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The effect of saline water on growth and production indicators of *Zea mays* L. and salt accumulation in the soil

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Abstract

The experiment was applied at Al-ssaouira Research Station, General Authority for Agricultural Research-Ministry of Agriculture, Wasit, Iraq. The study aim was to study the response of *Zea mays* L. (106 cultivar) to salinity levels of irrigation water during different stages of growth, and to study the state of salt accumulation in the soil and water efficiency and the relative production. Clay mixture soil and using irrigation water of different salinity have been used. It has an electrical conductivity of 1.2 deS/m (S1) (River water), 3 deS/m (S2), 6 deS/m (S3), and add requirements of 20% washing, and three times for plant growth: M1: germination stage, M2: flowering stage, M3: maturity stage.

The experiment parameters represented the time of irrigation water management and according to the types, as: F1: Irrigation with S1 saline water for all growth stages, F2: Irrigation with S2 salinity water for all growth stages, F3: Irrigation with salinity water S3 for all growth stages, F4: Irrigation with water S1 through M1, S2 through M2, S3 through M3, F5: Irrigation with water S2 through M1, S3 through M2, S1 through M3 and F6: Irrigation with water S3 through M1, S1 through M2, S2 through M3.Some indicators of the growth of the crop and the accumulation of salts in the soil after the harvest time were monitored.The results indicated that the treatments F1 and F4, which represent irrigation with fresh water during the early stages, were superior to the rest of the treatments. There were no significant differences between these two treatments in terms of plant height, number of grains/ weight of 500 grains, and this differs significantly from other treatments, especially the stages that represent giving Saline irrigation (S3) during all stages of growth. For the dry weight and the total grain yield, it was found that the treatment F1 was superior, which indicates the administration of fresh water during the early stage (M1). This means the role of quality irrigation water during the sensitive stages of growth. This has become clear for this crop that the early stages are more sensitive than the other stages. Therefore, a reduction of the total plant yield or grain yield, occurred during the stages in which saline water qualities (S3) are given in all stages of growth (F3), or this water was given during sensitive stages, including M1, followed by irrigation with fresh water during the second stage (M2) of plant growth and is F6. Therefore, the largest relative loss of the yield occurred during these treatments, while the relative loss of the yield decreased in the other treatments,Water efficiency may be used for treatments that are irrigated with fresh water (F1) compared to other treatments. This is evidence of the preservation of the crop at this salinity and a small decrease in water efficiency for the treatments that represent giving the second type of water in the early stages (F2 and F5). It is through the double decrease of the relative production yield of the coefficients (F1 and F4) which represent the administration of fresh water (S1) either during all stages of growth or the early stages of growth.

Key words: saline water, growth, *Zea mays*, salt accumulation, soil
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Introduction

The fresh water lack for irrigating crops in dry and semi-dry regions has forced farmers to introduce instead sources through the use of low quality water to irrigate some crops, including many strategic crops. There are important sources in Iraq, including drainage and groundwater, but the safe use of this water requires the adoption of good management in terms of quality, date and method of add to the soil or irrigate these crops, to prevent or reduce salt accumulation and maintain an acceptable level of production of these crops. Therefore, there are a number studies in this field, which adopted the giving of drainage water according to the stages of growth with the adoption of giving drainage water and according to the stages of growth with the adoption of methods of succession of this water or mixing it with good quality water according to the stages of growth. It is also required to use irrigation water as washing requirements to treat the case of unwanted salt accumulation in the soil that resulting from poor management of this high or medium salinity water [Bakht, et al (2011].

The modern irrigation methods, including drip irrigation, to ensure reducing the quantities of irrigation water given to more than half. Thus, the wet section in this way is limited compared to other irrigation methods, and thus reduce soil salinity levels in the section surrounding the plant. There is another study that includes the response of different varieties of barley to irrigation with salt water during the different stages of growth. This comes through the addition of saline irrigation water during the stages of growth that is not sensitive to salinity and avoiding the stage of emergence or germination because it is sensitive to salt water (Bano& Fatima (2009) also found that the role of different quantities and types of irrigation water in the composition and growth of this crop, in addition to the distribution of some ions in the soil, which caused a significant decrease in some nutrients and basic elements and an increase in the concentration of soil ions, including calcium, magnesium, sodium, chloride, and others. Therefore, the effect on the equilibrium state of these ions and this leads to a decrease in the yield and other growth indicators.

