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EVALUATING THE RESPONSES OF SOME WHEAT LANDRACES AND CULTIVARS CULTIVATED LOCALLY IN SAUDI ARABIA TO THREE SOURCES OF IRRIGATION WATER

Sultan F. ALSHARARI[1], Ibrahim A.A. ALMOHISEN[1]

[1] Department of Biology, Faculty of Science and Humanities, Quwayiyah, Shaqra University, Saudi Arabia.

Corresponding author:
Ibrahim A.A. Almohisen
ibraheem@su.edu.sa

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Abstract

This study was aimed to investigate the response of some wheat (*Triticum aestivum* L.) landraces to three irrigation sources, freshwater (FW), well water (WW), and treated municipal wastewater (TMW), regarding the impact on growth, yield, and grains elements contents. The results showed that the various wheat landraces irrigated with treated wastewater were significantly taller (117.3 cm) with multi tillers (22 tiller plant^{-1}), had maximum spikes per plant (2.6), and longer weighty spikes (14.5 cm & 12.1 g). Landraces L1(Burr), L2 (Baldy Burr), C7 (Yecora Rojo), had maximum tillers, L4 (Alssamaa Burr), L5 (Bahaal Burr), L7 (Yecora Rojo) had more spikes per plant and the longer weighty spikes were recorded in L5 Baldy Burr, L1(Burr), heavy spikes were reported in L5 (Bahaal Burr) and L1(Burr). Moreover, these landraces had the highest yield per plant and 1000 grains weight (49.8 g, 12.5 g) respectively. The N, P, K, and Mg contents were increased under TMW, and their levels in landraces and cultivars in order are 3>L2>L4>L5>L1>C6>C7. Even Cu, Fe, Mn, Zn levels were higher in various landraces irrigated with TMW, however, L3, L2, and L4 had maximum contents of all microelements. TMW irrigation enhanced growth, yield, and grain quality in terms of essential elements. The irrigation of landraces L1, L4, L5 with TMW may be a feasible alternative for sustainable wheat production and safe water in arid regions such as Saudi Arabia.

Keywords: Grain. Growth. Wastewater. Water. Yield.

1. Introduction

Bread wheat (*Triticum aestivum* L.) is one of the oldest and the most cultivated cereal species worldwide and plays a major role in food security and provides essential nutrition to the world population (De Santis et al. 2018; Ul-Allah 2018). It is grown in an area of more than 220 million hectares under diverse environmental and geographical locations, with the production of more than 749 million tons and its yield is lower by 15% in developing counties compared to the developed world (FAO 2016). The main reasons for lower wheat yields are low genetic potential of available wheat cultivars, less availability and lower quality of irrigation water, and poor management of biotic and abiotic stresses (REhman et al. 2015). The arid and semi-arid regions occupy 30% of the total land area within 80 countries of the world, mainly in Asia and Africa where 40% of the world population lives there (Ijaz et al. 2019). These areas are characterized by low annual rainfall (< 250 mm) and inadequate irrigation facilities), which will impact wheat productivity and ultimately the food security. It has been reported that water scarcity will be double in the next 30 years, especially in arid and semiarid regions of the world (BALON; DEHNAD 2006). There are major factors limiting the availability of irrigation water for agriculture in the near future: competition for freshwater due to fast urbanization and industrialization (Jabeen et. al. 2015; Shao et al. 2017), fluctuation of rainfall, and the depletion of surface water resources (Chalise et al. 2017; Wada 2016), which limit the crop development and yield in many parts of the world. Thus, it is essential to search for alternative resources of water for maximizing wheat production to fulfill the dietary needs of the human population. There are some water sources like sewage water and well water, which can be used for irrigation purposes in the future. Generally, wheat germplasms face increasing impacts from abiotic stresses, which affect plant growth, biomass, and grain yields. The increase of wheat productivity is required to meet increasing world consumption needs (AMIRI et al., 2018). Water scarcity is one of the major factors limiting sustainable agricultural development in arid and semi-arid regions. The key factor of sustainable agricultural production in arid and semi-arid regions is strategic water resource management. Saudi Arabia is characterized by high-temperature variability, low annual rainfall, no natural perennial flow, and limited groundwater reserves (Chowdhury and Al-zahrani 2013). In arid and semiarid climates, due to the severe pressure on nonrenewable water resources, drought, and the increasing urbanization, optimum use of all available water resources including municipal wastewater is considered (Galavi et al. 2010; Fonseca et al. 2007; Mohammad et al. 2007). Wastewater contains elements that are needed for plant nutrition. Therefore, determining the correct method of using wastewater is very important to reduce the adverse effects associated with wastewater irrigation, and obtain the optimum yield (Mousavi et al. 2013). The importance of food security, utilizing wastewater for crop production and in accordance with Cabinet decrees (No. 66 dated 08/12/2015 and No. 39 dated 18/10/2016) to ban the cultivation of crops with high water demand, such as wheat. Therefore, searching for alternative irrigation water resources has become a critical issue for sustainable agriculture in Saudi Arabia. For that reason, this study aimed to evaluate potential uses of treated wastewater for wheat crop irrigation, with respect to the assessment of growth and yield of some landraces of wheat and its effect on levels of elements (macro and microelements) in grain comparing to traditional irrigation water.

