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Full Length Research Paper

The desalination of salt water fix for irrigation by electrodialysis and its effects on the germination, growth and seed yield of wheat (*Triticum durum* Desf. Var. Karim)

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Morocco is characterised by a semi-arid climate and by unlimited conventional fresh water especially underground water. Electrodialysis experiment to desalinise water for irrigation was conduced on underground water from the north of Morocco. The effects of the use of desalted water on the germination and growth and seed yield of wheat were monitored to determine the best yield from use of desalted water for irrigation of wheat.

Key words*:* Electrodialysis, desalination, wheat, germination, production.

INTRODUCTION

The deleterious effects of the use of salt water on the productivity of agricultural crops are well known (Baaki, 1987; Cheeseman, 1987; Cramer, 1990; Hamza, 1980; VAN Hoorn, 1991). Morocco is characterized by a semi-arid climate and by limited conventional fresh water especially underground water particularly at the south of the country. The water use potential exceeds the 20 billion m-^{3} yr consisting of 16 billion m-^{3} per yr of surface water and 4 billion m-^{3} per yr of underground water. The percentage of the used water in agriculture exceeds the 75%. With the increase of agricultural activities and decreases of surface water resources because the dryness of these two last decades, the use of under ground water becomes frequent. This is the case in some regions in Morocco. However the salinity of much underground water exceeds the standards for irrigation of many crops and the use of this water resource decreases the yield of agricultural crops. Despite its high cost, sometimes the desalination of brackish water appears as the only non conventional solution. Many studies were carried out on the use of saline waters as sources of water for irrigation (Hell et al., 1998; Bannoud, 2001; El-kady and El-Shibini, 2001; Sheikhet et al., 1999; Kone, 2002) The aim of this work is to study the effect of the use of desalting water by electrodalysis at various salinities on the germination and the production of wheat (*Triticum durum* Desf. Var.Karim). This studies were conduced using an under ground water having a conductivity of 10 mS/cm, of the Gharb region in the North of Morocco were some water resources are frequently brackish. The electrodialysis is a membrane process using the electrical potential to cause transfer of ion through ion selective membranes. It’s a widely used electromebrane process especially for desalination of brackish water and reduction of sodium chloride concentration from seawater. Recently electrodialysis has been successfully employed in the *purification of many food products such as* milk, sugar and wine (El khatabi, 2001; Bonnin, 1988; Cherif et al., 1988; Meyer, 1990)

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MATERIALS AND METHODS

The desalination operations were conduced using an electrodialysis pilot supplied by EURODIA. Co-equipped with two ion exchange membrane especially AFN and CMX manufactured by TOKUYAMA Corporation for desalination. Tables 1 and 2 give the characteristics of electrodialysis pilot and membranes used. The principle of Elect-

Table 1. The electrodialysis pilot characteristics.

	Pilot TS 2-10
Active area of MEA and MEC (cm^2)	200
Number of MEA	10
Number of MEC	12
Number of Cellules	10
Product compartment :	
Volume (l) Flow (l/h)	2 180
Concentrate compartment :	
volume (l) Flow (l/h)	2 180
Electrodes :	
Volume (l) Flow (l/h)	2 150

Table 2. The electrodialysis membranes characteristics.

Membrane Type	Basic Composition	Area Resistance [a] ($.cm^2$)	Transport Number [b]	Exchange Capacity [c] (méq/g)	Membrane Thickness (mm)
CMX	Acid fort	2.5-3.5	0.98	1.7	0.18
AFN	Base forte	0.4-1.5	0.98	2.75	0.18

[a] Equilibrated with 0.5N NaCl solute, at 25°C.
[b] Measured by electrophoresis with seawater. Current Density : 2 (A/dm^2), at 25°C.
[c] In form Na^+ to MEC or Cl^- to MEA

Table 3. Chemical characteristics of raw water.

ECi	Soluble cations(méq/l)				Soluble anions (méq/l)				
dS/m	Ca^{2+}	Mg^{2+}	K^+	Na^+	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}	NO_3^-
10	24	16	0.12	55	0.7	1.9	89	6.21	0.12

rodialysis operation is shown in Figure 1. The desalination operations were carried out on an underground water of souk Tlet at station of the Regional office of the Agricultural Development of Gharb (Office Regional de la Mise en Valeur Agricole du Gharb) (ORMVAG). The mean characteristics of the untreated water are given in Table 3. The analysis of the taken sa-mple of the treated water was carried out following standard meth-ods already described.

