EFFECTS SOIL COVERING AND CONTROLLED WATER TABLE ON DATE PALM GROWTH AND THE ROOT ZONE SALT BALANCE IN SOUTHWEST OF IRAN

EFFETS DE LA COUVERTURE DU SOL ET DU CONTROLE DE LA NAPPE PHREATIQUE SUR LA CROISSANCE DU DATTIER ET LE BILAN DE SALINITE DE ZONE RACINIERE AU SUD-OUEST DE L'IRAN

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ABSTRACT

Drought, shallow saline water table and subsequent salinisation are the major problems in arid and semi arid in Iran. The establishment period of date palm plant is highly sensitive to these problems and need special management program. Lysimeter experiments were conducted to evaluate the influences of shallow saline water table on the salt balance of root zone and date palm growth. These experiments were carried out in three replicated split–plot design including 3 levels groundwater salinity (main plot; S1= <4, S2= 8 and S3=12 dS/m); two levels soil surface cover (sub plot: M1= no mulch and M2= date palm leaves mulch) and two water table depths (D1=60 and D2=90 cm). The results showed that mulching help to increase salt leaching and decreased soil EC with water table at 60 cm depth. The maximum decrease was 2.55 dS/m in treatment D1S1M2. The EC of root zone soil increased in treatments without mulch, the maximum being 6.31 dS/m in treatment D1S3M1. The soil EC increased in all treatments with controlled water table at 90 cm depth. The maximum and minimum change of soil EC was 6.5 and 2.64 dS/m in treatments D2S3M1 and D1S1M2, respectively. The ANOVA analyses indicated that mulch has a significant effect on salt change rate of the root zone at 1% level. However, levels of salinity did not have a significant difference. Similar results were obtained for both depths of the water table. The survival rate of plants was 100% in all of treatments. The date palm plants tolerated soil salinity till 14.29 dS/m. Mulch improved the growth of date palm plant. With controlled water table at 60 cm, the new leaf and leaflet numbers were 4.33 and 117.67 in treatment D1S3M2. These indexes were 4 and 120.33 for

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depth of 90 cm (D2S2M2). The ANOVA analyses indicated salinity had no significant effect on vegetative indexes. However soil surface covering had significant influence on leaflet production in 1 and 5 % level for controlled water table at 60 and 90 cm depth, respectively. Therefore, with management of shallow saline water tables and soil surface cover date palm establishment occurs without harmful symptoms.

Key words: *salinity, water table, mulch, date palm.*

RESUME

Les régions arides et semi arides de l'Iran sont affrontées par les problèmes tels que la sécheresse, la nappe phréatique saline peu profonde et la salinisation. La période de croissance du dattier est fortement sensible à ces problèmes et exige un programme spécial de gestion. L'expérimentation par le lysimètre a été faite pour évaluer l'effet de la nappe phréatique saline peu profonde sur le bilan de salinité de zone racinère et la croissance du dattier. Ces expérimentations ont été effectuées dans trois répétitions de la conception du champ divisé, y compris 3 niveaux de salinité d'eau souterraine (champ principal : S1 = < 4, S2 = 8 et S3=12 dS/m); deux niveaux de couverture du sol de surface (sous champ : M1 = sans paillis et M2 = paillis des feuillies de dattier) et deux niveaux de la profondeur de la nappe phréatique (D1=60 et le cm D2=90).

Les résultats ont montré que le paillis a aidé dans lessivage du sel et dans la réduction de l'EC du sol, la profondeur de la nappe phréatique étant de 60 cm. La réduction maximale était de 2,55 dS/m dans le traitement D1S1M2. L'EC du sol de zone racinère a augmenté dans les traitements sans paillis, le maximum étant de 6,31 dS/m dans le traitement D1S3M1. L'EC du sol a augmenté dans tous les traitements avec le contrôle de la nappe phréatique à la profondeur de 90 cm. Le changement maximal et minimal de l'EC du sol était de 6,5 et 2,64 dS/m dans les traitements D2S3M1 et D1S1M2 respectivement. Les analyses d'ANOVA ont indiqué que le paillis a exercé un effet significatif sur le taux de changement du sel de la zone racinère au niveau de 1%. Cependant, les niveaux de salinité n'avaient aucun effet significatif. Les résultats ont été recueillis pour les deux profondeurs de la nappe phréatique. Le taux de survie de plantes était de 100 % dans tous les traitements. Les dattiers ont toléré la salinité du sol jusqu'au niveau de 14,29 dS/m.

