

Biological Characteristics of Early-Ripening Plum Varieties in the Central Old Mountain Region

Biološke karakteristike ranih sorti šljive u središnjem dijelu Staroplaninskog područja

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BIOLOGICAL CHARACTERISTICS OF EARLY-RIPENING PLUM VARIETIES IN THE CENTRAL OLD MOUNTAIN REGION

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SUMMARY

In the period from 2020 to 2022, the biological and pomological characteristics of the early ripening plum varieties 'Ruth Gerstetter', 'Tuleu Timpuriu', 'Katinka', 'Tegera', 'Hanita', 'Cacaks Early', 'Cacaks Beauty', 'Green Renclode' and 'Top First®' were investigated in the experimental plantations of the Research Institute of Mountain Livestock Breeding and Agriculture Trojan (RIMSA) - Trojan. The parameters analyzed included the flowering phenophases, ripening time, pomometric and physicochemical characteristics of the fruit, and yield of the trees, in each case in comparison with the standard variety 'Cacaks Beauty'. In the period studied, the earliest flowering was observed in 'Tuleu Timpuriu' (April 7-12), while 'Ruth Gerstetter' had the longest flowering period (15 days). The shortest flowering phase (12 days) was observed in 'Cacaks Early', which also bore the largest fruit (55.30 g). Early ripening plum varieties grown in the Trojan region have a lower dry matter value compared to the standard. The highest values of total polyphenols were found in 'Katinka' (376.83 mg/g), followed by 'Tuleu Timpuriu' (303.22 mg/g). The highest yield was observed in the standard variety (44 kg/tree), followed by 'Cacaks Early' and 'Katinka' (31-32 kg/tree). Varieties 'Green Renclode', 'Hanita' and 'Tegera' are not only suitable for fresh consumption but also show potential for processing into juices, nectars and distillates.

Key-words: plums, *Prunus domestica*, morphology, pomometric, biochemistry

INTRODUCTION

Plum production in Bulgaria is characteristic of the mountainous regions, where the tradition of cultivation dates back to the distant past. Today's old varieties of plum have reached a complete biological balance under in the given agro-ecological conditions. In contrast, modern fruit growing and breeding programs in many European countries now offer new plum varieties with different ripening times, high and stable productivity and fruit quality that changing consumer preferences.

Fruit quality is one of the most important factors the market success of a variety (Butac et al., 2015). It is determined by the physicochemical characteristics (shape, size, stone, taste, color, odor and balance of soluble solids and acids), but also by the harvest dates (ripening time) and the time of availability fresh fruit on the market (Butac et al., 2009).

The current trend of climate change compels fruit growers to look for solutions to stabilize crop yields while

ensuring the profitability production. In addition, it is necessary to take into account the demands of the market, which, in addition to quality, also emphasize the trend of biosustainable cultivation in fruit production (Nečas et al., 2021).

The potential yields of fruit trees are strongly influenced by climatic conditions that regulate dormancy and subsequent flowering (Whitney et al., 2021). Like many other temperate species, *Prunus* species go through a dormant period in autumn and winter and need to be protected from potentially damaging weather conditions. This dormant period ends when chilling hours have been reached, depending on the variety. According to the forecasts of the Intergovernmental Panel on Climate Change

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(IPPC), the global average temperature is expected to rise by around 2 °C over the next 30 years. The lack of winter chilling is a limiting factor for fruit tree cultivation in temperate climates, which will prompt breeders to develop new that require less chilling time to end winter dormancy. Insufficient chilling can lead to reduced bud burst and uncoordinated flowering, both of which can result in significant yield losses. As global warming leads to an increase in winter temperatures in many fruit growing regions, there is an increasing need for research into the prediction of tree phenology prediction, the development of phenological models and the integration of ecophysiological and genetic processes (Schiffers, et al., 2021).

Milatović (2021) investigated 26 early and mid-late ripening plum cultivars in the Belgrade region over a period of eight years (2012-2019) and analyzed growth, yield and fruit weight characteristics. Compared to the cultivar 'Cacaks Beauty', which was used as a control, 17 cultivars achieved a significantly lower yield throughout the fruiting period. The fruit weight ranged from 22.9 g for 'Katinka' to 67.7 g for 'Reeves'. The varieties 'Valor', 'Reeves', 'Cacaks Best' and 'Valerija' were recognized for their high yield and large fruits.

