Evaluation of raspberry cultivars grown in the western Serbia region

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Abstract

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A trial was conducted to determine biological and pomological traits of raspberry cultivars grown in western Serbia region (2003–2006) with the aim to introduce those with the most desirable properties into production. The studies included morphometrical properties of fruits, i.e. number of drupes and seed mass, as well as yield properties viz. yields per shoot, meter and unit of land area. Fruits of cv. Tulameen and selection K 81-6 (4.28 g and 4.11 g, respectively) were larger than those of cv. Willamette (3.40 g) which, in this respect was superior to cvs Meeker (3.29 g) and Latham (2.40 g). The greatest number of drupes was recorded in selection K 81-6 (94.97), whereas drupes were fewest in cv. Latham (54.79). As regards seed mass, cv. Tulameen performed the best (2.68 mg), while cv. Latham recorded only 1.49 mg. Seed mass in the cultivars and selection studied was significantly higher in dry seasons, i.e. the first and third year of study. The greatest average number of shoots per meter and total number of shoots per hectare were observed in cv. Willamette (5.51 and 22,026; respectively), while, in this regard, cv. Tulameen (5.43 and 21,712; respectively) and selection K 81-6 (5.43 and 21,711; respectively) had the poorest performance. Cv. Willamette gave the highest yields per shoot (449 g), meter (2,475 g) and unit land area (9,900.49 kg/ha), whereas the yields examined were the lowest in cv. Latham (5,692.08 kg/ha) which also had the highest percentage of misshapen fruits (2.06%). The third year of study recorded the highest number of misshapen fruits in all the cultivars and selection studied (2.00%).

Keywords: varieties; selection; yield; fruit quality

According to Veljković et al. (2010), raspberry is grown on about 60,000 ha globally, and its annual production ranges from 340,000 to 460,000 tons. With an average production of 75,145 t during the period 2001 to 2010 the Republic of Serbia is the world's largest raspberry producer (Petrović, Leposavić 2011).

At present, raspberry is grown on about 13,500 ha in Serbia, primarily in the regions of Arilje Ivanjica, Bajina Bašta, Brus, Valjevo, Guča, Kosjerić, Krupanj, Mionica and Čačak. It is also grown on smaller scale in some other areas of the country (Leposavić, Cerović 2009). In Serbian raspberry plantations, cv. Willamette has been the predominant cultivar for many years now, accounting for 90% (Milutinović et al. 1993) of total raspberry growing area. Cv. Meeker is grown on about 5%

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of the total area, although it has shown an upper growing trend in recent years.

With the exception of cv. Tulameen, other cultivars included in the official assortment list, along with cv. Latham and selection K 81-6, are not commercially grown, and are found only sporadically in non-commercial plantations.

Nenadić (1975) classified cultivars according to fruit size into three categories, viz. Gradina, Malling Promise, Malling Exploit (Class I), Willamette (Class II), and Lloyd George and Valjevka (Class III). Joublan et al. (2002) reported on large fruits and high production (9,983 kg/ha) of cv. Tulameen.

According to Daubeny and Anderson (1991) high quality fruits of cv. Tulameen recommend it for different forms of utilization, primarily for fresh consumption. Moore (1993) established a positive correlation between fruit weight, and number and weight of drupelets. The studies also revealed correlation between drupelets weight and fruit weight.

According to numerous authors, morpho-physiological and technological characteristics of raspberry fruit greatly depend not only on cultivar specificities, but also environmental factors and agrotechnique. Marinkovic et al. (2008) reported that yield and fruit quality were significantly affected by adverse growing conditions. The results of the study revealed the most severe impact of the factors on cv. Willamette, which averagely yielded 2.2 t/ha over the trial period.

The present study was, therefore, undertaken to assess major biological and pomo-technological characteristics of cvs Tulameen, Latham, Meeker and selection K 81-6, compared to the standard cv. Willamette, and establish their suitability for cultivation in the western Serbia region. The environmental factors that affected the expression of genetic potential of the studied raspberry cultivars and selection were also included in the assessment.

