Using saline reclaimed water on almond grown in Mediterranean conditions: deficit irrigation strategies and salinity effects

Gaetano Alessandro Vivaldi, Salvatore Camposeo, Giuseppe Lopriore, Cristina Romero-Trigueros and Francisco Pedrero Salcedo

ABSTRACT

The main objective of this study was to acquire agronomic knowledge about the effects of irrigation with saline reclaimed (RW) and desalinated DESERT (DW) water and different irrigation strategies: control full irrigation (FI) and regulated deficit irrigation (RDI) on leaf nutrients, tree growth and fruit quality and yield of almond trees in pots. Our results showed that RW had the highest concentration of some valuable agronomic nutrients such as N, but also of phytotoxic elements (Na and Cl^{-}). Na leaf concentration on RW treatments reached toxic levels, especially under RDI, and toxicity symptoms were shown. Regarding tree growth, cumulate trunk diameter on RW-RDI was significantly lower than on the control treatment and shoot growth was reduced from the beginning of the irrigation season in RW treatments. Maximum yield was reached on RW-FI, 18% higher than the control treatment. However, RDI strategies influenced negatively on yield, being 23% less in RW and 7% less in DW although water productivity was not significantly reduced by water stress. These findings manifest that the combination of RW and RDI can be a promising future practice for almond irrigation, but long-term studies to establish suitable management practices must be developed.

Key words | abiotic stress, ion toxicity, yield

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INTRODUCTION

At the global level, the World Economic Forum has reported the three most important problems that humanity must to solve in the next years to be climate change, terrorism and increase of self-centeredness (Global Risks 2018). As an effect of climate change, in Europe the frequency and intensity of droughts and their environmental and economic damages have drastically increased over the past 30 years: between 1976 and 2006 the number of areas and people affected by droughts went up by almost 20% and the total costs of droughts amounted to EUR 100 billion (EC 2012). The droughts of the summer of 2017 may further illustrate the dimensions of economic loss; the Italian farming sector alone was predicting losses of EUR 2 billion (EC 2018). In particular, in Puglia region, which exhibits a Mediterranean climate characterized by hot, dry summers, requires a high volume of irrigation water because many hectares of permanent crops (olive, grapes, almond etc.) and fresh-cut vegetables account for 80% of the region's irrigated land (Arborea *et al.* 2017). In this context, one of the most representative permanent crops irrigated is almond with 19,878 ha cultivated (34% of total almond orchards in Italy) and with a production of 27,510 tons of almond (34.5% of total Italian production) (ISTA 2017).

It has been estimated that Apulian regional farmers have drilled more than 200,000 wells, whose extensive exploitation is causing the progressive salinization and depletion

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of relevant portions of the regional aquifers, reducing the water available for agriculture (Pedrero *et al.* 2018). This phenomenon is particularly relevant along the coastline, where a sharp increase of salinity has been recorded, with groundwater salinity ranging from 2.0 g L^{-1} (inner area) to 10.0 g L^{-1} (next to the coast) (Maggiore *et al.* 2001).

The two most common water quality factors which can influence the infiltration rate of water into soil are water salinity and its sodium content relative to the calcium and magnesium content, also referred to as sodium-adsorption ratio (SAR) (Ayers & Westcot 1985). A high salinity water will result in increased infiltration. When a soil is irrigated with water characterized by high SAR, a soil with high sodium absorption surface soil develops, which weakens the soil structure. Subsequently, the surface soil aggregates disperse into much smaller particles which can clog soil pores.

Considering the partial wetting pattern and irregular root water uptake in drip-irrigated orchards, the difficulty in applying and interpreting standard water balance techniques and salt accumulation in the plants requires a large number of measurements (Ben-Asher 1979). The understanding of salt accumulation dynamics could also be supported by mathematical modeling of transport phenomena of nutrients into the vadose zone. Typically, this combination is accomplished by means of data assimilation techniques that make use of data in order to dynamically correct the model in a stochastic framework (Berardi & Vurro 2016; Berardi *et al.* 2016).

