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Long Term Effects of Reclaimed Water on Rose and Carnation Cut Flower Crops in Soil and Soilless Media

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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 and three carnation cultivars 'Voyore, Diana and Chad' was investigated in two separate experiments for two successive years 2003 and 2004 in two planting media soil and Zeotuff. After two years of growing roses and carnations in soil using reclaimed wastewater for irrigation, Ca reached intermediate concentrations, Mg very highly accumulated, Na showed high levels, P showed low levels, while K was very highly accumulated in both soil depths. Mn, Cu and Zn showed no accumulation in soil, Fe reached high levels in both years of irrigation in the two depths. According to the optimum nutrient's levels in rose tissue declared by the literature, the only macro and micro element's 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. While it was recorded for Mg in the tissue of carnations regardless of cultivar in tuff medium during both years and Fe in both media during the first year only, regardless of water treatment.

Key words: Rose, carnation, salinity (RW) reclaimed water

INTRODUCTION

The rapidly expanding population of Jordan has generated an ever-increasing volume of reclaimed water, which has raised question as to how this low quality water should be managed and possibly recycled for the benefit of the society. The challenge for agriculture is represented by the extreme difficulty to sustain respond to a high consumption levels demand of water currently required by growers, particularly because of limited water resources. This makes cheap water a dream to most Jordanian growers. 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; Kretchmer *et al*., 2002) leading to increased mineral composition in plants tissue, influencing plant performance (yield and quality of produce). However, benefits can be gained from this water such as conserving of fresh water sources, reducing the use of synthetic fertilizer and improving soil properties (soil fertility) and producing higher yields (Kretchmer *et al*., 2002).

Since each reuse opportunity has its place as an option. Reclaimed water (RW) is applied mainly to field crops (Middle East Water Shortage, 2000). Citrus trees irrigation in Florida (Parson *et al*., 1997). The highway landscapes in Egypt (Heliopolis, 2001) and cut flowers crops (Maloupa *et al*., 1999; Safi *et al*., 2005 a,b). In Jordan, our opportunity is to explore potential alternative crops to make use of this low quality reclaimed water. One of the proposed alternatives is to irrigate high commercial valued cut flower crops such as Roses and Carnations creating new dimension on RW reuse in agriculture.

Roses have been classified as high salinity tolerant up to 3-4 dS m^{-1} level (Kotuby Amacher *et al*., 2000), or sensitive (Chimonidou, 1997) or highly salt sensitive (Western Australia Department, 2003) with EC level as low as 0.8-1.0 dS m^{-1}. On the contrary, it is reported that roses could resist up to 6 dS m^{-1} without affecting yield and quality of roses produced (Chimonidou, 1997). On the other hand, Carnations are reported to be slightly salt sensitive 1.5-2.3 dS m^{-1} (Western Australia Department, 2003) to moderate tolerant 2-3 dS m^{-1} (Kotuby-Amacher *et al*., 2000).

This study is conducted for two successive years at the National Center for Agricultural Research and Technology Transfer NCARTT, Jordan and funded by the Arab Fund for Economic and Social Development for the objectives to assess an opportunity of saline reclaimed water reuse in irrigation Rose and Carnation in two media, soil and Zeotuff.

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Table 1: Soil chemical proportions before planting

Chemicals characteristics	0-20	20-40
pH Meq L^{-1}	7.80	7.80
EC dS m^{-1}	0.65	0.55
Total (+) Meq L^{-1}	6.31	5.43
Ca Meq L^{-1}	2.20	1.70
Mg Meq L^{-1}	3.00	2.66
Na Meq L^{-1}	1.11	1.07
Cl Meq L^{-1}	20.00	15.00
HCO_3 Meq L^{-1}	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)	0.074	0.074
Fe (ppm)	1.05	1.05
Zn (ppm)	2.30	4.80
NO_3 (ppm)	12.80	18.60

Table 2: Chemical proportions of the reclaimed water used in irrigation

	EC	TDS	Na	Mg	Ca	Cl	HCO_3		P	K	NO_3	Zn	Fe	Cu	Mn	Cd
pH	(dS m^{-1})	(ppm)	--------------------(Meq L^{-1})--------------------					Na (%)	--------------------(ppm)--------------------							
7.5	3.07	1964	13.4	7.4	7.30	13	8.25	47.6	2.0	47.4	48.7	0.0443	0.421	0.006	0.019	0.006

