Impacts of Wastewater Irrigation on Growth, Yield and Salts Uptake of Barley

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Abstract: Treated wastewater is promising water resource as alternative or supplementary source for fresh water to be used in agriculture specially for areas of water shortage and crops with good potential of tolerating saline water. In this study long-term irrigation with fresh and wastewater on growth and yield of seven non-local cultivars (S42IL107, BW284, BW281, G400, Scarlett, Bowman and BW290) of Barley (Hordeum vulgare L.) showed that (1) barley cultivars irrigated with both fresh and wastewater had in general the same growth vigor and growth nature, (2) The cultivars irrigated with wastewater gave nearly twice the yield of that irrigated with freshwater. BW290 cultivar showed the best and highest yield among the seven cultivars while S42IL107 had the weakest prostrate growth, (3) The use of wastewater in irrigation increased the nitrogen (N), Phosphorous (P) and potassium (K) contents in soil profiles affecting its texture, (4) barley proved to be a salt-tolerant crop with considerable economic importance, Barley could tolerate saline water until (5μs) without any shortage in the yield of the crop, and (5) barley irrigated with both wastewater and freshwater needed nearly the same time to emergence, stem elongation, flowering and maturity and consequently, wastewater irrigation of barley is a promising water resource as alternatives for fresh water.

Keywords: Barley, wastewater irrigation, fresh water irrigation, growth, yield, salts uptake.

1. INTRODUCTION

Availability of water and food supplies are vital elements for human life and his developmental activities and sustainability. The availability of renewable water resources to maintain various human needs in Palestine is poor, under conflict, and declining with time in quality and quantity. Therefore, for arid and semi-arid areas such as Palestine, alternative and supplementary water resources options such as the reuse of treated wastewater and brackish water gaining much importance at present and are expected to be obligatory in the near future [1,2].

The discharge of wastewater, untreated or partially treated, into surface water is a potential environmental threat. At the same time, treated and untreated wastewater is increasingly used as a source of water for agriculture. Polices, rules, and regulations of treated effluent reuse developed differently in different countries depending on climate, physical environment, economic progress and institutional strengths. Consequently, countries are facing different problems and impacts on barley and soils.

Wastewater laden irrigation water affects the barley growth and yield [3] and the accumulation of toxic heavy metals are biomagnified at different trophic levels through food chain. The accumulation, however, depends on barley species, type of elements, its bioavailability, redox, pH, cation exchange capacity, dissolved oxygen, temperature and secretion of roots [4-6].

The importance of barley as an integral part of the farming system in the West Bank was apparent. The majority of the farmers grow barley as a feed for their own livestock and only 16% produce it as a cash crop for sale. About 12% of barley growers who owned animals sold part of the total production, or part of the straw, that exceeded their needs [7]. The West Bank considered as the center of origin and genetic diversification of barley. Indications from archaeological remains suggest that the crop was domesticated about 10000 years ago from a two-rowed wild relative *H. vulgare* ssp. *Spontaneum* [7, 8]. Most of the cultivated barley in the region is landraces, which have evolved directly from the wild progenitor [9]. Landraces, which have been developed over many generations by farmers' selection for desirable traits, tend to be genetically heterogeneous and well adapted to their specific agro-ecological environment [10].

It was noted that irrigation water and soil salinity are important environmental factors that has serious effect on the yield, growth, and uptake of salts by plants [11,12].

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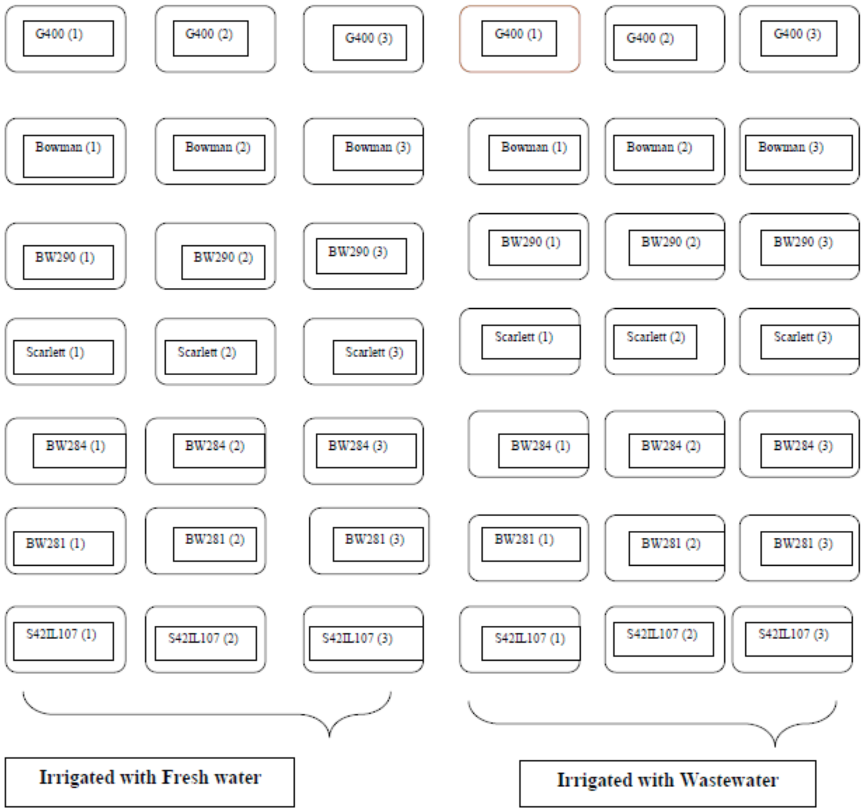

Figure 1: Arrangement of Barley containers irrigated with fresh water and wastewater.

