



# Effects of partial root-zone drying irrigation and water quality on soil physical and chemical properties



Abdullah Alrajhi\*, Simon Beecham, Ali Hassanli

School of Natural and Built Environments, University of South Australia, Mawson Lakes, SA, Australia

## ARTICLE INFO

### Article history:

Received 8 August 2016

Received in revised form 7 December 2016

Accepted 13 December 2016

### Keywords:

Partial root-zone irrigation

Deficit irrigation

Recycled wastewater

Soil hydraulic conductivity

Soil pH

Nutrients

South Australia

## ABSTRACT

Using recycled wastewater (RW) is considered to be a strategic choice for overcoming water scarcity worldwide, so there is a pressing need to improve irrigation and nutrient uptake to sustain crop yields and at the same time to reduce the negative impacts of RW. In the present study, tomato plants (*Lycopersicon esculentum* Mill. var. "Azmier") were exposed to three different water qualities: recycled wastewater (RW); fresh municipal tap water (FW); and a blend of RW and stormwater (BW), in combination with five irrigation scenarios: full irrigation (FI) full plant water requirement; deficit irrigation (DI), with 75% and 50% of FI as DI<sub>75</sub> and DI<sub>50</sub>, respectively; and partial root-zone drying (PRD), with 75% and 50% as PRD<sub>75</sub> and PRD<sub>50</sub>, respectively. The effects of these treatments on soil hydraulic conductivity ( $K_s$ ), soil pH, root growth, leaf area (LA) as well as the residual phosphorus (P), potassium ( $K^+$ ), calcium ( $Ca^{2+}$ ) and magnesium ( $Mg^{2+}$ ) in the soil were investigated. The results showed that there was no significant difference in the soil  $K_s$ . However, different types of irrigation waters significantly affected the soil pH, while irrigation scenarios had no effect on soil pH. Also, irrigation scenarios influenced root growth and LA, while PRD scenarios lowered soil P,  $K^+$ , and  $Mg^{2+}$  concentration compared to DI. The results also showed that water quality influenced canopy coverage 107 days after planting (DAP). It is clear that PRD is a promising scenario for sustaining agriculture in areas with high water scarcity.

© 2016 Elsevier B.V. All rights reserved.

## 1. Introduction

Recycled wastewater (RW), used as an irrigation source in arid and semi-arid regions, is considered a cost-effective solution (Valipour and Singh, 2016; Yannopoulos et al., 2015). For agricultural, industrial and urban non-potable purposes, many countries in arid and semi-arid regions use RW as a viable alternative water source (Costa et al., 2016; Angelakis and Gikas, 2014). Also, the use of RW is a strategic choice for sustainable water management (Qadir et al., 2003). In Australia, the use of RW is currently practised efficiently and it has proven to be a feasible alternative source for irrigating crops (Angelakis and Gikas, 2014). Agricultural activities in Australia consumed 280 Gig litres of recycled water in 2004–05, and South Australia was the highest user of recycled water for urban agriculture, with 18,929 Mega litres in 2008–09 (ABS, 2010).

To tackle drought stress, RW could be employed; however salt and nutrient accumulation in soil should be quantified. RW is a source of nutrients, particularly nitrogen and phosphorous, and is used by growers as a fertiliser for crop production (Keremane and

McKay, 2007), and this may enhance the growth and yield of crops (Bell and Henschke, 2005). However, RW may also be harmful to the environment. Stewart et al. (1990) reported that RW significantly increased the pH level of the soil profile, while phosphorus, sodium, calcium, and magnesium concentrations also increased in the upper 35 cm layer of the soil. To ensure optimal yield and to minimise potential environmental risks, growers should provide adequate and balanced nutrition (Hamilton et al., 2005). In general, to avoid leaching and potential contamination of groundwater resources, the application of RW should be carefully evaluated for nutrient loading by considering the actual demand of crops. Reducing irrigation applications over the growing season will also decrease the leaching of nutrients from the root-zone, resulting in less groundwater contamination.

