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EVALUATION OF GROWTH AND YIELD OF VARIOUS BARLEY CULTIVARS IRRIGATED WITH ARTIFICIAL WASTEWATER

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Abstract

The research was implemented in order to study the effect of irrigation with artificial wastewater on soil, plant growth and the crop yield of seven barley cultivars. The experiment was conducted at the new campus of An-Najah National University. The seeds were planted in the spring season and irrigated with two water types (Fresh water as control and artificial wastewater), with three replicates for each treatment. Chemical analysis have been used for determining the mineral contents of the soil of the experiment for each variety and each type of water for nitrogen (N), phosphorus (P), potassium (K) and total dissolved salts (TDS). Barley proved to be a tolerant crop with considerable economic importance. Highest yield was obtained from cultivars irrigated with the artificial wastewater which gave nearly twice the yield and spike weight than the cultivars irrigated with fresh water. In addition, it gives higher spikes length and higher stem weight. The growth vigour as well as the growth period (from days to emergence to maturity) were not affected with the type of water and only depend on the type of the seeds. The chemical analysis of N, K and P represents the following: (N% – Root > N% – Spike, N% – Stem), for potassium, (K% – Stem> K% – Root, K% – Spike) and the phosphorous (P% – Spike > P% – Stem, P% – Root). In addition, artificial wastewater is a promising water resource as alternatives for fresh water to be used in agriculture specially crops with high tolerance to salinity such as barley since the use of wastewater in irrigation affects the soil texture through increasing the concentrations of some constituents such as N, K and P.

***Keywords**: Fresh and artificial wastewater, Barley cultivars, Plant growth, Crop yield*

1. INTRODUCTION

Water is a vital resource for human life and activities including industry, reaction, and agriculture, but a severely limited one in most countries of the Mediterranean region such as Palestine. Therefore, there is an urgent need to conserve and protect fresh water and to use the water of lower quality for irrigation [1]. The use of treated artificial wastewater (sewage water) in countries poor in water resources is less expensive and considered an attractive source of irrigation water and the interest in reusing artificial wastewater for irrigation is rapidly growing in these countries [2]. Consequently, the reuse of artificial wastewater for agriculture is highly encouraged [3]. Irrigation with treated artificial wastewater is considered an environmentally sound wastewater disposal practice compared to its direct disposal to the surface or ground water bodies [4]. In addition, artificial wastewater is a valuable source of plant nutrients and organic matter needed for maintaining fertility and productivity levels of the soil [5]. On the other hand, artificial wastewater may contain undesirable chemical constituents and pathogens that pose negative environmental and health impacts [6]. Consequently, mismanagement of artificial wastewater irrigation would create environmental and health problems to the ecosystem and human beings [7]. The majority of the research conducted on artificial wastewater reuse in agriculture focuses mainly on its short-term effect on plant growth and development with little attention to the changes induced in the soil fertility and chemistry parameters.

Many states and local governments have reacted by placing restrictions on the use of potable water for irrigation, instead requiring the use of reclaimed or other secondary saline water sources [8].

The first use of artificial wastewater in irrigation was historically backed to two thousand years ago in Greece. Artificial wastewater reuse in agriculture is recognized worldwide as an alternative water and nutrient source [9]. Recycling artificial wastewater is one solution in facing up to the increasing demand for water resources for irrigation. At the same time, it is a natural way of reducing the environmental impacts and providing the nutrients (mainly nitrogen and phosphorous) which will fertilize the soil [10]. The increasing usage of brackish, low quality, and treated effluent water in agriculture increased the need to quantify the impact of irrigation water quality on the irrigated crops. Rapid urban population growth has put enormous pressures on limited freshwater supplies. Wang and Chang found that the use of reclaimed simulated wastewater in irrigation reduce the porosity of soil and reduce nutrient holding capacity [11]. In Jordan, researchers attempted to use saline water for the irrigation of barley and onion. Feigin et al. [12] found that irrigation with artificial wastewater increases soil salinity, nutrient contents, pathogens, and trace metal concentrations in soil. They found also that suspended solids clog the soil pores. Dojlido [13] observed that high levels of sodium in irrigated water can effects on soil structure, infiltration, and permeability rates. Sadeh and Ravina [14] applied a model to field crops in the Negev, in three case studies, using existing linear and non-linear relationships between yield and irrigation and between yield and salinity. Model coefficients were estimated from experimental data. Results were consistent with actual yield of corn and cotton in the single season cases. Simulation of wheat growing in the winter with supplemental irrigation with brackish water for 13 years showed interesting results of accumulation of soil salinity and reduction of yield. The model can be easily applied to other crops and growing areas. It can be used for the analysis of long-term soil salinization processes. Viviani and Iovino [15] carried out a laboratory experiment to investigate the effect of using artificial wastewater in irrigation on the hydraulic conductivity of loam and clay soils. The loam soil hydraulic conductivity was reduced to about 80% of the initial value after infiltration of 175 mm of municipal artificial wastewater with total dissolved solids in the range of 57 to 68 mg/l. Reductions in hydraulic conductivity were more remarkable in the clay soil. Irrigation with wastewater was common in Germany in the sixteenth century and in England in the nineteenth century, while in the United States, the use of synthetic wastewater is back to the seventies of the nineteenth century [16] Agriculture accounts for 70 - 95% of the water taken in certain developing countries.