2. Material and Methods

Study site and Plant materials

A field experiment was carried out at the experimental farm of the Agricultural Experimental and Research Station (Derab), Faculty of Food and Agricultural Sciences, King Saud University, Riyadh (24°42'N latitude and 46°44'E longitude, Alt. 600 m), Saudi Arabia (Map1), during the wheat growing season (December- April), to evaluate growth, yield and elements accumulation in grains of five bread wheat (*Triticum aestivum L.*) landraces and two exotic varieties cultivated in some areas of Saudi Arabia (Table 1). The five landraces and the two cultivars were collected from the National Gene Bank, Agricultural Research Center (ARC), Minister of Environment, Water and Agriculture, Riyadh, Kingdom of Saudi Arabia. The experiment was arranged in a randomized complete block design (RCBD), with three replicates under three different irrigation water sources, freshwater (FW), well water (WW), and treated wastewater (TMW). The total plot area was 3.2 m^2, 8 rows (2.00× 0.20 m), and 20 plants in each plot. The chemical and physical characteristics of three-irrigation water treatment are explained in Table 2. The hand-drilled method was used to sow seeds of landraces and cultivars (140 kg ha^{-1} on December 15, 2018. The fertilization process was performed during the land preparation**,** as 70 kg of superphosphate (16% P_2O_5) and potassium sulfate (42% K_2O) per hectare**.** While the recommended dose of N (100 Kg N ha^{-1}) was also applied in three split equal doses in the form of ammonium nitrate (33.3% N) at sowing, during tillering, and anthesis stage. All the agricultural practices were implemented according to the conventional production practices followed in the Riyadh area. The irrigation process was carried out consistent with the standards followed by the farmers in the Riyadh region as recommended by the Ministry of Environment, Water, and Agriculture.

Soil and irrigation water analysis

Samples of the soil sites were taken for physical and chemical analysis according to the methods depicted by Cottenie et al. (1982) and Burt (2004). Soil samples were oven-dried at 105°C to a constant weight. Total element concentrations in soil were determined using nitric acid as described by Cottenie et al. (1982) and Burt (2004). Concentrations of, Ni, Pb, Zn, Cu, (mg kg^{-1}) were determined using an inductively coupled plasma-mass spectrometer (ICP-MS) (Ultima 2 JY Plasma). Soil physical and chemical properties were measured according to (Cassel and Nilsen 1986; Gee and Bander 1986; Rhoades 1982) as shown in Table 2. Also, the chemical properties of irrigation water were estimated according to Richards (1968) as shown in Table 2. Water irrigation was analyzed according to the methods described by American Public Health Associated (APHA) (2005).

Map 1. Map of Agricultural Experimental and Research station King Saud University, Riyadh.

Table 1. List of studied bread wheat landraces.

Serial	Local Name	Accession ID number	Collected location status
[1]L1	Burr	573	Al-Quwarah (Al-Qassi Province), Saudi Arabia
L2	Baldy Burr	181	Gazan (Jizan Province), Saudi Arabia
L3	Burr	317	Al-Khabraa (Al-QassiProvince), Saudi Arabia
L4	Alssaaa Burr	357	North Ad-Dahnaa (North of the edial of Saudi Arabia), Saudi Arabia
L5	Bahaal Burr	21	Tair, Alajah (Riyadh Province), Saudi Arabia
[2]C6	Classic Burr	---	Cultivar, USA
C7	Yecora Rojo	---	Cultivar, sei dwarf, early mature, USA

[1]L: landrace. [2]C: cultivar; ID: identifying information.

Measurements of growth and yield 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. The number of spikes per plant determined as the count of spikes per plant 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. At maturity stage, the inner four rows of each subplot unit were harvested to estimate yield traits, ten guarded plants were randomly collected from each plot for subsequent measurements as follows i.e., plant height (cm), spike length (cm), number of tillers, number of spikes, spike weight(gm), 1000-grain weight(gm) and grain yield per plant.

Element's determination in soil and plant

At harvest, three plants were collected at random from each landrace of the field plots (three replicates for each water treatment). Grains were ground. Half gram of grounded seeds of wheat grains was wet digested using a Sulphuric-perchloric-acids mixture ($HClO_4$+ H_2SO_4) acids according to the procedure of Chapman and Pratt (1962). Total Nitrogen (N) in plant samples was determined by Kjeldahel technique Jackson (1973). Total K and Na in plant samples were determined by Flame photometer as described by Jackson (1967). The total content of (N, P, K, Ca, Mg, Cu, Fe, Mn, and Zn) in plant samples was determined by inductively coupled plasma spectrometry (ICP-MS) (Ultima 2 JY Plasma) city and country.

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

Physicochemical properties of soil		Physicochemical properties of irrigation water			
			Freshwater	Well water	Municipal wastewater
pH	8.46	EC (dS m^{-1})	7.01	8.20	6.96
EC (dS m^{-1})	0.37	HCO_3+ CO_3(mg/Kg)	0.65	3.08	1.92
HCO_3+ CO_3(mg/Kg)	0.80	TDS (ppm)	0.3	2.94	3.5
TDS (ppm)	239	Cl	418	2089	1186
Cl	2.00	SO_4	3.5	10.4	9.2
SO_4	0.90	EC (dS m−1)	2.74	3.45	6.54
Available N (mg) kg−1)	29.00	N (mg kg^{-1})	0.10	6.30	11.95
Available P (mg) kg−1)	5.83	P (mg kg^{-1})	1	12.30	17.00
Available K (mg) kg−1)	189.33	K (mg kg^{-1})	0.37	0.34	0.42
Ca (mg L^{-1})	0.14	Ca (mg L^{-1})	1.65	2.87	8.75
Mg (mg L^{-1})	0.20	Mg (mg L^{-1})	0.91	1.36	2.05
Na (mg L^{-1-1})	1.24	Na (mg L^{-1})	3.62	7.94	8.02
Available micronutrient (mg kg−1)		Micronutrient (mg) kg−1)			
Fe	11.98	Fe	0.58	18.02	83.11
Cd	0.00	Cd	Nil	0.02	0.1
Cu	5.11	Cu	Nil	1.40	2.46
Mn	1.95	Mn	1.95	9.23	20.24
Pb	0.00	Pb	Nil	1.7	4.8
Zn	0.00	Zn	0.0	2.0	2.7

pH: hydrogen potential. EC: electrical conductivity; ds: decisiemens; TDS: total dissolved solids.

