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Effect of plant regulators on fruit quality of pear (*Pyrus communis* L.) cultivars 'Williams' and 'Abate Fetel'

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Abstract. This study presents results of two-year research (2016–2017) of effect of plant growth regulators GA_{4+7} 1.8% + BA 1.8% and Prohexadione-Ca (applied individually or in combination) on fruit quality of pear cultivars 'Williams' and 'Abate Fetel'. Examination of these effects was conducted by analysis of the fruit weight, dimensions (length and width), fruit firmness, total soluble solids content, and number of seeds per fruit. Within both studied cultivars, application of GA_{4+7}+BA in the full flowering phenophase proved to be most effective considering the fruit size. Individual application of the Prohexadione-Ca during the same phenophase did not significantly affect fruit characteristics of the observed cultivars.

Key words: pear, planth growth regulators, morphometric characteristics of fruit, fruit quality, seeds

Introduction

Considering fruit production in Bosnia and Herzegovina in 2016, pear production was on the second place, immediately after the apple. Most common pear cultivar in nursery production of Republic of Srpska is 'Williams', followed by 'Santa Maria' used as a pollenizer (Davidović, 2015). Cultivars 'Abate Fetel', 'Morettini' and 'Conference' are represented to a lower percentage. Almost identical assortment structure is observed in commercial orchards as well. Pear production in Bosnia and Herzegovina is limited by a number of challenges: dominant use of wild pear (*Pyrus communis* L.) seedlings as a rootstocks, pseudogley soil with low pH value and productivity, low fruit set of growing cultivars, etc. The pear producers have to apply all the necessary measures which can increase the profitability of production. In the last years, there is an increase in use of plant growth regulators (PGRs), with the goal to establish balance between vegetative growth and fertility, and to increase fruit quality. Application of different PGRs could induce adequate fruit set, and represents a successful method for increasing yields in young pear trees (Lafer, 2008), especially in the orchard with large number of cultivars (Petri, 2001). Combining gibberellins and Prohexadione-Ca in the treatments of pears leads to extensive fruit set, resulting in large number of fruits that are relatively small in size (Vercammen & Gommand, 2008). Application of GA_3, usually very effective in

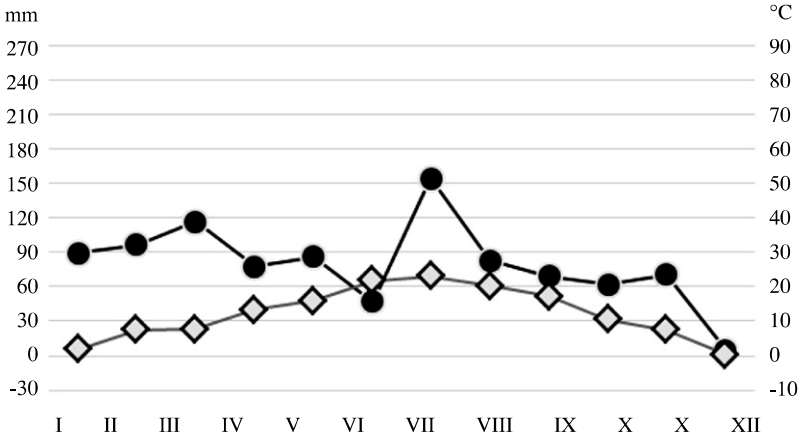
many pear cultivars, had a small efficiency in'Abate Fetel' (Vilardell et al., 2008). Several researchers (Lafer, 2008; Ouma, 2008; Vilardell et al., 2008; Vercammen et al., 2014) stated that application of phytohormones GA_{4+7}, GA_3 or their combination improved pear fruit set and fruit quality. Depending on the concentration, Prohexadione-Ca affected yield increase in'Williams' and 'Abate Fetel' (Lafer, 2008; Vilardell et al., 2008; Vercammen & Gommand, 2008). In combination with gibberellins, due to increase in total fruit number, individual fruit size decreased (Lafer, 2008). Competition between individual fruits reduces their size (Dussi et al., 2006), and has negative effect on other fruit characteristics: color, shape, firmness and shelf life (Radivojević et al., 2017). Prohexadione-Ca treatments did not negatively affect fruit set and generative buds differentiation (Bubán et al., 2004; Medjdoub et al., 2004; Asin et al., 2007). However, in some apple and pear cultivars, Prohexadione-Ca may reduce fruit size, as well as differentiation of generative buds (Smit et al., 2005). The aim of this research was to study the effect of PGRs on fruit quality of pear cultivars 'Williams' and 'Abate Fetel'.

