Effect of Water Quality on Evapotranspiration, Growth and Yield of Potato

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Abstract

The current study was carried out at Agricultural College, University of Baghdad in the vegetable farm / Department of Horticulture during 2012 autumn growing season. The objective of the study was to estimate the crop water requirement under different treatment of water quality, growth and yield of potato. The experiment design was complete randomized block design in three replicates. The main plots were for replicates, and sub plots for irrigation treatment as follows: Irrigated with River water (1.25 $dS.m^{-1}$) (RW), Saline water (4.00 $dS.m^{-1}$) (SW) and Sequences irrigated (one irrigation river water + two irrigation saline water) (RW+SW). The treatment irrigation was imposed at 35% depletion of available water. Plant height, leaf area index, number of stems/plant and fresh weight accumulation were significantly hardly affected by the salinity treatments. Actual evapotranspiration for potatoes during autumn season was 527 mm. The treatment of RW+SW irrigation water reduced in the mount of applied fresh irrigation water about by 173 mm.

KEYWORDS: Saline water, Evapotranspiration, Water Use Efficiency, Yield, Potato

1. INTRODUCTION

In less than fifty years the world population has doubled, world food supplies have decreased and energy, land, biological and water resources have become under great pressure, the ***United Nations*** **(2001)** estimate that approximately 9.4 billion people will be present by 2050. In arid and semi-arid regions, where growth is limited by water shortage or by water of poor quality, the use of saline water for crop production is often unavoidable. Most crops tolerate salinity up to a threshold level above which yields decrease as salinity increases (***Maas*** **1986**). However water availability is different among regions, with huge differences in different parts of the world and wide variations in seasonal and annual precipitation in many places. The average precipitation for most continents is about 700 mm/y, but this mean varies among within them. In fact if we consider the Iraq, we observe that has an average rainfall of less than 300 mm/y, but there is a great variability between arid and non arid zones (***Pimentel et al.***, **2004**).

Humans obtain all their nutrients from crops and livestock and these nutrient resources require energy, land and water for the productions. The importance of irrigation in agriculture is underlined when we consider that approximately 17% of croplands worldwide are irrigated and they produce about 40% of the world's food. Because of the increasing of world population we need to increase the irrigated areas, and this is possible if we rise the efficiency of water use. In fact water is already in very short supply in several countries, and many others also suffer locally from severe shortages (***FAO***, **2002**).

Many agricultural practices cause alteration of soil attributes that result in soil malfunction and degradation, and soil quality is a critical component of sustainable agriculture. The use of non conventional water resources can give serious consequences to crop productions and soil if management is not correct. Soil salinity problems and irrigation with saline water are widespread and it is estimated that include one third of all irrigated lands. Both humid and arid, semiarid regions are involved in this problem, even if it is more present in the second one. For example there is salinity soil hazard in Australia, India, Middle East, and Southwestern U.S.A., which are commonly arid and semiarid; nevertheless we have the same problems in Iraq.

The salinity problem is more acute in arid and semiarid regions due to the need of extensive irrigation, low annual rainfall that is not enough to meet evaporative need crops and relative scarcity of good quality water. Thus, even with relatively good quality water, the permanent irrigation practice causes the irrigated soil to be affected by an excess of soluble salts (***Bresler,* 1982**).

Potatoes are amongst the world's main food crops and their demand is increasing at a greater rate than many other food crops (***FAO,* 1995**). Potatoes are classified as moderately salt-sensitive (***Maas and Hoffman*, 1977**) particularly in the early growth stages, and as very sensitive to water stress (***Kleinkopf,* 1983**). The purpose of the present study was to provide additional information on the growth and development of potato under salinity water supply on physiological of plant and actual evapotranspiration.

