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IMPACTS OF THREE IRRIGATION WATER SOURCES ON GROWTH, YIELD AND GRAIN ELEMENTS CONTENT OF SOME SAUDI ARABIA BARLEY (*Hordeum vulgare* L.) LANDRACES

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Considering water scarcity in Saudi Arabia, flied experiment was performed to assess the growth, grain yield and grain elements content of locally cultivated barley (*Hordeum vulgare* L.). Ten landraces were irrigated with three irrigation water sources, tap water (TW), underground water (UW) and treated municipal wastewater (TMW). Significant increase of: growth such as height, tillers and spike length, and number and yield traits, 1000 grain weight and maximum yield per individual plant were recorded in plants treated with TMW compared to the other two irrigation treatments. Further, interaction of irrigation treatments and landraces significantly improved growth and plant yield of LR3 (Ad-Dilam local barley), LR5 (Buraidah local barley) and LR6 (Asir barley) treated with TMW (had the highest height, maximum tiller number, spikes length cm), and grain per spike and plant. Macro and microelement accumulation increased in the grain of barley landraces irrigated with TMW. However, trace elements levels did not exceed-safe limits, with exception of Cd in all barley landraces grain was higher > 0.2 mg $kg^{-1.}$ Nevertheless, landraces LR6 (Asir barley) LR7 (Buraydah barley) and LR8 (Hail barley) accumulated Cd within safe limit. TMW is a viable choice for some barley cultivation sustainability to safe drinking and ground water.
Keywords: Barley, Irrigation, growth, yield, elements, arid.

INTRODUCTION

Saudi Arabia as an arid country characterized by limited fresh water sources, low annual rainfall and not having natural permanent or seasonal bodies of water sources. Besides these harsh natural conditions, increasing population, and living standards lead to great pressure on the existing water resources (FAO, 2009; Zaharani *et al*., 2011). In a situation, using treated wastewater for irrigation is the most possible solution for saving fresh water and sustaining crop production. Using of treated wastewater for crop irrigation having benefits and vulnerability to hazard as revealed in many studies. The benefits include; reducing both stresses on freshwater resources, reducing the need for fertilizers while containing nutrients available for plants (Vergine *e*t *al*., 2017; Trat *et al*., 2016). Nevertheless, under certain conditions, properly treated wastewaters can primarily be used primarily predominantly in agriculture: as the presence of nutrients for instance N, P, K in the wastewaters make them suitable for use in fields. While risks included accumulation of chemical and biological contaminants in the soil and buildup of certain persistent pollutants in the food chain through crops irrigated with treated water (Elgallal *et al*., 2016; Becerra *et al*., 2015). An appropriate use of urban wastewater can prevent environmental pollution and reduces surface water and groundwater pollution. The using of urban wastewater for irrigation and industrial suburban areas in several parts of the world has become conventional (Nazari *et al*., 2006). Farmers in Saudi Arabia, especially in the Al-Sama, Al-Qassim, Samir and Al-Munawwarah Al-Muna Madinah areas had cultivated locally selected wheat and barley (Al-Turki *et al.*, 2019). Several generations of farmers in the Kingdom have inherited landraces of wheat and barley, the importance of these local barley landraces lies in their ability to adapt to the conditions of severe heat and drought. Both of these contribute to the value of conservation and sustainability as pure genetic resources in the gene banks for future generations of agricultural genetic resources. The barley genetic resources in the Saudi Arabia should therefore be protected by ex-situ conservation in national gene banks (Al-Turki *et al*., 2010; Al-Turki *et al*., 2019). The accessions of barley germplasm are maintained in Saudi Arabia by the Ministry of Environment, Water and Agriculture, respectively. *Hordeum vulgare* is one of the earliest domesticated crop species in the world, mostly consumed by human and used as animal feed. In recent times barley become as the fourth important cereal crop, grown in more than a hundred countries worldwide (Giraldo *et al*., 2019). Barley is adapted, to some extent, to adverse growing conditions related stresses of cold, drought, and poor soils (Gürel *et al*., 2016). Barley plays a major role in human and animal nutrition, so research efforts are needed for sustainable crop production, via the implementation of soil and crop technical practices and reducing the environmental impact (Roberts and Mattoo, 2018). Barley is one of the most critical foods in Saudi Arabia (Alamri and Al-Duwais, 2019). The food commodities value imports were $17.9 billion in 2016, with approximately $3.6 billion spent for wheat, barley, and poultry (FAO, 2018). Consider the government decision No. 335 issued on the cultivation restriction of some crops. To conserve groundwater research for alternative sources of irrigation water for crops is a must, especially when water scarcity is becomes the major environmental constrain facing sustainable crop. Therefore, this study was performed to investigate the opportunity for cultivating barley landraces using treated wastewater instead of traditional irrigation sources such as normal or fresh water and underground water in the Riyadh region, Saudi Arabia (Focusing mainly on growth and yield quantity and quality).

MATERIALS AND METHODS

***Study site and Plant materials*:** The study was performed at Agricultural Experimental and Research Station (Derab), Faculty of Food and Agriculture Sciences, King Saud University, Saudi Arabia, during the barley growing season (December - April), to investigate the impacts of three irrigation sources on growth, yield and accumulation of elements in grain of ten (*H. vulgare* L.) landraces cultivated in some area of Saudi Arabia (Table 1). All landraces

Table 1. List of thirteen barley landraces used in this study.

