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The 'Valjevka' plum cultivar: key performance in the growing conditions of Troyan region

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Abstract. The study targeted to assess major phenological and agronomic traits such as flowering and fruit ripening time, as well as the yield and main characteristics of the fruit from three plum cultivars: 'Valjevka', 'Kystendilska' and 'Stanley'. The research was conducted at the experimental plum plantation at the Research Institute of Mountain Stockbreeding and Agriculture in Troyan over 2019–2022. This study aimed to compare the 'Valjevka' with the two cultivars mentioned above, which are widely used in plum production in Bulgaria. Among the cultivars studied, 'Valjevka' showed the earliest and 'Kystendilska' the latest flowering and ripening times. Cultivar 'Stanley' was characterized by the highest values of yield, fruit morphological and fruit chemical properties, while 'Valjevka' surpassed 'Kystendilska' in terms of the values of the mentioned properties. The variations in the onset of the flowering phenophase were more pronounced between the individual experimental years than between the cultivars. Additionally, the yield and morphometric characteristics of the fruit varied significantly within the same cultivar, depending on the growing conditions of each experimental year. Based on the obtained results, the cultivar 'Valjevka' can be recommended for commercial growing in the Troyan region.

Keywords: plum, cultivar, flowering and ripening time, fruit

Introduction

The European plum (*Prunus domestica* L.) is a stone fruit species that is grown mainly in the temperate zone of the northern hemisphere. European plum fruits are suitable for fresh consumption, drying, and processing into various products (jam, juice, compote, brandy). Plums are considered a functional food due to the high content of bioactive compounds such as dietary fiber, sorbitol, phenolic compounds, and minerals (Radović et al., 2020).

Plum is a traditionally cultivated fruit tree species in Bulgaria. It is predominantly grown in mountainous regions, as it has more modest agroecological requirements compared to other types of fruit trees (Vitanova et al., 2010). Plum orchards occupy 57% of the cultivated land area in the Troyan region (Minev & Stoyanova, 2012). Production of plums in Bulgaria is characterized by monoculture orchards. Until the 1980s, the 'Kystendilska' cultivar dominated, comprising almost 90% of the orchards (Georgieva & Serbezova, 2018). This cultivar is characterized by

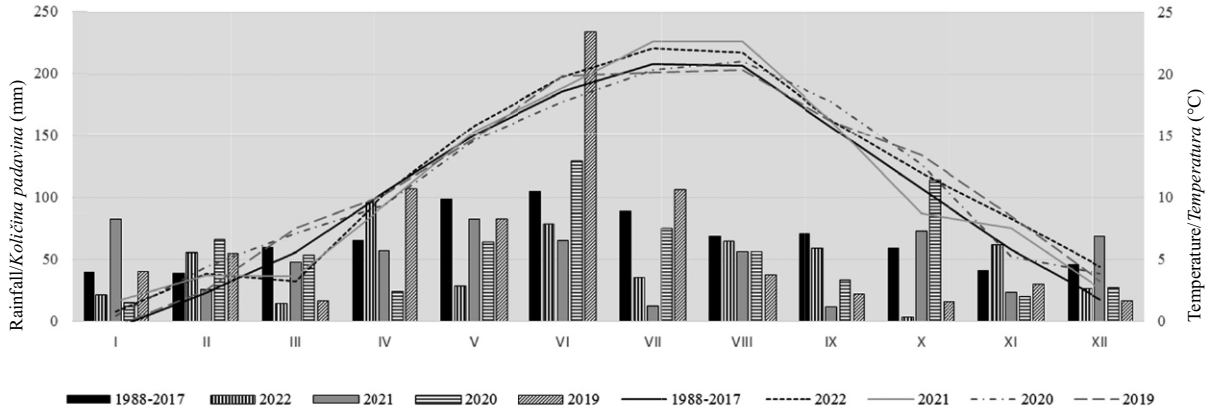
excellent taste and quality of fruits, that are suitable for drying and distillation (Minkov et al., 2021). According to data given by Spasov et al. (1970), in addition to the above-mentioned 'Kystendilska' also has significant disadvantages, such as small fruit size and sensitivity to the *plum pox virus* (PPV). For this reason, the share of the cultivar 'Kystendilska' in Bulgarian plum plantations has significantly decreased (Dinkova et al., 2007), leading to its replacement by 'Stanley'. Currently, the most widespread cultivars are 'Kystendilska' and 'Stanley' (Todorova et al., 2022). In addition to the aforementioned cultivars, 'Gabrovska' and 'Čačanska Lepotica' are also grown to a certain extent (Georgieva & Serbezova, 2018).