The aim of the present work was to study and assess the effects of long-term irrigation with fresh and wastewater on soil and barley growth, yield, and salt uptake.

2. MATERIALS AND METHODS

2.1. Experimental Set-up and Programe

Field experiment was conducted at the experimental station of the Water and Environmental Studies Institute (WESI), An-Najah National University, Nablus, during the 2014/2015 growing season in plastic containers (35 x 50 x 15 cm) filled with agricultural soil. All varieties were sown at the 13th of January 2014 in three complete randomized blocks (see Figure **1** and **2**). Each accession was represented by 15 barley seeds per replicate (15 seeds for every container at the beginning of the experiment).

2.2. Irrigation Procedure

Barley were irrigated twice per week by adding nearly 8 liters of water / container / week from sowing until the second leaf was fully expanded. After that the irrigation with wastewater was started using the same water regimen and quantity.

2.3. Water and Soil Quality

Chemical analysis of fresh water indicated good quality water withy low dissolved solids and no organic content while wastewater was with average local organic and solids content. Soil analysis indicated good quality soil with normal dissolved solids content and minor organic content (see Table **1**).

2.4. Barley Material

The experiment was carried out using seven introduced varieties of barley brought from the seed

Figure 2: Field setup of barley cultivars planting containers.

Table 1: Chemical Analysis of Fresh Water, Wastewater and Soil Used through the Experiment

Parameter	FreshWater	Wastewater	Soil
BOD, (mg/l)	0	400	5*
TDS (μs)	384	1492	350
pH	7.43	7.04	7.25
K (ppm)	10	88	210
N (%)	0.0072	0.0163	0.46
P (ppm)	0.62	3.30	1.5

* = gm organic matter/kg soil.

bank of Max Blanck Institute in Cologne, Germany, these were: G400 (cultivar No. 7), Bowman (cultivar No. 6), BW290 (cultivar No. 5), Scarlett (cultivar No. 4), BW284 (cultivar No. 3), BW281 (cultivar No. 2), S42IL107 (cultivar No. 1).

2.5. Measurements and Laboratory Analysis

The following section includes physical and chemical experimental measurements conducted either in the field or in the laboratory.

2.5.1. Potassium (K)

Dry ashing method was used at an ignition temperature of 550 - 600 °C followed by extraction in diluted HCl. The K content was obtained using the flame photometer (Model 410). Wasterman (1990).

2.5.2. Phosphorous (P)

Dry-ashing method was used to determine P content by burning the sample (soil or barley) in an oven for nearly 9 hours at an ignition temperature of 550-600°C then the ash was dissolved in distillated water. After that the samples were filtrated and titrated. Phosphorus content was measured using the spectra photometer (Model 21D) Wasterman (1990).

2.5.3. Nitrogen (N)

Nitrogen was analyzed by using nitrogen analyzer system (Kjeldal system). The samples were digested in concentrated H_2SO_4 with a catalyst mixture to raise the boiling temperature and to promote the conversion from Organic-N to NH_4-N. The NH_4-N from the digest is obtained by steam distillation, using excess NaOH to raise the pH. The distillate is collected in saturated H_3BO_3, and then titrated with dilute (0.04 N) H_2SO_4 to pH 5.0 to determines the nitrogen content. Wasterman (1990).

2.5.4. Determination of Dissolved Solids

Salinity is measured using a conductivity bridge. The salt content estimated by immersing the conductivity cell in the solution and taking the reading. For salt content of soil, the samples were filtrated and titrated then the conductivity meter used to determine the soil salinity Wasterman (1990).

2.5.5. Measurements of Vegetative Growth and Yield

During the growing season and before maturity, the following data were measured and recorded:

1. Days to emergence (the number of days from sowing until 90% of barley emerged).
2. Growth vigor (in a scale of 1-7, where 1 is weak growth and 7 is strong).
3. Growth nature (erect-prostrate).
4. Days to stem elongation (the number of days from barley emergence until the start of stem elongation).
5. Days to heading (the number of days from barley emergence until 90% of the barley per variety gave flowering).
6. Days to maturity (the number of days from barley emergence until maturity.
7. Tiller number (the actual count of the fertile numbers of tillers (spike bearing) per barley).
8. Spike length (distance from the base of the spike to the tip of the highest spikelet (excluding own) in cm).
9. Barley height (the distance between the ground level to the tip of the terminal spikelet in cm of the mother barley).
10. Total grain yield.
11. Vegetative biomass.

At the end of experiment fresh barley samples from all barley parts and from every cultivar and treatment were taken, oven-dried at 70°C for 48 hours, weighed, and stored for chemical analysis.

3. RESULTS AND DISCUSSION

3.1. Growth Results

Growth results listed in Table **2** shows that the growth nature was divided into two types: erect growth and prostrate growth. The growth nature and growth vigor were not affected by the irrigation water type. Barley cultivars S42IL107, Scarlett and BW290 have prostrate growth while BW281, BW284, Bowman and G400 have an erect growth. Significant differences were also observed between cultivars in growth vigor and tillering. Average tiller number was significantly affected by water type (from 1-3 to 2-6 for fresh water and wastewater respectively). The growth results showed that G400 was the strongest in both freshwater and wastewater whereas it was the lowest in average tiller number (see Table **2**).