Sharma and Agrawal studied the effect of using treated and untreated artificial wastewater for irrigation on soil and vegetable contamination by heavy metals in India. The study concludes that irrigation by treated or untreated artificial wastewater has increased the heavy metal concentrations of Zn and Mn in soil and plants of receiving area. Cadmium concentration in irrigation water was found to be above the permissible limit as set by world health organization (WHO) for irrigation of agricultural land at Dinapur and Lohta sites. Heavy metal concentrations in plants show significant spatial and temporal variations. Cadmium (Cd), lead (Pb), and nickel (Ni) were above the Indian permissible Limits [16]. Katerji et al. investigated the classification and salt tolerance of six barley varieties in a greenhouse experiment; it was found that varietal salt tolerance clearly affects the water use efficiency and the salt tolerance classification. Variety Melusine was the best for its combination of high yield and salt tolerance. Variety ISABON3, a salt tolerant land race originally from Afghanistan showed a larger grain and straw yield under non-saline and saline conditions [17]. Katerji et al. designed an experiment that deals with leaching requirements for barley growth under saline irrigation.

Hamdy analyzed soil samples for Ece, pH and SAR and they created the required ECw through mixing freshwater with saline by the proper ratio. He separated plots from each other by space with 2 meters between each plot and using drip irrigation. He found that crops response to salinity depends on plants species, soil texture, water holding capacity and composition of salts [18]. Herpin and Gloaguen [19] used secondary treated artificial wastewater over 3 years and 7 months to irrigate coffee (Coffea arabica L). The study revealed that treated artificial wastewater can effectively increase water resources for irrigation, however, innovative and adapted fertilizer/treated artificial wastewater management strategies are needed to diminish sodicity risks and to sustain adequate and balanced nutritional conditions in the soil plant system [19].

The objective of this study was to evaluate the impact of short-term application of synthetic (artificial) wastewater on soil fertility parameters and possible accumulation of metals in the soil-plant system by comparing several cultivars irrigated with both fresh and synthetic wastewater.

2. MATERIALS AND METHODS

A plastic containers (35 x 50 x 15 cm) filled with agricultural soil were used for sowing the plants. All barley varieties were sown in three complete randomized blocks each accession was represented by 15 plants per replicate. The experiment was carried out using seven varieties of barley, S42IL107, BW281, BW284, Scarlett, BW290, Bowman and G400.

Plants were irrigated twice per week by adding nearly 8 litres of water / container / week from sowing until the second leaf was fully expanded, 128 litters of artificial wastewater was used during the period and this amount determined according to the average rainfall in the city and the container space, after that the irrigation with artificial wastewater was started using the same water regimen and quantity.

In this experiment, and based on the definitions of artificial wastewater, artificial wastewater (not domestic simulated wastewater) was used by using animal waste with special characterization (BOD = 400 and salinity of 1% ds/m). BOD was measured for small sample of animal waste by using BOD device, then (NaCl) was added to reach the required salinity. This water with its characterise (BOD and TDS) used to simulate the artificial wastewater in this experiment (Table 1), which defined to be any water with waste (animal waste in our case and not domestic water).

Table 1: Chemical analysis of fresh water, synthetic wastewater and soil used through the experiment.

