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Chemical effect of reclaimed water on soil and rose plant grown in soil and tuff media

Safi, M.I., A. Fardous, M. Muddaber, S. El-Zuraiqi, L. Al-Hadidi and I. Bashabsheh

Water Management and Environment Research Program. National Center for Agricultural Research and Technology Transfer "NCARTT". Jordan, BALQA –Baq'a, P.O.Box 639, 19381. E-mail: sarsafi@yahoo.com

Abstract

The effect of three irrigation regimes of low quality water (the effluent of reclaimed wastewater from Ramtha treating plant) on soil, drained water and plant tissue chemical composition of First Red cut flower rose cultivar grown on three rootstocks *Rosa indica, Rosa canina,* and Natal Briar was investigated for two successive years 2003 and 2004 in two planting media soil and Zeotuff. Phosphorus showed intermediate levels in both depths. Potassium in soil accumulated at high levels, especially at 0-20 cm depth. Manganese, copper, and zinc showed no accumulation in soil, iron reached high levels in both depths of soil. Less salinity build up was shown by the three irrigation treatments in soil than water drained from tuff beds regardless of rootstock used for the First Red rose cultivar during the first year, 2003. Both EC and SAR reached a steady status throughout the second year 2004. Based on the nutrient standards mentioned for rose tissue in the literature, the only macro and micro element accumulation was recorded for sodium in the tissue of First Red rose planted in both media during both years and iron in both media during the first year only, regardless of water treatment.

Key words: Rose, *R. indica, R. canina, R. hybrida,* salinity, reclaimed water, media, rootstock, sodium, tuff

Introduction

In middle east region, the challenge for agriculture is represented by the extreme difficulty to sustain high consumption levels of water currently required by growers, particularly due to limited water resources. The rapidly expanding population of the region has generated an ever-increasing volume of reclaimed water, which has raised question as how this type of water should be managed and possibly recycled for the benefit of the society. The main potential risks of reclaimed water reuse in agriculture is heavy metals accumulation in the soil and acidification impact (Water Corporation, 2003; Amin, 2001; and Kretschmer *et al.*, 2002). However, beneficial influences can be gained from this water such as conserving fresh water sources, reducing use of synthetic fertilizer, and improving soil properties (soil fertility) and producing higher yields (Kretschmer *et al.*, 2002).

Reclaimed water is applied mainly to field crops (Middle East Water Shortage, 2000), citrus trees irrigation in Florida (Parsons *et al.,* 1997) and the highway landscapes in Egypt (Heliopolis, 2001). In Jordan, there is a scope to explore potential alternative crops to make benefit and reuse of this low quality reclaimed water. To give new dimensions on reclaimed water reuse in agriculture, one of the proposed alternatives is use for cut flower crops roses (*R. hybrida*) since it is planted on profitable and sustainable bases.

Roses have been classified as high salinity tolerant up to 3-4 dS/m level (Kotuby *et al.*, 2000), or sensitive (Chimonidou, 1997) or highly salt sensitive (Western Australia Department of Agriculture, 2003) with EC level as low as 0.8-1.0 dS/m. Moreover, it is also reported that roses could resist up to 6 dS/m without affecting yield and quality of roses produced (Chimonidou, 1997). This study was conducted for two successive years at the National Center for Agricultural Research and Technology Transfer "NCARTT", Jordan. to assess prospects of reclaimed water reuse and its chemical effects on soil and plants of cut flower rose cultivar grafted onto three rootstocks in soil and zeotuff (soilless culture system) under plastic house conditions.

Materials and methods

This study was carried out during 2003 and 2004 using Mini-plants of First Red cut flower rose cultivar grafted onto three rootstocks: *R. indica,* Major; *R. canina,* Inermis; and *R. hybrida,* Natal Briar. The plants were planted in a plastic house of 360m^2 area, controlled by pad and fan system in Ramtha area 60 km North of Amman. Two planting media in two separate experiments in the plastic house were used, the natural soil (soil chemical characteristics are shown in Table 1), and volcanic rock Zeotuff (soilless culture system). Experimental plots were made as 0.6 x 1 m area and 8 plants were planted in two rows spaced 25 × 40 cm for both cultural media. Soilless plots were made by 700µ black polyethylene mulch, sloped to 1.5% for excess water drain.