Birol & Haluk (2009). confirmed that there is an increase in the height of the *Zea mays* by increasing the amount of irrigation water. The reason for that may be due to the increase in the stock of it in the soil, which reduces the concentration of salts in the soil solution and provides a suitable environment for growth. Cha-Um & Kirdmanee (2009) report that alternating the administration of low-quality water with high salinity water (7-8 dS/m) led to significant differences in plant height values, plant dry weight decreased with increasing salinity of clay soil. Different types of irrigation water up to 8 dS/ m for the dry weight of plant. El Sayed (2011). showed that there is a decrease in the yield of *Zea mays* by 0% when the soil salinity was 10 deS/ m. This was confirmed by Feng, et al (2017) which mentioned that the yield was significantly reduced by 50%, or approximately 47.8% in the water treatments. Saline, whose salinity reaches 7.5 dS/m, and the value of the relative yield is up to 0% at soil salinity of 19 dS/m with a wash requirement of 15%. Other studies also indicated the importance of reducing the salinity effort by giving batches of irrigation water as washing requirements, with an effective puncture system when using saline or medium salinity water.

Therefore, the classification of Hichem *et al* (2009) indicated that the nature of the problem expected from the use of this water in the absence of determinants of its use, but it indicated the possibility of using this water when the soil and climate are exposed to hard conditions while adopting appropriate management factors for the crop and soil and preventing cases The deterioration of productivity when using this water without moving away from the sensitive stages of plant growth (Huang et al 2019). The quality of the irrigation water has an important effect in determining the productivity of the soil due to the salt accumulation that occurs due to use of irrigation water that contains a not small percentage of salts in the form of ions, which may affect the chemical and physical properties of the soil, biological activity and the nutrient readiness of the plant and this negatively affects the production. The research aims to test the management of giving irrigation water of different salinity to the *Zea mays* by adopting drip irrigation and during the different stages of crop growth and observing the expected levels of salt accumulation in the soil.

Materials and Methods

The experiment was applied at Al-Suwaira Research Station, 70 km south of Baghdad, Ministry of Agriculture, Iraq. Clayey mixed texture soils classified to the level of the TypicTorrifluvents has been used in the experiment. There is a network of effective combined field troughs with a depth of 2 m, and covered troughs of the plastic type are poured into it. Experiment site was selected and orthogonal plowing, leveling and dividing operations were performed into three bars, each bar representing a repeat. The Soil samples were dried, crushed and sieved with a sieve with a diameter of 2 mm.

The samples were mixed for homogenization and a composite. Samples were taken for depths 0-25 cm and 25-50 cm to determine some chemical and physical parameters of soil before planting (Table 1) and according to the standard methods contained in (Kaya et al 2013) .The particle sizes were estimated by the condensate method, the electrical conductivity was estimated using an EC-meter. The soil reaction was measured using a pH-meter, and calcium and magnesium were estimated by scavenging with freshest (EDTA) 0.01 C, sodium and potassium using a flame photometer, and chlorides by scanning with silver nitrate. 0.05 standards. Then these strips were passed by a grid with a distance between one cross and another 70 cm. The repetitions were cut into panels with dimensions of 3x4 m, so that each panel contains four crosses with lengths of 4 m. A distance of 2 m was left between one panel and another within each repeater and a distance of 4 m between one repeater and another to ensure that the irrigation water of different quality would not move or overlap between one panel and another or between one repeater to another.

Planting and fertilizing:

The planting was applied on 20/7/2024, the distance between one line and another was 75 cm, and the distance between one hole and another was 30 cm. The drip irrigation system was installed that the drippers were distributed among the meadows and placed one dotted on the site of each hole. The drippers and the irrigation system were calibrated to determine the irrigation periods needed to cover the water needs of the crop during each stage of growth.

