

RESEARCH ARTICLE

(Open Access)**Impact of partial rootzone drying and mulching on fruit quality and nutrient contents of raspberries**KUJTIM LEPAJA^{1*}, ENDRIT KULLAJ¹, LAVDIM LEPAJA¹ NAIM KRASNIQI²¹Department of Horticulture and Landscape Architecture, Agricultural University of Tirana, Tirana, Albania²Faculty of Agriculture and Veterinary, University of Prishtina, Kosovo**Abstract**

The aim of experiment was to determine fruit quality and nutrient elements in raspberry fruits after applied water stress - partial rootzone drying and mulching. Macro and micro elements of fruits were analysed in harvest time. The experiment was conducted in Kosovo (Prishtina region) during 2014 and 2015 in a one- to two- year old raspberry orchard of 1 ha using a nested experimental design. Four levels of budget irrigation were studied: 100% ET (control) lateral, two laterals (TL), side lateral (SL), and without irrigation (WI). Each treatment contained 10 plants, of which five plants per treatment were mulched with wood chips (size 1-2 cm) at a 10 cm layer in first year of experiment while, 20 cm in second year. Using two-way ANOVA we found significant changes in a series of fruit quality parameters and macro and micro elements. Irrigation had significant changes in: number of fruit, fruit diameter, fruit length, fruit weight, pH, Brix, K, Ca, P, Fe, Cu, Mg, Mn, B, Cr, Zn, and Ni; mulching had significant changes in: fruit weight, pH, Brix, K, Ca, P, Mg, Mn, Fe, Cu, Cr and Zn. Our results confirmed that in our climatic condition raspberry cultivation cannot be performed without irrigation, also PRD is an ideal water saving technique but in total yield, the highest values were found in two laterals followed by side lateral while, in macro and micro elements for most of them the highest values were found in treatment where was applied water stress.

Keywords: Polka, water stress, PRD, wood chips**1. Introduction**

Production of raspberry (*Rubus idaeus* L.) is considered of particular importance for the economy of Kosovo. Until now about 1500 ha are planted with raspberry. Raspberries are very sensitive to drought, so additional irrigation needs to be applied in dry regions. In regions where there is lack of water, it is necessary to apply PRD or RDI, to the extent where plants, especially their productivity, are not endangered [17].

Partial rootzone drying (PRD) is an innovative irrigation technique which is thought to reduce plants water consumption based on the induction of changes in the plants hormonal balance and chemical signaling of roots in the drying soil [1]. To stimulate these responses, under PRD one side of the root system is well watered, while the other falls dry. In the drying part of the roots increased amounts of abscisic acid (ABA) are produced which make the plant reduce its water consumption. Through the wet side of the root

system it is still well enough supplied to maintain fruit growth, while vegetative growth is reduced [4, 5]. Thereby fruit yield is widely unaffected or only slightly reduced and so water-use efficiency can be increased massively. This has been described for a variety of tree crops, such as grape-wine [5], apple [24], pear [11], citrus [10], raspberries [7] and olives [25]. However, the exact functioning of PRD is not well understood and especially in recent publications many researchers claim that the changes in water consumption are a common effect of drought stress, which can be obtained in the same way by controlled deficit irrigation (CDI), where water is uniformly applied to the whole root system [21,9,19] cit.[22].

It is suggested that plants under PRD performs better than under deficit irrigation (DI) when the same amount of water was applied [1,12,14].

The scope of the study was to define the irrigation regime that determines the best fruit quality indicators. PRD is quite common in other fruit species; however,

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for raspberries it is more or less un-investigated, and every research about PRD will contribute to knowledge about this culture.