The plants were irrigated by three irrigation regimes of the outlet reclaimed water of the Ramtha wastewater treatment plant with EC, 2.5-3.0 dS/m (water chemical characteristics used in irrigation are shown in Table 2) as follows: daily irrigation at levels of 120, 100 and 80% of the pan evaporation readings for the soilless system, and 100 % of the evaporation reading, every other day, every two days, and every three days for the soil experiments. Drip irrigation system was used with three filtering (sand, screen, and disc) process without any addition of fertilizers. Rose plant combinations and water treatments were arranged as Split-Plots in a randomised complete block design (RCBD) with four replications for each experiment. Disease pest control program was done when needed during the experiment duration. To assess chemical effects of reclaimed water reuse on soil and plants, data on the following parameters were collected: (i) soil chemical analysis at the end of each season, (ii) chemical analysis of drained water from soilless beds at the end of each season, (iii) salinity EC and Sodium Adsorption Ratio (SAR) values of soil and drained water during the experiment time. (iv) Chemical plant tissue analysis at the end of each season

All the results were statistically analysed and mean separation was performed using LSD (*P*=0.05).

Table 1. Soil chemical characteristics before planting

Parameter	Soil depth (cm)	
	0 - 20	20 - 40
pH	7.80	7.80
EC dS/m	0.65	0.55
Total(+)	6.31	5.43
Ca (Meq/L)	2.20	1.70
Mg (Meq/L)	3.00	2.66
Na (Meq/L)	1.11	1.07
Cl (Meq/L)	20.00	15.00
HCO_3 (Meq/L)	2.49	2.49
P (ppm)	24.50	21.10
K (ppm)	369.00	331.00
Cd (ppm)	0.03	0.03
Mn (ppm)	0.57	0.57
Cu (ppm)	0.07	0.07
Fe (ppm)	1.05	1.05
Zn (ppm)	2.30	4.80
NO_3 (ppm)	12.80	18.60
SAR	0.69	0.73

Results and discussion

There was no significant difference between the three water levels in their effect on the chemical composition of soil and drained water from the tuff beds. Table 3 shows that irrigation with saline reclaimed water caused noticeable increase in all macro and micro- elements concentrations at the end of the first year at both depths of the soil, except for the zinc that showed a decrease in its concentration at the end of the first year.

During the second year of irrigation with saline reclaimed water, no changes in magnesium, manganese, and nitrate concentration were recorded compared to their concentrations in both soil depths at the end of the first year (Table 3). Although concentrations of sodium, chloride, phosphorus, potassium, calcium, iron, and zinc increased at the end of the second year of irrigation in both depths of soil compared to their concentrations in the first year (Table 3).

For the drained water from tuff beds (Table 4) there was a high increase in the concentrations of sodium, magnesium, calcium, chloride, nitrate, copper, and cadmium elements during the first year of irrigation compared to the water source composition. However, most of the elements showed no further increase during the second year compared to the first year (Table 4).

The only increase in concentrations was recorded for sodium and chloride in the drained water from tuff beds compared to concentrations at the end of the first year (Table 4). The three levels of saline reclaimed water showed similar trends of progressive salinity build in the first year in the soil (regardless of depth) and drained water from tuff beds until July month (Fig. 1). After that they showed almost steady state to the end of the year 2003. However, salinity was greater in the drained water from tuff beds than in the soil beds. SAR values also increased progressively during the first year in both depths of soil 0-20 cm and 20-40 cm (Fig.1A).

It reached higher values in the upper depth 0-20 cm than in the lower depth 20-40 cm. In the drained water from the tuff beds, SAR reached higher values than in the soil (Fig. 1B). During the second year, no change occurred in salinity and the SAR values in the soil nor salinity in the drained water from tuff beds when irrigated with the three levels of saline reclaimed water (Fig. 2A).

Table 2. Reclaimed water chemical characteristics used in irrigation

Characterstics	Value
pH	7.50
EC dS/m	3.07
TDS (ppm)	1964.00
Na (Meq/L)	13.40
Mg (Meq/L)	7.40
Ca (Meq/L)	7.30
Cl (Meq/L)	13.00
HCO_3 (Meq/L)	8.25
P (ppm)	2.00
K (ppm)	47.40
NO_3 (ppm)	48.70
Na(%)	47.60
Zn (ppm)	0.044
Fe (ppm)	0.421
Cu (ppm)	0.006
Mn (ppm)	0.019
Cd (ppm)	0.006
SAR	4.490

Table 3. Soil chemical characteristics of rose beds irrigated with reclaimed water for two years

