Original scientific paper

Effect of irrigation on fruit quality and yield of 'Red Cap'apple cultivar depending on crop load

Đurović, D[1]., Mil1atović, D[1]., Đorđević, B.[1], Zec, G. [1], Radović, A.[2], Boškov Đ. [1]

[1]*Faculty of Agriculture, University of Belgrade, Nemanjina 6, Belgrade – Serbia*
[2]*Faculty of Agriculture, University of Niš, Kosančićeva 4, Kruševac – Serbia*

Corresponding author: Dejan Djurović dejan.djurovic@agrif.bg.ac.rs

Abstract

Effect of irrigation on fruit quality and yield of Red Cap apple variety depending on crop load were studied. The aim of the paper is to determine how many apple fruits can be left on trees in third vegetation, growth under different irrigation treatments (without irrigation, normal irrigation - control and increased irrigation - double irrigation rate). For the Red Cap variety in the third year after planting, in order to achieve good fruit quality and satisfactory yield, it is necessary to leave a maximum of 25 fruits per tree, or 3.5 fruits per $cm^2$of trunk cross-sectional area (TCSA). Different irrigation treatments have influence on the fruit size, the proportion of first class fruits, as well as the degree of ripeness of the fruits. Increased irrigation during the months of July and August affects these parameters, but to a lesser extent than the crop load. The largest irrigation effect on the increase of fruit size had trees from crop load III, who had 5,5 fruits per $cm^2$of TCSA. Increased irrigation during July and August had no statistically significant effect on tested parameters on trees that had less than 4,5 fruits per cm^2 of TCSA and trees that had more than 6,5 fruits per cm^2 of TCSA.

Key words: apple, irrigation, crop load, yield, fruit quality

Introduction

Successful cultivation of apple orchards in Serbia requires about 750 mm of precipitation per year (Mišić, 1994). Whether this quantity will actually be sufficient depends on the temperature of the air, the type of soil, the distribution of rainfall during the year, and the characteristics of the plantation itself (number of plants per ha, method of soil maintenance, crop load, etc.). The territory of Serbia is characterized by a continental pluviometric regime (Milosavljević, 1985). According to this regime, the greatest amount of precipitation is in June and November, and the lowest in February and October. The most critical months in terms of water supply are July, August and September, since the most important varieties of apple fruits ripen in late August, September and October. There is a water deficit almost every year in our country, in this period, as these are also the warmest months (besides June). We have to make up this deficit through irrigation, if we want successful production. Flowering is shorter and the fruit set is lower, if there is a water deficit in the first part of the growing season. The lack of water leads to a massive drop of the fruits before harvesting, while remaining fruits remain smaller and ripen earlier in the second part of the growing season. Also, due to the lack of water, bud differentiation for the next year has been reduced. In addition to water, the fruit load on the tree has a great influence on the quality of the fruit, its mass, as well as the differentiation of flower buds for the next year. Excessive yield leads to a significant decrease of fruit quality and significantly reduces the yield potential for the next year. It is well known that in conditions of "dry" fruit growing, one of the ways for the fruits to reach the proper size is to reduce the yield, that is, to reduce the number of fruits left on the tree. The aim of the paper is to determine how many apple fruits can be left on trees in third vegetation, growth under different irrigation treatments (without irrigation, normal irrigation - control and with increased irrigation - double irrigation rate).

Material and Methods

The experiment was carried out in the village of Novi Slankamen, Inđija municipality. Apple orchad has been planted in the autumn of 2016. The planting distance is 3.25 meters between the rows, and the distance within a row is 0.62 meters. The drip irrigation system was installed before planting. Two-year-old nursery trees with more than five feathers were used as planting material. The variety being tested is Red Delicious (Red Cap Valtod clone) grafted on M26 rootstock. Granny Smith variety is used as a pollinator. Polinator variety was planted along each pole. Tests were conducted in the spring and summer of 2019 while the trees were in third vegetation.

The size of trees was uniform and potential yield. In May 2019, after manual thinning, a trial was set up with varying degrees of crop load: load I (25 fruits per tree), load II (30 fruits per tree), load III (40 fruits per tree) and load IV (50 fruits per tree). The average air temperature in May was 15.0 ^{o}C, in June23.4, in July 23.3 and in August 24,8 ^{o}C. The highest rainfall was in May (130 mm) and the least in August (20 mm). In June rainfal was 120.8 mm, in July was

32,7 mm. Three different irrigation treatments were established during July and August: deficit irrigation (no watering), control irrigation (one lateral in a row) and double irrigation rate (two laterals in a row). In each irrigation regime, they were trees with all four crop loads treatments. Each treatment was represented by 10 trees (120 trees in total). Each plant was irrigated with 3.2 liters of water during the day in July and 4.8 liters of water during the day in August (control irrigation).

