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The effect of irrigation management with saline and fresh water on some soil properties and wheat crop growth (*Triticum aestivum* L.)

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Abstract

Arid and semi-arid regions suffer from a sharp decline in rainfall and scarcity of good fresh water. This forces them to use saline water for irrigation, which can affect the growth and productivity of plants in terms of quantity and quality. So, good management and specific methods are required in the use of irrigation water. A factorial experiment was conducted with three factors in a silty clay soil, including irrigation water salinity 3, 5 and 7 dS m^{-1} (S1, S2, and S3) respectively. Saline irrigation water level 100 and 66% of field capacity (W1 and W2) respectively. Fresh water (0.8≃1.1) 0, 50, and 100% of field capacity (F1, F2 and F3) respectively after tow rinses with saline water and its effect on wheat cultivation. Soil salinity and moisture content were estimated in the middle and end of the growing season at two depths 0-15 and 15-30 cm. The weight of 1000 grains and water productivity were calculated. The results showed an increase in soil salinity and moisture content with increasing irrigation water salinity for both depths. A decrease in soil salinity and moisture content with increasing irrigation water level and increasing fresh water level, for both depths. There was an increase in grain weight and water productivity with increasing saline irrigation water level, increasing fresh water level and decreasing irrigation water salinity. The triple interaction treatment when irrigated with water salinity 3 dSm^{-1}, 100% saline irrigation water level and 100% fresh water level of field capacity achieved the highest grain weight and water productivity of 45.17 g and 3.85 kg m^{-3} water respectively.

Keywords: irrigation water salinity level - fresh water level - grain weight- water productivity.

I. 1.Introduction

Due to the environmental conditions that many countries of the world such as high temperatures, long periods of light, scarcity of fresh water, fluctuations in the humidity of the root zone under a specific irrigation system, and the effect of the overlapping amount of irrigation water and salinity, all of these matters and more, this would hinder the agricultural process development.

The problem of fresh water scarcity is one of the main problems facing irrigated agriculture in arid and semi-arid regions. The competition for fresh water in the field of agriculture, industry, and city development has led to a sharp decline in fresh water that can be used for irrigation, which requires searching for alternative water resources of poor quality, such as saline water, that can be used during the agricultural season (Wallace, 2000). Anonymous (2009) indicated that the use of saline water in agriculture cannot be overlooked and its role as a water source for irrigating fields, but he stressed that the use of salt water must be accompanied by a good management method. Noshadi *et al*., (2013) also indicated the use of saline water must not be arbitrary (random), but rather it must be in accordance with a precise management program of applying a specific irrigation method and adopting a method for using this water to limit or reduce the effects resulting from the use of this water on the properties of the soil and plant yield and increasing the productivity of irrigation water. Naeimi and Zehtabian (2011) review of using saline water with fresh water, it was mentioned that there are two types of these methods: the mixing method strategy, or through the cyclic strategy. In applying this case, the use of good water in germination stage is required in within this application, Malash *et al*., (2008) mentioned in an experiment

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in which two irrigation methods were used, drip irrigation and sprinkler irrigation, with salinity of 3.0 and 4.5 dSm^{-1} and fresh water of 0.55 dSm^{-1}, and a mixing with a ratio of 40% fresh water and 60% saline water, alternative and periodically, which caused reduction in yield with mixed water irrigation treatment or periodic irrigation compared to 100% irrigation with saline water. As Malash *et al*., (2012) mentioned, crop production with saline water can be comparable to production when irrigated with fresh water with selecting salt-tolerant crops. While Panda *et al*., (2004) indicated that the basic principle of using saline water is that the accumulation of salts does not exceed the limit of the crop's salt tolerance, and that the lack of irrigation requires an increase in the efficiency of water use by reducing water consumption and achieving the least damage to crops production.

On the other hand, the use of saline water in irrigation in the long term has faced some negative criticism, even when using the alternating irrigation method, due to fears of salt accumulation over time. However, Verma *et al.*, (2013) found that the use of alternating irrigation of fresh and saline water did not lead to the accumulation of salts in the root zone in the long term. Wahba (2017) also found that wheat yield was not affected when using the alternating irrigation method with saline and fresh water compared to irrigation with saline water.

On the other hand, population growth around the world is steadily increasing, and this requires the provision of more food, which requires increasing the agricultural area and the efficiency of the agricultural unit. Wheat is considered one of the strategic economic crops, as it ranks second after corn in terms of global production, and first in terms of cultivated areas in the world. Which requires an increase in the agricultural area for this crop, but with the presence of water scarcity and an increase in the salinity of irrigation water, the matter requires searching for the use of techniques or management that would enhance and provide the crop's water requirements. The objective of this study were: i: trying to find a management for irrigation water to treating with the problem of water scarcity and increasing salinity study the effect of water shortage and increased salinity of irrigation water on some soil properties and crop production.

II. 2: Materials and methods of research

2.1 Location Experiment

A field experiment was conducted at the research station of Agriculture College, Basra University on the longitude and latitude lines for the site (30º 33́ 17″ N) (47º 44́ 53″ E) respectively. Soil samples were collected from two depths (0-15) (15-30) cm from different locations. It was mixed well to form a composite sample for every depth, air- dried, and passed through a diameter sieve 2 mm and kept in plastic containers, to estimate the soil properties as shown in the table (1)