Salinity issues derive from salt accumulation in the crop root zone to concentrations that result in a loss of yield. Toxicity problems can occur if certain constituents (mainly ions) in the irrigation water or native soil are taken up by the plant and accumulate to concentrations high enough to cause crop damage or reduced yields. The earliest symptoms of ion toxicity are typically caused by Cl^{-} excessive content in the leaves while Na^{+} tends to be retained in the roots, trunk, and branches, so its content in the leaves remains relatively low initially (Arshi *et al.* 2006; Najafian *et al.* 2008). The degree of damage depends on the uptake and the crop sensitivity (Ayers & Westcot 1985; Romero-Trigueros *et al.* 2014) and, in this sense, almond is classified as sensitive to salt stresses. For that reason, the aim of this work was to study the combined effects of saline reclaimed water and deficit irrigation strategy on vegetative behavior and fruit quality and yield of drip-irrigated almond trees during 1 year.

MATERIALS AND METHODS

Site characterization and irrigation treatments

The crop used in this experiment was the almond tree (*Amygdalus communis* L. cv. Genco grafted on a hybrid Rootpak 20® of *Prunus besseyi* × *Prunus cerasifera* L-H. Bailey and Ehrh.) planted in 100 L pots. The soil texture within the first 90 cm depth was classified as loam (44.78% sand, 12.32% clay and 42.90% silt) (USDA textural soil classification). Two irrigation water sources, DESERT water (DW) (which is a result of secondary treated wastewater treated with ultrafiltration, active carbon and reverse osmosis until reaching an EC_w of 1 dS m^{-1}) and reclaimed water (RW) (secondary treated wastewater coming from Bari wastewater treatment plant with EC_w 1.2 dS m^{-1} mixed with the brine produced in the DESERT prototype until reaching an EC_w of 3 dS m^{-1}) were examined. For each water source, two irrigation treatments, a full irrigation (FI) control treatment (irrigated throughout the growing season to fully satisfy crop water requirements) and a regulated deficit irrigation (RDI) treatment were established. The irrigation volume has been calculated by the water balance method, with restitution of 130% crop evapotranspiration (ET_c) lost in each irrigation interval and a RDI treatment irrigated at 80% of ET_c during the kernel-filling period. ET_c was calculated using Equation (1) recommended by the FAO (Allen *et al.* 1998):

$$ET_c = Kr\ Kc\ ET_0 \tag{1}$$

where Kr is the reduction coefficient (Kr = 0.75), Kc (0.40 Kc_{ini}, 0.90 Kc_{mid}, 0.65 Kc_{end}) is the crop coefficient, and ET_0 is reference evapotranspiration. ET_0 was calculated by the Penman–Monteith equation and all data were provided by a climate station located 100 m from the experimental platform. The water was supplied by drip irrigation with three pressure compensated drippers per tree, each with a flow rate of 2 L h^{-1}.

Irrigation water productivity (WP_i) was calculated as the ratio between the annual yield (kg $plant^{-1}$) and the applied water (m^3 $plant^{-1}$).

All trees received the same amount of N, P, K through a drip irrigation system. Weeds were eradicated in the orchard by applying the farmers' commonly used pest-control methods.

Irrigation water quality

Water samples from each irrigation water source were collected during the irrigation period (May–September) in order to characterize irrigation water quality. Two water samples per month, from each irrigation source, were collected in glass bottles, transported in an ice chest to the laboratory and stored at 5 °C before being processed for physical and chemical analyses. An inductively coupled plasma–optical emission spectrometer (ICP–OES ICAP 6500 DUO Thermo, UK) was used to determine the concentration of Na, K, Ca, Fe, B and Mg. Anions (Cl^-, Fl^-, NO_3^-, PO_4^{3-} and SO_4^{2-}) were analyzed by ion chromatography with a liquid chromatograph (Metrohm, Switzerland). EC_w was determined using a PC-2700 meter (Eutech Instruments, Singapore) and pH was measured with a pH-meter Crimson-507 (Crimson Instruments SA, Barcelona, Spain).