The plant was irrigated in July with 6.4 liters of water during the day in July, and 9.6 liters of water during the day in August (double irrigation rate). Fruits from all treatments were picked at the same time. Their classification was performed according to the diameter of the fruit into three categories: I class (diameter over 70 mm), II class (diameter between 65 and 70 mm) and III class (diameter below 65 mm). Ten randomly selected fruits from every tree were immediately measured for fruit firmness, soluble solids content, titratable acidity, and starch index. Fruit firmness was determined on two positions, red blushed and unblushed portion areas, at the equator of each fruit usinga press-mounted Effegi penetrometer (model FT 327,Alfonsine, Italy) with an 11.1-mm head (HARKER et al.1996).

Total soluble solids (TSS) was determined using a hand held refractometer with automatic temperature compensation (ATC-1 Atago, Tokyo, Japan). Starch pattern index (SPI) was determined with 0.1N iodine solution using the scale 1–10 (1/early ripe, 10/fully ripe). Titratable acidity (TA) was measured by titration with 0.1N NaOH, and expressed as percent of malic acid. Data were subjected to analysis of variance (ANOVA). Mean separation was done by Duncan’s multiple range test at 5 % levels of significance. Statistical procedures were performed using STATISTICA V5.5A STATSOFT.

Results and Discussion

Fruits were harvested on 31 of August. The number of fruits harvested per tree depending on load and irrigation regime was shown in table 1. The highest number of fruits was harvested from trees that were most loaded with fruits (load IV) and least from trees with load I.

The differences were statistically significant. On average, regardless of the degree of loading, the effect of different irrigation regimeon the number of harvested fruits per tree was not statistically significant. Also, the effect of different irrigation at each individual load level on the number of fruits harvested is not statistically significant.

Table 1. Number of fruits per tree

Irrigationtreatment	Crop load (number of fruits per tree)				Average
	I	II	III	IV	
Without irrigation	23.8a	29.4a	36.4a	47.0b	34.1a
Control	22.0a	27.2a	36.6a	42.0ab	31.9a
Double irrigation rate	24.0a	29.8a	36.4a	38.4a	32.1a
Average	23.3a	28.8b	36.5c	42.5d	

If we show the number of harvested fruits per cm^2 of TCSA, we obtain similar relationships as for the total number of harvested fruits per tree (table 2). The number of fruits harvested per cm^2 of trunk cross-sectional area was the lowest at load I (3.49) and the highest at load IV (6.69). The differences were statistically significant.

Table 2. Number of fruits per cm^2 of TCSA

Irrigation treatment	Crop load (number of fruits per tree)				Average
	I	II	III	IV	
Without irrigation	3.40a	4.51a	5.59a	6.85a	5.09a
Control	3.54a	4.83a	5.38a	6.55a	5.08a
Double irrigation rate	3.54a	4.66a	5.98a	6.66a	5.21a
Average	3.49a	4.67b	5.65c	6.69d	

The tress at load I had the highest fruit weight (166.3 g), while the trees at load IV had the smallest fruit weight (113.1 g). The difference in fruit weight between load III and IV is not statistically significant (table 3).

Depending on the irrigation regime, fruits on non-irrigated trees had statistically significantly lower fruit weight than fruits whose trees double irrigated.

Regarding the effect of irrigation at each crop load individually, a statistically significant difference only occurs at load III, between trees without irrigation (107.6 g) and double irrigated trees (137.8 g). The effect of irrigation on the fruit weight is only significant in trees at crop load III.

Table 3. Effect of irrigation on the fruit weight (g) depending on crop load

Irrigation treatment	Crop load (number of fruits per tree)				Average
	I	II	III	IV	
Without irrigation	164.0a	131.2a	107.6a	103.5a	126.6a
Control	162.5a	147.7a	117.4ab	117.0a	136.2ab
Double irrigation rate	172.5a	146.1a	137.8b	118.8a	143.8b
Average	166.3c	141.6b	120.9a	113.1a	

Depending on the number of fruits left on the tree, the highest yield was obtained on trees with load IV (4, 71 kg) and the lowest on trees with load I (3, 88 kg) (table 4).