Parameter	First year		Second year	
	0 – 20	20 – 40	0 – 20	20 – 40
pH	7.76	7.63	7.70	7.60
Ca (Meq/L)	11.33	10.22	18.99	15.10
Mg (Meq/L)	9.88	9.22	8.77	9.05
Na (Meq/L)	17.00	14.01	28.93	22.43
Cl (Meq/L)	17.21	16.38	34.16	28.11
HCO_3 (Meq/L)	2.44	2.44	2.48	2.48
P (ppm)	72.01	50.73	86.08	57.33
K (ppm)	754.84	589.43	832.06	663.56
Cd (ppm)	0.09	0.09	0.21	0.20
Mn (ppm)	2.70	2.70	2.98	2.98
Cu (ppm)	1.50	1.50	1.60	1.60
Fe (ppm)	8.01	8.15	30.56	20.58
Zn (ppm)	1.80	1.80	9.61	8.19
NO_3 (ppm)	88.30	88.30	90.50	90.50

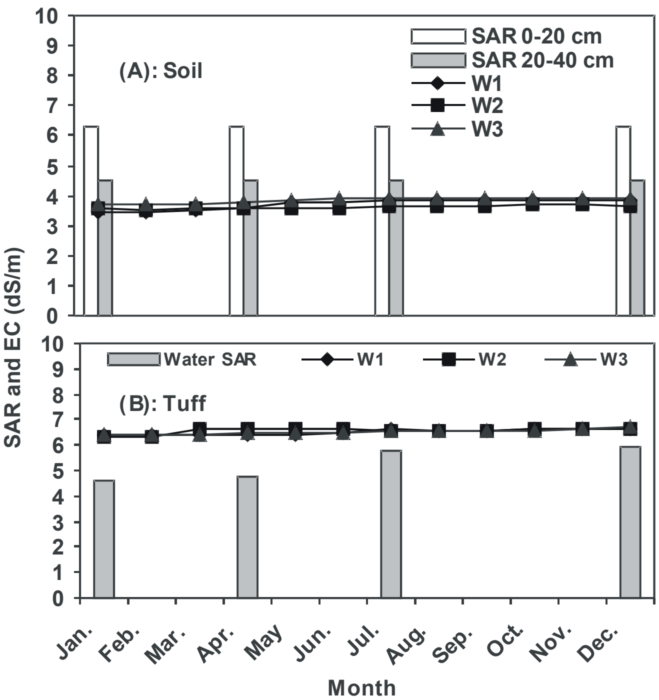

Fig. 1. Salinity and SAR variations in soil (A) and drained water of zeotuff (B) for experimental plots during season 2003 planted with First Red rose cultivar grown on three rootstocks. Water levels: For Soil: W1=(Every other day); W2= (Every two days); W3= (Every three days). And For Tuff: W1=(120%);W2=(100%); W3=80%) of the evaporation pan reading.

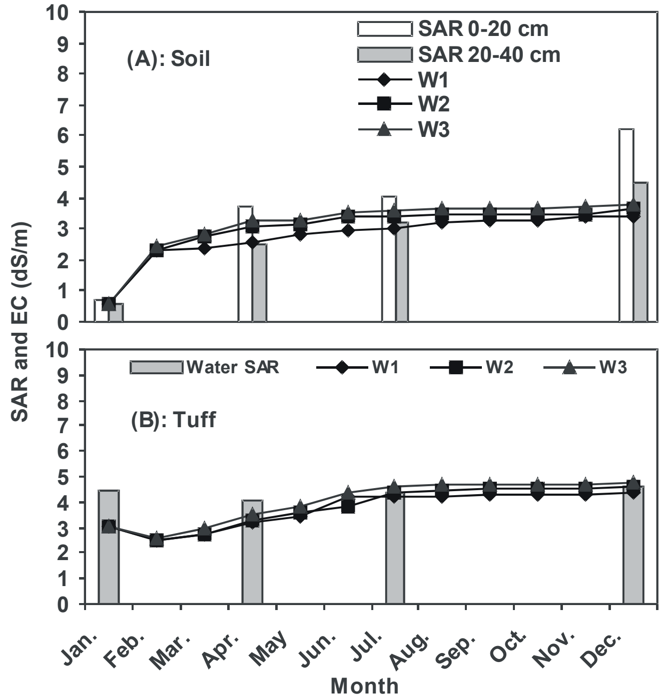

Fig. 2. Salinity and SAR variations in soil (A) and drained water of zeotuff (B) for experimental plots during season 2004 planted with First Red rose cultivar grown on three rootstocks.Water levels: For Soil: W1=(Every other day); W2= (Every two days); W3= (Every three days). And For Tuff: W1=(120%);W2=(100%); W3=80%) of the evaporation pan reading.

While only slight increase occurred to the SAR valus during the second year of experiment (Fig. 2B).

