

Effect of 6-benzyladenine and gibberellic acid application on productivity and fruit quality of plum cultivar ‘Čačanska Rodna’

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Abstract. Plum production in Serbia is mainly extensive, followed by low and unstable yields per unit of area and small fruits with poor quality. In order to improve production and increase fruit quality, the influence of 6-benzyladenine (BA) and gibberellic acid (GA₃) on fruit yield, size and storability was examined. The experiment was carried out 2016–2017 on cultivar ‘Čačanska Rodna’ grafted on the generative rootstock *Prunus cerasifera* Ehrh. with the *Prunus spinosa* L. as an interstock and vegetative rootstock ‘Wavit’. When the fruit diameter reached 10 mm in average, the following treatments were applied: 50 mg l⁻¹ BA, 100 mg l⁻¹ BA, 200 mg l⁻¹ GA₃ and the untreated control. Fruits were analysed at harvest, after cold-storage at 1 ± 1°C for 28 days (2016) and 20 days (2017) and after three days of shelf-life [28 + 3 (2016) and 20 + 3 (2017)].

BA treatments significantly increase yield and fruit size, while the effect of GA₃ was inconsistent. The highest yield and number of fruits per tree were achieved with the 50 mg l⁻¹ BA in both rootstocks. Yield was increased by 118% at the ‘Wavit’ rootstock and by 66% at *Prunus cerasifera*/*Prunus spinosa* rootstock, compared to the control. The exception was 2017 for the ‘Wavit’ rootstock when the highest yield was achieved in plum trees treated with 100 mg l⁻¹ BA. The colour expressed through chromaticity (C* – hroma) varied between years, rootstock and treatments. During fruit storage, the value of bioyield point decreased significantly. In 2016 storage of plum fruits reduced bioyield point for almost 50%, while in 2017 reduction was around 30%.

Key words: *Prunus domestica* L., ‘Wavit’, *Prunus spinosa*, bioregulators, storage, shelf life

Introduction

Plum (*Prunus domestica* L.) is traditionally grown in Serbia. Plum includes a high number of cultivars that are adapted to different environmental conditions and

enable the distribution over a wide area, which make it a very important fruit species (Blazek, 2004). Serbia is the leading country with 73,316 ha of production area under plums, but with a production of 7.6 t ha⁻¹ it ranks fourth in the world (FAOSTAT, 2021). The ex-

tensive plum production in Serbia together with large number of old cultivars in orchards, leads to low and unstable yields and small fruits with poor quality. Plum cultivar 'Čačanska Rodna' is a domestic cultivar created by crossing the 'Stanley' × 'Požegača' at the Fruit Research Institute in Čačak. 'Čačanska Rodna' is one of the leading plum cultivars with high yields but small fruits (Milošević & Milošević, 2011).

Application of plant bioregulators (PBRs) such as 6-benzyladenine (BA) and gibberellic acid (GA_3) during fruit development can affect tree productivity, fruit ripening and fruit quality, reduced deterioration during storage and thereby increasing the shelf life (Costa, 2012; Kirmani *et al.*, 2013). The synthetic cytokinin, benzyladenine stimulates cell division in the fruit in its early stages of development which affects the final size of the fruit (Stern & Flaishman, 2003). Gibberellic acid is a natural plant hormone that affects plant elongation, flowering, fruit set, production, leaf and fruit aging (Rodrigues *et al.*, 2012; Sharma & Singh, 2009).

Previous studies have determined the influence of BA and GA_3 on yield and fruit quality in pome fruits, but there is very little research in stone fruits, especially plums. Therefore, the aim of the study was to examine the influence of BA and GA_3 , applied in the early stages of plum cultivar 'Čačanska Rodna' fruit development, on the number of fruits per tree and fruit size which are two main factors that have direct influence on yield. Influence of PBRs on fruit color and firmness was also investigated, as these factors determine the degree of maturity.

Material and Methods

The experiment was conducted during the period 2016–2017 at the Experimental field for fruit growing of the Faculty of Agriculture at Rimski Šančevi (45°20'N and 19°50'E, 80 m above sea level), Novi Sad, Serbia. Plum cultivar 'Čačanska Rodna' was grafted on generative rootstock *Prunus cerasifera* Ehrh. with *Prunus spinosa* L. as an interstock and vegetative rootstock 'Wavit' with the planting distance of 4 m × 2 m (1,250 tree ha⁻¹).