2. Material and Methods

This field experiment was designed to assess the productive response and nutrient contents of 'Polka' raspberry plants after the application of PRD combined with mulching, were used in a commercial raspberry orchard. The experimental set up was a nested design, whereby the categories of nested factor within each level of the main factor are different, i.e. different plants of cv. Polka raspberry give rise to the leaf/fruit samples within each of the main irrigation treatment. Four levels of irrigation were applied: 100% of evapotranspiration (ET) as control standard lateral (one lateral-normal irrigation), with two laterals, side lateral and without irrigation. Orchard was planted in April 2014. Drip distance in the lateral pipe (euro drip irrigation) was 0.20 m while drip irrigation spend 1.6 L of water h⁻¹ drip⁻¹, (in two laterals treatment - each lateral spent 1.6 L of water h⁻¹ drip⁻¹, namely twice as much water as the other treatments). A total of 39 irrigation sets (one irrigation is made per 1 h 30 min) were applied. PRD was applied from end of the April until end of the September. Each treatment (each level of irrigation) has been in a row. For each treatment we used 10 plants, 5 of which were mulched with 10 cm thick layer of wood chips (1 to 2 cm, Holzdekor), totalling 40 plants for the entire experiment. Mulching material was placed in a row at a width of 0.80 m on July 20, 2014. Planting distances were 3 m between the rows and 0.40 m in the row. All fruits in all plants were

counted. Their size (diameter and length of fruits) was measured (mm) at the equator with a calliper (electronic digital calliper) using all fruits per plant, all the time during every harvest (1st measurement on August 6th and last measurement on October 17th, 2015). Average fruit weight was measured (grams) using an analytical balance for all fruits, each harvest.

During harvesting period for each cane 250 g were sent to the laboratory where the following quality indicators were analysed: pH, Brix, K, Ca, P, Mg, Mn, B, Fe, Cu, Cr, Zn, Ni, Pb.

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

3. Results and Discussion

Water shortages in the territory of Kosovo, especially during the vegetation period, necessitate intervention with supplemental irrigation, but the application of PRD or regulated deficit irrigation (RDI) can only start from the beginning or middle of June due to the fact that Kosovo has sufficient rainfall during May. Raspberries have shallow root system and are not enduring to moist and dry soils, therefore care should be taken regarding irrigation by making an irrigation program depending on climate conditions namely precipitation and soil moisture measurements with relevant instruments (irrometer/tensiometer). Our result confirmed that in our climatic condition raspberry cultivation cannot be performed without irrigation.

Table 1. The influence of partial rootzone drying and mulching on fruit quality of 'Polka' raspberry

Treatment	Number of fruits	Diameter of fruit (mm)	Length of fruit (mm)	Fruit weight (g)
Irrigation without mulch				
Normal irrigation	143.20 ^a	19.73 ^a	21.28 ^a	3.253 ^a
Two laterals	136.00 ^a	20.34 ^b	22.15 ^b	3.554 ^b
Side lateral	163.00 ^b	19.01 ^c	20.41 ^c	2.793 ^c
Without irrigation	85.00 ^c	17.23 ^d	17.28 ^d	1.669 ^d
Irrigation combined with mulch				
Normal irrigation	134.40 ^a	19.26 ^a	20.14 ^a	3.089 ^a
Two laterals	147.40 ^a	20.52 ^b	22.83 ^b	3.676 ^b
Side lateral	154.40 ^a	19.05 ^a	20.52 ^a	2.945 ^a
Without irrigation	102.40 ^b	17.32 ^c	18.34 ^c	2.026 ^c

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

Table 2. Average values of the parameters tested in fruits at harvest with differences between treatment

Treatment	pH	Brix	K	Ca	P	Fe	Mg
Irrigation without mulch							
Normal irrigation	3.41a	9.27a	481.13a	40.69a	163.30a	1.22a	40.05a
Two laterals	3.46b	9.35a	863.72b	36.67b	314.07b	2.50b	97.09b
Side lateral	3.30c	9.11b	858.55c	25.79c	435.50c	2.45b	79.53c
Without irrigation	3.45b	8.73c	864.29d	78.62d	436.79d	2.79c	113.04d
Irrigation combined with mulch							
Normal irrigation	3.50a	9.17a	1006.17a	41.57a	311.43a	4.16a	101.06a
Two laterals	3.36b	9.53b	893.78b	44.27b	316.67b	3.25b	94.78b
Side lateral	3.40c	9.53b	728.72c	26.11c	370.82c	1.98c	68.13c
Without irrigation	3.55d	8.86c	761.65d	57.73d	289.88d	3.61d	81.96d

