Bulgarian Journal of Agricultural Science, 24 (No 4) 2018, 648–653

Influence of irrigation management as partial rootzone drying on raspberry canes

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Abstract

Lepaja, K., Kullaj, E., & Lepaja, L. (2018). Influence of irrigation management as partial rootzone drying on raspberry canes. *Bulgarian Journal of Agricultural Science*, *24*(4), 648–653

The effects of partial rootzone drying (PRD) compared with other irrigation systems, namely 100% of evapotranspiration as control, two laterals, side lateral and without irrigation were evaluated in field-grown raspberry canes (cv. Polka) for the vegetative and productive response after applied water stress – PRD and mulching. The experiment was conducted in Kosovo during the years 2014, 2015 and 2016 on raspberry orchard of 1 ha using a nested experimental design. Per four levels of irrigation, for each treatment contained 10 plants, of which five plants per treatment were mulched to a 10 cm layer of wood chips. During the third year of experiment using ANOVA we found significant changes in a series of vegetative and productive indices. Irrigation had significant changes on number of leaves, leaf surface and area, LAI, shoot length, number of fruit, fruit diameter, fruit length, fruit weight and total yield. It should also be stressed that mulching had significant changes in number of leaves, leaf surface and area, LAI, fruit length, fruit weight and total yield. Our results confirmed that a moderate water stress reducing vegetative growth while total yield the highest values were found in two laterals. PRD can be successfully applied to raspberry orchard to reduce vegetative growth and increase total yield, too with significant water saving.

Keywords: raspberry; Rubus idaeus; water stress; PRD

Introduction

Water shortages in the territory of Kosovo, especially during the growing season, necessitate intervention with supplemental irrigation, but the application of partial root drying (PRD) can start from the beginning or middle of June as Kosovo has sufficient rainfall during May.

Partial rootzone drying (PRD) is an irrigation technique that was recently developed in Australia for grapes (Dry et al., 1996; Dry and Loveys, 1998). With PRD, only one half of the rootzone is irrigated whereas the other half is not. The physiological basis for PRD is that roots in drying soil produce abscisic acid (ABA) which is translocated to the shoots, indicating a developing soil-water deficit (Dry et al., 1996). Implementation of PRD irrigation requires that the watering system allow a wet and dry cycle in different areas of the root, independently if it is flood or pressurized irrigation (Loveys et al., 2000).

The quantity of water in raspberry production is important throughout the life of the planting. Too much water over a long period of time on poorly drained soil will cause plant root disease and plant loss. Climatic conditions determine water needs. When calculating the amount of water needed for raspberries using drip irrigation, only the root zone area needs to be irrigated. Drip irrigation applies water to a part of the root zone and does not broadcast the water as an overhead or flood method does, so it allows more efficient application of water to the desired crop (Funt and Ross, 2013).

PRD is a novel irrigation technique, which has found a wide application in the horticulture industry (Stoll et al., 2002). It is an irrigation technique where half of the root zone is irrigated while the other half is allowed to dry out.

The treatment is then reversed, allowing the previously well-watered side of the root system to dry down while fully irrigating the previously dry side. Regulated deficit irrigation (RDI) and partial root drying (PRD) are two irrigation methods that attempt to decrease the agricultural demand for water. PRD is an irrigation technique based on alternately wetting and drying opposite parts of the surface soil under which the plant root system is thought to be located. The advantages of PRD are: reduction of costs, minimization of nutrient and pesticide leaching to ground water, reduction of excess vegetative growth, quality improvements, it involves the use of a smaller amount than the calculated need for water etc. (Pulupol et al., 1996; Marsal et al., 2002; Kullaj, 2007; Tatullo et al., 2007; Posadas et al., 2008). Compared to regulated deficit irrigation (RDI), implementing the PRD technique is simpler, requiring only the adaptation of irrigation systems to allow alternate wetting and drying of part of the rootzone (Loveys et al., 2000).

