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Effect of graywater on soil chemical composition and yield of tomato plant

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Abstract

Jordan faces a future of very limited water supplies, graywater is one of the options that can bridge the gap and could help in water balances. Graywater is all wastewaters excluding toilet wastes; it can come from the sinks, showers, tubs or washing machine. An improved understanding of the effects of graywater reuse on the environment is required. A pilot project was done in Al-Balqa' Applied University Research Station to determine the possibility of using graywater as a source of water to irrigate vegetable crops that may eaten raw like tomato and to test the effect of graywater on soil chemical composition. The experiment was conducted by using Randomized Complete Block Design (RCBD) with two replicates in plastic house using three different sources of gray water (kitchen, ablution water and a mix between them), tap water as a control. Soil samples (before and after the season), representative gray water, nutrient and heavy metal contents in leaf and fruit of tomato plant were analyzed. It is concluded that no heavy metal accumulation neither in the soil nor in the plant. Also there was no significant difference between nutrient contents of leaves and fruits of tomato plants irrigated by different types of graywater treatments. On the other hand, tomato plants irrigated with ablution water gave significant higher yield than those irrigated with other sources of graywater or those irrigated with tap water. Graywater especially ablution water can be considered as a non-conventional source of irrigation water for vegetable crops.

Key words: Jordan, graywater, RCBD, drip irrigation, plastic house.

Introduction

Jordan is a water-scarce country. Water is not only associated with the available quantity but also with the quantity which should meet specified standards to be useful. Agricultural irrigation is the primary water consumer sector where it consumes about 32.5% of the available resources followed by the municipal and then the industrial sector. However, it is expected that by the year 2020 the amount of fresh water allocated for irrigation will drop in order to cater for the increase in water demand for municipal and industrial purposes [1].

Strategies at a country level aim at securing reliable supplies of water (in quantity and quality) for drinking water and irrigation in Jordan. Water deficiency in agriculture is achievable by the maximum development of water resources and the protection of existing water resources. Among these strategies is the use of graywater in agriculture which is being practiced in many parts of the world [8, 9].

Although graywater which is all wastewater excluding toilet waste [7] is considered by many researchers as health hazard, many others consider it clean and safe to be used in agricultural activities especially when it is properly managed to avoid it from direct contact with human.

Graywater had been used in agriculture as early as the 19th century in Santa Barbara, USA. Jappesen and Solley 1984 investigated the potential of graywater reuse in Australia, and they found that significant amount of fresh water saving can be achieved. Cyprus has initiated a subsidy program for households that wish to install graywater reuse systems for domestic landscaping and toilet flushing. There is also documentation of graywater reuse at certain hotels and at least one sports facility. Dual plumbing systems have also been introduced to allow the reuse of graywater in toilet flushing [4].

In Jordan some work had been done on graywater. A project is being done in Jordan by the Inter-Islamic Network on Water Resources Development and Management (INWRDAM), Amman, Jordan, where they installed more than 800 local units of graywater collection that are located in 90 villages. The results indicated that graywater can be considered as unconventional irrigation water source [10]. Another study was done by Al-Jayyousi to find the opportunity of reusing the graywater in Jordan for irrigation; he found it feasible to be used under specific conditions [2].

This paper reports a pilot project to determine the possibility of using graywater as a source of water to irrigate vegetable crops that may be eaten raw like tomato and to test the effect of graywater on soil chemical composition.

Methodology

This research was carried out during the winter of 2005/2006 using plants of tomato Khalia cultivar. The research was conducted in a plastic house (260 m^2) of a virgin soil in the experimental station of Al-Balqa' Applied University. The following parameters were measured: pH, EC, N, P, K, Ca, Mg, Na, Cl, CO_3, HCO_3, Cd and Ni. Laboratory analyses to measure the different elements were conducted according to the following procedure [6]. All samples were placed in a greenhouse for at least 3 days to allow air-drying. Samples were sieved using a 2 mm sieve. A soil paste was prepared by using a known volume of distilled water with a known weight of air-dried soil. The paste was left overnight to ensure the degree of soil saturation. The soil samples were individually subjected to a water extraction process, using a Büchner funnel.

The design of experiment was conducted by using Randomized Complete Block Design (RCBD) with four replicates under plastic house (Table 1). Plot area dimensions for each treatment was (7 m x 0.65 m). Irrigation was applied according to crop water requirements. Data were analyzed by using least significant differences (LSD) at 5% significant level according to the design used.