Le paillis a amélioré la croissance du dattier. La nappe phréatique contrôlée étant de 60 cm, le nombre des nouvelles feuilles et des feuilles étaient de 4,33 et 117,67 dans le traitement D1S3M2. Ces indices étaient de 4 et 120,33 pour la profondeur de 90 cm (D2S2M2). Les analyses d'ANOVA ont indiqué que la salinité n'avait aucun effet significatif sur les indices végétatifs. Cependant, la couverture de la surface du sol a exercé un impact significatif sur la production des feuilles au niveau de 1% et 5% de la profondeur de la nappe phréatique contrôlée de 60 et 90 cm respectivement. Donc, en raison de la gestion de la nappe phréatique saline peu profonde et de la couverture du sol de surface, la croissance de dattier n'est pas affectée par les symptômes nuisibles.

Mots clés : *Salinité, nappe phréatique, paillis, dattier.*

1. INTRODUCTION

Soil salinisation and water resources' shortage are two important problems in arid and semiarid regions. Many areas in south and southwest Iran (especially Khuzestan province) suffer from shallow saline water table and subsequent soil salinisation. The dominant orchard crop of this region is date palm, a crop that is tolerant to salinity. However, the establishment period of date palm is sensitive to salinity stress. Every year, farmers pay high prices to purchase and plant date palm, but many plants die due to the salinity from shallow saline water tables.

Many plants can uptake all or part of their water requirements from shallow water tables. However, the capillary rise of saline water table and its subsequent evaporation at the soil surface lead to soil salinisation (Tanji, 1990). Therefore, to prevent soil destruction, salt concentration in the root zone must be controlled for a longer period. Both excess and shortage of drainage will jeopardise the agricultural process. In contrast, successful water management for salinity control depends on adequate leaching. Plants absorb about 40%, 30%, 20% and 10% of their water requirements from the upper to lower quarter portions of the root zone (Ayers and Westcot, 1994). Consequently, the different portions of the root zone do not have the same effect on yield. Higher levels of salinity in the lower portion of the root zone have less influence on the yield when the upper portion is maintained at a relatively low level of salinity (Bernstein and Francois 1973; Bingham and Garber 1970; Shalhevet and Bernstein 1968; Lunin and Gallantin 1965; Wadleigh et al. 1947; Eaton 1941). Francios (1981) studied the effect of no leaching on alfalfa yield in a greenhouse. The plants were grown in a sandy loam soil with depths of 0.6, 1.2 and 1.8 m for periods of 9, 14 and 20 months, respectively, and irrigated by water with an EC of 1 dS/m. Yield was reduced by less than 25%, yet salt was stored in the lower portions of three different soil profile depths and did not begin to increase. When salts rose above a certain part of the root zone, yield was reduced severely. The higher the depth of the soil, the greater is its capacity to store salt with minimal yield reduction.

The cover of the soil surface (mulch) maintains moisture in the upper portion of the root zone and decreases salt accumulation. The result of a test conducted in Pakistan revealed that using organic mulch in comparison to plastic mulch reduced soil ECe and SAR by 53% and 45%, respectively (Chaudhry et al., 2004). Al-Dhuhli et al. (2010) concluded that mulching with shredded date palm leaves was the best management practice to conserve soil moisture and minimise salt accumulation in soil. In addition, sustaining soil moisture by mulch can help to leach salts in the next irrigation or rainfall (Rhoades et al., 1992).

Special irrigation and drainage management are needed to achieve sustainable agriculture. However, to obtain this type of management, it is necessary to recognise and fill the gaps in our understanding and knowledge. An area of concern is regarding farming management effects, such as mulching, and its relation to irrigation and drainage management for each crop type. The main objective of this study was to investigate mulching effects on the presence of shallow saline water table, on soil salt balance and date palm growth.

