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Effect of Saline Irrigation on Biomass Yield and Mineral Composition of Barley (*Hordeum vulgare* L.) under Greenhouse Conditions

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Abstract: A greenhouse experiment was carried out to determine the effect of saline irrigation on biomass yield, protein, phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg) composition of four barley (*Hordeum vulgare* L.) cultivars in a pot experiment. Mean biomass yield (drymatter) decreased significantly with increasing irrigation water salinity. The drymatter yield ranged between 56.1 g per pot (Qatifi) with water EC of 2.85 dS m^{-1} to 11.5 g per pot (Gusto) with water EC of 15.95 dS m^{-1}. The trend of biomass yield reduction among various cultivars (drymatter) was Gusto > Alkharji > Haili > Qatifi. Overall sequence of salt tolerance for different barley cultivars was Qatifi > Haili > Alkharji > Gusto. Mean protein contents ranged between 14.5-29.5% (Qatifi), 16.12-20.3% (Haili), 15.5-21.3% (Gusto) and 16.3-22.7% (Alkharji) among various barley cultivars receiving waters of different salinities. Mean concentration of different macro-elements in barley plants were 0.15-0.27% P, 2.2-4.6% K, 0.9-2.9% Na, 0.41-0.99% Ca and 0.31-0.82% Mg. The concentration of protein, sodium, calcium and magnesium increased while that of phosphorus and potassium decreased in barley plants increasing salinity of irrigation water. A comparison among different cultivars indicated that irrigation waters with EC of 13.75 dS m^{-1} and above reduced biomass yield to a significant level. In conclusion, there is an excellent potential for reasonable production of barley as forage crop containing appreciable protein contents and other essential mineral elements with irrigation water of EC upto 9.72 dS m^{-1} provided 15-20% extra water above crop water consumptive use is applied as leaching requirements to control soil salinity.

Key words: Water salinity, germination, biomass, protein, mineral concentration, leaching requirements

INTRODUCTION

Barley is the second most important cereal crop after wheat in Saudi Arabia. It is mainly used for consumption as feed for animals but also for humans being. Its seed is being imported in large quantities to feed animals as a staple food. Its production in Saudi Arabia has increased from 4500 tons (1982) to 230,000 tons[1] over a period of nineteen years. It is grown under a wide variety of soil, water and plant growth conditions. Heakal *et al.*[2] reported that drymatter yield at maturity of plant tops decreased with increasing salinity of irrigation water. Koszanski and Karczmarczyk[3] observed reduced plant height, grain yield and straw yield of spring barley and oats in a greenhouse experiment irrigated with undiluted or diluted seawater. Saline irrigation increased plant contents of N, P, K, Ca, Zn, but especially Mg and Na, but reduced Fe contents. Wilczek and Cwintal[4] stated that use of coal mine effluent containing 822-936 mg Cl and 669-785 mg Na dm^{-3} increased Na and Cl contents of barley straw more than those of grain. Essa[5] found that salinity stress induced a significant increase in plant leaf Na and Cl, but reduced the accumulation of K, Ca and Mg contents in all the cultivars. But Pal *et al.*[6] concluded that barley could be grown economically with irrigation water upto EC 16 dS m^{-1} under field conditions. Recently, Ghoulam *et al.*[7] concluded that high NaCl concentration in irrigation water caused a great reduction in fresh and dry weight of leaf and root of sugar beet. Also the water contents and the K concentration decreased but Na and Cl contents were highly increased in plant leaves. Wang *et al.*[8] observed 50% biomass yield reduction in elephant grass when EC_{iw} increased from 5 to 25 dS m^{-1}. Banuelos *et al.*[9] concluded that dry matter production and nodulation in faba bean were significantly affected by salinity level of 10 dS m^{-1}.

It is, therefore, important to study the performance and mineral composition of barley plants especially when saline irrigation water is to be used as a supplemental source of irrigation. This study was carried out to determine the effect of saline irrigation on biomass yield and mineral composition of different barley cultivars under greenhouse conditions.