The chemical composition of the graywater used in irrigation is shown in Table 2. All graywater treatments were collected from the campus of Al-Balqa' Applied University, including kitchen sink, mosque sink (ablution water) and a mixture of both treatments with a mixture ratio (1:1). In addition tap water was considered as a treatment. Chemical analyses conducted [3] demonstrate chemical properties of graywater (pH, EC, TDS, NO_3^- and PO_4^{-3}) (Table 2).

In order to study the existing condition of the chemical composition of soil before planting, three trenches (inlet, middle and outlet of the row) were dug, the trench was made between the drip lines each trench was 30 cm wide and 30 cm deep. From each trench, three samples were collected. The chemical composition of the soil before planting is shown in Table 3.

There are substances necessary for the metabolism and photosynthesis in plants including macronutrients (N, P, K), and some dissolved mineral salts may be phytotoxic or may become so at high concentrations. Specific elements (Cd, Ni, Hg, Zn, etc.) are toxic to plants. At the end of the growing season, plant samples (leaves and fruits) were collected from the middle of the plants in each experimental unit for plant nutrients (N, P and K) and heavy metals (Cd and Ni) analysis [5].

Results and Discussion

The irrigation system applied in this experiment is drip irrigation. It is expected to have minimum deep percolation or drainage out of the root zone. In case of drip irrigation system salt accumulation

Table 1. Design of the experiment by using randomized complete block design.

T_1	T_4	T_3	T_2
T_3	T_2	T_1	T_4
T_4	T_3	T_2	T_1
T_2	T_4	T_1	T_3

T_1: Mosque water (Ablution water).
T_2: Kitchen water.
T_3: Mix. (ablution water+kitchen water).
T_4: Tap water.

Table 2. Chemical composition of the gray water.

Source	pH	EC (dS/m)	TDS (mg/l)	NO_3^- (mg/l)	PO_4^{-3} (mg/l)
Mosque water (ablution water)	7.1	0.716	458	5.9	2.31
Kitchen water	6.6	6.966	5224	65.4	2.65
Mix. (ablution water + kitchen water)	6.7	3.020	2114	32.4	2.44
Tap water	8.3	1.100	704	19.1	

Table 3. Chemical composition of virgin soil before planting.

Parameter	Depth cm		
	0-20	20-40	40-60
pH	7.78	7.81	7.83
EC (ds/m)	0.70	0.66	0.73
P (ppm)	13.77	12.50	16.20
K (meq/l)	661.93	593.46	641.80
Ca (meq/l)	1.83	2.17	2.00
Mg (meq/l)	2.67	2.97	3.03
Na (meq/l)	1.30	1.41	1.38
K (meq/l)	0.80	0.79	0.92
Cl (meq/l)	2.50	2.50	2.50
HCO_3 (meq/l)	2.50	2.50	2.50
N %	0.12	0.08	0.09
Na %	21.08	21.16	20.43
SAR	0.88	0.91	0.88
ESP	0.05	0.07	0.05
Cd (ppm)	0.16	0.15	0.14
Ni (ppm)	0.60	0.65	0.58

confined to the upper layer of the effective root zone (0-20) cm. The results shown in Table 4 reflect the statistical analysis for the chemical composition of the soil at the end of the season. Data were analyzed by using least significant differences (LSD) at 5% significant level according to the design used.

The results show that the soil pH of all treatments (including the control) slightly declined (from 0.4 to 0.5 pH unit) compared with the soil pH (7.81) before the application of treatments (Table 4). This might be due to their content of degradable organic compounds resulting in a higher soil microbial activity, while irrigation water of different treatments obviously resulted in a considerable increase in soil EC (4- to 5-fold) higher than that of the uncultivated soil before irrigation. This means that these water sources including the tap water are a potential source of salt accumulation. However, the EC did not exceed 4 dS/m. Nevertheless, these water sources should be utilized with caution, in particular, if salt-sensitive crops are grown. According the definition of saline soils, this soil is not considered saline because the EC is less than 4 dS/m, SAR is very low and soil pH is lower than 8.3. However, the long-term effect of using graywater as a source of irrigation should be monitored.

Regarding the sodium ion, it is clear that these water sources were not a potential source of sodium. However, they were a potential source of other cations like Ca and K. The fact that the concentration of Ca ion was much higher than that of Na ion resulted in only a very slight increase in SAR. The concentration of bicarbonate ion in soil was considerably increased (8- to 9-fold higher than that before irrigation). This would contribute in raising the concentration of total soluble salts in the irrigated soil.