2. MATERIALS AND METHODS

To evaluate the effect of different management strategies on root zone salinity, lysimeter experiments was conducted. The sites for the lysimeters were situated at the Date Palm and

Tropical Fruits Research Institute of Iran in Ahwaz (N 31^0, 15’, E 48^0, 30’, 70 m a.s.l.; Fig. 1). This study was performed from March to December 2010, in three replicated split–plot designs, which included 3 levels of ground water salinity (main plot; S1= <4, S2= 8 and S3=12 dS/m) and two levels of soil surface cover (sub plot: M1= no mulch and M2= date palm leaves’ mulch) and for 2 water table depths (D1=60 and D2=90 cm) as shown in Table 1. The 36 experimental polyethylene drainage type lysimeters had 0.8 m inside diameter and 1.2 m depth, and were filled by loamy soil. In every lysimeter, one tissue culture date palm seedling (Cv. Berhii) was planted. Saline water was obtained by mixing the drainage and irrigation water. The Mariotte bottle was constructed with the method described by Moore (2004) and connected to each lysimeter to control the saline groundwater at D1 and D2 depths (Fig. 2).

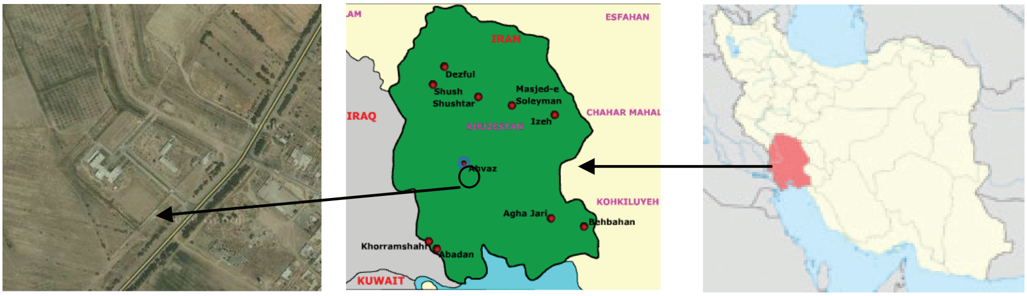

Fig. 1: Location of the experimental site

Table 1:Different treatment definitions

Water table depth	Treatment definition						Replication
D1 60 cm	S1 Ground water salinity<4 dS/m		S2 Ground water salinity=8 dS/m		S3 Ground water salinity=12 dS/m		3
	M1 without mulch	M2 with mulch	M1 without mulch	M2 with mulch	M1 without mulch	M2 with mulch	
D2 90 cm	S1 Ground water salinity<4 dS/m		S2 Ground water salinity=8 dS/m		S3 Ground water salinity=12 dS/m		
	M1 without mulch	M2 with mulch	M1 without mulch	M2 with mulch	M1 without mulch	M2 with mulch	

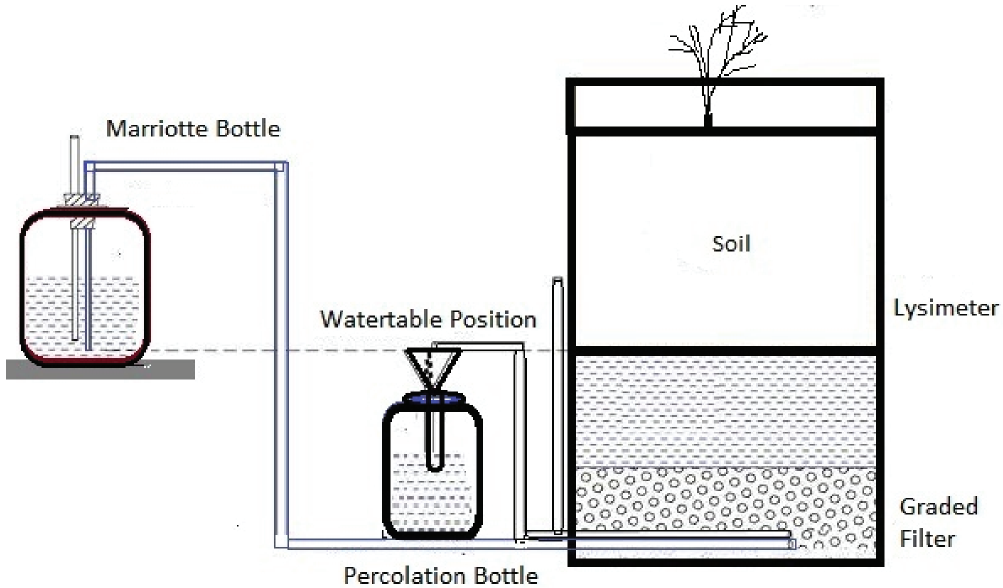

Fig. 2: Schematic diagrams of the Mariotte bottle and the lysimeter

2.1 Climatic data

Meteorological data of class A pan evaporation, rainfall, maximum and minimum temperature, relative humidity with wet and dry bulb, and wind speed, were recorded regularly at the climatic station close to the experimental site.