In addition, this study addresses the fact that over 95% of harvested raspberry fruits in Serbia end in global markets, while only negligible amounts are placed on local market. This export tendency necessitates keeping up with world trends in terms of assortment, fruit quality, and taste of consumers in developed countries of Europe and North America.

MATERIAL AND METHODS

The examinations were conducted in a raspberry trial plantation established on a gentle north-west facing slope in 2002 (Zdravljak site, Fruit Research Institute, Čačak – 43°50'N, 20°18'E and 649 m altitude).

Cvs Meeker, Latham, Tulameen and selection K 81-6 were included in the experiment, and cv. Willamette served as control cultivar. Raspberries were planted at spacing 0.33 × 2.5 m. A randomized block design system in four replications, with 50 plants per each replication was employed. Plants were grown on espalier with a wooden poles trellis and two rows of single wire set at a height of 80 and 160 cm.

The following pomological traits were studied: fruit weight (without receptacle) in 50 fruits (g), fruit length (mm), fruit width (mm) and drupelets characteristics (number in the aggregate, number of fruits and seed mass). As for yield parameters, total number of shoots, total number of shoots per meter, yield per shoot (kg), yield per unit land area (kg/ha) and percentage of fruits with underdeveloped, misshapen berries (100 fruits examined) were observed.

In spring, selected shoots were cut at two buds above the upper wire (at a height of 170 to 175 cm), and bound shoots were counted in all the four replications (66 m each) per each cultivar and selection. Yield involves cumulative amount of fruits harvested in a sample of 25 shoots designated, from the beginning to the end of harvest. Yield per meter and unit land area were computed by multiplying yield per shoot and total number of shoots per unit land area. The number of underdeveloped and misshapen fruits was determined on a sample of 400 fruits (100 fruits from each repetition) per each sample of cultivars and the selection.

The results were subjected to analysis of variance (ANOVA) of two factorial trial (Hadživuković 1991), where A stands for cultivar, and B for year. Significance of mean values of cultivars compared to control cultivar was carried out based on the Dunnett's test – one-way comparison (Dunnett 1955), whereas significance of differences in mean values per years and interaction means cultivar × year were assessed by the Duncan's multiple rank test (Duncan 1955). Significance of differences was determined at $P < 0.05$ and $P < 0.01$.

RESULTS AND DISCUSSION

Fruit weight in raspberry cultivars is very heterogeneous, which is due to cultivar specificities, agro-environmental conditions and agrotechnique. Results of fruit weight subjected to analysis of variance reveal significant differences among cultivars

Table 1. Morphometrical properties of fruit of raspberry cultivars and selection studied

Treatment		Fruit weight (g)	Fruit length (mm)	Fruit width (mm)	Number of drupelets	Seed mass (mg)
Cultivar (A)	Meeker	3.29^{ns}	19.48**	18.25^{ns}	84.16^{ns}	2.05^{ns}
	Latham	2.40**	15.92**	18.95*	54.79**	1.49**
	K 81-6	4.11**	23.40**	19.09**	94.97**	2.65**
	Tulameen	4.28**	24.67**	20.33**	88.19^{ns}	2.68**
	Willamette	3.40	20.78	17.99	87.60	2.19
Year (B)	2003	3.14^{b}	18.55^{b}	17.76^{c}	80.05	2.25^{b}
	2004	3.66^{a}	22.12^{a}	19.88^{a}	84.30	1.88^{c}
	2005	3.63^{a}	21.38^{a}	18.66^{b}	81.72	2.83^{a}
	2006	3.56^{a}	21.34^{a}	19.39^{ab}	81.70	1.88^{c}
ANOVA						
Cultivar (A)		**	**	**	**	**
Year (B)		**	**	**	ns	**
A × B		ns	**	**	ns	ns