The germination and production tests were conduced on a local variety of wheat (*Triticium Durum* Desf. Karim). It is a variety of Durum wheat, characterised by average straw yield, white in colour, big sized seeds long and vitreous in form, and clear or slightly amber in colour.

The seeds were sown in summer at the rate of seven seed per pot in pots filled with soil local ground. Each pot which has a dimension of 188 cm^2 and 10 cm height were filled with 3 kg of soil. The nutrients were supplied in solution as 45% super-triple phosphate as the source of phosphorus is corresponding to 178 kg/ha, 48 - 50% sulphate of potassium as the source of potassium corresponding to 240 kg/ha. 33.5% ammonitrate as a source of Azote corresponding to 537 kg/ha. Thus, each pot received 1.01 g of ammonitrate (33.5%), 0.33 g of super-triple (45%) and 0.47g of sulphate potassium (48 - 50%).

The irrigation was carried out with various desalted waters having different salinities at the rate of 300 ml per day and per pot. The experiments were replicated four times and the reproducibility is satisfactory.

Data obtained were subjected to one factor variance analysis and the treatment means were according to the NEWMAN-KEULS method

RESULTS AND DISCUSSIONS

Desalination by electrodialysis

The desalination operations were conducted following conditions already optimised in the laboratory. Various

	Pilot TS 2-10
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Number of MEA	10
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Number of Cellules	10
Product compartment :	
Volume (l) Flow (l/h)	2 180
Concentrate compartment :	
volume (l) Flow (l/h)	2 180
Electrodes :	
Volume (l) Flow (l/h)	2 150

Figure 1. Principle of desalting water by Electrodialysis.

Table 4. Chemical compositions of desalted water destine to irrigation.

ECi	**solubles cations (méq/l)**				**solubles anions (méq/l)**			
dS/m	Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	HCO_3^{-}	Cl^{-}	SO_4^{2-}	NO_3^{-}
W_0=0.9	0.36	0.84	0.005	8	0.3	5.15	3.9	0.09
W_1=2	0.96	1.04	0.005	17.0	0.6	12	4.20	0.11
W_2=4	2.07	3.93	0.025	33.5	1.0	32	4.96	0.12
W_3=6	5.8	6.8	0.045	43.5	1.1	50	5.45	0.12
W_4=10	24	16	0.12	55	1.9	89	6.21	0.12

water qualities were easily obtained by electrodialysis. Table 4 gives the mean parameters of the desalted water used for irrigation.

Germination

Table 5 gives the characteristics of the soil used for the experiment. The soil is characterized by a fine and ultrafine texture. The proportion of fine element (clay + silt) exceeds 90%, the quantity of sands is very small, and the content of organic matter is very low about 1.13% and low salt concentration. With regard to fertility, this soil is very poor, the exchangeable phosphorus and potass-ium were very low. The level of calcium is high and the content of the exchangeable bases are relatively high. Figure 2 shows the percentage of germination of wheat. The obtained germinations from the waters of different salinities (W_0, W_1 and W_2) are high and were respectively equal to 86, 75 and 76%. The percentage of germination was reduced in W_3 to 50% and in W_4 to 43%.Table 6 gives the germination rate for the different waters used in the irrigation and its variance analysis.

Height of stems

Plant height development in wheat was monitored. All of the stems were measured using a scale of 50 cm and by distinction between the knots. This parameter compares one treatment to the others and shows effect of the salinity on the growth of the plants. The measurements began 39 days after sowing, and were carried out each week.

Salinity affects physiological processes in wheat and these effects are translated into a reduction of the plant height (Figure. 3).

The results obtained with W_0 and W_1 are practically the same. A reduction in the growth of the stem is observed in the case of W_2, W_3 and W_4. This was about 90% for W_2

Table 5 . The soil characteristics used in the pot.