Material and Methods

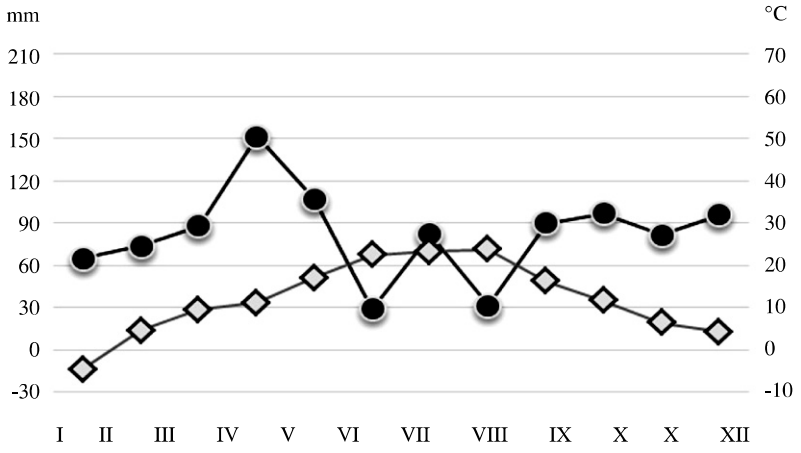
Research location and climate conditions. The application of Progerbaline LG (GA_{4+7}+ BA) and Prohexadione-Ca (Regalis®) was conducted in commercial orchard (owned by Dejan Popović), in village Palačkovci Donji, Municipality Prnjavor, which is located at the edge of Pannonian Basin. Locality is characterized by humid continental climate, specific for partially surrounded and narrow river valleys of the northwest of the Republic of Srpska. The elevation of the orchard is 160 *m* (44°55'36.2''N 17°44'48.1''E). Climatic conditions are presented by Walter climate diagram; they were uneven during the two years of research (Graphs 1 and 2).

First year of research (2016) characterized by all-year humid period, with the exception of short dry period at the beginning of June. Humid period was especially observed during July. During the second season (2017), two dry periods were observed (from the second half of May until the beginning of July, and from the second half of July until the half of September).

Plant material and experimental design. The orchard was established in 2010 with spacing 4 × 1.5 *m* (1,667 trees per hectare). The main cultivar is 'Williams', followed by 'Santa Maria' and 'Abate Fetel' as pollenizers; the research included 'Williams' and 'Abate Fetel'. The orchard was maintained according to the principles of spindle training system. Three PGR treatments were applied: treatment 1 (mark – t_1) – application of Prohexadione-Ca (2 *kg/ha* in the full flowering phenophase); treatment 2 (mark – t_2) – application of GA_{4+7} 1.8% + BA 1.8% (300 *ml/ha* in the full



Graph 1. Climate chart by Walter for 2016 (Prnjavor Munucipality)
Graf. 1. Klima dijagram po Walteru za 2016. godinu (opština Prnjavor)



Graph 2. Climate chart by Walter for 2017 (Prnjavor munucipality)
Graf. 2. Klima dijagram po Walteru za 2017. godinu (opština Prnjavor)

flowering phenophase); treatment 3 (mark – t_3) – application of GA4+71.8% + BA 1.8% (300 *ml*/*ha* in the full flowering phenophase) in combination with Prohexadione-Ca (2 *kg*/*ha*) applied 14 days after the full flowering, and Prohexadione-Ca (2 *kg*/*ha*) applied 21 days after it. Control group of trees (mark – k) was not treated. Each treatment included 15 trees of both cultivars (3 repetitions with 5 trees per repetition). The research included trees located in the middle of the row, with the principle of treating 5 trees and skipping 10 trees before treating next 5 trees. Trees for repetitions per treatment were chosen by the random sample method, considering row number and exact position in the row (upper, middle or lower parts of the row) with the aim of achieving the more representative sample. Treatments were performed manually, with the hand sprayer of 15 *l* tank volume.

Morphometric properties of fruits. Examination of PGRs effects on pear fruit quality was conducted by the analysis of followed parameters: fruit weight (technical scale Kern KB), fruit dimensions – length and width (digital caliper 0–150 *mm*, Kronen GmbH, Kehl am Rhein, Germany), fruit firmness (penetrometer PCE-FM200), soluble solids content (hand refractometer, Atago), and number of seeds per fruit. Fruit samples for the laboratory analysis were chosen by random sample method. In total, 20 fruits per treatment were analyzed.