The scope of the study (three years) was to determine the impact of PRD in combination with mulching on the vegetative and productive parameters where water resources are limited.

Materials and Methods

This field experiment was designed to assess the vegetative and productive response of 'Polka' raspberry plants after the application of PRD combined with mulching, were used in a commercial raspberry orchard in Kosovo (Prishtina region) during 2014, 2015 and 2016. ET was estimated using the FAO Penman Monteith approach (Allen et al., 1998). 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 (one lateral-control is located in the vicinity of canes while side lateral is located 20 cm apart of canes). Orchard is planted on April 2014. Drip distance in the lateral pipe was 0.20 m while drip irrigation spends 1.6 L h^{-1} of water per drip (in two laterals treatment- each lateral spends 1.6 L h^{-1} of water per drip, namely twice as much water as the other treatments). A total of 20 irrigations (one irrigation is made per 1 hour 30 min) were applied.

Each treatment (each level of irrigation) has been in a row. For each treatment we used 10 canes, 5 of which were mulched with a 10 cm thick layer of wood chips, totaling 40 canes for the entire experiment. Mulching material was placed in a row of a width of 0.80 m. Planting distances were 3 m between the rows and 0.40 m in the row.

To evaluate the effects of partial rootzone drying and its combination with mulching, we have compared both vegetative and fruiting parameters. Shoot length was measured (in cm) on all plants. Leaf counting for all plants was carried out on August. Leaf surface (cm^2) of 10 leaves per plants was conducted on September. Total leaf area and LAI measurement (m^2) was conducted on August.

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. Average fruit weight was measured (grams) using an analytical balance for all fruits, each harvest. Yield (in g/plant) was calculated at all period of the harvest time measuring the total weight of all fruits per plant.

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

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 endurable 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).

In Kosovo, at the beginning of the vegetative period trees have enough moisture supplied by the heavy spring rainfalls, as well as water reserves accumulated in the soil during winter from snow. This has happened for centuries, but with global warming it also can change, as it is increasingly witnessed in many countries with dry winters in one side, or spring floods on the other.

At present and more so in the future, irrigated agriculture will take place under water scarcity. Insufficient water supply for irrigation will be the norm rather than the exception, and irrigation management will shift from emphasizing production per unit area towards maximizing the production per unit of water consumed, the water productivity (Fereres and Soriano, 2007).

In the first year of our experiment using ANOVA two-way with post hoc testing we found that treatments without irrigation and side lateral had a reduced vegetative growth, with significantly lower values of shoot length, number of leaves, leaf surface, leaf area and LAI.

However, two lateral treatment gave higher values of these vegetative parameters compared to control and con-

Table 1
Average data for vegetation parameters with differences between treatments according to LSD testing (2014)

Treatment	Number of leaves	Leaf surface area (cm^2)	Leaf area (m^2)	LAI (m^2)	Shoot length (cm)
Irrigation without mulch					
Normal irrigation	162.80b	52.11a	8.470c	6.78c	106.60a
Two laterals	183.60b	60.22b	11.011b	8.81b	112.00a
Side lateral	135.80a	45.00c	6.104a	4.88a	98.20a
Without lateral	136.20a	50.16a	6.830a	5.46a	104.40a
Irrigation combined with mulch					
Normal irrigation	170.60b	52.11a	8.470c	6.78c	106.60a
Two laterals	182.00b	50.54b	9.231b	7.38b	118.00a
Side lateral	124.20a	48.48b	6.026a	4.82a	84.60b
Without lateral	131.20a	41.73a	5.470a	4.38a	116.00a

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

sequently to all other treatments. It should also be stressed that mulching had significant changes in leaf surface, leaf area and LAI. PRD and mulching had a combined effect on leaf surface. With mulch the highest values of vegetative parameters were found in two laterals treatment, followed by normal irrigation (control), side lateral and lastly without irrigation.