2.2 Irrigation

The date palm plants were irrigated with the water of Karoon River in which the EC ranged from 1.35 to 2.98 dS/m during the experiment. The volume of irrigation water was calculated by using Eq. (1) and (2) (Allen et al., 1998):

$$ET_c = ET_0 \times K_c \quad (1)$$

$$ET_0 = K_p \times E_{pan} \quad (2)$$

The same amount irrigation water was applied to all the treatments. Leaching requirement was not considered in the study.

2.3 Soil Salinity

The increase or decrease in the amount of salts present in the soil can be calculated by measuring the salt concentration and the amounts of irrigation, precipitation, drainage water, and capillary rise in each application. According to Aragües (1996), the general salt balance equation is presented in Eq. (3):

$$C_iW_i - C_dW_d - M_{hc} + (M_{sp} - M_{sd}) + M_{is} + M_{pre} + M_{afm} + M_{pr} + M_{iwr} - M_{dp} = 0 \quad (3)$$

Where:

C_i = salt content of the irrigation water (mg/L)

W_i = amount of irrigation water (L)

C_d = salt content of the drainage water (mg/L)

W_d = amount of drainage water (L)

M_{hc} = salt removal by harvesting of the crops (mg)

M_{sp} = precipitation of salts in the soil (mg)

M_{sd} = dissolution of salts in the soil (mg)

M_{is} = initial salts present in the soil (mg)

M_{pre} = salt mass in rainfall (mg)

M_{afm} = salts added by fertilisers and other amendments to the soil (mg)

M_{pr} = salts removed by runoff due to rainfall (mg)

M_{iwr} = salts removed by runoff due to irrigation (mg)

M_{dp} = salt mass leached below the root zone (mg)

The rate of capillary rise from the groundwater was estimated as the volume of water supplied from the Mariotte bottle to maintain the desired groundwater depths for various treatments. This volume was measured before every irrigation event.

The following assumptions and calculations were considered to obtain the various inputs for equation (3):

- For the lysimeter condition, M_{pr}, M_{iwr}, M_{dp}, M_{afm} and M_{hc} are equal to zero.
- M_{sp} and M_{sd} were considered as equal.
- Regarding the precipitation volume and the effect of precipitation on the quality of irrigation water; average elec¬trical conductivity (EC) was calculated from equation (4) (Elias Azar, 2003):

  $$EC_{(i+pre)} = (D_{pre}\,EC_{pre} + D_i\,EC_i)/(D_{pre} + D_i) \quad (4)$$

  C_i and C_d were estimated with Eq. (5) (Rhoades et al. 1992):

  $$C\ (\text{mg/L}) = 640 \times EC\ (\text{dS/m}) \qquad \text{for } EC < 5 \quad (5)$$

  $$C\ (\text{mg/L}) = 800 \times EC\ (\text{dS/m}) \qquad \text{for } EC > 5$$

- The salt content of soil was calculated from equations (6) to (8) (Kahlown et al. 2005):

  $$M_{is} = C \times W \quad (6)$$

  $$C = 640\ (\text{or } 800) \times \sum_1^n EC_e \quad (7)$$

  $$W = A \times \theta_{sat} \times D \quad (8)$$

Where:

M_{is} = total salt content of the soil (mg) to depth D

C = average salt concentration in saturation extracts (mg/L) to depth D

W = total amount of water in saturated soil (L) to depth D

EC_e = electrical conductivity of the saturation extracts from the soil layers (dS/m).In this case,the thickness of the soil layers was considered as 25cm.

n = number of soil layers to depth D

θ_{sat} = water content at saturation was calculated as 0.64 (mm/mm) using a bulk density of 1.67 gr/cm^3

D = soil depth (mm)