Data analysis. Measured pear fruit characteristics were presented with standard descriptive measures i.e. mean ($\overline{X}$) and standard error of the mean ($S\overline{x}$). Differences between factors were analyzed by fitting the general linear models and where the significance level was indicated, post hoc Tuckey's HSD test was used. Established level for the statistical significance of the studied differences was set at $p<0.05$, which is further elaborated in perspective of the research objectives, together with the observed effect size and the agronomical significance of the effects. For the statistical analysis, SPSS 22 (IBM) software was used.

Results and Discussion

Fruit weight is determined by genotype, but also significantly influenced by growing conditions and application of adequate agro- and pomotechnical measurements. During the research period, larger variations in the average fruit weight (Tab. 1) were observed in 'Abate Fetel', compared to cultivar 'Williams'. Cultivar specificities, climate effects and effects of the applied treatments had a statistically highly significant impact to the average fruit weight.

Analysis of fruit weight indicated highly significant interaction between applied treatments and years ($p<0.001$), as well as cultivars and years ($p<0.001$). In 2017 year, control variant had significantly smaller

Tab. 1. Average fruit weight (*g*) of the pear cultivars treated by plant regulators (2016–2017)
Prosečna masa ploda (g) sorti kruške tretiranih biljnim regulatorima rasta (2016–2017)

	'Williams'		'Abate Fetel'	
	2016	2017	2016	2017
t_1	190.6 ± 5.9	154.8 ± 1.9	216.7 ± 9.8	162.2 ± 9.3
t_2	256.6 ± 10.5	188.7 ± 4.6	262.6 ± 10.8	189.8 ± 7.2
t_3	228.1 ± 7.8	150.5 ± 3.7	237.6 ± 7.3	152.1 ± 6.2
k	214.1 ± 9.3	123.7 ± 3.1	237.9 ± 6.6	112.31 ± 8.9
F_c		7.73**		
F_y		415.67**		
F_t		5.22**		

$F_{y\times c}$ = 16.42**;$F_{c\times t}$ = 0.77; $F_{y\times t}$ = 18.39**; $F_{y\times c\times t}$ = 2.31

** Statistically highly significant/*Statistički visoko značajna* (p<0.01); *Statistically significant/*Statistički značajna* (p<0.05); c – cultivar/*sorta*; y – year/*godina*; t – treatment/*tretman*

fruit in comparison to the treatments in both cultivars (p<0.001). 'Abate Fetel' had larger fruits compared to the 'Williams', which was to be expected considering their varietal differences (Gliha, 1997; Mratinić, 1999). Differences at the level of cultivar and year, as well as applied treatments were evident in both observed cultivars during the research period. If PGRs were applied during the flowering phenophase, average fruit weight of the pear increased, regardless of the application of the individual (Hegazi, 2011) or the combined treatment (Dreyer, 2013; Taher et al., 2005). Single application of Prohexadione-Ca in 2016 did not significantly affect increase of the average fruit weight. Average fruit length value (Tab. 2) was higher in 2016, within both observed cultivars.

Cultivar differences concerning average fruit length, as well as season and applied treatment, proved to be of a high statistical significance. 'Abate Fetel' had larger average fruit length in both years, compared to the cultivar 'Williams'. The largest average fruit length in 'Abate Fetel' was observed using treatment with GA_{4+7}+BA (121.0 *mm* during 2016, and 113.8 *mm* during 2017). The largest average fruit length in 'Williams' was observed using GA_{4+7}+BA treatment in combination with Prohexadione-Ca, in both years of research (98.5 *mm*; and 87.7 *mm*, respectively). Average fruit width (Tab. 3) was significantly different for two years of research, in both observed cultivars, and with significantly lower values for the season 2017. Seasonal difference in 'Williams' was observed with GA_{4+7}+BA application compared to the control group in both years. For the season 2017, difference between all three treatments was observed compared to the control group of 'Abate Fetel'.