**significant differences among means at $P < 0.05$ and $P < 0.01$ based on the Dunnett's test and ANOVA results (F-test); A, B treatments in cultivars and years; ns – non-significant; $^{a-c}$ non-justified differences at $P < 0.01$ based on the Duncan's multiple range test

and years, which is the indicative of considerable impact of environmental factors on fruit weight (Table 1). Compared to cv. Willamette (control), cv. Tulameen and the selection studied had significantly larger fruit ($P < 0.01$), while cv. Latham had significantly lower fruit weight ($P < 0.01$) and cv. Meeker exhibited no significant differences. The results obtained are in agreement with other reports in the literature (Nenadić 1975; Koron 2004).

The comparison of cvs Willamette and Meeker, two most commonly grown cultivars in major raspberry growing areas of Serbia, showed that in all observed years cv. Willamette had larger fruits, which is in agreement with the results of Kempler et al. (2005). Considerably lower fruit weight was recorded in the first observed year, and no significant differences in fruit weight were evidenced over the rest of the trial period. Apart from a significant influence of meteorological factors on fruit weight in the second and third years, manure applied in spring 2004 and its extended activity also had a marked impact on fruit weight.

In addition to the significant impact of cultivar specificities and years, analysis of variance of fruit length revealed significant cultivar × year interaction, which points to the different reaction of cultivars in the study period (Table 1). Compared to the control, significantly higher fruit length was observed in cv. Tulameen and selection K 81-6 ($P < 0.01$), while cvs Meeker and Latham had a significantly lower performance in this respect ($P < 0.01$).

As in fruit weight, significantly higher fruit length was noticed in second, third and fourth years. As regards fruit length, the existence of significant interaction between cultivar × year points to different behaviour of cultivars in the study period (Fig. 1a); due to the lower value of cv. Tulameen in the first year, it is compared to its average value during the study period, and very low variability of cv. Willamette. In the first observed year, cv. Tulameen had a lower fruit weight in comparison with the general average over the study period. Both fruit weight and length in cultivars and the selection studied were highly influenced by low precipitation in the second part of the growing period, accompanied by high temperatures. This effect was the most pronounced in cv. Tulameen. In the first year, cvs Meeker and Latham had significantly lower values than that recorded in control. In the ensuing two seasons, when all the cultivars and selection had the highest fruit length except cv. Meeker that did not significantly differ from control, significant differences were noticed in Tulameen and selection K 81-6 (significantly higher) and cv. Latham (significantly lower). Significantly greater fruit length compared to control was observed in the fourth year in cv. Tulameen and K 81-6, and significantly lower in cv. Latham.

As for fruit width, analysis of variance (Table 1) revealed significant differences among cultivars, years and their different reactions in different years (cultivar × year). Compared to control, considerably higher values were observed in cv. Tulameen,

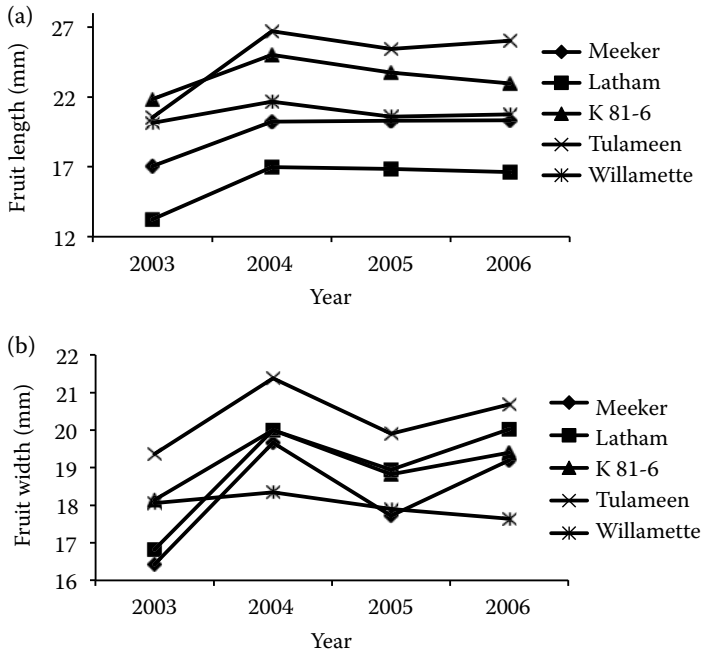

Fig. 1. Fruit (a) length (mm) and (b) width (mm) of raspberry cultivars and selection (interaction)

