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Plum cultivars Zlatka and Pozna Plava (*Prunus domestica* L.) bred at the Fruit Research Institute in Čačak

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Abstract

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This study was carried out to compare the most relevant biological characteristics and field resistance to economically important diseases of the new (Zlatka and Pozna Plava) and standard plum cultivars (Čačanska Lepotica and Čačanska Rodna) in the Region of Čačak. The experimental area climate belongs to the temperate type. The mean annual air temperature during the experimental period was 12.65°C, and humidity was 80.4%. The average annual rainfall was 571.2 mm. The ripening time of the cv. Zlatka occurred between August 3–23, while the cv. Pozna Plava ripened between August 26–September 25. Compared to cv. Čačanska Lepotica, cv. Zlatka had a significantly lower mean fruit weight, reducing sugars and total acids content, but a significantly higher proportion of flesh, yield and sucrose content. Compared to cv. Čačanska Rodna as the standard cultivar, cv. Pozna Plava had a significantly higher mean individual fruit weight and total acids content, but also a significantly lower orchard yield and sweetness measured as fruit soluble solids, total sugars, reducing sugars and sucrose content. As regards the field resistance to economically important diseases such as red leaf spot, rust, fruit root, pockets plum disease and sharka disease, both new cultivars demonstrated better results than the reference cultivars.

Keywords: new cultivars; ripening time; fruit quality; resistance/tolerance

Breeding new cultivars of European plum (*Prunus domestica* L.) has been a major plant-breeding programme of the Fruit Research Institute in Čačak, Republic of Serbia, since its establishment in 1946 (Ogašanović et al. 2005). Domestic cultivars – both the autochthonous ones and the best-quality introduced ones were included in the parental combinations within the planned hybridisation programmes, with the aim of creating quality table cultivars and combined-traits cultivars (Ogašanović et al. 1996). So far, 15 cultivars have been developed at the Fruit Research Institute (Milenković et al. 2006; Ogašanović et al. 2008a,b, 2012). During 1980s, the hybridisation process was expanded to include cultivars with good pomological characteristics, which had previously proved as a good source of resistance or tolerance to sharka (PPV). Selection was directed towards developing sharka-resistant and tolerant cultivars (Ranković et al. 1994). This programme produced the cv. Zlatka (Zelta Butilkovidna × Large Sugar Prune) in 2008 (Ogašanović et al. 2008a) and it was protected at the territory of the Republic of Serbia. The cv. Pozna Plava (self-pollination of cv. Čačanska Najbolja) was recognised in the same year (Ogašanović et al. 2008b). Apart from the Republic of Serbia, this cultivar has been protected in the European Union since 2009, under the name of Cacak Späte.

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The aim of this work was to describe the most essential biological and pomological characteristics and reactions to economically important plum diseases under field conditions in the new plum cvs Zlatka and Pozna Plava. The obtained results will have a practical significance as a base for possible recommendation of the examined cultivars for commercial planting. The scientific significance of the study is reflected in the increase of the gene fund of sources with desirable properties.

MATERIAL AND METHODS

Plant material and experimental design. The research was conducted at the experimental plum orchard at the Ljubić facility of the Fruit Research Institute in Čačak (43°53'N, 20°20'E, 250 m a.s.l.). The orchard was set up in 2002, using one-year old plantings of cvs Zlatka, Pozna Plava, Čačanska Lepotica and Čačanska Rodna, grafted on Myrobalan seedlings (*Prunus cerasifera* Ehrh.). The planting was performed at 6 × 5 m planting distance (333 trees/ha), using the random block system with five trees in three replications. Cv. Čačanska Lepotica was used as the standard for the cv. Zlatka, while cv. Čačanska Rodna was the standard for cv. Pozna Plava. The compared cultivars have similar flowering period, harvest interval and utilisation value of fruit. The cultivation system is the pyramidal crown – central leader crown with 5 to 7 spirally arranged scaffold branches (Mišić 1996), and the plantation was treated with standard agrotechnical and pomo-technical measures.

