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Irrigation Water Conservation and Sandy Soils Management in Saudi Arabia

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Abstract

Water management practices in conserving water for arid land are essential for sustaining agriculture in sandy calcareous soils, which represent more than 45% of the cultivated soils in Saudi Arabia. The present study aims to investigate the effect of drip irrigation method (surface and subsurface), natural deposits, three irrigation levels and two different water quality on water use efficiency (WUE) and yield of tomato crops, and the distribution of salts and water contents. A two experiments, field and greenhouse, were conducted in order to achieve the stated objectives.

The purpose of this study was to investigate the effect of irrigation (levels & methods) using three types of clay deposits on tomato yield, water use efficiency (WUE) and the distributions of soil moisture and salts in the root zone of sandy calcareous soils. Field experiment was conducted at the college experimental station in 2003-2004 season. The soils are non-saline, calcareous ($CaCO_3$ ranges from 269 to 353 gkg^{-1} soil) and sandy in texture, while irrigation water has high salt content (TDS=3300 mgL^{-1}) and moderate alkalinity (SAR=7.69). Natural clay deposits were collected from different regions in Saudi Arabia e.g. western region (Khulays) and central region (Dhruma and Rawdat areas). The three amendments (Khulays, Dhruma and Rawdat) were applied in each row as a subsurface thin layer at a depth of 15 - 20 cm and at rates of 1 and 2% of the soil. The experiment include surface (S) and sub-surface (SS) drip irrigation, with four irrigation water applied 234 mm (T1), 330 mm (T2), 388.5 mm (T3), and 564.5 mm (T4) for entire season. Twenty-seven soil samples were collected before irrigation from the root zone area on a grid bases (15 cm apart) around the dripper and at three growth stages i.e. vegetative, flowering and fruiting. Samples were collected from the lower and higher amendment rate treatments and then water contents were determined by gravimetric method after oven drying at 105^{o}C. Salt distributions were assessed by measuring EC in 1:1, soil to water extract, then three dimension figures for water and salt distributions in the root zone area were introduced using Matlab software for the collected soil samples. Results of analysis of variance for the tomato fruit yield and water use efficiency (WUE) as affected by water regime, surface and subsurface drip irrigation and types and rates of amendments showed significant differences between the means. Data showed that differences due to water regime and interaction between amendments rates and water regime were highly significant (1% level) for both tomato fruit yield and WUE. Results indicated that moisture content of subsurface treated layer increased dramatically, while salts accumulated at the surface and away from the emitters in subsurface drip irrigation. The advantage of subsurface drip irrigation was related to the relative decrease in salt accumulation in the root zone area where the plant roots were active and water content was relatively high.

Keywords: Drip irrigation, clay deposit, tomato yield

Introduction

The sustainable use of scarce water resources in Saudi Arabia is a priority for agricultural development. The pressure of using water in agriculture sector is increasing to create ways to improve water use efficiency and taking a full advantage of available water. Therefore, adoption of modern irrigation techniques is needed to be emphasized to increase water use efficiency. Drip irrigation is the most effective way to apply directly water and nutrients to plants and not only save water but also increases yields of vegetable crops (Tiwari et al., 1998a,b; Tiwari et al., 2003). Bryla et al. (2003) reported that drip irrigation improved production and water use efficiency of faba bean in California using different levels of irrigation based on percentage of evapotranspiration. Ayars et al. (2001) reported from their studies on subsurface drip irrigation and furrow irrigation in the presence of shallow saline ground water that yield of the drip irrigated cotton improved during the 3-year study, while that of furrow irrigated cotton remained constant. Also, tomato yields were greater under drip irrigation than under furrow irrigation in the same study from the first year. Lamm and Trooien (2003) reported that a successful application of subsurface drip irrigation for 10 years in Kansas, USA reduced the irrigation water use for corn by 35 – 55% compared with more traditional forms of irrigation. The purpose of this study was to investigate the influence of irrigation levels, surface, and subsurface drip irrigation on tomato yield, water use efficiency, water and salts distributions and rooting pattern in irrigated sandy calcareous soils amended with different rates of natural clay deposits.

Materials and Methods

A Field experiment was conducted at the College of Agricultural Research Station at Dirab, Saudi Arabia during 2003–2004 season. The soil is non-saline, non-sodic calcareous and sand and the irrigation water is highly saline and moderately sodic. Natural clay deposits were collected from different regions in Saudi Arabia e.g. western region (Khulays) and central region (Dhurma and Rawdat areas). Deposit samples were prepared by grinding and sieving through a 2mm sieve. Some physical and chemical characteristics of representative samples are presented in Table 1.