Parameter	Fresh Water (FW)	Simulated wastewater (WW)	Soil
TDS (mg/l)	384	1492	350
K (ppm)	4.8	88	210
N (%)	0.0072	0.0163	0.46
P (ppm)	0.62	3.30	1.5

The harvesting was done manually in order to be sure that there were no impurities in the harvest and to insure accuracy. After harvesting grains of each sub block were separated and weighted. Chemical analysis has been used for determining the mineral contents of the soil of the experiment for each variety and each type of water for N, P, K and TDS, 170 samples were analyzed during this experiment, 85 samples For freshwater and 85 for artificial wastewater divided as: 63 plant samples (21 root, 21 spike and 21 stem), 21 soil samples and finally the water sample. These tests were performed at An-Najah National University Laboratories. Each test was done in accordance to standard methods of analyses for soil and water [20].

Ms-Excel and SPSS programs were used to manipulate and analyze the data. Model was developed to express the results. Analysis of variance (ANOVA) and mean separation were conducted using procedure of SPSS software, version 15.0. Multiple comparisons among pairs of lines were performed using the Duncan-test.

3. RESULTS AND DISCUSSION

Growth Results

The growth nature and vigour of the different barley cultivars irrigated with both fresh and artificial wastewater were observed during the experiment period are shown in Table (2). Results showed that the growth nature was divided into two types: erect growth and prostrate growth.

Table 2: Growth nature for the barley irrigated with fresh and wastewater.

Line	Growth Vigour Order (1-7)		Growth Nature (erect-prostrate)		Average tiller no.	
	FW	WW	FW	WW	FW	WW
S42IL107	7		Prostrate		3	4
BW281	5		Erect		1	5
BW284	4		Erect		1	5
Scarlett	3		Prostrate		2	5
BW290	6		Prostrate		3	6
Bowman	2		Erect		2	6
G400	1		Erect		1	2

(1) Strong growth, (7) weak growth

The growth results showed that G400 was the strongest in both freshwater (FW) and artificial wastewater (WW) whereas it was the lowest in average tiller number, where S42IL107 showed the weakest growth vigour among the cultivars with an average tiller number of 3 and 4 in fresh water and artificial wastewater respectively.

Table (3) shows the growth parameters of the seven cultivars irrigated with both water types.

Table 3: Growth results for the barley irrigated with fresh and wastewater.

Barley cultivars	Days from sowing to emergence		Days from sowing to stem elongation		Days from sowing to maturity	
	FW	WW	FW	WW	FW	WW
S42IL107	11.00^{a}	10.67^{a}	62.33^{b}	61.00^{b}	153.00^{a}	152.67^{a}
BW281	8.67b^{c}	9.00^{bc}	47.00^{c}	47.00^{c}	152.33^{ab}	151.33^{b}
BW284	10.33^{a}	10.67^{a}	40.33^{d}	39.67^{d}	151.33^{b}	151.00^{b}
Scarlett	9.33^{b}	9.67^{ab}	39.00^{e}	37.67^{e}	150.00^{c}	149.76^{c}
BW290	10.33^{a}	10.33^{a}	71.67^{a}	71.33^{a}	151.33^{b}	152.00^{ab}
Bowman	8.33^{cd}	8.67^{c}	38.67^{e}	38.00^{e}	149.33^{c}	148.76^{cd}
G400	7.67^{d}	8.33^{cd}	36.33^{f}	35.67^{f}	147.67^{d}	147.76^{d}

* Means with the same letter per column are not significantly different ($p \leq 0.05$).

* Days to (emergence, stem elongation, flowering , maturity) are **not significant** relating to the water type at $p \leq 0.05$ %.

It was found that the growth of barley cultivar type (G400) that irrigated with fresh water during the planting period (four month nearly) indicates that this cultivar type was the strongest type in growth among the seven cultivars, it required 8 days to emergence, 36 days for stem elongation, 52 for flowering and 148 days to mature since the planting day, when the same barley type (G400) irrigated with artificial wastewater, it was noticed that the growth was better in terms of yield. However, it required the same time for emergence, stem elongation, flowering and mature as well as fresh water.

The growth of barley cultivar type (S42IL107) that irrigated with fresh water during the planting period (four month nearly) indicate that this cultivar type was the weakest type in growth among the seven cultivars, it required 11 days to emergence, 62 days for stem elongation 70 for flowering and 153 days to mature since the planting day. When the same barley type (S42IL107) irrigated with artificial wastewater, it was noticed that the growth was better in terms of yield. However, it required the same time for emergence as artificial wastewater, 61 days stem elongation, 60 flowering and153 to mature.

The results shows that both cultivars irrigated with freshwater and simulated wastewater had nearly the same time for flowering and mature, it is important to combine yield and growth result to improve that plants irrigated with artificial wastewater had higher yield than that irrigated with fresh water and mature at the same period.