Rose tissue mineral composition was compared with the optimum nutrient levels decleared by the Agriculture Western Australia, 1998. There was no significant difference between the three rose rootstocks with regard to their effect on chemical composition of the tissue of First Red rose cultivar irrigated with the three levels of saline reclaimed water during both years planted in both media. Fig. 3 shows that there were no accumulation of nitrogen, phosphorus, potassium, calcium, and magnesium in the rose plant tissue (regardless of rootstock) planted in both media when irrigated with the three levels of saline reclaimed water during both the years. Accumulation was recorded only for sodium in the tissue of rose planted in tuff medium during the first year and both media during both the years irrigated with the three levels of water (Fig. 3). During the first year of experiment, the only micro-element accumulation in the tissue of rose plants was iron in both the media, when irrigated with the three levels of water (Fig. 3).

No accumulation was recorded for other micro-elements manganese, zinc, and copper in the rose plant tissue during this year. Additinally, no accumulation was noticed in the tissue of rose planted in both media during the second year of experiment irrigated with the three levels of saline reclaimed water (Fig. 3). During the first year in soil only the higher level of water (every other day) caused this accumulation of sodium in the rose tissue compared to the other two water levels, every two days and every three days.

In second year of irrigation with reclaimed wastewater (Table 3), calcium concentrations in soil reached intermediate levels (18.99, 15.1 meq/L) while magnesium reached up to very high levels (8.77, 9.05 meq/L) for both depths compared to the FAO (1980) limits (17.6-40 meq L^{-1} for calcium and >8 meq L^{-1} for magnesium). Sodium concentrations in soil reached (28.93, 22.43 meq/L) however, it still less than the high levels (32 meq/L) of Ilaco (1985). Phosphorus showed intermediate levels (86.08, 57.33 ppm) for both depths compared to Bookers (1984) category (80-200 ppm) for the USA, while high concentration of potassium accumulated in soil, specially at 0-20 cm depth , 754.84 and 832.06 ppm (Table 3) for both years, respectively compared to the limits (156 ppm) of FAO (1980).

Manganese, copper, and zinc showed no accumulation in both depths of the soil at the end of both years (Table 3). They were within lower levels as per standards of FAO (1980), while iron reached high levels in both years of irrigation at the two depths of soil.

All properties and nutrient contents of the reclaimed water used in irrigation (Table 2) were within the Jordanian standards limits of 2002 for reclaimed domestic water allowed for agricultural irrigation. After two years of irrigation with such water (Table 4), drained water from tuff beds had characteristics that are still within the limits of the Jordanian standards (2002). No accumulation for any of the macro and micro nutrients was recorded.

Less salinity build up was shown by the three irrigation treatments in soil than the tuff drained water when planted with First Red rose cultivar regardless of rootstock used during the first year 2003 (Fig. 1). Soil plots showed salinity build up to 3.7 dS/m, while the drained water of the tuff plots reached up to 4.7 dS/m. This was accompanied by gradual increase of the SAR value in