The three amendments (Khulays, Dhurma and Rawdat) were applied in each row as a subsurface thin layer at a depth of 20 - 25 cm and at rates of 1 and 2% of the soil. The experiment included surface (S) and sub-surface (SS) drip irrigation with four irrigation levels 234 mm (T1), 330 mm (T2), 388.5 mm (T3), and 564.5 mm (T4) over the entire season. The 30 m x 30 m field plot was divided into four equal subplots for the irrigation levels (T1, T2, T3, and T4). The experiment was laid out following the complete randomized block design with three replicates for each treatment. Each treatment consists of 7 drippers (2.8 m tubing) and the distance between two rows was about 1 m. Tomato (*Lycopersicon esculentum L.* cv. Bascal) seedlings were transplanted on 15 November 2003 with three seedlings at each dripper. Irrigation was commenced after transplantation and continued every other day until the end of experiment. Twenty soil samples were collected before irrigation from the root zone area on a grid bases (15

cm apart) around the dripper at the three growth stages. Samples were collected from the lower and higher amendment rate treatments and then water contents were determined by gravimetric method after oven drying at 105°C. Salt distributions were assessed by measuring EC in 1:1, soil to water extract, then contour maps for water and salt distributions in the root zone area were introduced using Surfer Software (Golden Software, 2000) for the collected soil samples. Measurement of roots distribution was conducted through trench profile technique according to Bohn (1979). Fruits were picked five times and the total yield was recorded.

Results and Discussions

Results in Table 2 indicate that amendments type significantly affected fruit yield and WUE compared to the control. Dhurma clay deposit resulted in producing the highest average fruit yield and as well as WUE followed by Khulays and Rawdat. The difference in yield could be due to the clay deposit characteristics and the variation in CaCO3 content, ECe, CEC and the type of clay minerals. The increase in the amount of irrigation water significantly affected the fruit yield and WUE. The yield was the highest (73.67 ton ha $^{-1}$) at T4 (564.5 mm) and reduced to 32.89 ton ha $^{-1}$ in T1 (234 mm), a stress treatment. The decrease in yield at low water application could be both due to the unavailability of water and the possible accumulation of salts in root zone area as a result of using a high saline water (TDS = 3300 ppm) where no proper leaching took place. An increase in the irrigation amount did show a definite trend in WUE. Differences in tomato fruit yield and WUE due to irrigation method were significant. Yield increase in subsurface irrigation was higher over surface irrigation while WUE did not show any significant difference between the two irrigation methods. It seems that subsurface drip irrigation creates more suitable conditions in the root zone area for the plant growth, which is in agreement with the result reported by Lamm and Trooien (2003). The application of clay deposits could have positive effects on soil texture, structure, swelling, increasing CEC and soil water retention, hence resulting in improved soil water contents in the tomato root zone.

Water and salt distributions in the amended soil and non-amended soil (control) for both surface and subsurface drip irrigation as affected by type and amount of clay deposits applied and various irrigation water regimes are also discussed.

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Table 1. Some physical, chemical, mineralogical and fertility characteristics of the clay deposits used in the experiment.

Location	Dhruma	Khulays	Rawdat
	Physical and Chemical properties		
Sp %	63.0	53.0	74.0
EC_e dSm^{-1}	7.15	22.0	3.35
pH soil paste	7.97	7.25	7.59
SAR	16.10	2.30	0.86
$CaCO_3$ gKg^{-1}	30.0	30.0	420.0
O.M. gKg^{-1}	19.3	29.0	88.7
CECCmol Kg^{-1}	29.8	39.6	21.6
Clay %	60.0	60.0	59.0*
Silt %	12.0	36.0	40.0
Sand %	28.0	4.0	1.0
Texture	Clay	Clay	Clay
	Clay Mineralogy		
Smectite	++	++++	++++
Kaolinite	++++	++	+
Vermiculite	-	+	+
Accessory Minerals	Q	Q,F	Q
	Fertility Status		
N			
P mKg^{-1}	2.9	2.0	21.4
Fe $mgKg^{-1}$	14.87	12.92	155.0
Zn $mgKg^{-1}$	0.97	1.30	1.97
Mn $mgKg^{-1}$	2.65	2.17	43.3
Cu $mgKg^{-1}$	0.84	1.35	2.98

* after the removal of $CaCO_3$, SAR Sodium Adsorption Ratio, CEC Cation Exchange Capacity.
++++ High, ++ Medium, + Low, Q quartz, F Feldspars.

