Partial root drying: New approach for potato irrigation

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Abstract: Drought is one of the most common environmental stresses that may limit agricultural production worldwide. To overcome the drought problems efficiently, an innovative sustainable irrigation technique called Partial Root Drying (PRD) was proposed. PRD 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. The PRD benefit is in the terms of improved water-use efficiency (IWUE). The aim of presented work was to compare the effects of PRD with full irrigation (FI) on yield of field-grown potato, and to test for effects of PRD on IWUE, tuber yield and quality. The experiments were conducted during 2007 and 2008 seasons. In PRD treatment in 2007 season 70% of the irrigation water in FI was applied to one half of the root system, although in 2008 season PRD was applied dynamically (by replacing 70% PRD with 50% PRD in last two weeks). Irrigation scheduling was based on evapotranspiration and soil water data (measured by TDR). Experimental results for both seasons confirmed that with PRD irrigation it is possible to increase IWUE, save water for irrigation and increase quality of potato tuber (starch content).
Keywords: potato, PRD, yield, IWUE, starch, sugars

Introduction

Drought is one of the most common environmental stresses that may limit agricultural production worldwide. Many vegetables, including potato, have high water requirements and supplemental irrigation is necessary for successful production (Fabeiro et al., 2001). However, in many countries as a consequence of global climate changes and environmental pollution, water use for agriculture is reduced (FAO, 2002).
To overcome the drought problems efficiently, an innovative sustainable irrigation technique called Partial Root Drying (PRD) was proposed. Partial root drying (PRD) 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. Comparing to other irrigation methods implementation of the PRD technique is simple and requires only the adaptation of irrigation systems in a such way to allow alternate wetting and drying of part of the root zone (FAO, 2002). The PRD results for different plant species (including potato) demonstrated the benefit of these methods in terms of improved water-use efficiency (Davies et al., 2000; Liu et al., 2006; Shanhazari et al., 2007). The aim of the presented research was to apply and assess the effects PRD technology on potato yield, yield quality and irrigation water use efficiency in the field trial in Serbia.

Materials and methods

The experiment with potato was conducted in the opened field situated in the farm for growing vegetables ("Salate Centre"), 10 km north of Serbian capital Belgrade. The soil of field site is a silty-clay and it was developed on alluvial deposit. Potato seeds tubers (*Solanum tuberosum* var. Liseta) were planted in the beginning of April. During the

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vegetation seasons plants were treated against weeds and fungal disease and regularly fertilized.

Irrigation system applied was subsurface drip irrigation and the irrigation management included partial root drying (PRD) and full irrigation (FI). For the FI treatment, one drip line was placed in the top of the ridge although in PRD treatment two drip lines were operated separately and were placed in parallel in the top of the ridge. In both investigated seasons the irrigation started during the tuber filling and ended 2 weeks before final harvest. The soil water content in FI treatment was kept close to field capacity. In PRD treatment one side of the row was irrigated while the other was kept dry and plants received 70% or 50% of FI depending of investigated season. During 2007 year PRD treated plants received 70% of the irrigation water of FI, although in 2008 the PRD system was applied as 70% of FI and 50% of FI (last two weeks of irrigation period). The PRD irrigation was shifted between two sides of the plants every 5 to 7 days depending on soil water content. Measurements of soil water content were done by TDR probes (Time domain reflectometer, TRASE, Soil Moisture Equipment Corp., USA) twice per week and these data were used to adjust irrigation water requirement during growing seasons. At the end of the vegetation seasons, analyses of tuber yield, irrigation water use efficiency (IWUE) and tubers quality were carried out. Potato yield was calculated as tuber fresh weight per plant, IWUE as the ratio of tuber fresh mass and irrigation water applied in during vegetation season. The tuber harvest quality was characterised by analysing of starch (after isolation followed by acid hydrolysis detected as reducing sugar) and soluble reducing sugars (by Luff-Schoorl's method, ISI, 2002).

The measured traits have been analyzed for statistically significant differences by Student's unpaired *t*-tests (Sigma Plot 6.0 for Windows - SPW 6.0, Jandel Scientific, Erckhart, Germany.

Results and discussion

The climate in field side is continental type with hot and dry summers and cold and rainy winters. As in the rest of Serbia, farm suffers from water deficit during the main growing season. Precipitation data (Fig.1) showed that during the experimental period (from April to the end of August) the precipitation was lower in 2008 than in 2007, although the mean temperature were similar in both seasons (Fig.1). Due to lower precipitation in 2008, comparing to 2007 (about 50mm) and higher evapotranspiration (about 20mm) during the growing season, the water deficit was bigger in 2008 comparing to 2007 and thus the number of irrigation and amounts of applied water was increased in 2008 comparing to 2007.