2.2. Chemical and physical properties of the study soil

Soil acidity (pH) was measured in saturated soil paste extract described by Jackson (1958), electrical conductivity (EC) was measured in soil extract (1:1) for the two depths (0-15) (15-30) cm using Conductivity meter (WTW) (Page *et al*., 1982). Carbonate minerals were estimated using 1N hydrochloric acid with 1N sodium hydroxide in the presence of phenolphthalein indicator as in Richards (1954). Soil organic carbon was estimated according to the Walkley-Black(1937).The percentage of organic matter was calculated by multiplying the percentage of organic carbon by the conversion factor 1.724. The soil bulk density (ρb) was determine using core method. The particle density(ρs) was estimated using Pycnometer (Black 1965). The total porosity (f) was calculated as follows f=(1-ρb/ρs) ×100 (Black ,1965). The soil texture was determined using the pipette method, as described in (Black 1965). the concentrations of dissolved ions were estimated in the soil extract (1:1) and as follows: the concentrations of calcium Ca^{+2} and magnesium Mg^{+2} was estimated in Richards (1954). sodium Na^{+} and potassium K^{+} were estimated in a flame photometer (PFP7) Jenway. Carbonate, bicarbonate, and chloride ions were estimated by titration as described in Richards (1954). Sulfate ions ($SO4^{-2}$) were determined

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using turbidity method by spectrophotometer at a wavelength of 490 nm, (Chesnin and yein ,1950). The sodium adsorption ratio (SAR) was calculated from the following relationship:

SAR= $\frac{\text{Na}}{\sqrt{\text{Ca+ Mg}}}$,the concentrations of ions in mmol L^{-1}.

ESP as Al-Badran, (2015): ESP = ***A+B(D)SAR*** A, B and D = constants of the equation 72.561, -64.724 and 0.962 respectively.

2.3. Irrigation water samples

The Water samples were prepared according to the required salinity (3,5 and 7 dS m^{-1}) by using drainage water (EC=10 dS m^{-1}) and dilute it using the following relationship (Ayers and Westcot 1985).

ECi = [(ECa× a) + ECb(1-a)]

ECi: The electrical conductivity of the blended water (dS m^{-1})

ECa: Electrical conductivity of dilute water (dS m^{-1})

a: proportion of dilute Water in blend

ECb: Electrical conductivity of drainage water (dS m^{-1}) (table 2**).**

Table 1. Chemical and physical properties of the study soil.

Property		The value		Unit
pH		**7.89**		
EC (1:1)		**12.98**		**dS m^{-1}**
Carbonate minerals		**460**		**g kg^{-1}**
Organic Matter		**1.30**		**g kg^{-1}**
SAR		**9.84**		**$(mM\ L^{-1})^{1/2}$**
Cations and Anions	**Ca^{+2}**	**20.28**		**mM L^{-1}**
	Mg^{+2}	**22.35**		
	Na^{+}	**64.21**		
	K^{+}	**2.11**		
	HCO_3^-	**7.09**		
	SO_4^{-2}	**14.10**		
	Cl^-	**116.03**		
Soil texture	**sand**	**56.24**	**loam**	**g kg^{-1}**

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	Silt	345.16	
	clay	598.60	
particle density		2.54	$Mg\ m^{-3}$
Bulk density		1.41	
Total porosity		45	%

2.4 Field experiment :Itwas conducted to planted wheat cultivation at the Agricultural Research Station, College Agriculture, Basra University, Karma Ali site, which included the following factors: irrigation water salinity (S) 3, 5, and 7 dS m^{-1},(S1,S2 and S3) respectively irrigation water (W) (100% and 66%) of field capacity(W1and W2) respectively, and fresh water ratio (F) (0.8≃1.1) dS m^{-1} after every two irrigations with the saline water at the following levels (0%, 50% and 100%) of the field capacity(F1,F2 and F3) respectively. Experimental units were 3×3×2×3 = 54 (irrigation water salinity × saline irrigation water level × fresh water level) respectively.

The Chemical Properties of water sample were estimated as described in Standard Methods (2005).

Table 2. Chemical Properties for Water Irrigation

Property		The value			Unit
pH		7.90	7.56	7.32	
EC		3	5	7	$dS\ m^{-1}$
Cations	Ca^{+2}	5.16	11.23	18.30	$mM\ L^{-1}$
	Mg^{+2}	4.5	12.10	17.03	
	Na^{+}	9.10	17.10	23.82	
	K^{+}	0.55	1.20	6.02	
Anions	Cl^{-}	20	49.88	75	
	SO_4^{-2}	2.55	4.68	9.52	
	HCO_3^{-}	2.64	6.20	7.76	
	CO_3^{-2}	0	0	0	
SAR		2. 93	3.83	4.85	$(mM\ L^{-1})^{1/2}$

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The depth of ground water in the study area is 90 cm. The manure was added at level 120 t ha^{-1} . The mineral fertilizer was added as level of 200Kg N ha^{-1} at twice ,100 Kg p ha^{-1} and 120 Kg K ha^{-1}, mixing with soil before planting .140 Kg ha^{-1} seeds of Wheat (*Triticum aestivum L*) was planted on the 6 lines for each experimental unit. After that the field was irrigated with water salinity :1.5 dS m^{-1} until germination, then conducted with experimental treatment. Leaching requirements (20%) as (FAO,2003) (Food and Agriculture Organization of the United Nations), then calculated the amount of water Irrigation from the following equation **(Du Plessis, 1986)**: **Vi=** $\frac{FC}{1-LR}$ whereas: Vi: Volume of irrigation water, FC: field capacity and LR: Leaching Requirement .

5.2: Measurements Plant

It was completed the grains were weighed after the straw was separated using an electronic balance, and then the weight of 1000 grains was calculated in grams. The plants were dried after harvesting in the oven at a temperature of 65°C, then calculate the dry weight (g).

6.2 Soil analysis

Soil samples were taken during the middle and end of the season to depths of (0-15) cm and (15-30) cm to measure the electrical conductivity in the soil filtrate (1:1) using an EC-meter type WTW. The soil moisture content was measured using the gravimetric method.Then the percentage of moisture was calculated from the following relationship as in Black *et al*., (1965):

Pw= $\frac{MW}{MS} \times \mathbf{100}$ **,** Where Mw = weight of moist soil(g), Ms = dry soil weight (g)

Water productivity (W.P) was calculated as: the following relationship as in Xiaoyuan ,B.*et al*.,(2024)

WP = $\frac{\textbf{Yiled}}{\textbf{Irrigation water quantit}}$

A factorial experiment was used according to a completely randomized design (CRD) with three replicates. SPSS program was also used in the statistical analysis to calculate the least revised significant difference (RLSD) below a significant level of 0.05.