Study code	Accession ID number	Local name	Collected location status
LR 1	2	Unaizah local barley	Unaizah (Al-Qassim Province)
LR 2	572	Al-Qassim local barley	Al-Qassim (Al-Qassim Province)
LR 3	91	Ad-Dilam local barley	Ad-Dilam (Riyadh Province)
LR 4	299	Asir local barley	Asir (Asir Province)
LR 5	192	Buraidah local barley	Buraidah (Al-Qassim Province)
LR 6	288	Asir local barley	Asir (Asir Province)
LR 7	568	Buraydah local barley	Buraydah (Al-Qassim Province)
LR 8	546	Hail local barley	Hail (Hail Province)
LR 9	746	Hail local barley	Hail (Hail Province)
LR10	363	Al Riyadh local barley	Al Riyadh (Riyadh Province)

Table 2. Characteristics of the soil at the experimental field and irrigation treatments.

Physicochemical characteristics of soil			Physicochemical characteristics of irrigation water				Standards of TMW
				Tap water	Underground water	Treated wastewater	
pH	8.46			7.01	7.40	7.18	6.0–8.4^{+}
EC (dS/ m)	0.37			0.65	3.59	1.96	5.1^{+}
TDS (ppm)	239.00			418.00	2089.00	1186.00	2500^{+}
Soluble anions (mg L^{-1})							
HCO_3+ CO_3	0.80			0.30	2.94	3.50	-
Cl	2.00			3.50	10.40	4.70	-
SO_4	0.90			2.74	3.45	6.54	
Soluble Cations (mg L^{-1})							
Available- N	60.50		N	0.10	6.30	11.95	-
Available- P	28.00		P	1.00	12.30	17.00	-
Available- K	105.70		K	0.37	0.34	0.42	-
Ca	3.60		Ca	1.65	2.87	8.75	200^{+}
Mg	19.50		Mg	0.50	1.36	2.05	150^{+}
Na	3.20		Na	3.62	7.94	8.02	-
Micro-elements (mg kg^{-1})							
Fe	11.98	-	Fe	0.08	0.58	0.58	5.0^{+}
Cd	0.00	3.0*	Cd	0.00	0.12	0.10	0.2^{++}
Cu	5.11	140*	Cu	0.00	>0.01	>0.01	0.4^{+}
Mn	1.95	-	Mn	0.01	0.07	0.20	0.2^{+}
Ni	0.00	75*		0.00	0.00	0.00	-
Pb	0.00	300*	Pb	0.00	0.00	0.00	0.1^{+}
Zn	0.00	300$_{*1}$	Zn	0.00	2.00	2.70	4.0^{+}

*European Union (EC) ,2002, $^{+}$MWE, 2005. , $^{++}$FAO, 1985.

originated from the germplasm collection of the National Gene Bank of Agricultural Research Center (ARC), Ministry of Environment, Water and Agriculture, Riyad, Saudi Arabia.

***Field experiment and cultivation practices*:** The experiment was laid out in randomized complete block design (RCBD), with three irrigation water treatments, tap water (TW), underground water (UW) and treated municipal wastewater (TMW) as explained in Table 2. Each plot consists of eight rows (2.00× 0.20 m) in total 20 plants per each plot (plot area 3.2 m^2). On 15th December seeds of landraces were sown using hand-drilled method at a rate of 140 kg per hectare. During land preparation and before seeds sowing, amounts of 70 kg (P_2O_5) per hectare as super phosphate form (16% P_2O_5) and potassium sulphate (42% K_2O), 100 Kg per hectare of K_2O, were added to the soil. As recommended, an amount of N (100 Kg N per ha) was also applied in three divided equal doses in the form of ammonium nitrate (33.3% N). The first does was applied at sowing, the second dose during tillering and the third dose at anthesis stage. All agricultural practices from seed sowing until harvesting were carried out according to the recommended conventional production practices in the Riyadh sated by Ministry of Environment, Water and Agriculture of Saudi Arabia.

***Soil, grain and irrigation water analysis*:** For physical and chemical analysis of soil, the samples were taken as the methods of Cottenie *et al*. (1982) and But (2004). After soil samples collection, they were oven dried at 100±5°C until they reached a constant weight. Determination of grains metal contents such as Cd, Ni, Pb, Zn, and Cu were done by using inductively coupled plasma-mass spectrometer (ICP-MS) (Ultima 2 JY Plasma). The methods of (Cassel and Nilsen1986; Gee and Bander 1986; Rhoades, 1982) were used for estimation of Soil physical and chemical properties (Table 2). As shown in Table 2 chemical properties of irrigation water were estimated according to Richards (1968) and method of American Public Health Association (APHA) (2005).

***Measurements of growth parameters*:** The length of the main culm measured from the soil surface to the tip of the main spike. The total number of tillers per plant was counted when all spikes were at the full ripe stage. Spikes per plant were counted when all plants were at full maturity. Spike length (cm) the main spike of each plant at complete maturity was measured from base to tip, excluding awns in cm.

***Estimation of yield characteristics*:** At maturity stage, the yields and yield components estimated by harvesting most inner rows (4 inner rows) from each subplot unit traits, ten guarded plants were randomly collected from each plot for subsequent measurements as follows: height of plant (cm), spike length (cm), number of tillers, number of spikes, spike weight (gm), 1000-grain weight (gm) and grain yield per plant.