3.1.1. Days to Emergence

Results showed that there was no significant effect of water type on days to emergence whereas there was

Table 2: Growth Nature for the Barley Irrigated with Fresh Water

Line	Growth Vigor Order (1-7)		Growth Nature (erect-prostrate)		Average tiller no.	
	FW	WW	FW	WW	FW	WW
S42IL107	7 "weak"		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"strong"		erect		1	2

significant difference between cultivars in days to emergence. Days to emergence ranged from 8 days (G400) and 11 days (S42IL107).

3.1.2. Days to Stem Elongation

Days to stem elongation were not significantly affected by water type whereas significant differences were reported between cultivars within treatments and it ranged between 36 days for G400 to 71.5 days for BW290.

3.1.3. Days to Flowering

Results showed that cultivars irrigated with wastewater or freshwater required nearly the same number of days to flowering. BW284 as well as G400 were the first genotypes in flowering (51 days after sowing). G400 and BW284 are reported to carry the non-functional allele *elf3* and *hvlux1* respectively. Both alleles are responsible for early flowering in barley [13]. Bowman showed significantly longer days to flowering (70 days from sowing). Bowman is known to carry Ppd-H1 allele responsible for late flowering in barley [14]. BW281 showed significant lower days to flowering from Bowman which is due to the fact that it carries the mutant allele of Ppd-H1 [14].

Growth results of barley irrigated with fresh *water* and wastewater are listed in Table **3** and discussed in more detail in the following sections.

3.1.4. Days to Maturity

Barley cultivars irrigated with both freshwater and wastewater had the same days to maturity. G400 was the first type mature within 148 days since the planting in both fresh and wastewater, followed by Bowman. While S42IL107 was the last type mature within 153

Table 3: Growth Results of Barley Irrigated with Fresh Water and Wastewater

Barley lines	Days to Emergence		Days to Stem Elongation		Days to Flowering		Days to Maturity	
	F.W	WW	F.W	WW	F.W	WW	F.W	WW
S42IL107	11.00 ^{a}	10.67 ^{a}	62.33 ^{b}	61.00 ^{b}	70.33 ^{b}	69.33 ^{b}	153.00 ^{a}	152.67 ^{a}
BW281	8.67 ^{bc}	9.00 ^{bc}	47.00 ^{c}	47.00 ^{c}	61.33 ^{c}	61.00 ^{c}	152.33 ^{ab}	151.33 ^{b}
BW284	10.33 ^{a}	10.67^{a}	40.33^{d}	39.67 ^{d}	51.33 ^{e}	50.67 ^{e}	151.33^{b}	151.00 ^{b}
Scarlett	9.33 ^{b}	9.67 ^{ab}	39.00 ^{e}	37.67 ^{e}	53.67 ^{d}	53.67 ^{d}	150.00 ^{c}	149.76 ^{c}
BW290	10.33 ^{a}	10.33 ^{a}	71.67 ^{a}	71.33 ^{a}	75.67 ^{a}	75.67 ^{a}	151.33^{b}	152.00 ^{ab}
Bowman	8.33 ^{cd}	8.67 ^{c}	38.67 ^{e}	38.00 ^{e}	70.33 ^{b}	69.67 ^{b}	149.33^{c}	148.76 ^{cd}
G400	7.67 ^{d}	8.33^{cd}	36.33^{f}	35.67 ^{f}	51.33 ^{e}	51.33 ^{e}	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 ≤ 0.05 %.

Table 4: Yield Results of Barley Irrigated with Fresh Water and Wastewater

Barley lines	spike/barley		Spike weight, g		spike length, cm		Barley yield (g)		barley height, cm		Root weight (g)		Stem weight (g)	
	F.W	WW	F.W	WW	F.W	WW	F.W	WW	F.W	WW	F.W	WW	F.W	WW
S42IL107	2.86^{a}	62^{a}	0.39^{b}	63^{a}	7.53^{d}	16.50^{a}	1.13^{d}	9.90^{a}	32.87 a	39.53^{a}	0.39^{cd}	2.10^{a}	0.40^{c}	3.27^{a}
BW281	1.23^{b}	114^{a}	0.66^{ab}	4.10^{ab}	6.33^{e}	12.50^{d}	1.56^{bcd}	9.43^{a}	35.70^{a}	39.10^{a}	0.41^{cd}	1.84^{a}	0.63^{abc}	3.21^{a}
BW284	1.36^{b}	3.09^{ab}	0.58^{ab}	0.65^{c}	12.17^{b}	11.33^{e}	1.26^{cd}	3.62^{b}	27.10^{b}	280^{cd}	0.27^{d}	0.42^{b}	0.44^{c}	2.15^{abc}
Scarlett	1.60^{b}	5.28^{a}	1.08^{a}	1.84^{bc}	10.80^{c}	13.30^{cd}	2.54^{ab}	54^{b}	35.63^{a}	25.50^{c}	1.03^{a}	0.54^{b}	0.55^{bc}	1.86^{bc}
BW290	1.40^{b}	2.59^{ab}	1.07^{a}	2.10^{bc}	12.20^{b}	12.90^{d}	2.51^{ab}	5.66^{b}	33.50^{a}	23.53^{d}	0.54^{bc}	0.64^{b}	0.87^{ab}	3.11^{a}
Bowman	1.57^{b}	3.07^{ab}	1.08^{a}	1.85^{bc}	11.30^{c}	150^{bc}	2.82^{a}	6.51^{ab}	35.63^{a}	38.93^{a}	0.64^{b}	2.13^{a}	0.95^{a}	2.90^{ab}
G400	1.13^{b}	1.66^{b}	0.83^{ab}	0.79^{c}	153^{a}	15.20^{b}	2.18^{abc}	3.02^{b}	37.23^{a}	29.80^{b}	0.67^{b}	0.60^{b}	0.68^{abc}	1.71^{c}