To expand the assortment of plums in commercial orchards in Bulgaria, efforts have been made to create new varieties that are highly tolerant or resistant to PPV, with good sensory characteristics and favorable economic traits (Zhivondov & Bozhkova, 2010). In addition, there is ongoing work to introduce and test foreign plum cultivars under Bulgaria's agro-ecological conditions. According to the results published by Dragoyski et al. (2014), the 'Valjevka' cultivar is one of the plum genotypes whose fruits are comparable in quality to those of 'Kystendilska'. This variety was developed at the Fruit Research Institute, Čačak. It is a high-yielding cultivar, tolerant to PPV, producing high-quality dark blue fruits that are suitable for drying and the production of premium-quality brandy (Milenković et al., 2006; Lukić et al., 2016).

This study aimed to examine the most important phenological and pomological traits, as well as the yield, of the 'Valjevka' cultivar under the agroecological conditions of Troyan over a multi-year period (2019–2022). For comparison, the 'Stanley' and 'Kystendilska' cultivars were also included in the research, as these are the most widely cultivated varieties in the area. By comparing the cultivar 'Valjevka' with the other two cultivars, the research would contribute to a better understanding of 'Valjevka' adaptability to local growing conditions and potential benefits for commercial plum production in the Troyan region. Also, the study conducted over several years would have provided valuable data on the variability and consistency of these traits across different growing seasons.

Materials and Methods

The study was conducted from 2019 to 2022 in the plum experimental orchard of the Research Institute of Mountain Stockbreeding and Agriculture in the Troyan region. The orchard was established in 2004 with one-year-old trees of the cultivars 'Valjevka', 'Stanley', and 'Kystendilska', planted at a 5 m × 5 m distance, and trained as a freely growing crown. The soil in the orchard is medium sandy clay with low humus content. The climate of the area is favorable for temperate fruit species, including European plum. According to data from 30 years (1988–2017), the average annual air temperature in the region is 10.6°C, and the total annual precipitation is 780 mm (Graph 1). Early autumn frosts usually occur in late October, while the last spring frosts occur in mid-April.



Graph 1. Average monthly air temperature and total monthly rainfall for 30 years (1988–2017) and the period of study (2019–2022)
Grafikon 1. Prosečna mesečna temperature vazduha i ukupna mesečna suma padavina za tridesetogodišni period (1988–2017. godine) i period ispitivanja (2019–2022. godine)

The investigation included phenological properties (flowering and ripening time), yield, morphometric (fruit and stone weight, the share of stone, fruit dimensions – length and diameter, and fruit stalk length), physical (fruit firmness), and chemical (soluble solids content, total acids content, content of tannins and anthocyanins) properties of fruits as well as their colour.

The BBCH scale (Meier, 2018) was used to determine the dates of the beginning and end of flowering, as well as ripening time (stages 61, 67, and 87, resp.).

The yield per tree (kg) was determined for 3 trees in 3 replicates of each investigated cultivar using the ACS System Electronic Scale (Zhejiang, China).

Electronic scale KERN 572 (Stuttgart, Germany) served for measuring fruit and stone weight (g), while fruit (length, width, thickness) and stalk (length) dimensions (mm) were measured by digital caliper Rexxer RE-06-005, 150 mm (Grodzisk Mazowiecki, Poland). The above-mentioned measurements were performed on a sample of 25 fruits in 3 replicates and showed an average for each cultivar in each year.

Soluble solids content (°Brix) was determined by refractometer RHB-32 with a range of 0.0–32.0 °Brix (Shenzhen City, China), while the Luff-Schoorl method (Egan et al., 1981) was used for determination content of total and inverted sugars and sucrose (%). The content of total acids (%) expressed as malic acid was determined by titration with 0.1 N NaOH up to pH 8.1, using phenolphthalein as an indicator. The contents of tannins (%) and anthocyanins (mg kg^{-1} FW) were determined according to the methodologies described by Fuleki & Francis (1968). All investigated parameters of the chemical composition of fruits were shown as average values for the cultivar.

