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Impact of Irrigation with Saline Water on Soil and Crop Yields
-El Fjé Region Medenine-

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Abstract: The main objective of this study was to follow the soil saltiness and its effect on his physical and chemical characteristics following the irrigation by brackish water as well as the tolerance of some varieties to salt. The water used for irrigation comes from a boring that pumps water from the water table of wadi el Fjé (Medenine, Tunisia). The flow of pumping is estimated to 15 l/s. This brackish water has a high salinity with more than 8 dS/m as electrical conductivity and 6000 mg/l as a dry residue. In order to study the tolerance for the salt, two varieties of barley were used: Ardhaoui (local variety) and Pakistani (variety introduced from Pakistan). During the experiment, monitoring of water and soil characteristics was realized. Measurements have focused on physical and chemical analysis of soil and irrigation water taking into consideration the irrigation mode: drip irrigation, improved flooding irrigation, flooding irrigation and spraying irrigation.

The results indicate that the salinity for the plots irrigated by brackish water, increase on the surface for all treatments especially during dry season, except those irrigation by the drip system where the surface salinity is relatively low. The electrical conductivity in the soil is correlated with the content of the Sodium and the chloride. The sulphate levels are also high mainly in the deep layers. However, during the dry season, the sulphates are carried by capillary to surface layer. This experiment indicates also that the two varieties of barley (Ardhaoui and Pakistani) have great capacity for resistance to water and soil salinity, especially for flooding improved technique.

Keywords: Arid climate, Barley, Brackish water, Irrigation techniques, Soil salinity

1. Introduction

The phenomenon of soil salinity is a major obstacle to improve yields in arid areas, especially when water resources are limited and generally of poor quality. Indeed, the lack of rainfall and high evaporation makes intense use of irrigation required which leads to the extension and amplification of this phenomenon. So many research activities have been undertaken to overcome these problems through the development of techniques to reduce soil salinity and the identification of tolerant species to salinity. Thus, our objectives are:

- To study the effect of irrigation with brackish water in soil in arid zones.
- To identify the impact of irrigation on soil salinity and crops yields.
- To study the resistance of some crops to soil and water salinity: Barley (varieties Ardhaoui and Pakistani).

2. Materials and Methods:

2.1. Location of the study area

The perimeter of El FJE is located 22 km north-eastern of Medenine (Tunisia). It covers an area of 174 ha and it is limited on the north by the Institute of Arid Regions (IRA) which is part of the perimeter, by wadi El FJE on the south and by private farms on the east.

2.2. Experimental trials

This experiment (**Fig. 1**) was conducted at the Training Center and Agricultural Development of El FJE Medenine in which a barley crop has been installed. After levelling, the experimental plot was divided into four parcels. In each one, four irrigation systems (improved flooding, drip irrigation, flooding and spraying) were used to irrigate the two varieties of barley (Ardhaoui and Pakistani).

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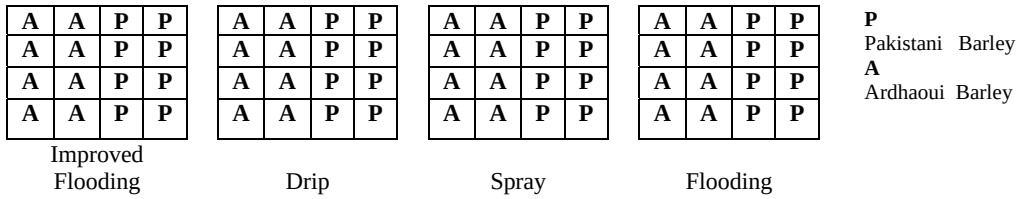


Fig. 1. Experimental plot of Barley.

2.3. Sampling of water and soil

The soil study concerned the morph structural description of soil profile and a chemical analysis laboratory of samples of each soil layer. In addition, soil samples were collected each month by auger according to different depths (25, 50 and 75 cm); and were the subject of a laboratory analysis which concerned: pH (pH-meter), EC (conductivity-meter), the ionic balance (Na^+: spectralphotometer flame emission, SO_4^{2-}: UV absorption spectralphotometer) of soil solution, the rate of gypsum (turbid metric method), limestone (volumetric dosing) and total organic matter (organic carbon dosing).

Water samples were also collected and analysed: pH, EC, the total dissolved salts (Afnor method) and ionic balance (K^+: spectralphotometer flame emission, Ca^{2+} and Mg^{2+}: atomic absorption spectrometry). These physical and chemical analysis of water and soil were conducted in the soil laboratory of the Institute of Arid Regions (IRA) Medenine.