***Elements determination in soil and plant*:** Three replicates per irrigation treatment were collected randomly from each landrace in the plots. Grains were ground. Half gram of grounded seeds of barley grains was wet digested using sulphuric-perchloric-acids mixture ($HClO_4$+ H_2SO_4) acids according to Chapman and Pratt protocol (1962). Total Nitrogen (N) in plant samples was determined by Kjeldahel technique (Jackson, 1973). Total K and Na in plant samples was determined by Flame photometer as described by Jackson (1967). The total content of minerals (N, P, K, Ca, Mg, Cd, Cu, Fe, Mn, Ni, and Zn) in plant samples were determined by inductively coupled plasma spectrometry (ICP-MS) (Ultima 2 JY Plasma).

***Statistical analysis*:** Using Multivariate Analysis of Variance (MANOVA) to test the variation between independent factors (irrigation treatment, landraces and interaction between treatment and landraces), LSD method is used to differentiate between means of growth, yield parameters and elements content within treatments and land races by using Pair wise comparison. All statistical analysis was performed by using SPSS. Before using the MANOVA, the assumption of correlated dependents variables is tested. The results of conducted correlation showed that all correlations were positive and in the moderate range; $p < 0.01$), signifying the appropriateness of MANOVA which conducted to test if there is statistically significant effect of irrigation treatment, landraces and interaction effect of irrigation treatment × landraces (independent variables) on a range of dependent variables such growth traits and elements concentration in grains.

RESULTS

***Effect of main factors and their interaction on Growth and Yield Parameters*:** The results of MANOVA Pillai's Trace showed that there is a statistically significant effect of treatments irrigation by normal water (TW), underground water (UW) and treated wastewater (TMW)), landraces of barley and interaction between them on growth and yield parameters (Table 3). Test of between subject effects on growth and yield parameters showed a significant difference in general between growth and yield parameters included in

Table 3. Multivariate test (Pillai's Trace) MANOVA for growth traits, yield and elements of barley.

Effect	Growth traits, yield			Macro and microelements		
	Value	F –value	P - value	Value	F –value	*P* - value
Treatment	1.55	27.0	0.00	1.99	106.0	0.000
landraces	3.23	5.72	0.00	7.23	21.6	0.000
Treatment*land races	3.23	2.86	0.00	9.17	16.76	0.000

Table 4. Effect of irrigation treatments and landraces on growth and yield parameters of barley.

Main factors		Plant height(cm)	Tiller number	Spike length(cm)	Spike weight(g)	Spike number	1000-GW(g)	Y/P(g)
Treatments	TW	73.55^{b}	9.16^{b}	8.52^{b}	1.50^{b}	7.43^{b}	9.16^{b}	11.11^{b}
	UW	59.81^{c}	6.96^{c}	6.81^{c}	1.23^{c}	5.16^{c}	6.96^{c}	6.47^{c}
	TW	93.59^{a}	12.10^{a}	10.32^{a}	1.96^{a}	10.33^{a}	12.10^{a}	20.50^{a}
	p-value	***	***	***	***	***	***	***
Landraces	LR1	73.68^{c}	9.33^{b}	8.19^{b}	1.93^{c}	7.44^{bc}	36.28^{b}	15.07^{cd}
	LR2	79.17^{b}	8.33^{c}	8.76^{b}	0.98^{h}	6.67^{c}	35.56^{b}	6.64^{g}
	LR3	86.44^{a}	9.89^{a}	8.83^{b}	2.05^{b}	8.22^{ab}	45.46^{a}	17.42^{ab}
	LR4	73.80^{bc}	10.32^{a}	7.28^{c}	1.58^{e}	8.44^{a}	36.34^{b}	13.89^{d}
	LR5	69.91^{cd}	10.33^{a}	8.00^{bc}	1.84^{d}	8.67^{a}	45.13^{a}	16.62^{bc}
	LR6	88.83^{a}	9.11^{b}	8.47^{b}	2.38^{a}	7.44^{bc}	31.72^{c}	18.41^{a}
	LR7	85.63^{a}	8.56^{c}	8.68^{b}	1.55^{e}	6.78^{c}	34.33^{b}	11.49^{e}
	LR8	69.11^{cd}	9.00^{bc}	8.89^{b}	1.15^{g}	7.44^{bc}	36.87^{b}	9.06^{f}
	LR9	65.06^{d}	10.22^{a}	10.44^{a}	1.28^{f}	8.33^{ab}	34.27^{bc}	11.62^{e}
	LR10	64.89^{d}	9.00^{bc}	8.00^{bc}	0.914^{h}	7.00^{c}	29.61^{c}	6.75^{g}
	p-value	***	***	***	***	***	***	***

; p< 0.001, *; p< 0.0001 and NS; not significant – GW;grain weight, Y/P; yield per plant

Table 5. Interaction effects of treatments and landraces on growth and yield characteristics of barley.