III. 3. Results and Discussion

3.1 Soil salinity

The effect of the main factors, salinity of irrigation water(S) 3,5 and 7 dsm^{-1}, the level of saline irrigation water (W) (66.100% of field capacity) and the level of fresh water (F) (0,50,100%) shown Statistical differences at the level (0.05>P) on soil salinity and for the two depths 0-15 cm and 15-30 cm at the end of the season as in Table (4,3).

There was an increase in soil salinity with the increase in the level of irrigation water salinity for both depths. In contrast, there was a decrease in soil salinity with the increase in the level of saline irrigation water, and a decrease in soil salinity with the increase in the added amount of fresh water for the two depths. This indicates that there is an accumulation of dissolved salts in the root zone with the increase in salinity of irrigation water, while salts are Leaching and do not accumulate relatively, with the increase in the level of fresh water, and that irrigation with fresh water contributed effectively to reducing the effect of soil solution salinity after displacing dissolved ions away from the root absorption sites. These results are consistent with Amer (2010).

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As for the effect of the interaction between the study factors on soil salinity, the results of the statistical analysis showed that there are significant differences (0.05<P) First, for the binary interaction between (F×S) and the interaction treatment of 3 dSm^{-1} with the level of fresh water 100% gave the lowest soil salinity for the depth 0-15 cm (Table 4,3). This is logical due to the low salinity of the irrigation water used (3 dSm^{-1}) in addition to the role of fresh water at the level of 100% at the limits of field capacity and its efficiency in pushing dissolved salts away from the root zone (Ehsan et al., 2009).

Table 3. Soil salinity (EC) to depth 0-15cm in mid- growth season under different treatments.

W×F	Irrigation water salinity dS m^{-1} (S)			saline irrigation water level (%W)		Fresh water level (%F)	
	S3	S2	S1				
	7	5	3				
11.70	13.70	11.17	10.50	100	W1	0	F1
12.78	15.39	12.10	10.84	66	W2		
10.31	2.431	10.10	8.39	100	W1	50	F2
11.27	13.58	11.03	9.21	66	W2		
8.21	10.07	8.81	5.75	100	W1	100	F3
9.25	10.94	9.78	7.04	66	W2		
ns	0.58			RLSD 0.05			
F	12.64	10.50	8.62	S			
	0.32			RLSD 0.05			
12.24	14.42	11.64	10.67	0		F×S	
10.79	13.01	10.56	8.80	50			
8.73	10.50	9.29	6.39	100			
0.32	0.35			RLSD 0.05			
W							
10.07	11.98	10.03	8.21	100		W×S	
11.10	13.30	10.97	9.03	66			
*	ns			RLSD 0.05			

RLSD 0.05: Ato Significant difference at 0.05 level, ns: no significant

Secondly, the treatment (W×S) in which the interaction of salinity 3 dS m^{-1} with the level of saline irrigation water at the 100% that to surpass the rest of the interaction treatments at the depth of 30-15 cm. Therefore, this indicates that the availability of suitable moisture for the soil and plant at the field capacity limits with the presence of leaching requirements can prepare a better soil medium for plant growth compared to the other treatments (Table 4,3). These results are close to the Heidarpour *et al*., (2009).

Thirdly, the triple interference (S×W×F) and its effect on soil salinity. There were statistical differences (0.05>P) between the factors of this interaction and the two depths 15-0 and 15-30 cm as in Table (3-4). The interaction (S) 3 dSm^{-1} and (W) 100% and (F) 100% gave the lowest soil salinity with values of 5.75 and 7.10 dS m^{-1} respectively. While there were no statistical differences between the of the binary interaction (W×F) at the two depths and at the two times. Tables (3-4) also show that the electrical conductivity values of the soil solution increased with increasing depth. This is due to the fact that the movement of dissolved salts is from the movement of water, meaning that water is the one that transports the dissolved salts in it, which has the highest concentration at the wetting front. Therefore, the movement

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of water downwards is what contributed to the transfer of dissolved salts and the increase in their concentration at a depth of 15-30 cm compared to a depth of 0-15 cm.

Table 4. Soil salinity (EC) to depth 15-30cm in mid- growth season under different treatments.

W×F	Irrigation water salinity dS m^{-1} (S)			saline irrigation water level (%W)		Freh water level(%F)	
	S3	S2	S1				
	7	5	3				
14.72	17.35	15.85	10.96	**100**	**W1**	**0**	**F1**
15.77	18.94	16.56	11.82	**66**	**W2**		
13.43	16.74	14.11	9.44	**100**	**W1**	**50**	**F2**
14.71	17.95	15.60	10.58	**66**	**W2**		
10.46	13.23	11.14	7.01	**100**	**W1**	**100**	**F3**
11.85	16.01	10.44	9.11	**66**	**W2**		
ns	0.66			**RLSD 0.05**			
F	16.70	13.95	9.82	**S**			
	0.24			**RLSD 0.05**			
15.25	18.14	16.21	11.39	0		**F×S**	
14.07	17.35	14.85	10.01	50			
11.16	14.62	10.79	8.06	100			
0.24	0.45			**RLSD 0.05**			
W							
12.87	15.77	13.70	9.13	100		**W×S**	
14.11	17.63	14.20	10.50	66			
*	0.36			**RLSD 0.05**			

RLSD 0.05: Ato Significant difference at 0.05 level, ns: no significant

It is also noted that the EC values are mostly higher at the end of the season than in the mid-season at the same depth. It is believed that this is due to the continued addition of water (number of irrigation times) throughout the season, which adds with it the dissolved ions carried, which may cause an increase in their accumulation at the end of the season compared to the mid- season. Which gives the impression that the efficiency of washing salts is not proportional to the amount of water added and the dissolved salts it carries. I.e. the salts added by the irrigation water used to the soil are more than the salts carried by the water in the leaching process and the movement downward away from the studied depth of 15-30 cm. In addition to the possible effect of the groundwater level (90cm) and its proximity to the soil surface contributes to raising the salinity of the soil solution by capillarity action of water near to the soil surface, as well as obstructing the water movement downward away from the root zone.