Biological and fruit quality traits measurement. The date of the fruit ripeness was recorded at the time of full ripeness, when the fruits adopted their typical cultivar-specific features. Twenty-five fruits in three replications were randomly selected to determine average fruit weight using the Mettler balance (± 0.01 g accuracy; Toledo, USA) and the data were expressed in grams per fruit. Proportion of fruit flesh was calculated as the ratio of the mass of the edible portion of the fruit to the total fruit mass (%). The fruit yield per unit of orchard area was determined by calculation, as the product of multiplying the yield per tree and the number of trees per hectare, expressed through t/ha. Ripening time, fruit weight, proportion of fruit flesh and yield were studied for four years, from 2008 to 2011.

Five chemical parameters of the fruit (soluble solids, total sugars, reducing sugars, sucrose content, total acids) were measured at commercial maturity. Soluble solids content (°Brix) was determined by a hand refractometer (Carl Zeiss, Jena, Germany). Total sugars and reducing sugars were determined as fresh weight basis using the Luff-Schoorl method (Egan et al. 1981). Total acids were measured by neutralisation to pH 7.0 with 0.1 N NaOH, the data being presented as percentage of malic acid. Sucrose content was calculated by multiplying the difference of the total and reducing sugars contents by the 0.95 coefficient. Chemical parameters were studied for three years, from 2008 to 2010.

Field resistance to causal agents of the economically most important plum diseases. The testing of the field resistance to causal agents of the economically most important plum disease included: red leaf spot (*Polystigma rubrum* Pers. DC), rust (*Puccinia-pruni spinosae* Pers.: Pers.), fruit rot (*Monilinia laxa* (Aderhold & Ruhland) Honey), pockets plum disease (*Taphrina pruni* Tul.), Sharka disease (*Plum pox virus*). The level of symptoms was determined by frequency and intensity of attack in natural conditions of infections. The frequency of attack was determined by the number of organs (leaves, twigs or fruits) affected by the disease. The intensity of attack represents the percentage of coverage with symptoms per organs. The method used to identify the infections was based on visual observation considering the symptoms shown by infected plants. Symptoms intensity was determined on a scale from 1 to 9 (1 – no symptoms, 3 – minor symptoms, 5 – moderate symptoms, 7 – strong symptoms, 9 – very strong symptoms) recommended by IBPGR (1984). The observations on the intensity and frequency of attacks were made: (a) on leaves in the case of *Polystigma rubrum* and *Puccinia-pruni spinosae* (1 – no symptoms, 3 – individual spots on a small number of leafs, 5 – individual or numerous spots on a large number of leaves, 7 – symptoms on almost all leaves and covering more than a half of the leaf area, 9 – the leaves are declining), (b) on fruits, twigs and blossoms in the case of *Monilinia laxa* (1 – no symptoms, 3 sporadic symptoms on flowers and/or fruits, 5 – symptoms on a large number of flowers and/or fruits, 7 – symptoms on a half of flowers and/or fruits and sporadic symptoms on twigs, 9 – symptoms on almost all flowers or/and fruits and a large number of twigs); (c) on fruits in the case of *Taphrina pruni* (1 – no symptoms, 3 sporadic symptoms on fruits, 5 – symptoms on 30% of fruits, 7 – symptoms on a half of fruits, 9 – symptoms on almost all of

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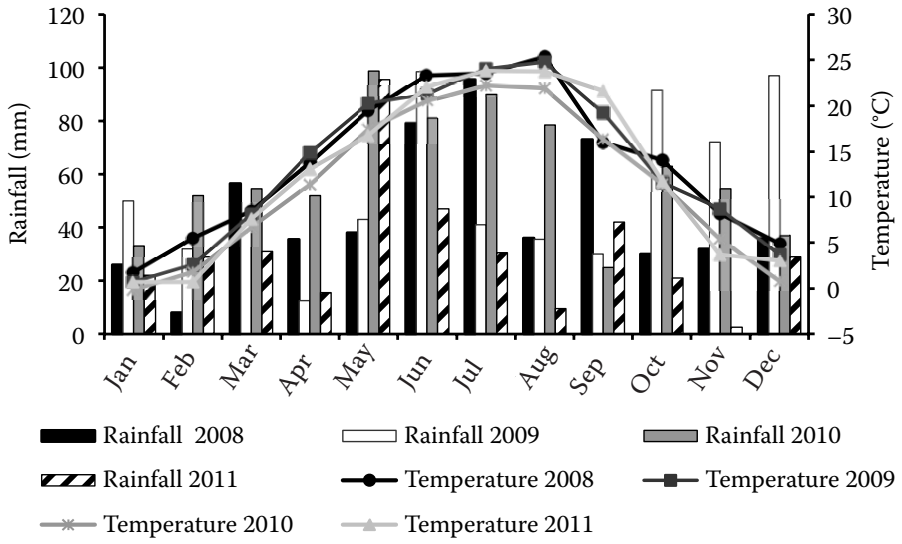