Tab. 2. Average fruit length (*mm*) of the pear cultivars treated by plant regulators (2016–2017)
Prosečna dužina ploda (mm) sorti kruške tretiranih biljnim regulatorima rasta (2016–2017)

	'Williams'		'Abate Fetel'	
	2016	2017	2016	2017
t_1	87.0 ± 1.9	82.7 ± 1.2	107.9 ± 2.5	108.4 ± 2.4
t_2	90.5 ± 1.0	72.6 ± 2.0	121.0 ± 3.0	113.8 ± 2.9
t_3	98.5 ± 1.4	87.7 ± 2.4	118.0 ± 3.4	99.9 ± 2.8
k	95.8 ± 1.8	74.7 ± 0.9	110.2 ± 1.8	90.4 ± 3.3
F_c		302.01**		
F_y		107.58**		
F_t		10.72**		

$F_{y\times c}$ = 1.06;$F_{c\times t}$ = 3.54*; $F_{y\times t}$ = 13.43**; $Fy_{\times c\times t}$ = 2.06

**Statistically highly significant/*Statistički visoko značajna* (p<0.01); *Statistically significant/*Statistički značajna* (p<0.05); c – cultivar/*sorta*; y – year/*godina*; t – treatment/*tretman*

Tab. 3. Average fruit width (*mm*) of the pear cultivars treated by plant regulators (2016–2017)
Prosečna širina ploda (mm) sorti kruške tretiranih biljnim regulatorima rasta (2016–2017)

	'Williams'		'Abate Fetel'	
	2016	2017	2016	2017
t_1	69.5 ± 0.7	62.7 ± 0.7	71.7 ± 1.9	60.5 ± 1.1
t_2	75.2 ± 0.9	68.9 ± 0.9	74.8 ± 1.5	66.2 ± 1.0
t_3	72.0 ± 0.9	62.6 ± 0.7	69.0 ± 2.2	62.1 ± 0.9
k	70.4 ± 0.8	60.4 ± 0.6	73.1 ± 0.9	54.6 ± 1.5
	F_c	0.94		
	F_y	1.49		
	F_t	1.00		

$F_{y\times c}$ = 1.08;$F_{c\times t}$ = 1.00; $F_{y\times t}$ = 0.98; $Fy\times_{c\times t}$ = 0.99

**Statistically highly significant/*Statistički visoko značajna* (p<0.01); *Statistically significant/*Statistički značajna* (p<0.05); c – cultivar/*sorta*; y – year/*godina*; t – treatment/*tretman*

Obtained results are in accordance with the citations of the other authors on the effects of PGRs application on characteristic of pear fruit. Combination of cytokinin 6-BA and gibberellin GA_{4+7} (applied 14 days after full flowering) had a positive correlation with the increase in fruit size of the pear cultivars 'Spadona' and 'Koskia', without induction of any deformities (Stern, 2008). According to Stern & Flaishman (2003), 100 *mg* l^{-1} 6-BA stimulated fruit growth of the pear cultivars 'Koskia' and 'Spadona', without negative effect on fruit shape, number of seeds and reccurent bloom. Effect on size (width and length) and weight in cultivar 'Nakai' (*Pyrus pyrifolia* Brum.) was observed with treatment of BA 250 *mg* l^{-1} (Kundu et al., 2013). According to Dreyer (2013), combination of GA_{4+7} and Prohexadione-Ca in cultivars 'Abate Fetel' and 'Forelle' significantly increased fruit size (weight, length and width). Vercammen et al. (2014) stated that application of $Gibb_3$ had a negative effect on fruit size and yield in 'Conference' cultivar.

Total soluble solids content in fruits (Tab. 4) was highest in 'Abate Fetel' trees treated with GA_{4+7}+BA in season 2016 (12.7%), and for 'Williams' trees using the same treatment in season 2017 (12.4 %).

Effect of the applied treatment, year, as well as interaction year × cultivar, on the total soluble solids content proved to be of a high statistical significance. Differences in soluble solids content were observed comparing the control group with applied treatments at both examined cultivars and for the both years of re-

Tab. 4. Total soluble solids content (%) in fruits of the pear cultivars treated by plant regulators (2016–2017)
Sadržaj rastvorljivih suvih materija (%) u plodu sorti kruške tretiranih biljnim regulatorima rasta (2016–2017)

	'Williams'		'Abate Fetel'	
	2016	2017	2016	2017
t_1	11.8 ± 0.1	11.1 ± 0.1	12.2 ± 0.3	11.3 ± 0.2
t_2	11.5 ± 0.2	12.4 ± 0.1	12.7 ± 0.2	11.3 ± 0.2
t_3	11.8 ± 0.2	11.9 ± 0.3	11.8 ± 0.2	11.1 ± 0.2
k	11.1 ± 0.3	11.2 ± 0.3	11.3 ± 0.2	11.0 ± 0.1
	F_c	0.04		
	F_y	16.49**		
	F_t	4.27**		