- Means with the same letter per column are not significantly different ($p \leq 0.05$).
- Spike/barley, Spike weight (g) , Spike length (cm) , Barley yield (g) , barley height (cm) Root weight (g) and Stem weight (g): **Significant** at p ≤ 0.05 % relating to the water type.
- Spike/barley, Spike weight (g) , Spike length (cm) , Barley yield (g) , barley height (cm) Root weight (g) and Stem weight (g) **Significant** at p ≤ 0.05 %. relating to the cultivar type at p=0.05%.

days for freshwater and wastewater. Days to maturity was close for the seven cultivars, which mean that if farmers start planting some weak cultivars earlier they could harvest the barley in the same time with the cultivars that mature earlier.

3.2. Yield Results

Yield Results are listed in Tables **4** and **5** and discussed in the following sections.

3.2.1. Average Spike/Barley

Barley irrigated with wastewater gave nearly twice yield higher than that irrigated with fresh water. Table 5 represents the total average spike numbers and the number of the seeds for every cultivar. During the experiment and according to many factors, some seeds were not grown in the container and that explained the differences between the various barley cultivars.

From data listed in Table **5**, it was noticed that Scarlet cultivar had a full grown seeds (15 out of 15), followed by G400, Bowman, BW290 and finally BW281 that had 14 seeds out of 15 when irrigated with fresh water. For BW284 irrigated with fresh water, it had 10 seeds out of 15, and this seed loss could be explained by the uncontrollable damage that was noticed in the container during the experimental period. For wastewater, Bowman had complete number of seeds (15 out of 15), where S42IL107 had (14 seeds out of 15), followed by BW281 and scarlet that lose 2 seeds with total (13 out of 15), while BW284, BW290, and G400 had 12 seeds out of 15.

It was observed that the spike number of the cultivars that irrigated with wastewater was nearly twice the number of that irrigated with fresh water, taking in consideration that there’s a relation between the seeds number and the spikes grown: as the seeds number is higher, the spikes obtained was with higher numbers too. The results showed that there was adverse correlation between the increasing salinity concentration of the irrigated water and grain yield, straw yield, and height of barley.

3.2.2. Average Spike Weight

Barley irrigated with wastewater gave nearly twice weight of spikes higher than that irrigated with fresh water (See Table **4**). It could be observed that Bowman and Scarlett had the same spike weight (1.08) gm when irrigated with freshwater, followed by BW290. While in wastewater, S42IL107 was the best in spike weight with (6) gm followed by BW281 (4.1) gm.

3.2.3. Average Spike Length

Barley irrigated with 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 concentration wastewater if compared with freshwater. See Table **4**.

It could be observed that G400 and had the taller spike length (153) cm when irrigated with freshwater, followed by BW290 and BW284 that had nearly the same length of (12 cm). While in wastewater, S42IL107 was the best in spike length with (16.5) cm followed by Bowman (15) cm.

There is a differences observed among the cultivars types irrigated with fresh water, BW281 was the shortest spike length with (6.33) cm and G400 had the best spike height followed by BW290, BW284, Bowman with (11.30) cm average height, and finally Scarlett and S42IL107 whish was the second worst type after BW281 with (7.53) cm. For the wastewater, S42IL107 was the best with (16.5) cm followed by G400 (15.2) cm, while Bowman was better than BW284, BW290 and scarlet, BW284 showed the worst results with (11.3) cm spike height.

Table 5: Average Spike/Barley of Barley Irrigated with Freshwater

Line	Seeds number out of 15		Total Spike number		spike/barley	
	FW	WW	FW	WW	FW	WW
S42IL107	11	14	30	65	2.86	6
BW281	14	13	18	66	1.25	11
BW284	10	12	14	39	1.33	3.1
Scarlett	15	13	24	69	1.62	5.3
BW290	14	12	20	35	1.39	2.6
Bowman	14	15	22	46	1.57	3.1
G400	14	12	16	21	1.13	1.7

Table 6: Average Soil pH of Barley Irrigated with Freshwater and Wastewater

Barley lines	Soil pH before		Soil pH after	
	F.W	WW	F.W	WW
S42IL107	7.5[a]		7.64[b]	7.62[a]
BW281	7.5[a]		7.73 [a]	7.44[b]
BW284	7.5[a]		7.59[bc]	7.51[ab]
Scarlett	7.5[a]		7.52[c]	6.63[e]
BW290	7.5[a]		7.13[f]	7.10[c]
Bowman	7.5[a]		7.23[e]	6.72[ed]
G400	7.5[a]		7.42[d]	6.76[d]

- Means with the same letter are not significantly different.
- *Soil H before is not significant at p ≤ 0.05 % for both fresh and wastewater.
- *Soil PH after is significant at p ≤ 0.05 % relating to the cultivar type and the water type at p=0.05%.