Fig. 1. Climatic conditions during the period of study in the Region of Čačak

fruits); and (d) on leaves, fruit and branches in case *Plum pox virus* (1 – no symptoms, 3 – symptoms on leaves, 5 – symptoms on leaves and fruits, but without premature fruit drop, 7 – symptoms on leaves and fruits and premature fruit drop, 9 – symptoms on leaves and fruits, premature fruit drop and dead branches). The degree of symptoms on the tested cultivars represents a mean value for four years of observation, from 2008 to 2011.

Climatic conditions. The Čačak Region climate belongs to the temperate type with hot summers and cold winters. During the experimental period, climatic data were provided by the Experimental Meteorological Station of the Fruit Research Institute in Čačak. From the climatic point of view, it can be said that the climate conditions were within the normal values for the experimental region (Fig. 1). The mean annual air temperature was 12.65°C and humidity 80.4%. The average annual rainfall was 571.2 mm. The temperature was not a limiting factor for plum growing during the period of the study. The annual rainfall was at the lower limit, compared to optimum conditions for plum, with a possible impact on the values of the studied parameters of fruit quality and yield. During April and May, as the period when the conidia starts to germinate and grow, the values of air temperature and humidity needed for fungus development were assured by natural conditions, so that the climatic conditions needed for the evolution of studied fungus could be considered as normal.

Data analysis. The obtained results were analysed using the Fisher model analysis of variance (ANOVA) using the software package Microsoft Office Excel 2003. The degree of relevance of differences between the cultivars was determined using the LSD test, with the probability level of $P \leq 0.05$.

RESULTS AND DISCUSSION

All of the examined plum cultivars ripened in the period from July17 until September 23. The new plum cultivars were later ripening compared to the corresponding standard (Fig. 2). The ripening time of cv. Zlatka, occurring on average between August 3 and 23, coincided with the gap between the ripening time of the cvs Čačanska Lepotica and Čačanska Rodna. Cv. Pozna Plava recorded the latest ripening time and an exceptionally long harvesting period, in the interval from August 26 until September 25 (Fig. 2).

The difference in fruit ripening time between the new and the standard plum cultivars is important from the aspect of the continual market supplies of fresh fruits, which is also one of the main goals in plum selection activities (Paunović et al. 2011). Considering the fact that genotypes with an earlier or later ripening time have an advantage at the market (Neumüller 2010), Cv. Pozna Plava stands out due to its late ripening time and long process of fruit ripening. Apart from the production purposes, this cultivar has a potential significance in the future projects of plum selection, since the ripening time is one of the well-known genotype-specific characteristics (García-Mariño et al. 2008) and a long harvest period occurs as a result of a cultivar's specific ability to maintain the corresponding firmness of the flesh (Blažek, Pišteková 2009).

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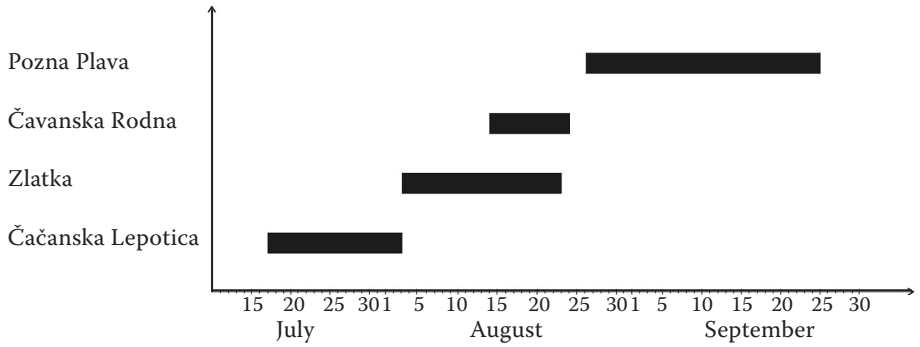

Fig. 2. Average ripening time of new and standard plum cultivars in Čačak conditions

Cv. Zlatka, compared to cv. Čačanska Lepotica, had significantly lower fruit weight but a higher proportion of fruit flesh and yield (Table 1). The results presented in Table 1 show that the cvs Pozna Plava and Čačanska Rodna did not demonstrate significant differences in their respective values of proportion of fruit flesh, while at the same time significant statistical differences were determined in the fruit weight and yield (Table 1). Cv. Pozna Plava had higher fruit weight but lower yield.