3. RESULTS AND DISCUSSION

3.1 Salt balance

The salt balance was calculated by using equation 3 for each lysimeter soil. Fortunately, as indicated in Table 2, most of the salts added to the soils had been probably leached from the root zone. Compared to the other treatments, the highest salt added to the soil was from D1S3M1 and D2S3M1. In these treatments, the salt change rates were 0.88 and 1.172 Kg per lysimeter from D1S3M1 and D2S3M1, respectively. In treatments D1S1M2, D1S2M2 and D1S3M2, soil was leached, while the highest salt change rate was observed in treatment D1S1M2. As shown in Fig. 3, with increasing salinity, the rate of leaching decreased. In other treatments of soil covering, D2S1M2, D2S2M2 and D2S3M2, mulch was able to maintain soil moisture and decrease evaporation; as a result, the least salt change rate occurred in the root zone (Table 2 and Fig. 4). Rhoades et al. (1992) also reported that mulch was successful in aiding in the leaching of salt from the soil.

Table 2: Average of salt change rate (Δs) (kg/lysimeter) in every treatment

Salinity of ground water	Δs (kg/lysimeter)	
	Without mulch(M1)	With mulch(M2)
	D1 = 60 cm	
S1= < 4 dS/m	0.644	-0.938
S2= 8 dS/m	0.863	-0.424
S3= 12 dS/m	0.880	-0.118
	D2 = 90 cm	
S1= < 4 dS/m	0.738	0.319
S2= 8 dS/m	1.141	0.620
S3= 12 dS/m	1.172	0.104

In a controlled water table at a depth of 60 cm (D1), the highest increase in salt change rate in the root zone was 0.88 kg per lysimeter from treatment D1S3M1, whereas the highest decrease in salt change rate was 0.938 kg per lysimeter in treatment D1S1M2. Generally, by increasing ground water salinity, the soil salt above the water table in treatments without mulch increased, whereas by decreasing ground water salinity, the soil leaching into the treatments with mulch increased (Fig. 3).

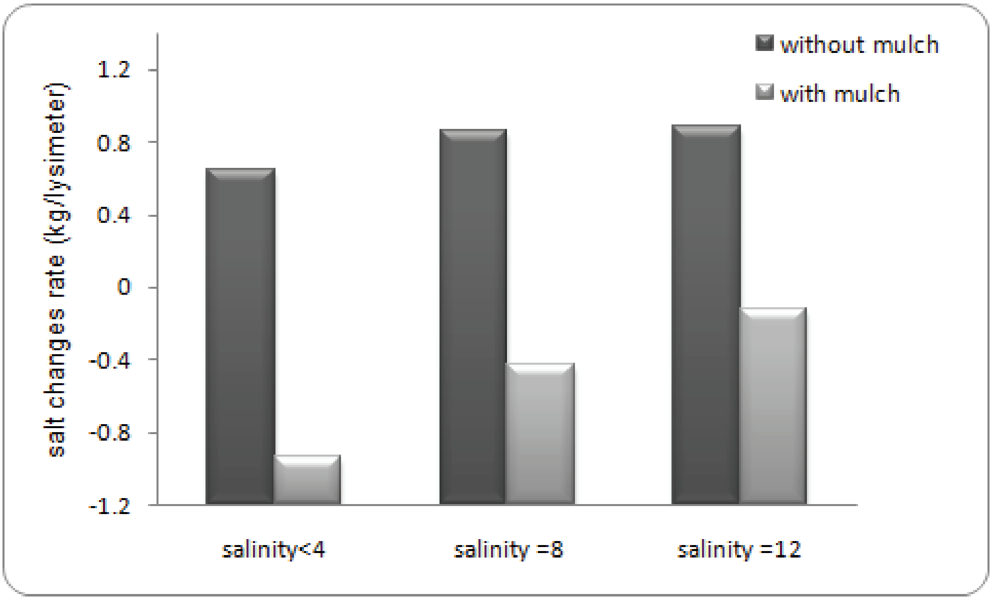

Fig. 3: Salt change rate of every treatment at the 60 cm depth of the water table

