ISSN 1644-0692
www.acta.media.pl

ACTA SCIENTIARUM POLONORUM *Acta Sci. Pol. Hortorum Cultus, 15(5) 2016, 3-14*

FIELD PERFORMANCE OF MICROPROPAGATED *Rubus* SPECIES

Aleksandar Leposavić[1], Djurdjina Ružić[1], Žaklina Karaklajić-Stajić[1], Radosav Cerović[2], Tatjana Vujović[1], Edward Żurawicz[3], Olga Mitrović[1]

[1] Fruit Research Institute, Čačak, Republic of Serbia

[2] Innovation Center, Faculty of Technology and Metallurgy, Belgrade, Republic of Serbia

[3] Research Institute of Horticulture, Skierniewice, Poland

Abstract. The objective of this study was to test yield and fruit quality of the red raspberry 'Meeker' and the blackberry 'Čačanska Bestrna' propagated using the standard method (ST) and *in vitro*, by tissue culture (TC). The monitored parameters included the total number of canes, cane number per one metre of the planted row, yield per cane (raspberry) or per bush (blackberry) and total yield. Monitoring fruit quality parameters included the weight and dimensions of fruit, the number, weight and dimensions of individual drupelets and weight of drupelet seeds. No significant differences were determined either for the total number of canes and/or the cane number per row metre in plants originating from both types of planting material in both genotypes. Significant differences were observed to the advantage of the raspberry ST plants, in the total yield, as well as the fruit weight in the blackberry ST plants. A significantly higher weight of drupelet seeds was observed in TC plants of both genotypes. Concerning the organoleptic assessment of fruits, no significant differences were recorded between fruits coming from ST and TC plants.

Key words: raspberry, blackberry, planting material, yield, fruit quality

INTRODUCTION

For many years, Poland has been the leading producer of red raspberry (*Rubus idaeus* L.) in the world. According to the Central Statistical Office (GUS), 120,000 tonnes of

Corresponding author: Djurdjina Ružić, Fruit Research Institute, Čačak, Republic of Serbia, e-mail: djinaruzic@gmail.com

the fruit was collected in this country in 2013 [Lewandowski et al. 2015]. Republic of Serbia with the annual output of 65,000 tonnes, is the second largest world producer of raspberries [Leposavić et al. 2015]. About 50 thousand tonnes of the fruit comes from Chile, 13 thousand tonnes from the United Kingdom, 11 thousand tonnes from France, and 10 thousand tonnes from China [Lewandowski et al. 2015].

Poland's position has been strengthened by the introduction into cultivation of new Polish varieties resulting from the breeding programme conducted for over thirty years by the Research Institute of Horticulture in Skierniewice [Lewandowski et al. 2015].

However, the red raspberry is a most commonly produced berry fruit in Western Serbia, where the most typically grown cultivars are 'Willamette' (92%) and 'Meeker' (5%). The other cultivars ('Tulameen', 'Glen Ample', 'Polana' and 'Polka') occupy 3% of the cultivated area [Leposavić et al. 2013].

The Republic of Serbia is the leading producer of blackberry in Europe, and is the world's fourth blackberry producer [Strik et al. 2007]. The most commonly grown cultivar is 'Čačanska Bestrna' (more than 70% of all cultivars). Other cultivars such as 'Thornfree', 'Loch Ness', 'Black Satin', 'Dirksen Thornless' and others, are grown to a much smaller extent [Cerović and Leposavić 2011].

The majority of orchards have been set up using the material propagated from commercial orchards, resulting in low yield, poorer fruit quality and short productive life of most of the raspberry and blackberry plantings despite the Law on Seeds and Planting Material [Official Gazette RS No. 101/2005] which prohibits the use of planting material produced in this manner. The basic precondition therefore for an effective and cost-efficient production is to use true-to-type, healthy planting material produced in nurseries exclusively intended for the propagation of the planting material.

The *in vitro* propagation by tissue culture as a method of vegetative propagation of plants/fruits offers many advantages such as fast propagation of uniform clones, obtaining a large number of plants from a single initial explant in short time, obtaining healthy planting material, and the possibility of the year-round production in laboratory conditions [Ružić and Lazić 2006]. The impact of many factors on the *in vitro* micropropagation of raspberries and blackberries was studied [Ružić and Cerović 1998, Tsao and Reed 2002, Zawadzka and Orlikowska 2006, Zawadzka and Orlikowska 2009, Isac et al. 2009, Ružić et al. 2009, etc.].

