INT. J. BIOL. BIOTECH., 15 (3): 513-520, 2018.

SALT ACCUMULATION UNDER BURIED DIFFUSER VS. DRIP IRRIGATION METHODS OF NETTING GREENHOUSE TOMATOES CULTIVATION IN QATAR

Masoud.J.Al–marri[1], Osman A. Elsharief Abdalla[1], Mohammed Al-Masri[1], Mohammed I. Abubaker[1], M. Mohamed[2] and R. Hichem[3]

[1]*Department of Agricultural Research, Ministry of Municipality & Environment Doha, Qatar*
[2]*Eremology and Combating Desertification Lab.,Institut des Regions Arides (IRA),Tunise.*
[3]*Institut Superieur Agronmique Chott Meriem,Sousse,Tunisie*
For corresponding: mjmmarri@mme.gov.qa

ABSTRACT

Net greenhouse tomatoes were produced under surface conventional drip irrigation and newly introduced subsurface buried diffusers irrigation methods in Qatar during 2016/2017 season to evaluate the effects of the two methods as to salt build up/accumulation in the root zone. Irrigation water was supplied at three levels 100, 75 and 50% of crop water consumption. Measurement values of soil salinity collected one month after planting and at the end of the experiment for 0-7.5 cm, 7.5-15cm and 15-30 cm soil depths were evaluated. No significant effects were obtained but observations had indicated favorable lesser soil salinity conditions under buried diffuser at the early stage of plant growth and the association of this irrigation method with consistently lower ECe values throughout the duration of the experiment. The two methods seemed to be comparable as to their effect as water-saving technologies. Under 100% level of irrigation, the buried diffuser irrigation method was significantly more effective in reducing soil salinity. Soil salinity became 27.74 % lesser than 100% irrigation level, whereas at 75% and 50% levels of irrigation this method of irrigation did not significantly reduce soil salinity. Drip irrigation method, on the contrary to the buried irrigation method reduced but insignificantly soil salinity at 75 & 50% levels of irrigation by 37.68 and 47.76%, respectively.

Keywords: irrigation methods, subsurface buried diffuser, net greenhouse tomato, salt accumulation**.**

INTRODUCTION

Agricultural development activities in Qatar focus on developing modern irrigation systems, improving product quality, introducing modern technologies such as protected and intensive farming, diversifying cropping patterns and enhancing guidance, organizational and monitoring mechanisms.

The tropic-dry and hot weather existing in Qatar leads to a climatic water-balance deficit situation. Rains usually occur in the winter months (November through March/April). The amount of rainfall can vary significantly as it can in most desert areas. The annual rainfall is ranging between 65 and more than 100 mm/year. The usually brief rain occasions can occur as sporadic and sometimes very heavy showers for short intervals and as such becoming storms that would often flood the tiny desert ephemeral stream channels known locally as wadis. The lack of rainfall recharge to groundwater or surface water consequently lead to water scarcity in one hand which when coupled with high rates of groundwater withdrawal for agricultural consumption make the country experiences an extremely high level of water stress. The sun shines almost every day of the year with few overcast days. Other inhospitable climatic features for cropping are high temperatures and high relative humidity which are common in the summer months and strictly restrict plant growth season to the period September to April. The mean summer and winter temperatures are 34°C and 19 °C respectively, but temperatures can reach as high as 39 °C in the summer peak to as low as 7 °C in the winter. Since most of the country consists of a stony sand desert, a small part of the country houses different vegetation zones, where openness characterizes its vegetation. Soil salinity and the abundance of rainfall are the primary controls for wild plant growth.

Hence, agricultural sector remains heavily dependent on groundwater. The lack of permanent rivers or other surface water resources in Qatar has led to an over dependence on groundwater resources, mainly groundwater aquifers, for agricultural irrigation. On the other hand, the risk that the country's groundwater will become unfit for crops or human consumption is increasing as a result of the intrusion of salty sea water into fresh water aquifers. The situation is aggravated too by the fact that farmers continue unavoidably to overexploit the desert state’s aquifers. More than two-thirds of wells in Qatar are classified as “moderately saline,” making the water harmful to salinity-sensitive crops and causing damage to the soil. This condition emphasized the occurrence of this worse irrigation water resource situation. It is well established that the annual rate of extraction is almost four or even more times that of recharge. Over-mining of aquifers has resulted in falling water tables and groundwater and consequent soil salinization have reduced agricultural productivity.