Leaf measurements

The leaf nutritional analysis was carried out at the end of the irrigation season. Twenty dried leaf tissues per plant were milled into fine pieces (1–2 mm) and approximately 0.5 g of each sample was extracted with 1 mL 30% H_2O_2 and 9 mL concentrated HNO_3 using microwave-assisted pressure digestion. Total elements as B, Ca, Fe, K, Mg, Mn, Na, P and Zn were determined on these extracts by inductively coupled plasma–optical emission spectrometry (ICP–OES ICAP 6500 DUO Thermo, UK). Chloride anions were determined by ion chromatography with a Chromatograph Metrohm (Switzerland) in the dried leaves which were ground and digested with a mix of nitric acid (4 mL) and hydrogen peroxide (1 mL). Nitrogen total content (g·100 g^{-1}) was measured too (Flash EA 112 Series, UK and Leco TruSpec, Saint Joseph, USA).

Tree growth patterns

Tree growth measurements were carried out during the experimental period to evaluate the influence of the irrigation treatments on plant vegetative behavior. In particular, during the irrigation season (May–October 2017) every 15 days, trunk diameter and shoot growth were monitored and for each parameter the cumulated percentage of trunk diameter and shoot was calculated by using Equation (2):

$$y = \frac{y2 - y1}{y2} + ycumulated \quad (2)$$

Statistical analysis

Statistical analysis was performed as a weighted analysis of variance (ANOVA; statistical software IBM SPSS Statistics v. 21 for Windows). The Shapiro–Wilk test ($P > 0.05$) was used to evaluate the normality of the data. Tukey's HSD test ($P \leq 0.05$) was used for mean separation.

RESULTS AND DISCUSSION

Water sources and leaf nutrients

The two irrigation water sources showed significant differences in concentration of quality parameters measured, being significantly higher in RW than in DW (Table 1). Regarding EC_w, RW showed the highest level, with values close to 3 dS m^{-1}, while for DW the EC values were lower, close to 1 dS m^{-1}. Most of the stone fruit trees are sensitive to salt stresses and their productivity gradually reduces at salt concentrations above 1.5 dS m^{-1} and down to 50% of normal yield at the salt concentration of 4 dS m^{-1} (Maas & Hoffman 1977; Ottman & Byrne 1988). According to Grieve et al. (2012), the threshold of EC_w where an almond crop shows significant yield losses, even in the absence of specific-ion effects, is 1.5 dS m^{-1}. Thus, RW treatments double that threshold. About SAR, DW showed values close to 3.7 and RW almost double: 7.2. The higher salinity level observed in

Table 1 | Chemical parameters for DESERT Water (DW) and secondary treated reclaimed water mixed with brine (RW)

Parameters	Units	DW	RW	*t*-test	Limits (DL 185/2003)
pH		7.53 ± 0.31	8.15 ± 0.20		6–9.5
EC_w		1.00 ± 0.15	3.00 ± 0.45	**	3
SAR		3.7 ± 0.42	7.2 ± 1.52	***	10
SO_4^{2-}	mg l^{-1}	97.98 ± 16.2	227.4 ± 37.5	***	500
Fl^-	mg l^{-1}	0.22 ± 0.09	0.38 ± 0.11	n.s.	-
Cl^-	mg l^{-1}	198.1 ± 54.1	379.5 ± 72.3	*	250
Ca	mg l^{-1}	56.28 ± 11.3	121.3 ± 22.1	*	-
K	mg l^{-1}	20.67 ± 8.81	42.76 ± 6.30	*	-
PO_4^{3-}	mg l^{-1}	1.3 ± 0.61	3.1 ± 0.52	*	2
B	mg l^{-1}	0.14 ± 0.06	0.15 ± 0.07	n.s.	1.00
Fe	mg l^{-1}	0.04 ± 0.01	0.04 ± 0.01	n.s.	-
Na	mg l^{-1}	148.4 ± 53.2	353.2 ± 48.7	**	-
NO_3^-	mg l^{-1}	15.83 ± 2.53	36.16 ± 9.28	*	-
Mg	mg l^{-1}	20.9 ± 5.40	35.5 ± 6.10	*	-

Each datum represents the mean of ten values ± the standard deviation measured on water samples collected during 2017.
Mean content ($n = 10$). Significance level: *$p < 0.05$; **$p < 0.01$; ***$p < 0.005$.

RW was mainly due to the high concentration of Cl^- (379.5 mg L^{-1}) and Na (353.2 mg L^{-1}), although Ca and SO_4^{2-} were also higher in RW (Table 1). Taking into account the Italian regulation containing technical standards for the reuse of reclaimed water, DL 185/2003, only Cl^- and PO_4^{3-} concentrations from RW exceed the limits; pH, $EC_{w,}$ SAR, SO_4^{2-} and B levels were within the limits established by the standard.