Deficit irrigation (DI) is a reliable technique for improving water savings and is considered to have potential for sustainable production (Ruiz Sánchez et al., 2010). The DI technique is based on the application of water to the entire root-zone, however the plant is given less water than the potential evapotranspiration. There is another water saving technique known as partial root-zone drying (PRD), this strategy involves the irrigation of only one part of the root-zone while the other part is exposed alternately to soil drying.

\* Corresponding author.

E-mail address: [alraj002@myemail.unisa.edu.au](mailto:alraj002@myemail.unisa.edu.au) (A. Alrajhi).

PRD can result in higher water use efficiency, water savings and improved fruit quality in tomato crops (Sun et al., 2013).

Nutrient fertilisation has also played a significant part in crop production and N, P and K<sup>+</sup> in particular are known to affect yield (Isitekhale et al., 2013). P is considered to be one of the most limiting nutrients in agricultural production, so the importance of improving phosphorus use efficiency in agricultural production is vital as P is a non-renewable natural resource (Sun et al., 2015). P losses through leaching are negligible in non-irrigated environments due to the low mobility into the soil profile (Fixen and Bruulsema, 2014). Bünemann et al. (2013) found that soil P bioavailability was significantly affected by soil drying and wetting cycles. Moreover, high soil water content often led to higher P bioavailability under irrigation conditions (Suriyagoda et al., 2014). In addition, Wang et al. (2010a) found that the transformation of organic compounds to inorganic nutrients in soil can be influenced by irrigation management. The K<sup>+</sup> required for normal plant growth is higher than the rate of K<sup>+</sup> release from a fixed position in the soil, thus addition of K<sup>+</sup> in fertilisers is required for plant development, and it also improves fresh fruit quality, fruit set and yield (Kafkafi and Tarchitzky, 2011). The leaching of K<sup>+</sup> in sandy soils with low organic matter is high (Obreza, 2003). Also, DI practices with wetting and drying could increase potassium-fixation in silicate minerals, decreasing the possible K<sup>+</sup> leaching, so irrigation management is very important to reduce K<sup>+</sup> loss as well as the potential contamination of soil and ground water. RW has different concentrations of the major cations (K<sup>+</sup>, Ca<sup>2+</sup>, Mg<sup>2+</sup>, and Na<sup>2+</sup>) that can affect the soil base saturation. The K<sup>+</sup> concentration in RW is relatively low, with levels generally varying between 10 and 30 mg L<sup>-1</sup>. The application of wastewaters with high K<sup>+</sup> concentrations and the long-term application of RW may cause a decrease in the soil's hydraulic conductivity (Arienzo et al., 2009).

Applying DI and PRD strategies may reduce the potential harmful effects of RW on the soil environment, as well as on surface water and groundwater sources, by reducing the nutrient loading. Although, the effects of RW in soil environment is very well established as well as the role of DI and PRD in agricultural water management. Less investigations have been covered the potential impacts of DI and PRD on soil chemical and physical properties using different water qualities. The main objective of this paper is to determine the effects of irrigation scenarios involving DI and PRD, using different water quality, on soil nutrients and soil hydraulic conductivity (Ks) during a tomato growing season in a glasshouse experiment.

## 2. Materials and methods

### 2.1. Experimental conditions

Experiments were conducted under glasshouse conditions at the Mawson Lakes campus of the University of South Australia (−34.9290° S, 138.6010° E). The temperature in the glasshouse was set at 25 ± 2.5° C and 20 ± 2.5° C during the days and nights, respectively. The maximum relative humidity was 81%, and the minimum relative humidity was 18%. Large PVC pots (60 cm diameter and 75 cm deep) were divided into two equal zones with plastic sheets