Trees were treated with bioregulators when mean fruit diameter reached the size of 10 mm in average. The applied treatments were: 50 mg l⁻¹ BA (Gerba 4LG), 100 mg l⁻¹ BA and 200 mg l⁻¹ GA_3 (L-Gobbi, Italy). Untreated trees served as a control treatment. Field trial was established as a randomized block design. Each treatment replicated five times, with one whole tree per replicate. At the time of harvest the yield for each tree was measured and expressed as a kilogram per hectare (kg ha⁻¹). The number of fruits per tree was calculated as ratio between the yield per tree and the average fruit weight. A sample of 10 fruits was taken from each tree (50 fruits per treatment) and three linear dimensions (length, width and thickness) were measured on each fruit. The geometric mean diameter was calculated by using formula: $D_g = (LWT)^{1/3}$ (Ertekin *et al.*, 2006). Fruit volume was calculated using the formula $4\pi r^3/3$, where $r = [L + W + T]/6$ (Milić *et al.*, 2019).

After measuring the yield and fruit dimensions, a total of 5 kg of the fruits were stored in cooling chamber at 1 ± 1°C and 95 ± 1% RH. Storage of fruits lasted for 28 days in 2016 and 20 days in 2017. After storage one half of stored fruits were analysed while other half were left for another three days, at room temperature (shelf life) after which are those fruits also analysed.

Colour was measured in CIELab system with Chroma Meter CR-400 (Konica Minolta, Japan) and colour measurement was expressed as Chroma (C*) which represent colour intensity. Colour measurements were carried out on plum fruits with intact epicuticular wax coating. Bioyield point – value in N in which 8 mm probe penetrates into the fruit flesh causes irreversible damage, was measured with TA.XTPlus Texture Analyser (Stable Micro Systems, England, UK) with 30 kg load cell. Colour and bioyield point measurements were carried out on 50 plum fruits before, one day after storage period and after shelf life.

Significance of experimental factors application of bioregulators, rootstock and storage on plum fruit was determined by ANOVA ($p \leq 0.01$ and $p \leq 0.05$) followed by Duncan's Multiple Range Test ($p \leq 0.05$). For all calculations STATISTICA 13 software was used (StatSoft Inc., Tulsa, USA).

Results and Discussion

The research has proven that rootstock and bioregulator treatment as the experimental factors are statistically significant effect on the yield and the number of fruits per tree (Tab. 1). In the present research, plum trees treated with BA had higher yields and number of fruits per tree compared to the untreated control. During the whole experimental period yield and number of fruits per tree were significantly higher on ‘Wavit’ rootstock compared to *Prunus cerasifera*/*Prunus spinosa* rootstock in all treatments, including the control treatment. The highest yield and number of fruits per tree on both rootstocks were obtained in the treatment of 50 mg l⁻¹ BA except for trees grafted on ‘Wavit’ in 2017, where the highest yield was observed on trees treated with 100 mg l⁻¹ BA. BA is widely used in apple (Son et al., 2020) and pears (Bound, 2021) for fruit thinning which leads to reduction in the number of fruits per tree and an increase in fruit weight (Milić et al., 2018; Gabardo et al., 2019). However, the use of bioregulators in stone fruit often has an inconsistent response to fruit set and yield (Lenahan et al., 2006; Canli & Pektas, 2015), which is why they do not have wider application. ‘Čačanska Rodna’ is a cultivar that is prone to alternate bearing (Blažek & Pišteková, 2012), and because of that we assume that this charac-

teristic influenced a large difference in the amount of yield between years.

The final fruit size is associated with the density and size of parenchyma cells present in the apple fruit mesocarp (Milić et al., 2017). It was proven that the application of BA in early fruit development results in increased cell division rate and consequently on the increase of the final fruit size at harvest (Canli et al., 2015; Abdel-Mohsen & Kamel, 2015). This potentially can affect fruit size and yield consequently, explaining the effect of 6-benzyladenine in the present research.

Fruit size is determined by geometric mean diameter and fruit volume (Tab. 2). Results obtained in present study showed that rootstock had no effect on fruit size, while application of bioregulator and interaction between main factors (rootstock × treatment) influenced geometric mean diameter and fruit volume in 2016 and 2017, respectively. The smallest fruit size on both rootstocks in 2016 was observed in control trees, while the highest geometric mean diameter and volume had fruits from the trees treated with 100 mg l⁻¹ BA. Previous studies have found that a higher concentration of BA resulted in a higher fruit thinning and fruit size of pear and peach (Barreto et al., 2018; Canli & Pektas, 2015). This was confirmed in 2016, where the 100 mg l⁻¹ BA resulted in a higher fruit thinning,