Table (1) Chemical and physical parameters of the study samples

depth (cm)	Ph	ECds/m	Dissolved ions (Meq/L)						Soil Separators (g/kg)			Soil
			Ca	Mg	Na	Cl	SO_4	HCO_3	sand	silt	clay	
0-25	7.5	3.8	11.8	7.4	20.3	11.4	25.6	1.6	296	353	351	clay
25-50	7.6	5.3	14.3	9.9	28.7	21.6	29.8	1.9	311	365	324	mixture

Irrigation water is characterized by the specifications Table (2). This water was prepared using the following equation:
Concentration of the mixing water = (concentration of river water × part of river water) + (concentration of draining water × part of draining water)
Since the concentration = the electrical conductivity of water measured in dS m^{-1}.

Table (2) some chemical properties of the irrigation water

Water type	Code	EC	pH	Dissolved ions (Meq/L)						
				Ca	Mg	Na	K	CL	SO_4	HCO_3
River water	S 1	1.2	7.5	5.4	2.6	3.4	0.1	4.8	3.6	2.6
Salty water	S 2	3.0	7.6	12.4	8.6	22.9	0.2	24.1	16.2	4.0
	S3	6.0	7.5	17.3	13.7	30.4	0.4	32.4	21.9	6.3

The crop was planted by placing 5 seeds in each hole. Then thinning operations were applied to 3 plants after two weeks from the date of emergence. The grafting and control of the pests were carried out by feeding the developing tops with diazinium pesticide (10%) and in the first two batches after 20 days from emergence (Kaya et al 2013).
The fertilization process was applied by add 150 kg/N ha^{-1} in two batches and phosphate fertilizer was added in the form of triple superphosphate at a level of 60 kg/P ha^{-1} and 150 kg/K ha^{-1} of potassium sulfate fertilizer. The experiment parameters are: Irrigation water quality: The first type is the water of the Tigris River, its electrical conductivity was 1.2 dS/m (S1), saline water and its electrical conductivity was 3 dS/m (S2).
The drainage water and its electrical conductivity was 6 dSsiemens/m. The experiment also included irrigation water quality management treatments depending on the stages of growth and was divided into the following stages:
M1: germination and elongation stage
M2: branching and flowering stage
M3: maturity and harvest stage
The treatments were distributed as follows:
F1: S1 irrigation through M1 + M2 + M3
F2: S2 irrigation through M1 + M2 + M3
F3: Irrigation with S3 through M1 + M2 + M3
F4: Irrigation with water S1 through M1 and S2 through M2, S3 through M3
F5: Irrigation with water S2 through M1, S3 through M2, and S1 through M3
F6: Irrigation with water S3 through M1, S1 through M2, and S2 through M3

A complete randomized block design (RCBD) was used with three replications. Diesel pumps were used to withdraw fresh and saline irrigation water from special concrete tanks and the main irrigation pipe network, which feeds the drip irrigation system pipe network. The irrigation date and the operating periods of the system were adopted to ensure the preparation of the calculated amount of water for each irrigation based on the depletion of 60% of the ready water for the surface layer. Soil models were taken for depths 0-25 and 0-50 cm and for all treatments to follow the level of salt accumulation in the soil. The growth of the crop and the harvest was followed up. The indicators were measured during the growth periods, as the weights of the grains and the dry matter were calculated, and a statistical analysis was conducted for them to estimate the least significant difference between the means.

Results and Discussion

Plant height

According to the growth stages, it is clear that plant heights for seven plants may differ within each experimental unit and for the different irrigation water quality parameters (Köşkeroğlu & Tuna (2010) . The results showed that F1 and F4 treatments represent irrigation with fresh water during all stages of growth and during the first stage, respectively. They were significantly superior to the rest of the treatments, where the highest height was

163.7 cm, which significantly different from F3. It represents irrigation at level S3 for the quality of irrigation with saline water for all growth stages. It has reached 130.17 cm for this treatment, and it recorded a decrease of 20% compared to the comparison F1, while it achieved a decrease of 17% compared to the treatment of irrigation with type S2 throughout the growing season F2 (figure 1). The height rates of F4 treatment significantly increased compared to F3 and F6 treatments. Both of them represent irrigation with saline water (S3) during the M1 stage due to the plant being exposed to salt stress during the early growth periods, due to the plant's exposure and sensitivity to high salinity levels during this stage. The value of the plant height also increased for F4 and F2 treatments, compared to F3 and F5 treatments.