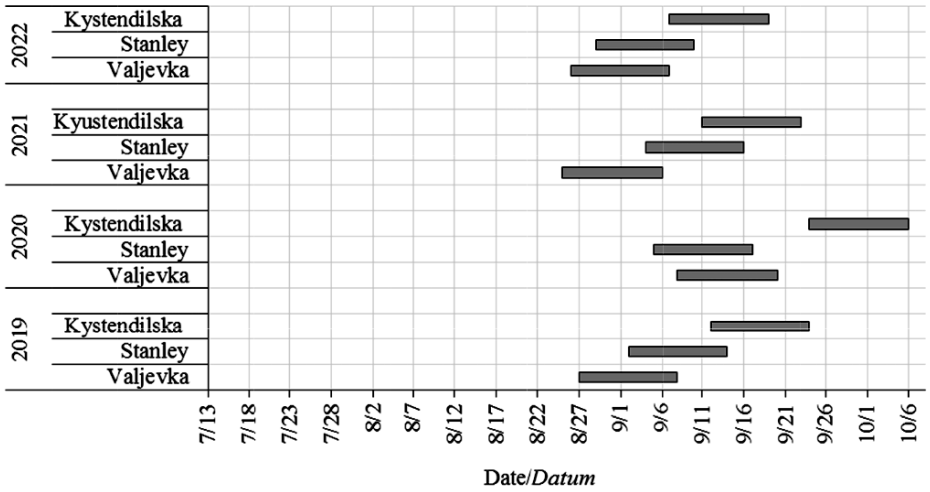
Fruit skin and fruit flesh firmness were determined using a digital penetrometer FHT-15, by measuring both sides of fruits. Color parameters were measured by Color meter CM-200S, separately for the fruit skin and fruit flesh. The indicators are reported according to the CIE Lab system. The color coordinates L, a, and b were observed during the measurement: L – color brightness; +a – red colour; -a – green colour; +b – yellow colour; -b – blue colour. The value of the colour tone or the dominant wavelength is represented by the a/b ratio and H (hue angle) = b/a. In the evaluation of H, we used the most widely accepted international criterion of assigning the angle. The measurements of fruit skin and fruit flesh firmness and color were performed on the sample of 25 fruits collected in 2022.

The obtained data were processed using the statistical method of analysis of variance (ANOVA) at $p = 0.05$ level of significance, using Excel 2019. The arithmetic means of investigated fruit morphometric parameters were compared using the test of Least Significant Differences (LSD test) for significance threshold of $P \leq 0.05$; $P \leq 0.01$ and $P \leq 0.001$.

Results and Discussion

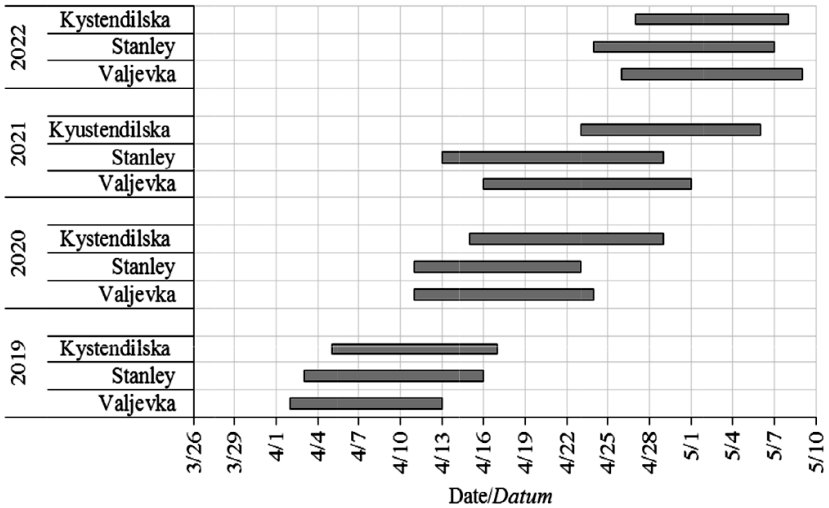
Regardless of the cultivar studied, during the period of the study, the trend of a gradual delay in the beginning of flowering phenophase was observed (Graph 2). The difference in terms of the beginning of the flowering phenophase between the earliest (2019) and the latest (2022) year was 17 days. The above-mentioned can be explained by the temperature conditions before and during the flowering phenophase in the study area. Namely, during 2020 and 2021, the air temperatures in the last decade of March and the first decade of April were below 6°C, which delayed the beginning of flowering compared to 2019. The March of 2022 (Graph 1) was characterized by negative air temperatures and abundant amounts of precipitation, so the beginning of flowering was delayed until the last ten days of April. A pronounced influence of weather conditions on the flowering time of plum varieties has also been established in studies of Nyéki (2002) and Szabó (2003).

