the genetic capabilities of the varieties. In 2020, Serbian varieties showed significantly higher yields, compared to the previous year, whereas Stanley and 'Kyustendilska plum' gave lower yields (Figure 4).

In the extremely dry 2021, the lowest yields were reported for 'Čačanska rana' and 'Čačanska najbolja' (4-10 kg), which are early ripening. 'Stanley', 'Kyustendilska plum', and 'Čačanska lepotica' had yields of 26-34 kg per tree, as a result of the higher yields than in previous years and droughts, the depletion of trees led to a sharp drop in yields (Figure 4.)

In 2022, harvests were not reported. The reason for this is that after the abundant full blossoming at the end of April, the minimum temperatures at the beginning of May (2/4.05.) fell to 1.7-3.2°C (Figure 1). They were measured in the meteorological station on the territory of RIMSA, but in the orchard and the specific location of the area they were from 0°C to -3°C. Their influence lasted for more than an hour (between 5 and 6 in the morning), which in the initial phase of the development of the fruit-set (petal fall - formed fruit-set) caused the freezing of a large part of the fruit organs and the fruit yield was completely compromised.

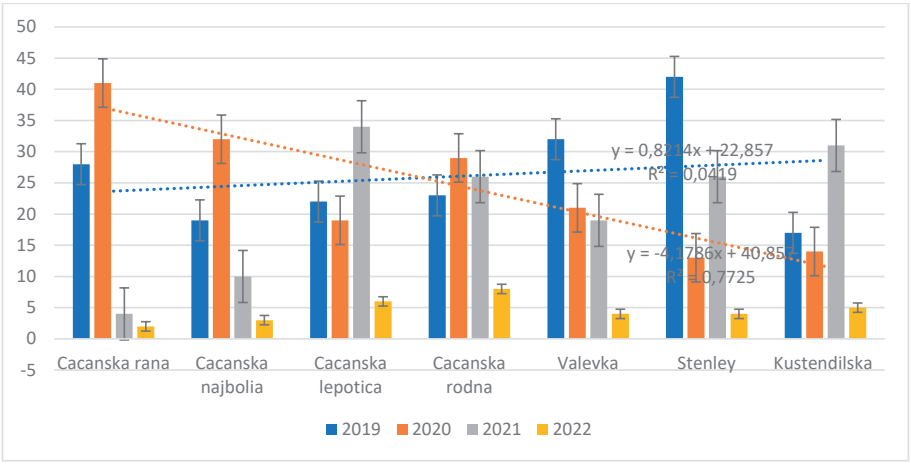

Figure 4. Fruit yield (kg/tree)

If the optimal agrotechnical events and plant protection are, the average optimal yields per variety would be 60-80 kg per tree.

Figure 4 shows that in 2019 the yield trend line corresponds to the linear regression y=0.6025x+22.857, with a coefficient of determination R^2 = 0.0419, i.e. the variance of the outcome variable (yield) is dependent on the action of the factor variable (variety) by 4.2%. In 2020, with the equation y = (-4.2236) x+40.857, R^2 = 0.7704, the influence of the variety on the yield is 77.04%.

CONCLUSIONS

Climatic changes are in the direction of warmer winters, which causes an earlier vegetation onset, but the flowering phases were delayed due to cold weather in the spring months.

For the entire study period, it was found that the phase from flowering to harvest maturity was shortened, due to an increase in the average temperatures in July, August, and September. Early ripening of the fruits was provoked and the end of the vegetation occurred more quickly.

The studied varieties are suitable to create a plantation, according to the flowering periods, since the phenophase overlaps from 6 to 10 days in all of them.

To obtain favorable conditions for growth and fruit-bearing in the Central Balkan Mountain region, the introduced Serbian varieties require changes in cultivation technology and adaptation to changes in the global climate.

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