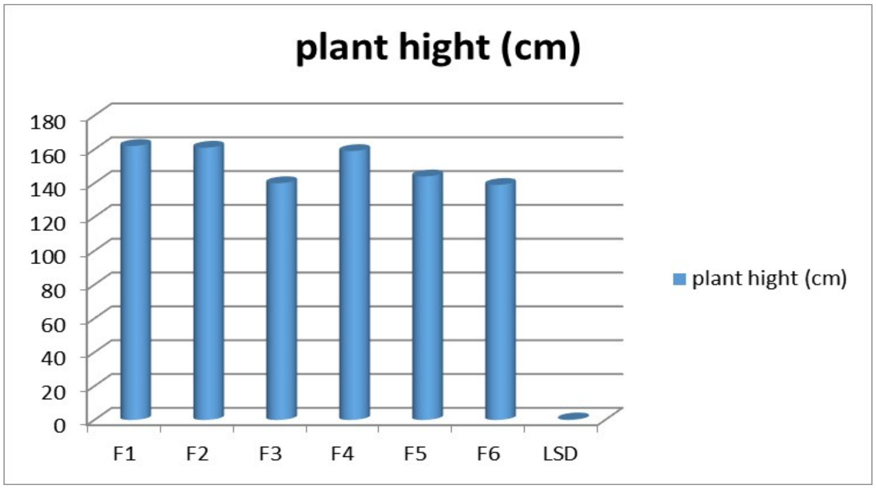

Figure (1) plant height means with different irrigation water quality parameters

Dry weight:

The F1 has been represented continuous administration of fresh water during all growth stages. While a decrease in the dry weight of the plant is observed when using fresh water for the second and third stages (Figure 2)(Lykhovyd et al 2019) indicated about the role of less saline water in improving the size and height of the vegetative growth of plants. It is also noted that the dry weight of F2 treatment, which represents giving water of level S2 during the stage (M2), and water quality of S3 during all stage (M3).

The dry weight decreased by (45%) for F3 and 15% for F2 treatments, compared with the treatment of giving fresh water (S1) in all stages of growth (F1) and mixed water (S2) in the second stage of growth, which means the role of giving irrigation water qualities during growth periods. The F1 treatment also outperformed the rest of the treatments for the positive role of fresh water, especially in the early stages of the growth of the crop, which was reflected on the weight of the dry matter of the plant. Treatment F4 outperformed by 23% and 29% for F5 and F6 treatments, respectively, and it comes through the role of fresh water in the first stage of plant growth (M1) compared to the other stages (M2 and M3).