In order to diversify plum production in Bulgaria and to adapt to the conditions of the central Old Mountain region, plum cultivars from Romania, Serbia and Germany were introduced and studied under various aspects.

The aim of this study is to present the biological characteristics of early ripening plum cultivars grown in the semi-mountainous region of RIMSA Troyan, which are of interest to consumers in the early fresh fruit market due to o their quality and rich biochemical composition.

MATERIAL AND METHODS

The study was conducted on the area of RIMSA Troyan (42°53'N 24°43'E, an altitude of 420 m), during the period 2020–2022. The plum varieties 'Ruth Gerstetter', 'Tuleu Timpuriu', 'Katinka', 'Tegera', 'Hanita', 'Cacaks Early' ('Cacanska rana'), 'Cacaks Beauty' ('Cacanska lepotica'), 'Green Renclode' ('Zelena Renkloda'), 'Top First®' were grafted on *Prunus cerasifera* rootstocks, planted in a 5 x 4 m scheme and are now in the full ripening phase. Trees were trained as free-growing crowns and cultivated under non-irrigated conditions and with usual agro-technological practices. The prevailing soils are medium-sandy-clay with low humus content.

The region's climate is favorable for the cultivation of fruit species, including plums. The average annual temperature over a 30-year reference period (1988-2017) is 10.6 °C, with a total recorded annual precipitation is 780 mm. Early autumn frosts typically occur in late October, while the latest spring frost are observed around mid-April (Figure 1).

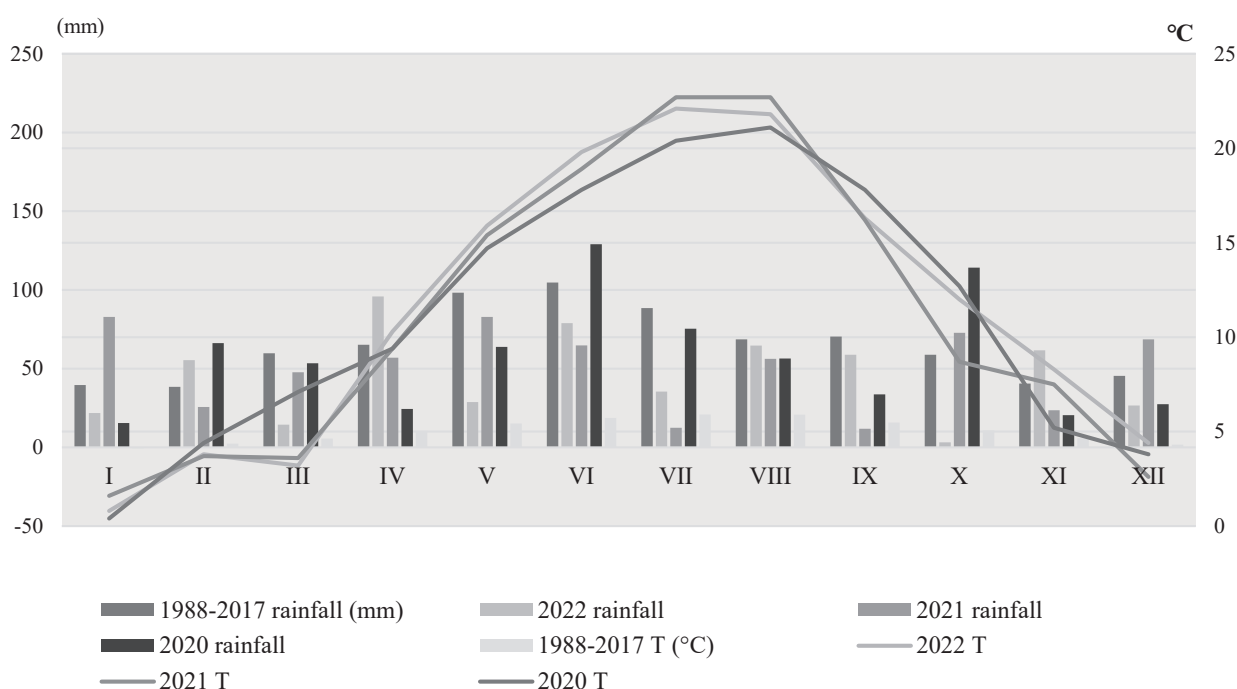


Figure 1. Average monthly temperature (°C) and total monthly precipitation (mm) for the 30-year reference period (1988-2017) and the study period (2020-2022)

