RESEARCH ARTICLE **(Open Access)**

The Ratio between Leave and Fruit Parameters on 'William' Pear Orchard Affected by Regulated Deficit Irrigation and Mulching

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Abstract

This field experiment was designed to assess the ratio between leave and fruit parameters on young 'William' pear trees after applied regulated deficit irrigation (RDI) and mulching. Experiments related to deficit irrigation and particularly regulated deficit irrigation (RDI) or partial rootzone drying depend heavily on weather conditions. Using a water budget methodology, four levels of irrigation, specifically 100% of evapotranspiration (ET) as control and deficits of 80%, 60% and 40%, were applied to 10 trees during the season, 5 of which were mulched with wood chips at a 10 cm layer in first year of experiment while, 20 cm in second year. The experiment was conducted in Kosovo during 2013-2015 on a pear orchard of 10 ha using a nested experimental design. Using two-way ANOVA we found significant changes in a series of leave and fruit parameters. Our results confirmed that a moderate water stress increase yield while, reducing excessive vegetative growth. Regulated deficit irrigation (40 %) has contributed to the reduction on leaf surface, leaf area, LAI. In addition, RDI affected to increase fruit numbers but decreasing fruit size. Compared with first year of experiment during 2015 in treatment 40 % were achieved 5 kg more than 2013 year. Except this, mulching had a positive effect on all parameter values measured compared to non-mulched trees. Our result indicated that regulated deficit irrigation can be successfully applied to pear also, RDI is an ideal water saving technique.

Keywords: Williams, water stress, wood chips, regulated deficit irrigation (RDI)

1. Introduction

Deficit irrigation (DI) is a system for the management of soil water to impose periods of water deficit plant in such a way as to be economically advantageous. It involves the use of a smaller amount than the calculated need for water **[13]**. In other words, DI aims at stabilizing yields and at obtaining maximum crop water productivity rather than maximum yields **[25]**. Most studies on European pear orchards have confirmed that a moderate water stress maintains or increases yields while reducing excessive vegetative growth **[4,6,11,19,23]**. Pear tree response to RDI was studied in a mature commercial orchard (*Pyrus communis* L. cv. 'Blanquilla') in Lleida. DI during both stages I or II of fruit growth affected fruit production by increasing fruit numbers but decreasing fruit size, while over-irrigation strongly reduced fruit numbers **[22]**.

The goal of the initial RDI work in the 1970s in Australia and New Zeland was to reduce vegetative growth and thus, summer pruning in excessively vigorous late maturing peach trees. In such conditions associated water savings were of secondary importance. The researchers were successful in maintaining or even increasing yield (large fruit size) when they stressed the trees only at stages of slow fruit growth and saved about 25% of potential ET **[21]**. Researchers in Spain and California tried to reproduce these results under different conditions and failed **[10,12]**. This illustrates the specificity of RDI results and how transferability requires making adjustments to variety, soil type and evaporative demand **[9]**, also deficit irrigation has been reported to increase flowering and fruit number in pear trees **[20]**, but in the last two decades deficit irrigation techniques including regulated deficit irrigation have been developed for controlling excessive vegetative growth or saving water **[18]**. Determination of the age of the

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tree to start the RDI is highly dependent on genotype and rootstock. Implement new age leads to an insufficient formation of the crown of the tree while on the other hand initially intended as an early implementation of RDI **[15]**.

This study aimed at defining the effects of a various levels of deficit irrigation in combination with mulching on the vegetative and productive growth of young pear trees.

2. Material and Methods

Ten ha orchard of pears was planted on April 2011 in Kosovo. The experimental set up was a nested design, with trees of cv. 'William' on BA29 rootstock. Pear orchard was under an anti-hail system. ET was estimated using the FAO Penman Monteith approach **[1]**. Four levels of irrigation were applied, 100% of evapotranspiration (ET) as control (1.6 L h^{-1} of water per drip) and water deficit in 80% of full ET (1.28 L h^{-1} per drip) 60% of full ET (0.96 L h^{-1} per drip) and 40% (0.64 L h^{-1} per drip). Drip distance in the lateral pipe was 0.60 m. For each treatment we used 10 trees, 5 of which are mulched at e thickness of 10 cm, in second and third year 20 cm, totalling 40 trees for the entire experiment. Mulching material consisted in wood chips placed in a row of a width of 0.60 m and was set to at 21.05.2013 (10 cm and 13.04.2014. 20 cm). Planting distances were 3.5 m between the rows and 1.3 m in the row.

