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EFFECT OF SUBSURFACE DRIP IRRIGATION SYSTEM DEPTH ON SOIL WATER CONTENT DISTRIBUTION AT DIFFERENT DEPTHS AND DIFFERENT TIMES AFTER IRRIGATION

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ABSTRACT

To properly manage subsurface drip irrigation (SDI), and increase the efficiency of the water use while reducing water losses due to evaporation, the precise distribution of water around the emitters must be known. In this paper, we'll evaluate how different irrigation depths applied with SDI affected the redistribution of soil moisture in the semiarid climate of Tunisia. Data shows that with suitable management, SDI at 35cm depth can achieve higher efficiency rates with limited water to maximize yields. The objective of this work was to evaluate soil moisture distribution before and after irrigation in an experiment carried out in the Higher Institute of Agronomy of Chott Meriem under subsurface drip irrigation. The results show that soil moisture is relatively more stable for subsurface drip irrigation buried at 35cm (T3) than those buried at 5 (T1) and 20cm (T2) with a slight difference except of water's contributions. There was greater increase in volumetric soil water content for T3 than for T1 and T2 with statistically significant increases.

Keywords: Subsurface drip irrigation, depth, Surfer, water content.

RESUME

Pour bien gérer l'irrigation localisée souterraine (SDI), et accroître l'efficacité de l'utilisation de l'eau, tout en réduisant les pertes d'eau dues à l'évaporation, la distribution précise de l'eau autour du goutteur doit être étudiée. Dans cet article, nous allons évaluer la redistribution de l'humidité dans le sol à différentes profondeurs du système d'irrigation dans le climat semi-aride de la Tunisie. Les données montrent que la gestion appropriée de ce système d'irrigation enfouie à 35cm de profondeur peut atteindre le taux de rendement le plus élevé. L'objectif de ce travail était d'évaluer la distribution humidité du sol avant et après l'irrigation dans une expérience menée dans l'Institut Supérieur Agronomique de Chott Meriem sous irrigation goutte à goutte souterraine. Les résultats montrent que l'humidité du sol est relativement plus stable pour irrigation goutte à goutte enterré au souterrain de 35 cm (T3) que pour ceux qui sont enterrés à 5 (T1) et 20 cm (T2) avec une légère différence, sauf des contributions eau. Il y avait une différence significative de la teneur en eau du sol volumétrique pour T3 (a) que pour les T1 et T2 (b).

Mots clés: irrigation goutte à gutte souterraine, profondeur, Surfer, teneur en eau.

INTRODUCTION

The sustainability of agricultural production depends on conservation and appropriate use and management of scarce water resources especially in arid and semi-arid areas where irrigation is required for the production of food and cash crops (Douh and Boujelben, 2011). The first field experiment in the United States with a subsurface drip irrigation system was established on a lemon orchard at Pomona, California in 1963 and on an orange orchard near Riverside, California in 1964 (Davis, 1974). The first research and demonstration study on a private grower's trees was in an avocado orchard in San Diego, California in 1969. About the same time trials were started using drip irrigation and plastic mulch on strawberries and tomatoes also in and around San Diego (Davis and Bucks, 1983). Colaizzi et *al*. (2009) stated that in 1984 cotton farmers installed the first SDI equipment in Texas HP. However, many of the early established SDI's malfunctioned due to poor management in terms of root intrusion and inappropriate irrigation scheduling (Bhattarai, 2005). These issues were later solved by the development of anti-root intrusion emitters and maintenance techniques, leading to a faster increase of SDI adoption by farmers. Skaggs et *al.* (2004) compared HYDRUS-2Dsimulations of flow from a subsurface drip irrigation line source with observed field data involving a sandy loam soil and a SDI system with a 6 cm installation depth and 3 discharge rates. At the High Institute of Agronomy of Chott Meriem Tunisia, an experimental was conducted to compare the effect of surface and subsurface drip irrigation on water saving and yield of eggplant (Douh and Boujelben, 2010). The results indicated that subsurface drip irrigation (SDI) leads to a greater yield making significant water saving 23.2% rather than surface drip irrigation. Douh and

Boujelben (2012) found a very good agreement between simulated and observed soil moisture data. According to the research results, optimum dripline depth for corn plant was found to be 0.35 m. But, it was no significantly effect on crop water use efficiency. The objective of this work was to evaluate soil moisture distribution before and after irrigation in an experiment carried out in the higher Institute of Tunisia under subsurface drip irrigation.