3.2Moisture content(pw)

The results in Figures 1 show the effect of the main experimental factors on the soil moisture content (%) at the middle of the growing season depending on the soil depth. It is noted that there are significant differences in the effect of the irrigation water salinity (S). The moisture content of the irrigation water salinity treatment 3 dS m^{-1} was the lowest value compared to the rest of the treatments by 22.79, 26.19 and 28.16% for levels 3, 5 and 7 dS m^{-1} respectively. The results also showed significant differences for the irrigation level factor (W) (100 and 66%) of the field capacity and the fresh water level factor (F) (0, 50 and 100%) of the capacity according to the soil depth. As the results showed that the soil moisture content values for the irrigation water level treatments (100 and 66%) and for the two depths were 25.06 and 26.37% and 25.74 and 27.21% respectively, while the moisture content values

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were 24.80, 25.47, 26.87% and 25.87, 26.18 ,27.38% for treatments 0, 50 and 100% for fresh water level and tow depths respectively.

As for the effect of the interaction between the study factors on the moisture content, the results of the statistical analysis showed that there are significant differences (0.05>P). First, the binary interaction between irrigation water salinity and fresh water level (F×S) as in Figure (2), shows that the interaction factor 3 dSm^{-1} with fresh water level 0% gave the lowest moisture content for both depths compared to other interaction factors. While the treatment of fresh water level 100% and irrigation water salinity 7 dSm^{-1} gave the highest moisture content reaching 29.36 and 29.28% for both depths respectively.

Secondly, the binary interaction of irrigation water salinity and the level of saline irrigation water(W×S) as in Figure (3) in which the interaction treatment of salinity 3 dS m^{-1} and saline irrigation water level at the field capacity limits of 100% gave the lowest moisture content of (21.72 and 24.46) % for the two depths respectively compared to the other interaction treatments. The interaction treatment of salinity 7dS m^{-1} and saline irrigation water level of 66% gave the highest moisture content of (28.50 and 29.46) % for the two depths respectively.

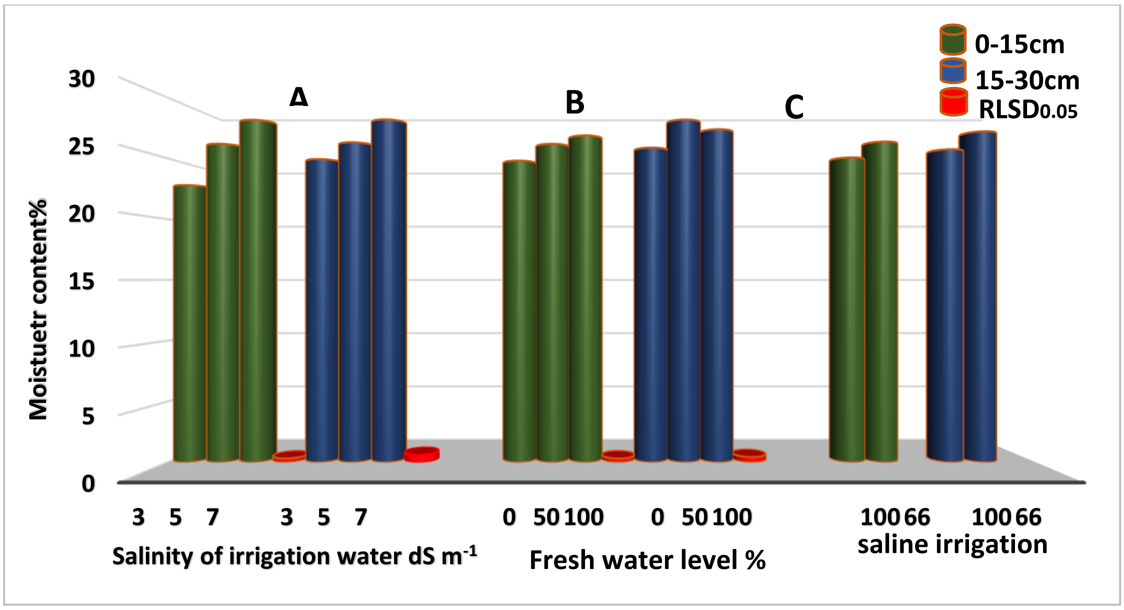

Fig.1 Soil moisture content with different salinity of irrigation water (A) Fresh water level (B) and saline irrigation water level (C) at mid-season and for both depths.

