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European Journal of Applied Engineering and Scientific Research, 2012, 1 (4):228-234
(http://scholarsresearchlibrary.com/archive.html)

ISSN: 2278 – 0041

Subsurface drip irrigated potato (*Solanum tuberosum* L.) with saline water under Tunisian climate

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ABSTRACT

Field experiment was conducted at the Higher Institute of Agronomy of Chott Meriem (Tunisia) during the growing season (2011/2012) to investigate the effects of water quality on water‘s dynamic in soil (water potential, soil moisture distribution, water's stock in soil) and water use efficiency (WUE) to produce potato (Solanum tuberosum L.). Irrigation management treatments were fresh (1 dS m^{-1}) and saline waters (4 dS m^{-1}). Subsurface drip irrigation was used, a rate of 4 L h^{-1} applied at the same irrigation duration and interval. The results indicate that water content is more uniform using the saline water varies from 15 to 23% than treatment varies from 10 to 26%. The recorded changes occurred due to improving soil water distribution in root zone are explained by the increased salinity and the existence of a root system more intense level of treatment. Water quality has no direct effect on water use efficinency.

Keywords: dynamic in soil, soil moisture, water use efficiency, potato, saline water.

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INTRODUCTION

The scarcity of fresh water in arid regions makes saline water a valuable alternative water source for irrigation. The national water strategy of Tunisia focuses on water as a prime natural resource, a basic human need and a precious naturel asset.it is vital for the achievement of a full potential of Tunisia agricultural sector in order to get food self-sufficiency and security [1]. Water scarcity in arid and semi-arid regions is a major concern for water and agricultural authorities around the world. High performance irrigation system such as subsurface drip irrigation system (SDI) is often recommended to surmount this problem and to dramatically increase the efficiency of water use over that of traditional irrigation system [2]. Subsurface drip irrigation has been shown to successfully increase efficiency of water application and to increase yield of many crops [3, 4]. It provides small water quantities at elevated frequencies so as to maintain relatively high water content and available nutriment concentration within the root zone [5]. Soil and water salinity in the arid regions are continuously increasing [6]. Globally, more than 770 000 km² of the lands are affected by secondary salinization, 20% of the irrigated areas and about 2% of the agricultural lands [7]. In Tunisia, soils affected by salts cover about 1.5 million hectares, around 10% of the total country area. About 30% of irrigated areas are affected by salts in different degrees [8].

Subsurface drip irrigation is a valuable irrigation method in arid and semi-arid regions. However, little research has been reported that evaluates effects of salinity on establishment of potato plant with SDI in Tunisia. For this object, we studied the effects of irrigation water salinity (ECw), (1.5 and 4 dS m^{-1}) on soil water dynamic and salt distribution with SDI buried at 25 cm during the growing season 2012.

MATERIALS AND METHODS

Experimental Site

The experiment was conducted at the Higher Institute of Agronomy of Chott Mariem, Tunisia. The climate is tropically Mediterranean with 230 mm annual rainfall and an average of 6 mm day^{-1} evaporation from a free water surface. The soil is sandy loam with basic infiltration rate of 214.3 mm h^{-1}, bulk density of soil was found to be 1.61 g cm^{-3} for the layer à 0- 80 cm. potatoes "*Solanum tuberosum* L." was seeded March 14 with row spacing of 80 cm and in row spacing of 40 cm.

Experimental design and measurement

Tow qualities of water were used to irrigate potatoes with 1.5 and 4 dS m^{-1} salinity with subsurface drip irrigation (SDI). Drip tubing (GR type, 16 mm diameter) with 40 cm emitter spacing built in each delivering 4 l h^{-1} at 1 bar pressure was used in SDI (4 drip tubing for each quality of water). The subsurface laterals were buried at depths of 25 cm. Weather data was obtained from a weather station located adjacent to the experimental area. The water potential in the soil was measured by means of probes "Watermark". The measurements are taken daily at 15, 30 and 60 cm depth. Time Domain Reflectometry technique (TDR) was used to determine soil volumetric moisture using portable soil moisture monitoring system "TRIME FM". The vertical profile of soil water content in every tube was determined from measurements of volumetric soil water. Soil moisture content was measured daily and the gravimetric sampling technique and steel rings were used to calibrate the TDR display unit. Six measurement tubes were installed for each quality of water. The measures were made by a layer of 10 cm in a tube of 1 m length. The measurement tubes were located just under the dripper 0 and 20 cm apart from the dripper. Water's stock in soil is calculated as integrating the soil volumetric moisture relative to the domain D composed of the elementary soil volumes.