MATERIALS AND METHODS

Experimental site

The experiment was conducted at the Higher Institute of Agronomy of Chott Mariem, Tunisia (Longitude 10°38′ E, Latitude 35°55′ N, altitude 15 m) from May to July 2010. The climate is typically Mediterranean with 230 mm annual rainfall and an average of 6 mm day^{-1} evaporation from a free water surface. In winter, the average minimum temperature is of 6 °C and the average maximum is of 18 °C, while in summer average minimum is of 23 °C and average maximum is of 38 °C. The soil is sandy loam with average basic infiltration rate of 14 mm h^{-1}. Bulk density of soil was found to be 1.40 g cm^{-3} for the layer 0-60 cm. the porosity is calculated assuming a soil particle density (d_p) of 2.65 mg m^{-3} for mineral soils and B_d is bulk density. Porosity = 1 – (B_d/d_p). The field was precision graded to approximately 1 mm m^{-1} slope. Maize (*Zea mays* L.) was seeded the 1st of May with row spacing of 80 cm and in-row spacing of 40 cm and the whole planting area is 1,000 m^2 (25 m × 40 m). The experiment was carried out using subsurface drip irrigation system in 5, 15 and 30 cm (Figure 1).

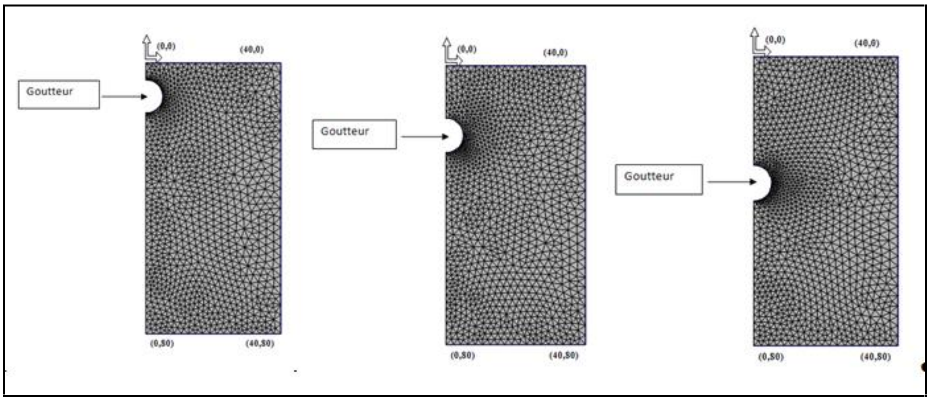

Figure 1 : Location of the dripper respectively at 5, 20 and 35 cm depth

The experiment was carried out in the field involved both infiltration and redistribution and movement of the moisture front. Soil water content changes were recorded using the moisture sensors, was carried out with an average emitter discharge of 4 $L.h^{-1}$. Soil moisture was recorded 2 hours before the irrigation, 2, 4, and 6 h after the irrigation experiment started. Soil samples were then taken from locations 0, 20, and 40 cm away from the emitter and at 10, 20, 30, 40, 50 and 60 cm depths, to characterize the soil water content in the wetting pattern. The TDR (Time Domain Reflectometry) technique was used to measure 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 irrigation system. The measures were made by a layer of 10 cm in a tube of 1 m in length. The measurement tubes were located just under the dripper 0 and 20 cm apart from the dripper, respectively and in the middle of the in-row spacing at 0, 20 and 40 cm, respectively. This value of the volumetric water content was used in the numerical simulations.

Soil hydraulic parameters

Soil hydraulic parameters for the soil were estimated using the ROSETTA (Schaap et *al.*, 2001) software. ROSETTA is a software package that evaluates pedotransfer functions that use neural network models to predict soil hydraulic parameters from soil texture and related data for the van Genuchten–Mualem model (Van Genuchten, 1980). The parameters required for the most complex ROSETTA model are the bulk density, percentages of sand, silt, and clay, and water contents for pressures of−33 and−1500 kPa. For these input variables by soil layers, ROSETTA predicted the following soil hydraulic parameters of the van Genuchten Mualem model: α, n, m and λ (Table 1).