Due to a possible occurrence of genetic variability that on one side may be determined by genetic specificity, and on the other by the cumulative action of plant growth regulators used in micropropagation (especially cytokinins) for a prolonged time in subculturing, it is necessary to secure longer monitoring of the *ex vitro* cultures [Bite and Petrevica 2002]. A particularly strong impact on variability has a number of subcultures. To avoid this problem, the international certification scheme for the *Rubus* species strictly limits the maximum number of subcultures to 10 [EPPO 2009].

Research projects into behavioural patterns of the *ex vitro* plants/fruits are very important. The following general phenomena have been observed in fruit species originating from tissue culture: higher vigour and yield, sporadic occurrence of juvenility and a slightly larger fruit weight [Velchev and Toshkov 2005, Georgieva et al. 2009, Gantait et al. 2010]. These phenomena have been observed in the research focusing on the plum cultivar 'Stanley' [Popov 1993].

The objectives of the research reported here was to asses a potential of using *in vitro* micropropagation in the mass production of raspberry 'Meeker' and blackberry 'Čačanska Bestrna' aiming at obtaining healthy, genetically stable, physiologically uniform and true-to-type planting material, in comparison to conventionally propagated material.

MATERIALS AND METHODS

Plant material, experiment design, parameters monitored. The investigation was conducted over a three-year period, 2011−2013. The experimental orchard with red raspberry 'Meeker' and blackberry 'Čačanska Bestrna' was established at the 'Čačak' facility of the Fruit Research Institute in Čačak in 2010 (43°53.654' North latitude and 20°20.619' East longitude, altitude of 245 m above the sea level). The terrain on which the orchard was set up is flat, and the rows were positioned along North-South orientation. The soil is of the alluvial type (pH 6.7; low humus content – 2.65%; high phosphorus level – 15 mg·100 g^{-1} dry soil; high potassium level – 20.4 mg·100 g^{-1} dry soil).

The orchard was established using planting material of 'Meeker' and 'Čačanska Bestrna', propagated by the standard method (ST plants) [Leposavić et al. 2003] and by *in vitro* tissue culture (TC plants) [Ružić et al. 2009]. Both types of plant material were planted comparatively using the block system, with the 3 × 0.33 m planting distance for the raspberry and 3 × 1.5 m planting distance for the blackberry. The orchard, which has an area of 180 m^2, is covered with stabilised UV net and equipped with a drip irrigation system. The planting system that was applied was the espalier system, as the most superior and most commonly used system for growing raspberry and blackberry in the conditions of the Republic of Serbia [Leposavić et al. 2013].

Maintenance of the plots followed the standard agro and pomo-technical measures. The fruit-bearing canes were treated in the spring, when they were first selected and tied, before they were shortened to the height of two buds above the supporting wire, i.e. at a height of 170−175 cm. The number of the tied canes of raspberry and blackberry was determined by counting in four repetitions, for each plant material type. The yield data were collected by measuring all of the picked fruits in a sample comprising 20 marked canes, from the beginning (average 14th June – raspberry; 17th July – blackberry) until the end (average 16th July – raspberry; 30th August – blackberry) of the harvest. The yield per unit of area was calculated multiplying the yield per cane (kg) by the total number of canes per unit of area (kg·ha^{-1}) in raspberry. As regards blackberry, the yield per unit of area was calculated multiplying the yield per bush (3–5 bearing canes per bush) by the total number of bushes (2.222) per unit of area (kg·ha^{-1}).

Over the season examined, fruits were picked at commercial maturity stage in three different terms (beginning, middle and the end of harvest season). Pomological parameters included the fruit weight and dimensions, as well as the number, weight and dimensions of individual drupelets and the weight of the drupelet seeds. The dry matter was determined by drying the fruit in a laboratory dryer Sperimatik SP 11 (Instrumentaria, Zagreb, Croatia), at 105°C and 101.3 kPa pressure, while the content of the soluble solids was determined by manual refractometer Carl Zeiss 3828 (Carl Zeiss, München, Germany).