The strategies adopted for water security in the country confirms efficient agricultural practices as one important solution among many other listed solutions taking into account that agriculture places heavy demands on Qatar's water system. To ensure the efficient use of water, surface drip and/or sub-surface irrigation systems are among the well-recognized modern water-saving technologies. These should be combined with policies that are leading to changing crop selection to stress tolerant (e.g. Heat, salinity & drought) varieties and to species which require less water . Indeed, this will also assist reduce irrigation demand and water wastage in the Agriculture sector.

Drip irrigation allows for the application of water under low pressure through low-flow emitters (2-20 liters/hour). Water is provided either above (surface drip irrigation) or directly into the root zone which is called subsurface drip irrigation(SDI). Surface drip irrigation is used field row-crops crops, while subsurface drip irrigation is used widely for annual crops. Modern drip irrigation installations are becoming more durable. In this study, it is believed that buried diffuser a bottom-up sub-surface irrigation system developed in Tunisia (Chahbani, 2012) and is a proven innovation which received several international awards may provide an improvement in terms of better water use efficiency compared to the current country-wide used surface drip irrigation system. The mesh-covered greenhouse tomato cultivation in Qatar has also been depending on surface drip irrigation for plant watering. This targeted buried diffuser irrigation method is expected to play a key-role in arid regions, such as Qatar, being an ultimate water saving method. It was stated earlier (Ayars *et al*., 1999), that subsurface drip irrigation systems, which apply irrigation water directly into the root zone instead of on the surface, lend themselves as an improvement tool of maximizing water use efficiency. This procedure reduces soil water evaporation losses from the wet bulb as the soil surface is not wetted, especially in trees (low-density crops).

The accumulation of salt in the upper root zone was pointed out as the principal deficiency among some other drawbacks of the subsurface drip irrigation system (Fujimaki *et al.*, 2012), due to the difficulty to have salts leached out by water from the buried emitter compared to surface drip irrigation. Several researchers (Lazarovitch *et al*., 2006), (Provenzano, 2007) and (Gil *et al*., 2011) had also observed this phenomenon. The hydraulic properties of the soil could be an additional cause. This variation of emitter's discharge can lead to an overall change in the spreading pattern of the irrigation water (Lazarovitch *et al*., 2006; Rodríguez-Sinobas *et al*., 2009a, b). Minimizing salt accumulation in the root zone to properly manage this irrigation system become a crucial need. Despite to the aforementioned in an investigation which covered results of some previous works handling different crops, soils, and cropping conditions(Camp,1998) with the aim to compare yields under different methods of irrigation it was found that crop yields for subsurface drip systems were equal to or better than the other systems in all cases. A case according to him that pertains to the efficient use of water and nutrients. Product quality was similarly found to be significantly improved (Phene *et al*., 1987). Apart from their many advantages especially their high-water use efficiency trait still current subsurface drip-irrigation systems exhibits some more serious drawbacks because of burying both the laterals and emitters. This negatively affects the expansion of subsurface irrigation methods and limits it to a consistently very limited cultivation area although some versions of subsurface irrigation were being to be in use since ancient times (Bainbridge, 2001). The other shortcomings include the higher cost of the system, emitters clogging and breakage problems due to the intrusion of roots or the suction of solid particles from the soil matrix, and the difficulty of detecting and repairing potential leakage problems. Irrigation with saline water which was typically the case in Qatar may benefit from the better moisture and salinity distribution confined to the subsurface drip irrigation in comparison to surface drip irrigation. Reasonable yields can be obtained (Gideon, *et al.*, 1999). These distribution patterns explain, to some extent, the reaction of trees to a saline-water application under this irrigation method.

he buried diffuser was designed and laid down on the ground in a way to avoid and overcome most of the earlier mentioned drawbacks and disadvantages of subsurface drip irrigation methods. Thus, it was found essential to test it under Qatar conditions in comparison to the current drip irrigation method in use as a reference. As soil is the basis of all terrestrial ecosystems, degraded soil due to secondary salinization means lower crop productivity, reduced biodiversity, and reduced human welfare. The sub-surface irrigation method is a new water-saving irrigation technology. It is capable of applying small amounts of water directly to the plant root zone where the water is needed, and these small amounts can be applied frequently to maintain favorable moisture conditions in the root zone. This study aims to compare the two irrigation methods which are the conventional surface drip (D) and the buried diffuser subsurface drip method (S) on the tomato cultivation in a net greenhouse. Salt accumulation in the very shallow soil profile of the crop planting-beds which comprises the root zone was targeted in this study and used as an indicator for the evaluation.