Statistical analysis

Multivariate Analysis of Variance (MANOVA) was used to test the variation between main factors (irrigation treatment, landraces, and interaction between treatment and landraces) LSD (Pairwise comparison) used for the comparison of means. All statistical analysis was carried out by using SPSS.

3. Results

Effect of irrigation treatments on growth and yield

The three irrigation water treatments significantly ($P<0.000$) affected all growth and yield traits of different wheat plants (Table 3 and 4). Wheat plants irrigated by TMW were taller (117.3 cm) with multi tillers (22 tiller $plant^{-1}$), had maximum spikes per plant (2.6 spikes/plant), and longer weighty spikes (14.5 cm & 12.1 g). Moreover, these plants had a greater yield per plant (49.8 g $plant^{-1}$) and higher 1000 grains weight (12.5 g) when compared to the other types of irrigation water (Table 5).

Table 3. Multivariate tests.

Effect	Value	F	Hypothesis df	Error df	Sig.
Treatments	1.52	16.68	14.00	74.00	0.000
Landraces	3.68	9.27	42.00	246.00	0.000
Treatments * Landraces	2.84	2.39	84.00	294.00	0.000

Effect of landraces on growth and yield

The effect of landraces on plant growth and yield traits was highly significant (Table 3 and 4). Table 5 showed that plant height of Landraces L3, C6, L5, and L1 (128, 120, 119 and 116 cm) but landraces L1, L2 and C7), had maximum tillers (22) while landraces L4, L5, and C7 had more spikes per plant (more than 20 spikes) and the longer spikes were recorded in L5, C7 and L1, heavy spikes were reported in L5, L2, L1, C6 and C7 consequently (111.3, 10.3 and 10.2 g). Moreover, these landraces plants had a greater yield per plant (between 32- 51 g plant^{-1}) and higher thousand grains weight (11-12 g).

Table 4. Tests of Between-Subjects Effects.

Source of variation	Dependent Variable	Type III Sum of Squares	df	mean Square	*F*	P-value
Treatments	Plant height (cm)	9692.67	2	4846.33	253.80	0.000
	Tiller number	612.69	2	306.34	209.78	0.000
	Spike number	16.53	2	8.27	574.07	0.000
	Spike length (cm)	220.22	2	110.11	28.67	0.000
	Spike weight (g)	134.57	2	67.29	70.65	0.000
	1000 grain weight(g)	239.65	2	119.83	42.65	0.000
	Yield / plant (g)	2931.09	2	1465.55	2148.58	0.000
Landraces	Plant height (cm)	31503.08	6	5250.51	274.97	0.000
	Tiller number	312.76	6	52.13	35.69	0.000
	Spike number	8.30	6	1.38	96.08	0.000
	Spike length (cm)	228.76	6	38.12	9.93	0.000
	Spike weight (g)	31.71	6	5.28	5.55	0.000
	1000 grain weight	162.60	6	27.10	9.65	0.000
	Yield / plant (g)	1958.76	6	326.46	478.61	0.000
Treatments ×Landraces	Plant height (cm)	2039.11	12	169.93	8.89	0.000
	Tiller number	49.52	12	4.13	2.83	0.006
	Spike number	1.06	12	0.09	6.14	0.000
	Spike length (cm)	49.33	12	4.11	1.07	0.408
	Spike weight (g)	11.43	12	0.95	1.00	0.466
	1000 grain weight(g)	27.68	12	2.31	0.82	0.628
	Yield /plant (g)	94.12	12	7.84	11.49	0.000

df: degree of freedom. F: variance of the group means; Sig. significant; P-value: is the level of marginal significance.

Table 5. Effect of irrigation treatments and landraces on growth and yield traits.

Experimental factor	means of dependent variables						
	Plant height (c)	Tiller number	Spike number	Spike length (cm)	Spike weight (g)	1000 grain weight(g)	Yield /plant (g)
Irrigation	***	***	***	***	***	***	***
FW	100.62 ^{b}	18.67 b	1.90 ^{b}	12.48 ^{b}	10.05 ^{b}	9.81 ^{b}	43.25 ^{b}
WW	86.95 ^{c}	14.38 ^{c}	1.33 ^{c}	9.95 ^{c}	8.48 ^{c}	7.76 ^{c}	33.24 ^{e}
TMW	117.29 ^{a}	22.00 ^{a}	2.59 ^{a}	14.52 ^{a}	12.09 ^{a}	12.52 ^{a}	49.82 ^{a}
Landraces/Cultivar	***	***	***	***	***	***	***
L1	116.11 ^{b}	21.78 ^{a}	1.45 ^{e}	13.44 ^{ab}	10.01 ^{a}	11.22 ^{ab}	43.90 ^{c}
L2	75.00 ^{c}	21.56 ^{a}	1.64 ^{d}	9.11 ^{c}	9.57 ^{b}	7.11^{c}	44.98 ^{b}
L3	128.00 ^{a}	17.33 ^{bc}	1.62 ^{d}	10.33 ^{c}	9.68 ^{b}	8.33 ^{bc}	38.58 ^{e}
L4	75.22 ^{c}	18.22 ^{b}	2.34 ^{b}	11.89 ^{bc}	8.23 ^{c}	9.89 ^{b}	39.72 ^{d}
L5	118.78 ^{b}	16.67 ^{c}	2.07 ^{c}	15.11 ^{a}	9.01 ^{bc}	12.00 ^{a}	31.61^{e}
C6	120.11 ^{b}	17.33 ^{bc}	1.95 ^{d}	12.67 ^{b}	10.68 ^{a}	10.67 ^{ab}	50.89 ^{a}
C7	78.11 ^{c}	21.78 ^{a}	2.50 ^{a}	13.66 ^{ab}	9.57 ^{b}	11.00 ^{ab}	40.00 ^{d}