3.2.4. Average Barley Weight

Barley irrigated with wastewater gave higher yield than that irrigated with fresh water and that's all lead to that there was significant increase in barley yield for the concentration wastewater if compared with freshwater (See Table **4**). Bowman had the higher yield (2.82) gm when irrigated with freshwater, followed by BW290 and scarlet that had nearly the same yield of (2.5 gm). While in wastewater, S42IL107 was the best in yield with (9.9) gm followed by BW281 (9.4) gm.

3.2.5. Average Barley Height

The average barley height listed in Table **4** shows there was a significant increase in barley height for the wastewater irrigated barley if compared with that of freshwater. G400 had the higher height (37.23) cm when irrigated with freshwater followed by BW281, then Bowman and scarlet that had nearly the same height of (35.63 cm). While in wastewater, S42IL107 was the best in height with (39.5) cm followed by BW281 (39.1) cm.

3.2.6. Average Root Weight

Average root weight listed in Table **4** showed that barley irrigated with both wastewater and fresh water had nearly the same root weight with slightly difference in means. Scarlet had the higher root weight (1.03) gm when irrigated with freshwater followed by G400 then Bowman and BW290. While in wastewater, S42IL107 was the best in root weight with (2.1) gm as well as Bowman, then followed by BW281 (1.8) gm.

3.2.7. Average Stem Weight

It was noticed that the barley irrigated with wastewater gave higher stem weight than that irrigated with fresh water. Bowman had the higher stem weight (0.95) gm when irrigated with freshwater, followed by BW290, then G400 and BW281 that had (0.63 gm). While in wastewater, S42IL107 was the best in stem weight with (3.3) gm followed by BW281 (3.2) gm.

3.3. Barley Uptake of Salts

3.3.1. pH Content

Table **6** represents the average soil pH of barley cultivars irrigated with freshwater and wastewater. There's a significant difference among barley cultivars after the soil was irrigated either with fresh water or wastewater. Soil acidity was mostly higher than that before irrigation (see Table **6**).

3.3.2. Total Disolved Solids (TDS)

Soil salinity increased by nearly 3 times according to the type of water (see Table **7**). This increase is probably due to that wastewater had a salinity of TDS=1492 µs which is four times the salinity of the fresh water 384 µs (see Table **7**).

For the barley cultivars that irrigated with freshwater, a slightly increase in the salinity comes from the freshwater (384 µs), Bowman had the highest soil salinity (458 µs) and BW281 had the least soil salinity of (760.5) µs whish indicate that this cultivar is good tolerance to the salinity of the soil and could absorbed higher amount of salinity.

3.3.3. Salinity in Root

The salinity of the root listed in Table **7** showed that barley irrigated with wastewater absorbed higher salinity than (three times more) that irrigated with fresh water. For freshwater, S42IL107 cultivar absorbed the

Table 7: TDS of Barley Irrigated with Freshwater and Wastewater

Line	TDS-Soil Before (µs)	TDS-Water (µs)		TDS-Soil After (µs)		TDS-Root (µs)		TDS-Spike (µs)		TDS-Stem (µs)	
		F.W	WW	F.W	WW	F.W	WW	F.W	WW	F.W	WW
S42IL107	350.00^{a}	384.00^{a}	1492.00^{a}	228.33^{f}	11490^{b}	119.67^{a}	190.30^{e}	1653^{d}	391.00^{c}	113.00^{cd}	209.00^{d}
BW281	350.00^{a}	384.00^{a}	1492.00^{a}	3053^{d}	760.50^{e}	115.00^{a}	428.30^{a}	240.33^{bc}	556.70^{a}	198.33^{a}	240.00^{c}
BW284	350.00^{a}	384.00^{a}	1492.00^{a}	396.67^{b}	1212.30^{a}	1153^{a}	207.70^{e}	183.00^{d}	4050^{c}	98.33^{e}	210.70^{d}
Scarlett	350.00^{a}	384.00^{a}	1492.00^{a}	393.67^{b}	1165.70^{b}	107.33^{a}	248.30^{d}	120.67^{e}	281.30^{d}	97.67^{e}	267.00^{b}
BW290	350.00^{a}	384.00^{a}	1492.00^{a}	332.33^{c}	906.00^{d}	95.96^{a}	343.30^{b}	322.85^{a}	4490^{b}	103.69^{de}	317.70^{a}
Bowman	350.00^{a}	384.00^{a}	1492.00^{a}	458.00^{a}	1015.70^{c}	111.84^{a}	403.70^{a}	228.08^{c}	393.30^{c}	119.09^{c}	212.00^{d}
G400	350.00^{a}	384.00^{a}	1492.00^{a}	269.33^{e}	10350^{c}	106.67^{a}	313.30^{c}	263.95^{b}	441.00^{b}	137.63^{b}	212.00^{d}

- Means with the same letter are not significantly different.
- All the above variables were significant except the soil TDS before relating to the water type at $p \leq 0.05$ %.
- All the above variables were significant except soil TDS before, water TDS, root TDS irrigated with freshwater relating to the cultivars type at $p \leq 0.05$ %.

highest salinity by the root with TDS=119.67 µs while BW290 absorbed the lowest salinity with TDS of 95.96 µs. For wastewater, S42IL107 cultivar absorbed the lowest salinity by the root with TDS=190.3 µs while BW281 absorbed the highest salinity with TDS of (428.3) µs.