MATERIALS AND METHODS

Study site overview

The experiment was conducted at Al Utouriya Agricultural Research Farm (25°13′18″N 51°28′58″E) of the Department of Agricultural Research, Ministry of Municipality and Environment. The country is situated in the Arabian Peninsula within the Arabian Gulf.

Experiment design

A field experiment was conducted during the winter season extending over the years 2016 and 2017. Table (1) shows the average values of the physiochemical properties of the soil mixture of the planting bed of the net greenhouses. It was sandy loam to sandy clay loam soil with low organic matter content (0.66-0.94%), moderate pH (7.85-7.96 and high calcium carbonate (29.32-33.46%) content.

Table 1. Soil Physiochemical Properties(Average).

Soil Depth	**Clay <2 Micron**	**Silt 2-50 Micron**	Sand 50-2000 Micron	**Water Holding Capacity(Volumetric Percentage)**			**s.p.**	**PH**	**EC**	**CaCO3**	**O.M**
cm	**%**			**F.C***	**P.W.P***	**A.W.***			**dS/m**	**(%)**	**(%)**
0-7.5	20.61	9.22	70.17	16.29	9.72	6.57	44.11	7.87	10.64	29.32	0.94
7.5-15	21.61	8.33	70.06	16.65	9.77	6.88	45.87	7.85	10.74	31.73	0.66
15-30	20.61	8.56	70.84	15.97	9.50	6.47	43.64	7.96	7.15	33.46	0.73

F.C. = Field capacity; P.W.P. = Permanent wilting point; A.W. = Available water; S.P = Saturation percent

The measurements for the 30 cm deep soil in a volumetric percentage unit of the field capacity were in the range of 11.28-18.49 with an average of 15.97-16.65. The permanent wilting point measurements in volumetric percentage were in the range of 6.98-11.69 with an average of 9.5-9.77. Both were determined by the membrane method. The total soil available water calculated using each field capacity measurement value and its corresponding wilting point measurement for the full extent of the tomato planting bed depth were in the range of 4.3-8.30% with an average of 6.47-6.88 in volumetric percentage. The soil salinity, expressed in terms of electrical conductivity (ECe) average values were 7.5-10.64 deciSiemens per metre. The ECe measured one month after transplanting of the crop in the net greenhouse, were in the range of 2.23-26.3 dS/m. In this experiment, two drip irrigation methods were applied: Conventional Drip (D) and the newly introduced buried diffuser (S), each at three irrigation levels viz: 100%,75% and 50% of the crop water consumption. The S method used a network composed of plastic diffusers which are connected each to a 2mm-diameter tube connected to a standard regulating dripper to provide with a stable water flow to the diffuser. The 2mm tubes were linked to an above-ground sub-pipe of 13 mm-diameter used as the main water supplying source within each net greenhouse. The sub-pipe was branching from the main 50 mm pipe which was connected in its turn to an elevated tank (300-gallon capacity,1 m above ground surface).No water pumping was needed. Irrigation water from the tank was passing irrigation water through a water meter giving out readings for each one irrigation event. When water is turned on, the diffusers become filled with water. The buried diffuser installation was made ready by pre-digging one hole in the planting row, a diffuser is buried in each hole at a depth of about 10 cm. The transplanting was manually implemented The D method was performed with the same three irrigation volumes. The same transplanting geometry was followed. Six ground rows isolated by 1.25-m-space were used in each net greenhouse.

The experiment was conducted in 6 classic net greenhouses (area= 9mX39m). A split-plot design with three replications (two net greenhouses/replication) was used with irrigation methods as main plots and irrigation levels as subplots (three levels/net greenhouse). The following experimental protocols were adopted:

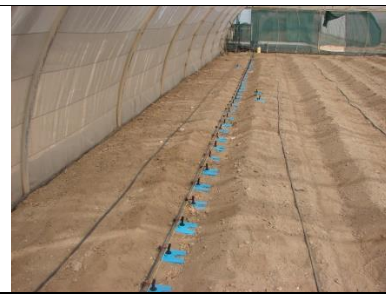
Factor A: Irrigation method (main plots accommodated in an entire net greenhouse unit):

a. Conventional Drip irrigation (D)
b. Subsurface Buried Diffuser (S)