Tab. 1. Productivity of the ‘Čačanska Rodna’ plum tree treated with 6-benzyladenine and gibberellic acid (2016–2017)

Tab. 1. Produktivnost stabala šljive Čačanska rodna tretiranih sa 6-benziladeninom i giberelinom (2016–2017)

Rootstock Podloga	Treatment Tretmani	Yield/Prinose (kg ha ⁻¹)		Number of fruits per tree Broj plodova po stablu	
		2016	2017	2016	2017
‘Wavit’	50 mg l ⁻¹ BA	19.713 a	20.916 ab	532 a	767 a
	100 mg l ⁻¹ BA	19.605 a	22.416 a	496 a	741 ab
	200 mg l ⁻¹ GA ₃	15.218 b	19.875 ab	403 b	694 ab
	Control/Kontrola	8.966 c	20.833 ab	263 c	704 ab
<i>Prunus cerasifera</i> / <i>Prunus spinosa</i>	50 mg l ⁻¹ BA	9.483 c	20.625 ab	249 cd	704 ab
	100 mg l ⁻¹ BA	6.766 cd	18.458 b	162 de	611 bc
	200 mg l ⁻¹ GA ₃	8.813 c	10.500 c	245 cd	389 d
	Control/Kontrola	4.066 d	12.958 c	112 e	529 c
Rootstock/Podloga (A)		**	**	**	**
Treatment/Tretman (B)		**	**	**	**
A × B		*	**	*	ns

ns – nonsignificant; * Significant at $p \leq 0.05$; **Significant at $p \leq 0.01$; The different letters refer to the significant differences according to the Duncan’s Multiple Range test ($p \leq 0.05$) / ns – nije značajno; * značajno na nivou $p \leq 0,05$; ** značajno na nivou $p \leq 0,01$; Različita slova označavaju statistički značajne razlike na osnovu Dankanovog testa ($p \leq 0,05$)

Tab. 2. Effect of 6-benzyladenine and gibberellic acid on fruit size

Tab. 2. Uticaj 6-benziladenina i giberelina na veličinu ploda

Rootstock <i>Podloga</i>	Treatment <i>Tretmani</i>	Geometric mean diameter <i>Srednji geometrijski prečnik</i> (mm)		Fruit volume <i>Zapremina ploda</i> (cm ³)	
		2016	2017	2016	2017
‘Wavit’	50 mg l ⁻¹ BA	38.0 ab	32.8 bcd	30.0 ab	19.4 b
	100 mg l ⁻¹ BA	38.7 a	33.6 abc	31.6 a	20.9 ab
	200 mg l ⁻¹ GA ₃	38.4 ab	33.8 abc	30.5 a	20.9 ab
	Control/ <i>Kontrola</i>	36.6 b	34.6 a	26.8 bc	22.3 a
<i>Prunus cerasifera</i> /	50 mg l ⁻¹ BA	36.8 b	35.0 a	28.5 abc	23.1 a
<i>Prunus spinosa</i>	100 mg l ⁻¹ BA	38.8 a	34.1 ab	31.4 a	21.5 ab
	200 mg l ⁻¹ GA ₃	37.4 ab	32.3 cd	28.3 abc	19.5 b
	Control/ <i>Kontrola</i>	36.5 b	31.6 d	26.3 c	17.1 c
Rootstock/ <i>Podloga</i> (A)		ns	ns	ns	ns
Treatment/ <i>Tretman</i> (B)		**	ns	**	ns
A × B		ns	**	ns	**

ns – nonsignificant; **Significant at $p \leq 0.01$; The different letters refer to the significant differences according to the Duncan's Multiple Range Test ($p \leq 0.05$) / *ns – nije značajn; ** značajno na nivou $p \leq 0.01$; Različita slova označavaju statistički značajne razlike na osnovu Dankanovog testa ($p \leq 0.05$)*

reduced the number of fruits per tree and at the same time a larger fruit size compared to the 50 mg l⁻¹ BA.

Effects of GA₃ were inconsistent. Gibberellic acid significantly increased yield and number of fruits per tree in 2016 and fruit volume on *Prunus cerasifera*/*Prunus spinosa* rootstock in 2017.