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: *Rosa indica*, *Rosa canina* and *Rosa hybrida*, Natal Briar and three carnation cultivars Voyore, Diana and Chad. The plants were grown separately each in a plastic house of 360 m^2 area, controlled by pad and fan system in Ramtha area 60 km north of Amman. Two planting media in two separate experiments for each plant type were used: The natural soil (soil chemical characteristics are shown in Table 1 and volcanic rock Zeotuff (soilless system). Rose experimental plots were made as 0.6×1 m area and 8 plants put in two rows spaced 25×40 cm, while carnation experimental plots were 1×1 m in size with 32 plants per m^2 in both cultural media. Soilless plots were made by 700 μ black polyethylene mulch with the slope of 1.5% for drainage of the excess water.

Each plant type was irrigated by three irrigation regimes of one type of water; the effluent of reclaimed water from the Ramtha wastewater treatment plant (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 two days, every three days and every four days for the soil experiments. Drip irrigation system was used with three steps of filtering (sand, screen and disc) without any addition of fertilizer. Rose rootstocks and carnation cultivars and watering treatments were arranged as split-plots in a randomized complete block design with four replications. Uniform plastic house shading was used in summer. Disease and pest control program performed as needed during the experiment time.

To assess chemical effects of reclaimed water reuse, data on the changes in soil, drained water and plant tissue mineral composition were collected, tabulated and figured for both planting media.

RESULTS AND DISCUSSION

There was no significant difference between the three water levels in their effect on the chemical composition of the soil, drained water and plant tissue of the roses and carnations. The results in tables and figures show the mineral changes in these components regardless of water treatment, rose rootstock, or carnation cultivar.

Roses: Using reclaimed water in irrigation caused noticeable buildup in salinity levels dS m^{-1} and increased all macro and micro-elements concentrations at the end of the first year in both depths of the soil (Table 3). Except for the Zinc element that showed a decrease in its concentration at the end of the first year.

During the second year of irrigation with the reclaimed water, only a slight change was recorded for the soil salinity in both depths. While 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). 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: Soil chemical characteristics, planted to roses irrigated with RW for two years

	After 1 year		After 2 years	
Chemical characteristics	0-20	20-40	0-20	20-40
pH (Meq L^{-1})	7.76	7.63	7.70	7.60
EC (dS m^{-1})	3.63	3.69	3.68	3.71
Ca (Meq L^{-1})	11.33	10.22	18.99	15.10
Mg (Meq L^{-1})	9.88	9.22	8.77	9.05
Na (Meq L^{-1})	17.00	14.01	28.93	22.43
Cl (Meq L^{-1})	17.21	16.38	34.16	28.11
HCO_3 (Meq L^{-1})	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)	0.085	0.085	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

Table 4: Chemical characteristics of drained water from tuff beds planted to roses plants irrigated with RW for the two years

Chemical characteristics	1 year of irrigation	2 years of irrigation
pH	7.90	8.00
EC (dS m^{-1})	5.27	5.34
Na (Meq L^{-1})	19.21	25.32
Mg (Meq L^{-1})	14.80	15.40
Ca	19.80	20.82
Cl	37.80	38.90
HCO_3	6.32	6.30
P (ppm)	2.01	2.20
K (ppm)	30.32	32.84
NO_3	318.40	331.50
Zn	0.042	0.038
Fe	0.11	0.10
Cu	0.01	0.01
Mn	0.01	0.01
Cd	0.011	0.01

For the drained water from tuff beds (Table 4) there was a high increase in the salinity levels and 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, in addition to a slight increase in salinity level (Table 4).

The only increase in concentrations were recorded for Sodium and Chloride in the drained water from tuff beds compared to concentrations at the end of the first year (Table 4). It seems that salinity levels showed an increase at the end of the first year and it was almost in a steady status throughout the second year. However, salinity was greater in the drained water from tuff beds than in the soil beds.

Rose tissue mineral composition was compared with the optimum nutrients levels declared by the Agriculture Western Australia, 1998. There were no significant differences between the three rose rootstocks in regard to their effect on the chemical composition of the tissue of first red rose cultivar irrigated with the three levels of reclaimed water during both years planted in both media. Fig. 1 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 RW during both years. The only accumulation was recorded for the Sodium in the tissue of first red rose planted in tuff medium during the first year and both media during both years irrigated with the three levels of water (Fig. 1).