$$S=\iiint\theta\,(dx,dy,\,dz)\,dxdydz \qquad (1)$$

S: Water's stock in soil (L^3/drop)
D: Domain or volume of soil (L^3)
$\theta_{(x,y,z)}$: Soil volumetric moisture relative to the node point of coordinates x, y, z.
dx, dy and dz take different values according to the grid bases to cover the set of the domain integration D.

The variation of the soil volumetric moisture (ΔS) in the domain D between two instant t and (t+dt) is (dt=1day)

$$\Delta S=S_{(t+dt)}-S_{(t)} \qquad (2)$$

RESULTS AND DISCUSSION

Soil characteristics

The soil physical properties were evaluated in the laboratory at the Higher Institute of Agronomy of Chott Mariem, to acquire information regarding the study plots and for subsequent analysis pertaining to the irrigation scheduling and sensor evaluations. The results are presented in table 1. Bulk density at the layer of 25-60 cm depth was higher than the top soil indicating that this layer is compacted than the others.

Table 1. Measured soil's hydraulic parameters

Layer		**0-25**	**25-60**	**60-80**
Soil class		Sandy loam	Sandy loam	Sandy loam
	%sand	91.2	92	90
Texture	%silt	4	4.4	7.2
	%clay	4.8	3.6	2.8
Water content	θ_r (%)	51.7	48.2.	46.2
	θ_s(%)	37.22	33.41	35.36
Hydraulic conductivity	K_s(cm/min)	0.256	0.213	0.209
Bulk density	Bd(g/cm^3)	1,56	1,68	1,61

Water's dynamic in soil

1. Water potential in the soil

Potential of the water in the soil in different depths 30, 45 and 60 cm for subsurface drip irrigation under tow qualities of water are presented in figure 1 and 2 respectively.

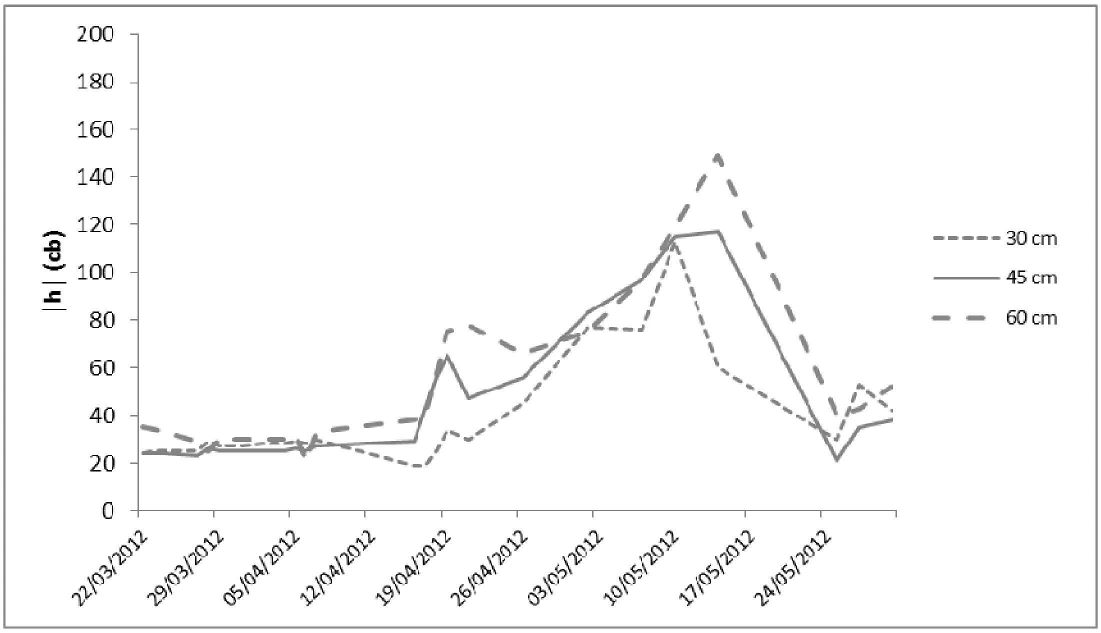

Figure 1. Soil water potential under irrigation from water dam (Witness)