Yield Components

Variations in yield and quality can occur because of variations in genetics, treatment, and other growing conditions. Statistical analysis makes it possible to determine whether a difference among types is real or whether it might have occurred due to other variations in the field. S42IL107 was the best cultivar in the spike/plant when irrigated with freshwater with percent (2.86), while in artificial wastewater, scarlet was the best with (5.3) spike/plant. For both fresh and artificial wastewater, G400 was the worst with (1.13) spike/plant .in freshwater and (1.7) spike/plant in the artificial wastewater.

Among the types, nearly no significant could be observed, S42IL107 had the higher yield (average spike/plant), while BW284, Scarlett, Bowman, BW281, BW290, and finally G400 had nearly the same average with no significant (Means with the same letter are not significantly different). Figure (1) below summarize the results obtained. For the average spike length (cm), high significant could be observed among the type of water, the plants irrigated with artificial wastewater gave higher spikes length than that irrigated with fresh water and that's lead to that there was significant increase in spikes length for the artificial wastewater if compared with freshwater. High significant could be observed among the type of water, the plants irrigated with artificial simulated wastewater gave nearly twice weight of spikes higher than that irrigated with fresh water. That is lead to that there was significant increase in spikes weight for the artificial wastewater if compared with freshwater (See the Figures 2, 3, and 4).

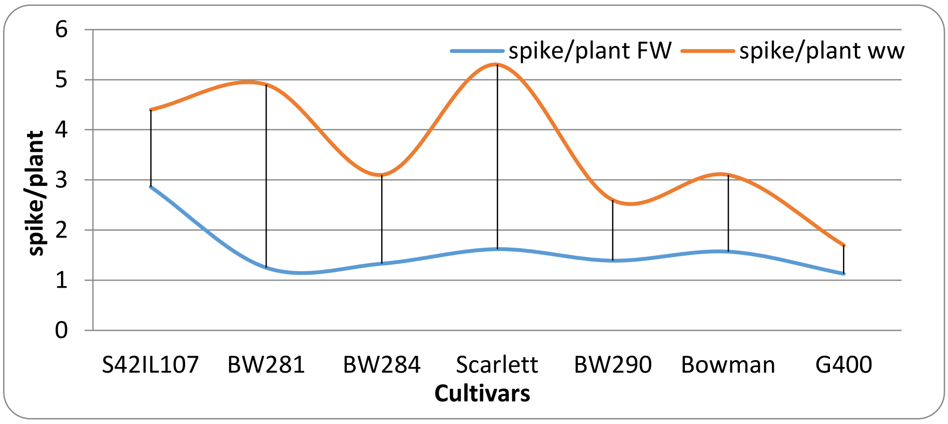

Figure (1) Average spike/plant of barley irrigated with freshwater and artificial wastewater.

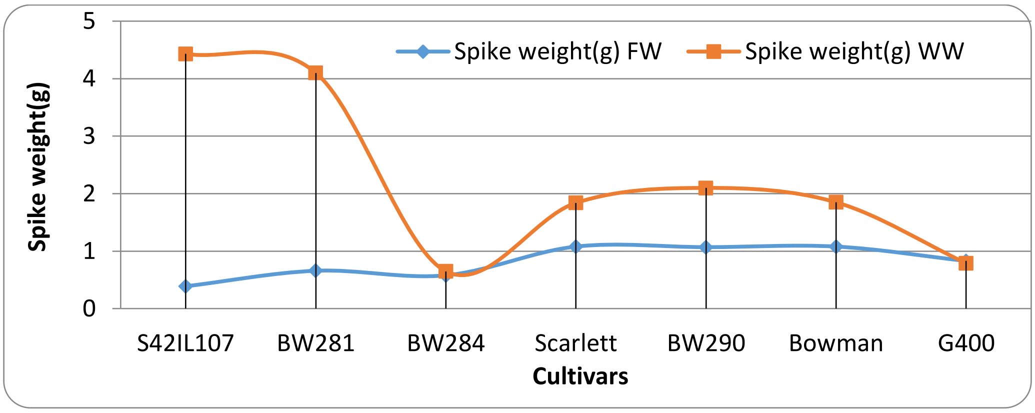

Figure (2) Average spike weight of barley irrigated with freshwater and artificial wastewater