Among the cultivars studied, ‘Kystendilska’ showed the latest flowering time and the shortest flowering phenophase (12.5 days on average). ‘Stanley’ and ‘Valjevka’ had similar results in the first and second years of study, while in 2021 and 2022 the flowering started ‘Stanley’ a couple of days earlier in comparison with ‘Valjevka’. The obtained results are in accordance with the results previously published by Milenković et al. (2006) and Lukić et al (2016). Bearing in mind that ‘Stanley’ is a cultivar of late flowering time (Neümuller, 2010), the flowering time of ‘Valjevka’ can be classified as late, while ‘Kystendilska’ is characterized by a very late flowering time.



Graph 2. Flowering phenophase of investigated plum cultivars (2019–2022)
Grafikon 2. Fenofaza cvetanja ispitivanih sorti šljive (2019–2022. godine)

The earliest ripening time was observed in the cultivar 'Valjevka', whose fruits ripened at the end of August and the beginning of September (Graph 3). This was followed by the 'Stanley', whose fruits ripened during the first and second decades of September. The 'Kystendilska' exhibited the latest ripening, that occurred in the second half of September and, in some years (notably 2020), in the first half of October. The duration of the ripening period was similar for all the investigated cultivars. Previously published results indicated that the investigated cultivars had similar ripening times and duration of the ripening in the Troyan region (Dragoyski et al., 2009; Popski et al., 2023).



Graph 3. Ripening phenophase of investigated plum cultivars (2019–2022)
Grafikon 3. Fenofaza sazrevanja plodova ispitivanih sorti šljive (2019–2022. godine)

During the study period, the highest yield was recorded in the 'Stanley' cultivar, with an average of 21.25 kg per tree, while the 'Kystendilska' cultivar had the lowest yield (16.75 kg per tree; Table 1). The most productive year was 2019, with an average yield of 30.33 kg/tree, while the lowest yields for all examined cultivars were observed in 2022 (4.33 kg per tree). The reasons included late spring frosts that occurred in the Troyan region between May 2nd and May 4th, as well as very high summer temperatures accompanied by prolonged drought during the ripening period (Graph 1). The growing conditions may also explain the disagreement between our results and those of Dragoyski et al. (2009) and Glišić et al. (2018), whose indicate slightly higher yields for the cultivar 'Valjevka' and lower yields for the cultivar 'Stanley'.

The highest values of fruit and stone weight, as well as fruit dimensions, were determined in the 'Stanley' cultivar, across all study years (Table 2). The 'Valjevka' cultivar followed, while the 'Kystendilska'

Table 1. Yield per tree (kg per tree) of investigated plum cultivars during the period 2019–2022
Tabela 1. Prinos po stablu (kg po stablu) proučavanih sorti šljive u periodu 2019–2022. godine

	2019	2020	2021	2022	Average/*Prosek*
'Valjevka'	32.00	21.00	19.00	4.00	19.00
'Stanley'	42.00	13.00	26.00	4.00	21.25
'Kystendilska'	17.00	14.00	31.00	5.00	16.75
av	30.33	16.00	25.33	4.33	19.00
stdev	12.58	4.36	6.03	0.58	2.25
cv (%)	41.48	27.24	23.79	13.32	11.84

av*: average value/*srednja vrednost*; stdev: standard deviation/*standardna devijacija*; cv: coefficient of variation/*koeficijent varijacije*

Table 2. Fruit morphometric properties of investigated plum cultivars during the period 2019–2022
Tabela 2. Morfometrijske osobine ploda proučavanih sorti šljive u periodu 2019–2022. godine