The storage as the factor in both years had an effect on chroma value and consequently on appearance of plum fruit. On the other hand, the factors rootstock and treatment affected the colour intensity of fruits only in 2017. In 2016, the difference in chroma value at harvest could be observed in GA₃ treatment compared to the control. In the same experimental year, 100 mg l⁻¹ BA treatment reduced chroma in fruits grown on ‘Wavit’ rootstock while 50 mg l⁻¹ BA increased chroma value in fruits grown on *Prunus cerasifera*/*Prunus spinosa*. In 2017, the differences in chroma value at harvest were observed only in fruits grown on *Prunus cerasifera*/*Prunus spinosa* rootstock and treated with BA, while on the ‘Wavit’ rootstock there were no statistical differences among treatments. After the storage and shelf life, the difference in chroma compared to the respected control fruits were observed only in 2016 in fruit grown on ‘Wavit’, and treated with 50 mg l⁻¹ BA (Tab. 3). At harvest, chroma values inconsistently affected by bioregulator treatments. After storage and shelf life, chroma values were not

statistically different among treatments. This could be caused by the fact that we took measurements with fruit skin wax cover in contrast to Eroglu & Sen (2015) and Harman & Sen (2016) where differences in chroma values were observed on fruit without wax cover treated with GA.

Bioyield point was influenced by all experimental factors, except the rootstock in the first year of investigation. In 2016, fruits treated with 100 mg l⁻¹ BA and grown on *Prunus cerasifera*/*Prunus spinosa* had reduced bioyield point at harvest compared to the control, while in 2017 fruits grown on the same rootstock and treated with 100 mg l⁻¹ BA and GA₃ increased bioyield point. In 2017, fruit grown on ‘Wavit’ had higher bioyielded point only when treated with 100 mg l⁻¹ BA (Tab. 4). As expected, the bioyield point of plum fruits was significantly reduced after cold storage compared to its values at harvest. After cold storage and shelf life there were no differences observed between bioregulator treated and untreated fruits, with the exception of fruit grown on *Prunus cerasifera*/*Prunus spinosa* and treated with GA₃ in 2016 in which bioyield point was significantly higher. In 2016, the 28 days storage of plum fruits reduced bioyield point for almost 50%, while in 2017 reduction was around 30% for the period of 20 days.

Tab. 3. Effect of 6-benzyladenine and gibberellic acid on chroma C*

Tab. 3. Uticaj 6-benziladenina i giberelina na „chroma C“

Rootstock Podloga	Treatment Tretman	Chroma C*					
		2016			2017		
		0	28+1	28+3	0	20+1	20+3
‘Wavit’	50 mg l ⁻¹ BA	9.57 a-d	7.27 h	8.07 c-h	3.53 k	5.38 gh	6.85 cde
	100 mg l ⁻¹ BA	9.08 c-f	7.37 h	9.37 a-c	4.34 ijk	6.42 def	6.56 de
	200 mg l ⁻¹ GA ₃	8.83 c-g	7.56 gh	9.21 b-c	4.60 hij	4.68 hij	6.46 def
	Control/Kontrola	10.52 ab	7.43 gh	9.57 a-d	4.22 ijk	7.58 bc	7.34 bcd
<i>Prunus cerasifera</i> / <i>Prunus spinosa</i>	50 mg l ⁻¹ BA	10.69 a	8.05 c-h	7.66 gh	5.08 ghi	7.07 cd	5.90 efg
	100 mg l ⁻¹ BA	9.30 b-e	8.30 c-h	7.36 h	5.53 fgh	6.49 def	6.34 def
	200 mg l ⁻¹ GA ₃	9.68 abc	7.57 gh	8.10 c-h	4.26 ijk	8.09 ab	6.65 cde
	Control/Kontrola	8.24 d-h	7.82 fgh	7.06 h	3.93 jk	8.58 a	6.81 cde
Rootstock/Podloga (A)			ns			**	
Treatment/Tretman (B)			ns			**	
Storage/Skladištenje (C)			**			**	

ns – nonsignificant; **Significant at $p \leq 0.01$; The different letters refer to the significant differences according to the Duncan’s Multiple Range Test ($p \leq 0.05$) / ns – nije značajno; ** značajno na nivou $p \leq 0.01$; Različita slova označavaju statistički značajne razlike na osnovu Dankanovog testa ($p \leq 0.05$)