2. MATERIAL AND METHODS

Experimental site and climate: The experiment was carried out during autumn seasons of 2011- 2012 in field of Agricultural Collage- University of Baghdad /Abu-Graib- Baghdad, Iraq (33º 20´ N, 44º 12´ E; elev. 34.1 m). Potato (*Solanum tuberosum* L.) was planted on soil of EC_e (2.71 $dS.m^{-1}$), pH (7.52), organic matter (12.13 g kg^{-1}), silt clay texture (Sand=110 g kg^{-1}, Silt=470 g kg^{-1} and Clay = 420 g kg^{-1}) with average bulk density of 1.42 $Mg.m^{-3}$ and soil content moisture 0.332 cm^3cm^{-3} at field capacity and wilting point equal 0.164 cm^3cm^{-3}, The contents of nutrition in soil - available N, P and K are 267, 285 and 10.21 mg. kg^{-1}, respectively. Soil properties were determined using the standard laboratory methods (**Black, 1965 a & b**). Averages of annual temperature, relative humidity, wind speed and total annual precipitation are presented in Table 1.

Table 1- Some climatic parameters of the experimental region

Month	Average wind speed ms^{-1}	Average sunshine $mj\ m^{-2}$	Rainfall mm
September	2.78	39.13	0.0
October	1.78	18.71	0.0
November	1.52	11.67	0.9
December	1.34	9.52	6.5

Crop management and experimental design: The experimental design was Randomize Complete Block Design with three replicates. The main plots were for replicates, and sub plots for irrigation treatment as follows:

1. Irrigated with River water (1.25 $dS.m^{-1}$) (RW)
2. Irrigated with Saline water (4.00 $dS.m^{-1}$) (SW)

3. Sequences irrigated (one irrigation river water + two irrigation saline water) (RW+SW)

The results of Table 2 show the chemical properties for river and saline water.

Planting took place on September 15, 2011 using seeding rate of 2000 $kg.ha^{-1}$ in 75 cm spaced rows with net plot size of 12 m × 4.5 m, each experimental unit consisted of 6 rows. Irrigations were scheduled when soil water content in the root zone was depleted by the crop to specific fraction of the available water (irrigation was imposed at 35% depletion of available water). The soil depth of the effective root zone is increased from 0.15 m at planting to 0.50 m in bulking and tuber enlargement stages. Measured amount of water were delivered to the furrows using water meter gages. Soil water content was measured gravimetrically method 1-2 days before and 2-3 days after irrigation. In this study irrigation treatment were analyzed (every-furrow irrigation in which water is always applied to every furrow, uses open-end furrows and is known as the conventional continuous furrow application). Actual evapotranspiration values (*ET*, mm) for all treatments were calculated as in equation 1 (***Allen et al. 1998***):

$$I + P = ET_a + D + \Delta S \dots\dots\dots (1)$$

Where P is the rainfall (mm); I is the irrigation applied to individual plots (mm); D is the deep percolation; and Δs is the change in water storage of the soil profile (mm). Since the amount of irrigation water was only sufficient to bring the water deficit to field capacity, deep percolation was ignored. Irrigation water use efficiency (WUE_{IR}) was estimated by equation (2) using the model given by ***Howell et al.* (1990)**, which is yield produced per cubic meter of irrigation water.

$$WUE_{IR} = \frac{Y_a}{D} \dots\dots\dots (2)$$

All plots received basic application of 300 kg N, 250 kg P_2O_5 ha^{-1} and 400 kg K_2SO_4 ha^{-1}. Granular fertilizers were hand spread before planting. Phosphorus source was di-ammonium phosphate, applied at once before planting. Nitrogen source was urea 46-0-0, split two times during growing season.

Table 2- Some chemical properties of water irrigation used

Properties		River Water	Saline Water
pH	---	7.4	7.3
EC	dS. m-1	1.25	4.0
Ca	$mmol\ L^{-1}$	2.9	3.8
Mg		1.6	6.8
Na		4.2	16.9
K		0.02	0.18
Cl		5.6	12.7
HCO_3		1.4	6.5

CO_3		---	---
SAR	$(mmol\ L^{-1})^{1/2}$	1.69	5.19

During the growing season, plant height and leaf area were determined. Harvesting was carried out on 2 January, 2012. Potato tubers were then graded visually into marketable (>3.5 cm in diameter) and cull (<3.5 cm, bruised, green or sprouted tubers). Marketable and total tuber yield were determined by weight, and only marketable tuber data is reported in this manuscript. Also measured the electrical conductivity and sodium adsorption ratio (SAR) in different period of season by equation (3) at depth soil 20, 40 and 60 cm:

$$SAR = \frac{[Na^{+}]}{\sqrt{\frac{[Ca^{++}]+[Mg^{++}]}{2}}} \dots\dots\dots\dots(3)$$

Data were analyzed using SAS (***SAS, 2001***) and differences among treatments tested according to LSD $_{0.05}$.