K 81-6 ($P < 0.01$) and cv. Latham ($P < 0.05$). In the second observed year, fruit width was significantly higher than in the third season in all cultivars and selection studied. Fruit width was markedly lower in the first year than in other years of study. With regard to fruit width, significant cultivar × year interaction indicates different behaviour of cultivars during the study period (Fig. 1b). Negligible variations were observed in cv. Willamette, contrary to the other cultivars which, in this respect, were considerably influenced by external factors. The existence of non-significant differences among cv. Willamette and the studied raspberry cultivars and selection was due to the low variability of cv. Willamette in the first year. In the ensuing years, compared to control cultivar, significant differences were observed in cv. Tulameen (in all years) and cv. Latham (in the fourth year).

As for the number of drupelets, analysis of variance pointed to the significant differences only among the studied raspberry cultivars and selection (Table 1). Compared to control, the number of drupelets recorded was significantly higher in selection K 81-6 ($P < 0.01$) and significantly lower in cv. Latham ($P < 0.01$).

Analysis of variance of seed mass inferred significant differences among cultivars and years (Table 1). Compared to control cultivar, seed mass was higher in cv. Tulameen and selection K 81-6 ($P < 0.01$), and significantly lower in cv. Latham ($P < 0.01$). The results concerning drupelets and fruit weight confirm the reports of Moore (1993) who suggested the existence of correlation between the factors above. All raspberry cultivars and selection studied were responsive to meteorological fluctuations, which confirmed the absence of cultivar × year interaction. Seed mass in cultivars and selection studied was significantly higher in the first and third year, whereas it was the lowest in the second and fourth year. This can largely be attributed to the impact of meteorological factors, primarily rainfall deficiencies, as in years with unfavourable climatic conditions seed mass was significantly higher in cultivars and selection studied.

According to Petrović and Leposavić (2011), the applied espalier system is the most suitable and most commonly used training system in growing raspberry in Serbia. The number of shoots left per meter varies among cultivars and plantations. In cv. Willamette, mostly in mid-intensive plantations, 6–7 shoots are left to grow. However, in highly intensive plantations, which are raised on good soil and provided with irrigation, 5 shoots are needed at most, whereas in cv. Meeker, 3–4 shoots per meter are regularly left to grow.

The study results of yield parameters are shown in Table 2. Relatively small variations in the number of shoots might be due to the fact that bearing plants were selected in spring, at bud swell, whereby frozen, damaged and unproductive shoots were not bound. With regard to the average number of shoots per meter, i.e. total number of shoots per hectare, analysis of variance points to the significant impact of cultivar specificities as well as the significant interaction between cultivar × year (Table 2). Although analy-

Table 2. Yield of raspberry cultivars

Treatment		Average number of shoots/m	Total number of shoots/ha	Yield per shoot (g)	Yield per meter (g)	Yield per unit land area (kg/ha)	Percentage of misshapen fruits
Cultivar (A)	Meeker	5.48^{ns}	21,910^{ns}	413**	2,263**	9,050.78**	1.00^{ns}
	Latham	5.46**	21,833**	261**	1,423**	5,692.08**	2.06**
	K 81-6	5.43**	21,711**	419**	2,273**	9,092.05**	1.00^{ns}
	Tulameen	5.43**	21,712**	375**	2,036**	8,143.17**	1.19^{ns}
	Willamette	5.51	22,026	449	2,475	9,900.49	0.75
Year (B)	2003	5.46	21,828	356^{c}	1,942^{c}	7,770.21^{c}	1.05^{b}
	2004	5.47	21,866	403^{b}	2,206^{b}	8,826.42^{b}	0.90^{b}
	2005	5.46	21,843	349^{d}	1,909^{d}	7,636.43^{d}	2.00^{a}
	2006	5.45	21,814	425^{a}	2,317^{a}	9,269.79^{a}	0.85^{b}
ANOVA							
Cultivar (A)		**	**	**	**	**	**
Year (B)		ns	ns	**	**	**	**
A × B		**	**	**	**	**	ns