Grafikon 1. Prosječna mjesečna temperatura (°C) i ukupna mjesečna količina oborina (mm) za 30-godišnje referentno razdoblje (1988. –2017.) te razdoblje istraživanja (2020. –2022.)

The observed parameters in the research (Laboratory of RIMSA Troyan)

- Phenological calendar - flowering and ripening dates were recorded using calendar dates; the BBCH scale was used for variety assessment (Meier, 2001).
- Fruit and stone weight (g), determined on a KERN precision scale with an accuracy of 0.01 g.
- Fruit and stone size (mm) height, width and thickness - determined on a Digital Caliper
- Yield (kg/tree), the harvested fruits per tree from 3 trees in 3 replicates
- Fruit shape index (FSP) – calculated as the ratio of average height to average width ($FSP = 1$ indicates round fruits; $FSP > 1$ or $FSP < 1$ indicates elongated or flattened fruits, respectively), (Brewer et al., 2006).
- The Shape index was determined, and according to UPOV standards (Table 3), fruit shape was classified on a scale from 1 to 6 (UPOV 44. Fruit: shape in lateral view): oblong - 'Grand Prize' 1; elliptic - 'Empress', 'Victoria' 2; circular - 'Fortune', 'Mirabelle de Nancy' 3; oblate - 'Althanova' 4; ovate - 'Hanita', 'Stanley', 'Valjevka' 5; obovate (oboval) - 'Elena', 'President' 6.
- Chemical composition of fresh fruit:
 - Dry matter (%) - determined refractometrically RNB -32 (0-32 Brix).

- Sugars (%) - total, invert, and sucrose, analyzed using the Schoorl and Regenbogen method (Donchev et al., 2001).
- Organic acids (%) - malic and citric acids, measured by titration with 0.1N NaOH (Donchev et al., 2001).
- Vitamin C (mg/%) - determined using the Tilman method (Donchev et al., 2000).
- Tanning substances (%) - analyzed using the Levental method (Donchev et al., 2000).
- Anthocyanins (mg/%) - measured according to Fuleki et al., (1968).
- Total polyphenols (mg/g) - determined using the Singleton and Rossi (1965).

RESULTS AND DISCUSSION

In 2020 and 2022, the green button phase for all studied varieties began 90 calendar days from the start of the year (around April 1). In 2021, it occurred earlier, after 88 days (at the end of March), and lasted longer. The temperature in the last ten days of March was 3.9 °C, with 20 mm of precipitation. At the beginning of April, the temperature was 6.3 °C, which is 4 °C lower than in 2022 for the same period and 1.5 °C lower than in 2020, (Table 1. Climate - ten days period). This triggered the green button phase, but precipitation between April 1 and 10 delayed and prolonged its progression.

Table 1. Average daily temperatures and total amounts of precipitation (Mart and April – 10 days, 2020-2022)

Tablica 1. Prosječne dnevne temperature i ukupne količine oborina (ožujak i travanj – 10 dnevna, 2020.-2022.)

		March / Ožujak			April / Travanj		
		1-10	10-20	21-31	1-10	10-20	21-30
2020	Rainfall / Oborine (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	Rainfall / Oborine (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	Rainfall / Oborine (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

In 2022, the green button phase occurred later, but during the first ten days of April, it quickly transforms into a white button stage (BBCH 59, Figure 2) due to a temperature of 11°C. That year, the flowering period was shorter (11-14 days) because of continuous rainfall throughout the phase (45 mm), which partially compromised the harvest and resulted yields below commercial threshold. In 2021, the flowering period (BBCH 61-71) lasted 13-18 days (Figure 2). Precipitation during this

phase was around 28 mm, with lower amounts at the beginning of April and less than 10 mm towards the end of the month (Table 1), meaning it did not significantly affect flowering. After flowering began, precipitation was minimal (4.6 mm by the end of April), which favored a normal and prolonged flowering period, in line with the biological characteristics of the varieties, providing good conditions for pollination and fertilization of the flowers.