3.3.4. Salinity in Spike

Spikes of barley irrigated with wastewater absorbed higher salinity than that irrigated with fresh water (see Table **7**). It was observed that the spike salinity of barley irrigated with wastewater was three times more than that irrigated with freshwater. For freshwater, BW290 cultivar absorbed the highest salinity by the spike with TDS=322.85 µs while Scarlet absorbed the lowest salinity with TDS of 120.67 µs. For wastewater, Scarlett cultivar absorbed the lowest salinity by the spike with TDS=281.3 µs, while BW281 absorbed the highest salinity with TDS of (556.7) µs. There is a differences observed among the barley cultivars types irrigated with fresh water, BW290 absorbed the highest amount of salinity by the spikes with TDS of 322.85 µs followed by G400 BW281 and Bowman with TDS of 228.08 µs. For the wastewater, BW281 was the best with TDS of 556.7 µs while Scarlett showed the worst results with TDS of 281.3 µs.

3.3.5. Salinity in Stem

Results indicated that stems of the barley irrigated with wastewater absorbed higher salinity (three time more) than that irrigated with fresh water (see Table **8**). For freshwater, BW281 cultivar absorbed the highest salinity by the stem with TDS=198.33 µs while Scarlett absorbed the lowest salinity with TDS of 97.67 µs. For wastewater, S42IL107 cultivar absorbed the lowest salinity by the stem with TDS=209 µs, while BW290 absorbed the highest salinity with TDS of (317.7) µs. For fresh water, BW281 absorbed the highest amount of salinity by the stem with TDS of 198.33 µs followed by G400 Bowman and S42IL107 that had (113) µs , and BW284 and Scarlett were the worst with TDS of 98.33 µs.

3.3.6. Analysis

By comparing the salinity of the stem with the root and spike salinity, it could be observed that the spike absorbed more (two times) salinity than root and stem (see Table **7**). Similar studies were carried on barley cultivars showed nearly the same results. Alshammary et. al., 2004 [15] conducted an experiment using four barley cultivars which were Qatifi, Gusto, Alkharji, Haili, and using five different concentrations of water salinity ranging from 2.85 ds/m up to 15.95 ds/m. Results of this experiment showed that there was adverse correlation between the increasing salinity of the irrigated water and decreasing production of grain yield, straw yield and height of barley. The tolerance of the barley cultivars used in this experiment to salinity differs from one cultivar to another [16]. It was indicated that poor management of saline water may increase soil salinity to a level higher than crop tolerance, so soil washing with excess fresh good quality water is required [17,18].

As a result, irrigation water salinity negatively affects barley growth and production. Because each barley cultivar absorbs different amount of salts, it is important to select barley cultivars which are more tolerant to and/or absorb more salinity. Based on the

Table 8: Nitrogen Data of Barley Irrigated with Freshwater and Wastewater

Line	N-soil before %	N-water %		N-Soil After %		N-Root %		N-Spike %		N-Stem %	
		F.W	WW	F.W	WW	F.W	WW	F.W	WW	F.W	WW
S42IL107	0.46^{a}	0.0072^{a}	0.0163^{a}	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	0.46^{a}	0.0072^{a}	0.0163^{a}	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	0.46^{a}	0.0072^{a}	0.0163^{a}	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	0.46^{a}	0.0072^{a}	0.0163^{a}	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	0.46^{a}	0.0072^{a}	0.0163^{a}	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	0.46^{a}	0.0072^{a}	0.0163^{a}	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	0.46^{a}	0.0072^{a}	0.0163^{a}	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 are not significantly different.
- All the above variables were significant except the soil N% before and the spike N% relating to the water type at $p \leq 0.05$ %.
- All the above variables were significant except the (soil N% before, water N%) relating to the cultivars type at $p \leq 0.05$ %.

results obtained, it was found that that the yield of the barley depends mainly on two variables; the type of water used for irrigation and the type of the cultivar [19].

3.4. Nitrogen Content

Results showed that the wastewater contain (0.0163- N %) twice the nitrogen content of freshwater 0.0072 - N%. It was observed that the soil nitrogen content has decreased for both the cultivars irrigated with fresh and (see Table **8**). Nitrogen content of barley cultivars irrigated with wastewater was nearly twice than that irrigated with freshwater. For freshwater, G400 cultivar absorbed the highest nitrogen content by the soil among the other types with N%=0.21 while BW281 absorbed the lowest nitrogen content with N% of (0.13). For wastewater, nearly all the barley cultivars absorbed the same amount of nitrogen from the soil, with N% =0.2, while BW281 absorbed the lower nitrogen content with %N of (0.1).

3.4.1. Nitrogen (N %) in Root

Results showed that the cultivars irrigated with wastewater absorb more nitrogen content by the root than the cultivars irrigated with freshwater (see Table **8**). For freshwater, BW281 cultivar absorbed the highest nitrogen content by the root with N%=0.62 while BW284 absorbed the lowest nitrogen content with N% of (0.45). For wastewater, BW290 cultivar absorbed the highest nitrogen content by the root with N%=1.4 while Scarlett absorbed the lowest nitrogen content with N% of (0.7).