Table 2. Effect of clay deposits (type and rates), irrigation regimes and irrigation methods on Tomato yield (ton ha^{-1}) and WUE (kg m^{-3}).

Treatments	Yield (ton ha^{-1})	WUE (kg m^{-3})
	Effect of clay deposits type	
Dhruma	56.34 A	14.64 A
Khulays	51.13 B	13.72 AB
Rawdat	50.49 B	13.44 B
$LSD_{0.05}$	3.52	1.12
	Effect of irrigation water regimes	
T1	32.89 D	14.04 A
T2	42.81 C	12.96 B
T3	61.24 B	15.76 A
T4	73.67 A	13.04 B
$LSD_{0.05}$	4.07	1.28
	Effect of irrigation methods	
Surface drip	50.76 B	13.84
Subsurface drip	54.55 A	14.04
$LSD_{0.05}$	2.88	n.s.
	Effect of amendment rates	
Control	49.89 B	13.28 B
1%	54.34 A	14.52 A
2%	53.71 A	14.08 AB
$LSD_{0.05}$	3.53	1.12

*The same letter in each column represents no significant difference at 5% level

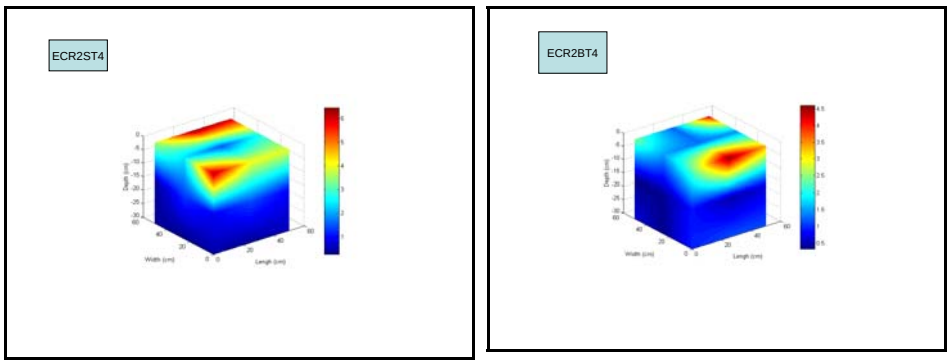

Fig. 1 Effect of irrigation level of Salinity distribution.

ترشيد مياه الري و إدارة الترب الرملية الزراعية في المملكة العربية السعودية

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تهدف الإدارة الجيدة لمياه الري إلي ترشيد المياه ورفع كفاءة استخدامها وزيادة إنتاجية المحاصيل خصوصاً في المناطق الجافة و شبه الجافة حيث تنتشر الترب الرملية كما هو الحال في معظم المناطق الزراعية في المملكة العربية السعودية.

أجريت تجربتان في الموسم 2005-2006م، الأولى في الحقل المفتوح و الأخرى في الصوبة المحمية لدراسة تأثير المحسنات الطبيعية على إنتاجية محصول الطماطم و على كفاءة استخدام مياه الري وتوزيع الرطوبة و الملوحة في التربة. و لتحقيق أهداف الدراسة استخدم نوعين من المحسنات الطبيعية (رواسب طبيعية ومادة عضوية)، ونظامي ري بالتنقيط (سطحي وتحت سطحي)، ومياه ري مختلفة الملوحة (1.0 و 3.0 دسيسمن/م) بالإضافة إلي ثلاث مستويات من الري، وكررت كل معاملة ثلاثة مرات.

اوضحت النتائج زياد معنوية في محصول الطماطم بزيادة كمية مياه الري في حين قلت كفاءة استخدام المياه بزيادة كمية المياه المضافة. كذلك اوضحت النتائج إن مياه الري المختلفة الملوحة كان لها تأثير معنوي على إنتاجية الطماطم، ولكن لم تظهر أي فروق معنوية بين الري السطحي وتحت السطحي في البيت المحمي.

أكدت الدراسة إن إضافة المحسنات الطبيعية للتربة الرملية لها دور مهم في زيادة المحتوى الرطوبة و الحد من تراكم الأملاح بالقرب من المنقطات.