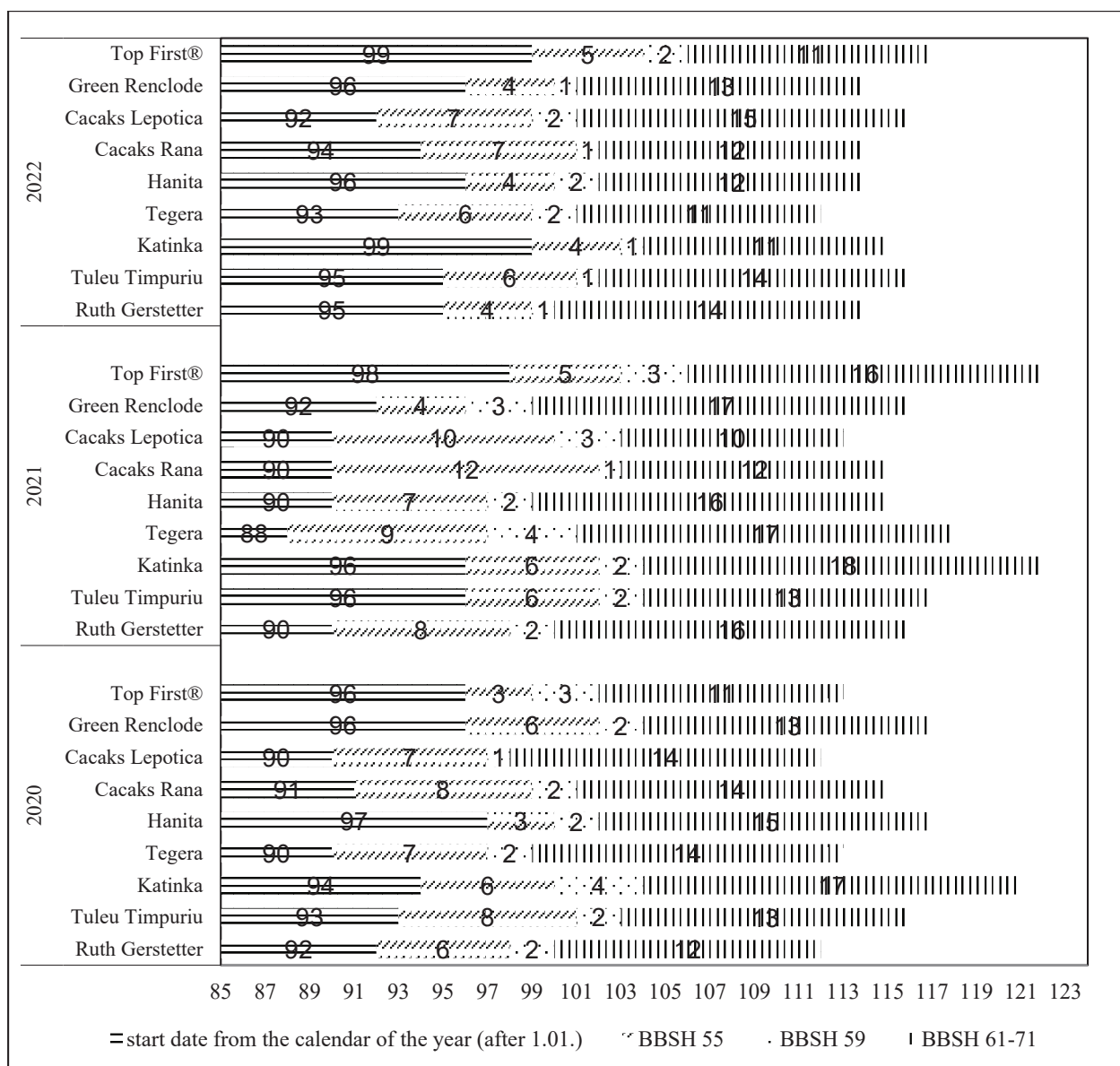


Figure 2. Phenophases of flowering of plum cultivars according to BBCH scale 55, 59 and 61-71 (2020-2022)

Grafikon 2. Fenofaze cvatnje sorti šljive po BBCH skali 55, 59 i 61-71 (2020.-2022.)