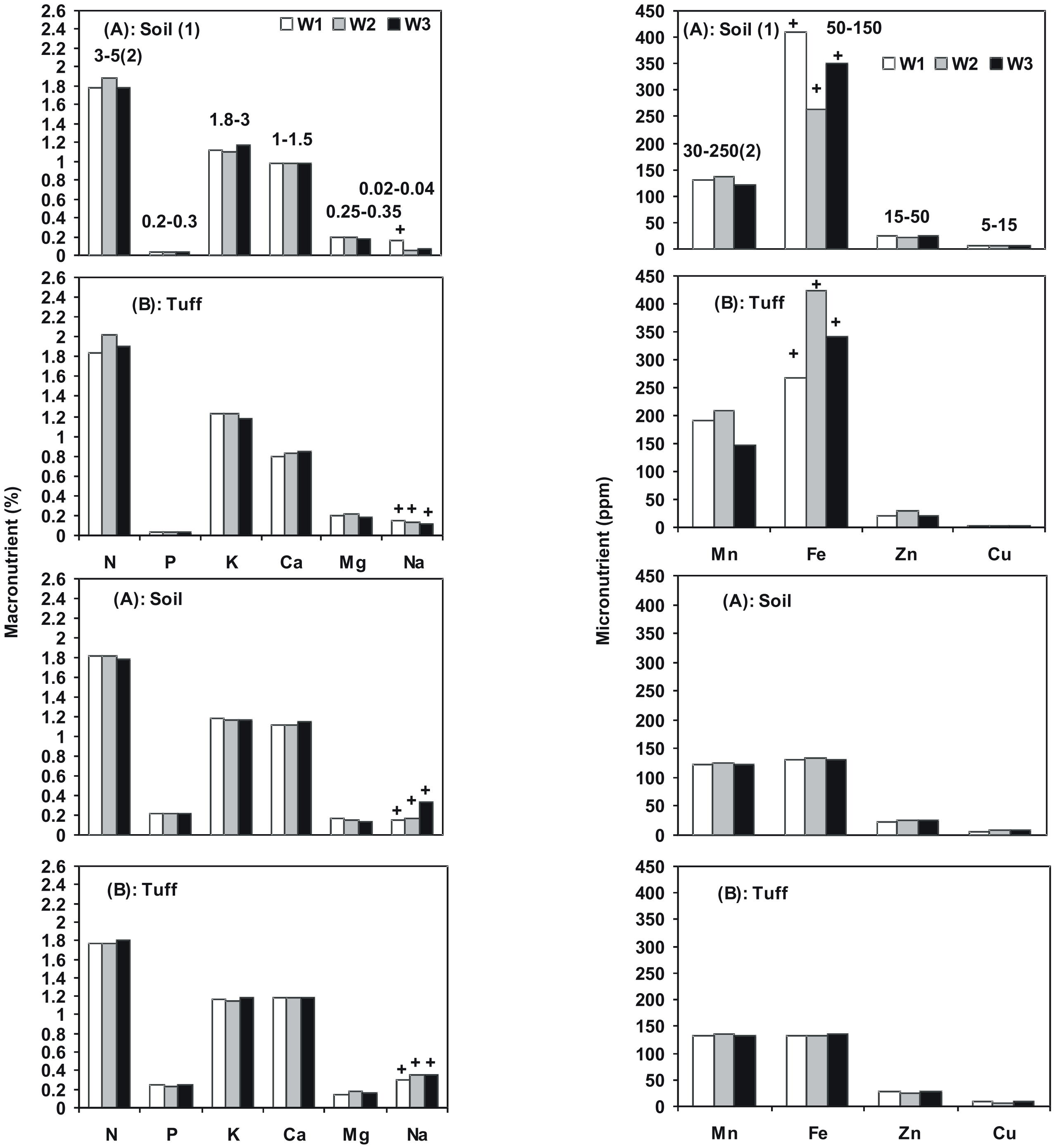

Fig. 3. Macro and micro-element contents in rose plant tissue irrigated with three levels of reclaimed water from Ramtha during 2003 and 2004. (1): Water levels: For Soil: W1=(every other day); W2= (every two days); W3= (every three days) and for Tuff: W1=(120%);W2=(100%); W3=80%) of the pan evaporation reading.

both the media. However, SAR value of the soil was still less than the FAO (1980) standards at 0-20 cm depth and much less at the 20-40 cm depth (Fig. 2).

Both EC and SAR reached a steady status throughout the second year 2004 (Fig. 2). By the end of year 2004, soil salinity, 3.92 dS/m (Fig. 2) was still within the very slightly saline category of the USDA (1969), 2-4 dS/m. Salinity (6.68 dS/m) of drained water from tuff beds exceeded the 3.2 dS/m allowed by the Jordan standards (2002). While the SAR value of 5.9 was much less than 9 that stated in the standards.

According to the optimum nutrient levels in rose tissue given by the Agriculture Western Australia (1998), the only macro and micro element accumulation was recorded for sodium in the tissue of First Red rose planted in both media during both years and iron in both media during the first year only, regardless of water treatment (Fig. 3)

After two years of irrigation with reclaimed wastewater phosphorus showed intermediate levels in both depths, potassium considerably accumulated in soil, especially in the depth 0-20 cm. Manganese, copper, and zinc showed no accumulation in soil, iron reached high levels in both years of irrigation in both depths of soil.

Less salinity build up was shown by the three irrigation treatments in soil than the tuff drained water when planted with First Red rose cultivar regardless of rootstock used during the first year (2003). Both EC and SAR reached a steady status in the second year (2004).

Table 4. Chemical characteristics of drained water from tuff beds irrigated with RW for the two years

Parameter	Year	
	First	Second
pH	7.90	8.00
Na (Meq/L)	19.21	25.32
Mg (Meq/L)	14.80	15.40
Ca (Meq/L)	19.80	20.82
Cl (Meq/L)	37.80	38.90
HCO_3 (Meq/L)	6.32	6.30
P (ppm)	2.01	2.20
K (ppm)	30.32	32.84
NO_3 (ppm)	318.40	331.50
Zn (ppm)	0.04	0.04
Fe (ppm)	0.11	0.10
Cu (ppm)	0.01	0.01
Mn (ppm)	0.01	0.01
Cd (ppm)	0.01	0.01

As per published optimum nutrient levels for rose, the only macro and micro element accumulation was recorded for sodium in the tissue of First Red rose planted in both media during both years and iron in both media during the first year only.

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