During the first year of experiment, the only micro-element accumulation in the tissue of rose plants was Iron in both media when irrigated with the three levels of water (Fig. 1). No accumulation was recorded for the other micro-elements Manganese, Zinc and Copper in the rose plant tissue during this year. Additionally, no accumulation was noticed in the tissue of first red rose planted in both media during the second year of experiment irrigated with the three levels of RW (Fig. 1). During the first year in soil only the higher level of water (every two day) caused this accumulation of Sodium in the rose tissue compared to the other two water levels, every three days and every four days.

After two years of irrigation with RW (Table 3), the concentrations in soil, Calcium reached intermediate levels (18.99, 15.1 meq L^{-1}) while Magnesium reached up to very high levels (8.77, 9.05 meq L^{-1}) for both depths compared to the FAO limits 1980 (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^{-1}) however, it still less than the maximum high levels (32 meq L^{-1}) of Ilaco 1985. Phosphorus showed intermediate levels (86.08, 57.33 ppm) for both depths compared to Bookers's category 1984 (80-200 ppm) for the USA, while Potassium very highly accumulated in soil, specially in the depth 0-20 cm, 754.84 and 832.06 ppm (Table 3) for both years, respectively compared to limits of the FAO (1980) (156 ppm).

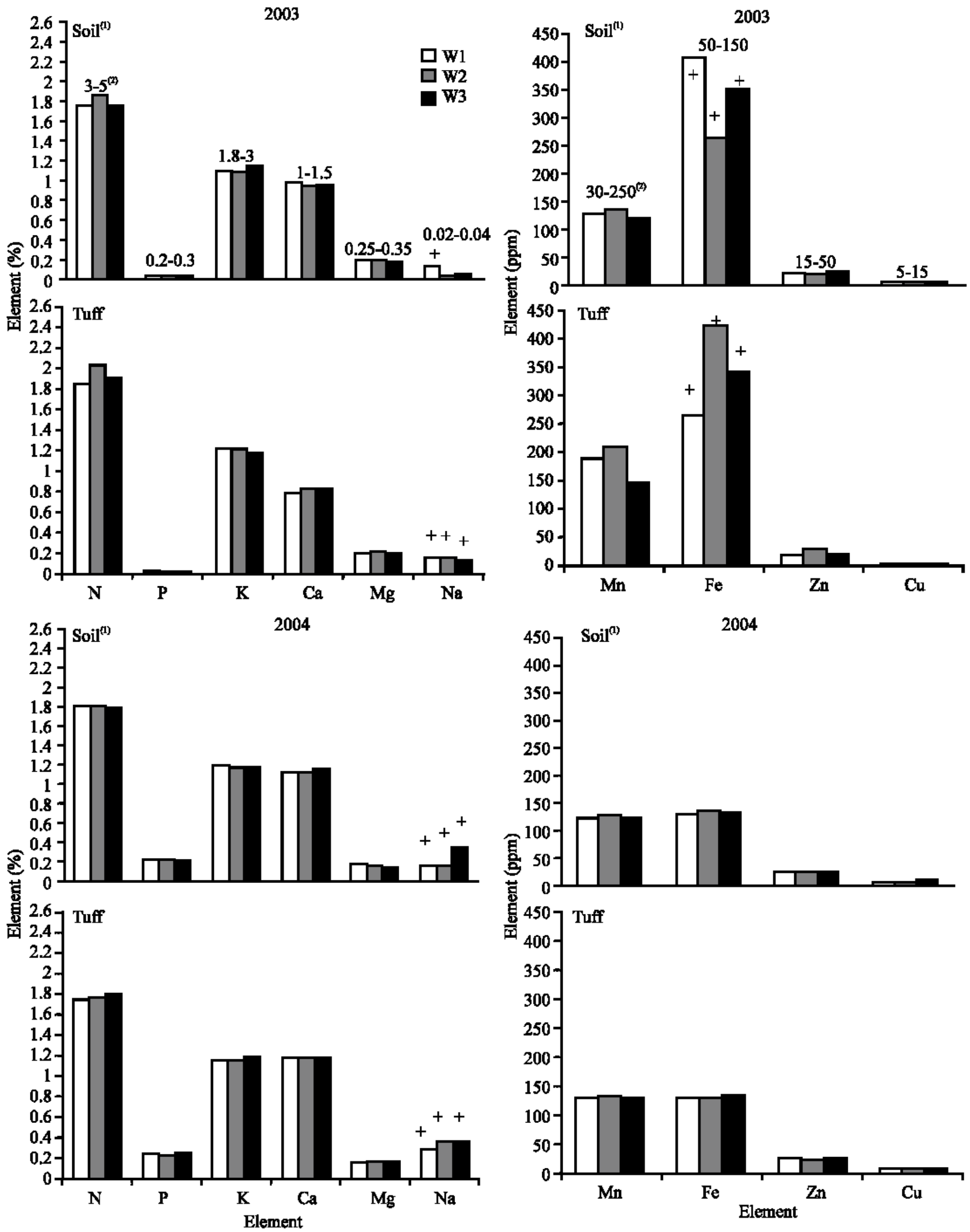

Fig. 1: Macro and micro-elements content in rose plant tissue irrigated with three levels of reclaimed water/Ramtha, 2003 and 2004, (1): Water levels: For Soil: W1 = (Every other day); W2 = (Every two days); W3 = (Every three days). And For Tuff: W1 = (120%); W2 = (100%); W3 = 80%) of the evaporation pan reading. (2): Optimum elements levels according to Agriculture Western Australia, 1998. (+): Element% exceeded the optimum levels compared to reference

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 declared by FAO (1980), while Iron reached high levels in both years of irrigation in the two depths of soil.

All properties and nutrient contents of the RW used in irrigation (Table 2) are 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 of 2002. No accumulation for any of the macro and micro nutrients was recorded.

Less salinity build up was shown by irrigation with RW in soil than the tuff drained water when planted with first red rose cultivar regardless of rootstock used during the first year 2003 (Table 3 and 4). Soil plots showed salinity build up to 3.71 dS m^{-1} after two years of reuse (Table 3). While the drained water of the tuff plots reached up to 5.34 dS m^{-1}. Soil salinity, 3.71 dS m^{-1} was still within the very slightly saline category of the USDA 1969, 2-4 dS m^{-1}. Salinity 5.34 dS m^{-1} of drained water from tuff beds exceeded the 3.2 dS m^{-1} allowed by the Jordanian standards of 2002.