Table 1 : Hydraulic parameters estimated by Rosetta function according Van Genuchten Mualem model

		0-25cm	25-60cm	60-85cm
Teneur en eau	**θ_r [%]**	0,0457	0,0389	0,0345
	θ_s[%]	0,4855	0,4300	0,3948
Paramètres de Van Genuchten	**α**	0,2172	0,0138	0,0177
	n	1,2596	1,6094	1,4580
	m	0,2061	0,3787	0,3141
	λ	0,5000	0,5000	0,5000
Conductivité hydraulique	**Ks [cm/h]**	1,3404	-	-
Densité apparente	**Bd [g/cm^3]**	1,7000	1,6300	1,5700

Moisture distribution patterns

It's important to wet a relatively large part of the potential root system and have a large enough volume of moisture soil to promote root intention and water uptake. Water distribution in soil profile was presented by contour maps. For each treatment, six locations around the selected dripper was considering and spacing at 0, 20 and 40 cm for measurements which located parallel with plant row and at 20 cm for those located at perpendicular to plant row. Moisture content for each location has been measured by a layer of 10 cm until 70cm. This procedure was carried out for all treatments before and after irrigation. The contour maps were derived considering that, there's symmetry around the emitter for both left and right hand side. The total number of moisture data points was 24 points by depth. These 24 point were arranged in a matrix of 3 columns and 6 rows and the program (SURFER 8) was used for developing moisture content lines. Kriging method was used for the calculation of the intermediate points at equal distances. Each intermediate point was estimated from neighbors using a linear regression model. Contour maps for moisture distribution with depth were constructed by averaging the data of three columns in each layer for each depth. This will produce a lane of contours parallel to the irrigation line for each treatment.

Statistical analysis

Results were examined statistically by using the analysis of variance (ANOVA) procedure from the Statistical Analysis System (SAS 9.1 for Windows; SAS

Institute Inc., Cary, NC). PROC GLM. F-Tests were considered significant at the 0.05 level of probability and Fisher's protected least significant difference (LSD) was used to compare treatment means for significant ($p \leq 0.05$) effects.

RESULTS AND DISCUSSION

Soil moisture distribution before and after the irrigation

To study how much water that soil maintains in root zone post irrigation, the soil moisture content was measured within soil depth and around the dripper 2, 4 and 6 hours after irrigation experiment started. Figure 2 demonstrate the contour maps of soil moisture distribution for all treatment at a depth of 10 cm from the soil surface.

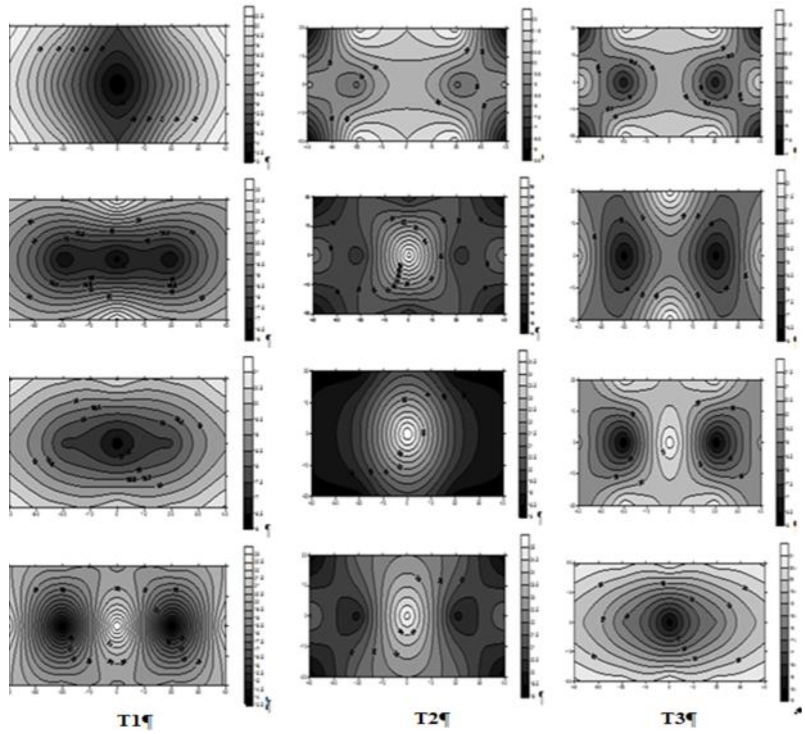

Figure 2 : Soil moisture distribution respectively 2 hours before the irrigation 2, 4, and 6 h after the irrigation under subsurface drip irrigation at 5(T1), 20 (T2) and 35 cm depth (T3)