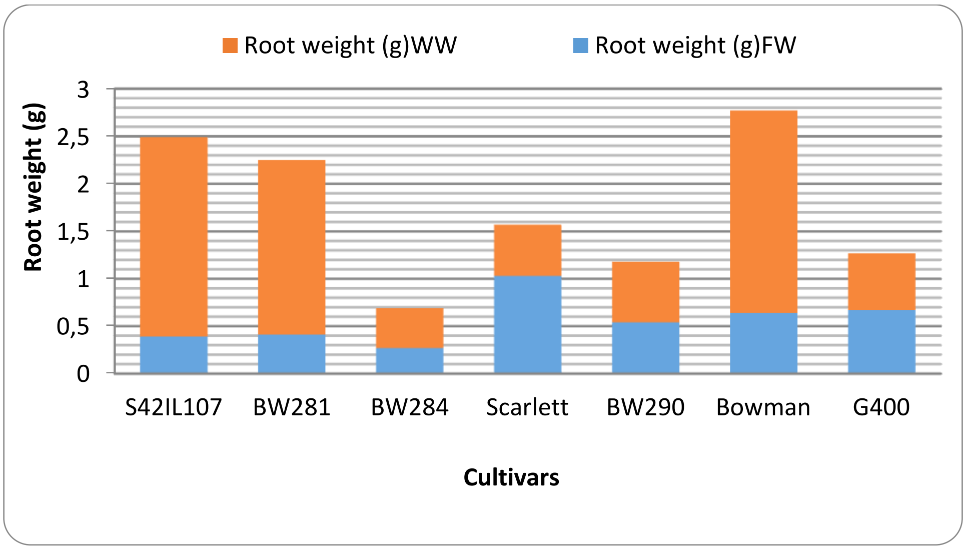

Figure (3) Average root weight (g) of barley irrigated with freshwater and artificial wastewater.

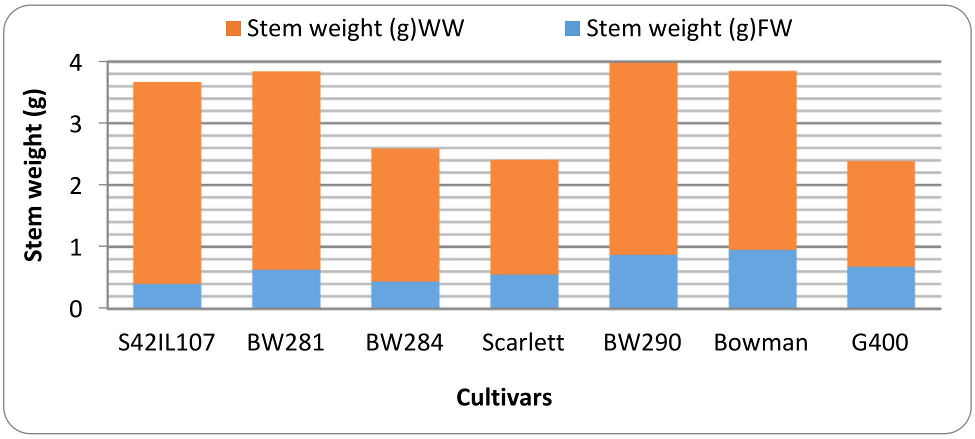

Figure (4) Average stem weight (g) of barley irrigated with freshwater and artificial wastewater.

Barley Uptake of nutrient
1. Nitrogen

Nitrogen comparison between barley cultivars irrigated with fresh water and simulated wastewater after and before irrigation process in Table 4. Nitrogen concentration in plant shoots was reported to be higher when grown with artificial wastewater; and it is found that N recovery in plants with artificial wastewater was higher than the N recovery in plant material grown with fresh water. These results were attributed to significant increase in soil N with artificial wastewater irrigation compared with the control. These results were attributed to significant increase in soil N with artificial wastewater irrigation compared with the control.

On the other hand, Papadopoulos and Stylianou [22] reported that during the third irrigation season for trickle irrigation cotton (Gossypium hirsutum L. cv.), the NO_3-N in petioles was greater with the treated effluent supplemented with no N, also in lamina; NO_3-N was greater at sampling of the lower N level. Our results are in agreement with the result of Papadopoulos and Stylianou [22].