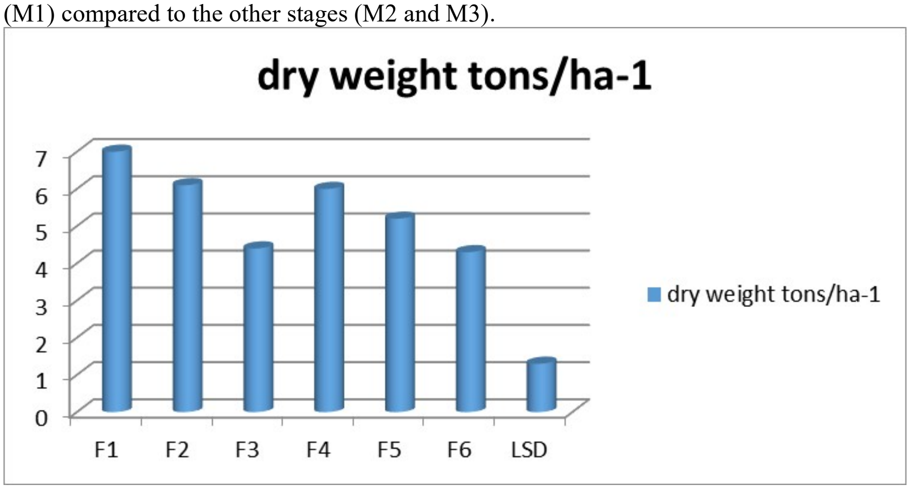

Figure (2) dry weight means with different types of irrigation water

Number of grains

Figure (3) present number of grains of the different types and dates of irrigation. It is clear that F3 has been recorded the least significant value compared to other treatments. However, it is noted that F1 was superior to F4 and this is due to the administration of fresh water during the early stage (M1), while there was a decrease for F3 and F2 treatments by (48% and 22%) compared to the comparison treatment, and this case represents their participation with it in the continuation of irrigation With fresh water during the first stage (M1) only. Which shows the role of fresh water during the first stage in increasing the number of grains for this (F1), which not significantly different from F4, and there was a significant decrease for F5 and F6 of 28% and 37%, respectively, due to the role of fresh water during the sensitive stages of the growth of the crop and this confirms the importance of avoiding the sensitive stages of plant growth (Malik, et al (2022) , that is, giving saline water (S2 and S3) during the second and third stages (M2 and M3) and for both treatments.

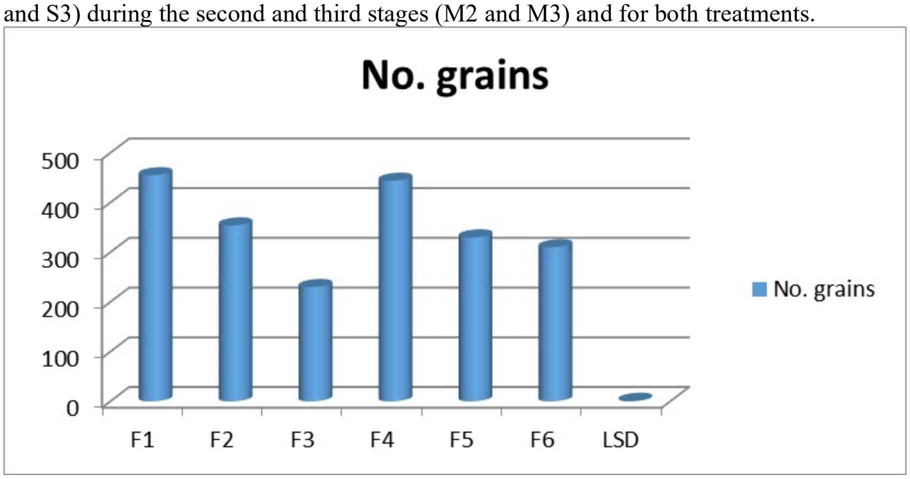

Figure (3) number of grains of different treatments of the types of irrigation water

Weight 500 grains

It is clear F1 treatment was significantly superior to irrigation with fresh water during all growth stages, which did not significantly different with F4, while there was a decrease for F2 and F3 treatments compared to F1 treatment by 13% and 25%, respectively, than the control treatment, which does not differ from the conditions of F4 treatment. This may be due to the adoption of fresh water quality during the early stages of plant growth (M1), which helped reduce the effect of water salinity in these stages (Nehela et al ,2021) while a decrease in the weight of 500 grains was observed in the F5 and F6 treatments compared to the comparison by 16% and 20%, respectively, While the differences between them were not significant, and this may also be due to the role of fresh water (S1) during the first stage (M1), where the water quality was adopted as S2 and the adoption of giving salt water (S3) for both treatments respectively during the first stage, where the water quality was of little clarity in This indicator is during the first stage (M1).