***, **, *: Significant at probability p≤0.001, p≤0.01 and p≤0.001 (Fisher's test).FW: freshwater; WW: well water; TMW: treated municipal wastewater; The letters a, b, c, d, e and f refer to the difference between means obtained by the SPSS method.

Interaction Effect of treatments and landraces on growth and yield

The irrigation treatments and landraces interaction had a significant effect on plant growth in terms of plant height, tillers, and spikes number except for spike length. Yield traits were not significantly affected with exception of grain yield per individual plant (Table 4 and 5). Comparing the growth means of the wheat plant, Figure 1 indicated plants of L3and L1 had maximum height (132 and 120 cm), while the least height was recorded in plants of L2 andC7 (71 and 72 cm) under irrigation by FW. Landraces (L3 and C6) treated with WW were taller (111 and 106 cm), while plants of L2 and L4 had the shortest height (67 and 68 cm). Maximum heights under TMW irrigation were reported in plants of L1 and L3 (143 and 142cm). In contrast, plants of L4 had minimum height (84 cm). Plants tillering not so far differ from plants height, L1, L3 had more tillers under FW and TMW, while C7 and L5 plants were shorter. L4 and C7 had more spikes and L1, L3 and L4 had the least number of spikes per plant under all irrigation treatments. Plants of L5 had maximum spike length under all treatments, and L2 plants had minimum spikes per plant. Comparing the interaction effect of treatments and landraces on yield performance of the wheat plant, Figure 2 indicated, plants of C6, L1, and L3 had maximum spikes weight (11.3,10.7, and 10.3 g), and the least spikes weight recorded in plants of L4 (8.7g) under irrigation by freshwater. Spike's weight of C6 plants treated with WW gave 9.7 g, while plants of L4 and L5 had the least spike weight (7.3 g). Under TMW irrigation the highest spikes weight (13 g) was obtained in C6 and C7 plants and minimum spikes weight was in plants of L4. The maximum yield per plant under the three-irrigation treatment was found in plants of C6 (58, 52, and 42) under TMW, FW, and WW respectively, with exception of L1 and L2 yield (53 and 55 g) under TMW. The yield of L3 (29 g) under WW. The highest 1000 seed weight was recorded in L5, and the least was obtained in L2 under all treatments (Figure 3).

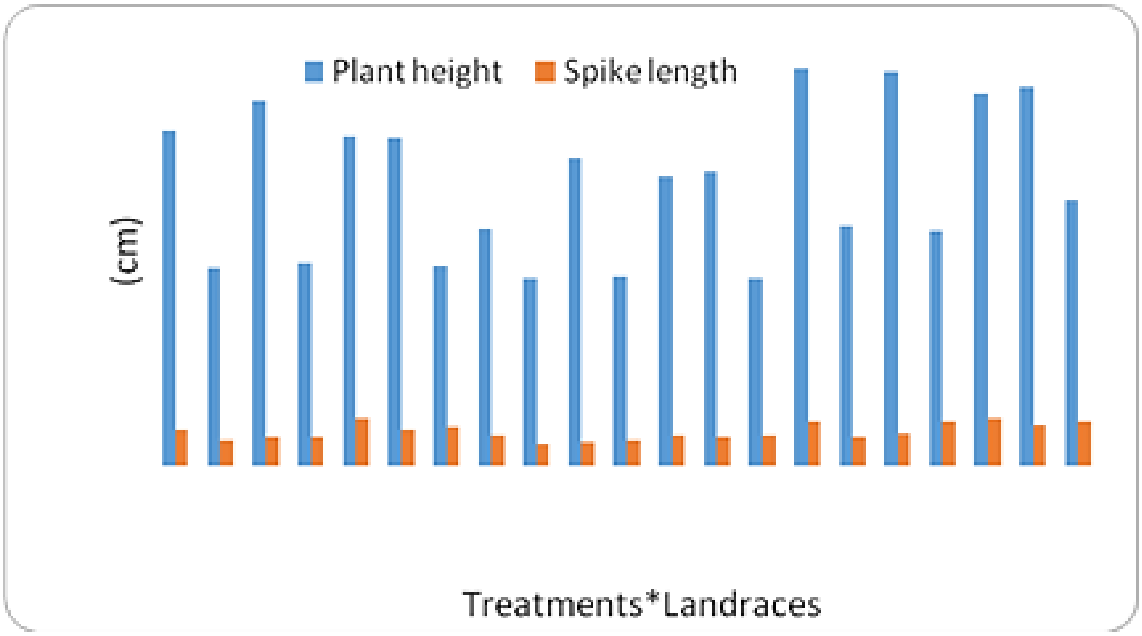

Figure 1. Interaction effect of treatments*landraces on plant height and spike length (cm).