Table (4): Nitrogen data of barley irrigated with freshwater and artificial wastewater

Cultivar line	N%-Soil After		N%-Root		N%-Spike		N%-Stem	
	FW	WW	FW	WW	FW	WW	FW	WW
S42IL107	0.14^{e}	0.17^{c}	0.49^{f}	1.07^{d}	1.37^{f}	1.60^{f}	0.56^{c}	0.63^{f}
BW281	0.13^{f}	0.15^{d}	0.62^{a}	0.93^{e}	1.41^{e}	1.70^{e}	0.65^{b}	0.63^{f}
BW284	0.17^{b}	0.19^{b}	0.45^{g}	0.95^{e}	1.58^{b}	2.10^{b}	0.82^{a}	0.85^{d}
Scarlett	0.14^{d}	0.21^{a}	0.53^{d}	0.70^{f}	1.56^{c}	1.90^{c}	0.54^{e}	0.88^{c}
BW290	0.14^{f}	0.22^{a}	0.60^{b}	1.43^{a}	1.45^{d}	1.80^{d}	0.36^{f}	0.94^{b}
Bowman	0.15^{c}	0.15^{d}	0.51^{e}	1.22^{b}	1.55^{c}	1.80^{c}	0.56^{c}	0.79^{e}
G400	0.21^{a}	0.22^{a}	0.59^{c}	1.12^{c}	1.78^{a}	2.50^{a}	0.55^{d}	0.99^{a}

* Means with the same letter per column are not significantly different ($p \leq 0.05$).

2. Potassium (K)

Plant absorbed the K through the root and the spike and stem and that is related to the fact that the K is slowly move in the soil in addition to that it react with the elements found in the artificial wastewater and thus decreased in the plants. The results showed that (K% – Stem> K%- Root, K% - Spike), the cultivars irrigated with artificial wastewater absorb less K content by the spike than the cultivars irrigated with freshwater. For freshwater, Scarlett cultivar absorbed the higher K content by the spike among the other types with K=72.33 ppm while Bowman absorbed the lower K content with K of (35.93) ppm. For artificial wastewater, Scarlett cultivar absorbed the higher K content by the spike among the other types with K=93.1ppm while G400 absorbed the lower K content with K of (22.4) ppm.

Table (5): Potassium data of barley irrigated with freshwater and artificial simulated wastewater

Cultivar line	K-Soil After (ppm)		K-Root (ppm)		K-Spike (ppm)		K-Stem (ppm)	
	FW	WW	FW	WW	FW	WW	FW	WW
S42IL107	12.77^{g}	83.30^{f}	28.67^{b}	7.50^{d}	64.33^{abc}	39.60^{c}	116.67^{b}	106.70^{b}
BW281	15.17^{f}	173.00^{c}	31.67^{ab}	26.50^{b}	66.00^{ab}	58.40^{b}	136.33^{a}	113.70^{a}
BW284	36.67^{b}	136.70^{d}	16.03^{c}	8.70^{d}	61.00^{bc}	40.20^{c}	104.00^{c}	68.90^{d}
Scarlett	29.13^{c}	103.40^{e}	37.53^{a}	21.40^{c}	72.33^{a}	93.10^{a}	114.00^{b}	50.80^{e}
BW290	44.43^{a}	193.70^{b}	27.33^{b}	36.30^{a}	57.17^{c}	91.40^{a}	105.10^{c}	84.70^{c}
Bowman	20.13^{e}	112.20^{e}	11.77^{c}	8.60^{d}	35.93^{d}	45.50^{c}	95.17^{d}	87.40^{c}
G400	25.83^{d}	234.00^{a}	12.83^{c}	4.30^{e}	42.00^{d}	22.40^{d}	69.30^{e}	20.90^{f}

*Means with the same letter per column are not significantly different ($p \leq 0.05$).

It could be observed from the results that the spike absorbed more K than the others part of the plant that irrigated with the same type of water, also it could be noticed that the plants irrigated with artificial wastewater absorbed less K content than the cultivars irrigated with freshwater.

3. Phosphorous (P)

The soil of the cultivars irrigated with artificial wastewater contain more phosphorous than the soil irrigated with freshwater, the phosphorous absorbed mainly in the spike whish had the higher P% compared with amount absorbed by both the stem and the root ,where the P% of the root was nearly higher than the stem (P% – Spike > P%- Stem, P% - Root) .No significant observed in the soil P before the irrigation, where a significant could be observed among the type of water for the soil P after the irrigation process .

It was also noticed that the plants irrigated with artificial wastewater had higher P than that irrigated with fresh water, there was a significant increase in P content in soil for the concentration artificial wastewater if compared with freshwater.