2.4. Statistical analysis

The general linear model of SAS software was used.

3. Results and Discussion:

3.1. Soil Study

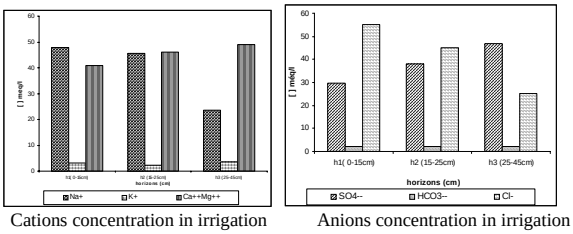
It is a sandy soil (USDA, 1957) with low content in organic matter (**Table 1**), its EC increases with the depth (from 5 dS/m in the surface layer to 8 dS/m in depth). This may be explained by an increase of the gypsum concentration with the depth (the Mio-Pliocene: clay and gypsum constitute the bed rock of the soil).

Table1. Soil characteristics.

Depth (cm)	EC (dS/m)	Ca CO 3 Total (%)	Gypsum (%)	Organic mater (%)	pH
0-15 cm	5.32	5.55	0.37	0.92	7.11
15-25 cm	7.99	8.33	1.5	0.18	7.23
25-45 cm	8.57	8.33	3.45	0.07	7.15

3.2. Irrigation water

The chemical analysis of irrigation water shows a total dissolved salts ranging between 5.2 and 6.05 g/l and an electrical conductivity ranging from 7 to 8 dS/m according to the seasons and the exploitation rate of ground water. Irrigation water salinity (USLS, 1954) is high, with sulphate sodium chloride facies and high alkaline risk.



Cations concentration in irrigation water

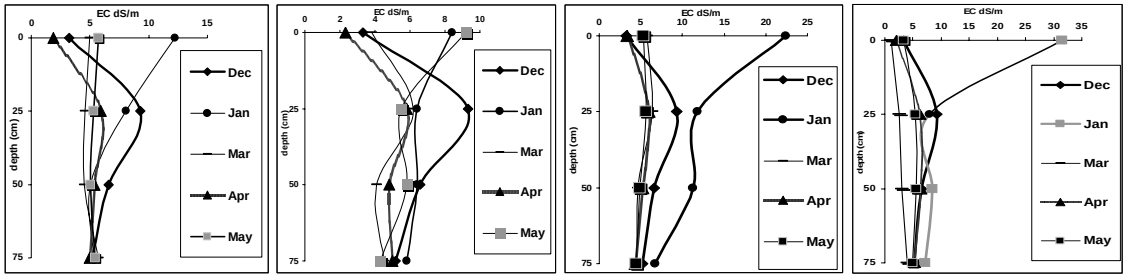
Anions concentration in irrigation water

Fig. 2. Ionic balance of irrigation water.

3.3. Impact of irrigation water on soil electric conductivity and Sodium content

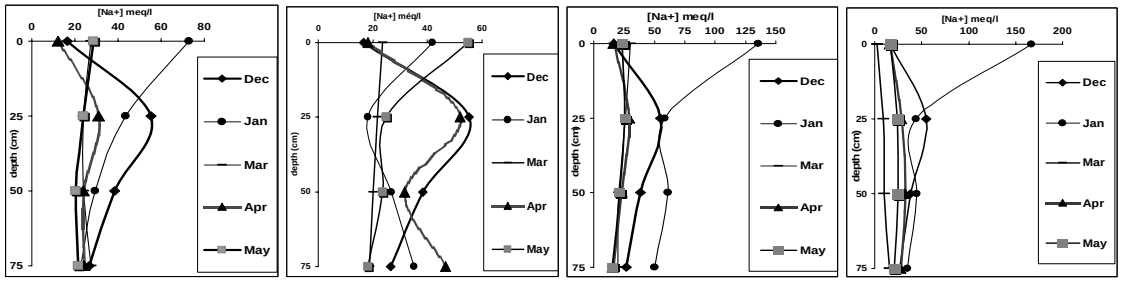
The irrigation system has an effect on salinity and crop yields, in terms of quantity and quality. For this reason, comparing the effect of irrigation on soil salinity is important to preserve our resources in the ground against the degradation mainly by salinisation.

According to the vertical variation of soil salinity as a function of time (**Fig. 3**), we note that before sowing (December 2006), the salinity profile was homogeneous for different treatments with a significant increase for the layer 25 cm attributed to low rainfall (Precipitation = 1.4 mm). Also, an increase in the salt concentration on the surface was identified for all treatments in January 2007 due to an important



Improved Flooding Drip Spray Flooding

Fig. 3. Vertical variation of salinity as a function of time.