The obtained parameters of fruit weight of cvs Čačanska Lepotica and Čačanska Rodna are in agreements with previous research (Ogašanović et al. 1996; Milenković et al. 2006). Lower values of the cv. Zlatka fruit weight are in compliance with the findings of Neumüller et al. (2010), stating that PPV-resistant genotypes are typically characterised by a lower fruit mass. Contrary to the results of Blažek and Vávra (2007), and in agreement with the findings of Milošević and Milošević (2011), our study did not confirm a positive impact of cv. Čačanska Najbolja on the fruit weight in the hybrid progeny. The cv. Pozna Plava recorded a significantly lower fruit mass compared to cv. Čačanska Najbolja as its self-pollinated parent (Milenković et al. 2006). The results found in literature concerning the yield of cvs Čačanska Rodna and Čačanska Lepotica (Ogašanović et al. 2005) differ from the results of our research. The observed differences occurred as a result of the different agro-ecological conditions, orchard age, planting system, level of implementation of agro-technical measures and other factors. The cv. Zlatka recorded a higher yield than cv. Čačanska Lepotica, as a cultivar known for its consistent and high cropping. Compared to cv. Čačanska Rodna, the cv. Pozna Plava recorded a lower average yield. In order to achieve a high and regular cropping for the cv. Pozna Plava, it will be necessary to make a proper selection of the pollination cultivars (Đorđević et al. 2011).

The results of the research into the chemical composition of the fruit of the new and standard plum cultivars are shown in Table 2. While a higher sucrose content was recorded in the fruits of the cv. Zlatka cultivar, the values of soluble solids content, total sugars content, reducing sugars content and total acids were higher in the fruits of cv. Čačanska Lepotica. The variance analysis revealed that the reducing sugars content, sucrose content and total acids in the cvs Zlatka and Čačanska Lepotica recorded statistically significant differences (Table 2).

All the parameters of the biochemical composition of cvs Pozna Plava and Čačanska Rodna fruits were statistically significantly different (Table 2). Higher total acids value was found in the fruits of cv. Pozna Plava, while the values of other parameters of the chemical composition were higher in the fruits of cv. Čačanska Rodna.

The most important parameters of the bio-technological composition of the cv. Zlatka fruit mainly corresponded to the level of cv. Čačanska Lepotica

Table 1. Pomological properties and yield of the evaluated cultivars

Cultivar	Fruit weight (g)	Flesh percentage (%)	Yield (t/ha)
Zlatka (new)	23.14 ± 0.25^{b}	95.86 ± 0.29^{a}	1.92 ± 0.05^{a}
Čačanska Lepotica (ref.)	34.75 ± 0.21^{a}	95.03 ± 0.16^{b}	1.39 ± 0.01^{b}
Pozna Plava (new)	23.83 ± 0.12^{a}	95.57 ± 0.07^{a}	1.03 ± 0.20^{b}
Čačanska Rodna (ref.)	22.97 ± 0.04^{b}	95.05 ± 0.18^{a}	1.83 ± 0.02^{a}

different lower-case letters show the significant difference at $P \leq 0.05$ by LSD test; ref. – reference (standard) cultivar

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Table 2. Biochemical composition of fruits of the cvs Zlatka and Čačanska Lepotica