Table 4. Effect of irrigation on the yield per tree (kg) depending on crop load

Irrigation treatment	Crop load (number of fruits per tree)				Average
	I	II	III	IV	
Without irrigation	3.89a	3.86a	3.89a	4.86a	4.12a
Control	3.59a	3.98a	4.28ab	4.90a	4.19a
Double irrigation rate	4.16a	4.39a	5.03b	4.37a	4.49a
Average	3.88a	4.07a	4.40ab	4.71b	

There was no statistically significant difference between load I, II and III. Yield per tree was the highest in double irrigation treatment, but this increase is not statistically significant. Many studies have shown that deficit irrigation reduces final fruit size and yield of apples (Ebel et al., 1993, Mpelasoka et al., 2001).

A statistically significant difference only occurs with load III, where the double irrigation treatment had a significantly higher yield (5.03 kg) than the non-irrigation trees (3.89 kg).

From the point of view of placing fruit on the market, only fruits over 70 mm in diameter have economic significance. The Effect of irrigation on the proportion of fruit with diameter larger than 70 mm (%) depending on crop loa is shown in table 5. The highest proportion of first class fruits (diameter over 70 mm) have trees at load I (over 84%), and the smallest trees at load IV (only 23,6%). The difference is statistically significant. Trees that are double-watered, on average, have the highest proportion of fruits over 70 mm (58.9%), and this difference is statistically significant compared to non-watered trees (40.3%).

Table 5. Effect of irrigation on the proportion of fruit with diameter larger than 70 mm (%) depending on crop load

Irrigation treatment	Crop load (number of fruits per tree)				Average
	I	II	III	IV	
Without irrigation	88.7a	32.6a	24.4a	15.4a	40.3a
Control	71.9a	67.3b	26.1a	27.1a	48.1ab
Double irrigation rate	92.7a	59.6b	54.9b	28.3a	58.9b
Average	84.4c	53.2b	35.1a	23.6a	

Regarding the effect of irrigation at each load individually, a statistically significant difference in the proportion of first-class fruits occurs at load II between normal irrigation (67.3%) and without irrigation (32.6%), as well as at load III, between double irrigation rate (54.9%) and normal irrigation (26.1%) and no irrigation (24.4%).

The quality of the fruit, in addition to its external properties, depends on the chemical composition, and for this reason tables 6 and 7 show the content of total soluble solids (TSS)and total acids (TA), depending on the tree load and irrigation regime.

Table 6. Effect of irrigation on total soluble solids (TSS) in fruit depending on crop load

Irrigation treatment	Crop load (number of fruits per tree)				Average
	I	II	III	IV	
Without irrigation	12.4	10.8	12.1	10.2	11.38 a
Control	11.1	13.8	10.7	11.6	11.80 a
Double irrigation rate	12.5	11.7	11.3	12.3	11.95 a
Average	12.00 b	12.10 b	11.37 a	11.37 a	

Trees that were less loaded with fruits had higher content of soluble solids than trees that had a higher number of fruits (table 6).In our research, we did not find that irrigation has an effect on total soluble solids (TSS) in fruit, unlike the Djurovic at al. (2015) where the highest total soluble solids (TSS) was measured in fruits whose trees were not irrigated

The effect of irrigation intensity and different crop loadon the content of total acids in the fruit was not found (table 7). Kilili at al. (1996) also found that deficit irrigation did not affect the total acids content in fruit.

Table 7. Effect of irrigation on total acids (TA) in fruit (%) depending on crop load

Irrigation treatment	Crop load (number of fruits per tree)				Average
	I	II	III	IV	
Without irrigation	0.20	0.17	0.17	0.23	0.19 a
Control	0.19	0.21	0.22	0.19	0.20 a
Double irrigation rate	0.18	0.23	0.19	0.20	0.20 a
Average	0.19 a	0.20 a	0.19 a	0.21 a	

Trees that have more fruits had a higher firmness of the fruit (Table 8).The fruits from load IV had an average fruit firmness of 115 N, while the fruits from load I had a fruit firmness of 92 N.

An increase in fruit firmness in load IV may be an indirect effect of fruit size reduction. Smaller fruits tend to be firmer (Mpelasoka et al., 2000, Volz et al., 2003). Different irrigation had no significant effect on fruit firmness.