According to the optimum nutrient's levels in rose tissue declared by the Agriculture Western Australia 1998, the only macro and micro element's 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. 1).

Carnations: Table 5 shows that irrigation with the RW caused a noticeable increase in all macro and micro-elements concentrations in the soil at the end of the first year in both depths of the soil, except for Zn element that showed a decrease in concentration in the depth 20-40 cm. By the end of the first year, salinity level increased in both soil depths (Table 5).

During the second year of irrigation with RW, no changes in Mg, Mn, Cu and NO_3 concentrations were recorded compared to their concentrations in both soil depths at the end of the first year (Table 5). Na, Cl, Fe and Zn continued in their increase showing higher concentrations at the end of second year. P showed a steady state in the upper depth 0-20 cm during the second year while its concentration increased in the lower depth 20-40 cm (Table 5). K concentration increased at the end of the second year of irrigation compared to the first year. No further increase in the NO_3 concentration observed during the second year compared to the first year of irrigation with reclaimed water in both depths of the soil. The only increase was recorded for the NO_3 during the first year compared to the original status of the soil. Additionally, by the end of the second year only a slight change was recorded in salinity level of both depths compared to first year (Table 5).

Drained water from tuff beds (Table 6) there was a high increase in the concentration of Na, Mg, Ca, NO_3, Mn and Cd elements during the first year of irrigation compared to the water source composition. However, all the elements showed no further increase during the second year compared to the first year. Using RW showed trends of high salinity build-up in soil and drained water during the first year of irrigation (Table 5 and 6) and a slight salinity increase at the end of the second year. However, salinity was greater in the drained water from tuff beds than in the soil beds.

Nutrient's proportions of the carnation tissue were compared with the optimum levels declared by Van Dein and Elgar (1998) and Hill (2002). There was no significant difference between the three cultivars in regard of their tissue mineral composition in both media when irrigated by the three levels of RW during both years. Figure 2 shows that regardless of cultivar, there was no accumulation of N, P, K, Ca and Na in the carnation plant tissue planted in both media, irrigated with the three levels of RW at the

Table 5: Soil chemical proportions after planting with carnations and irrigated with RW for the two years