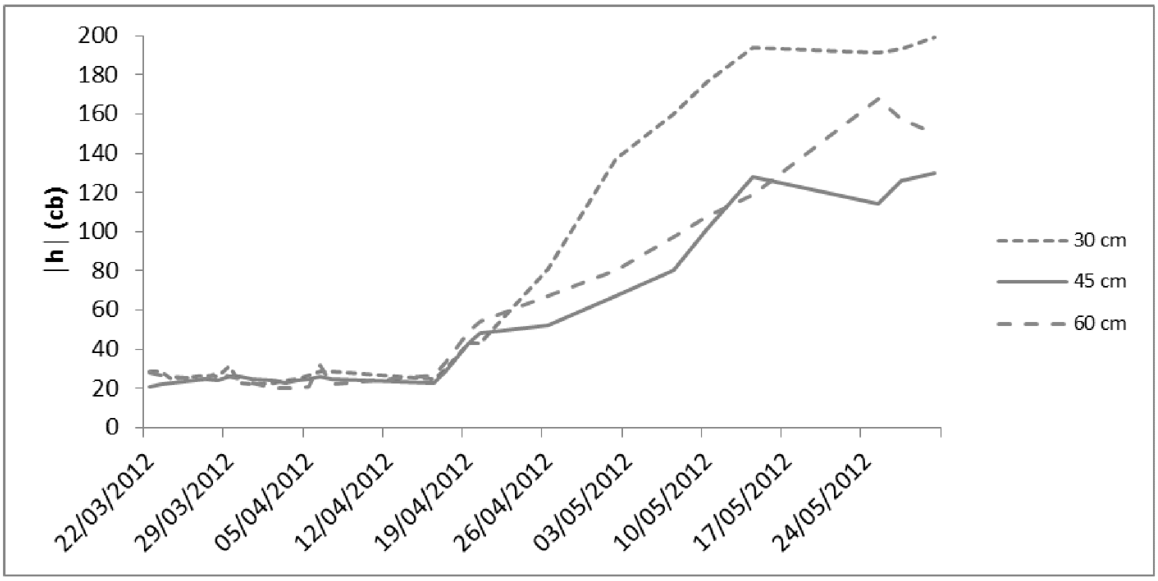

Figure 2. Soil water potential under irrigation by salt water

Figure 1 shows the results of measurements of water potential in soil for irrigation water from the dam (CE=1 dSm^{-1}) versus time and at different depths (30, 45 and 60 cm). Note that the suction between 22±3 and 39±3cb at the beginning of the cycle, measures the lowest are found at the deepest layer (45-60 cm), so this layer feeds those above or the root system is at the surface. From the tuberization stage, water potential values become higher. This is due to increased water needs of the plant and water loss by evaporation. We recorded voltage drops free for the first two horizons after each irrigation or rain, indicating a wetting of the soil at 45 cm depth.

Figure 2 shows the results of water potential in soil for subsurface drip irrigation with saline water that has an electrical conductivity of 4dSm^{-1} 2.8 (treatment) from a shallow well function of time at different depths 30, 45 and 60 cm. Suction oscillates between 23 ± 3 and 33 ± 3 cb at beginning of the cycle, measures the lowest are found at the deepest layer 45-60cm. However, one month after planting and because of climatic conditions that become relatively more severe and increased need for irrigation water tension of water increases and becomes very important. Because of salt stress water tension in the soil remains high despite the intense rainfall of 24 and 25 May, unlike the water potential witness.

2. Soil moisture

Soil moisture in different depths under tow quality of water with subsurface drip irrigation is presented in figures 3 and 4 respectively.