During the study period, flowering occurred the earliest in the varieties 'Cacaks Beauty' and 'Tegera', while it was the latest in 'Katinka'. The harvest maturity period (BBCH stage 81) remained consistent across the three years for most of the studied varieties. An exception was 'Ruth Gerstetter', whose fruits ripened around July 20 in 2020, but approximately August 10 in the following two years – 20 days later. Similarly, 'Cacaks Beauty' ripened about five days later in 2021 and 2022 compared to 2020. In contrast, 'Hanita' and 'Cacaks Early' showed an oppo-

site trend, ripening slightly later in 2020 than in 2022, when they ripened 2-3 days earlier. 'Top First®' ripened five days earlier in 2020 (July 19) compared to 2022 (July 23). The average yields over the study period (Table 2) ranged from 11 kg per tree ('Top First®') to 44 kg per tree ('Cacaks Beauty'). Higher yields were recorded for 'Cacaks Beauty', 'Cacaks Early' and 'Katinka' (approximately 30 kg), while 'Hanita', 'Tegera' and 'Tuleu Timpuriu' had moderate yields (24-29 kg). The lowest yields were observed in 'Ruth Gerstetter' and 'Top First®' (11-17 kg.).

Table 2. Ripening time of plum cultivars (Fruit ripe for picking - BBCH 87)*Tablica 2. Vrijeme dozrijevanja sorti šljive (dozrelost za berbu - BBCH 87)*

Variety / Kultivar	2020	2021	2022	Yield kg/tree (avg.2020-2022) / Prinos kg/stablu
Ruth Gerstetter	20 July	11-13 July	11-13 July	17
Tuleu Timpuriu	29 July	01-04 August	29-31 July	24
Katinka	27 July	25-27 July	26-28 July	31
Tegera	03 August	02-04 August	04-06 August	26
Hanita	16 August	18-20 August	12-14 August	24
Cacaks Early	21 July	19-22 July	18-20 July	32
Cacaks Beauty	05 August	09-11 August	09-11 August	44
Green Renclode	07 August	08-12 August	03-05 August	29
Top First®	23 July	19-21 July	18-20 July	11

The attractiveness of the plum varieties to consumers and their market success largely depend on fruit size and shape. The largest fruits were observed in 'Cacaks Early' (51.35 g), followed by 'Top First®' (49.08 g) and 'Green Renclode' (48.78 g). Their stone mass exceeded 2 g, with a relative share of 4.2 % to 4.6 %, which is not particularly high compared to the other studied varieties. The highest relative stone mass was recorded in 'Hanita'

(6.25 %) and 'Tegera' (5.30 %), as these varieties produce smaller fruits ('Hanita' 28.73 g; 'Tegera' 32.69 g) with stones weighing 1.7-1.8 g. The lowest stone percentage (4.2 %) was found in 'Green Renclode' (Table 3). The average petiole length across the group was about 10-11 mm. The shortest petioles were recorded in 'Top First®' (9.98 mm), while the longest were found in 'Hanita' (13.41 mm).

Table 3. Pomometric properties of the studied plum varieties (2020-2022)*Tablica 3. Pomološka svojstva istraživanih sorata šljive (2020.-2022.)*