Treatment ×Landraces	Plant height(cm)	Tiller number	Spike length (cm)	Spike number	Spike weight (g)	1000-GW (g)	Y/P(g)
TW ×LR1	66.6±1.5	9.00±1.0	8.3±0.3	7.00±1.0	2.10±0.08	38.51±.94	14.68±2.6
TW ×LR2	72.1±.76	8.66±1.5	8.3±0.5	7.00±1.0	0.97±0.02	35.52±1.7	6.77±0.8
TW ×LR3	79.6±5.6	9.66±.57	8.8±0.8	8.00±1.0	1.86±0.04	46.90±1.7	14.85±1.5
TW ×LR4	75.5±2.6	10.33±1.2	7.3±1.5	8.33±1.2	1.62±0.02	36.54±2.5	13.56±1.9
TW ×LR5	66.6±2.5	9.66±0.6	8.0±0.5	8.00±1.0	1.75±0.02	46.32±4.5	14.03±1.8
TW ×LR6	93.6±2.0	7.33±0.5	8.3±0.3	6.00±1.0	2.28±0.02	35.15±3.1	13.69±2.2
TW ×LR7	86.3±1.5	8.66±0. 7	9.1±2.5	7.00±1.0	1.38±0.36	34.75±3.2	9.89±3.9
TW ×LR8	64.6±3.7	9.33±0.5	9.1±0.3	7.66±0.7	1.08±0.01	33.21±2.8	8.28±0.6
TW ×LR9	67.1±3.1	10.33±0.5	9.6±0.4	8.66±0.4	1.13±0.04	34.81±1.4	9.83±0.3
TW ×LR10	63.0±1.0	8.66±1.2	8.2±0.4	6.66±1.2	0.82±0.03	30.81±0.3	5.53±1.2
UW ×LR1	57.4±2.4	7.66±1.5	6.0±1.8	6.00±1.0	1.22±0.10	28.43±1.4	7.35±1.6
UW ×LR2	56.0±4.3	6.33±1.2	6.9±0.9	4.66±0.5	0.88±0.01	25.48±2.1	4.11±0.5
UW ×LR3	60.3±2.5	8.66±0.5	7.3±1.1	7.00±1.0	1.48±0.07	34.74±4.3	10.34±1.0
UW ×LR4	62.2±3.9	8.00±1.7	6.0±0.5	6.00±1.7	1.25±0.02	26.17±2.4	7.53±2.3
UW ×LR5	56.9±2.7	7.33±.57	6.8±0.8	5.66±0.6	1.61±0.02	36.17±4.5	9.16±1.0
UW ×LR6	63.6±4.0	6.33±1.2	6.3±0.6	4.33±1.2	2.19±0.01	24.83±3.1	9.50±2.5
UW ×LR7	76.5±1.7	5.66±0.6	6.6±1.5	4.00±1.0	1.08±0.01	23.27±1.1	4.31±1.1
UW ×LR8	55.0±6.1	6.33±1.5	7.1±1.2	4.66±1.5	0.92±0.01	31.50±13	4.31±1.4
UW ×LR9	55.3±3.2	6.66±0.5	8.1±.0.7	4.66±0.5	0.96±0.04	23.23±3.1	4.49±0.7
UW ×LR10	54.6±3.7	6.66±0.6	6.6±0.6	4.66±0.5	0.76±0.02	23.17±2.6	3.58±0.4
TMW ×LR1	97.0±1.0	11.33±0.5	10.1±0.6	9.33±0.6	2.47±0.24	41.89±1.0	23.16±3.5
TMW ×LR2	109.3±8.1	10.00±1.0	11.0±8.5	8.33±0.7	1.08±0.02	45.68±2.0	9.02±0.4
TMW ×LR3	119.3±2.1	11.33±1.5	10.3±0.5	9.66±1.2	2.80±0.10	54.73±1.5	27.06±1.5
TMW ×LR4	83.6±3.5	12.66±1.5	8.5±0.5	11.00±1.0	1.87±0.02	46.31±1.5	20.57±1.5
TMW ×LR5	86.1±2.7	14.00±1.5	9.1±0.3	12.33±0.6	2.16±0.04	52.90±1.5	26.65±1.5
TMW ×LR6	109.1±4.6	13.66±1.5	10.7±.0.2	12.00±1.0	2.67±0.03	35.19±1.5	32.02±1.5
TMW ×LR7	94.0±3.6	11.33±1.5	10.2±0.3	9.33±0.5	2.17±0.02	44.95±1.5	20.28±1.5
TMW ×LR8	87.6±5.1	11.33±1.5	10.3±1.5	10.00±1.0	1.46±0.04	45.90±1.5	14.58±1.5
TMW ×LR9	72.6±2.3	13.66±1.5	13.5±0.5	11.66±1.5	1.75±0.05	44.77±1.5	20.54±1.5
TMW ×LR10	77.0±2.0	11.66±1.5	9.1±0.3	9.66±2.1	1.15±0.04	34.85±1.5	11.14±1.5
p-value	***	***	NS	***	***	NS	***

; p< 0.001, *; p< 0.0001 and NS; not significant

the model (Table 4 and 5). Furthermore, there is a significant difference among treatments and landraces growth parameters. Regarding the effect of interaction between treatment and landraces of barley on the parameters, there is a significant difference between parameters except for spike length and 1000- grain weights per plant is demonstrated in Table 4.