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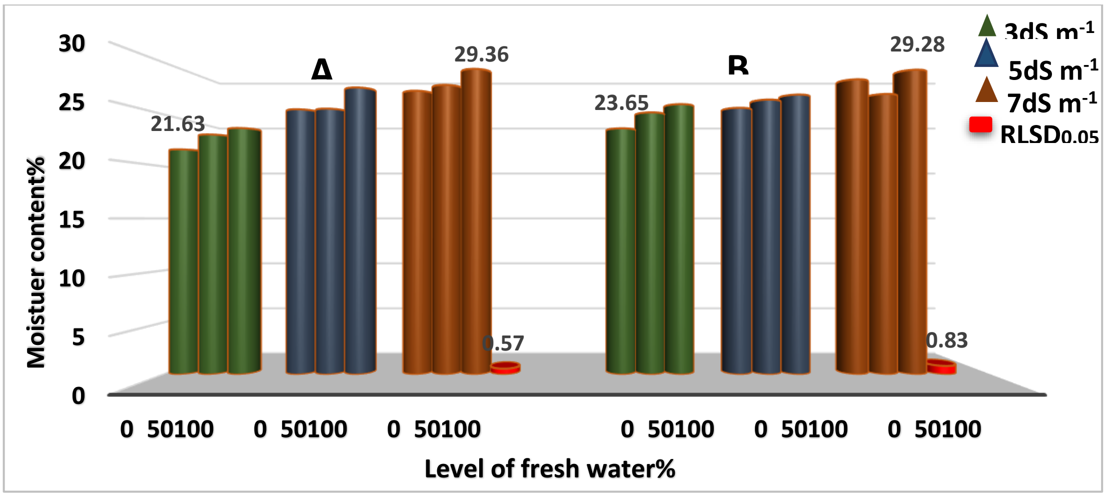

Fig. 2 Soil moisture content of the interaction between irrigation water salinity and fresh water level for two depths A (0-15) cm and B (15-30cm) at mid-season.

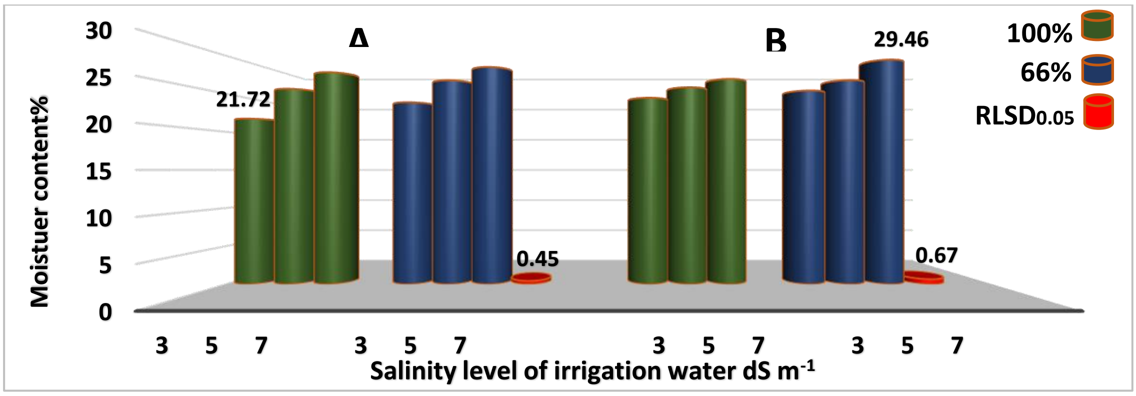

Fig. 3 soil moisture content of the interaction between the irrigation water salinity and the saline irrigation water level for the two depths A (0-15) cm and B (15-30cm) at mid-season.

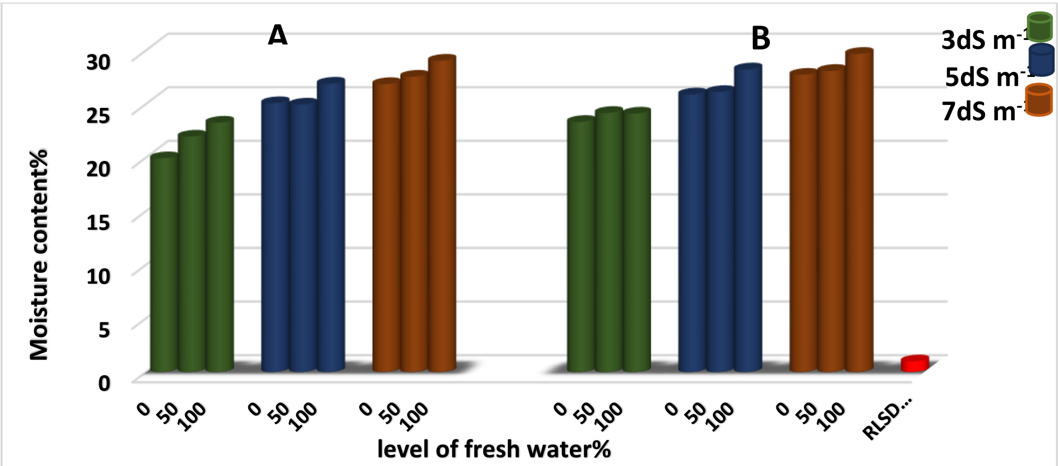

Fig. 4 Soil moisture content of the triple interaction between irrigation water salinity saline irrigation water level salty (A)100%, (B)66% and fresh water level for depth (0-15cm) at mid-season

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While there were no statistical differences for the binary interaction between irrigation water salinity (W) and the fresh water level (F) for both depths.

The triple interaction of irrigation water salinity, saline irrigation water saline level and fresh water level (F×W×S) and its effect on moisture content, as there were statistical differences (0.05>P) between this for the depth of 0-15 cm only, Fig. 4. The triple interaction treatment of irrigation water salinity 3dS m^{-1}, irrigation water level 100%, and fresh water level 0% gave the lowest moisture content of (19.94) % while the triple interaction treatment of irrigation water salinity7dS m^{-1} saline irrigation water level 66% and fresh water level 100% the highest moisture content reached (29.68) %. But there not statistical differences between the triple interaction treatment for depth 15-30 cm**.**

The results show that soil moisture had a higher value for the various factors at a depth of 15-30 cm compared to the surface depth of 0-15 cm. This is because the surface depth is closer to the effect of sunlight, which leads to a higher evaporation rate compared to the subsurface depth, in addition to the spread of the root system being at a higher rate in the surface depths compared to the subsurface depths. This is close to what Hassan (2013) reached in his study in which he used low-salinity water.2.0-2.3 dSm^{-1} and high-water salinity 7-8 dSm^{-1} and four irrigation treatments: first, irrigation with high water salinity, second, irrigation with low water salinity, third, alternating irrigation as a two-cycle high water salinity and low water salinity, and fourth, alternating irrigation as a three-cycle high water salinity twice and low water salinity. In clay soil, there is a variation in the moisture content of the soil with depth, as the values increased with increasing depth, especially at a depth of 15-30 cm. This is attributed to the fact that the depth of 0-15 cm is more exposed to external influences such as heat and wind, which increases evaporation rates from this depth.