Factor B: Irrigation level (subplots each was comprised of two rows):

a. Level One (Full irrigation) 100% of crop water consumption
b. Level Two 75% of crop water consumption
c. Level Three 50% of crop water consumption

Tomato, Ezebella which is commonly grown in the country, was planted in the experiment. In all net greenhouses, 3-4 weeks old seedlings were transplanted 40 cm apart in each row and each plant was served with one dripper/ containing diffuser in the case of both irrigation methods. Each net greenhouse had a total of six rows. The following are some illustrations:

Buried Diffuser	
	

Buried Diffuser	Conventional Drip
	
	

Fertilizer application besides all Qatari long-practiced agricultural recommendations were followed.

Sample collection, measurement, and statistics:

The soil samples at two events, one month after planting and at the end of the experiment were collected and sent to the laboratory for the measurement of some selected soil parameter. Soil samples were collected at successive soil profile depths of 0–7.5, 7.5–15, and 15–30 cm soil depth for each irrigation level within both irrigation methods. The dried soil samples were ground to pass a mesh of 2 mm mesh-size. Soil samples were analyzed mainly for ECe which was used to track changes in soil salinity. Analysis of variance (ANOVA) was carried out, and the significance level used was p = 0.05.

RESULTS AND DISCUSSION

Difference in soil salinity depth-wise:

Accumulation of salts in concentrations detrimental to plant growth is a constant threat to irrigated crop production. Data showed that ECe values were consistently lower under buried diffuser compared to the conventional drip at the three different irrigation levels (Fig.1 and 2). These differences observed between irrigation methods could mainly be attributed to differences in soil moisture content since the irrigation water supplies (quantities) were similar. A similar result was evidenced earlier (Oron *et al*., 1999) and (EL Mokh *et al*., 2014), where it was concluded that the induced soil salinity with subsurface drip irrigation is lower than that in the case of surface drip irrigation. Under buried diffuser, ECe values decreased with depth. Drip irrigation to some extent underwent the same ECe trend with soil depth, except for the salt accumulation exhibited in the 7.5-15 cm soil depth in the case of ECe values measured for the after one-month soil samples of the 50% irrigation level. This finding is in agreement with results shown in an investigation on jujube trees under surface versus subsurface drip irrigation (Sun *et al*., 2016). This study indicated that subsurface drip irrigation was found to be a more suitable irrigation method than drip irrigation for these trees. The average desalination ratio calculated in the soil layer at 0–50 cm depth at a distance of 30 cm from the vertical tube was 25.2%.

Soil salinity (ECe in dS/m) under two irrigation methods & at three irrigation levels for net greenhouse tomato in Qatar

Fig. 1. At One month after planting.

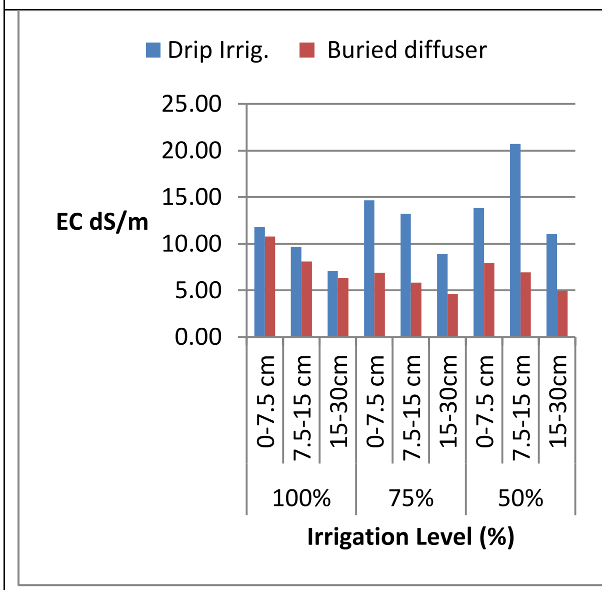
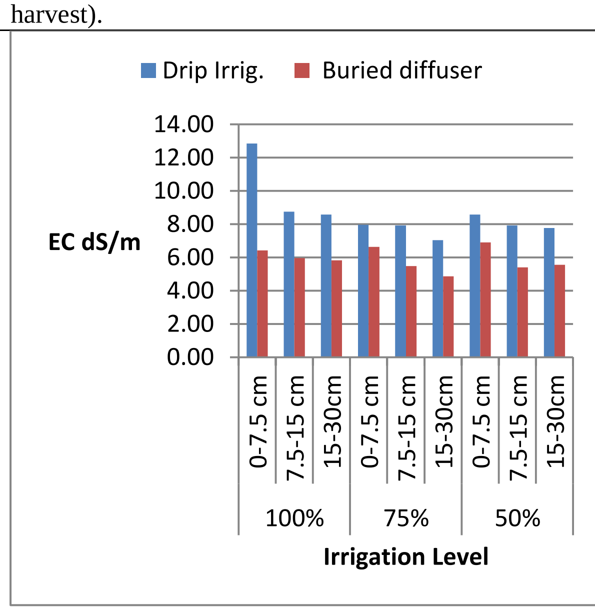