	Fruit weight *Masa ploda* (g)	Stone weight *Masa koštice* (g)	Share of stone *Udeo koštice* (%)	Fruit lenght *Visina ploda* (mm)	Fruit width *Širina ploda* (mm)	Fruit thickness *Debljina ploda* (mm)	Fruit stalk length *Dužina peteljke ploda* (mm)
2019							
'Valjevka	30.98	1.50	4.84	46.23	34.69	33.54	16.42
'Stanley'	43.68	2.32	4.21	49.03	38.04	37.12	17.10
'Kystendilska'	21.39	0.90	5.31	40.42	29.48	30.35	16.73
2020							
'Valjevka'	24.24	1.30	5.36	43.98	31.88	31.23	11.57
'Stanley'	37.35	2.20	3.38	48.83	36.43	36.38	16.66
'Kystendilska'	17.75	0.60	5.89	37.67	28.35	28.77	11.96
2021							
'Valjevka'	28.90	1.60	5.54	48.18	32.46	32.93	13.08
'Stanley'	37.56	2.26	3.90	51.93	34.62	36.43	13.86
Kystendilska'	15.40	0.60	6.02	35.5	26.51	27.20	11.85
2022							
'Valjevka'	19.83	1.19	6.00	40.6	29.13	30.20	15.74
'Stanley'	35.76	2.14	6.12	48.32	34.97	36.03	18.00
'Kystendilska'	15.04	0.92	5.98	34.97	26.47	28.00	15.02
LSD = 0.05	5.02	0.20		2.65	1.87	1.87	2.25
LSD = 0.01	7.04	0.28		3.72	2.62	2.62	3.16
LSD = 0.001	9.95	0.40		5.26	3.70	3.70	2.25

cultivar had the smallest fruits. Additionally, the 'Stanley' cultivar exhibited the smallest proportion of stone relative to the total fruit weight, whereas the 'Kystendilska' showed the lowest values in this regard. Similar to yield, all studied cultivars recorded the lowest values for the morphometric parameters of the fruit in 2022 and the highest in 2019, which can also be attributed to unfavorable climatic conditions. In general, the fruit morphometric characteristics of the 'Valjevka' cultivar obtained in this study were in line with the results reported by Milenković et al. (2006) and Lukić et al. (2016). On the other hand, Dragoyski et al. (2009), Glišić et al. (2018), and Milošević et al. (2019) reported lower values for the fruit morphometric parameters of the cultivar 'Stanley'.

It is known that the content of soluble solids plays an important role in the acceptance of certain plum cultivars by consumers (Crisosto et al., 2004), and late-ripening cultivars should have more than 17% soluble solids (Neumüller, 2010). The results presented in Table 3 show that the average content of soluble solids in the cultivars investigated in our study varied from 18.00% ('Valjevka') to 20.20% ('Kystendilska'). The highest content of total sugars (10.90%), the lowest content of total acids (0.67%), and the highest sugar-acid ratio (16.27) were found in the cultivar 'Stanley'. 'Valjevka' had the highest content of tannin substances (0.186%), while 'Kystendilska' was characterized by the highest content of inverted sugars (7.70%) and anthocyanins (17.58 mg/100 g FW). The presence of sucrose was not detected in the fruits of the 'Kystendilska', which makes them potentially suitable for inclusion in the diet of diabetics. The results of previous studies (Milenković et al., 2006; Glišić et al., 2018; Milošević et al., 2019; Tomić et al., 2019; Paunović et al., 2020) indicate somewhat higher values for the studied parameters of the chemical composition of fruits in 'Valjevka' and 'Stanley', which may be due to applied agrotechnical measures (Day et al., 1992) and climatic conditions (Mitrović et al., 2006).

Cultivars 'Valjevka' and 'Kystendilska' had a similar value of fruit skin firmness (12.34 kg cm^{-2} and 12.0 kg cm^{-2}, respectively) and fruit flesh firmness (1.62 kg cm^{-2}), while in the 'Stanley' considerable higher values of the mentioned parameters were determined (Table 4). In terms of skin brightness (Table 4), the highest value was found for the fruits of cultivar 'Valjevka' (L=32.70), while for those of 'Kystendilska' and 'Stanley' similar values were determined (31.95 and 31.54, respectively). The fruit flesh was the brightest in 'Stanley' (41.28), followed by 'Valjevka' (37.25). The negative values of b (-1.62 for 'Valjevka' and -1.01 for 'Stanley') indicate that the fruit skin of these varieties is blue in color. On the other hand, the flesh of the fruit in investigated cultivars was predominantly yellow, with b values ranging from 23 for 'Kystendilska', followed by 28 for 'Valjevka' to 33.33 for 'Stanley'.