A sensory analysis was conducted in order to assess the organoleptic features of the fresh fruits. Fruits sampling (25 fruits per each replication) involved three harvest stages previously described. Sensory analyses were carried out by a panel of five judges trained to assess fruit attributes, using the point system for the appearance (0−5), taste (0−8), aroma (0−2) and consistency (0−5), with the maximum score of 20. Results presented in Tables 3–8 are means from three sampling terms.

Statistical analysis. All tests were performed in triplicate and the results are presented as mean values. Differences between mean values were compared by LSD test in two-way analysis of variance (ANOVA) using MSTAT-C statistical computer package (Michigan State University, East Lansing, MI, USA). Differences with P values of > 0.05 were considered insignificant.

RESULTS AND DISCUSSION

Results concerning the number of mature canes at the end of the vegetation, the number of fruit-bearing canes per row metre and the total number of canes per hectare, presented in Table 1 and Table 2 show that there were no significant differences between the ST and TC raspberry and blackberry plants.

Table 1. Number of canes and yield parameters of raspberry cultivar 'Meeker'

	Treatment		No. of mature canes/row meter (end of vegetation)	Average no. of bearing canes/row meter	Total no. of bearing canes/ha	Yield/cane (kg)	Total yield (kg ha^{-1})
Type of planting material (A)	ST		11.8	5.6	18.860	0.43	8.244 a
	TC		11.9	5.4	18.497	0.38	7.082 b
Year (B)	2011		12.5	5.5	18.197 b	0.33 b	6.130 c
	2012		11.9	5.4	17.738 b	0.53 a	9.465 a
	2013		11.3	5.6	20.100 a	0.39 b	7.906 b
A × B	2011	ST	12.7	5.5	18.230	0.36 b	6.677
		TC	12.3	5.5	18.165	0.31 b	5.582
	2012	ST	12.0	5.5	18.150	0.54 a	9.922
		TC	11.8	5.3	17.325	0.52 a	9.009
	2013	ST	10.8	5.8	20.200	0.42 ab	8.656
		TC	11.8	5.5	20.000	0.35 b	7.156
ANOVA	A		ns	ns	ns	ns	*
	B		ns	ns	*	*	*
	A × B		ns	ns	ns	*	ns

Values within each column followed by the same letter are not significantly different at the P ≤ 0.05 by LSD test; ns – not significant; ST – standard planting material; TC – tissue culture plants

The relatively small variation interval for the number of fruit-bearing canes per row metre and the total number of canes per hectare are explained by the applied pomo-

technical treatment, i.e. the fruit-bearing canes in both fruit species are selected in the spring, at the moment of bud swelling. According to Leposavić et al. [2015], tying of frost damaged, non-productive canes is avoided in this way.

Table 2. Number of canes and yield parameters of blackberry cultivar 'Čačanska Bestrna'

	Treatment		No. of mature canes/row meter (end of vegetation)	Average no. of bearing canes/row meter	Total no. of bearing canes/ha	Yield/bush (kg)	Total yield (kg ha^{-1})
Type of planting material (A)	ST		5.5	4.5	14.571	7.01	15.578
	TC		6.1	4.8	15.173	6.74	14.983
Year (B)	2011		4.8 b	4.3	14.165	5.69 c	12.650 c
	2012		5.5 b	4.5	14.850	7.25 b	16.107 b
	2013		7.0 a	5.1	15.600	8.62 a	19.166 a
A × B	2011	ST	4.7	4.2	13.887	6.01 c	13.373 c
		TC	5.0	4.3	14.442	5.20 c	11.565 c
	2012	ST	5.0	4.3	14.025	7.43 b	16.507 b
		TC	6.0	4.8	15.675	7.07 b	15.707 b
	2013	ST	6.8	5.0	15.800	7.97 b	17.719 b
		TC	7.3	5.3	15.400	9.28 a	20.612 a
ANOVA	A		ns	ns	ns	ns	ns
	B		*	ns	ns	*	*
	A × B		ns	ns	ns	*	*

Values within each column followed by the same letter are not significantly different at the $P \leq 0.05$ by LSD test; ns – not significant; ST – standard planting material; TC – tissue culture plants