Table 8. Effect of irrigation on fruit firmness (N) depending on crop load

Irrigation treatment	Crop load (number of fruits per tree)				Average
	I	II	III	IV	
Without irrigation	81	102	104	116	101 a
Control	93	105	111	116	106 a
Double irrigation rate	102	121	113	114	102 a
Average	92a	109 b	109 b	115bc	

The content of starch in the fruit is a very significant indicator of the degree of ripeness of the fruit. From table 9, we can conclude that at the time of harvest, the more mature were the fruits from trees that were more loaded with fruits, compared to those that had less fruit.

The effect of irrigation on the degree of ripeness of the fruits is also evident. Increased irrigation slows down the ripening of fruits, so at the time of harvest, the least ripe fruits were from trees that were double irrigated (starch content 2.71) and the most ripe fruits from treeswithout irrigation (starch content 3.08)

Table 9. Effect of irrigation on starch pattern index (SPI) depending on crop load

Irrigation treatment	Crop load (number of fruits per tree)				Average
	I	II	III	IV	
Without irrigation	2.33	3.33	3.50	3.17	3.08 b
Control	2.17	3.00	3.50	3.00	2.92 ab
Double irrigation rate	2.83	2.17	2.83	3.00	2.71a
Average	2.44 a	2.83b	3.28 c	3.06 d	

Đurovic et al. (2015) also found that deficit irrigation increases fruit ripening. Leib et al. (2005) did not found a significant effect of treatment on the starch pattern index for ‘Fuji’.

Conclusion

Different crop load levels of trees and different irrigation treatment have a significant impact on the yield and quality of the fruit of the Red Kap apple variety in the third year after planting. Different loading of trees with fruits has a significant effect on the yield in kg per tree, on the size of the fruit, on the proportion of first class fruits, as well as on the degree of ripeness of the fruits. For the Red Kap variety in the third year after planting, in order to achieve good fruit quality and satisfactory yield, it is necessary to leave a maximum of 25 fruits per tree, or 3.5 fruits per $cm^2$of TCSA. Different irrigation treatments have influence on the size of the fruit, on the proportion of first class fruits, as well as on the degree of ripeness of the fruits. Increased irrigation during the months of July and August affects these parameters, but to a lesser extent than the crop load. The largest irrigation effect on the fruit size increase had trees from load III, who had 5,5 fruits per $cm^2$of TCSA. On trees that had less than 4,5 fruits per $cm^2$of TCSA and those with more than 6,5 fruits per $cm^2$of TCSA increased irrigation during July and August had no statistically significant effect on tested parameters.

References

Đurović, D., Mratinić, E., Milatović, D., Durović, S., Dordević, B., Milivojević, J. and Radivojević, D. 2015. Effects of partial rootzone drying and deficit irrigation of ‘Granny Smith’ apples on fruit quality during dtorage. Acta Hortic. 1099: 455-461

Ebel, R. C., Proebsting, E.L. and Patterson, M. E. 1993. Regulated deficit irrigation may alter apple maturity, quality and storage life. HortScience 28:141-143

Kilili, A. W., Behboudian, M. H. and Mills, T. M. 1996. Postharvest performance of ‘Braeburn’ apples in relation to withholding of irrigation at different stages of the growing season. J. Hort. Sci. 71:693-701.

Leib, G.B., Caspari, W.H., Redulla, A.C., Andrews, K.P. and Jabro, J.J. 2005. Partial rootzone drying and deficit irrigation of ‘Fuji’ apples on a semi-arid climate. Irrig. Sci. 24:85-99.

Mišić, P. 1994. Jabuka. Nolit, Beograd.

Milosavljevic, M. 1985. Klimatologija, Naučna knjiga , Beograd

Mpelasoka, B.S., Behboudian, M.H. and Mills, T.M. 2000. Improvement of fruit quality and storage potential of ‘Braeburn’ apple through deficit irrigation. J. Hort. Sci. Biotechnol. 75:615-621.

Mpelasoka, B.S., Behboudian, M.H. and Mills, T.M. 2001. Effects of deficit irrigation on fruit maturity and quality of ‘Braeburn’ apple. Sci. Hort. 90:279-290.

Volz, R.K., Harker, F.R., Lang, S. 2003. Firmness decline in ‘Gala’ apple during fruit development. J. Am. Soc. Hort. Sci. 128:797-802.