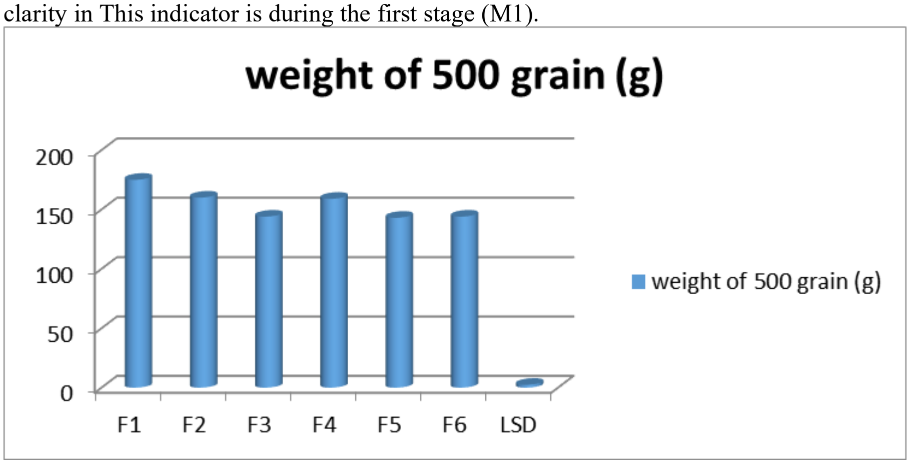

Figure (4) weight of 500 grainswith different types of irrigation water

5- The total yield

The results showed that the weight of the total yield according to the different irrigation parameters in terms of the quality and timing of irrigation water according to the growth stages of the plant. It is clear that F1 has significantly outperformed the other treatments, as it reached the highest degree of decrease in yield when F3 (61%) and the lowest decrease in F4 (10%), and this indicates the importance of giving fresh water during the early stage (M1) (Figure 5). The treatments (F2, F5), they were adopted at the level of S2 during the M1 stage. They achieved a slight decrease (10%) compared to the control treatment. As for the other treatments (F3, F6), irrigation with saline water (S3) was adopted in the early stages (M1) and this might be the main reason for the decrease in the effect of saline irrigation during the early stages and fruit setting (M1 and M2).

Therefore, the stage of germination and the development of seedlings are more sensitive to salinity. It is preferable to exclude saline water during these stages (M1) to maintain great production. The results found that the relative loss in yield for different treatments have been reaches 62%, 49%, 23%, 18% for treatments F3, F6, F2, and F5, respectively, which represent the treatments in which saline water was used during the early stages of growth. However, the relative loss of the yield was only 10% for the F4 treatment, which represents the use of saline water during the late stages of growth. These results are agreed with (Malik et al., 2022) as the amount of reduction in the yield depends on the concentration of dissolved salts, the type of crop, its different stages of development and weather conditions. The alternating the administration of salt and fresh water with providing the necessary washing requirements leads to different levels of yield reduction (Riffat& Ahmad (2020). Also, the periodic irrigation of fresh and saline water in the cultivation of wheat and maize crops in an agricultural cycle did not lead to a significant reduction in the yield (Saboor et al ,2021).