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

Table 3. Average values of the parameters tested in fruits at harvest with differences between treatment

Treatment	Mn	B	Zn	Cu	Cr	Ni	Pb
Irrigation without mulch							
Normal irrigation	0.88a	0.65a	0.51a	0.34a	0.03a	0.55a	<0.1
Two laterals	0.86b	1.10b	0.60b	0.43b	0.24b	0.91a	<0.1
Side lateral	1.01c	0.87c	0.74c	0.49c	0.08c	0.68a	<0.1
Without irrigation	2.25d	1.71d	0.88d	0.53d	0.14d	1.04a	<0.1
Irrigation combined with mulch							
Normal irrigation	1.87a	1.30a	0.91a	0.46a	0.69a	1.03a	<0.1
Two laterals	1.32b	1.08b	0.76b	0.45b	0.03b	0.88a	<0.1
Side lateral	1.19c	0.85c	0.45c	0.28c	0.10c	0.42b	<0.1
Without irrigation	1.09d	1.50d	1.72d	0.24d	0.62d	1.49c	<0.1

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

Application of partial rootzone drying respectively four different levels of irrigation in raspberry in combination with mulch is a new thinks (innovation), and each result will contribute to the knowledge of this culture and PRD.

The use of mulch at 10 cm thick layer has influenced most of the parameters increasing their values as well as suppressing weeds compared to non-mulched treatment [15].

Tables 1, 2 and 3 summarize the results after application of PRD and mulching on fruit quality parameters and nutrient contents of 'Polka' raspberries, and differences between treatments according LSD testing. We found significant changes in a series of fruit quality parameters which confirms the results of other authors [2] and nutrient elements [18].

During the year 2015 according ANOVA we found significant changes in a series of fruit quality parameters and macro and micro elements. Irrigation had significant changes in: number of fruits, fruit diameter, fruit length, fruit weight, pH, Brix, K, Ca, P, Mg, Mn, B, Fe, Cu, Cr, Zn and Ni. It should also be

stressed that mulching had significant changes in: fruit weight, pH, Brix, K, Ca, P, Mg, Mn, Fe, Cu, Cr and Zn.

In the treatment without mulch on productive parameters (Table 1), the highest values were found in two laterals treatment, followed by normal irrigation (control), side lateral and lastly without irrigation while, in the treatment with mulch for length of fruit and number of fruits the highest values were found in two laterals, followed by side lateral, normal irrigation and lastly without irrigation. Our results are consistent with other authors [23] concerning some parameters. Number of fruits influences other productive parameters, especially in their average weight.

High nutritional values of raspberry fruit make this crop highly demanded all around the world. Different cultivars have different nutrient values. However, changes in these values depend also on a number of factors such as climate, cultural practices, irrigation etc. Tables 2 and 3 are presented the results of macro and micro nutrients.

For some of the elements (pH, Ca, Fe, B, Zn, Cr and Ni) the lowest values were found in side lateral (PRD).

The results showed that the highest and lowest values are different between treatment without mulch and with mulch. Also, according LSD testing the most part of nutrients had differences between each treatment but, however, for some nutrients/parameters PRD has given similar results to those obtained with other treatments, with no clear advantage.

4. Conclusions

Even if application of partial rootzone drying combined with mulch is a new thinks (innovation) our results indicate that this combination can be successfully applied to raspberry orchard. Except this, PRD is an ideal water saving technique and can improve fruit quality in terms of physical and chemical quality, while mulch reduce evaporation, prevent weeds, add organic matter, increase production. In our climatic condition raspberry cultivation cannot be performed without irrigation, therefore the use of PRD it is an advantage.

5. References

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