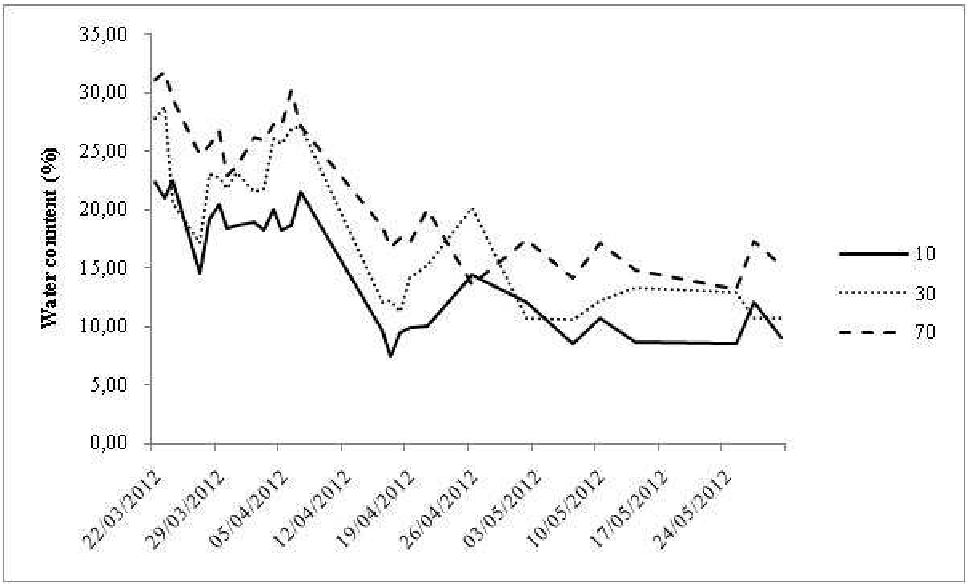

Figure 3. Volumetric water content in soil under subsurface drip irrigation from a dam

During the month of March the humidity varies between 23.5 and 25% for both 30 and 70 cm depths against moisture by registered for the surface layer varies between 19 and 23.4%. This difference is under the effect of evaporation. Nevertheless, from May 5 to May 19 the moisture up to 5% and peaks of 25.4% while the curve water content for the intermediate layer follows the same shape with the curve of 10 cm which remains stable with a phase shift of 5%. The moisture decrease between the layers is essentially backed to the infiltrated water and development of plant root system. In absence of irrigation and due to hard climatic conditions moisture content decreases to a minimum of 4% for the three depths.