MATERIALS AND METHODS

The experiment was carried out in greenhouse at Al-Muzahmiyah Research Station, Natural Resources and

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The experimental treatments were a sandy soil , four barley cultivars namely Qatifi, Gusto, Haili and Alkharji, with five irrigation water salinities (2.85, 5.86, 9.72, 1375 and 15.95 dS m^{-1}) and having three replicates. In all there were 60 pots. The experiment was laid out by following a Split Plot Design.

Procedure: The experiment was carried out in plastic pots with a mean diameter of 24 cm and a height of 20 cm. Sandy soil (sand 90%, silt 6% and clay 4%) with a pH of 7.72, electrical conductivity of saturation extract (EC_e) of 1.35 dS m^{-1}, Sodium Adsorption Ratio (SAR) of 2.75 and a field capacity of 8.25% by weight was used for experiment. The soil was collected from the Research Station, King Abdulaziz City for Science and Technology, Al-Muzahmiyah about 70 km west of Riyadh, air-dried and passed through 2 mm sieve. Each pot was filled with 10 kg of soil upto 15 cm height which left about 5 cm for irrigation. Most agricultural soils of Saudi Arabia are sandy and calcareous in nature[10].

Four barley (*Hordeum vulgare* L.) cultivars namely Qatifi, Haili, Alkharji (local cultivars) and Gusto (an American cultivar) were planted. Five groundwater samples with water salinity ranging from 2.85 to 15.95 dS m^{-1} and SAR from 4.5 – 37.1 were collected from Al-Muzamiyah area. The mean chemical composition of irrigation waters is given in Table 1.

Barley was planted in each pot on March 10, 2004 at a rate of 130 kg seed ha^{-1} (about 20 seeds per pot). Enough irrigation water was applied to maintain field capacity plus 15% as a leaching requirement to maintain soil salinity within acceptable limits for normal plant growth. The water requirement for barley crop was calculated according to Al-Zeid *et al.*[11] recommended for the area. The amount of irrigation varied between 1.50-2.00 liters per pot per irrigation with an interval of 2 to 3 days between each irrigation during the growing period. On the average, a total of 1.75 liters of water per irrigation per pot was applied manually with the help of a graduated cylinder as a surface irrigation. The crop received a total of 23 irrigations during the growth period with an average of 2-3 irrigations during a week. The total quantity of irrigation water applied came to 40.25 L per pot for the total growing period of 75 days.

Crop growth parameter such as total biomass was recorded on whole pot. The plant samples were collected, washed with 0.01N HCl and then rinsed with distilled water, dried in an oven at 75°C to a constant weight, ground in a Wiley Mill and stored for chemical analyses. The plant material was analyzed for mineral composition by the wet digestion method of Page *et al.*[12]. The total growing period of the crop was 75 days starting from March 15 to May 30, 2004.

The soil samples were also collected at the time of crop harvesting, air-dried and stored for analyses. The soil physical and chemical analyses were done according to the methods described in USDA Handbook No. 60[13]. The data were subjected to analysis of variance techniques[14].

RESULTS AND DISCUSSION

Biomass (dry matter) yield: The dry matter yield decreased significantly with increasing irrigation water salinity (Table 2). The biomass (dry matter) yield per pot (g) ranged between 15.0-56.1 (Qatifi), 12.5- 49.1 (Haili), 11.5-42.8 (Gusto) and 12.8-56.2 (Alkharji) in different water salinity treatments. The difference in yield of Qatifi cultivar was not significant between W-1 and W-2 as well as between W-4 and W-5 treatments ($LSD_{0.05}$ = 4.967). The difference in yield of Haili cultivar was not significant between W-1 and W-2 as well as between W-4 and W-5 treatments ($LSD_{0.05}$ = 5.895). The difference in yield of Gusto cultivar was not significant between W-2 and W-3 as well as between W-4 and W-5 treatments ($LSD_{0.05}$ = 3.879). The difference in yield of Alkharji cultivar was significant among all the treatments ($LSD_{0.05}$ = 3.465). The barley biomsss (dry matter) yield decreased significantly with an increase in irrigation water salinity for all the cultivars. Based on irrigation water EC of 15.9 dS m^{-1}, the sequence for yield decrement was Qatifi < Haili < Alkharji < Gusto. The local barley