Physical characterstics	
Granulometric	
Fine ground (%)	100
Clay (%)	51.2
Fine silt (%)	40.8
Big silt (%)	0.1
Fine sand (%)	4.3
Big sand (%)	3.3
Hydraulic’s properties :	
Equivalente humidity (%)	39,5
Chemical characteristics	
Organic matter (walkley-black) (%)	1.13
Organic carbon (%)	0.66
Total organic matter (Azote) (Kjeldahl) (%)	0,06
NH_4^+(ppm)	43,2
NO_3^- (ppm)	49,6
C/N	7,38
Total calcium (calcimétre Bernard) (%)	12.7
Available phosphor (Olsen) (°/₀₀)	0.010
Exchangeable potassium (°/₀₀)	0.100
Water pH	8.69
Salinity (remove1/5 mmhos/cm/25°)	0.25
Exchangeables bases (méq/100g)	
Calcium	23.68
Magnésium	12.32
Sodium	1.87
Potassium	0.21
Cationic exchange capacity (CEC méq/100g)	39.00

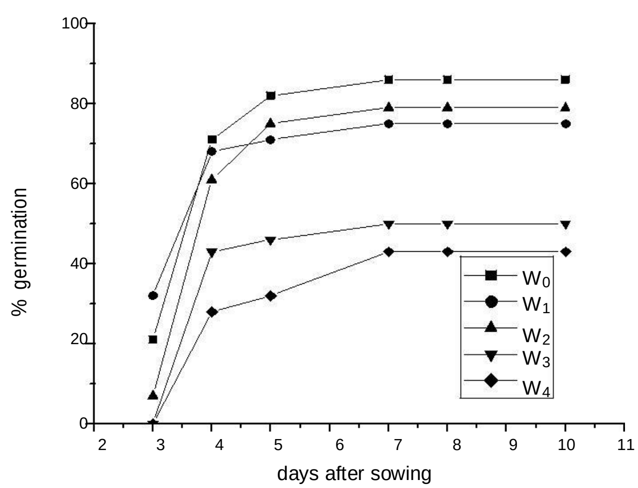

Figure 2. Evolution of percentage of germination according to time.

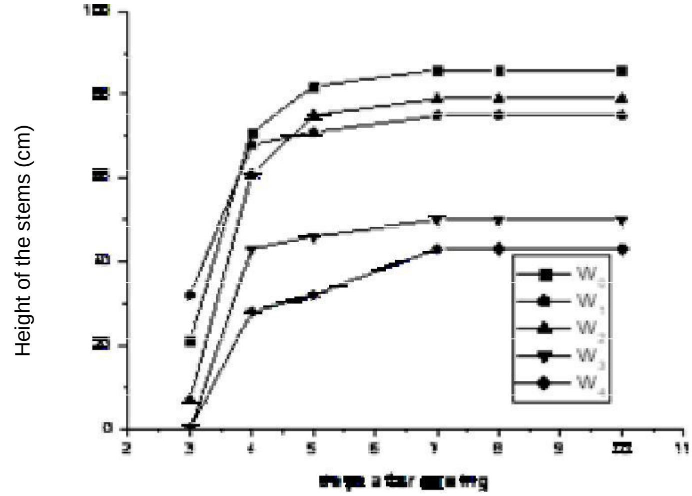

Figure 3. Variation in the length of the stem according to time date (days).

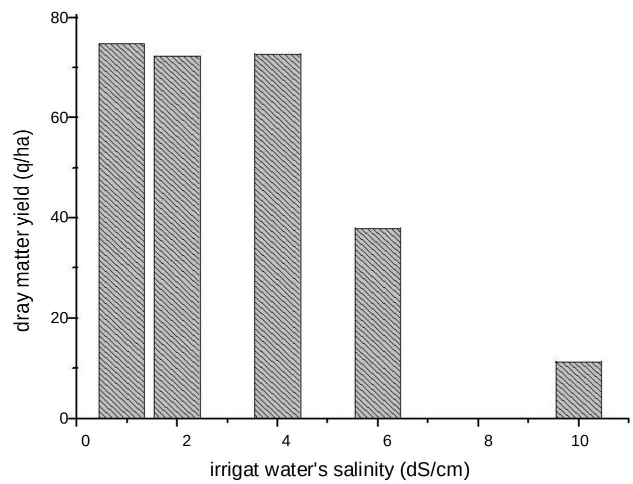

Figure 4. Variation of the matter dries according to the salinity of the water of irrigation

/W_0, 22% for W_3/W_0 and 30% for W_4/W_0. These results were confirmed by the analysis of the variance given in Table 7.