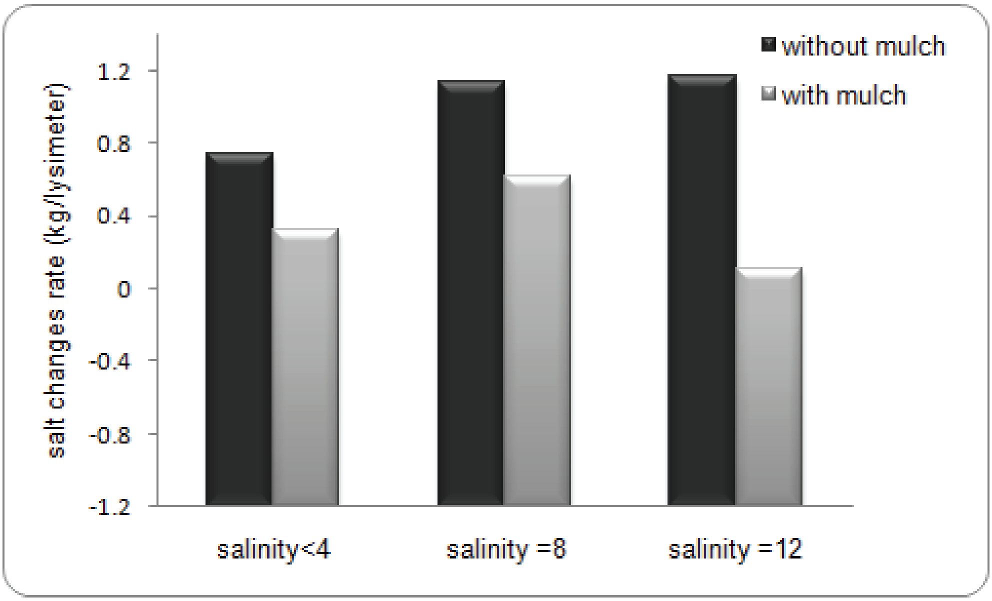

Fig. 4: Salt change rate of every treatment at the 90 cm depth of the water table

At depth (D2), the highest increase in the salt change rate was 1.172 kg per lysimeter, which belonged to treatment D2S3M1. At this depth, by increasing ground water salinity, the soil salt above the water table in treatment without mulch increased.

In lysimeters with soil surface cover (M2), less salt was added to the root zone soil. The minimum added salt change rate was 0.104 kg per lysimeter in the presence of ground water salinity at 12 dS/m (Fig. 4). This result was probably due on the soil structure properties as large joints and cracks are able to transfer water easily. As shown in Table 3, the factor of mulch had a significant influence (1%) on the existing salt amount, for D1. However, in D2, the treatments had no considerable differences. The soil electrical conductivity (ECe) in all the treatments tended to be in an equilibrium state (Table 4).

In treatments M1 (at both depths), ECe increased at the end of the experiments due to groundwater salinity. In treatments D1S1M2, D1S2M2 and D1S3M2, sustained moisture helped in the leaching and subsequent decrease of ECe. The maximum and the minimum values of ECe were 14.29 and 6.73 for treatments D2S3M1 and D1S1M2, respectively.

Table 3: ANOVA analyses (MS) of existing salt and salt change rate at 2 different depths of soil

Source	Degrees of Freedom	60 cm depth Salt changes rate	Existing Salt	90 cm depth Salt changes rate	Existing salt
Replication	2	0.170	0.457	0.134	0.191
Factor A(ground water salinity)	2	0.439 ns	0.009 ns	0.194 ns	0.07 ns
Error	4	0.399	0.257	0.189	0.804
Factor B (mulch)	1	7.470 **	5.687 **	2.016 **	1.972 ns
AB	2	0.128 ns	0.019 ns	0.182 ns	0.265 ns
Error	6	0.116	0.23	0.052	0.701
Total	**17**				

*, ** Significant at P=5% and 1%, respectively; ns- not significant

Table 4: ECe Average for every treatment

Salinity of ground water	Without mulch (M1)		With mulch (M2)	
	Initial ECe	Existing ECe	Initial ECe	Existing ECe
	D1 = 60 cm			
S1= < 4 dS/m	11.25	13.96	9.28	6.73
S2= 8 dS/m	10.35	13.05	8.81	7.22
S3= 12 dS/m	7.12	13.43	8.18	7.20
	D2 = 90 cm			
S1= < 4 dS/m	9.00	12.26	8.30	10.94
S2= 8 dS/m	5.41	12.16	6.31	9.75
S3= 12 dS/m	7.70	14.29	12.56	9.43

The drainage of these soils in combination with the irrigation systems played an important role in the accumulation of salt in the root zone. Figs. 5 and 6 show the subtractive process of drainage water EC in two controlled water table depths.