	After 1 year		After 2 years	
Chemical characteristics	0-20	20-40	0-20	20-40
pH	7.83	7.83	7.70	7.90
EC (dS m^{-1})	3.28	3.34	3.31	3.44
Ca (Meq L^{-1})	12.43	15.33	17.99	16.10
Mg	10.90	11.10	11.10	11.10
Na	22.83	23.46	27.42	32.36
Cl	29.16	34.40	37.49	43.33
HCO_3	2.50	2.50	2.51	2.51
P (ppm)	40.07	39.80	40.78	51.95
K	488.84	465.71	508.57	506.22
Cd	0.066	0.072	0.19	0.20
Mn	3.50	3.50	3.52	3.52
Cu	1.80	1.80	1.81	1.81
Fe	8.58	7.85	18.60	25.86
Zn	2.30	2.30	7.99	6.53
NO_3	96.80	96.80	96.90	96.90

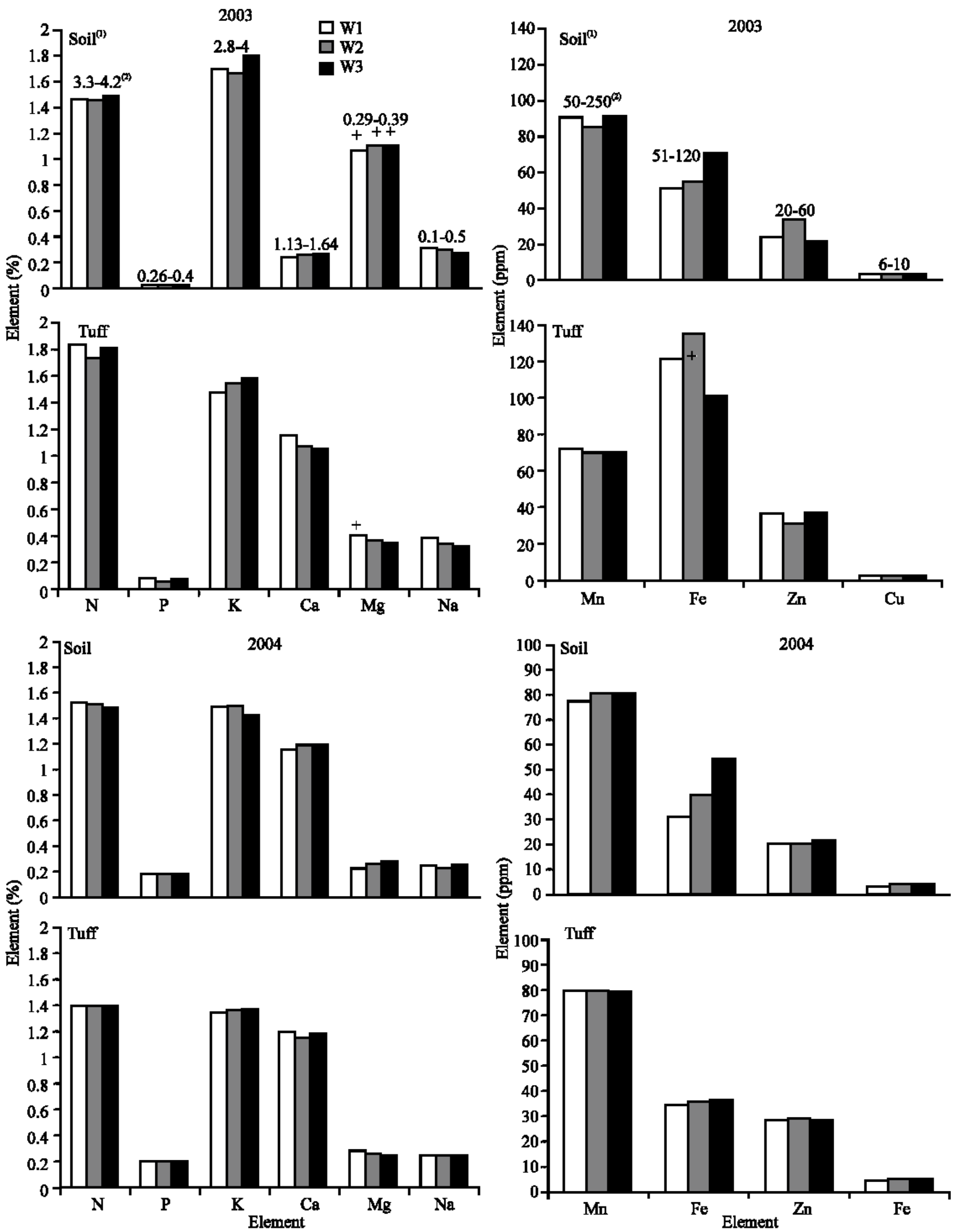

Fig. 2: Macro and micro-elements content in carnation plant tissue irrigated with three levels of reclaimed water/Ramtha, 2003 and 2004 (1): Water levels: For Soil: W1 = (Every two days); W2 = (Every three days); W3 = (Every four days). And For Tuff: W1 = (120%); W2 = (100%); W3 = 80%) of the evaporation pan reading. (2): Optimum elements levels according to Van Dein and Elgar 1998 and Hill, R. J. 2002. (+): Element% exceeded the optimum levels compared to reference