3.4.2. Nitrogen (N%) in Spike

For freshwater, G400 cultivar absorbed the highest nitrogen content by the spike with N%=1.78 while S42IL107absorbed the lowest nitrogen content with N% of (1.37). For wastewater, G400 cultivar absorbed the highest nitrogen content by the spike with N%=2.5 while S42IL107 absorbed the lowest nitrogen content with N% of (1.6).

3.4.3. Nitrogen (N%) in Stem

Barley cultivars irrigated with wastewater absorb more nitrogen content by the stem than the cultivars irrigated with freshwater (see Table **8**). For freshwater, BW284 cultivar absorbed the highest nitrogen content by the stem with N%=0.82 while BW290 absorbed the lowest nitrogen content with N% of (0.36). For wastewater, G400 cultivar absorbed the highest nitrogen content by the stem with N%=1 while BW281 and S42IL107 absorbed the lowest nitrogen content with N% of (0.6).

3.5. Potassium (K) Content

Potassium (K) content in barley irrigated with fresh water and wastewater after and before the irrigation process are listed in Table **9**. It could be observed that cultivars irrigated with wastewater absorbed less amounts of the potassium in the root, than spike and stem (highest absorbed). For freshwater, BW290 cultivar absorbed the highest potassium in the soil with K=463 ppm while S42IL107 absorbed the lowest with K of (12.77) ppm. For wastewater, G400 absorbed the highest potassium with K of (234) ppm, while S42IL107 absorbed the lowest amount with K (83.3) ppm.

Table 9: Potassium (K) Data of Barley Irrigated with Freshwater and Wastewater

Line	K-soil before %	K-water %		K-Soil After %		K-Root %		K-Spike %		K-Stem %	
		FW	WW	FW	WW	FW	WW	FW	WW	FW	WW
S42IL107	210.00^{a}	100^{a}	88.0^{a}	12.77^{g}	83.30^{f}	28.67^{b}	7.50^{d}	653^{abc}	39.60^{c}	116.67^{b}	106.70^{b}
BW281	210.00^{a}	100^{a}	88.0^{a}	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	210.00^{a}	100^{a}	88.0^{a}	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	210.00^{a}	100^{a}	88.0^{a}	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	210.00^{a}	100^{a}	88.0^{a}	463^{a}	193.70^{b}	27.33^{b}	36.30^{a}	57.17^{c}	91.40^{a}	105.10^{c}	890^{c}
Bowman	210.00^{a}	100^{a}	88.0^{a}	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	210.00^{a}	100^{a}	88.0^{a}	25.83^{d}	234.00^{a}	12.83^{c}	50^{e}	42.00^{d}	22.40^{d}	69.30^{e}	20.90^{f}

- Means with the same letter are not significantly different.
- All the above variables were significant except K-soil before relating to the water type at $p \leq 0.05$ %.
- All the above variables were significant except the (K soil before) and the (K water) relating to the cultivars type at $p \leq 0.05$ %.

Soil before planting contained (210) ppm potassium and after planting, the potassium content in the soil decreased for both the cultivars irrigated with fresh and wastewater. So soil irrigated with wastewater absorbed more potassium than that with freshwater. The increase in potassium content of wastewater was nearly 3 times more than that of freshwater. This could be related to the amount of potassium found in the wastewater: the applied wastewater contained (88) ppm potassium while fresh water contained (10) ppm.

3.5.1. Potassium (K) in Root

It was also noticed that the roots of barley irrigated with fresh water absorbed higher K content than that irrigated with wastewater (see Table **9**). From Table **9**), results showed that the barley cultivars irrigated with wastewater absorb less potassium content by the root than the cultivars irrigated with freshwater. For freshwater, Scarlett cultivar absorbed the highest potassium by the root with K=37.53ppm while Bowman absorbed the lowest with K of (11.77) ppm. For wastewater, BW290 cultivar absorbed the highest potassium content by the root with K=36.3 while G400 absorbed the lowest with K of (5) ppm.

3.5.2. Potassium (K) in Spike

Results showed that the barley cultivars irrigated with wastewater absorb less potassium content by the spike than the cultivars irrigated with freshwater (see Table **9**). For freshwater, Scarlett cultivar absorbed the higher potassium content by the spike among the other types with K=72.33 ppm while Bowman absorbed the lower potassium content with K of (35.93) ppm. For wastewater, Scarlett cultivar absorbed the higher potassium content by the spike among the other types with K=93.1ppm while G400 absorbed the lower potassium content with K of (22.4)ppm. It could be observed from the results that the spike absorbed more potassium than the others part of the barley that irrigated with the same type of water, also it could be noted that the barley irrigated with wastewater absorbed less potassium content than the cultivars irrigated with freshwater.

3.5.3. Potassium (K) in Stem

From Table **9**, it was also observed that the stems of the barley irrigated with freshwater absorbed higher potassium than that irrigated with wastewater. For freshwater, BW281 cultivar absorbed the highest potassium by the stem with K=136.33 ppm while G400 absorbed the lowest potassium with K of (69.3) ppm. For wastewater, BW281 cultivar absorbed the highest potassium by the stem with K=113.7 ppm while G400 absorbed the lowest with K of (20.9) ppm.