Improved Flooding Drip Spray Flooding

Fig. 4. Vertical variation of sodium in the soil.

rising during this month because of the high temperature and the lack of rainfall. Indeed, for the drip irrigation system, the EC has not exceeded 10 dS/m, while for all other irrigation system, a high concentration of salts was recorded at the surface: it exceeded 20 dS/m for the improved flooding irrigation system and the spraying irrigation system and more than 31dS/m for flooding irrigation system. Thus, the drip irrigation system helps to maintain soil salinity to levels relatively low compared with other systems, especially during dry periods.

Since irrigation water has a sulphate sodium chloride facies, the sodium (**Fig. 4**) and chloride variation follows exactly the changes in the EC and has therefore confirmed our results on the salinity of the soil. These experimental results are confirmed by a statistical analysis (**Table 2**) of variance and a comparison of averages using the general linear models of SAS software.

3.4. Vertical Variation of sulphates in the soil as a function of time

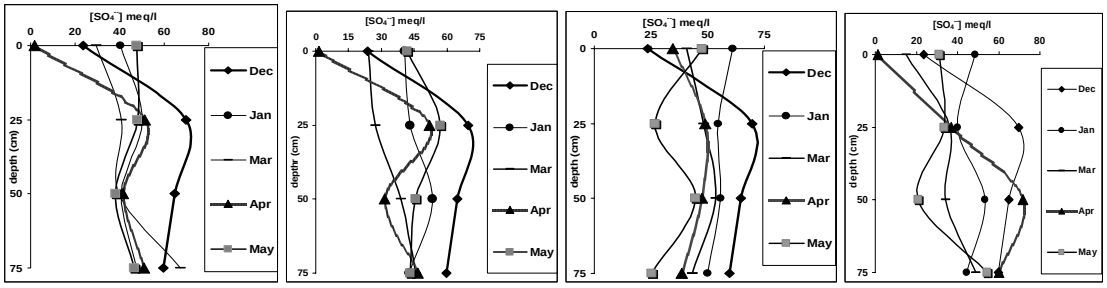
The sulphate concentration in the soil (**Fig. 5**) depends mainly on two factors time and depth. It appears that the effect of the irrigation system is hidden by other factors: gypsum content among others. The sulphate levels are high in depth because the soil bedrock is the miopliocene with a high concentration

Table 2. Comparing averages for EC and Na variables for factors time, depth and irrigation system.

	Modality	EC (dS/m) Averages	*	Na (meq/l) Averages	*
Time (months)	January	10.77	A	57.51	A
	March	5.36	B	24.24	B
	April	4.58	B	22.90	B
	May	4.40	B	20.05	B
Depth (cm)	0	9.52	A	52.94	A
	25	6.51	B	31.37	B
	50	5.99	B	28.66	B
	75	5.40	B	26.04	B
Irrigation System	Improved Flooding	5.90	A	30.14	A
	Drip	5.70	A	27.80	A
	Spray	7.90	B	40.30	B
	Flooding	8.02	B	40.55	B

***The averages with the same letter are not statistically different**

of gypsum. However, in dry period (January and May), the sulphates are carried by a capillarity rising to the soil surface.



Improved Flooding Drip Spray Flooding

Fig. 5. Vertical Variation of sulphates in the soil.

3.5. Effect of irrigation water on barley yield

The effect of irrigation on the yield of barley is variable. We note that the technique of spray irrigation allows for good water management but it is subject of some criticism (Slama, 2004) (including burning and early senescence of leaves).

- The drip irrigation although it allows for saving water, it can lead to spatial heterogeneity of salinity and poor leaching salts.
- For flooding irrigation does not save water particularly in arid areas where water is precious and rare. Thus, the flooding improved irrigation could giving the best crop yield.

It should be noted that the production of two varieties of barley (Ardhaoui and Pakistan) was low for all treatments (because of birds). However, depending on the status and vigour of plants, there is no difference between the two varieties concerning their resistance to soil and water salinity.

4. Conclusions

The soil salinity variation during irrigation by saline water is high on the surface for the different treatments especially during dry period except for the drip irrigation system where the surface salinity is relatively low.

The EC in the soil is well correlated with sodium and chloride. The sulphate levels are high in depth. However, during the dry period, the sulphates are carried by a capillarity rising to the soil surface. The two varieties of barley (Ardhaoui and Pakistani) have great capacity for resistance to water and soil salinity especially for improved flooding irrigation system.

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