Table 3. Chemical composition of fruit of investigated plum cultivars during the period 2019–2022
Tabela 3. Hemijske osobine ploda proučavanih sorti šljive u periodu 2019–2022. godine

	Soluble Solids *Rastvorljive suve materije (°Brix)*	Total sugars *Ukupni šećeri* (%)	Inverted sugars *Invertni šećeri* (%)	Sucrose contents *Sadržaj saharoze* (%)	Total acids *Ukupne kiseline* (%)	Sugar acid ratio *Odnos između šećera i kiselina*	Tannin substances *Tanini* (%)	Anthocyanins *Antocijani* (mg/100 g FW)
'Valjevka'	18.00	9.20	5.70	3.33	0.87	10.57	0.187	5.32
'Stanley'	18.20	10.90	5.38	5.27	0.67	16.27	0.166	3.71
'Kystendilska'	20.20	7.70	7.70	0.00	0.80	9.63	0.166	17.58
av*	18.20	9.27	6.26	4.30	0.78	12.16	0.17	8.87
stdev	1.30	1.60	1.26	1.37	0.10	3.59	0.01	7.59
cv (%)	7.14	17.28	20.08	31.90	13.01	29.56	7.01	85.52

av*: average value*/srednja vrednost*; stdev: standard deviation*/standardna devijacija*; cv: coefficient of variation*/koeficijent varijacije;* FW: fresh weight*/sveža masa*

Table 4. Firmness and color parameters of skin and flesh of investigated plum cultivars
Tabela 4. Čvrstina ploda i parametri boje pokožice i mezokarpa ploda proučavanih sorti šljive

	'Valjevka'	'Stenley'	'Kystendilska'
		The skin/*Pokožica*	
L*	32.70	31.54	31.95
a	2.67	1.89	5.00
b	-1.62	-1.01	0.42
a/b	-0.70	5.66	1.09
b/a	-0.61	-0.53	0.08
Firmness (kg/cm^2)	12.34	14.08	12.08
		The flesh/*Mezokarp*	
L	37.25	41.28	29.72
a	-2.38	-7.84	-5.53
b	28.31	33.33	23.15
a/b	-0.10	-0.23	-0.24
b/a	-11.89	-4.25	-4.19
Firmness (kg/cm^2)	1.62	5.22	1.62

* L: brightness/*osvetljenost*; a: red-green coordinates/*crveno-zelene koordinate*; b: blue-yellow coordinates/*plavo-žute koordinate*.

Conclusions

Based on the results of the study, it can be concluded that, in terms of morphometric and some chemical characteristics of the fruit, as well as yield, the cultivar 'Valjevka' showed better results compared to 'Kystendilska'. Considering these factors, along with the tolerance of 'Valjevka' to PPV and the suitability of its fruits for various types of processing, this cultivar can be recommended for commercial production in the Troyan region. Additionally, the results of multi-year studies have shown a pronounced influence of climatic conditions on both the timing and progression of specific phenophases, as well as on the yield and fruit characteristics of the studied cultivars in different years. The impact of climate change, along with identifying appropriate measures for plum production, should be a priority in future research.

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SORTA ŠLJIVE VALJEVKA: NAJVAŽNIJE OSOBINE U USLOVIMA REGIONA TROJAN

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Sažetak

Istraživanje je imalo za zadatak da prouči ključne fenološke i agronomske osobine, kao što su vreme cvetanja i vreme sazrevanja, prinos i najvažnije osobine ploda tri sorte šljive (Valjevka, Kystendilska i Stanley). Ispitivanja su sprovedena u eksperimentalnom zasadu šljive Instituta za planinsko stočarstvo i poljoprivredu u regionu Troyan, u periodu 2019–2022. godine. Cilj istraživanja je bio da se uporede osobine sorte Valjevka sa osobinama druge dve pomenute sorte koje su u velikoj meri gaje u komercijalnim zasadima šljive u Bugarskoj. Među proučavanim sortama, Valjevka se odlikovala najranijim, a Kystendilska najkasnijim vremenom cvetanja i sazrevanja ploda. Za sortu Stanley su bile karakteristične najviše vrednosti prinosa, kao i najviše vrednosti pročavanih morfometrijskih i hemijskih osobina ploda. U pogledu pomenutih parametara sorta Valjevka je nadmašila sortu Kystendilska. Odstupanja u pogledu početka fenofaze cvetanja su utvrđena i između pojedinih eksperimentalnih godina. Uočene razlike između pojedinih eksperimentalnih godina su bile veće u odnosu na razlike među sortama. Pored toga, prinos i morfometrijske osobine ploda iste sorte su pokazali visoku zavisnost od uslova gajenja zastupljenih u pojedinim godinama. Na bazi dobijenih rezultata sorta Valjevka se može preporučiti za gajenje u regionu Trojan.

Key words: šljiva, sorta, vreme cvetanja i sazrevanja, plod