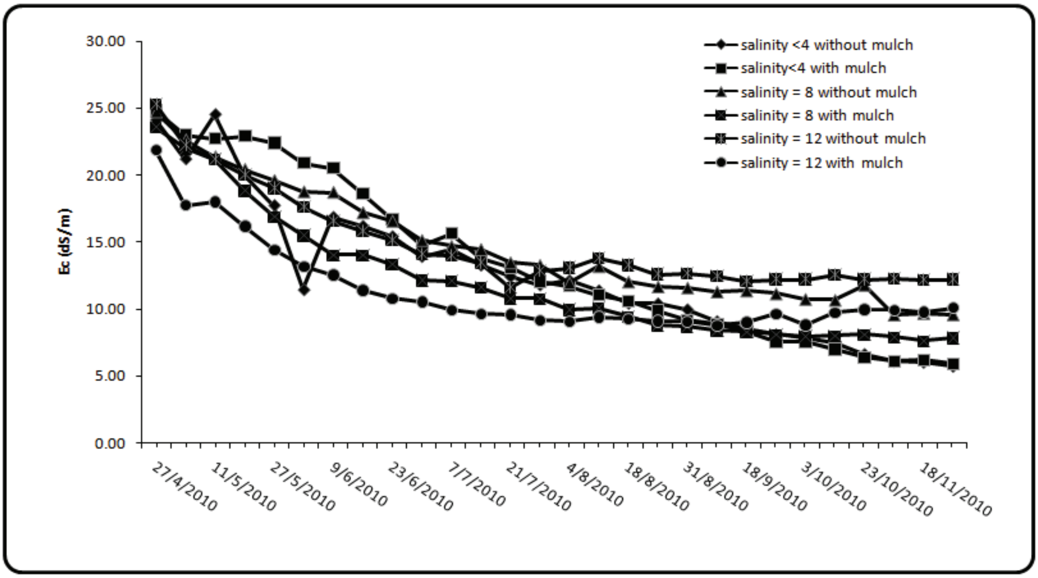

Fig. 5: Drainage water EC decrease of every treatment at the 60 cm depth

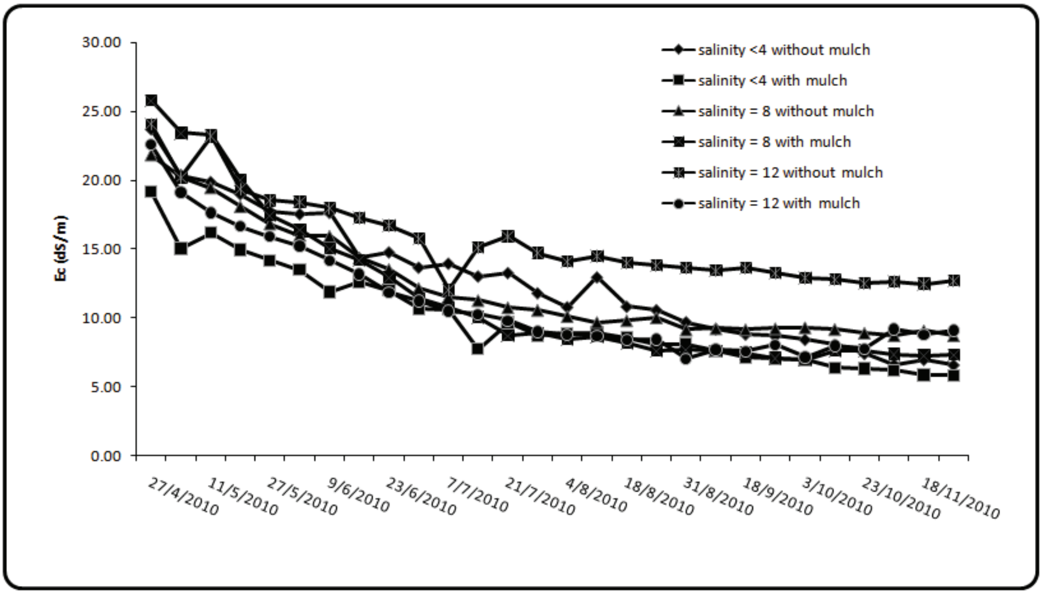

Fig. 6: Drainage water EC decrease of every treatment at the 90 cm depth

3.2 Growth of Date palm plants

Generally, treatments with soil cover showed a greater reduction in the electrical conductivity of drainage water than uncovered soil. The maximum and minimum drainage water ECs were observed in treatments D2S3M1 and D1S1M2. By increasing ground water salinity, the drainage water EC at the end of the experiment increased. In the controlled water table at a depth of 60 cm, the highest amount of reduction was observed in treatment D1S1M2 (Fig. 5). However, at the other depth, the maximum reduction occurred in treatment D2S2M2 (Fig. 6). At both the depths, drainage water EC of ground water salinity at 12 dS/m was increased after 5 months, whereas drainage water EC in treatments D1S1M1, D1S1M2, D2S1M1 and D2S1M2 were almost similar after 7 months. It should be considered that the total amount of precipitation was 74.1 mm during the entire experimental period, and by increasing the amount of precipitation in the winter, the root zone salts would have probably leached more The vegetative growth characteristics, such as the height of plants, trunk circumference, leaf and leaflet number, and leaf length and width, were measured at the beginning and the end of the experiment. Difference of these indices was considered as the rate of growth. The survival rate of the plants was 100% in all the treatments. In contrast, date palm plants tolerated soil salinity to a greater extent. The highest EC of soil was 14.29 dS/m in treatment D2S3M1. Ramoliya & Pandy (2003) reported the survival and growth of date palm in soil with EC to be approximately 12.8 dS/m. Mulch improved the growth of date palm plant. In experiments with the controlled water table at a depth of 60 cm, the new leaf and leaflet numbers were 4.33 and 117.67, respectively, in treatment D1S3M2. In treatment D2S2M2, these indices were 4 and 120.33 for a depth of 90 cm.