Parameters	Soluble solids (°Brix)	Total sugars (%)	Reducing (%)	Sucrose (%)	Total acids (%)
Zlatka (new)	16.03 ± 0.05[a]	10.87 ± 0.09[a]	6.52 ± 0.05[b]	3.98 ± 0.13[a]	0.92 ± 0.07[b]
Čačanska Lepotica (ref.)	16.15 ± 0.27[a]	11.02 ± 0.22[a]	7.22 ± 0.09[a]	3.39 ± 0.22[b]	1.06 ± 0.09[a]
Pozna Plava (new)	21.92 ± 0.63[b]	13.98 ± 0.72[b]	7.69 ± 0.31[b]	5.72 ± 0.38[b]	0.91 ± 0.06[a]
Čačanska Rodna (ref.)	22.94 ± 1.21[a]	14.49 ± 0.39[a]	7.97 ± 0.45[a]	6.11 ± 0.13[a]	0.66 ±0.12[b]

different lower-case letters show the significant difference at $P \leq 0.05$ by LSD test; ref. – reference (standard) cultivar

as the standard cultivar, which is used in various plume breeding programmes owing to its fruit quality (Ogašanović 2002). The cv. Pozna Plava features a slightly lower fruit quality than the standard cv. Čačanska Rodna, which is well-known for its outstanding fruit quality (Ogašanović et al. 1996; Milenković et al. 2006). The value of soluble solids content in the cv. Pozna Plava was above the value of 17°Brix, as a benchmark stated by Neumüller (2010) for the later-ripening cultivars. The value of soluble solids content in the examined plum cultivars, as one of the quality parameters that determines the acceptability of fruits by consumers, corresponded to the fluctuation range of 12~32°Brix stated by Neumüller (2010) and were above the value of 12°Brix given by Crisosto et al. (2004) for European plum cultivars.

Field resistance to causal agents of economically the most important diseases

Fig. 3a shows the degree of occurrence of the economically significant plum diseases observed in the cvs Zlatka and Čačanska Lepotica. No symptoms of *Taphrina pruni* were observed, whereas the *Monilinia laxa* symptoms were sporadic in the cv. Zlatka and at a medium level in cv. Čačanska Lepotica. Also, cv. Čačanska Lepotica demonstrated medium sensitivity to *Polystigma rubrum* and *Puccinia pruni-spinosae*, while cv. Zlatka showed low sensitivity to these causal agents. No sharka symptoms were detected either on the leaf or the fruit of cv. Zlatka even after 6–7 years of cultivation, despite the disease pressure from the surrounding infected plum trees. In the same conditions, due to the natural infection by aphids, the leaves of cv. Čačanska Lepotica showed moderate symptoms of the disease (Fig. 3a).

The cv. Pozna Plava demonstrated a low level of sensitivity to *Polystigma rubrum*, compared to a medium level of Čačanska Rodna. Both cultivars showed a low level of sensitivity to *Puccinia pruni-spinosae*. While *Monilinia laxa* was traceable only in cv. Čačanska Rodna, symptoms of *Taphrina pruni* were detected only in cv. Pozna Plava. The symptoms of sharka were found in both cultivars. In the cv. Pozna Plava, only