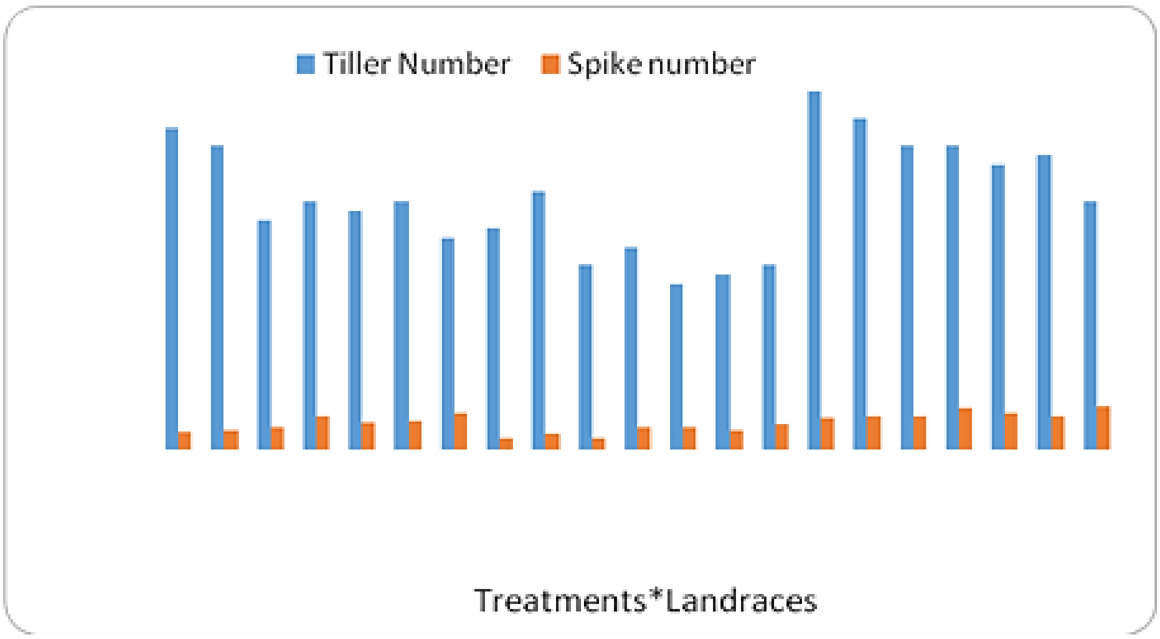

Figure 2. Interaction effect of treatments*landraces on tiller and spike number per plant.

Effect of irrigation treatments on grain elements content

Statistical analysis (Multivariate test, and tests of Between-Subjects Effects) indicated that the main interaction effects of irrigation treatments and landraces of wheat on macro and microelements content in grains were highly significant (Table 6 and 7). Comparing the three irrigation treatments, the average concentration of N, P, K, Mg, Cu, Fe, Mn, and ZN in various wheat plants was higher under TMW (the concentration of these four elements in order of TMW> FW> WW), while plants irrigated with FW accumulated higher content of Ca in their grain (Table 8).

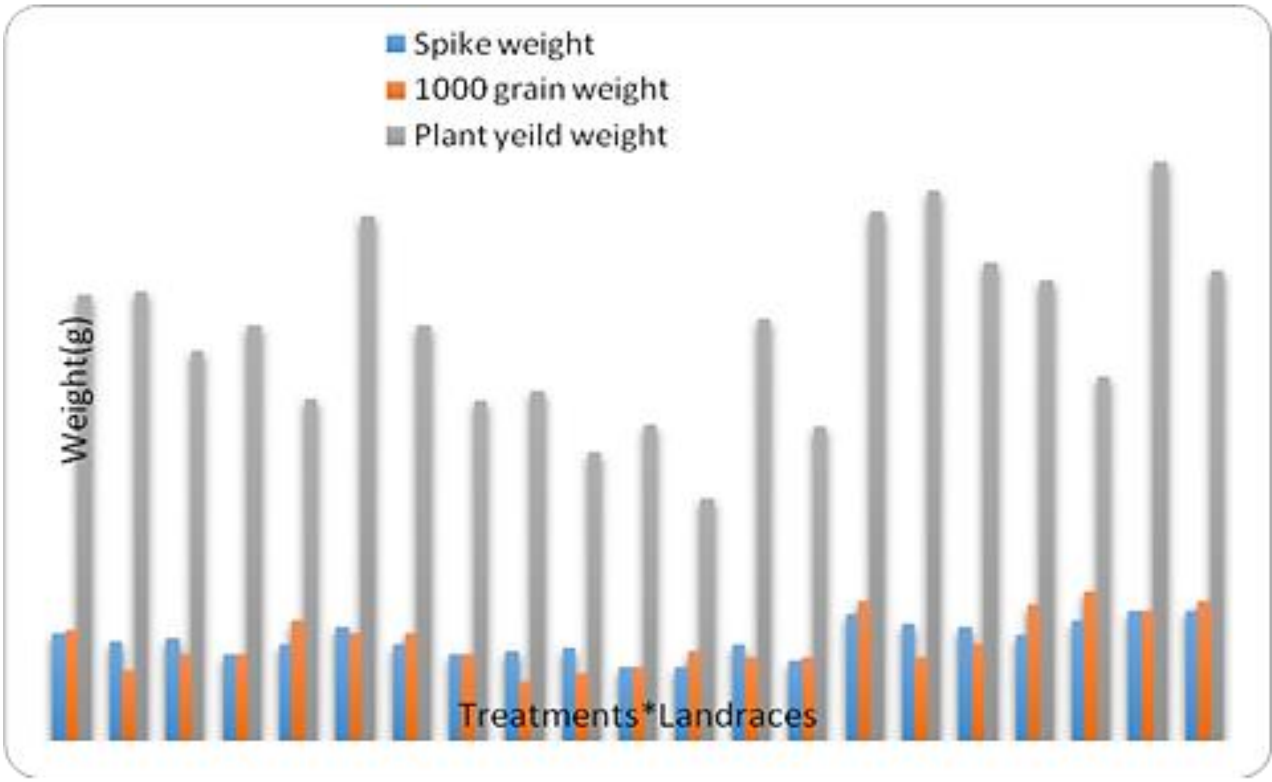

Figure 3. Interaction effect of treatments*landraces on spike weight, 1000 grain and plant yield weight (g).