The ANOVA analyses (Table 5 and 6) indicated that salinity had no considerable effect on the vegetative indices. However, soil surface covering had a significant influence on leaflet production at 1% and 5 % levels for D1 and D2, respectively. The salinity and mulching had no significant influence on other vegetative growth characteristics.

Table 5: ANOVA analyses (MS) of the change in growth characteristics at the 60 cm depth of soil

Source	Degrees of Freedom	Height	Circum-ference	Leaf number	Leaflet number	Leaf length	Leaf width
Replication	2	81.267	0.704	0.5	191.167	9.238	37.914
Factor A(water table salinity)	2	82.444 ns	0.802 ns	1.167 ns	366.167 ns	4.082 ns	0.324 ns
Error	4	54.076	2.259	0.167	374.083	6.691	27.459
Factor B (mulch)	1	5.894 ns	0.467 ns	2.00 ns	2496.889**	31.575 ns	6.833 ns
AB	2	87.221 ns	0.269 ns	0.167 ns	378.389 ns	1.514 ns	3.187 ns
Error	6	35.913	1.625	0.611	137.889	39.248	13.03
Total	**17**						

*, ** Significant at P=5% and 1%, respectively; ns- not significant

Table 6: ANOVA analyses (MS) of the change in growth characteristics at the 90 cm depth of soil

Source	Degrees of Freedom	Height	Circum-ference	Leaf number	Leaflet number	Leaf length	Leaf width
Replication	2	138.067	2.122	0.389	42.722	104.231	4.797
Factor A(water table salinity)	2	2.617 ns	0.502 ns	0.889 ns	1066.056ns	90.4 ns	44.27 ns
Error	4	34.347	0.671	0.722	431.222	52.34	29.558
Factor B (mulch)	1	379.961ns	0.002 ns	1.389 ns	1800.0 *	26.185ns	8.405 ns
AB	2	155.434ns	4.787 ns	0.222 ns	561.167	3.544 ns	3.583 ns
Error	6	76.643	2.952	0.611	272.278	23.75	36.355
Total	**17**						

*, ** Significant at P=5% and 1%, respectively; ns- not significant

4. CONCLUSIONS

Although salinity of water and soil are two important factors for agriculture, by ensuring accurate and correct management, sustainable agriculture is a possibility. Water table management and farming practices, such as mulching and controlling the water table might maintain salt balance in the root zone. In this study, date palm plants could tolerate salinity stress up to 14 dS/m, as well as survive and grow under a controlled water table and mulching, without leaching. However, for proper maintenance of salt balance and adequate growth, there is a need to apply sufficient leaching for a long period of time.

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