	Fruit weight / Masa ploda (g)	Stone weight / Masa koštice (g)	Share of stone / Udio koštice (%)	Length / Dužina (mm)	Width / Širina (mm)	Thickness / Debljina (mm)	Fruit shape index / Oblik (C – circular; O – ovate; E – elliptic)	Fruit stalk length / Duljina stapke ploda (mm)
Ruth Gerstetter	35.14	1.65	4.70	40.27	38.09	36.77	1.076 / C	10.17
Tuleu Timpuriu	37.75	1.66	4.39	45.29	38.91	37.03	1.193 / O	10.60
Katinka	28.13	1.23	4.37	41.52	34.34	33.54	1.223 / O	10.89
Tegera	32.69	1.73	5.30	45.80	34.28	36.55	1.293 / O	10.32
Hanita	28.73	1.80	6.25	41.89	34.02	34.58	1.221 / O	13.41
Cacaks Early	51.35	2.32	4.51	50.22	40.39	39.25	1.261 / E	12.62
Cacaks Beauty	37.52	1.74	4.63	42.97	37.30	38.81	1.129 / O	9.15
Green Renclode	48.78	2.07	4.25	41.22	42.32	42.44	0.973 / C	12.47
Top First®	49.08	2.29	4.66	50.81	44.05	39.95	1.210 / O	9.98
LSD 0.05	6.90	0.48		3.25	3.22	2.80		
av.	38.80	1.83	4.78	44.44	38.19	37.66	1.18	11.07
st. dev.	8.88	0.34	0.63	3.90	3.62	2.76	0.10	1.43
cv. %	22.90	18.80	13.11	8.77	9.49	7.32	8.52	12.91

Table 4. Correlational between plum fruit quality properties*Tablica 4. Korelacije između svojstava kvalitete ploda šljive*

	Fruit weight / Masa ploda (g)	Stone weight / Masa koštice (g)	Length / Dužina (mm)	Width / Širina (mm)	Thickness / Debljina (mm)	Dry matter / Suha tvar (%)	Acids / Kiseline (%)
Fruit weight (g)	1						
Stone weight (g)	0.879673	1					
Length (mm)	0.616109	0.690833	1				
Width (mm)	0.919271	0.757583	0.492477	1			
Thickness (mm)	0.89498	0.765673	0.328565	0.854619	1		
Dry matter (%)	-0.00689	0.222173	0.424559	-0.13158	0.047422	1	
Acids (%)	-0.44442	-0.25187	-0.40769	-0.59476	-0.32642	-0.21107	1

Strong correlations ($r = 0.879673$) were found between fruit mass (g) and stone mass (g); ($r = 0.91927$) fruit mass (g) and fruit width (mm), and ($r = 0.89498$) fruit mass (g) and fruit thickness (mm), (Table 4). The

regression coefficient ($R^2 = 0.7738$) between fruit mass and stone mass is expressed by the equation $y = 0.0341x + 0.5088$ (Figure 3).

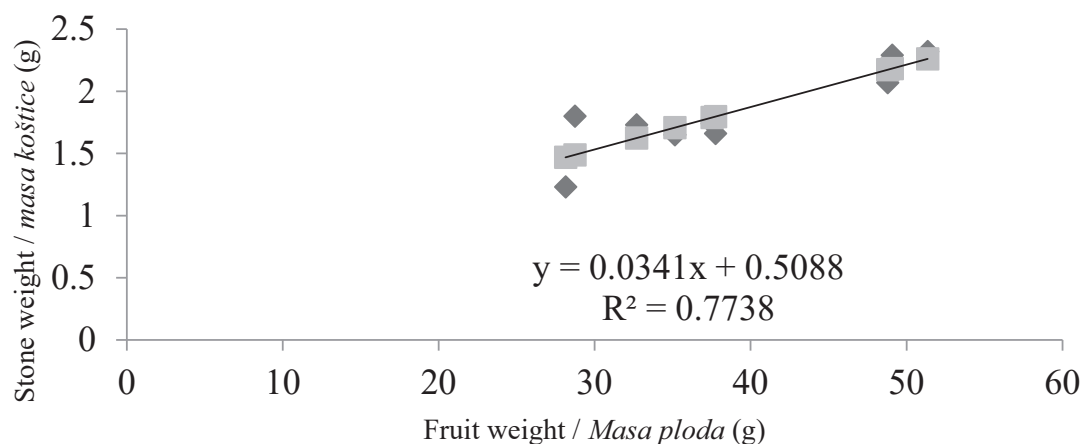


Figure 3. Regression equation between fruit mass (g) and stone mass (g)

Grafikon 3. Regresijska jednačba između mase ploda (g) i mase koštice (g)

Mesa et al., (2021) reported the highest and most significant correlations between fruit weight and equatorial diameter ($r = 0.96$), as well as linear regressions describing the relationship between the chlorophyll I absorption index (AD) and fruit growth.