As it can be seen from the results of vegetative parameters (Table 1), in all parameters (number of leaves, leaf surface cm^2, leaf area m^2, LAI m^2 and shoot length cm) we observed a reduction in vegetative growth without being influenced in the productive parameters (Dry et al., 1996, 2000; Stoll et al., 2002; Grant et al., 2004; Spreer et al., 2007).

In the fruiting measurements, the treatment without irrigation showed a reduced generative growth compared to control, with significant changes in the number of fruits, fruit diameter, fruit length, fruit weight and total yield. The side lateral treatment gave a lower number of fruits and total yield (g/plant) but other parameters were not different from control. The highest values of productive parameters were found in two lateral treatment followed by normal irrigation (control), side lateral and lastly without irrigation. Mulching had significant changes in the number of fruit and total yield while PRD and mulching had a combined effect on fruit length and fruit weight. In mulch the highest values of productive parameters were found in two laterals treatment, followed by normal irrigation (control), side lateral and lastly without irrigation.

Concerning some parameters (fruit weight and total yield) researched by Stoll et al. (2002), our results are consistent with the authors concerned.

As shown in the Table 2, the number of fruits influences other fruiting parameters, especially in their average weight than in diameter and length of fruit and total yield.

In second year of experiment (Tables 3 and 4), we found significant changes in a series of vegetative and fruiting parameters which confirms the results of other authors (Davies et al., 2000). All values of vegetative and productive parameters were higher in two laterals treatment except for number of fruits. We found that PRD treatments had a reduced

Table 2
Average data for reproductive parameters with differences between treatments according to LSD testing (2014)

Treatment	Number of fruits	Diameter of fruit (mm)	Length of fruit (mm)	Fruit weight (g)	Total yield (g/cane)
Irrigation without mulch					
Normal irrigation	180.40b	20.93b	24.46b	4.24c	765.90c
Two laterals	175.60b	20.88b	24.55b	4.39c	769.71b
Side lateral	152.20a	20.29b	24.09b	4.00b	609.53c
Without lateral	147.00a	18.99a	22.37a	3.12a	458.57a
Irrigation combined with mulch					
Normal irrigation	209.00b	20.68b	23.71a	3.66a	764.22c
Two laterals	200.20b	21.06b	25.12b	4.50b	900.30b
Side lateral	152.80a	20.71b	24.37b	4.20b	651.16c
Without lateral	151.40a	19.16a	23.12a	3.39a	513.49a

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

Table 3
The influence of partial rootzone drying and mulching on vegetative parameters of 'Polka' raspberry canes (2015)

Treatment	Number of Leaves	Leaf surface area (cm^2)	Leaf area (m^2)	LAI (m^2)	Shoot length (cm)
Irrigation without mulch					
Normal irrigation	178.80 a	36.32 a	0.65 a	1.94 a	139.20 a
Two laterals	201.20 b	42.67 b	0.85 b	2.56 b	148.00 a
Side lateral	142.80 c	30.13 c	0.43 c	1.28 c	114.00 b
Without lateral	108.00 d	23.93 d	0.25 d	0.76 d	93.60 c
Irrigation combined with mulch					
Normal irrigation	189.80 a	36.76 a	0.69 a	2.07 a	145.18 a
Two laterals	208.00 b	43.57 b	0.90 b	2.71 b	154.20 b
Side lateral	152.20 c	34.28 c	0.52 c	1.55 c	133.60 c
Without lateral	121.00 d	25.45 d	0.30 d	0.91 d	99.00 d

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

vegetative growth on all parameters. Irrigation levels significantly influenced on number of leaves, leaf surface and area, LAI, shoot length, number of fruit, fruit diameter, fruit length, fruit weight and total yield. Mulch significantly influenced on number of leaves, leaf surface and area, LAI, shoot length and fruit weight. Results obtained could be mainly due to weather conditions, namely temperature and rainfall during experimentation. Moreover, crop techniques variations, type of soil, age of plants etc., should be considered because of the fact that long-term plant responses to RDI or PRD are more accurate than short-term responses (Lepaja et al., 2015b).