Effect of landraces grain elements content

Effect of landraces revealed that wheatlandraces L1, L2, and L3 had accumulated higher contents of N, P, K, Ca, and Mg. the contents of these elements in the five landraces and two cultivars were in order of L3>L2>L4>L5>L1>C6>C7. as well these landraces had accumulated higher contents of Cu, Fe, Mn, and Zn. The overall contents of these elements in landraces and cultivars were in order of Cu content L1>L2 & L 3>L4>L5> C6>C7, Fe content L2>L1>L3>L4>L5>C6>C7, Mn content L3>L5>L2>L4>C6>C7, Zn content L3>L2>L3>L4>L5>C6>C7 (Table 8). While Zn grain content in L3 (76.90 mg kg^{-1}).

Interaction effect of treatments and landraces grain elements contents

The interaction effect of the two main factors (irrigations treatments and landraces) on grain elements content was highly significant (Table 6 and 8). When comparing the means of macroelements concentration in the grain of landrace, the results showed that the highest contents of N, P, K, Ca, and Mg reported in grain were 2.81,0.34,0.39,0.12 and 0.1 mg kg^{-1} recorded in L3 and L4 irrigated with TMW comparing to other landraces and cultivars (Figure 4). The results demonstrate that microelements content in grain of landraces and cultivars under the three irrigation treatments, as follows the highest contents (41, 137, 79, 77 mg kg^{-1}) of Cu, Fe, Mn and Zn were recorded in the grain of L1, L2, L3 irrigated by TMW, while C7 had the least content of these elements under the effect of the three irrigation water (Figure 5).

Table 6. Multivariate test.

Effect	Value	F	Hypothesis df	Error df	Sig.
Treatments	1.998	2804.872	24.000	64.000	0.000
Landraces	5.528	35.137	72.000	216.000	0.000
Treatments * Landraces	8.024	7.062	144.000	504.000	0.000

df: degree of freedom. F: variance of the group means; Sig. significant; P-value: is the level of marginal significance.

Table 7. Tests of Between-Subjects Effects.

Source	Dependent Variable	Type III Sum of Squares	df	mean Square	F	Sig.
	N	2.103	2	1.051	13246.980	0.000
	Ca	.002	2	.001	39.789	0.000
	K	.039	2	.019	71.787	0.000
	P	.038	2	.019	390.613	0.000
Treatments	Mg	.005	2	.003	185.444	0.000
	Cu	10.823	2	5.412	2841.083	0.000
	Fe	437799.552	2	218899.776	20525.180	0.000
	Mn	591.214	2	295.607	8996.729	0.000
	Zn	970.936	2	485.468	352.396	0.000
	N	6.122	6	1.020	12857.027	0.000
	Ca	.001	6	.000	4.281	0.002
	K	.011	6	.002	6.821	0.000
	P	.013	6	.002	44.140	0.000
Landraces	Mg	.001	6	.000	11.778	0.000
	Cu	17.555	6	2.926	1536.083	0.000
	Fe	8304943.260	6	1384157.210	129785.771	0.000
	Mn	722.344	6	120.391	3664.063	0.000
	Zn	1569.977	6	261.663	189.939	0.000
	N	.863	12	.072	906.307	0.000
	Ca	.001	12	.000	3.991	0.000
	K	.012	12	.001	3.616	0.001
	P	.005	12	.000	9.301	0.000
Treatments * Landraces	Mg	.000	12	3.254E-5	2.278	0.025
	Cu	3.612	12	.301	158.042	0.000
	Fe	813011.234	12	67750.936	6352.680	0.000
	Mn	79.189	12	6.599	200.841	0.000
	Zn	408.998	12	34.083	24.741	0.000

df: degree of freedom. F: variance of the group means; Sig. significant; P-value: is the level of marginal significance .

Table 8. Effects of treatments and landraces on macro and microelements content.