Table 1: Mean chemical composition of irrigation waters

Water No.	pH	EC (dS m^{-1})	TDS	Ca^{2+}	Mg^{2+}	Na^+	K^+	HCO_3^-	Cl^-	SO_4^{2-}	SAR
			mg L^{-1}								
W-1.	7.5	2.85	1824	253	94	331	18	77	43	1393	4.50
W-2.	7.8	6.45	4128	185	83	793	23	180	919	2037	12.13
W-3.	7.80	9.72	6220	303	54	1160	55	176	2231	2439	16.05
W-4.	7.9	13.75	8800	716	111	3045	36	180	3600	3095	27.89
W-5.	8.0	15.85	10,208	842	142	4200	23	170	4953	3835	37.10

EC = Electrical Conductivity, TDS = Total Dissolved Solids, SAR = Sodium Adsorption Ratio

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cultivars showed more salt tolerance than the imported cultivar Gusto.

Protein contents: Mean protein contents (%) of plants ranged between 14.5-29.5 (Qatifi), 16.7-20.3 (Haili), 15.5-21.3 (Gusto) and 16.3-22.2 (Alkharji) irrigated with waters of different salinities (Table 2). The protein contents increased significantly with an increase in irrigation water salinity compared to the control water (EC of 2.85 dS m^{-1}) [$LSD_{0.05}$ of 9.812 (Haili), 3.240 (Qatifi), 4.443 (Gusto) and 5.992 (Alkharji)]. This could be attributed to the stunted plant growth (low biomass yield) receiving highly saline irrigation water thus resulting in more accumulation of N in barley plants. However, increasing trend in the protein content of plants was observed with increasing irrigation water salinity.

Mineral composition of plants: Nitrogen Mean nitrogen contents (%) of barley plants ranged between 2.3-4.7 (Qatifi), 2.7-3.3 (Haili), 2.5-3.4 (Gusto) and 2.6-3.6 (Alkharji) irrigated with waters of different salinities (Table 3). The nitrogen contents of plants increased significantly with an increase in irrigation water salinity compared to the control treatment [$LSD_{0.05}$ of 1.546 (Qatifi), 0.518 (Haili), 0.710 (Gusto) and 0.979 (Alkharji)]. The higher N contents in plants under highly saline irrigation could be due to stunted plant growth thus resulting in more accumulation of nitrogen. Koszanski and Karczmarczyk[3] also reported increase in nitrogen contents of barley plants receiving saline irrigation.

Phosphorus: Mean P contents (%) of barley plants ranged from 0.15-0.27 (Qatifi), 0.16-0.27 (Haili), 0.17-0.28 (Gusto) and 0.13-0.19 (Alkharji) receiving waters of different salinities (Table 3). There was a significant increase in P in barley plants with an increase in irrigation water salinity compared to the control treatment (EC_i = 2.85 dS m^{-1}). The P contents showed significant increase up to water salinity of 9.7 dS m^{-1}. Although the P contents showed increases with increasing water salinity but the difference was not significant [$LSD_{0.05}$ of 0.048 (Qatifi),).066 (Haili), 0.055 (Gusto) and 0.361 (Alkharji)]. Koszanski and Karczmarczyk[3] also reported an increase in P contents of barley plants as water salinity increased.