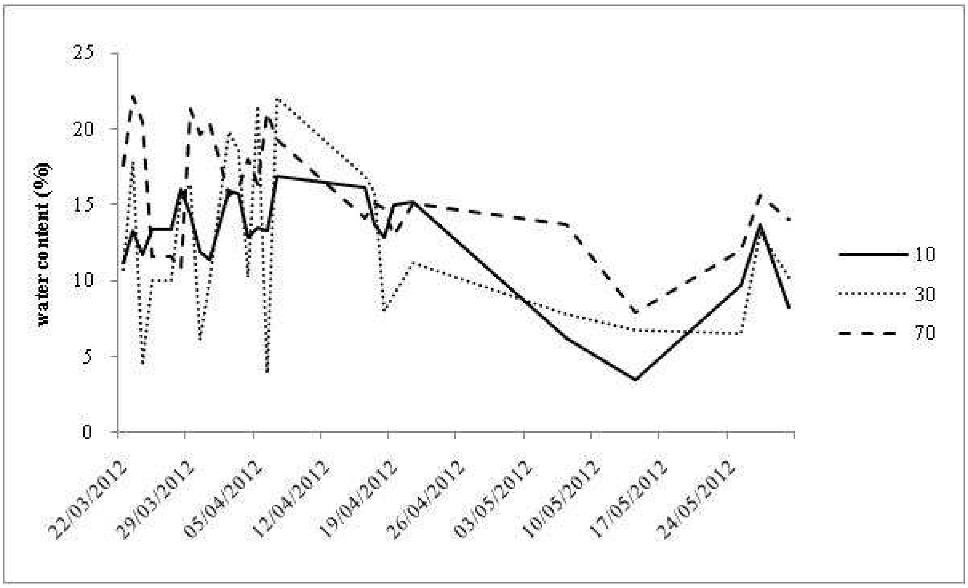

Figure 4. Volumetric water content in soil for irrigation with saline water

An examination of the previous figure shows that for 3 depths the water content is almost identical with a slight phase shift. Water content is similar for the three layers and oscillates between 5% and 27% before April 5. However, after this date a water content difference of 5% was saved for the two layers 10 and 30 cm, against the water content in the layer of 70 cm is constant for the reason that the root system doesn't reach this depth. Douh and Boujelben [9] evaluate the soil moisture distribution under drip irrigation system buried at 5, 20 and 35 cm and proved that a depth of 35 cm allowed more uniform moisture compared to 5 and 20 cm and that the highest values of moisture was recorded at deeper layer for all the treatments.

The moisture variation of the control and treatment was not significant in the last layers 30 and 70 cm. At the same time interval, we noticed a large variability between the moisture of fresh and saline water. Indeed, it varies between 15 and 26% for irrigation water from the dam and 5 and 27% for irrigation with saline water. However, the variation of moisture for the treatment at 10 cm depth follows the same shape as curves 30 and 70 cm. The water content was more uniform using the fresh water and it oscillated between 15 and 23% relative to the treatment 10 to 26%. The recorded changes are explained by the increased salinity and the existence of a root system more intense level of treatment.

3. Variation of water stock

The water stock is calculated by integrating the function θ (x, y, z) in domain D (40 * 80 * 75 cm^3) through the various measures of soil water contents at different depths and at different points, we calculated the stock in water in the soil and monitoring its evolution in time.

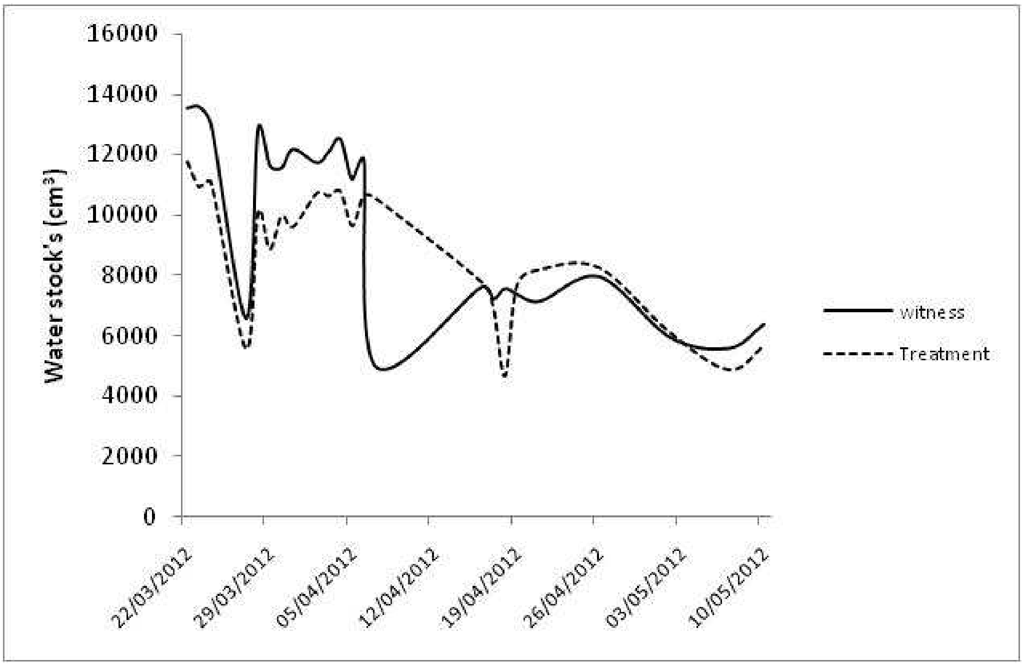

Figure 5. Evolution over time of stock in soil water for irrigation by the dam water (Witness) and irrigation with saline water (treatment)

From March 22 to April 5 the two curves follow the same shape with a difference of 6 mm/drop. After April 5, water stock for the treatment varies only in two positions relative to witness. Because the root water extraction in the witness is decreased to 5000 cm^3 in stock against the curve of water treatment does not follow the same pace that of witness, this small change is due the effect of salts on water absorption by the plant. Under the action of rain the salts are leached therefore the plant is being able to absorb water. Douh and Boujelben [9] found the amplitude of water stock's was more restricted in subsurface drip irrigation at 35 cm depth than 5 and 20 cm. Lamm et *al* [10, 11] have reported that a successful application of subsurface drip irrigation for 10 years in Kansas, USA reduced the irrigation water use be corn from 35 to 55% compared with traditional forms of irrigation.