Experimental factor	Element Content (mg /kg)								
	N	P	K	Ca	Mg	Cu	Fe	Mn	Zn
Irrigation treatments	***	***	***	***	***	***	***	***	***
FW	1.75^{b}	0.28^{b}	0.31^{b}	0.12^{a}	0.08^{b}	38.90^{c}	47.55^{c}	72.53^{b}	65.77^{c}
WW	1.65^{c}	0.25^{c}	0.29^{c}	0.11^{ab}	0.07^{c}	39.28^{b}	55.72^{b}	67.923^{c}	68.45^{b}
TMW	2.08^{a}	0.31^{a}	0.35^{a}	0.11^{ab}	0.09^{a}	39.91^{a}	67.84^{a}	75.36^{a}	75.11^{a}
Landraces/Cultivar	***	***	***	*	***	***	***	***	***
L1	1.79^{d}	0.27^{bc}	0.29^{c}	0.11^{ab}	0.09^{a}	40.10^{a}	100.63^{b}	71.87^{e}	71.90^{c}
L2	1.45^{g}	0.30^{a}	0.32^{b}	0.12^{a}	0.08^{b}	39.80^{b}	118.78^{a}	73.46^{c}	74.68^{b}
L3	2.25^{b}	0.29^{a}	0.34^{a}	0.120^{a}	0.09^{a}	39.82^{b}	67.87^{c}	77.47^{a}	76.90^{a}
L4	2.30^{a}	0.27^{b}	0.32^{b}	0.10^{c}	0.08^{b}	38.70^{d}	31.35^{de}	72.05^{d}	68.81^{d}
L5	1.85^{c}	0.28^{b}	0.31^{b}	0.08^{d}	0.07^{b}	39.23^{c}	29.27^{e}	74.06^{b}	69.37^{d}
C6	1.66^{e}	0.27^{b}	0.31^{b}	0.07^{c}	0.08^{b}	39.23^{c}	26.69^{f}	67.53^{f}	65.93^{e}
C7	1.51^{f}	0.25^{c}	0.32^{b}	0.08^{c}	0.08^{b}	38.63^{e}	24.67^{g}	67.10^{g}	60.88^{f}

***, *: Significant at probability p≤0.001 and p≤0.001 (Fisher's test). FW: freshwater; WW: well water; TMW: treated municipal wastewater; the letters a, b, c, d, e, f and g refer to the differences between means obtained by the SPSS method.

4. Discussion

The results showed that L1 and L3 plants have grown well under all irrigation treatments, while L2 and L4 had shorter plants in all treatments especially under WW (Table 6, Figure 1, 2 and 3). In general, L1 and C6 had the highest yields under FW and TMW. L5 and 6 under WW, as conclusion L1 and L3 grown well under all treatments, but L1, L5, and C6 grown well and had higher yield under TMW. L2, L4 had reduced growth and fewer yields and C7 is moderate. The results stated that TMW irrigation significantly improved some wheat landraces (L1, L5, and C6) growth in terms of height, tillering, spikes number, and length. This may be due to the improvement of soil nutrients irrigated by TMW and the ability of plants to absorb it without causing toxicity. This finding was in line with any studies such as Khan et al. (2009) in the survey found that sunflower growth characteristics were substantially increased by treated wastewater. Galavi et al. (2009) reported that the existence of specific nitrogen and potassium in wastewater improved plant growth, cell reproduction and plant resistance, and eventually stem diameter increased in sorghum. In several studies, treated municipal wastewater has been reported to improve the growth of different plants (Fonseca et al. 2007). Under irrigation of treated wastewater, Hussain et al. (1996) found an increase in wheat yield wastewater, an increase of maize grain (Vazquez-Montiel et al. 1996; Oron et al. 1999). Treated wastewater contains nitrogen and phosphorus which enhanced plant growth, such as wheat (Kenneth 2018). Overall, L3 is the landrace that had the highest N, P, K, Ca, and g in grain under TMW compared to all other landraces under all three irrigation treatments. Obviously, the results concluded that TMW increases macro and microelements concentration in the grain of the studied landraces. Landraces L3 had higher contents of microelements under the TMW effect. In addition, wheat plants irrigated by TMW had the highest contents of trace elements although all landraces had approximately the same contents of Cu and Fe, but L1, L2, and L3 grain had the highest content of Fe. The grain of L3 had the highest Mn content. Regarding interaction effect, in germinal L1, L2 and L3 accumulated the highest content of trace elements. Previously increasing of heavy elements in wheat parts under sewage water was reported by Karatas et al. (2006). Certainly, sewage water consists of several macro and micro-nutrients, which can improve crop growth (Singh and Agrawal 2008; Srinivas et al. 2014; Galal and Shehata 2015; Anwar et al. 2016). for instance, Rattan et al. (2005) found a high amount of phosphorus, potassium, sulfur, zinc, and manganese in sewage water which improved the soil organic matter contents (38–79%) than the well water. Sewage water application also reduced the soil pH by 0.4 units. However, the concentration of Cu was higher than the permissible concentration in the plant system, which is 10.0 ppm (World Health Organization (WHO) 1996), Zn content, is less than the safe limit (99.4 mg kg^{-1}) of FAO/WHO (2001). This study designated that various wheat landraces and cultivars investigated in this study were significantly ($p < 0.01$) differed in their plant height, tiller and spike number, yield (grain yield per plant). These variations of traits may be attributed to the different genetic structures of the studied landraces, which are associated with yield. This genetic diversity may be used for the development of wheat cultivars to specific climatic conditions to maximize productivity (Ogbonnaya et al. 2017), especially under arid climates.