Dried matter (Straw + Seeds).

The results on shoot biomass obtained with W_0, W_1 and W_2 are practically the same. A great reduction of wheat dry matter was obtained in the case of W_3 and W_4. The reduction ratio is about 49% for W_3 and 85% for W_4 (Figure 4). The analysis of the variance given in Table 8 shows that the behaviour obtained with W_0 and W_1 present a homogeneous group which are significantly different from those obtained with W_0.

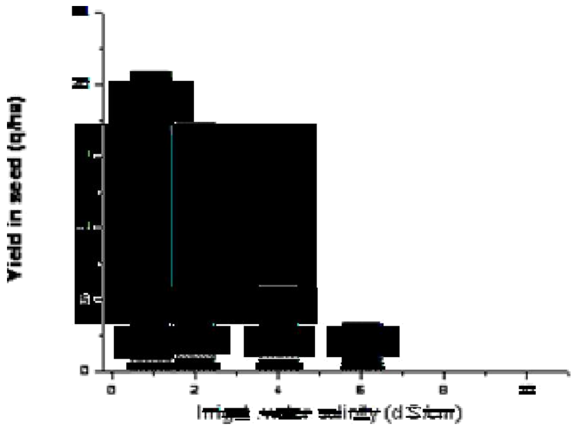

Figure 5. Variation of seed yield of wheat according to the salinity of the water of irrigation

Table 6. Analyze statistical of germination parameters.

Treatment	Germination rate (%)	Homogeneous groups	PPAS
W_0	85.71	A	2 - 21.47
W_1	78.60	AB	3 - 26.25
W_2	75.00	AB	4 - 29.22
W_3	60.71	AB	5 - 31.38
W_4	49.99	B	

Table. 7 Analyze statistical of wheat stems.

Treatment	Height of the stems (cm)	Homogeneous groups	PPAS
W_0	47.88	A	2 – 5.10
W_1	47.00	A	3 – 6.24
W_2	38.04	A	4 – 6.94
W_3	37.13	A	5 – 7.46
W_4	30.25	B	

Table 8. Analyze Statistical of total dry matter yield.

Treatments	Dry matter yield (%)	Homogeneous groups	PPAS
W_0	74.67	A	2 – 9.97
W_1	72.23	A	3 – 12.18
W_2	60.39	B	4 – 13.56
W_3	37.94	C	5 – 14.56
W_4	8.86	D	

Yield of Seeds.

Figure 5 shows that the production of seeds decreases with increasing salinity of the desalted water. The best results were obtained with W_0 with a rate of 82%. A great reduction was observed in the case of W_2 and W_3. Practically no seed yield was obtained with the untreated water W_4.

Table 9. Analyze statistical of seed yield in wheat.

Treatments	Yield of seeds (q/ha)	Homogeneous groups	PPAS
W_0	21.02	A	2 – 4.16
W_1	17.30	A	3 – 5.09
W_2	5.89	B	4 – 5.67
W_3	3.38	BC	5 – 6.09
W_4	0	C	

The variance analysis following NEWMAN-KEULS method given in Table 9 shows that the results obtained with W_0 and W_1 constitute an homogenous group.

Conclusion

Using an improved electrodialysis stack equipped with selective ion-exchange membranes, a desalination operation was easily conducted and various qualities of water were obtained. The results obtained on the germination, growth and seed yield of wheat irrigated with these desalted waters shown are as follows:

- The best results were obtained with the desalted water W_0 having a conductivity of 1 mS/cm. The performance decreases with increasing salinity.
- Wheat seeds showed an ability to germinate when grown and irrigated with desalted water whose salinity is equal to or lower than 4 mS/cm.
- The percentage of germination was greater than 70%, for W_0, W_1 and W_2.
- For the higher salinity of the desalted water, the performances of the irrigated wheat decreased due to the high osmotic pressure which inhibits water absorption. Also the high concentrations of Na^+ and Cl^- have an unfavourable effect on the wheat performance. The presence of the high Ca^{2+} content in the case of the higher salinity can limit the absorption of Na^+, K^+ and Mg^{2+}.
- The trouble is in assimilation of the biogenic salts generated in addition to the imbalance in the absorption of Bo, Zn, Fe and Mn. This leads to a decrease in the growth of the wheat and in its shoot biomass and seed yield.

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