3. RESULTS AND DISCUSSION

Irrigation with saline water led to a continuous increase in soil salinity (Fig. 1) and sodium adsorption ratio (Fig. 2). In general, owing to frequent irrigation and leaching, relatively constant soil salinity is maintained in the root zone (***Bernstein and Francois 1973***). Thus, the final values of EC at a depth of 60 cm were 2.6, 7.1 and 4.9 dS m^{-1} in treatments RW, SW and RW+SW, respectively higher than planned at the beginning of the experiment, and the soil salinity increased by about 173% and 88% in SW and RW+SW compared with RW. The SAR content final in treatments RW, SW and RW+SW at a depth of 40 cm were 1.4, 5.6 and 2.5, respectively and the SAR ratio increased by about 300% and 78% in SW and RW+SW compared with RW (Fig. 2).

The results obtained in our experiment highlight the differences that have occurred in soil salinity and sodium adsorption ratio, that this difference is due to the difference in the quality of water used in irrigation and climatic conditions that have helped to collect salts in the soil, when evaporation causes an increase transmission salts from the bottom to the top, as well as higher salinity in irrigation water.

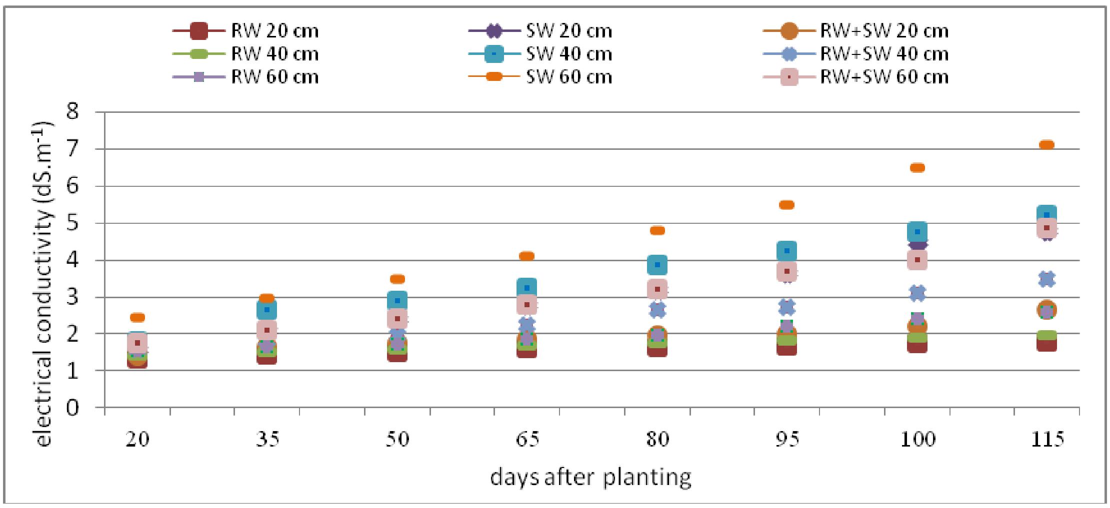

Fig. 1- Electrical conductivity (EC) of the soil layer extracts

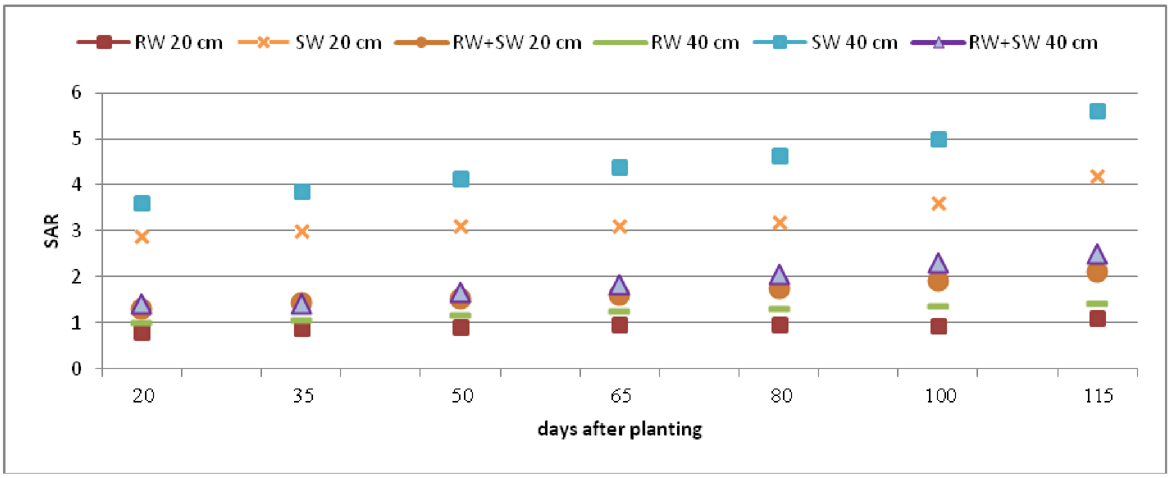

Fig. 2- Sodium Adsorption Ratio (SAR) of the soil layer extracts

Plant height, number of stems/plant and leave area index were significantly affected by salinity water (Table 3). Plant height was reduced by about 43% and 23% in treatments SW and RW+SW compared with the RW treatment. The number of stems/plant and leave area index in treatments RW, SW and RW+SW were 4.15; 4.21, 2.15; 1.85 and 3.21; 3.26, respectively. All growth parameters were strongly affected by salinity, a salt-specific effect appears as salt injury in the old leaves, leading to their death. Loss of only a few leaves does not affect plant growth, but if the rate of leaf death approaches the rate of new leaf production, a substantial drop in the supply of assimilates to the growing leaves can occur, leading to a significant suppression in plant growth. In our experiment, leaf death which reduced leaf number was responsible for the decrease in leaf area (**Bruria and Nadler, 1995**).