Tab. 4. Effect of 6-benzyladenine and gibberellic acid on bioyield point

Tab. 4. Uticaj 6-benziladenina i giberelina na „bioyield point“

Rootstock Podloga	Treatment Tretman	Biyield Point (N)					
		2016			2017		
		0	28+1	28+3	0	20+1	20+3
‘Wavit’	100 mg l ⁻¹ BA	1259 bc	639 c-h	333 jk	860 bc	418 hi	278 ij
	50 mg l ⁻¹ BA	1450 a	674 efg	306 k	813 bcd	570 fg	279 ij
	200 mg l ⁻¹ GA ₃	1295 abc	739 def	352 ijk	793 bcd	622 efg	328 ij
	Control/Kontrola	1306 ab	512 ghi	313 k	692 def	564 fg	314 ij
<i>Prunus cerasifera</i> / <i>Prunus spinosa</i>	100 mg l ⁻¹ BA	1124 c	557 gh	287 k	1102 a	730 cde	292 ij
	50 mg l ⁻¹ BA	1408 ab	551 gh	243 k	892 b	619 efg	239 j
	200 mg l ⁻¹ GA ₃	1257 bc	898 d	491 hij	1132 a	725 cde	343 ij
	Control/Kontrola	1312 ab	832 de	288 k	900 b	517 gh	311 ij
Rootstock/Podloga (A)			ns			**	
Treatment/Tretman (B)			**			**	
Storage/Skladištenje (C)			**			**	

ns – nonsignificant; **Significant at $p \leq 0.01$; The different letters refer to the significant differences according to the Duncan’s Multiple Range Test ($p \leq 0.05$) / ns – nije značajan; ** značajno na nivou $p \leq 0.01$; Različita slova označavaju statistički značajne razlike na osnovu Dankanovog testa ($p \leq 0.05$)

Conclusion

In the present research, the positive influence of bioregulators on yield of ‘Čačanska Rodna’ was confirmed. In general, the application of BA at a concentration of

50 mg l⁻¹ affected the increase in yield and number of fruits per tree, while the fruits treated with 100 mg l⁻¹ BA were somewhat larger. In relation to BA the influence of GA₃ was inconsistent.

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UTICAJ 6-BENZILADENINA I GIBERELINA NA PRODUKTIVNOST I KVALITET PLODA SORTE ŠLJIVE ČAČANSKA RODNA**Gordana Barać^{1*}, Zoran Keserović¹, Jasna Mastilović², Žarko Kevrešan², Biserka Milić¹, Nenad Magazin¹, Maja Milović¹, Jelena Kalajdžić¹, Aleksandra Bajić²**¹Univerzitet u Novom Sadu, Poljoprivredni fakultet, Trg Dositeja Obradovića 8, 21000 Novi Sad, Republika Srbija

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²Univerzitet u Novom Sadu, Naučni institut za prehrambene tehnologije, Bulevar Cara Lazara 1, 21000 Novi Sad, Republika Srbija**Rezime**

Proizvodnja šljive u Srbiji je uglavnom ekstezivnog tipa, praćena niskim i nestabilnim prinosima po jedinici površine i sitnim plodovima lošeg kvaliteta. U cilju poboljšanja proizvodnje i povećanja kvaliteta ploda ispitivan je uticaj 6-benziladenina (BA) i giberelina (GA₃) na prinos, krupnoću i skladištenje plodova. Ogled je sproveden 2016–2017. godine na sorti Čačanska rodna kalemljenoj na generativnu podlogu *Prunus cerasifera* Ehrh. sa međupodlogom *Prunus spinosa* L. i vegetativnu podlogu Wavit. Kada je prosečan prečnik ploda dostigao 10 mm primenjivani su sledeći tretmani: 50 mg l⁻¹ BA, 100 mg l⁻¹ BA, 200 mg l⁻¹ GA₃ i netretirana kontrola. Plodovi su analizirani u berbi, nakon skladištenja na 1 ± 1°C u trajanju od 28 dana (2016. godine) i 20 dana (2017. godine), i tri dana nakon iskladištenja [28 + 3 (2016.) i 20 + 3 (2017.)]. Tretmani BA značajno su povećali prinos i

krupnoću ploda, dok je efekat GA₃ bio nekonzistentan. Najveći prinos i broj plodova po stablu postignuti su sa primenom 50 mg l⁻¹ BA kod obe podloge. Prinos je povećan za 118% na podlozi Wavit i za 66% na podlozi *Prunus cerasifera*/*Prunus spinosa* u poređenju sa kontrolom. Izuzetak je bila 2017. godina kada je najveći prinos na podlozi Wavit postignut na stablima šljive tretiranim sa 100 mg l⁻¹ BA. Boja plodova izražena kroz hromatičnost (C* – chroma) varirala je između godina, podloge i tretmana. Tokom skladištenja plodova, vrednost „bioyield point-a“ značajno je opala. U 2016. godini skladištenje plodova smanjilo je „bioyield point“ za skoro 50%, dok je u 2017. godini smanjenje iznosilo oko 30%.

Ključne reči: *Prunus domestica* L., Wavit, *Prunus spinosa*, bioregulatori, čuvanje, trajašnost