end of both years. The only accumulation was recorded for Mn in the tissue of carnations planted in soil medium, irrigated with the three levels of water and the higher level of water in tuff medium (120%) during the first year (Fig. 2). No micro-element accumulation was observed in the tissue of the carnations planted in the two media during both years, irrigated with the three levels (Fig. 2). The only micro element's accumulation in the tissue is recorded for Fe in tissue of plants grown in the tuff medium irrigated at 100% EP level with reclaimed water during the first year (Fig. 2).

After two years of irrigation with reclaimed wastewater (Table 5), Ca concentrations in soil reached intermediate levels (17.99, 16.1 meq L^{-1}) while Mg reached up to very high levels (11.1 meq L^{-1}) for both depths compared to the FAO limits (1980) (17.6-40 meq L^{-1} for Ca and >8 meq L^{-1} for Mg). Na concentrations reached (27.42, 32.36 meq L^{-1}) however, it still within the maximum levels (32 meq L^{-1}) of Ilaco (1985). P showed low levels (40.78, 51.95 ppm) for both depths according to Bookers's category (1984) (30-70 ppm) for the USA. K was very highly accumulated, 508.57, 506.22 ppm (Table 5) for both depths respectively compared to limits of the FAO (1980) (156 ppm). Mn, Cu and Zn showed no accumulation in both depths of the soil at the end of both years (Table 5), while Fe reached high levels in both years of irrigation in the two depths of soil according to levels declared by FAO (1980).

Table 6 shows that drained water from tuff beds had characteristics that are still within the limits by Jordanian Standards (2002). No accumulation for any of the macro and micro nutrients was recorded. Less salinity build-up was observed in soil than the tuff drained water when planted with carnation plants regardless of cultivar or water level during the first year 2003 (Table 5). By the end of year 2004, soil salinity, 3.44 dS m^{-1} (Table 5) was within the very slightly saline category of the USDA 1969, 2-4 dS m^{-1}. Salinity 6.25 dS m^{-1} (Table 6) of drained water from tuff beds highly exceeded the 3.2 dS m^{-1} allowed by the Jordanian standards of 2002.

According to the optimum nutrient levels in rose tissue declared by Van Dein and Elgar (1998) and Hill (2002), the only macro and micro element accumulation was recorded for Mg in the tissue of carnations regardless of cultivar in both media and Fe in tuff medium during the first year only, regardless of water treatment (Fig. 2).

Table 6: Chemical proportions of drained water from zeotuff beds after planting with carnations and irrigated with RW for the two years

Chemical characteristics	1 year of irrigation	2 years of irrigation
pH	8.10	8.10
EC dS m^{-1}	5.55	6.25
Na (Meq L^{-1})	27.87	28.30
Mg (Meq L^{-1})	15.00	15.22
Ca	20.70	20.92
Cl	39.00	40.14
HCO_3	6.00	6.00
P (ppm)	2.14	2.25
K (ppm)	33.60	33.80
NO_3	326.23	340.40
Zn	0.049	0.05
Fe	0.02	0.11
Cu	0.02	0.02
Mn	0.20	0.20
Cd	0.01	0.01

CONCLUSIONS

After two years of growing roses and carnations in soil using reclaimed wastewater for irrigation, Ca reached intermediate concentrations, Mg very highly accumulated, Na showed high levels, P showed low levels, while K was very highly accumulated in both soil depths. Mn, Cu and Zn showed no accumulation in soil, Fe reached high levels in both years of irrigation in the two depths.

Higher salinity build-up was observed in the drained water of tuff beds than in soil planted with roses and carnations regardless of rootstock or cultivar. It seems that salinity levels reached almost a steady status throughout the second year of RW reuse in irrigation.

According to the optimum nutrient's levels in rose tissue found in the literature, the only macro and micro element's accumulation was recorded was 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. While it was recorded for Mg in the tissue of carnations regardless of cultivar in tuff medium during both years and Fe in both media during the first year only, regardless of water treatment.

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