Fy×c = 6.97**;Fc×t = 2.45; Fy×t = 2.32; Fy×c×t = 0.51

**Statistically highly significant/*Statistički visoko značajna* (p<0.01); *Statistically significant/*Statistički značajna* (p<0.05); c – cultivar/*sorta*; y – year/*godina*; t – treatment/*tretman*

search. Effect of PGR application on the total soluble solids content is slightly higher for 'Abate Fetel', especially in season 2016, compared to the 'Williams', which had lower concentration of total soluble solids in fruits in both years of the research. Differences between two seasons of research may be partially attributed to climatic factors i.e. differences of climatic conditions during the period of research. Fruits of 'Williams' had higher firmness (Tab. 5) compared to 'Abate Fetel' in both observed years. In both cultivars average fruit firmness was higher in 2016; in 'Abate Fetel' fruit firmness was very uniform by years.

Tab. 5. Average fruit firmness (kg/cm^2) of the pear cultivars treated by plant regulators (2016–2017)
Prosečna čvrstina ploda (kg/cm^2) sorti kruške tretiranih biljnim regulatorima rasta (2016–2017)

	'Williams'		'Abate Fetel'	
	2016	2017	2016	2017
t_1	10.9 ± 0.4	9.4 ± 0.2	6.1 ± 0.4	6.4 ± 0.3
t_2	10.1 ± 0.3	6.0 ± 0.2	6.6 ± 0.3	6.8 ± 0.2
t_3	12.7 ± 0.3	6.4 ± 0.2	6.4 ± 0.3	6.5 ± 0.3
k	12.2 ± 0.2	7.6 ± 0.3	8.4 ± 0.4	6.0 ± 0.1
F_c		463.81**		
F_y		360.69**		
F_t		2.96**		

$F_{y\times c}$ = 189.48**; $F_{c\times t}$ = 4.54**; $F_{y\times t}$ = 25.14**; $F_{y\times c\times t}$ = 15.44**

**Statistically highly significant/*Statistički visoko značajna* (p<0.01); *Statistically significant/*Statistički značajna* (p<0.05); c – cultivar/*sorta*; y – year/*godina*; t – treatment/*tretman*

The difference between years was observed in cultivar 'Williams' for treatment 1 and 2 in 2016, and in 'Abate Fetel' for treatment 2 in 2017 compared to the control group. Cultivar specificities, applied treatment and year of research, as well as interactions of all of the factors had statistically highly significant influence on average fruit firmness.

The application of PGRs showed no significant influence on seed formation and seed number (Tab. 6). Petri (2002) stated that PGRs application for improvement of fruit set had better effects if there was a large number of cultivars exists, due to the multiple pollination.

Tab 6. Average seed number per fruit of the pear cultivars treated by plant regulators (2016–2017)
Prosečan broj semenki u plodu sorti kruške tretiranih biljnim regulatorima rasta (2016–2017)

	'Williams'		'Abate Fetel'	
	2016	2017	2016	2017
t_1	10.1 ± 0.5	9.7 ± 0.2	9.4 ± 0.2	8.9 ± 0.3
t_2	10.2 ± 0.1	10.0 ± 0.1	8.3 ± 0.4	8.1 ± 0.3
t_3	10.0 ± 0.1	9.9 ± 0.1	9.7 ± 0.2	9.6 ± 0.3
K	9.7 ± 0.2	9.8 ± 0.1	9.2 ± 0.2	9.2 ± 0.2
F_c		61.83**		
F_y		0.12		
F_t		8.65**		

$F_{y\times c}$= 0.05;$F_{c\times t}$ = 12.23**; $F_{y\times t}$ =1.48; $F_{y\times c\times t}$ = 1.64

**Statistically highly significant/*Statistički visoko značajna* (p<0.01); *Statistically significant/*Statistički značajna* (p<0.05); c – cultivar/*sorta*; y – year/*godina*; t – treatment/*tretman*

Importance of PGRs on fruit development is more pronounced in unfavorable climatic conditions (low temperatures and therefore reduced bees flight), when their application can influence formation of parthenocarpic fruits (Silva & Herero, 2008).