The high concentration of macro- and meso-nutrients in RW could allow for a significant reduction in fertilizer application, as has been seen studies of fruit trees irrigated with reclaimed water (Pedrero *et al.* 2014; Vivaldi *et al.* 2017). In this sense, the nutritional contribution of RW in terms of nitrogen, phosphorus and potassium during 2017 was 15.7 and 35.8 kg NO_3^- ha^{-1}, 1.85 and 4.41 kg PO_4^{3-} ha^{-1}, 71.99 and 149.9 kg K ha^{-1} for DW and RW respectively.

Regarding leaf nutrients (Table 2), trees irrigated with RW resulted in higher concentrations of some valuable agronomic nutrients such as N (NO_3^-), but also of leaf phytotoxic elements (Na and Cl^-). There has been little documentation on the effect of soil salinity on Na and Cl levels on almond trees, although Na concentrations of about 0.2–0.5 g 100 g^{-1} (leaf dry weight) and Cl concentrations of about 0.5–1.0 g 100 g^{-1} generally cause toxicity problems in most deciduous fruit trees (Bernstein 1980; Boland *et al.* 1993).

Symptoms of toxicity were visually found on the leaves of trees irrigated with RW. Because Na^+ and Cl^- injury symptoms are similar (Grattan *et al.* 2015), leaf tissue sampling was carried out to verify the damaging constituent.

Na concentration did not exceed the limit cited above in any treatment; however trees irrigated with RW, especially under RDI, showed triple the Na than DW trees, reaching sufficiently toxic levels to cause damage to the leaves. With respect to Cl^- concentration, all treatments exceeded the limit, mainly RW ones.

Most experiments have focused on the deficit irrigation tolerance of different rootstocks and cultivar combinations (Goldhamer *et al.* 2006; Egea *et al.* 2010; Phogat *et al.* 2013). Regarding salt tolerance, besides the osmotic potential effect, fruit trees are very sensitive to leaf Cl^- and Na toxic concentrations depending on rootstocks and cultivars (Aragüés *et al.* 2014). It has been demonstrated that there is a very high variability in most of the rootstocks used on almond trees. For example, peach–almond hybrid rootstocks had lower leaf concentrations of sodium (0.0434 vs 0.3260 g 100 g^{-1}) and chloride (0.027 vs 0.131 g 100 g^{-1}) in comparison with the peach rootstocks after 20 years of the trial with

Table 2 | Leaf mineral analysis for both water sources, DESERT water (DW) and secondary treated reclaimed water mixed with brine (RW), and for both irrigation strategies, FI and RDI

Elements	DW-FI	DW-RDI	RW-FI	RW-RDI
N (g 100 g^{-1})	2.03 ± 0.07 **b**	2.10 ± 0.09 **b**	2.34 ± 0.05 **a**	2.41 ± 0.07 **a**
B (mg/kg)	31.4 ± 1.98	32.0 ± 4.02	32.2 ± 2.88	30.4 ± 1.90
Ca (g 100 g^{-1})	1.83 ± 0.16	1.47 ± 0.08	1.67 ± 0.10	1.80 ± 0.19
Cl (g 100 g^{-1})	1.21 ± 0.49 **a**	1.67 ± 0.38 **ab**	1.89 ± 0.99 **ab**	2.28 ± 0.83 **b**
Fe (mg/kg)	47.1 ± 2.52	49.6 ± 2.71	50.5 ± 3.02	50.6 ± 6.01
K (g 100 g^{-1})	1.70 ± 0.06 **a**	1.71 ± 0.10 **a**	1.54 ± 0.05 **b**	1.49 ± 0.09 **b**
Mg (g 100 g^{-1})	0.45 ± 0.03	0.34 ± 0.04	0.39 ± 0.03	0.38 ± 0.04
Mn (mg/kg)	110 ± 5.09	95.9 ± 4.20	96.5 ± 4.01	97.4 ± 5.99
Na (g 100 g^{-1})	0.06 ± 0.01 **b**	0.05 ± 0.01 **b**	0.14 ± 0.03 **a**	0.19 ± 0.04 **a**
P (g 100 g^{-1})	0.13 ± 0.01	0.14 ± 0.01	0.14 ± 0.02	0.13 ± 0.01
Zn (mg/kg)	16.3 ± 1.86	16.9 ± 2.01	18.9 ± 2.78	15.7 ± 1.42