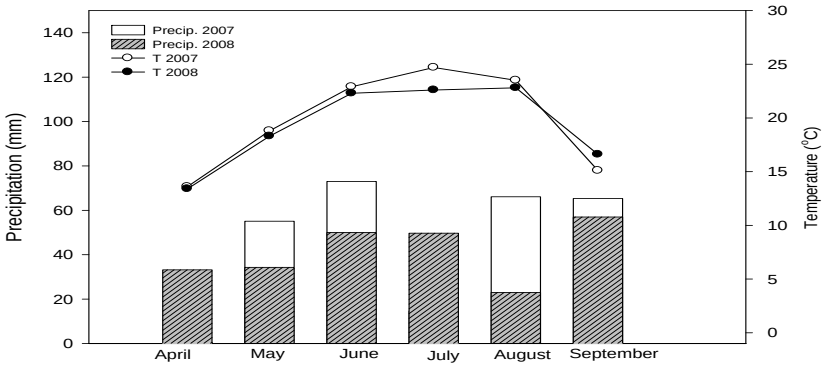

Figure 1. Average precipitation and mean temperature in the area of the field trial during growing seasons of 2007 and 2008

Comparison between investigated years showed that yield in 2008 seasons was ca. 20% higher than in 2007 season (Table 1). It is well known that potatoes are very sensitive to soil moisture stress (Onder et al., 2005) and, thus, the increased number of irrigation in 2008 had positive effect on yield. Comparing to FI the PRD treatment had a reducing effect on yield in both investigated years (20 and 12% for 2007 and 2008, respectively). In the literature there is an inconsistency on the effects of the PRD on potato yield. Our results are in agreement with the results of Liu et al., (2006) which showed that yield was reduced in potato plants exposed to PRD and comparing to FI treatments. However, the results of Shanhazari et al., (2007) showed that with the PRD treatments maintenance of yield and number of tubers could be achieved. Comparison between PRD treatments in investigated 2007 and 2008 seasons showed that yield of PRD treated crops in 2008 ca. 65% higher than in 2007 years. These results confirmed that the dynamic approach of PRD, when during the late tuber filling stages the PRD 70% was replaced by PRD 50%, had a positive effect on yield.

Table 1. The effects of applied irrigation treatments on yield and irrigation water use efficiency (IWUE) of potato grown in 2007 and 2008 years (means ± S.E)

Treatments	2007 year			2008 year		
	Tuber FW ($t\ ha^{-1}$)	Irrigation water applied ($m^3\ ha^{-1}$)	IWUE ($kgha^{-1}m^{-3}$)	Tuber FW ($t\ ha^{-1}$)	Irrigation water applied ($m^3 ha^{-1}$)	IWUE ($kgha^{-1}m^{-3}$)
FULL	45.73± 1.31	1970	23.21± 0.66	55.40± 1.53	2770	20.00± 0.55
PRD	36.74± 3.13	1300	28.26± 2.41	49.24 ±3.86	1410	34.92± 1.28

The PRD treatment in both years (especially in 2008) resulted in highly significant increases in IWUE especially during 2008. Compared with FI, the PRD treatment saved 670 m^3/ha (2007 season) and 1360 m^3/ha (2008 season) of irrigation water, leading to a

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21% and 75 % (for 2007 and 2008, respectively) increase of irrigation water use efficiency. Similar data were also obtained by other authors (Liu et al., 2006; Shanhazari et al., 2007).

Table 2. Biochemical characteristics of the tubers of investigated potato plants exposed to PRD and FI treatments during 2007 and 2008 years (means ± S.E)

Treatments	2007 year		2008 year	
	Reducing sugars (g kg^{-1} FW)	Starch (% on FW)	Reducing sugars (g kg^{-1} FW)	Starch (% on FW)
FULL	6.76	13.72	6.30	13.78
PRD	6.22	15.02	5.32	15.04

Some of the potato tuber quality data are shown in Table 2. The concentrations of quality parameters (starch and reducing sugars) in both investigated years fitted the range of values that have usually been reported for potato tubers with no indication of promoting undesirable changes when potatoes are intended for further processing (Nourian et al., 2003). Technological quality with regard to starch content in tubers of PRD comparing to FI-treated plants showed an increased effect in both years. Comparison between treatments in both years showed that PRD treatments negligibly but not significantly reduced the content of sugars comparing to FI treatment.

Conclusions

Experimental results for both seasons confirmed that with PRD irrigation it is possible to increase IWUE, save water for irrigation and increase quality of potato tuber (starch content). Also, results indicated that PRD should be applied as a dynamic system which depends not only on available water for crops but also on crop growth stage. In general, two potatoes growing seasons confirmed that PRD could be useful strategy to save water for irrigation. This could be especially important for countries facing with drought and limited water resources for agricultural production as it is current situation in Serbia or other Western Balkan countries.

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