From the phosphorous (P) data of the soil, it is observed that the phosphorous content of the plants irrigated with artificial wastewater was nearly 2 times more than that irrigated with freshwater. For freshwater, G400 cultivar absorbed the higher phosphorous content by the soil among the other types with P=0.92 ppm while BW290 absorbed the lower phosphorous content with P of (0.19) ppm. For artificial wastewater, G400 absorbed the higher phosphorous content with P of (1.7) ppm, while S42IL107 absorbed the lower amount (0.3) ppm. There is a differences observed among the cultivars types irrigated with fresh water , G400 was absorbed the highest amount of phosphorous content by the soil with (0.92) followed by Scarlett and Bowman that had (0.37)ppm , followed by BW284, and BW281 and finally S42IL107 which had the second lowest amount of phosphorous content.

For the artificial wastewater, S42IL107 was the lowest with (0.3) ppm where G400 was the highest with (1.7) ppm

Table (6): Phosphorous (P) data of barley irrigated with freshwater and artificial wastewater

Cultivar Line	P-Soil After (ppm)		P-Root (ppm)		P-Spike (ppm)		P-Stem (ppm)	
	FW	WW	FW	WW	FW	WW	FW	WW
S42IL107	0.20^{d}	0.30^{f}	0.27^{b}	3.70^{c}	0.47^{c}	5.10^{a}	0.09^{d}	3.50^{b}
BW281	0.23^{d}	0.40^{e}	0.15^{bc}	5.20^{a}	0.26^{d}	4.00^{ab}	0.21^{cd}	4.20^{a}
BW284	0.24^{d}	0.40^{e}	1.35^{a}	4.50^{b}	0.32^{cd}	3.20^{b}	1.30^{a}	4.20^{a}
Scarlett	0.63^{b}	0.80^{c}	1.30^{a}	3.20^{c}	0.45^{c}	4.00^{ab}	0.47^{b}	2.60^{c}
BW290	0.19^{d}	1.30^{b}	0.10^{c}	1.30^{d}	2.66^{a}	4.00^{ab}	0.09^{d}	0.60^{d}
Bowman	0.37^{c}	0.70^{d}	0.28^{b}	0.90^{de}	0.22^{d}	4.60^{a}	0.26^{c}	0.80^{d}
G400	0.92^{a}	1.70^{a}	0.29^{b}	0.74^{e}	1.69^{b}	4.60^{a}	0.33^{c}	0.72^{d}

*Means with the same letter per column are not significantly different ($p \leq 0.05$).

DISCUSSION

Decreasing fresh water in the world has become a critical problem in many countries. Groundwater and surface water sources are the single largest water use in arid and semiarid regions for crop irrigation. One potential irrigation water resource is treated wastewater for agricultural fields located near urban centers. In addition, treated wastewater can contribute an appreciable amount of necessary nutrients for plants. The suitability of reclaimed water for specific applications depends on water quality and usage requirements. The main factors that determine the suitability of recycled water for agricultural irrigation are salinity, heavy metals, and pathogens, which cause adverse effects on human, plants, and soils [21].

The most appropriate wastewater treatment to be applied before effluent use in agriculture is that which will produce an effluent meeting the recommended microbiological and chemical quality guidelines both at low cost and with minimal operational and maintenance requirements [22]. The biomass production of barley as an animal feed measured as fresh weight and dry weight in farm per one meter, compared to crops grown in the control (where artificial wastewater was never applied) biomass production was significantly higher. Both added artificial wastewater and nutrients provided with artificial wastewater application can be attributed to such increase in biomass production.

Similar results were reported by Day et al. [23] who observed that wheat irrigated with simulated wastewater produced taller plants, more heads per unit area, heavier seeds, higher grain yields than did wheat grown with pump water alone. They attributed this increase to the nitrogen and phosphorus in the added simulated wastewater. The results showed that the barley cultivars irrigated with both fresh and artificial wastewater had in general the same growth vigour and growth nature, G400 had the best erect growth vigour while S42IL107 had the weakest prostrate growth, also the branch numbers of cultivars irrigated with artificial wastewater was more than that for freshwater. Plants irrigated with both artificial wastewater and freshwater required the same time to (emergence, stem elongation, flowering and maturity) with no significant observed among the water types, while a significant observed among the barley types.