Each point is the average ± SE of the four inner trees per treatment.
Letters denote statistically significant differences at $p < 0.05$ level between treatments for each element.

almond trees irrigated with moderately high sodium, 6.35 meq/L (SAR = 3.06), and low chloride, 0.75 meq/L (Doll *et al.* 2014). According to Najafian *et al.* (2008), the low Na concentration in the leaves under salt stress conditions can be explained because it was demonstrated that some rootstocks restrict Na uptake from roots to leaves, such as GF-677 rootstock. In addition, it depends on rootstocks; some of them accumulated more Na^+ in the leaves, such as Bitter Almond rootstock, while others accumulated more Cl^-, such as Garnem rootstock (Zrig *et al.* 2016). In our study, the rootstock used (hybrid Rootpak 20®) did not limit Na uptake since in RW-FI and RW-RDI treatments, Na leaf was increased about 130% and 220% with respect to DW-FI while Cl^- only 54% and 100% with respect to DW-FI (Table 2). This toxic anion (Cl^-) appears to have a determinant role in the sensitivity of fruit trees to soil salinity, and the increased uptake of Cl combined with a limited production of new leaves, as we will see below, can lead to its build-up to toxic levels (Zrig *et al.* 2011).

Saline conditions can rapidly reduce the capacity of roots to absorb essential nutrients from the soil (Türkana & Demiral 2009). An excess or deficiency of the major elements in a plant's tissues may cause disorders with respect to nutrient availability, uptake, transport or partitioning within the plant (Zrig *et al.* 2016). It is known that maintaining enough supply of Ca^{2+} and K^+ in saline soil solution is a key factor in controlling specific ion toxicities, especially in crops prone to Na^+ and Cl^- toxicity. Potassium and Ca^{2+} are essential for plants; Ca^{2+} plays an integral role in cell membrane integrity, signal transduction and the control of enzyme activity, while K^+ is involved in a number of metabolic processes such as photosynthesis, enzyme activation, protein synthesis, osmotic adjustment, and as a counter ion to both inorganic anions and organic biopolymers (Arshi *et al.* 2006). K^+ uptake and transport in plants are strongly depressed in the presence of Na^+ and enhanced by Ca^{2+} supplements. In our experiment, Ca^{2+} and K^+ in RW irrigation water were double those in DW (Table 1). Hence, the logic behind the experiment is the common assumption that increasing water Ca^{2+} and K^+ concentrations would shift root uptake in favor of Ca^{2+} and K^+ at the expense of Na^+, thus protecting plant tissues from the adverse effects of high NaCl salinity. However, this did not occur. The excess sodium in the soil solution did not create differences in either of these nutrient cations on leaves, as has been cited on other experiments (Grattan & Grieve 1998). Ca concentration was at the recommended limits for all treatments, even RW treatment (<3.5 g 100 g^{-1}) (Walsh & Steinhilber 2005), maybe because of Na interaction on the roots as it was not absorbed on the leaves (Table 2). In the same way, K concentration was significantly lower in RW treatments despite the fact that the saline irrigation water presented more K than the DW.

A high K/Na ratio under saline conditions could be considered a selection criterion for salt tolerance in *Prunus* (Najafian *et al.* 2008). In our study, the K/Na ratio for each treatment was calculated and RW treatments showed the lower values: 28.77, 33.55, 11.34 and 7.90 for DW-FI, DW-RDI, RW-FI and RW-RDI, respectively. This low K^+/Na^+ ratio could result in a reduction of plant growth (Dejampour *et al.* 2012), as discussed below. Therefore, in our case, sodium ions caused disturbances in calcium and potassium nutrition, as quoted by Läuchli & Grattan (2014).

Moreover, it is known that chloride can reduce nitrate uptake by crops (Grattan & Grieve 1998). In our case, despite the high Cl content in the RW, we observed an increase of leaf total N in both RW treatments due to the high level of N in the water.