**significant differences among means at $P < 0.05$ and $P < 0.01$ based on the Dunnett's test and ANOVA results (F-test); A and B – treatments in cultivars and years; ns – non-significant; $^{a-d}$non-justified differences at $P < 0.01$ based on the Duncan's multiple range test

sis of variance showed a non-significant difference among years, a significant influence was manifested through the significant interaction between cultivar × year, i.e. through the different cultivars response in some years. Except for cv. Meeker, the average number of shoots was significantly different from control cultivar. Significantly fewer shoots per meter and hectare were recorded in cvs Latham, Tulameen and K 81-6 ($P < 0.01$).

The existence of significant interaction between cultivar × year was due to the large number of shoots in control cultivar (first year) and cv. Meeker (second year), and a small number of shoots in K 81-6 (third year), compared to their overall average in the study period (Fig. 2). Therefore, in the first year, a significantly greater number of shoots was observed in control cultivar. In the second year, compared to control, a significantly greater number of shoots was obtained by cv. Meeker, while cv. Tulameen and K 81-6 had significantly fewer shoots. In the third year, compared to control, considerably fewer shoots were recorded only in K 81-6. In the fourth observed year, no significant differences were recorded among cultivars and selection studied.

Yield per shoot is a cultivar trait which can be substantially affected by environmental conditions, whereby the influence varies among cultivars (analysis of variance, Table 2). Compared to the studied raspberry cultivars and selection, a significantly higher yield per shoot ($P < 0.01$) was obtained by cv. Willamette, which is in agreement with the results of Eyduran et al. (2008). However, the obtained results are not in agreement with those of Marinković et al. (2008), which to some extent can be attributed to growing conditions in their study which were somewhat unsuitable for raspberries. In addition to differences among the cultivars studied, significant differences were evidenced in respect of yield per shoot and years of study. Yield was the highest in the fourth year, followed by the second, first and third years. Yield per

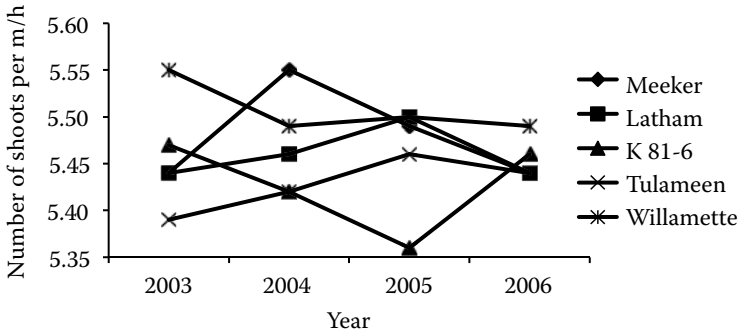

Fig. 2. Average and total number of shoots per meter and per hectare of raspberry cultivars and selection (interaction)