The reason for the decrease in moisture content as a result of irrigation with water of different salinities and the increase in moisture content with increasing salinity of irrigation water is due to the decrease in water absorption by plants under conditions of high osmotic pressure (low water potential) due to soil salinity resulting from irrigation with saline water as well as the decrease in root growth and spread, thus contributing to reducing water consumption by the plant. This is consistent with Al-Halfi (2016) that the use of high irrigation water 7.5-8.0 dSm^{-1} led to an increase in moisture content values of clay soil, while it was the lowest values for soil irrigated with electrically conductive water are 3.5-4 dS m^{-1}, and it was found that the soil moisture content decreases vertically and horizontally as it moves away from the dripper. Also, the accumulation of salts in the soil core leads to the deterioration of the soil structure, which contributes to reducing its porosity and reduces the movement of water in the soil, especially in the subsurface depths.

As for the results of the soil moisture content at the end of the growing season, Figure (5) showed statistical differences (0.05>P) for the main factors and for the depths 0-15 and 15-30 cm. The treatments irrigated with water with a conductivity of 3 dSm^{-1} gave the lowest rate of moisture content percentage, which reached 19.39 and 21.40% for the two depths, respectively. While the highest rates of moisture content were in the treatments irrigated with water with conductivity of 7 dSm^{-1}, which reached 23.54 and 25.33% for the two depths respectively, this is due to the effect of salinity of irrigation water in reducing water absorption by the plant due to the increase in osmotic potential and thus the decrease in water potential in the soil solution as a result of the increase in salt concentration or it may come through the lack of root growth and spread due to the increase in salt concentration, which reduces the water absorbed from the soil through the roots in addition to the deterioration of soil structure and its physical properties with the increase in of irrigation water salinity, and this is what Mansouri *et al.*, (2014) reached in their study of the effect of three salinity levels of irrigation water 2, 8 and 12 dSm^{-1}, on the moisture content of a silty clay soil that there is an increase in moisture content with the increase in the salinity level of irrigation water. And the value of moisture content at a depth of 60-30 cm is much higher than its value at a depth of 0-30 cm.

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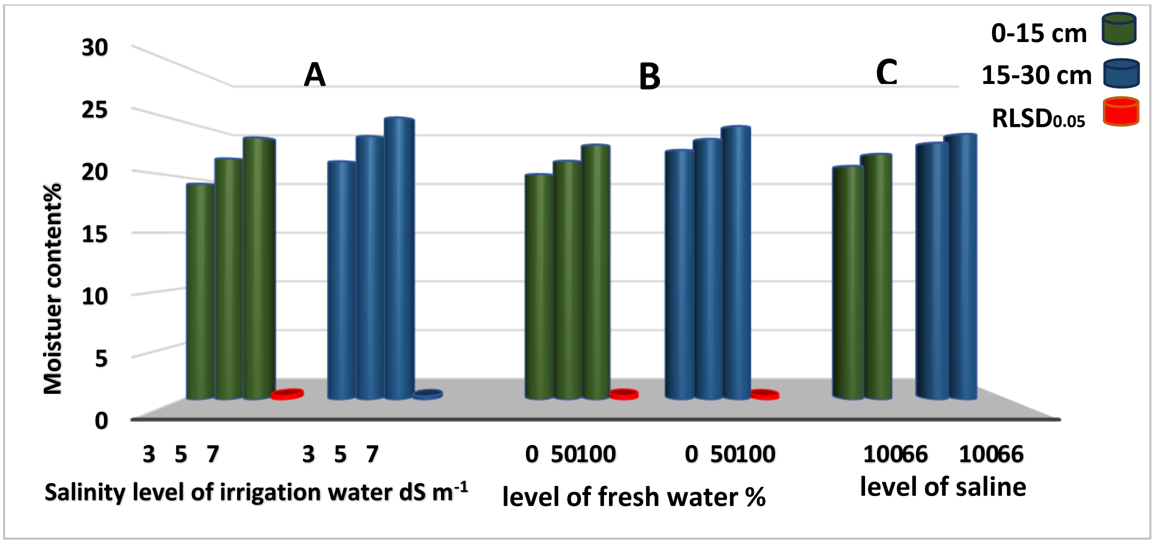

Fig. 5 Soil moisture content with different irrigation water salinity (A) fresh water level (B) and saline irrigation water level (C) at the end of the season for tow depths

While there were no statistical differences between the two-way interaction factors of saline irrigation water salinity and fresh water level (S×F) and the binary interaction between the saline irrigation water level and the fresh water level (W×F) and the interaction between the salinity of the irrigation water and the saline irrigation water level (S×W) for both depths.

The triple interaction of irrigation water salinity, saline irrigation water level and fresh water level (F×W×S) and its effect on moisture content, as there were statistical differences (0.05>P) between the factors of this interaction for the depth of 15-30 cm only as in (Fig-6). The triple interaction treatment of irrigation water salinity 3 dSm^{-1}, irrigation water level 100% and fresh water level 0% gave the lowest moisture content of (19.85) %. While the triple interaction treatment of irrigation water salinity 7 dSm^{-1}, saline irrigation water level 66% and fresh water level 100% gave the highest moisture content of (26.56) %. There were no statistical differences between the interaction factors at the depth of 0-15 cm. It is also noted in general that the moisture content values at the end of the season were lower than in the middle of the season for both depths, this may be due to external influences such as temperature and wind, which increase evaporation rates, as well as plant growth and soil structure deterioration.