As far as concerns vegetative parameters (Table 3), the highest values of leaf number, surface, area, LAI and shoot length were found in two laterals treatments, followed by normal irrigation, side lateral and lastly without lateral. These results indicate that canes have shown a positive reduction in vegetative growth to PRD treatment (Dry et al., 1996, 2000; Stoll et al., 2002; Grant et al., 2004; Spreer et al., 2007). The use of mulch at 10 cm thick layer has influenced most of the parameters increasing their values as well as suppressing weeds (Table 3) compared to non-mulched treatment (Lepaja et al., 2015a).

Results presented here provide support for the suggestion that application of PRD has reflected to reduction of vegetative mass without negatively affecting fruit production compared to control treatment (Stoll et al., 2002; Grant et al., 2004).

In the treatment without mulch on productive parameters (Table 4), 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 total yield, 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.

In our climatic conditions it can not be thought that raspberry cultivation can be performed without irrigation. In our study total yield in treatment without lateral-no irrigation (140.50 g without mulch and 207.36 g with mulch) is the result of rainfall in spring. In treatment with mulch the yield

Table 4
The influence of partial rootzone drying and mulching on productive parameters of 'Polka' raspberry canes (2015)

Treatment	Number of fruits	Diameter of fruit (mm)	Length of fruit (mm)	Fruit weight (g)	Total yield (g/cane)
Irrigation without mulch					
Normal irrigation	143.20 a	19.73 a	21.28 a	3.253 a	465.87 a
Two laterals	136.00 a	20.34 b	22.15 b	3.554 b	483.27 a
Side lateral	163.00 b	19.01 c	20.41 c	2.793 c	455.01 a
Without lateral	85.00 c	17.23 d	17.28 d	1.669 d	140.50 b
Irrigation combined with mulch					
Normal irrigation	134.40 a	19.26 a	20.14 a	3.089 a	414.96 a
Two laterals	147.40 a	20.52 b	22.83 b	3.676 b	541.42 b
Side lateral	154.40 a	19.05 a	20.52 a	2.945 a	454.99 a
Without lateral	102.40 b	17.32 c	18.34 c	2.026 c	207.36 c

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

Table 5
Average data for vegetation parameters with differences between treatments according to LSD testing (2016)

Treatment	Number of Leaves	Leaf surface area (cm^2)	Leaf area (m^2)	LAI (m^2)	Shoot length (cm)
Irrigation without mulch					
Normal irrigation	200.80a	44.82a	0.89a	2.69a	156.00a
Two laterals	210.00a	44.55a	0.95a	2.87a	158.00a
Side lateral	194.20b	38.26b	0.74b	2.23b	141.00b
Without lateral	67.40c	24.72c	0.16c	0.50c	69.80c
Irrigation combined with mulch					
Normal irrigation	207.00a	45.52a	0.94a	2.82a	157.00a
Two laterals	214.60a	46.98a	1.00b	3.02b	161.00a
Side lateral	195.20b	40.02b	0.82c	2.45c	145.00b
Without lateral	76.20c	30.68c	0.23d	0.70d	73.00c

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

Table 6
Average data for reproductive parameters with differences between treatments according to LSD testing (2016)

Treatment	Number of fruits	Diameter of fruit (mm)	Length of fruit (mm)	Fruit weight (g)	Total yield (g/cane)
Irrigation without mulch					
Normal irrigation	198.40a	19.58a	20.55a	3.274a	647.77a
Two laterals	200.00a	20.54b	22.27b	3.543b	708.46b
Side lateral	202.00a	19.49a	20.65a	3.471a	698.61b
Without lateral	98.60b	17.25c	18.28c	1.820c	178.91c
Irrigation combined with mulch					
Normal irrigation	193.40a	19.63a	20.58a	3.403a	654.71a
Two laterals	199.60a	20.72b	22.96b	3.732b	742.70b
Side lateral	203.60a	19.61a	20.94a	3.541a	719.95b
Without lateral	110.80b	17.39c	18.39c	2.079c	230.26c

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

is higher than without mulch as a result of the effect of mulch to save moisture.