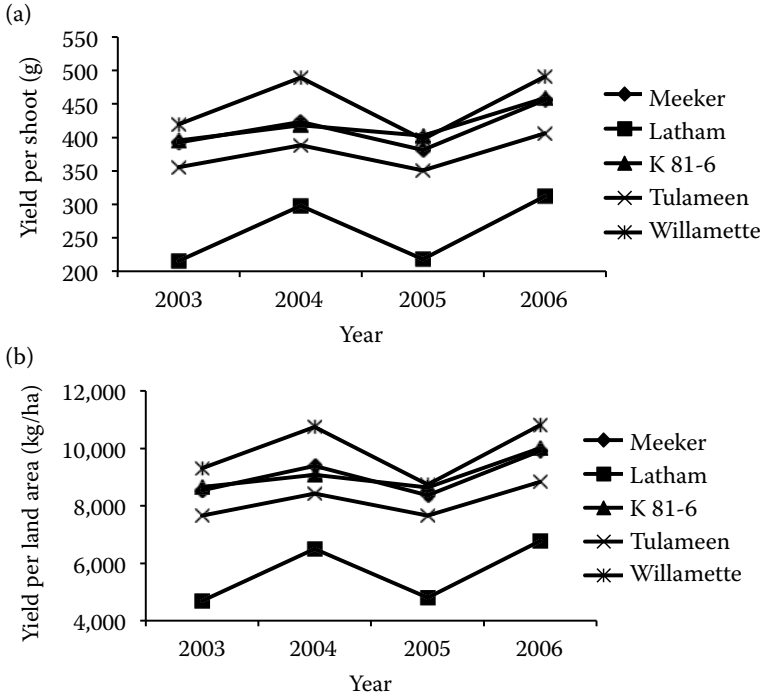

Fig. 3. Yield (a) per shoot (g) and (b) per land area (kg/ha) of raspberry cultivars and selection (interaction)

shoot in the first year was low, as was expected, given the fact that it was the first production year, while in the other years it mainly depended on rainfall and its distribution over the growing period.

Compared to cvs Willamette and Latham, the significant cultivar × year interaction was due to the relatively low variability of yield per shoot in K 81-6, cvs Meeker and Tulameen (Fig. 3a). Except for K 81-6 in the third year, compared to control, significantly lower yield per shoot was obtained in raspberry cultivars and selection studied. Given the low variability of the number of shoots per meter, yield per unit land area is in excellent agreement with yield per shoot. Therefore, analysis of variance of yield per meter and yield per unit land area, as well as differences among cultivars, years and interaction means (Fig. 3b) are largely in agreement with the results obtained for yield per shoot. Minor inconsistencies in differences among cultivars in some years were the result of slight differences in the number of shoots per meter or unit land area.

Both yield and its variability in cultivars and selection studied may account for their extensive growing under certain agro-environmental conditions. Low variability of the selection K 81-6 compared to the other cultivars and given the yield in extremely dry season 2003 indicated the potential of the selection K 81-6 for growing under less favourable growing conditions. Yield of cv. Willamette was significantly higher in all observed years (except for the selection K 81-6 in the third year) than in the other cultivars. However, high variability of this cultivar in terms of yield suggests caution when recommending this cultivar for cultivation under certain climatic and soil conditions.

As for the percentage of underdeveloped, misshapen berries, analysis of variance showed significant differences among cultivars and years, indicating that the expression of this trait might be highly influenced by environmental factors. A significantly higher rate of underdeveloped, misshapen berries compared to control was recorded in cv. Latham, while among the other cultivars and control no significant differences were observed. This phenomenon in cv. Latham can be explained by its latest flowering time whereby this phenophase mainly coincided with periods of high temperatures and relatively low humidity. This resulted in poor fertilization in this year, and higher percentage of underdeveloped, misshapen fruits accordingly. To confirm the statement, in the third year, which was characterized by extremely high temperatures and low humidity during flowering phenophase and fertilization periods, a significantly higher percentage of underdeveloped and misshapen fruits were observed in all cultivars and selection studied, compared to the other years.

CONCLUSIONS

As a cultivar trait, yield is significantly affected by agro-environmental and meteorological condi-

tions, and their impact is highest in years with temperature extremes. Under environmental conditions of western Serbia, cvs Willamette and Meeker were the most productive, while cv. Latham had the poorest performance in all observed years, which questions the efficiency of its production. Cv. Tulameen and K 81-6 had larger fruits than cv. Willamette, whereas fruits were smaller in cvs Meeker and Latham.