Conclusion

In both observed cultivars, the best results concerning fruit size were achieved by application of GA_{4+7}+BA in the period of full flowering. Application of GA_{4+7}+BA had a positive effect on fruit width in both cultivars, as well as fruit length in 'Abate Fetel'. Slightly longer fruits were observed in 'Williams' cultivar with application of combined GA_{4+7}+BA and Prohexadione-Ca. There was a positive correlation between all treatments and total soluble solids content in fruits. Fruit firmness had higher value in 'Williams' compared to 'Abate Fetel' in both years of the research. Application of plant growth regulators did not show any significant effect on the number of seeds. The greatest effect on fruit characteristics was observed with the application of GA_{4+7}+BA. Individual application of Prohexadione-Ca during the flowering did not have significant effect on the characteristics of the observed cultivars.

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UTICAJ BILJNIH REGULATORA RASTA NA KVALITET PLODA KRUŠKE (*Pyrus communis* L.) SORTI VILIJAMOVKA I ABATE FETEL

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Rezime

Kruška je pored jabuke i šljive najvažnija vrsta voćaka u Bosni i Hercegovini. Najzastupljenija sorta u proizvodnji kruške na teritoriji Republike Srpske je Vilijamovka, dok se kao njeni oprašivači najčešće koriste sorte Santa Marija i Abate Fetel. Kruška se uzgaja u sistemu vretena, a kao podloga se zbog karakteristika zemljišta, najviše koristi sejanac divlje kruške (*Pyrus communis* L.). U cilju regulisanja rasta i rodnosti, kao i dobijanja plodova zadovoljavajućeg kvaliteta, poslednjih godina u redovnoj proizvodnji se koriste i biljni regulatori rasta. Cilj istraživanja je ispitivanje uticaja biljnih regulatora rasta na kvalitet plodova sorti Vilijamovka i Abate Fetel uzgajanih u sistemu vretena na sejancu divlje kruške (*Pyrus communis* L). Ispitivanje je izvršeno u proizvodnom voćnjaku Dejana Popovića u selu Palačkovci Donji, opština Prnjavor, tokom 2016. i 2017. godine. Klimatski uslovi su bili dosta neujednačeni po godinama istraživanja, što je moglo imati određenog uticaja na ispitivane karakteristike. U zasadu su primenjena tri tretmana: tretman 1 – Proheksadion-Ca u količini 2 *kg*/*ha* u fazi punog cvetanja; tretman 2 – GA_{4+7} 1.8% + BA 1.8% u količini 300 *ml*/*ha* u fazi punog cvetanja i tretman 3 - GA_{4+7} 1.8% + BA 1.8% u količini 300 *ml*/*ha* u fazi punog cvetanja uz primenu Proheksadion-Ca u količini 2 *kg*/*ha* 14 dana posle fenofaze punog cvetanja, i 2 *kg*/*ha* Proheksadion-Ca 21 dan posle fenofaze punog cvetanja. Ispitivanje uticaja biljnih regulatora rasta na kvalitet ploda kruške obavljeno je kroz analizu mase ploda, dimenzija (dužine i širine) ploda, čvrstoće ploda, sadržaja rastvorljivih suvih materija i broja semenki u plodu. Najveća krupnoća plodova, bez obzira na godinu i sortu konstatovana je kod plodova na stablima tretiranim sa GA_{4+7}+BA. Kod obe ispitivane sorte u 2017. godini, krupnoća plodova na kontrolnim stablima bila je statistički značajno manja u odnosu na krupnoću plodova na stablima u tretmanima. Statistički visoku značajnost pokazale su sortne razlike kao i uticaj godine i primenjenog tretmana u pogledu dužine ploda. Prosečna širina ploda je bila dosta neujednačena između godina istraživanja, sa značajno nižim vrednostima u 2017. godini kod obe ispitivane sorte, a što se dovodi u vezu sa masom ploda. Sadržaj rastvorljive suve materije u plodovima bila je najveća kod stabala tretiranih sa GA_{4+7}+BA kod sorte Abate Fetel u 2016. godini (12,7 %), a kod sorte Vilijamovka u 2017. godini (12,4 %). Nije utvrđena značajna razlika u broju semenki između kontrolnih i tretiranih stabala. Kod obe ispitivane sorte najbolje rezulate u pogledu krupnoće plodova dala je primena GA_{4+7}+BA u periodu punog cvetanja. Individualna upotreba Proheksadion-Ca u vreme cvetanja nema značajniji uticaj na karakteristike ploda ispitivanih sorti.

Ključne reči: kruška, biljni regulatori rasta, morfometrijske osobine ploda, kvalitet ploda, semenke