With the exception of the yield per cane, the yield per unit of area of the ST raspberry was significantly higher when compared to the TC raspberry, which is contrary to the results obtained by Bite and Petrevica [2002], examining the yield and fruit characteristics of the 'Norna' raspberry propagated using the standard and *in vitro* methods (tab. 1). On the other hand, no differences in the yield were observed in blackberry (tab. 2). In their study of the *ex vitro* performance of certain raspberry cultivars and hybrids, Velchev and Toshkov [2005] concluded that the TC plants typically had a higher yield and a greater fruit weight, the finding also supported by Georgieva et al. [2009]. Also, the *in vitro* propagated strawberry plants exhibited significantly more vigourous morphological growth and earlier flower induction when compared to plants propagated through the runners [Gantait et al. 2010]. Recently research published by Żebrowska et al. [2015] showed that in spite of the phenotypic changes observed in strawberry plants derived from *in vitro* culture, their agronomic value was equal or superior in comparison to conventionally propagated plants. However, the 'Stanley' plum originating from TC demonstrated a lower yield and slightly smaller fruits then ST plants [Popov 1993].

Significant differences in the yields per cane (raspberry) or per bush (blackberry) and per unit of area were also observed in relation to the growing season, in both types of the material in both species. The highest yield was recorded in the second (raspberry) and third (blackberry), whereas the lowest was observed in the first year. The low yield in the first year was expected, given the fact that in their first fruit-bearing season, nei-

ther raspberry nor blackberry attains full productivity due to the insufficiently developed root system and the canes.

The collected data related to the morphometric characteristics of the fruits are shown in Tables 3 and 4.

Table 3. Morphometric characteristics of fruits in raspberry cultivar 'Meeker'

	Treatment		Fruit weight (g)	Fruit dimensions (mm)		
				length	width	thickness
Type of planting material (A)	ST		3.11	17.45	18.31	16.72
	TC		3.04	17.90	18.17	16.55
Year (B)	2011		2.52 c	16.49 b	17.00 b	15.10 b
	2012		3.07 b	16.60 ab	17.23 ab	15.88 ab
	2013		3.82 a	20.33 a	20.92 a	19.43 a
A × B	2011	ST	2.53	16.20	16.80	15.10
		TC	2.50	16.83	17.20	15.10
	2012	ST	3.16	16.54	17.46	16.09
		TC	2.98	16.66	16.99	15.67
	2013	ST	3.83	20.09	21.17	19.51
		TC	3.81	20.57	20.66	19.35
ANOVA	A		ns	ns	ns	ns
	B		*	*	*	*
	A × B		ns	ns	ns	ns

Values within each column followed by the same letter are not significantly different at the $P \leq 0.05$ by LSD test; ns – not significant; ST – standard planting material; TC – tissue culture plants

Table 4. Morphometric characteristics of fruits in blackberry cultivar 'Čačanska Bestrna'

	Treatment		Fruit weight (g)	Fruit dimensions (mm)		
				length	width	thickness
Type of planting material (A)	ST		7.87 a	24.47	20.77 a	19.94 a
	TC		7.38 b	25.07	19.91 b	19.35 b
Year (B)	2011		6.52 b	21.67 c	18.58 c	17.63
	2012		9.38 a	29.68 a	22.18 a	21.67
	2013		6.93 ab	25.11 b	20.80 b	20.31
A × B	2011	ST	6.54	21.67	18.99	17.89
		TC	6.50	21.67	18.17	17.37
	2012	ST	9.67	29.97	22.17	21.72
		TC	9.08	29.39	22.19	21.61
	2013	ST	7.53	25.55	21.99	21.06
		TC	6.33	24.66	19.61	19.55
ANOVA	A		*	ns	*	*
	B		*	*	*	ns
	A × B		ns	ns	ns	ns

Values within each column followed by the same letter are not significantly different at the $P \leq 0.05$ by LSD test; ns – not significant; ST – standard planting material; TC – tissue culture plants

Obtained results indicate that no major differences between the ST and TC raspberry plants were determined regarding the fruit weight and its dimensions. On the contrary, the ST blackberry fruits weighed significantly more in comparison to the fruits harvested from TC propagated plants.