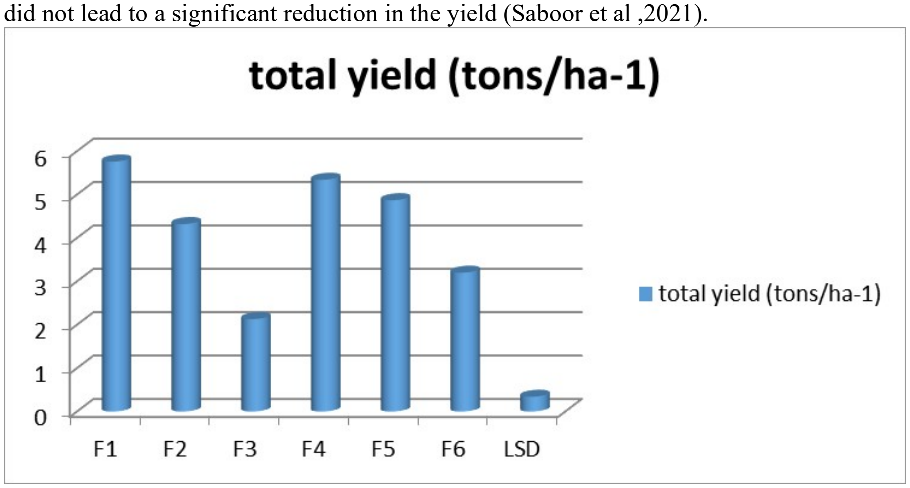

Figure (5) total yield effected to different parameters of water quality

Water use efficiency and relative yield

The results recorded the amount of water used during the season (fresh water + salt water), the value of which was 9962 mm for this crop, which was prepared through the drip irrigation system during 74 operating hours to meet the crop's need for this water, part of which was fresh water and part of salt water. It is save 42%, 100%, 49%, 55% and 59% of fresh water for treatments F2, F3, F4, F5 and F6, respectively (Table 3). It is also evident from that F3 gave a relative production of 38% compared to (F1) which represents continuous irrigation with fresh water throughout the growing season, and this (F3) may not differ significantly from (F6), while the treatments gave values indicating relative production and it may be economical for coefficients F2, F4, and F5 were 77%, 90%, 82%, respectively.

Table (3) irrigation water quantities and the relative production and water use efficiency

Treatments	Fresh water		Salt water		Total of water use (mm)	Relative production	water use efficiency
	hours	Water depth (mm)	hours	Water depth (mm)			
F1	74	992	---	---	992	100%	0.57
F2	43	576	31	415	992	77%	0.44
F3	-	-	74	992	992	38%	0.21
F4	38	509	36	482	992	90%	0.51
F5	33	442	41	549	992	82%	0.47
F6	30	402	44	589	992	50%	0.20

The results indicate that the values of water use efficiency of irrigation water used during the season. The efficiency of saline water use decreased for all stages of growth (F3) and its value reached 0.21, which does not differ significantly from (F6), while the highest efficiency of water use was during F1 and this is clear evidence to increase the efficiency of the use of fresh water in the first place and to treat the use of this water in the first stage of the growth of the crop (F4). The reason may be due to the role of these treatments in maintaining the same growth and production in the conditions of using saline water in the stages that are less sensitive to the salinity of irrigation water compared to draining saline water in the stages sensitive to this water, and consequently there is a clear decrease in the growth and production of the crop and this is reflected in the level of the total production of the crop. In these stages, because of the reduction of root uptake of its water needs in these treatments, these results agree with (Sozharajan & Natarajan ,2016).

In this context, it is possible to indicate a decrease in the efficiency of water use and a decrease in the yield when using saline water is due to the low ability of the plant to extract water from the soil with high salinity due to the high salt stress conditions in the soil, despite the fact that water is available in the root area. In the same time, it is noted that the strategy of periodic irrigation between fresh water and saline water during the periods of crop growth leads to the balance of saline water in the root area and thus reduce the loss of the crop of this plant.

Salt accumulation during the growing period of the crop

It is noted from the following that the average electrical conductivity values for the surface layer soil and for a depth (0-25 cm) amounted to 4.0 dSi m^{-1}, while it reached 4.2 dSi m^{-1} for the soil layer representing depth (0-50 cm) and these values are represented before planting. However, the values of the electrical conductivity of the soil to these depths varied after the completion of the agricultural season, according to different treatments, and this indicates its role in the process of irrigation water management in terms of quality and quantity during the stages of crop growth.

Table (4) Soil salinity (0 - 25) and (0 - 50) cm depths before and after planting

Treatments	Soil salinity (0-25 cm)		salt accumulation	Soil salinity (0-50 cm)		salt accumulation
	before	After		before	After	
F1	3.8	5.1	5	3.6	4.2	5
F2	4.0	8.2	60.5	4.3	5.6	33.3
F3	4.1	13.8	170.5	4.0	11.7	178.5
F4	3.9	6.7	31.3	4.9	8.6	104.7
F5	4.0	9.4	84.3	4.3	10.3	145.3
F6	4.4	12.8	150.9	4.2	11.1	164.2