Table 3- The effect of salinity water on plant height, number stem/plant and leave area index of potatoes

Treatment	High of plant (cm)	Number of stems/plant	Leave area Index
RW	65.23	4.15	4.21
SW	37.45	2.15	1.85
RW+SW	50.12	3.21	3.26
LSD 0.05	4.76	0.31	0.42

Data on the amounts of applied irrigation water and measured actual evapotranspiration for all treatments during the growing period are presented in Table 4. Actual evapotranspiration for potatoes during autumn season was 527 mm. The treatment of RW+SW irrigation water reduced in the mount of applied fresh irrigation water about by 173 mm. Irrigation with RW (River Water) caused significant increasing in yield potatoes and reached to 26670 $kg.h^{-1}$ and 21230 $kg.h^{-1}$ in irrigation with RW+SW, while SW treatment reduced in total yield 14453 $kg.h^{-1}$ (Table 4). Early research reports that seasonal potato ET ranged from 350 to 800 mm for different climatic and environmental conditions (***Panigrahi et al., 2001; Ferreira and Carr, 2002; Shock et al., 2003; Onder et al., 2005 and Ati et al., 2010***).

In case of irrigation with saline water, plant becomes less able to extract water from the soil with high salinity, due to circumstances tension saline although water is available for the plant in the root zone, as well as lower indicators the vegetative growth (high of plant, number of stems/plant and leaves area index) that negatively affect on the quantity of products of photosynthesis, growth and yield.

Table 4 - Amounts of irrigation water applied, actual evapotranspiration and yield of potato

Treatment	Irrigation water applied (mm)	Actual evapotranspiration *ET* (mm)	Yield (kg.ha^{-1})
RW	520	527.4	26670
SW	520	527.4	14453
RW+SW	173+347	527.4	21230
LSD 0.05			552

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