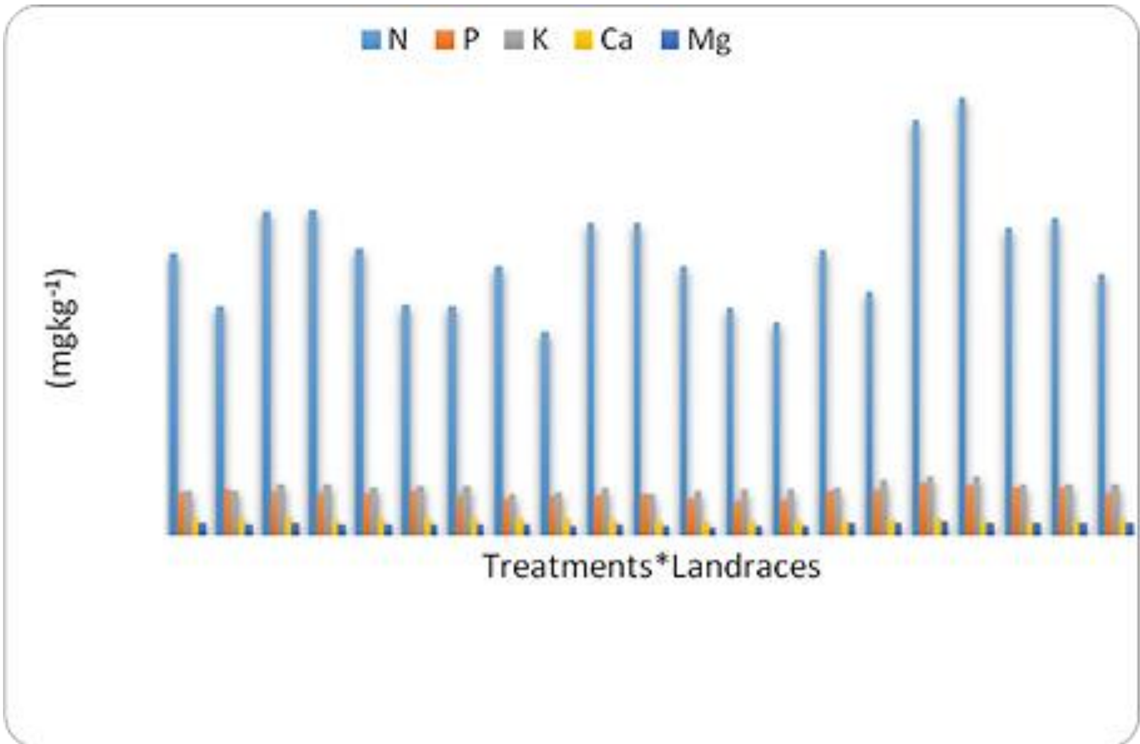

Figure 4. Interaction effect of irrigation treatments*landraces on N, P, K, Ca &g content in grain.

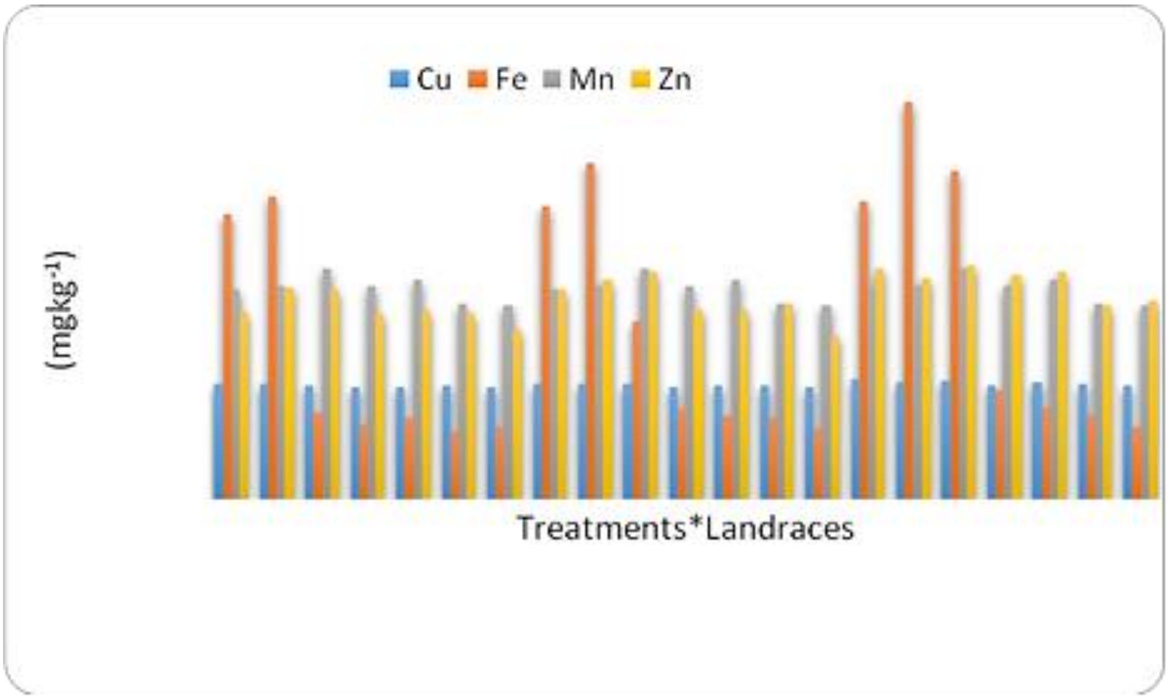

Figure 5. Interaction effect of irrigation treatments*landraces on Cu, Fe, Mn, and Zn content in grain.

5. Conclusions

The use of treated wastewater enhanced the performance of different wheat landraces followed by irrigation with fresh water against the well water which was attributed to the build-up of macronutrients (total nitrogen, available phosphorus, and extractable potassium) and improvement in the soil organic matter in the experimental soil. The improvement in wheat performance was visible through improvement in the plant height, tillers, spikes, spike length, 1000 grain weight, and grains weight per plant. Thus, the sewage water might be used as an alternate source of irrigation in those arid lands where the canal and well water are not available for irrigation purposes. However, some wheat landraces grain contained higher amount of needed elements for dietary intake (like Fe, Mg, Cu, and Zn), accordingly, an investigation is needed in future long-term studies under arid climates to avoid any health risk, as wheat is a major food of any people across the world, including Saudi Arabia.

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