Therefore, it led to a change in the values of the total grain yield of the plant. It was found that by increasing the electrical conductivity values of the surface layer (0-25 cm), the values of this crop were reduced by different coefficients, which are (F2, F3, F4, F5, F6) respectively. It is refer to the management of irrigation water through the difference in the alternation of fresh water with salt water during the growth stages. Observing this, the results find that the values of soil salinity during the end of the season and at this depth may not reflect the expected reduction level of the crop. The salinity level of irrigation water during the growth stages has the greatest role in this reduction, which is achieved by giving the crop to this water and during the sensitive stages of crop growth. For the second depth (0-50 cm), it was found that the yield was achieved by (992.3, 455.8, 148.6, 166.6, 405.8) kg/ha for the treatments (F2, F3, F4, F5, F6) respectively, and this happened due to the electrical conductivity of the soil during its height of one unit. It was found that the values of reduction in the yield and for most of the treatments there were no clear differences between them and this indicates that the level of change of soil salinity for this layer is clearer than the level of reduction obtained when combined with soil salinity compared to the first layer (0-25 cm).

It is clear that the values of the level of salt accumulation that occurred for depths (0-25 cm) and (0-50 cm) at the end of the season and for various treatments compared to the treatment of continuous irrigation with fresh water (F1). The salt accumulation was calculated through the following equation:

$$\text{X 100Salt accumulated \%} = \frac{(EC_{ir} - EC_{sw})}{EC_{sw}} \quad -$$

Salt acc % = percentage of salt accumulation in the soil

EC ir = electrical conductivity of the soil and for various parameters (dsi m^{-1})

EC sw = electrical conductivity of soil for comparison F1 treatment dsim^{-1}

Table (4) has been showed that the largest level of salt accumulation as a percentage is at treatments F3 and F6 for both depths, and this means that salt accumulation occurs at these two treatments as a result of giving saline irrigation water (S3) during the three stages of crop growth (M1, M2, and M3) and giving saline water (S3) during the first stage of crop growth (M1), while the two treatments (F2, F3) gave moderate values for the level of salt accumulation and for the two depths. The F4 treatment gave the lowest average level of saline accumulation due to the role of alternating fresh water with saline water and its role in reducing the level of saline accumulation that may occur after planting the crop, hence the importance of these treatments in maintaining the values of the relative and total yield that were within the limits of the economic yield (more than 50%), so such periodic use of water types and according to the growth stages of the crop. Also of the importance of this strategy is the process of intermittent washing of salts by fresh water during drip irrigation, and thus the movement of salts outside the humidification area and the formation of a saline ring far from affecting the plant, and thus the plant can move away from these salt accumulations from the surrounding area, which continue in the distance, washing and movement of salts away about the root total spreading area (Stefanov et al ,2021. There may be compatibility between the values of the relative accumulation of salts and the level of leaching of a part of these salts added through different irrigation treatments. The reason for not obtaining this compatibility is the lack of sufficient leaching of salts, especially for continuous irrigation treatments with saline water (Suganya et al ,2020, Tuna et al ,2007).in addition to the drip irrigation method that can provide the water need For the crop only without giving an additional amount to cover the surface of the earth and wash the accumulated salts away from the area where the roots of the crop spread (Ullah & Bano,2015,. Zhang, et al ,2021).

Conclusions

The study conclude that levels of salt accumulation was different according to the different treatments and the levels of soil surface coverage depending on the plant density for these treatments, so we find in the F3 treatment the highest level of salt accumulation (170.5 and 178.5) for the depths 0-25 and 0-50 cm, respectively, due to irrigation with saline water (S3) during periods of growth Yield compared to other parameters (F2, F4, F5, F6). This may be attributed to the movement of water and its connection to the salt distribution in the soil body with the difference in the moisture distribution of these transactions and in all directions, where the area is the source of preparation for moisture and the direction of the borders of the wet front in all directions (radial movement) and thus the efficiency of washing salts is low in this way, where the Giving the actual water requirement of the crop, thus the washing efficiency is low, especially in clay soils. However, we find that the F4, F5, and F6 treatments have contributed to saving about 50% of the fresh water, and the relative production has decreased to the values of 90%, 82%, 50% according to the different treatments of the strategies of giving salt water and fresh water during the periods of crop growth, so we find that the management of the use of Water plays an important role in improving some soil properties and limiting the level of salt accumulation in the soil, which was reflected in the relative yield values of these treatments.

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