to stop water movement between the two zones. The experimental soil was a homogenised sandy soil, with 1.32 g cm<sup>-3</sup> bulk density, 32% porosity and 26% field capacity. The texture of the soil was sandy loam with a pH of 7.7, electrical conductivity (EC) of 1.2 dS m<sup>-1</sup>, sodium absorption ratio (SAR) of 1.7, total carbon (TC) 26.7 g kg<sup>-1</sup>, total nitrogen (TN) 2 g kg<sup>-1</sup>, phosphorus (P) 0.7 g kg<sup>-1</sup>, potassium (K<sup>2+</sup>) 2 g kg<sup>-1</sup>, calcium (Ca<sup>2+</sup>) 10 g kg<sup>-1</sup>, magnesium (Mg) 2 g kg<sup>-1</sup> and was 0.3 g kg<sup>-1</sup> for sodium (Na<sup>2+</sup>).

Tomato is one of the world's most important vegetable crops (Scholberg et al., 2000), and is a dominant crop in South Australia. In 2013 from July to October for 149 days, tomato plants (*Lycopersicon esculentum* Mill. var. "Azmier") were transplanted into the containers at the end of their initial growth stage (30 days after germination) according to FAO56 (Allen et al., 1998).

### 2.2. Experiment design and irrigation treatments

The tomato plants were hand-irrigated with three different water qualities, namely recycled wastewater (RW) from the Boli-var wastewater treatment plant, which treats a large portion of the Adelaide municipal metropolitan wastewater, fresh municipal tap water (FW); and a blend of RW and stormwater (BW). The physical and chemical characteristics of the three irrigation waters are shown in Table 1. The experimental testing programme started with FW and full irrigation (FI) for all plants. Irrigation was applied twice per week throughout growing season with adequate water volumes to restore the soil moisture to field capacity at each irrigation cycle for FI scenarios. Calcium nitrate and "Hydroflex T 8-9-39" were used to fertigate the plants. Fertigation concentrations were calculated and adjusted based on irrigation volumes to guarantee that each plant received an equal amount of nutrients. Ten days after transplanting the three water qualities were applied along with the following five different irrigation scenarios:

- Full water requirement (FI) for both sides of the root-zone.
- Partial root zone drying (PRD) using 75% of FI added alternately to each side of the root-zone (PRD<sub>75</sub>).
- PRD using 50% of FI added alternately to each side of the root-zone (PRD<sub>50</sub>).
- Conventional deficit irrigation (DI) using 75% of FI added to both sides of the root-zone (DI<sub>75</sub>).
- DI using 50% of FI added to both sides of the root-zone (DI<sub>50</sub>).

The irrigation scenarios were calculated at each irrigation interval based on soil moisture content, which was monitored continuously over multiple depths at 10 cm intervals, before and after irrigation, with three replicas of each treatment, using a Sentek Diviner 2000 device. For FI scenarios, ET (in litres) at irrigation day (i) was calculated as:

$$ET_{FI,i} = V \times [(\theta_{FC} - \theta_{1,i}) + (\theta_{FC} - \theta_{2,i})] \quad (1)$$

Where:

ET is irrigation water (in litres) needed for day i

V is the volume of soil in each pot side (in litres)

$\theta_{FC}$  is the soil water content (vol.%) at field capacity

**Table 1**  
Chemical and physical characteristics of irrigation waters.

Water Quality	pH	EC	TN	TC	Ca	K	P	Mg	Na	SAR
		dS m <sup>-1</sup>	mg L <sup>-1</sup>	mg L <sup>-1</sup>	mg L <sup>-1</sup>	mg L <sup>-1</sup>	mg L <sup>-1</sup>	mg L <sup>-1</sup>	mg L <sup>-1</sup>	
FW	7.14	0.91	0.0	13	21	3	0	5	31	1.57
RW	7.43	2.6	15	42	39	33	0.2	33	275	7.75
BW	7.27	1.3	10	40	40	20	0.2	22	164	5.16

FW = Fresh tap water, RW = Recycled wastewater, BW = Blend of RW and stormwater.

Download English Version:

<https://daneshyari.com/en/article/5758558>

Download Persian Version:

<https://daneshyari.com/article/5758558>

[Daneshyari.com](https://daneshyari.com)