Another phytotoxic element is boron. Its toxicity on fruit trees is common in arid and semi-arid environments (Pedrero *et al.* 2014); however in our assay B concentration was under the toxicity levels in all plants ($<50\ mg\ kg^{-1}$) (Walsh & Steinhilber 2005) and there were no significant differences among treatments.

No difference on C content was seen among DW and RW treatments (data not shown), maybe because of the rootstock. On the contrary, it has been shown that other rootstocks such as GF-677 have a photochemical limitation to photosynthesis when the almond plant is under salt stress (Najafian *et al.* 2008).

The rest of the micronutrients (Zn, Fe and Mn) and heavy metals (Cr, Cu and Al, data not shown) analyzed were all in the recommended range for all treatments.

Plant growth and yield

Plant growth was measured as the cumulated percentage of trunk diameter and cumulated percentage of shoot diameter (Figures 1 and 2), since those are the agronomic parameters most sensitive to water deficit and salt stress in young almonds (Nortes 2008).

Trunk growth was significantly reduced only by the combination of water and saline stress (RW-RDI). Hence, salinity from RW did not affect trunk diameter when plants were irrigated covering 100% of their water needs, showing a certain tolerance to salt stress.

Shoot growth showed a clear difference between RW and DW from the beginning of the irrigation season: RW-FI and RW-RDI reduced their shoot growth with respect to the control treatment, although there were no significant differences among treatments due to the high standard deviation of the data. Other studies showed the scion apical growth sensibility of the rootstock Rootpac 20 to drought stress, compared with other rootstocks used on almond trees such as Cadaman, GF 677 and Rootpac R (Jiménez *et al.* 2013). In our study, water stress (DW-RDI) did not affect shoot growth but it was the salt stress which reduced

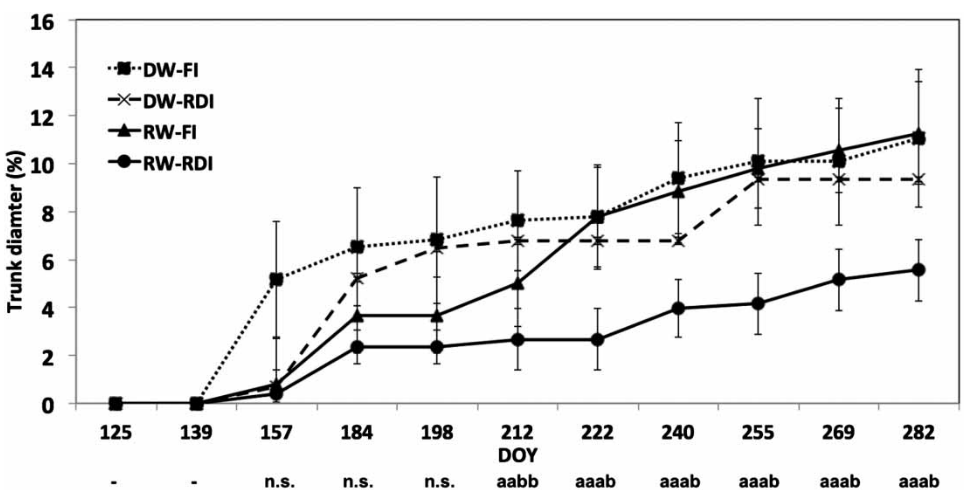

Figure 1 | Cumulated percentage of trunk diameter (%) for both water sources, DESERT water (DW) and secondary treated wastewater mixed with brine (RW) and for both irrigation strategies, FI and RDI. Each point is the average ± SE of the four inner trees per treatment during 2017. Letters denote statistically significant differences at $p < 0.05$ level between treatments for each date.