In third year of experiment (Tables 5 and 6), we found significant changes in a series of vegetative and fruiting parameters which confirms the results of other authors (Davies et al., 2000). Irrigation had significant changes on number of leaves, leaf surface and area, leaf area index (LAI), shoot length, number of fruit, fruit diameter, fruit length, fruit weight and total yield. It should also be stressed that mulching had significant changes in number of leaves, leaf surface and area, LAI, fruit length, fruit weight and total yield. The study provides further positive support of PRD irrigation strategy in the region according to climate conditions in Kosovo. In particular, reduction of the irrigation water applied during the entire season to only one side of the root-zone did not reduce yields compared to conventionally irrigated plants. Differences in water quantity resulted in some reduction of vegetative growth of raspberries canes.

If compare three levels of irrigation, normal irrigation, two laterals and side lateral, the lowest values were found in side lateral, followed by normal irrigation. Recently the use of mulch is present in orchards for many reasons, the main ones being to prevent weeds, to reduce evaporation and to add organic matter on soils. From a practical viewpoint, an appropriate mulch will significantly reduce the amount of irrigation needed for all landscapes, and in some cases it can eliminate it altogether (Pfammatter and Dessimoz, 1997). Mulch is an ideal water saving technique. In addition, it has been showed that mulching has an impact on reducing the number of weeds, having zero weeds, by not being able to take the fertilization and humidity from the trees (Greenly and Rakow, 1995) which is reflected in size and weight of the fruits, number of fruits and quality of fruits.

In the third year of the experiment, the highest values for the all parameters were achieved in treatments with mulching.

Conclusion

Climate change in our country is reflected in the increase of temperature during the year and the growing season for about 2°C, while rainfalls are reduced. Based on our investigations on the partial rootzone drying under the agroecological conditions of Kosovo (Prishtina region) on raspberry orchard for three years, several conclusions can be drawn.

With the current climatic conditions, we can conclude that raspberry cultivation cannot be performed without irrigation, include fruit quality and production. After each growing season at the end of the treatment period (normal irrigation, two laterals, side lateral, without irrigation) of partial rootzone drying (PRD) application, we found changes in a series of vegetative and productive indices, based on ANOVA. The highest values were found in two laterals, followed by side lateral, normal irrigation (one lateral). Our results confirmed that a moderate water stress reduces vegetative growth. PRD can be successfully applied to raspberry orchard to reduce vegetative growth and increase total yield. Mulch is an ideal water saving technique, which is reflected in size and weight of the fruits, number of fruits as well as in the quality of the fruits.

References

Allen, R. G., Pereira, L. S., Raes, D., & Smith, M. (1998). Crop evapotranspiration: Guidelines for computing crop water requirements. FAO Irrigation and drainage paper 56. Fao, Rome.

Davies, W. J., Bacon, M. A., Stuart Thompson, D., Sobeih, W., & González Rodríguez, L. (2000). Regulation of leaf and fruit growth in plants growing in drying soil: exploitation of the plants' chemical signal system and hydraulic architecture to increase the efficiency of water use in agriculture. *Journal of Experimental Botany*, *51*(350), 1617-1626.

Dry, P.R., Loveys, B. R., Botting, D., & Düring, H. (1996). Effects of partial root-zone drying on grapevine vigour, yield, composition of fruit and use of water. In *Proc. 9th Aust. Wine Ind. Techn. Conf., Adelaide, Australia, 1996*, 126-131.