Heavy metal concentrations (Cd and Ni) in soil were increased (6- to 7-fold for Cd and almost 2-fold for Ni) compared to their concentrations in soil before irrigation. However, these concentrations were far below the hazardous level. Nevertheless, the long-term effect of using graywater might cause an accumulation of these metals in irrigated soils.

Table 4. Chemical analysis of soil after planting.

No.	Treatment	pH	EC (µS/cm)	K (meq/l)	Ca (meq/l)	Mg (meq/l)	Cl (meq/l)	HCO_3 (meq/l)	Na (ppm)	Total cations	SAR	Cd (ppm)	Ni (ppm)
1	Tap	7.353a	2540.0a	4.630a	13.500a	3.583b	2.667a	20.43a	10.600a	24.27a	0.884a	0.9541ab	1.1059a
2	Kitchen	7.287a	3391.7a	5.166a	17.583a	6.500a	6.667a	20.73a	19.733a	37.24a	2.231a	1.0167a	1.1167a
3	Mosque	7.397a	2735.0a	4.200a	13.667a	5.583a	2.500a	20.83a	15.333a	27.61a	1.357a	1.0190a	1.1037a
4	Mixed	7.283a	3336.7a	5.045a	16.333a	5.500a	4.330a	23.30a	17.533a	33.37a	1.907a	0.8722b	1.0489a

Table 5 shows the effect of graywater on nutrient contents of tomato leaves. Statistical analysis shows that tomato leaf contents of N, P, K and heavy metals (Pb, Cd, and Ni) have no significant differences between different treatments. On the other hand, graywater had the same effect as tap water (control), especially on the tomato leaf contents of heavy metals. In addition, there was significantly increased phosphorus content in kitchen water as compared to the tap water. This result indicates the capability of using graywater in irrigation of tomato crops as there is no increase in heavy metal contents. This result also indicates that these types of graywater used in this experiment were very safe as irrigation water. Tomato fruit contents of N, P, K and heavy metals (Pb, Cd and Ni) also had no significant differences between treatments (Table 6). This result demonstrates that graywater has no adverse effect on tomato plant concerning the content of heavy metals which reflects the ability of introduce graywater as alternative source of irrigation for vegetable crops. Tomato plants irrigated with ablution water gave significantly higher total yield as compared with other types of gray water or tap water (Table 7).

Conclusions

It is concluded that there was no heavy metal accumulation neither in the soil nor in the plant. Also there was no significant difference between nutrient contents of leaves and fruits of tomato plants irrigated by different types of graywater treatments. On the other hand, tomato plants irrigated with ablution water gave significantly higher yield than those irrigated with other sources of graywater or those irrigated with tap water. Graywater, especially ablution water, can be considered as a non-conventional source of irrigation water for vegetable crops.

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Table 7. Effect of gray water on total yield of tomato plants.

Treatment	Yield (kg/house)
Tap water	1736 b
Ablution water	2273 a
Kitchen water	1694 b
Mixed water	1801 b

Means within column having the same letters are not significantly different according to Duncan's Multiple Range test at 5% level.

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Table 5. Effect of graywater on nutrients content of a tomato plants leaves.

Treatment	N %	P%	K%	Pb (ppm)	Cd (ppm)	Ni (ppm)
Tap water	1.81 a	0.13 b	3.46 a	0.01 a	0.80 a	1.14 a
Ablution water	1.86 a	0.15 ab	3.72 a	0.01 a	0.79 a	1.23 a
Kitchen water	1.93 a	0.18 a	3.61 a	0.01 a	0.89 a	1.08 a
Mixed water	1.74 a	0.16 ab	3.25 a	0.01 a	0.94 a	1.29 a

Means within column having the same letters are not significantly different according to Duncan's Multiple Range test at 5% level.

Table 6. Effect of gray water on nutrients content of a tomato plants fruits.

Treatment	N %	P%	K%	Pb (ppm)	Cd (ppm)	Ni (ppm)
Tap water	1.63 a	0.21 ab	2.81 a	0.01 a	0.15 a	0.01 a
Ablution water	1.62 a	0.19 ab	2.46 a	0.01 a	0.12 a	0.01 a
Kitchen water	1.68 a	0.17 b	2.55 a	0.01 a	0.13 a	0.01 a
Mixed water	1.63 a	0.23 a	2.92 a	0.01 a	0.15 a	0.01 a

Means within column having the same letters are not significantly different according to Duncan's Multiple Range test at 5% level.