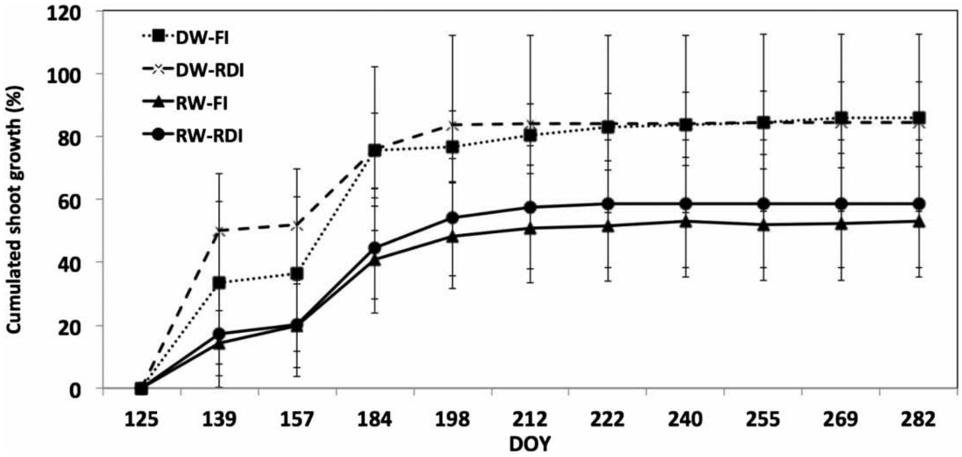

Figure 2 | Cumulated percentage of shoot diameter (%) for both water sources, DESERT water (DW) and secondary treated reclaimed water mixed with brine (RW) and for both irrigation strategies, FI and RDI. Each point is the average ± SE of the four inner trees per treatment during 2017.

this parameter, according to Zrig *et al.* (2016), where plants grafted onto GF677 showed a significant reduction in shoot extension in response to NaCl concentration.

In general, both saline stress from RW and its combination with RDI decreased tree growth.

With respect to yield, irrigation with saline water may greatly reduce almond yield, according to Nafajian *et al.* (2008). Nonetheless, our results showed that irrigation with saline RW did not reduce the total production since the maximum value was reached on RW-FI, 18% higher than DW-FI.

RDI strategies influenced negatively on yield, being 23% less on RW treatment and 7% less on DW (Table 3), although water productivity was not affected by water stress. RDI strategy also reduced significantly the shell and hull fresh weight when it was combined with DW, as in Nortes (2008), but did not reduce them when it was combined with RW. Thus, yield reduction on the RW-RDI treatment was due to a decrease in the number of fruit per plant but it was not due to a decrease in total fruit weight.

CONCLUSIONS

This study assessed the effects of irrigation with RW and deficit irrigation of almond trees on leaf nutrients, plant growth and yield. The results demonstrated that reclaimed water had high concentrations of valuable agronomic nutrients (N, P, K, Ca) of which N was significantly increased at leaf level in RW treatments. Nevertheless, the excess of salts from RW give rise to a Na and Cl^- toxic accumulation in the leaves and reduced the capacity of roots to absorb essential nutrients such as K and Ca, decreasing the K^+/Na^+ ratio. Regarding tree growth and yield, FI with RW did not affect total production or trunk diameter. However, RDI strategy reduced total production, mainly RW-RDI, due to

Table 3 | Fruit division production and water productivity for both water sources, DESERT water (DW) and secondary treated wastewater mixed with brine (RW) and for both irrigation strategies, FI and RDI

Treatments	Shell fresh weight (g)	Hull fresh weight (g)	Kernel fresh weight (g)	Water productivity (kg/m^3)
DW-FI	2.63 ± 0.76 **ab**	3.09 ± 1.20 **a**	1.07 ± 0.27	14.31
DW-RDI	2.51 ± 0.52 **b**	2.33 ± 0.43 **b**	1.01 ± 0.23	13.88
RW-FI	2.77 ± 0.51 **a**	3.15 ± 1.33 **a**	1.07 ± 0.24	11.77
RW-RDI	2.79 ± 0.52 **a**	3.10 ± 1.21 **a**	1.07 ± 0.24	13.76

Each point is the average ± SE of the four inner trees per treatment.
Letters denote statistically significant differences at $p < 0.05$ level between treatments.

a decrease in fruit number, and in the case of DW-RDI due also to a reduction in shell and hull fresh weight. RDI did not affect trunk diameter when it was combined with DW.

Therefore, in arid and semi-arid areas, such as southern Italy, the combination of saline reclaimed water and deficit irrigation strategy can be a promising future practice in almond tree irrigation but both should be carefully used. In addition, long-term studies to establish suitable management practices must be developed in order to ensure the sustainability of this high-value horticulture crop.

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