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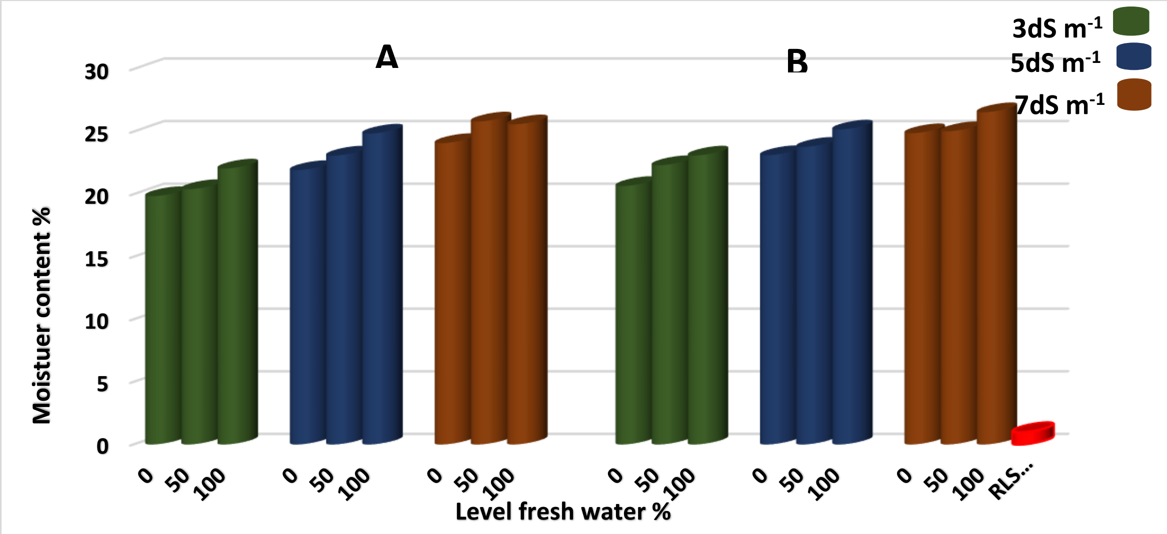

Fig.6 Soil moisture content of the triple interaction between the irrigation water salinity saline irrigation water level(A)%100, (B)%66 and fresh water level to depth (15-30 cm) at the end of the season.

3.3 Weight of 1000 grains

The study of production components (including this term) is a vital tool for ensuring crop quality (an indicator of grain quality) and improving productivity, which is reflected in determining prices in the market and indicating plant growth under good conditions and achieving high productivity.

The results in Table (5) showed statistical differences (P>0.05) between all main factors (F, W, S) as well as between all interactions of these factors.

It significantly exceeds the weight of 1000 grains with low salinity of irrigation water(S), the highest weight was 40.82 g when irrigated with salinity water with a of 3 dSm^{-1}. These results are close to the general trend of what was obtained by Liu *et al*, (2024) in the decrease in the weight of 1000 grains of winter wheat plants irrigated with water of 4.7 and 6.3 dSm^{-1}, but with insignificant differences under the conditions of his experiment. They also agreed with what was obtained by Prism and Turki (2019), as the weight of 1000 grains of wheat plants decreased with a significant difference with increasing the salinity of irrigation water from 3.0 to 6.0 dSm^{-1}. The results also showed the superiority of the irrigation level treatment with saline water (W1) by a value of 37.85 g and a significant difference compared to treatment (W2) and by an increase ratio of 5.9%. These results are generally similar to what was obtained by Bao *et al*., (2024) in the decrease in grain weight with a decrease in the irrigation water level with significant differences in some of them. While the values of the weight of 1000 grains increased with an increase in the irrigation level with fresh water (F) with significant differences, and the highest value was in treatment (F3) 40.28 g and an increase of 21.29% over treatment (F1).

Table .5 Weight of 1000 grains (g) under the effect of water salinity and level of both saline irrigation water and fresh water and the interaction between them.

W×F	Irrigation water salinity dS m^{-1} (S)			saline irrigation water level (%W)	fresh water level (%F)
	S3	S2	S1		
	7	5	3		

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34.00	29.86	34.04	38.10	**100**	**W1**	**0**	**F1**
32.43	28,066	33.13	36.09	**66**	**W2**		
38.04	33.45	38.80	41.88	**100**	**W1**	**50**	**F2**
35.83	30.59	36.06	40.85	**66**	**W2**		
41.55	37.59	41.91	45.17	**100**	**W1**	**100**	**F3**
39.00	33.92	40.14	42.96	**66**	**W2**		
0.39	0.71			**RLSD 0.05**			
F	32.10	37.34	40.82	**S**			
	0.24			**RLSD 0.05**			
33.21	28.96	33.59	37.09	0	F×S		
36.02	32.02	37.43	41.37	50			
40.28	35.75	41.02	44.06	100			
0.24	0.50			**RLSD 0.05**			
W							
37.86	33.63	38.25	41.72	100	W×S		
35.75	30.86	36.44	739.9	66			
*	0.37			**RLSD 0.05**			

The result of binary interaction (F×S) indicated to the superiority of treatment (F3×S1) which recorded a grain weight of 44.06 g statistically over the rest of the interaction treatments. While the lowest value in grain weight was 28.96 g for treatment (F1×S3) with an increase of 54.52%.

On the other hand, there were statistical differences in the binary interaction (F×W) The treatment (F3×W1) obtained the highest grain weight 41.55 g compared to the other interaction treatments, followed by the interaction treatment (F3×W2) with a weight of 39.00 g, and the lowest treatment was (F1×W2) with a weight of 32.43 g. As for the results of the binary interaction (W×S), the treatment (W1×S1) gave a statistical superiority ($P<0.05$) with a value of 41.72 g for grain weight compared to the rest of the treatments and an increase of 35.20% compared to the lowest grain weight values for the treatment (W2×S3) 30.86 g.