In 2013 first irrigation was applied at 22.05.2013, while the last irrigation was applied at 20.09.2013. A total of 19 irrigations (one irrigation lasted two hours) were applied. In 2014 first irrigation was applied at 21.06.2014, while the last irrigation was applied at 01.09.2014. A total of 9 irrigations (one irrigation lasted two hours) were applied. In 2015 first irrigation was applied at 27.06.2015, while the last irrigation was applied at 05.09.2015. A total of 32 irrigations (one irrigation lasted 150 minutes) were applied. Each treatment (each level of irrigation) has been in a row.

In 2013 numbering of leaves for all trees was carried out on June 11. Leaf surface area measurement (cm^2) of 5 leaves per tree was conducted on June 28th. Total leaf area per tree (m^2) was measured on July 1st. All fruits in all trees were counted. Their size was measured (in mm) at the equator with a caliber using 20 fruits per tree. Average fruit size was measured (in grams) at harvest using an analytical balance. Yield (in kg/tree) was calculated at the harvest time (September 6th) measuring the total weight of all fruits per tree.

In 2015 numbering of leaves for all trees was carried out on July 5th. Leaf surface area measurement (cm^2) of 5 leaves per tree was conducted on July 12th. Total leaf area per tree (m^2) was measured on July 12th. LAI (m^2) was calculated using the formula: (leaf area) x (number of trees per ha) / (10000), **[8]**. All fruits in all trees were counted. Their size was measured (in mm) at the equator with a caliber using 20 fruits per tree. Average fruit size was measured (in grams) at harvest using an analytical balance. Yield (in kg/tree) was calculated at the harvest time (August 16th) measuring the total weight of all fruits per tree.

Data from the measurements were analysed using ANOVA two–way with post hoc testing with StatPlus 2010 from AnalystSoft Inc. USA.

Our state has a moderate continental climate with a coastal impact which penetrates through the valley of the Drini i Bardhë moderating markedly continental climate elements **[14,16]**. In Kosovo average temperature multiyear is 10.3 °C, that of vegetation 16.5 °C, the coldest month is January (-0.9 °C) while the hottest month is July with 20.1 °C. Regarding the annual rainfall is 744.8 mm, and during the growing period is 346.7 mm which shows the need to intervene with supplementary irrigation. Water shortages in the territory of Kosovo, especially during the growing period, need supplemental irrigation. The amount of rainfalls for Peja region for a 30 – year period are 907.4 mm and 352.5 mm during the growing season.

3. Results and Discussion

The results of the research are presented after application of regulated deficit irrigation and mulching on the vegetative growth (Table 1) and productive parameters (Table 2) of William's pears. During the year 2013 according ANOVA, irrigation levels significantly influenced leaf surface and area. Although at first look, there are differences in the total number of leaves, ANOVA two ways doesn't show that since at the time of experimental set up, most leaves where already formed but it should be considered that also the rainfalls for May have been 113.1 mm. Leaf surface and leaf area measured later where affected by irrigation but not yet by mulching. The highest values of number of leaves were found in 80% irrigation, followed by 100% irrigation, 60% irrigation and lastly 40% irrigation. In mulch the highest values of number of leaves were found in 60%

irrigation, followed by 100% irrigation, 80% irrigation and lastly 40% irrigation.

During the year 2015 according ANOVA, irrigation levels significantly influenced leaf surface, leaf area, LAI, while, the highest values on these parameters were found in 100% irrigation, followed by 80% irrigation, 60% and lastly 40% of irrigation, these results indicate that with RDI trees have shown a positive reduction in vegetative growth **[2,11,18,21,24]**. Mulching had a positive effect on all parameter values measured compared to non-mulched trees **[15,17]**.

* Letters in each column (without or with mulch) represent significant differences at $P \leq 0.05$.

Table 1. The influence of regulated deficit irrigation and mulching on leaf parameters of young 'Williams' pear trees

Treatment	**Number of leaves**	**Leaf surface (cm^2)**	**Leaf area (m^2)**	**Number of leaves**	**Leaf surface (cm^2)**	**Leaf area (m^2)**	**LAI**
Year		2013			2015		
Irrigation without mulch							
100%	2576.80	16.54 a	4.29 a	4608.20	a 21.79	a 10.08	a 2.21
80%	2663.20	18.78 b	5.03 b	4701.80	b 20.30	a 9.52	a 2.09
60%	2005.20	16.13 a	3.21 c	4531.80	c 17.03	b 7.71	b 1.69
40%	2454.00	16.59 a	4.07 a	4733.80	d 14.28	b 6.74	b 1.48
Irrigation combined with mulch							
100%	2353.80	19.49 a	4.55 a	4532.80	a 22.41	a 10.16	a 2.23
80%	2326.80	18.94 a	4.42 a	4637.20	b 20.66	a 9.57	a 2.10
60%	2457.60	16.57 b	4.12 a	5380.40	c 17.71	a 9.51	a 2.08
40%	1961.60	16.76 b	3.24 b	4768.60	d 14.42	b 6.87	b 1.51