The varieties 'Cacaks Beauty' and 'Top First®' have a high dry matter content (17.70-17.00 %). 'Tegera' also has a high dry matter (17.20%) and total sugar content (10.97 %), with sugars primarily represented by invert sugar (7.65%) and a low sucrose content (3.19%). The highest total sugar content (5.18 %) was recorded in 'Ruth Gerstetter', which had the lowest dry matter content (13.05 %), (Table 5). Sucrose levels of 1.33 % and 1.14 % were recorded in 'Cacaks Beauty' and 'Top First®' respectively, making them suitable for diabetics. Additionally, these varieties had the lowest acid content (0.34 % and 0.70 %), which reduces their gluco-acidimetric index (IGA), with 'Cacaks Beauty' having a value of 11.80. For 'Top First®', the IGA was high (25) due to its lower total sugar content (8.70 %). The most balanced taste, based on the sugars-to-acid ratio, was observed in 'Ruth Gerstetter' (18.17), 'Green Renclode' (17.17) and 'Katinka' (15.09). Varieties with higher acid

content, such as 'Tuleu Timpuriu' and 'Hanita', exhibited lower IGA values.

In a study by Boškov et al., (2020), the cultivars 'Hanita' and 'Katinka' were rated highest for taste among a group of German plum varieties grown in the Belgrade area. Milatovic (2021) conducted research on various fruit properties (size, shape, skin color, flowering, taste, aroma, and pitting) to identify table varieties that align with consumer preferences. Based on a four-year evaluation of seven mid-early ripening plum varieties, 'Valeria' and 'Hanita' were recommended for cultivation in the Belgrade region. Both are suitable for fresh consumption, while 'Hanita' is also well-suited for fruit processing. The varieties 'Ruth Gerstetter' and 'Tuleu Timpuriu' presented large, visually appealing fruit, but their soluble dry matter content was relatively low. All early plum varieties in the present study exhibited vitamin C content ranging from 11 to 21 mg/%, with 'Hanita' (21.52 mg/%) and 'Green Renclode' (19.36 mg/%) standing out. Tannins (ranging from 0.08 to 0.14 %) and anthocyanins (5-8 to 20-23 mg/%) were also analyzed. The total polyphenols content varied significantly, with the highest values recorded in 'Katinka' and 'Tuleu Timpuriu' (> 200 mg/g). The coefficient of variation (cv. %) was 52.98 % (Table 5).

Table 5. Chemical composition of fresh plum fruits (2020-2022 average)

Tablica 5. Kemijski sastav svježih plodova šljive (prosjeak 2020.-2022.)

	Dry matter / Suha tvar (%)	Total sugars / Ukupni šećeri (%)	Inverted sugars / Invertni šećeri (%)	Sucrose / Saharoza (%)	Acids / Kiseline (%)	IGA / gluco-aci- dimetric index	Vitamin C (mg/%)	Tannins / Tanini (%)	Total poly- phenols / Ukupni poli- fenoli(mg/g)	Anthocyanins / Antocijanini (mg/%)
Ruth Gerstetter	13.1 c	15.18 a	7.50	7.54	0.84 a	18.17	11.44	0.11	144.02	6.94
Tuleu Timpuriu	13.8 c	7.23 c	4.70	3.61	0.83 a	8.68	17.01	0.07	212.78	13.54
Katinka	14.8 bc	8.60 bc	5.95	3.78	0.57 b	15.09	18.77	0.14	260.48	20.91
Tegera	17.2 ab	10.97 bc	7.65	3.19	0.92 a	11.88	13.49	0.14	48.37	12.9
Hanita	15.9 abc	8.08 c	5.97	2.33	0.96 a	8.42	21.52	0.13	173.00	10.92
Cacaks Early	15.3 abc	9.40 bc	6.85	2.42	0.76 ab	12.37	10.56	0.11	46.31	23.06
Cacaks Beauty	17.7 a	8.26 bc	7.33	1.33	0.70 ab	11.80	15.25	0.13	165.23	17.36
Green Renclode	14.4 bc	12.28 ab	3.53	8.09	0.72 ab	17.17	19.36	0.10	143.03	5.32
Top First®	16.0 abc	8.70 bc	7.50	1.14	0.34 a	25.59	17.60	0.08	67.19	8.06
aver.	15.44	9.86	6.33	3.71	0.74	14.35	16.11	0.11	140.05	13.22
st. dev.	1.63	2.53	1.44	2.50	0.19	5.40	3.71	0.02	74.20	6.20
cv. %	10.58	25.63	22.73	67.34	25.87	37.62	23.03	21.96	52.98	46.86