Table 2: Effect of saline irrigation on biomass yield and protein content of barley plants

	Barley cultivars			
EC_i (dS m^{-1})	Qatifi	Haili	Gusto	Alkharji
Biomass (Dry matter) Yield (g pot^{-1})				
2.85	56.11a	49.11a	42.84a	56.18a
6.45	50.96a	46.32a	27.75b	35.77b
9.72	26.10b	29.15b	23.63b	29.85c
13.75	17.13c	14.42c	13.10c	20.45d
15.95	14.96c	12.49c	11.52c	12.84e
Protein (%)				
2.85	14.48b	16.67b	15.46b	16.27b
6.45	15.13b	18.19ab	17.30ab	16.90ab
9.26	20.33ab	19.13ab	17.86ab	17.19ab
13.75	22.98ab	20.73a	18.50ab	22.29ab
15.95	29.54a	20.27a	21.27a	22.71a

Figures in a column with the same letter(s) are not significantly different by $LSD_{0.05}$

Table 3: Effect of saline irrigation on mineral composition of barley plants

	Barley cultivars			
EC_i (dS m^{-1})	Qatifi	Haili	Gusto	Alkharji
Nitrogen (%)				
2.85	2.32b	2.67b	2.47b	2.60b
6.45	2.42b	2.91ab	2.77ab	2.70abb
9.72	3.25ab	3.06ab	2.86ab	2.75ab
13.75	3.68ab	3.32a	2.96ab	3.57ab
15.95	4.73a	3.24a	3.40a	3.63a
Phosphorus (%)				
2.85	0.146b	0.162c	0.168c	0.134c
6.45	0.150b	0.178c	0.214bc	0.145bc
9.72	0.170b	0.188bc	0.221bc	0.174ab
13.75	0.266a	0.243ab	0.229ab	0.184a
15.95	0.252a	0.273a	0.276a	0.190a
Sodium (%)				
2.85	1.29c	1.64b	0.90d	1.16d
6.45	1.68bc	2.08ab	1.44c	1.25cd
9.72	1.73b	2.18ab	1.63c	1.49bc
13.75	2.04b	2.31ab	2.33b	1.50b
15.95	2.55a	2.44a	2.86a	2.65a
Potassium (%)				
2.85	3.67a	4.58a	4.15a	2.56a
6.45	3.32ab	4.47ab	4.07a	2.19b
9.72	3.17b	4.17ab	3.73a	2.07b
13.75	2.77c	3.97b	2.73b	2.04b
15.95	2.42c	2.59c	2.16b	1.55c
Calcium (%)				
2.85	0.413b	0.581b	0.517c	0.390c
6.45	0.427b	0.594b	0.650bc	0.465bc
9.72	0.461b	0.696b	0.713ab	0.671ab
13.75	0.696a	0.717b	0.752ab	0.641ab
15.95	0.828a	0.867a	0.844a	0.850a
Magnesium (%)				
2.85	0.351b	0.446a	0.479c	0.306
6.45	0.396ab	0.528a	0.570bc	0.330a
9.72	0.421ab	0.554a	0.603bc	0.372a
13.75	0.426ab	0.590a	0.711ab	0.388a
15.95	0.501a	0.641a	0.819a	0.407a

Figures in a column with the same letter(s) are not significantly different by $LSD_{0.05}$

Sodium (Na): Mean contents (%) of sodium of barley plants ranged between 1.3-2.6 (Qatifi), 1.64-2.4 (Haili), 0.9-2.9 (Gusto) and 1.2-2.7 (Alkhariji) irrigated with waters of different salinities (Table 3). The Na contents of plants increased significantly with an increase in irrigation water salinity compared to the control (water EC of 2.85 dS m^{-1}) [$LSD_{0.05}$ of 0.416 (Qatifi), 0.743 (Haili), 0.272 (Gusto) and 0.251 (Alkharji)]. The increase in Na contents of barley plants could be due to high Na contents of irrigation waters which were high at higher water salinity levels. The other possible reasons could be due to low biomass yield and stunted plant growth. The results agree with those of Wilczek and Cwintal[4] who reported that coal mine effluent containing 822-936 mg Cl and 669-785 mg Na dm^{-3} increased both Na and Cl contents of barley straw.

Potassium (K): Mean K contents (%) of plants ranged between 2.4-3.7 (Qatifi), 2.6-4.6 (Haili), 2.2-4.2 (Gusto) and 1.6-2.6 (Alkharji) under different irrigation water salinity treatments (Table 3). The K contents of plants decreased significantly with an increase in irrigation water salinity compared to the control treatment [$LSD_{0.05}$ of 0.416 (Qatifi), 0.569 (Haili), 0.803 (Gusto) and 0.221 (Alkhariji)]. The significant decrease in K contents of plants might be due to the competitive phenomenon between Na and K of the irrigation waters. Because Na contents were higher than K in all the irrigation waters thus resulting in absorption of more Na than K ion by the plants.