3.6. Phosphorous (P) Content

Barley irrigated with wastewater had higher P than that irrigated with fresh water, there was a significant increase in P content in soil for the concentration wastewater if compared with freshwater (see Table **10**). From the phosphorous (P) data of the soil, its observed that the phosphorous content of the barely cultivars irrigated with 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 wastewater, G400 absorbed the higher phosphorous content with P of (1.7) ppm, while S42IL107 absorbed the lower amount (0.3) ppm. This difference could be attributed to the amount of phosphorous found initially in the wastewater (3.3 ppm) compared to that of fresh water (0.62 ppm).

3.6.1. Phosphorous (P) in Root

Barley irrigated with wastewater absorbed higher P content than that irrigated with fresh water. For freshwater, BW284 cultivar absorbed the highest phosphorous by the root P=1.35 ppm while BW290 absorbed the lowest phosphorous of 0.1 ppm. For wastewater, BW281 cultivar absorbed the highest with P=5.2 ppm while G400 absorbed the lowest with P of 0.74 ppm.

3.6.2. Phosphorous (P) in Spike

Spikes of barley irrigated with wastewater absorbed higher P than that irrigated with freshwater (see Table 10). For freshwater, BW290 cultivar absorbed the highest phosphorous in spike with P=2.66 ppm while Bowman absorbed the lowest phosphorous with P of 0.22 ppm. For wastewater, S42IL107 cultivar absorbed the highest phosphorous content by the spike with P=5.1 ppm while BW284 absorbed the lowest phosphorous content with P of (3.2) ppm. It could be observed from the results that the spike absorbed more phosphorous than the others part of the barley that irrigated with the same type of water, also it could be noted that the barley irrigated with wastewater absorbed more phosphorous content than the cultivars irrigated with freshwater.

3.6.3. Phosphorous (P) in Stem

Table **10** represents that a significant could be observed among the salinity of water related to P-Stem. The stems of the barley irrigated with wastewater absorbed higher phosphorous than that irrigated with freshwater. Results showed that the cultivars irrigated with wastewater absorb more phosphorous content by the stem than the cultivars irrigated with freshwater. For freshwater, BW284 cultivar absorbed the highest phosphorous by the stem with P=1.30 ppm while S42IL107 and BW290 absorbed the lowest with P of (0.09) ppm. For wastewater, BW284 and BW281 cultivars absorbed the highest phosphorous content by the stem with P=4.2 ppm while BW290 absorbed the lowest content with P of (0.6) ppm. It could be observed that cultivars irrigated with wastewater absorb more amounts of the phosphorous through the root, spike and stem.

CONCLUDING REMARKS

The following concluding remarks were observed based on the results obtained in this experiment:

- The growth vigor as well as the growth period (from days to emergence to maturity) were not affected with the type of irrigation water and only depend on the type of seeds.
- G400 cultivar showed the best earliest growth results among the seven types
- Seeds with prostrate growth gave higher branch number, and this lead to a higher yield compared with that with erect growth.
- Barley yields vary relating to the type of water used for irrigation. The highest yield were obtained in the barley irrigated with wastewater, the cultivars irrigated with wastewater gave nearly twice the yield of that irrigated with freshwater. BW290 cultivar showed the best highest yield among the seven types.

Table 10: Phosphorous (P) Data of Barley Irrigated with Freshwater and Wastewater

Line	P-soil before %	P-water %		P-Soil After %		P-Root %		P-Spike %		P-Stem %	
		F.W	WW	F.W	WW	F.W	WW	F.W	WW	F.W	WW
S42IL107	1.50^{a}	0.62^{a}	3.30^{a}	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	1.50^{a}	0.62^{a}	3.30^{a}	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	1.50^{a}	0.62^{a}	3.30^{a}	0.24^{d}	0.40^{e}	1.35^{a}	70^{b}	0.32^{cd}	3.20^{b}	1.30^{a}	4.20^{a}
Scarlett	1.50^{a}	0.62^{a}	3.30^{a}	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	1.50^{a}	0.62^{a}	3.30^{a}	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	1.50^{a}	0.62^{a}	3.30^{a}	0.37^{c}	0.70^{d}	0.28^{b}	0.90^{de}	0.22^{d}	80^{a}	0.26^{c}	0.80^{d}
G400	1.50^{a}	0.62^{a}	3.30^{a}	0.92^{a}	1.70^{a}	0.29^{b}	0.74^{e}	1.69^{b}	80^{a}	0.33^{c}	0.72^{d}

- Means with the same letter are not significantly different.
- All the above variables were significant except the P-soil before relating to the water type at $p \le 0.05$ %.
- All the above variables were significant except the (P soil before) at $p \le 0.05$ %.

- Barley proved to be a salt-tolerant crop with considerable economic importance, Barley could tolerate saline water until (4 µs) without any shortage in the yield of the crop.
- The salinity uptake by barley was mainly in the root whish had the higher TDS compared with salinity absorbed by both the stem and the spike.
- Barley absorbed potassium through the stem, root, and spike, in decreasing order (K – Stem> K - Root , K% - Spike) .
- The soil irrigated with wastewater absorbed more phosphorous and nitrogen than the soil irrigated with freshwater (P – Spike > P - Stem, > P - Root, N – Root > N- Spike, N - Stem) and consequently, the quality of water used in irrigation affected soil texture.

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