The greatest number of drupelets was recorded in K 81-6, and the lowest in cv. Latham, whereas cvs Tulameen and Latham had the highest and lowest seed mass, respectively. Significantly higher seed mass in cultivars and selection studied was recorded in the third and first years.

Cv. Willamette had the highest average number of shoots per meter as well as total number of shoots per hectare, whereas K 81-6 and cv. Tulameen had the poorest performance in this respect.

The highest yield per shoot, meter and unit land area was recorded in control cultivar, and the lowest in cv. Latham, which also had the highest percentage of misshapen fruits primarily in the third year.

The obtained results suggest that environmental conditions of western Serbia are suitable for commercial growing of raspberry cultivars and selection studied, especially for cvs Willamette and Meeker which had the highest yield and fruit quality performance. Cv. Tulameen deserves attention as a cultivar primarily intended for fresh consumption. As a regular cropper, selection K 81-6 can be recommended for growing in less favourable growing conditions for processing or rapid freezing after harvest. This selection and cv. Latham may be of interest in breeding programs as a source of genetic variability.

References

Daubeny A.H., Anderson A., 1991. ''Tulameen" Red Raspberry. HortScience, *26*: 1336–1338.

Duncan D.B., 1955. Multiple range and multiple *F* tests. Biometrics, *11*: 1–42.

Dunnett C.W., 1955. A multiple comparison procedure for comparing several treatments with a control. Journal of the American Statistical Association, *50*: 1096–1121.

Eyduran S.P., Eyduran E., Agaoglu Y.S., 2008. Estimation of fruit weight by cane traits for various raspberries (*Rubus ideaus* L.) cultivars. African Journal of Biotechnology, *7*: 3044–3052.

Hadživuković S., 1991. Statistical Methods in Agricultural and Biological Research. Novi Sad, Faculty of Agriculture: 634. (in Serbian)

Joublan J.P., Banados P., Marchant A., 2002. Adaptacion y comportamiento de cultivares de frambueso en la provincia de Ñuble (Behavior of raspberry cultivars in the province of Ñuble). Agro sur, *30*: 15–27.

Kempler C., Daubeny A. H., Harding B, Finn C.E., 2005. 'Esquimalt' red raspberry. HortScience, *40*: 2192–2194.

Koron D., 2004. Testing of new raspberry varieties in Slovenia. Jugoslovensko voćarstvo, *38*: 67–72.

Leposavić A., Cerović R., 2009. Climate change and small fruits production in the Republic of Serbia. Acta Horticulturae (ISHS) 838: 55–58.

Marinkovic D., Djurovic S., Markovic S., Kempler C., 2008. Response of seven red raspberry cultivars to the environmental conditions of northern Serbia. Journal of the American Pomological Society, *62*: 178–184.

Milutinović M., Stanisavljević M., Tešović Ž., Nenadić D., Dragojlović D., 1993. Novi Jugoslovenski sortiment maline i kupine (New raspberry and blackberry varieties in Yugoslavia). Jugoslovensko voćarstvo, *27*: 97–104.

Moore P.P., 1993. Variation in drupelet number and drupelet weight among raspberry clones in Washington. Acta Horticulturae (ISHS) 352: 405–412.

Nenadić D., 1975. Odnos težine plodova u nekih sorti maline (Fruit weight in different raspberry cultivars). Jugoslovensko voćarstvo, *33-34*: 133–136.

Petrovic S., Leposavic A., 2011. Raspberry – New technologies of cultivation, preservation and processing. Čačak, Fruit Research Institute: 230. (in Serbian)

Veljković B., Leposavić A., Petrović S., 2010. Implementation of quality standards in raspberry production and processing. Journal of Mountain Agriculture on the Balkans, *13*: 778–801.

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