Table 2. The influence of regulated deficit irrigation and mulching on productive parameters of young 'Williams' pear trees (during 2013 and 2015)

Treatment	**No of fruit**	**Fruit weight g.**	**Total yield kg/tree**	**No of fruit**	**Fruit weight g.**	**Total yield kg/tree**
Year		2013			2015	
Irrigation without mulch						
100%	48.40 a	173.24 a	8.28 a	61.40 a	136.61 a	8.33 a
80%	31.00 b	176.86 a	5.38 b	62.60 a	124.51	7.70 a
60%	31.40 b	160.93 b	5.01 b	39.60 b	122.57	4.85 b
40%	29.60 b	190.93 c	5.53 b	82.20 c	114.29 b	9.93 c
Irrigation combined with mulch						
100%	33.20 a	184.80 a	6.07 a	59.60	125.65 a	7.36 a
80%	32.80 a	183.08 a	5.79 a	51.60 a	151.57 b	7.82 a
60%	34.00 a	184.95 a	6.07 a	56.80	130.34 a	7.35 a
40%	23.80 b	215.84 b	5.11 b	68.60 b	121.21 a	8.31 a

* Letters in each column (without or with mulch) represent significant differences at $P \leq 0.05$.

In the productive parameters during the year 2013 according ANOVA, irrigation levels significantly influenced total number of fruit, their weight and consequently total yield. In addition, mulching had a positive effect on all parameter values **[17]**.

The highest values of number of fruit were found in 80% irrigation, followed by 100% irrigation, 40% irrigation and lastly 60% irrigation. In mulch the highest values of number of fruit were found in 100% irrigation, followed by 80% irrigation, 40% irrigation and lastly 60% irrigation. For diameter of fruit and weight our results correspond with **[14]**. For weight of fruit our result are similar with **[3]**, but for diameter of fruit are approximate, which may be the result of differences in cultivar, tree age, and environmental conditions.

Also, during the year 2015 (Table 2) our results indicate that with RDI trees showed an increased production, respectively total yield. The highest values in total yield were found in 40% irrigation,

followed by 100% irrigation, 80% and lastly 60% of irrigation. Compared with first year of experiment during 2015 in treatment 100% irrigation were achieved only 1 kg more than 2013 year, in treatment 80% and 60% 2 kg more than 2 year ago while, in 40% were achieved 5 kg more than 2013 year. Our results correspond with **[2,4,6,7,11,19,21,22]**. DI during both stages I or II of fruit growth affects fruit production by increasing fruit numbers but decreasing fruit size, while over-irrigation strongly reduces fruit numbers **[22]**.

RDI has effect on number of fruit (increase) **[20,22]** but, decrease fruit size **[22]** in avarage about 50 g. According to number of fruits our result indicated that RDI contributes to improving pear production **[7]**. This study shows that RDI can be successfully applied to pear to control vigor without loss in fruit size and total yield **[5]**. The ratio between leaves/fruits is different for each species and cultivar **[8]** so, in our experiment during the year 2013 the ratio between leaves/fruit in treatment 100% of irrigation (control) were 62 leaves for fruit while, in treatment with deficit of irrigation were until 82 leaves for fruit. In the year 2015 the highest values is achivied in treatment 60% of irrigation with 104.57 leaves for fruit then in treatment 80% with 82.48 leaves for fruit. This ratio between leaves/fruit has influenced in weight of fruit, where the highest values is achieved in treatments with deficit irrigation.

4. Conclusions

Based on our investigations on the optimal deficit irrigation regime under the agroecological conditions of Kosovo and Dukagjini Plain in particular, under an intensive pear growing technology we demonstrated that regulated deficit irrigation and mulching can be successfully applied to pear orchard for reduction vegetative growth and to increase total yield. In productive parameters the highest values is achieved in treatment 40% of irrigation while, in vegetative parameters (number of leaves, leaf surface and area) the lowest values is achieved in tratment 40%. Mulching had a positive effect on all parameter values. Also, the results can be obtained primarily as a result of weather conditions. RDI affected to increase the ration between leaves/fruit.

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