Significantly heavier raspberry fruit were observed in the second and third year of cultivation in comparison to the first growing season. As for the blackberry, the highest fruit weight was recorded in the second year, whereas the lowest in the first.

During the trial, no malformations of fruits were found in the TC plants of either fruit species, which is additionally confirmed by Ružić et al. [2013] in support of the stability of the plant material propagated using this method.

No differences were observed in the number of drupelets in fruits between the two types of material in both fruit species (tabs 5 and 6). The ST raspberries recorded a significantly larger diameter of the drupelets compared to fruit collected from TC propagated plants, whereas the fruit collected from ST blackberries had a significantly larger height of the drupelets than the TC blackberries. Finally, drupelets seeds of both the TC raspberries and blackberries were considerably heavier than those coming from ST plants.

No significant differences were observed between the ST and TC plants of both fruit species regarding the total dry matter content and soluble solids (tab. 7). Regardless of the origin of plants, differences in the content of these matters were observed in the blackberry depending on the year of growth, with the lowest values being recorded in the third year. Thus, the values of the total dry matter in blackberry were reversely proportional to the amount of yield (tabs 2 and 7).

Table 5. Number and properties of drupelets in raspberry cultivar 'Meeker'

	Treatment		Number within a fruit	Height (mm)	Diameter (mm)	Shape factor	Weight of drupelet seeds[1] (g)
Type of planting material (A)	ST		96.02	4.96	3.43 a	1.51	2.05 b
	TC		94.97	4.87	3.21 b	1.58	2.29 a
Year (B)	2011		92.09 b	4.73 ab	2.86 b	1.69 a	2.15
	2012		93.45 ab	4.62 b	3.02 ab	1.58 a	2.12
	2013		102.10 a	5.47 a	4.24 a	1.31 b	2.23
A × B	2011	ST	89.83	4.91	2.88	1.76 a	1.93
		TC	94.35	4.54	2.84	1.63 abc	2.37
	2012	ST	97.11	4.56	3.28	1.41 bc	2.05
		TC	89.77	4.68	2.75	1.75 ab	2.20
	2013	ST	103.20	5.42	4.33	1.27 d	2.16
		TC	101.00	5.51	4.16	1.34 dc	2.29
ANOVA	A		ns	ns	*	ns	*
	B		*	*	*	*	ns
	A × B		ns	ns	ns	*	ns

Values within each column followed by the same letter are not significantly different at the $P \leq 0.05$ by LSD test; ns – not significant. ST – standard planting material; TC – tissue culture plants; [1] – weight of drupelet seeds is mean value of weight of 100 drupelet seeds from 3 repetitions

Table 6. Number and properties of druplets in blackberry cultivar 'Čačanska Bestrna'

	Treatment		Number within a fruit	Height (mm)	Diameter (mm)	Shape factor	Weight of drupelet seeds[1] (g)
Type of planting material (A)	ST		91.52	6.66 a	4.59	1.50	0.13 b
	TC		89.67	6.10 b	4.33	1.47	0.15 a
Year (B)	2011		84.74 b	6.33 c	4.26 ab	1.55	0.13 b
	2012		98.17 a	6.84 b	4.93 a	1.43	0.14 b
	2013		89.70 ab	5.71 a	4.07 b	1.44	0.15 a
A × B	2011	ST	82.53	6.29 b	4.35	1.51	0.11 d
		TC	86.95	6.38 b	4.18	1.59	0.15 ab
	2012	ST	101.07	7.29 a	5.11	1.44	0.13 c
		TC	95.27	6.39 b	4.74	1.41	0.14 b
	2013	ST	93.60	6.34 b	4.20	1.56	0.15 ab
		TC	85.80	5.08 c	3.94	1.31	0.16 a
ANOVA	A		ns	*	ns	ns	*
	B		*	*	*	ns	*
	A × B		ns	*	ns	ns	*

Values within each column followed by the same letter are not significantly different at the $P \leq 0.05$ by LSD test; ns – not significant; ST – standard planting material; TC – tissue culture plants; [1] – weight of drupelet seeds is mean value of weight of 100 drupelet seeds from 3 repetitions

Table 7. Chemical parameters of fresh fruit quality of raspberry cultivar 'Meeker' and blackberry cultivar 'Čačanska Bestrna'