For subsurface drip irrigation buried at 5 cm (T1), and before irrigation, the water content under the emitter is at the order of 13% and then increases away from the emitter to reach high values of 20 to 25%. Two hours after irrigation, the volumetric water content increases to 23% but remains low at the emitter to the location of the root system which exercises a water extraction at 20 cm on either side of the emitter. Four hours after irrigation, moisture increases with distance from the emitter and the spacing between the curves decreases therefore the change in water content decreases and the wetting front propagates toward the ends of the plan. After 6 hours of irrigation, the water content under the emitter reaches 23% and form circular curves around him which confirms it is the water source. For T2, before irrigation, the water content varies between 15 and 22%. After irrigation, the curves of equal water contents of circular shape around the dripper have the higher values of (29%) indicate that it’s the only source of water. After four hours of irrigation, we notice that the water content recorded at the emitter is approximately 24.5% and decreases away to the sides to reach values of 18%. After 6 hours and at 30 cm on either side of the dripper, the water content is around 13% where it has a maximum root density. For T3, before and just after irrigation, at 20 cm on either side of the emitter, low water content of about 17% due to root uptake has been registered. After 4 hours of irrigation, there is a high water content of about 21.5% due to the water source located at (0,0) and a low water content at 20 cm on both the other of the dripper. After 6 h of irrigation, the water content is low at the emitter of about 15% moisture and spreads to the ends up to 21% at 40 cm on either side of the dripper.

Changes between the pre- and post-irrigation soil sampling dates in the average volumetric soil water content were determined for each depth of subsurface drip irrigation. Taking into account the average change in total soil water from all sampling depths and considering the same number of positions for each lateral orientation, there was greater increase in volumetric soil water content for T3 than for T1 and T2 with statistically significant increases. The ANOVA allowed us to conclude a highly significant difference at the threshold of $\alpha = 5\%$ for root length. Indeed, the SNK were classified into three groups. The first class consists of subsurface drip irrigation system buried at 35cm the second consists of subsurface drip irrigation system buried at 20cm and the third class contains the underground irrigation to 5cm. The difference between the average water content of the three treatments referred to lost by evaporation.

Soil moisture distribution in different depths

The means of soil moisture distribution in different depths, for the irrigation systems buried at 5 cm (T1), 20 cm (T2) and 35cm depth (T3) are respectively 9.25 ± 2.72 , 13.01 ± 4.59 and 15.39 ± 4.97. Soil water content under T1 and T2 had large variation and higher trends for the 5 cm depth, ranging from a minimum of 7% to a maximum 17%, while at the depth of 20 and 35 cm varied from a minimum of 15% to a maximum of 26% (Figure 3). However, volumetric moisture content of soil varied between 18% and 33% for the depth 15 to 20 and 35 cm under T3. The water content values were equal with a slight difference lower than 6% which was relatively more stable than T1 and T2. In fact, the present study showed that soil water content increases after a rain or an irrigation. Nevertheless, water content decreases according to the time following an increase of needs of the plant and losses of water by evapotranspiration.

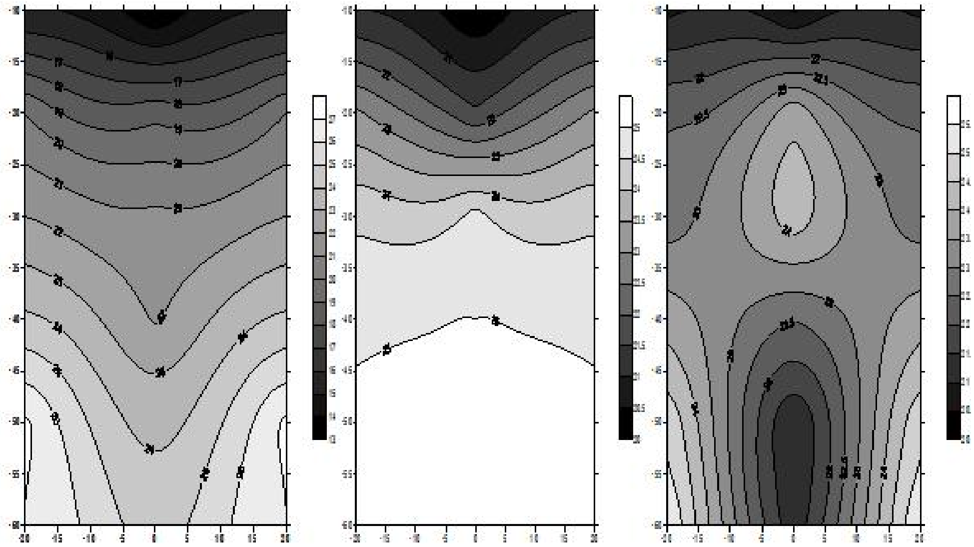

Figure 3 : Vertical Soil moisture distribution respectively under subsurface drip irrigation (T1), (T2) and (T3) 24 hours after an irrigation of one hour with 4lh^{-1} flow

The results show that soil moisture is relatively more stable for T3 than T1 and T2 with slight difference except of water's contributions. The study indicated that soil moisture content under subsurface drip irrigation at 35 cm depth was more uniform as compared to that at 5 and 20 cm; these results are confirmed by Singh (2007). The results provide evidence that 35 cm below the soil surface was so dry as it was hypothesized that SDI method would improve the water use efficiency of maize crop by minimizing the evaporative loss and delivering water directly to the root zone. Soil water content for the depth of 20 to 35 cm was higher in T3. These results are confirmed by Bajracharya and Sharma (2005) who put the same hypothesis to explain the amplification of water use efficiency of cucumber and tomato crops relatively to SDI. Neelam and Rajput (2008) verify that water distribution in the soil around a buried dripper mainly depends on soil texture, dripper discharge and root water uptake. Soil water distribution patterns varied at different stages of crop growth.