The estimated marginal means of growth and yield parameters under effect of different treatments and landraces. The means of all parameters are highest with treated water irrigation compared to other irrigation treatments, and lowest under underground water irrigation. For instance, the various landraces plants treated with TMW grew taller (height≈94 cm) had more grain (20.5 g/plant) while plants irrigated with underground water, had least height (height≈60 cm) and lower yield (6.4 g/palnt). Comparing the performance of all barley landrace, LR3 and LR6 are superior in growth and yield under various irrigation (e.g., plant height is 86.4 and 88.8 cm and grain yield per plant is 17.4 and 18.4 g) to other landraces. Results regarding interaction effect of irrigation treatments and landraces on growth and yield parameters (Table 5) indicated that plants of LR3 and LR6 treated with TMW had plant heights of (119.3 and109 cm), number of tillers (11 and 14), spikes length (2.7 and 2.8 cm), and 1000-grain weight (55 and 35 g) and highest grain per plant (27 and 32 g). On the other hand, plants of LR3 and LR5 treated with UW had grown better in terms of height, number of tillers, spikes length, and grain yield per plant, LR7 yield less grain compared to LR3 which has the highest grain yield per plant compared to all landraces.

Effects of main factors and their interaction on grain element contents: The MANOVA results for between subject effects as presented in Table 3 showed that there is a significant difference between the main factors (irrigation types and barley landraces) on grains macro and microelements contents. The levels of macro-elements and microelements (N, P, K, Mg, Cd, Cu, Fe, Mn, Ni and Zn) in various barley landraces grains are high under treated wastewater normal water and underground water respectively (Fig. 1&2). Notable finding is highest, Fe content (791 mg kg^{-1}) in grains of barley plants treated with TMW followed by underground water (408 mg kg^{-1}) and tap water irrigation (270 mg kg^{-1}) compared to the contents of all studied elements (Fig. 1, 2&3).

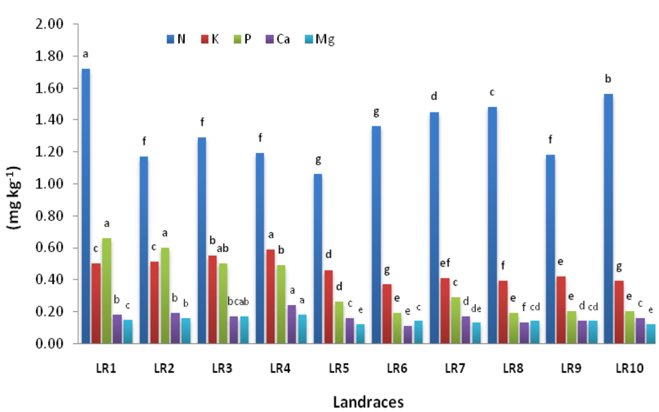


Figure 1. Effect of irrigation treatments on N, K, P, Ca and Mg contents in grain. Different letters indicate significant differences between irrigation treatment at *P* >0.01.

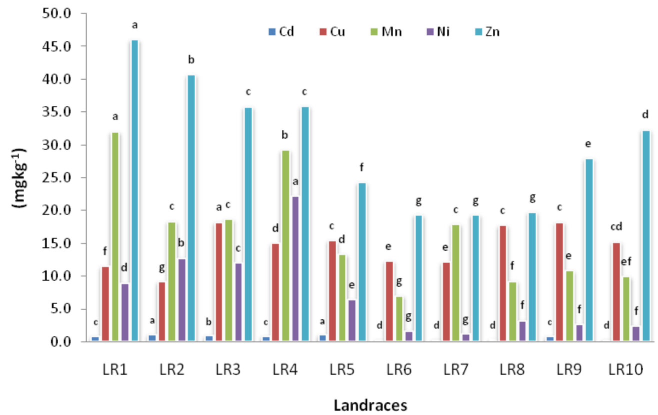
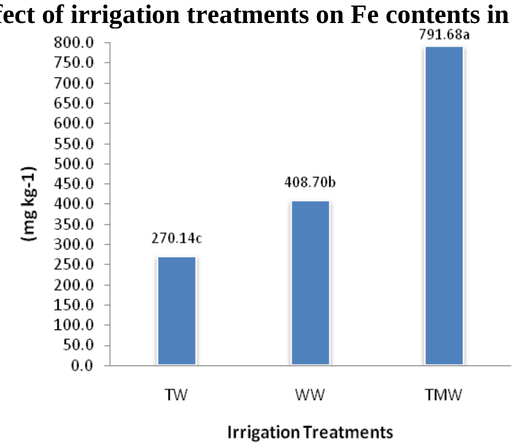


Figure 2. Effect of irrigation treatments on Cd, Cu, Mn, Ni and Zn contents in grain. Different letters indicate significant differences between irrigation treatment at P >0.01.

a. Effect of irrigation treatments on Fe contents in grain



b. Effect of barley landraces on Fe contents in grain

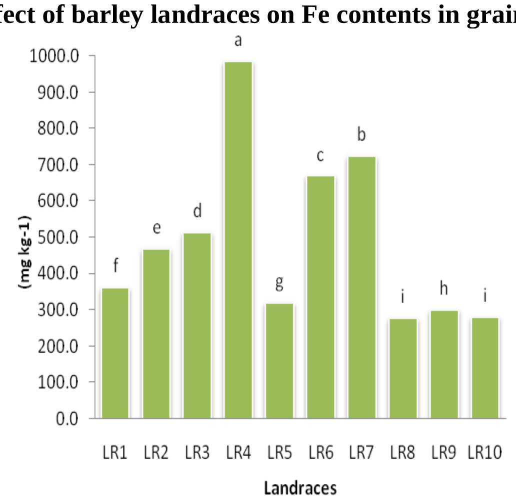


Figure 3. Effect of irrigation treatments and barley landraces on Fe contents in grain. Different

letters indicate significant differences between irrigation treatment at P >0.01.