Dry, P. R., & Loveys, B. R. (1998). Factors influencing grapevine vigour and the potential for control with partial rootzone drying. *Australian Journal of Grape and Wine Research*, *4*(3), 140-148.

Dry, P. R., Loveys, B. R., Stoll, M., Steward, D., & McCarthy M. G. (2000). Partial Rootzone Drying – an update. *Australian Grape grower and Winemaker*, 438a, 35-39.

Fereres, E., & Soriano, M. A. (2006). Deficit irrigation for reducing agricultural water use. *Journal of Experimental Botany*, *58*(2), 147-159.

Funt, R. C., & Ross, D. S. (2013). Soil and water management. In: *Raspberries, Crop Production Science in Horticulture,* CABI, series, *23*, 103-119.

Grant, O. M., Stoll, M., & Jones, H. G. (2004). Partial rootzone drying does not affect fruit yield of raspberries. *The Journal of Horticultural Science and Biotechnology*, *79*(1), 125-130.

Greenly, K. M., & Rakow, D. A. (1995). The effect of wood mulch type and depth on weed and tree growth and certain soil parameters. *Journal of Arboriculture*, *21*, 225-225.

Kullaj, E. (2007). *Advanced Biology of Fruit Crops*. FBM. UBT. Tirana, Albania, 313 pp. (in Albanian).

Lepaja, L., Kullaj, E., Lepaja, K., & Zajmi, A. (2015a). Effects of regulated deficit irrigation, mulching and their combination on fruit diameter growth of young 'William'pears. In *Proceedings. 50th Croatian and 10th International Symposium on Agriculture.* 16-20 February, 2015, Opatija, Croatia. p.580-584.

Lepaja, L., Kullaj, E., Lepaja, K., & Zajmi, A. (2015b). Vegetative and productive response of young ,Williams' pear trees to regulated deficit irrigation (RDI), mulching and their combinations. *Acta Hortic. 1094*, 351-356.

Loveys, B. R., Dry, P. R., Stoll, M., & McCarthy, M. G. (2000). Using plant physiology to improve the water use efficiency of horticultural crops. *Acta Hort*., 537, 187-199.

Marsal, J., Mata, M., Arbonés, A., Rufat, J., & Girona, J. (2002). Regulated deficit irrigation and rectification of irrigation scheduling in young pear trees: an evaluation based on vegetative and productive response. *European Journal of Agronomy*, *17*(2), 111-122.

Pfammatter, W., & Dessimoz, A. (1997). Influence de l'irrigation et de la couverture du sol sur le développement et le rendement de jeunes pommiers (Influence of irrigation and ground cover on development and yields of young apple trees). *Revue Suisse d'Viticulture, d'Arboriculture et d'Horticulture*, *29*(5), 301-304 (Fr).

Posadas, A., Rojas, G., Malaga, M., Mares, V., & Quiroz, R. (2008). *Partial root-zone drying: an alternative irrigation management to improve the water use efficiency of potato crops*. International Potato Center.

Pulupol, L. U., Behboudian, M. H., & Fisher, K. J. (1996). Growth, yield, and postharvest attributes of glasshouse tomatoes produced under deficit irrigation. *HortScience*, *31*(6), 926-929.

Spreer, W., Nagle, M., Neidhart, S., Carle, R., Ongprasert, S., & Müller, J. (2007). Effect of regulated deficit irrigation and partial rootzone drying on the quality of mango fruits (Mangifera indica L., cv.'Chok Anan'). *Agricultural Water Management*, *88*(1-3), 173-180.

Stoll, M., Jones, H. G., & Infante, J. M. (2002). Leaf gas exchange and growth in red raspberries is reduced when part of the root system is dried. *Acta Hort*. (ISHS) 585, 671-676.

Talluto, G., Farina, V., & Bianco, R. (2007). Growth, fruit yield and quality of 'Golden Delicious' apple trees under fixed partial rootzone drying. *Journal of Applied Horticulture*, *9*(1), 50-55.