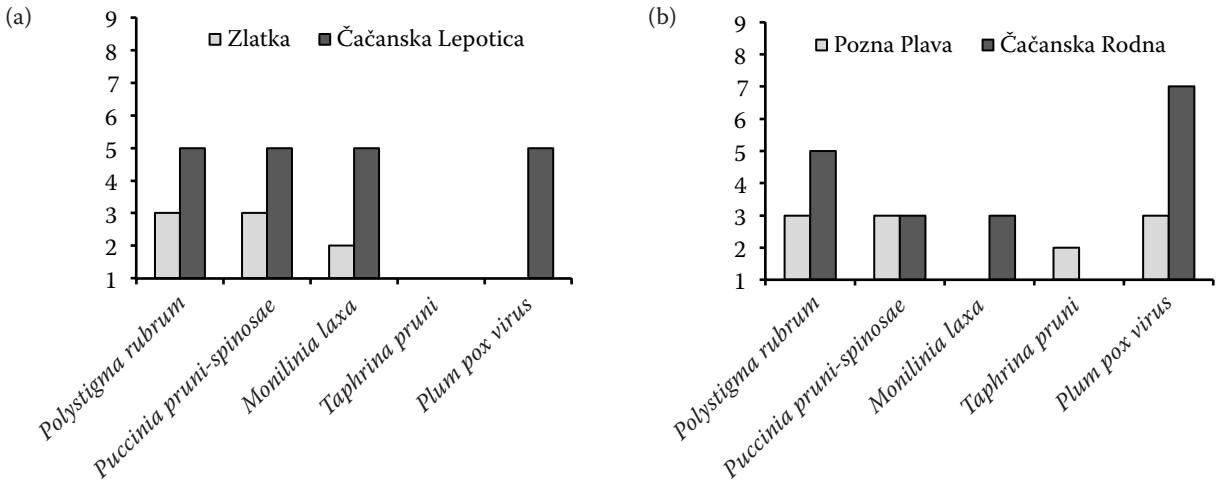

Fig. 3. Symptomatic response of (a) cvs Zlatka and Čačanska Lepotica and (b) cvs Pozna Plava and Cačanska Rodna to causal agents of the economically most important diseases under field conditions

symptom intensity scale (1–9): 1 – no symptoms, 3 – minor symptoms, 5 – moderate symptoms, 7 – strong symptoms, 9 – very strong symptoms

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the leaves showed mild symptoms of the disease. Cv. Čačanska Rodna showed symptoms both in the leaf and the fruit, in the form of a ring-shaped multicolour pattern which appears before the full maturity and disappears as the ripening progresses, while premature fruit drop was also observed (Fig. 3b).

Sharka is the most devastating disease of stone fruit trees. The loss from sharka during the last 30 years at the global level are estimated at about 45 million metric tons of European plums, with an estimated value 5,400 million Euros (Cambra et al. 2006). Introduction of resistant and tolerant cultivars into production is the only possible practical solution to the sharka virus problem (Ranković et al. 1994). Fungal plum diseases are most difficult to control in years with high temperature, high humidity and abundant rainfall. Blossom blight and brown rot of stone fruit is caused by *Monilinia laxa*, being a common and destructive disease of stone fruit (Rungjindamai et al. 2014). In the prevailing conditions of rainy and cold weather during the flowering period, the pockets plum disease may destroy the entire crop (Mišić 1996). The same author states that premature defoliation caused by the red leaf spot and rust may jeopardize the survival of fruit trees themselves. The EU regulations imposed the reduction of fungicides in controlling plant diseases (Rungjindamai et al. 2014). Among other approaches, culture technology using cultivars resistant or tolerant to diseases attack can contribute to this goal (Mitre et al. 2015). Creating new varieties tolerant or resistant to these diseases is a permanent goal in plum breeding (Milenković et al. 2006; Paunović et al. 2011) so that monitoring of the existing germplasm fund in the region and having a potential for use in hybridization in terms of resistance to economically important diseases, is a permanent objective in breeding activity. Hartmann and Neumüller (2009) presented the first step in breeding resistant cultivars as detecting genetically fixed differences in the behaviour of a single genotype of the respective species against a particular pathogen. The higher resistance or tolerance of the new cultivars to causal agents of the economically most important plum diseases, especially sharka, is a quality with large practical significance for production, as well as for inclusion of these cultivars into future breeding programmes. Both new cultivars showed a low degree of sensitivity to the most economically important fungal plum diseases. Cv. Zlatka showed no symptoms of sharka in field conditions. The obtained results can be explained by a high degree of quantitative resistance of this genotype to PPV (Kegler et al. 2000) or by a relative resistance to the virus vector (Zagrai et al. 2009). Cv. Pozna Plava became infected, but showed very mild symptoms. Such genotypes are marked like PPV tolerant and can be very successfully grown in areas where sharka is present (Ranković, Ogašanović 1995).

CONCLUSION

The results and the analysis thereof suggested that the cv. Zlatka has admirable characteristics of cropping, some chemical attributes, field resistance to causal agents of economically the most important fungal diseases and sharka disease that surpass the reference cv. Čačanska Lepotica. Cv. Pozna Plava showed a markedly later ripening time, longer harvest period, larger fruits and higher level field resistance to causal agents of fungal diseases and PPV tolerance than standard cv. Čačanska Rodna. We expect that, supported by further studies, both new plum cultivars can take their place in plum orchards, particularly in the regions where PPV is a limiting factor for plum growing. Studied varieties can have a significant place in the integrated production of plums. Also, they can be used as a basis in further plum breeding programmes, as a source of resistance or tolerance to the most important fungal diseases and sharka.

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