CONCLUSIONS

According to the biological characteristics of the varieties, 'Tegera' flowered the earliest and 'Katinka' the latest, lasting about 13-18 days. This timing depends entirely on the abiotic factors and the specific annual climatic conditions of the region. The varieties 'Cacaks Early' and 'Cacaks Beauty' are characterized by the highest fruit weight and the highest average yield during the observation. Although the cultivars 'Green Renclode' and 'Top First®' produced larger fruits, their yields were significantly lower. Early ripening plum varieties grown in the Troyan area had a lower dry matter content than the standard cultivar 'Cacaks Beauty'. The highest total polyphenol content was found in 'Katinka' (376.83 mg/g) and 'Tuleu Timpuriu' (303.22 mg/g). The most balanced taste, in terms of sugars to acids ratio, was found in 'Ruth Gerstetter', 'Green Renclode' and 'Katinka'. The biological characteristics of early plum varieties grown in RIMSA Troyan's the semi-mountainous region indicate good fruit quality and a rich biochemical composition, which makes them attractive to early-season consumers. The most desirable varieties include 'Ruth Gerstetter', 'Cacaks Early', 'Cacaks Beauty' and 'Top First®'. In addition, 'Green Renclode', 'Hanita' and 'Tegera' are not only suitable for fresh consumption but also show potential for processing into juices, nectars and distillates.

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BIOLOŠKE KARAKTERISTIKE RANIH SORTI ŠLJIVE U SREDIŠNJEM DIJELU STAROPLANINSKOG PODRUČJA

SAŽETAK

U razdoblju od 2020. do 2022. godine ispitivane su biološke i pomološke karakteristike ranih sorti šljive: 'Ruth Gerstetter', 'Tuleu Timpuriu', 'Katinka', 'Tegera', 'Hanita', 'Čačanska rana', 'Čačanska ljepotica', 'Zelena renkloda' i 'Top First'®. Istraživanje je provedeno u pokusnim nasadima Istraživačkog instituta za planinsko stočarstvo i poljoprivredu Trojan (RIMSA) – Trojan (Bugarska). Analize su uključivale mjerenje sljedeći parametri: fenofaza cvatnje, vrijeme dozrijevanja, pomometrijska te fizikalno-kemijska svojstva plodova i prinosa, a sve u usporedbi sa standardnom sortom 'Čačanska ljepotica'. Najranija cvatnja zabilježena je kod sorte 'Tuleu Timpuriu' (7.–12. travnja), a najduža cvatnja (15 dana) kod sorte 'Ruth Gerstetter'. Najkraću fazu cvatnje (12 dana) imala je sorta 'Čačanska rana', koja je ujedno rezultirala i najvećim plodovima (55,30 g). Rane sorte šljive uzgojene u trojanskom području imale su niže vrijednosti suhe tvari u usporedbi sa standardom. Najveći sadržaj ukupnih polifenola zabilježen je kod sorte 'Katinka' (376,83 mg/g) te kod sorte 'Tuleu Timpuriu' (303,22 mg/g). Najveći prinos imala je standardna sorta (44 kg/stablo), a slijede ju 'Čačanska rana' i 'Katinka' (31–32 kg/stablo). Sorte 'Zelena renkloda', 'Hanita' i 'Tegera' osim što su pogodne za svježju konzumaciju, pokazuju i veliki potencijal za preradu u sokove, nektare te destilate.

Ključne riječi: šljiva, *Prunus domestica*, morfologija, pomometrija, biokemija

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