	Treatment		'Meeker'		'Čačanska Bestrna'	
			total dry matter	soluble solids	total dry matter	soluble solids
			%			
Type of planting material (A)	ST		18.11	12.72	14.96	9.70
	TC		18.21	13.34	14.15	9.52
Year (B)	2011		17.75	13.23	15.15 a	10.47 a
	2012		18.85	12.86	14.99 a	9.67 b
	2013		17.89	13.00	13.52 b	8.70 c
A × B	2011	ST	17.76	13.13	14.65 ab	10.50
		TC	17.75	13.33	15.66 a	10.43
	2012	ST	18.90	12.45	16.00 a	9.87
		TC	18.80	13.27	13.98 ab	9.47
	2013	ST	17.69	12.57	14.22 ab	8.73
		TC	18.08	13.43	12.82 b	8.67
ANOVA	A		ns	ns	ns	ns
	B		ns	ns	*	*
	A × B		ns	ns	*	ns

Values within each column followed by the same letter are insignificantly different at the $P \leq 0.05$ by LSD test; ns – not significant. ST – standard planting material; TC – tissue culture plants

Based on the assessment of the appearance, flavour, aroma and consistency of the fresh fruits, although higher scores were awarded to the raspberry and blackberry plants propagated using the standard method, these differences were not significant (tab. 8).

Table 8. Organoleptic quality of fresh fruits of raspberry cultivar 'Meeker' and blackberry cultivar 'Čačanska Bestrna' (2011–2013)

Cultivar/type of planting material		Appearance (0–8)	Taste (0–6)	Aroma (0–2)	Consistency of fruits (0–4)	Total (0–20)
'Meeker'	ST	6.7 ±0.4	5.2 ±0.3	1.4 ±0.1	3.2 ±0.3	16.5 ±1.0
	TC	5.8 ±1.0	4.8 ±0.8	1.3 ±0.2	3.1 ±0.2	15.1 ±2.1
'Čačanska Bestrna'	ST	6.2 ±1.0	4.0 ±1.0	1.4 ±0.2	2.8 ±0.7	14.3 ±2.9
	TC	5.8 ±1.2	4.0 ±1.0	1.2 ±0.2	2.8 ±0.7	13.8 ±3.0
		ns	ns	ns	ns	ns

Data within each column were analysed by ANOVA; ns – not significant; ST – standard planting material; TC – tissue culture plants

A number of reports describe differences in the yield and fruit characteristics of some fruit cultivars propagated using the standard and *in vitro* methods, usually in favor of the TC [Ružić and Cerović 2001, Bite and Petrevica 2002, Żebrowska et al. 2015], but also in ST plants [Cerović and Ružić 1989, Popov 1993].

In terms of micropropagated plum 'Požegača', a significantly higher number of fruit set and yield per tree were observed [Ružić and Cerović 2001]. The results obtained with micropropagated sour cherry 'Šumadinka' showed only small differences in fruit weight between TC and ST plants, often in favor of TC plants, whereas biochemical indicators were in favor of ST plants [Ružić et al. 1991]. Cerović and Ružić [1989] found that pomological characteristics of TC strawberries 'Senga Sengana' and 'Čačanska Rana' were lower then those of ST in the first two growing seasons, which can strongly affect profitability of the commercial production. It is obvious that different plant species propagated *in vitro* showed different behaviour *ex vitro*, due to genetic specificity.

There is a possibility that TC plants may show better indicators after a certain number of years, i.e. when they have reached full maturity, by which time it is expected that any impact made by the plant regulators residues will have decreased or disappeared.

The obtained results indicate that this method can be used, although some examined parameters revealed better values in ST plants, that were statistically significant compared with the TC plants. Also, our finding have shown that such parameters as appearance, flavour, aroma and texture of the fresh fruits were not significantly different.

Knowing that the worldwide production of these types of materials is based on the *in vitro* micropropagation, it is assumed that by studying *ex vitro* behaviour of *in vitro* plants it would be possible to reduce the import of planting material and meet the demands of individual producers.