Regarding landraces, there is great variation between landraces in terms of elements concentration. LR1 recorded maximum contents of N, P, Mn and Zn, and minimum Cd, whereas LR4 recorded highest K, Ca, Mg, Fe, and Ni contents compared to other landraces (Fig. 5). The content of Fe in LR4 and LR7 is the highest compared to other landraces (986 and 724 mg kg^{-1}) Fig. 3a and b.). The results of the interaction between treatments and landraces confirm the results presented in the above section in that the concentration of macro and microelements of all landraces under treated wastewater irrigation is high compared to landraces irrigated with normal and underground water. AS shown in Fig. 1, the highest nitrogen concentration is recorded for LR1 under treated wastewater irrigation (2.31 mg kg^{-1}).

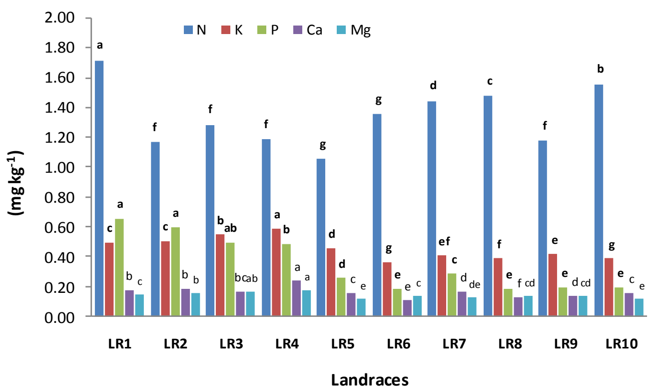


Figure 4. Effect of barley landraces on N, K, P, Ca and Mg contents in grain. Different letters indicate significant differences between landraces at P >0.01

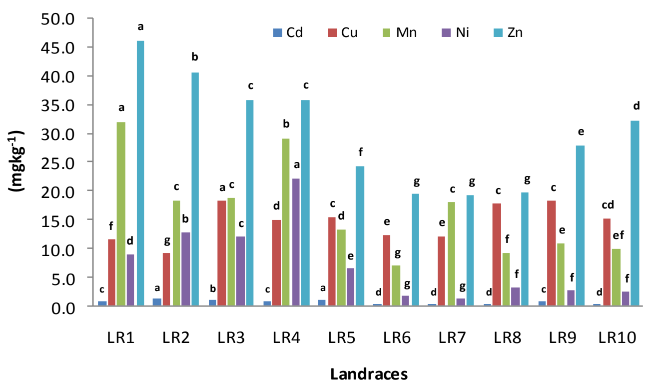


Figure 5. Effect of barley landraces on Cd, Cu, Mn, Ni and Zn contents in grain. Different letters indicate significant differences between landraces at *P* >0.01

DISCUSSION

***Physiochemical characteristics of soil and irrigation treatments*:** Characteristics of the soil at the experimental field and irrigation treatments (Table 2) indicated that they are not exceeding the critical levels documented previously by Abou-Seeda *et al*. (1997) who indicated that the critical or toxic limits of Cu, Zn, Pb, Ni, Cd, soil are 100, 300, 100, 100, 5 mg kg^{-1}, respectively. Moreover, the physiochemical characteristics of TMW are within standards of MWE (2005) and FAO (1985).

***Effect of main factors and their interaction on growth and yield traits*:** Treated wastewater improved growth performance and yield of all barley landraces, the maximum growth and yield parameters of all landraces were achieved when irrigated with treated wastewater compared to another types of irrigation water. Landraces irrigated with underground water registered the lowest means compared to other treatments. LR3 and to some extent LR6 were superior in terms of growth and grain yield components when irrigated with treated water compared to other landraces included in the experiment, while the performance of LR1, LR9 and LR10 is low in all treatments. This finding is the consistency of with results of previous research. Such as, Wafaa *et al.* (2018) observed maximum growth of the maize and barley seedlings treated with the sewage water. Hadithy *et al*. (2011), obtained an increase in the growth of growing crops in treating soils with different levels of wastewater. Majida *et al.* (2017) reported a significant increase in biomass and grain yield production of barley and vetch when irrigated with treated wastewater. However, one of the main reasons for barley growth enhancement is an abundance of necessary nutrients for growth in treated wastewater. It is obvious from the irrigation water analysis (Table 2), treated wastewater water contains substantial quantities of important nutrients (N, P, K, Fe, Mn, Zn, Cu, Cd, Pb) needed for barley crop which is confirmed by-Rattan *et al.* (2005) for urban wastewater rich source of nutrients, N, P, K and other nutrients required for plant growth. As the results of this study reported a reduction in growth and yields of most barley landraces irrigated with UW, the reason for that reduction may due sensitivity of these barley landraces to salinity, which is slightly above 3 EC. Although some growth parameters of LR3 were negatively affected by UW but, yield increased. This finding was explained previously by some research, who concluded, in general, fodder crops are sensitive to salinity early growth stages (such as germination stage) and then they tolerated throughout later growth stages (Guy, 2013; Inzamam-ul-Haq *et al*., 2019).

***Effects of main factors and their interaction on grain element contents*:** A deep discussion about some beneficial and harmful trace elements is needed for grain production safety and the conclusion of using TMW for irrigation of food crop. Iron is an essential element for human that plays a vital

Table 6. Interaction effects of treatments on barley landraces on grain elements content (mg kg^{-1}).