It is clearly observed that plants irrigated with artificial wastewater gave nearly twice yield higher than that irrigated with fresh water. Although, plants irrigated with both artificial wastewater and fresh water had nearly the same height with slightly different in mean, high significant could be observed among the types. BW281 had the higher plant height. The spikes average weight increased for the plants irrigated with simulated wastewater and also gave higher spikes length than that irrigated with fresh water, and this prove that the simulated wastewater is better in irrigation to obtain higher yield since it contain more useful nutrients that improve the plants growth and give higher yields .Plants irrigated with artificial wastewater had nearly the same root weight while plants irrigated with artificial wastewater gave higher stem weight than that irrigated with fresh water. In the average, the artificial wastewater is alkaline with basic pH value of 7.3 and had a moderate level of total dissolved solids (TDS) of 1490 mg L^{-1}. Simulated wastewater can provide N, P, and K in amount equal to 4, 10 and 8 time of the fertilizers requirement of the forage crops [24] The artificial wastewater contains considerable amount of nitrate, phosphate and potassium, which are considered essential nutrients for improving plant growth and soil fertility and productivity levels. Artificial wastewater irrigation increased significantly the soil N, P, and K. Several researchers reported accumulation of N, P, and K in the soil with artificial wastewater application, which was attributed to the original contents of these nutrients in the artificial wastewater, applied [25]. These results agree with those reported by, who found that extractable phosphorus was higher in soils irrigated with simulated wastewater than in soil irrigated with fresh water or rainfall water.

Plant essential nutrient (total N, P, and K) were higher in plants grown in soils irrigated with artificial wastewater for different cultivars. The soil of the types irrigated with artificial wastewater absorbed more nitrogen than the soil irrigated with freshwater, the increase in N content of artificial wastewater was nearly twice than that of freshwater. On the other hand, the roots, stems and the spikes of the plants irrigated with artificial wastewater absorbed higher nitrogen than that irrigated with fresh water. The enhancement of plant N content with artificial wastewater application indicates that wastewater application provided the soil with these nutrients, which enhanced required for plant growth and soil fertility.

However, nitrate content should be monitored periodically to avoid its accumulation to critical levels that might affect its quality for animal feeds.

The increase in K content of artificial wastewater was nearly 3 times more than that of freshwater which related to the amount of K found in the artificial wastewater. The roots of the plants irrigated with fresh water absorbed higher K content than that irrigated with artificial wastewater; the same results were obtained for the stem and the spike. The plants irrigated with artificial wastewater had higher P content than that irrigated with fresh water. The roots of the plants irrigated with artificial wastewater absorbed higher P content than that irrigated with fresh water; the same results were obtained for the stem and the spike.

Soil and crop quality parameters are significantly affected by artificial wastewater irrigation. The management of artificial wastewater irrigation and its composition mainly determines this. In addition, continuous irrigation with artificial wastewater may lead to accumulation of salts, plant nutrients and heavy metals beyond crop tolerance levels. Therefore, these concerns should be essential components of any management of artificial wastewater irrigation. On the other hand, plant growth, soil fertility and productivity can be enhanced with properly managed artificial wastewater irrigation, through increasing levels of plant nutrients and soil organic matter. It can be concluded, based on these results that proper management of artificial simulated wastewater irrigation and periodic monitoring of soil fertility and quality parameters are required to ensure successful, safe and long-term reuse of artificial wastewater for irrigation.

Conclusion

The following are the research main conclusions:

1- The yields vary relating to the type of water used for irrigation. The highest yield were obtained in the plants irrigated with artificial wastewater, the cultivars irrigated with artificial wastewater gave nearly twice the yield of that irrigated with freshwater. BW290 cultivar showed the best highest yield among the seven types.
2- The use of artificial wastewater in irrigation increases the N, P and K contents in soil profiles. The quality of water used in irrigation affects the soil through increasing the concentrations of some constituents such as N, K and P.
3- Soil irrigated with artificial wastewater contain more N than the soil irrigated with freshwater, the increase in N content of artificial wastewater was nearly twice than that of freshwater and that results in increase of the N content in the plant parts. The N accumulate mainly in the root which had the higher N% compared with amount accumulated by both the stem
and the spike, where the N% of the spike was nearly higher than the stem (N% – Root > N% – Spike, N% – Stem).
4- Plant absorbed the K through the root and the spike and stem and that is related to the fact that the K is slowly move in the soil in addition to that it react with the elements found in the artificial wastewater and thus decreased in the plants (K% – Stem> K% – Root, K% – Spike).
5- The soil of the cultivars irrigated with artificial wastewater contain more P than the soil irrigated with freshwater, the P absorbed mainly in the spike whish had the higher P% compared with amount absorbed by both the stem and the root, where the P% of the root was nearly higher than the stem (P% – Spike > P% – Stem, P% – Root). 2- Build up stations for treating wastewater for facing the water crises especially in arid regions.

Further studies are recommended about the crops that could be irrigated by the artificial wastewater by considering the health and safety aspects for the use of crop production and workers.

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