Water use efficiency

Water use efficiency (WUE):there was no sgnificant WUE difference between treatment and witness, the witness had the higher WUE (figure 6) value 88.63 kg $ha^{-1}mm^{-1}$ compared to treatment 83.75 kg $ha^{-1}mm^{-1}$, but the diferrence is not hihger So the wtaer quality has no direct effect on water use efficinency. The irrigation system has great effect on water use efficiency . Subsurface drip irrigation. improved WUE, since evaporation from the SDI systems was minimal, transpiration increased wich improved evaporative cooling of the crop canopy, increased stomatal opening, and photosynthesis [12]. In addition, subsurface drip irrigation allows uniform delivery of water directly to the plant root zone.this can increase use efficiency over other irrigation methods [9, 13].

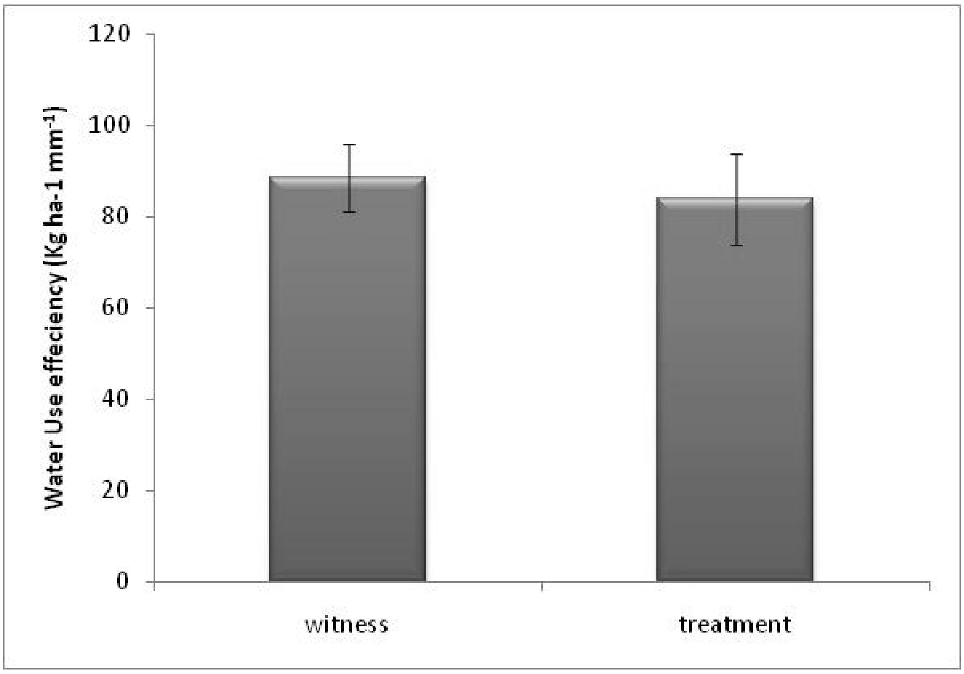

Figure 6. Quality of water effects on water use efficiency

CONCLUSION

This study indicate that the vegetative stage and climatic conditions and water quality have an important role in water potential variation and salt stress, the more salinity is elevated over the water potential is high. The volumetric water content varies between 15 and 26% for irrigation water from the dam and 5 and 27% for irrigation with saline water. The water content is more uniform using the dam water (15-23%) for the treatment or it varies from 15% (10-26%). The recorded changes are explained by the increased salinity and the existence of a root system more intense level of treatment. Moreover, irrigation water use efficiency was higher in witness than treatment. Subsurface drip irrigation allows uniform soil moisture, minimize the evaporative loss and delivery water directly to the plant root zone which can increase use efficiency, further observation we need to evaluate agronomic parameters irrigated in subsurface drip irrigation with this tow water quality.

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