Landraces × Irrigation	N	K	Ca	P	Mg	Cd	Cu	Fe	Mn	Ni	Zn
TW×LR1	1.68±0.01	0.50±0.05	0.18±0.01	0.63±0.01	0.16±0.01	0.60±0.10	4.4±.02	255.5±0.5	20.2±1.0	0.3±0.1	50.9±1.0
TW×LR2	1.26±0.02	0.52±0.02	0.22±0.02	0.66±0.01	0.18±0.01	0.96±0.20	5.8±.10	254.7±1.0	18.2±2.0	5.7±1.0	40.6±2.0
TW×LR3	1.39±0.03	0.58±0.02	0.20±0.02	0.46±0.01	0.17±0.01	0.70±0.10	6.7±.05	398.1±1.0	18.0±1.0	11.3±2.0	30.0±2.0
TW×LR4	1.18±0.02	0.55±0.05	0.40±0.02	0.43±0.01	0.17±0.01	0.74±0.06	9.1±.02	339.2±5.9	23.2±2.0	10.6±2.0	35.6±2.0
TW×LR5	1.04±0.02	0.44±0.04	0.19±0.02	0.27±0.01	0.13±0.01	0.91±0.01	12.7±.10	212.4±1.3	13.0±2.0	5.5±0.2	19.9±2.0
TW×LR6	1.38±0.02	0.37±0.04	0.13±0.01	0.19±0.01	0.11±0.01	0.21±0.01	7.8±.05	227.4±1.3	7.3±0.2	0.3±0.1	19.7±2.0
TW×LR7	1.46±0.02	0.47±0.01	0.24±0.02	0.27±0.01	0.12±0.01	0.21±0.01	10.5±.10	231.0±1.0	13.6±2.0	0.3±0.1	18.5±2.0
TW×LR8	1.47±0.03	0.38±0.01	0.15±0.02	0.20±0.01	0.10±0.01	0.21±0.01	16.6±.10	254.9±1.2	7.4±1.0	2.3±0.1	22.1±2.0
TW×LR9	1.18±0.02	0.40±0.01	0.16±0.03	0.18±0.01	0.10±0.01	0.51±0.02	16.4±.05	265.3±1.5	11.2±1.0	0.8±0.2	29.6±1.0
TW×LR10	1.47±0.03	0.39±0.01	0.270±.02	0.18±0.01	0.11±0.01	0.19±0.01	14.5±.05	262.6±1.5	9.7±0.1	0.3±0.1	32.6±2.0
UW×LR1	1.19±0.01	0.41±0.03	0.16±0.02	0.60±0.01	0.11±0.01	0.70±0.10	14.6±.20	284.0±1.0	2.4±0.2	11.5±1.0	35.6±1.0
UW×LR2	0.78±0.02	0.28±0.02	0.17±0.02	0.37±0.01	0.11±0.01	1.10±0.10	6.1±.05	547.6±1.0	10.0±1.0	9.2±1.0	23.0±2.0
UW×LR3	1.11±0.04	0.48±0.02	0.16±0.02	0.43±0.01	0.14±0.01	0.91±0.01	16.0±.2	448.0±1.0	16.5±1.0	11.7±1.0	27.9±1.0
UW×LR4	0.91±0.03	0.59±0.02	0.15±0.02	0.38±0.01	0.13±0.01	0.81±0.01	13.6±.02	1001.5±1.3	20.2±2.0	19.2±1.0	31.3±2.0
UW×LR5	0.79±0.02	0.43±0.04	0.14±0.02	0.17±0.01	0.10±0.01	1.03±0.06	14.6±.10	427.1±1.0	10.3±2.0	6.5±0.2	22.2±2.0
UW×LR6	1.22±0.02	0.34±0.03	0.09±0.01	0.17±0.01	0.18±0.01	0.31±0.01	9.6±.10	231.5±1.4	6.2±0.2	2.2±0.2	17.9±2.0
UW×LR7	1.35±0.02	0.37±0.01	0.13±0.02	0.18±0.01	0.13±0.04	0.31±0.01	12.1±.10	251.0±1.0	9.5±1.0	0.6±0.1	10.3±2.0
UW×LR8	1.46±0.02	0.37±0.01	0.11±0.02	0.17±0.01	0.18±0.01	0.47±0.37	17.2±.10	260.0±1.0	6.5±2.0	3.3±0.2	14.2±2.0
UW×LR9	1.16±0.02	0.39±0.01	0.12±0.02	0.16±0.01	0.18±0.01	0.55±0.01	18.6±.10	351.0±1.0	9.3±1.0	2.8±0.2	22.7±1.0
UW×LR10	1.420±.02	0.36±0.01	0.10±0.01	0.17±0.01	0.10±0.01	0.28±0.01	15.1±.10	285.3±0.5	7.7±0.1	3.3±0.2	29.4±2.0
TMW×LR1	2.31±0.01	0.61±0.02	0.21±0.01	0.75±0.01	0.18±0.01	1.10±0.10	15.4±.20	545.0±1.0	73.4±1.6	15.1±1.0	51.7±1.0
TMW×LR2	1.49±0.01	0.73±0.01	0.18±0.02	0.77±0.01	0.21±0.01	1.30±0.10	15.4±.10	603.7±1.0	26.9±1.0	23.4±1.0	58.6±1.0
TMW×LR3	1.39±0.04	0.60±0.02	0.17±0.02	0.62±0.02	0.21±0.01	1.11±0.01	31.9±.60	691.7±.60	21.6±1.0	13.0±1.0	49.5±2.5
TMW×LR4	1.48±0.02	0.65±0.02	0.180.02	0.67±0.01	0.25±0.01	0.91±0.01	22.3±.10	1620.0±2.0	44.2±2.0	36.7±1.0	40.8±2.0
TMW×LR5	1.36±0.02	0.51±0.03	0.17±0.02	0.34±0.01	0.14±0.02	1.20±0.10	19.0±.10	319.8±1.6	16.6±2.0	7.2±0.2	30.7±2.0
TMW×LR6	1.48±0.02	0.40±0.02	0.11±0.02	0.22±0.01	0.14±0.02	0.37±0.01	19.5±.10	1550.1±1.2	7.5±0.2	2.4±0.2	20.5±2.0
TMW×LR7	1.55±0.02	0.41±0.01	0.15±0.02	0.42±0.01	0.13±0.01	0.41±0.01	13.8±.10	1690.6±1.5	30.7±2.0	2.6±0.3	29.2±2.0
TMW×LR8	1.51±0.02	0.44±0.02	0.13±0.02	0.22±0.01	0.13±0.01	0.33±0.03	19.3±.10	320.0±2.0	13.8±2.0	4.0±0.2	23.0±1.0
TMW×LR9	1.22±0.02	0.47±0.02	0.14±0.01	0.27±0.01	0.13±0.01	1.33±0.15	19.6±.10	282.6±1.2	12.0±1.0	4.2±0.2	31.5±2.1
TMW×LR10	1.81±0.02	0.42±0.01	0.13±0.02	0.27±0.01	0.15±0.01	0.41±0.01	16.0±.10	293.1±0.9	12.3±2.0	3.6±0.1	34.9±1.0
p-value	***	***	***	***	***	***	***	***	***	***	***