CONCLUSIONS

Research on the field performance of micropropagated fruit species is important for evaluating the potential of the large-scale tissue culture propagation of the planting material. Many advantages of the *in vitro* propagation by tissue culture, primarily the fast and limitless production and the possibility of attaining a year-round production of plants, supported by the fact that no deformities of the fruits were detected, and with the same quality of fruits, absolutely justify the recommendation that planting material propagated in this manner ought to be used on a wider scale for establishment of raspberry and blackberry commercial orchards. However, a longer study on performance of TC plants is required to make sure that *in vitro* propagation method can be safely recommended for the propagation of raspberry and blackberry cultivars.

ACKNOWLEDGEMENTS

The study was financed from the funds of the EU FP7 KBBE-2010-4, Project No. 265942 (The sustainable improvement of European berry production, quality and nutritional value in changing environment: Strawberries, Currants, Blackberries, Blueberries and Raspberries – EUBerry, Subcontarct: WP2, Sub-task 2.1.1. 'Evaluation of physiological properties, yield parameters, organoleptic quality and chemical analyses of the fruits and disease resistance of raspberry and blackberry genotypes propagated with the standard technique and *in vitro*').

Authors kindly thank to prof. dr Kris Pruski (Department of Plant & Animal Sciences, Dalhousie University, Faculty of Agriculture, Canada) for all helpful suggestions during the manuscript writing.

REFERENCES

Bite, A., Petrevica, L. (2002). The influence of *in vitro* propagation on the field behavior of red raspberry variety 'Norna'. Acta Hortic., 585, 615–619.

Cerović, R., Ružić, Đ. (1989). Micropropagation of strawberry cvs Čačanska rana and Senga Sengana. Pomological-biochemical characteristics of micropropagated plants. Acta Hortic., 265, 353–358.

Cerović, R., Leposavić, A. (2011). Current state and perspectives of small fruit production in the Republic of Serbia. J. Mt. Agric. Balk., 14, 1156–1170.

EPPO (2009). Certification scheme for *Rubus*. PM 4/10(2) EPPO Bulletin, 39, 271–277. doi: 10.1111/j.1365-2338.2009.02308.

Gantait, S., Mandal, N., Prakash, K.D. (2010). Field performance and molecular evaluation of micropropagated strawberry. Recent Res. Sci. Technol., 2(5), 12–16.

Georgieva, M., Kondakova, V., Dragoyski, K., Georgiev, D., Naydenova, G. (2009). Comparative study of raspberry cv. Balgarski Rubin propagated by classical and *in vitro* methods. J. Pomology, 43, 81–86.

Isac, V., Popescu, A. (2009). Protocol for *in vitro* micropropagation of raspberry and plant regeneration by organogenesis. In: A guide to some *in vitro* techniques – Small fruits, Mezzetti, B., Ružić, Đ., Gajdosova, A. (eds.), COST Action 863, Brussels (Belgium), 14–23.

Leposavić, A., Blagojević, M., Rakićević, M. (2003). Propagation of blackberry cv Čačanska Bestrna by softwood cuttings. Cont. Agri., 52, 85–87.

Leposavić, A., Đurović, D., Keserović, Z., Popović, B., Mitrović, O., Miletić, N., Magazin, N. (2013). Evaluation of raspberry cultivars grown in the western Serbia region. Hortic. Sci. (Prague), 40, 1–7 .

Leposavić, A., Đurović, D., Keserović, Z., Jevremović, D. (2015). Vegetative and yield potential of cultivars and selection of raspberry cultivated in conditions of Western Serbia. Bulg. J. Agric. Sci., 21, 153–159.

Lewandowski, M., Żurawicz, E., Pruski, K. (2015). The effects of the growing season extension on Polish primocane-fruiting raspberry cultivars. Hortic. Sci. (Prague), 42, 203–208.

Official Gazette RS No. 54/93, 35/94, 43/94; Official Gazette RS No. 135/04; 18/05 and 101/2005: Law on seed and planting material.

Popov, S. (1993). Behaviour of the micropropagated Stanley plum cultivar in the plantation. Biotechnol. Biotec. Eq., 7, 21–23.

Ružić, Đ., Cerović, R., Nikolić, M. (1991). Field performance of micropropagated sour cherry cv. Šumadinka. J. Pomology, 25, 19–26. (In Serbian).

Ružić, Đ., Cerović, R. (1998). A rapid method of blackberry propagation. Acta Agric. Serb., 6, 55–61.