The results of the triple interaction (F×W×S) indicated that to statistical differences ($P<0.05$) between most of the interaction treatments and the highest value in grain weight was in the treatment (S1×W1×F3) 45.17 gm while the lowest treatment was (S3×W2×F1) with a value of 28.07 and an increase of 60.92%. From the results of table (5), it is clear that the role of high salinity of irrigation water and low level of saline irrigation water below field capacity in addition to low level of fresh irrigation water during rotation are behind the deterioration of the values of the studied items.

3.4 Water productivity

The results of the statistical analysis in table (6) show a significant effect ($P>0.05$) for the main factors (S, W, and F) in reducing water productivity values. The first main factor(S) shows that there is a decrease in water productivity with increasing salinity of irrigation water(S). Treatment 3 dS m^{-1} recorded the highest values for water use efficiency at 2.75 kg m^{-3} water and the lowest values for treatment 7 dS m^{-1}, which gave 1.24 kg m^{-3} water. The reason for the decrease in water consumption values with increasing salinity of irrigation water is attributed to the increase in osmosis potential in the root spread zone, which requires the plant to expend more energy to absorb water at the expense of root growth and spread, reducing its size and its ability to absorb water, which results in negative effects on the nutritional balance and vital processes within the plant such as photosynthesis, inhibiting enzymes and reducing the leaf area of the plant, reducing water consumption.(Dixit and Deli 2010) .As for the effect of the saline irrigation water level factor (W), the 66% of field capacity treatment recorded the highest values in water productivity, reaching 1.98 kg m^{-3} water, with significant differences from the 100% treatment, which achieved 1.94 kg m^{-3} water.

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The results showed that he effect of the factor of fresh water level (F) was an increase in water productivity values with an increase in the level of fresh water, as the treatment of 100% of field capacity recorded the highest values to the water productivity was 2.48 kg m^{-3} water and the lowest values for the 0% field capacity treatment were 1.51 kg m^{-3} water. Increasing the level of fresh water increases water productivity because good water provides a better environment for healthy plant growth, enhancing their ability to absorb nutrients, improving soil structure, reducing toxicity and salinization, and ultimately increasing the overall efficiency of water use in agricultural production.

As for the binary interaction (F×W) have significant differences $P<0.05$ in affecting water productivity efficiency, as the treatment with saline irrigation water level of 100% of field capacity and the treatment with fresh water level of 100% of field capacity gave the highest value of water productivity efficiency of 2.54 kg m^{-3} water and the lowest value for the treatment (F1×W1) was 1.44 kg m^{-3} water. Mixing saline water with fresh water may help improve productivity provided that salinity levels are controlled and effective irrigation techniques are provided, which is what was reached by (Ali and Rahman 2023).

As for the binary interaction (F×S) the results showed that increasing the level of fresh water increased the water productivity, in which the 3dS m^{-1} interaction treatment with a 100% fresh water level, as it recorded the highest water productivity of 3.69 kg m^{-3} water. While there were no statistical differences between the binary interaction factor (W×S).

Table .6 Productivity Watery (kg m^{-3} water) Under the influence of water salinity and level of both saline irrigation water and fresh water and the interaction between them.

W×F	Irrigation water salinity dS m^{-1}			irrigation water level %W		freshwater level %F	
	S3	S2	S1				
	7	5	3				
1.44	1.02	1.45	1.87	66	**W1**	0	**F1**
1.59	1.01	1.65	2.10	100	**W2**		
1.83	1.25	1.74	2.49	100	**W1**	50	**F2**
1.93	1.28	1.85	2.66	66	**W2**		
2.54	1.43	2.35	3.85	100	**W1**	100	**F3**
2.42	1.49	2.27	3.52	66	**W2**		
0.053	0.096			**RLSD 0.05**			
F	1.24	1.88	2.75	**S**			
	0.038			**RLSD 0.05**			
1.51	1.01	1.55	1.99	0		**S×F**	
1.88	1.26	1.80	2.58	50			
2.48	1.46	2.31	3.69	100			
0.038	0.066			**RLSD 0.05**			
W							
1.94	1.23	1.84	2.74	100		**S×W**	
1.98	1.26	1.92	2.76	66			
*	ns			**RLSD 0.05**			

RLSD 0.05: Least significant difference at 0.05 level ns: not significant

The results also showed that there are statistical (significant) differences between the triple interaction (S×W×F) in water productivity efficiency, as the irrigation treatment with 3 dSm^{-1} water at 100% of the field capacity and a fresh water level of 100% of the field capacity gave the highest values of water productivity efficiency of 3.85 kg m^{-3} water compared to the other treatments, while the interaction

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treatment gave the highest irrigation water salinity of 7 dSm^{-1} with a water quantity less than the field capacity of 66%, the lowest values of water productivity efficiency of 1.01 kg m^{-3} water with a statistically significant difference. The triple interaction between irrigation water salinity, fresh water level, and saline water level has a complex effect on water productivity, as increasing water salinity leads to a decrease in water productivity, but using good quality water can help to reduce the negative effects on plants. Zhang, L.*et al*., (2023).

IV. 4. Conclusions

The study showed that irrigation with water salinity of 3 dSm^{-1} compared to other saline water, as well as irrigation at the field capacity limits of 100% of this water compared to 66% of the field capacity, in addition to using rotation irrigation with fresh water at the limits of 100% of the capacity after every two irrigations of saline water compared to not rotating irrigation or using a level of 50% of the field capacity alone, gave the lowest soil salinity highest moisture content, grain weight and water productivity, and that the triple interaction of these factors was superior in the studied items compared to the other interactions. It can be recommended that the triple interaction treatment F3×W2×S1 can be adopted when good quality water is scarce.

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