; p< 0.001, *; p< 0.0001 and NS; not significant

role in the formation of hemoglobin, oxygen and electron transport in the human body (Kalagbor and Diri, 2014), and the maximum amount of Fe in food is 425 mg kg^{-1} according to The FAO/WHO (2001). The results showed, all landraces treated by TMW had Fe level >425 mg kg^{-1} and some landraces (L2, L4 and L4) treated with UW had Fe- content > 425 mg kg^{-1}, whereas Fe- content in grain of LR, L4, LR6 and LR7 were > 1000 mg kg^{-1}, when treated with wastewater irrigation. In contrast LR5, LR8, LR7, LR9 and LR10 accumulated Fe level of <425 mg kg^{-1} (Table 6).

Another trace element of concern is Mn which is an important element necessary for various biochemical processes (Saraf and Samant 2013). Manganese showed a maximum concentration (30-73 mg kg^{-1}) in barley, LR1, LR3, LR4, LR7 treated with TMW and a minimum (7-20 mg kg^{-1}) in other landraces treated with TMW and UW. A trace amount of Ni may be beneficial, but the higher levels of Ni becomes toxic (Onianwa *et al*., 2000). As can be observed from Table 6, the maximum concentration of Ni ranged from 23 to 37 mg kg^{-1} in L2 and L3 treated with TMW and the minimum was found in grains of the remaining 8 landraces. Zinc is an essential element and has an important role in the metabolism, growth, development of all organisms and its deficiency causes coronary heart diseases and various metabolic disorders (Saraf and Samant, 2013). LR1, LR2, LR3 and LR4 treated with TMW had a maximum concentration of Zn in grain 51, 59, 49, 41 mg kg^{-1}, respectively, which is less than the safe limit (99.4 mg kg^{-1}) of FAO/WHO (2001). While, the same landraces had moderate concentration (50, 41, 30, 36 mg kg^{-1}), as even TMW landraces accumulated minimum amount of Zn. Cd has been considered as highly toxic heavy metal and could harm even in low concentration, living organisms (Ambedkar and Muniyan, 2012). Cd has been considered as highly toxic heavy metal, and could harm even in low concentration, to living organisms (Ambedkar and Muniyan, 2012, 2012). Cd toxicity in humans could lead to many health problems such as anemia, renal injury, bone disorder and lung cancer (Edward *et al*., 2013). Obviously, in the results (Table 6), cadmium was detected in all barley landraces with higher concentrations of more than 0.2 mg/kg that exceeded the safe limit (0.20 mg kg^{-1} g) set by WHO/FAO (2007), except the three landraces LR6, LR7 and LR8. In general, the results indicate that the concentration of heavy metals in barley landraces was found to follow increasing order as; Fe > Zn> Mn > Cu > Ni > Cd. While heavy metals content in barley grain within safe limits as stated by FAO/WHO (2001). Accordingly, the levels of heavy metal in this study were within the safe limit with exception of Fe and Cd (Table 6).

***Conclusion*:** In conclusion, irrigation of barley landraces with treated municipal wastewater (TMW) improved growth, grain yield and increased essential elements concentration in grain within safe limits except Cd concentration compared with the other water sources. The results indicate that irrigation with waste water can be a possible viable alternate low-cost water source for crop production, especially some domestic landraces of barley with emphasis on future breeding to select most adaptive landraces or cultivars to irrigation with wastewater taking into consideration safe limits of heavy metals in grain and or other edible parts consumed by human or animals.

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