Conclusions

The observations were recorded on distribution of soil moisture content, in different depths under subsurface drip irrigation. This study indicated that soil moisture content under subsurface drip irrigation at 0.35 m depth was more uniform in comparison to that at 0.05 m and 0.20 m. Subsurface drip irrigation allows uniform soil moisture, minimize the evaporative loss and delivery water directly to the plant root zone which increases use efficiency and yield. Further observations are needed to determine whether corn production with SDI is feasible in the arid region to develop recommendations for farmers choosing to adopt the method. SDI systems are capable of applying small amounts of water directly to the plant root zone where the water is needed, and can be applied frequently to maintain favorable root zone moisture conditions. Improvements in yield and quality, and reduction in production costs are some of the potential benefits of SDI. It offers many advantages over surface drip irrigation such as reduced evaporation loss, precise placement, management of water, nutrients and pesticides leading to more efficient water use, greater water application uniformity and an enhanced plant growth and crop yield.

REFERENCES

BAJRACHARYA R.M., SHARMA S. (2005). Influence of drip-irrigation method on performance and yields of cucumber and tomato, Int J. Appl Sci Eng Tech. 1, pp 1-7.

BHATTARAI S.P. (2005). The Physiology of Water Use Efficiency of Crops Subjected to Subsurface Drip Irrigation, Oxygation and Salinity in a Heavy Clay Soil. Ph.d. diss. Central Qeensland University, Rockhampton, QLD, Australia.

COLAIZZI P.D., EVETT S.R., HOWELL T.A. (2005). Comparison of spray, LEPA, and SDI for cotton and grain sorghum in the Texas Panhandle. In Proceedings of the Central Plains Irrigation Conference. Sterling, CO. 16-17 Febr. 2005. Centr. Plains Irrig. Assoc. Colby, KS.

DAVIS S., BUCKS D.A. (1983). Drip irrigation. In Irrigation (formerly Sprinkler Irrigation), Fifth Edition, C. H. Pair, W.W.Hinz, R. E. Sneed, K. R. Frost, and T. J. Schiltz, (Eds.), Irrigation Assoc., Silver Spring, Maryland, pp 528-546.

DAVIS S. (1974). History of irrigation. Agribusiness News 10(7):1.

DOUH B., BOUJELBEN A. (2010). Etude de l’irrigation localisée souterraine sur la culture d’aubergine, *Eds Universitaires Européennes*, Numéro 6001, 124p.

DOUH B., BOUJELBEN A. (2011). Improving water use efficiency for a sustainable productivity of agricultural systems with using subsurface drip irrigation for maize (*Zea mays L.*), Journal of Agricultural Science and Technology B1 (JAST)**,** pp 881-888.

DOUH B., BOUJELBEN A. (2012). Subsurface drip irrigation and water management under semiarid climate. pp. 181-198, *In Advances in Environmental Research*., *Eds:* Justin A. Daniels, Nova Publisher Vol. 22, 249p.

NEELAM P., RAJPUT T.B.S. (2008). Dynamics and modeling of soil water under subsurface drip irrigated onion, agricultural water management 95, pp 1335–1349.

SCHAAP M.G., LEIJ F.J., VAN GENUCHTEN, M.Th. (2001). ROSETTA: a computer program for estimating soil hydraulic properties with hierarchical pedo-transfer functions. J. Hydrol. 251, pp 163–176.

SINGH D.K., RAJPUT T.B.S. (2007). Response of lateral placement depths of subsurface drip irrigation on okra (Abelmoschus esculentus), International Journal of Plant Production 1, pp 73-84.

SKAGGS T.H., TROUT T.J., SIMUNEK J., SHOUSE P.J. (2004). Comparison of HYDRUS-2D simulations of drip irrigation with experimental observations, Journal of Irrigation and Drainage Engineering 130, pp 304-310.

VAN GENUCHTEN M.Th. (1980). A closed-form equation for predicting hydraulic conductivity of unsaturated soils. Soil Sci. Soc. Am. J. 44, 892–898.