Calcium (Ca): Mean Ca contents (%) in barley plants ranged from0.43-0.83 (Qatifi), 0.58-0.87 (Haili), 0.52-0.85 (Gusto) and 0.39-0.85 (Alkharji) irrigated with water of different salinities (Table 3). The Ca concentration of plants increased significantly with a increase in irrigation water salinity than control treatment [$LSD_{0.05}$ of 0.207 (Qatifi), 0.141 (Haili), 0.181 (Gusto) and 0.267 (Alkharji)]. The significant increase in Ca contents of barley plants could be due to high Ca contents of irrigation waters which might have caused higher uptake of Ca by barley plants.

Magnesium (Mg): Mean Mg contents (%) of barley plants ranged from 0.35-0.50 (Qatifi), 0.45-0.64 (Haili), 0.48-0.82 (Gusto) and 0.31-0.41 (Alkhariji) under different water salinity treatments (Table 3). The Mg contents increased significantly with an increase in irrigation water salinity compared to the control treatment [$LSD_{0.05}$ of 0.107 (Qatifi), 0.337 (Haili), 0.200 (Gusto) and 0.125 (Alkharji)]. Although, the Mg contents increased with an increase in irrigation water salinity, but the Mg in barley plants did not increase at water salinities of 9.7 and above.

DISCUSSION

This research has shown that increase in irrigation water salinity decreased crop yield. Koszanski and Karczmarczyk[3] observed that irrigation with sea water, undiluted or diluted with equal volume of fresh water, reduced plant height, grain yield and straw yield of spring barley and oats. They also observed that saline irrigation increased plant contents of N, P, K, Ca, Zn and especially Mg and Na but reduced Fe contents. Iyengar *et al.*[15] found differential response of 13 barley cultivars irrigated with diluted sea water. The results of this study indicate that dry matter was affected significantly with irrigation water salinity. The results agree with those of Abdul *et al.*[16] who found significant reduction in plant growth and mineral composition with increase in irrigation water salinity.

The present study showed that the concentration of N, Na, Ca and Mg increased; whereas the concentration of K and p decreased with an increase in irrigation water salinity. Similarly, Essa *et al.*[5], Ghoulam *et al.*[7], Koszanski and Karczmarczyk[3], Iyengar *et al.*[15] reported significant reduction in plant dry matter, significant increase in plant protein, N, Na, Ca and Mg and a reduction in plant P and K contents when irrigated with diluted or undiluted seawater in various barley cultivars. It was also observed that dry matter yield decreased from 25-55% with water EC of 9.7 dS m^{-1} and 65-79% with water EC of 15.9 dS m^{-1}. The reduction in yield was more in Gusto followed by Alkharji, Haili and Qatifi cultivars. The difference in dry matter yield could be attributed to the differential response of each cultivar receiving irrigation water of different salinities and the genetic variability of plants. The results were supported by Wang *et al.*[8] and Banuelos *et al.*[9], Heakal *et al.*[2], Koszanski and Karczmarczyk[3], Iyengar *et al.*[15] who found significant yield reduction with increase in irrigation water salinity from 5 to 25 dS m^{-1}. The sequence for salt tolerance among various cultivars was Qatifi > Haili > Alkharji > Gusto.

In conclusion, an acceptable barley production in terms of dry matter could be obtained with irrigation water EC upto 9.72 dS m^{-1} having appreciable amount of protein and other essential mineral elements provided 15-20% excess water is applied as leaching requirements under a given set of experimental conditions. It was also observed that any further increase in irrigation water salinity could reduce the crop yield upto 50% or more which seems below the economical level. These findings were in agreement with those of Pal *et al.*[6] who found that barley could be grown economically with irrigation water upto of EC 14 dS m^{-1}.

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