Ružić, Đ., Cerović, R. (2001). Field performance of micropropagated plum cv. Požegača. Acta Agric. Serb., 11, 3–9.

Ružić, Đ., Lazić, T. (2006). Micropropagation as means of rapid multiplication of newly developed blackberry and black currant cultivars. Agric. Conspec. Sci., 71(4), 149–153.

Ružić, Đ., Vujović, T., Cerović, R. (2009). Protocol for *in vitro* micropropagation of blackberry, and plant regeneration by organogenesis. In: A guide to some *in vitro* techniques – Small fruits, Mezzetti, B., Ružić, Đ., Gajdosova, A. (eds.). COST Action 863, Brussels (Belgium), 24–29.

Ružić, Đ., Leposavić, A., Cerović, R., Karaklajić-Stajić, Ž., Vujović, T., Miletić, N., Žurawicz, E. (2013). Physiological properties of raspberry and blackberry propagated by *in vitro* micropropagation and standard techniques. J. Pomology, 47, 55–61. (In Serbian).

Strik, B.C., Clark, J.R., Finn, C.E., Bañados, P. (2007). Worldwide production of blackberries, 1995 to 2005 and predictions for growth. HortTechnol., 17, 205–213.

Tsao, W.V., Reed, B.M. (2002). Gelling agents, silver nitrate, and sequestrene iron influence adventitious shoot and callus formation from *Rubus* leaves. In Vitro Cell. Dev. Biol. Pl., 38, 29–32.

Velchev, V., Toshkov, A. (2005). Reproductive performances of micropropagated raspberry plants. J. Pomology, 39, 25–32.

Zawadzka, M., Orlikowska, T. (2006). The influence of FeEDDHA in red raspberry cultures during shoot multiplication and adventitious regeneration from leaf explants. Plant Cell Tiss. Org. Cult., 85, 145–149.

Zawadzka, M., Orlikowska, T. (2009). Influence of FeEDDHA on *in vitro* rooting and acclimatisation of red raspberry (*Rubus ideaus* L.) in peat and vermiculite. J. Hort. Sci. Biotechnol., 84, 599–603.

Żebrowska, J., Kaczmarska, E., Gawroński, J. (2015). Comparative studies on the agronomic value of *in vitro* and conventionally propagated strawberry (*Fragaria* × *ananassa* Duch.) plants. Acta Sci. Pol. Hortorum Cultus, 14(3), 25–35.

WYDAJNOŚĆ POLOWA MIKROROZMNAŻANEGO GATUNKU *Rubus*

Streszczenie. Celem badania było sprawdzenie jakości plonu i owoców czerwonej maliny 'Meeker' i jeżyny 'Čačanska Bestrna' rozmnażanych przy użyciu standardowej metody (ST) oraz *in vitro*, za pomocą hodowli adherentnej (TC). Monitorowanymi parametrami była całkowita liczba sadzonek długopędowych, liczba sadzonek na metrze, plon z sadzonki (malina) i plon z krzewu (jeżyna) oraz plon całkowity. Monitorowanie parametrów jakości owoców obejmowało masę i wymiary owoców, liczbę, masę i wymiary poszczególnych pestek oraz masę nasion. Nie stwierdzono żadnych istotnych różnic w całkowitej liczbie sadzonek ani w liczbie sadzonek na metr rzędu u roślin pochodzących z obydwu typów materiału sadzeniowego u obu genotypów. Zaobserwowano istotne różnice na korzyść roślin malin ST jeśli chodzi o plon całkowity, a także masę owoców roślin jeżyny ST. Istotnie większą masę nasion stwierdzono dla roślin TC obu genotypów. W ocenie organoleptycznej nie stwierdzono żadnych istotnych różnic między owocami pochodzącymi z roślin ST i TC.

Słowa kluczowe: malina, jeżyna, materiał sadzeniowy, plon, jakość owoców

Accepted for print: 27.04.2016

For citation: Leposavić, A., Ružić, D., Karaklajić-Stajić, Ž., Cerović, R., Vujović, T., Żurawicz, E., Mitrović, O. (2016). Field performance of micropropagated *Rubus* species. Acta Sci. Pol. Hortorum Cultus, 15(5), 3–14.