Fig. 2. At the end of the Experiment (After final harvest).

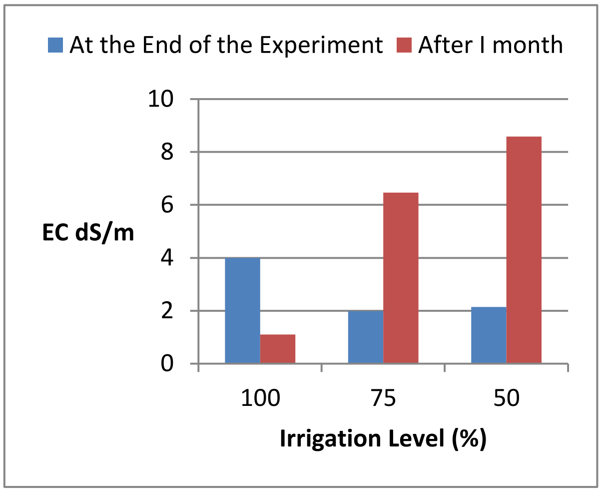


The difference in soil salinity (ECe) between the two methods of irrigation was obtained by subtracting the measured ECe value for the buried diffuser irrigation method from its correspondent measured value of the drip irrigation method. The higher difference was taken to indicate a relatively better leaching effect and the less salinity build-up in the crop root zone that could be attributed to the buried diffuser irrigation method. These differences at the early stage of the experiment followed the order 50>75>100%. At the end of the experiment, the reverse was true, where the differences followed 100>75 and 50% (Table 2, Fig.3). Hence, it could be concluded that, the leaching effect and the consequent lesser salt build-up in the root zone due to the buried diffuser method of irrigation was manifested best under the sufficient irrigation water supplies (the highest level of irrigation) an advantage which would rather continue to be questionable if the irrigation water would contain higher salinity content. The accumulation of salts around the root zone as a result of a relatively poor leaching of soil salinity due to this method was regarded as one of the disadvantages of the conventional drip irrigation method (Abou Kheira, 2009). Also, it could be inferred that the two methods were comparable as to their effect as water-saving technologies. Factors like the overlapping of the wetting zones of two adjacent emitters, soil hydraulic conductivity and discharge rate of the emitters also contribute to promoting a specific salt concentration pattern (Shalhevet, 1973).

Table 2. Difference in Soil salinity between the two Irrigation Method.

Irrig. Level	After I month	After Harvest
100%	0.97	6.44
	1.57	2.78
	0.77	2.75
Mean	1.10	3.99
75%	7.76	1.32
	7.40	2.45
	4.25	2.17
Mean	6.47	1.98
50%	5.87	1.67
	13.78	2.53
	6.10	2.22
Average	8.59	2.14

Fig. 3. Difference in Soil salinity Between the Two Methods of Irrigation.



Soil salinity- ANOVA:

Soil salinity- ANOVA:

Analysis of Variance was also used to elucidate the effects on soils salinity due to the tested irrigation methods. The ANOVA for the ECe values pooled over depth (Tables 3 & 4) has revealed significant two-way interactions (between irrigation method and irrigation level) only for the ECe values measured one month after planting. No indication of significance was obtainable for the sources of variation when taken separately, whether at one month after planting or at the end of the experiment.

Table 3. **One month after planting**: Mean ECe (dS/m) of soils under the two irrigations Methods & at the three irrigation levels.

Irrigation method	Mean ECe (dS/m) irrigation levels 100%	75%	50%	Average
D	9.50	12.26	15.20	12.32
S	8.40	5.79	6.61	6.93
Average	8.95	9.03	10.91	9.63

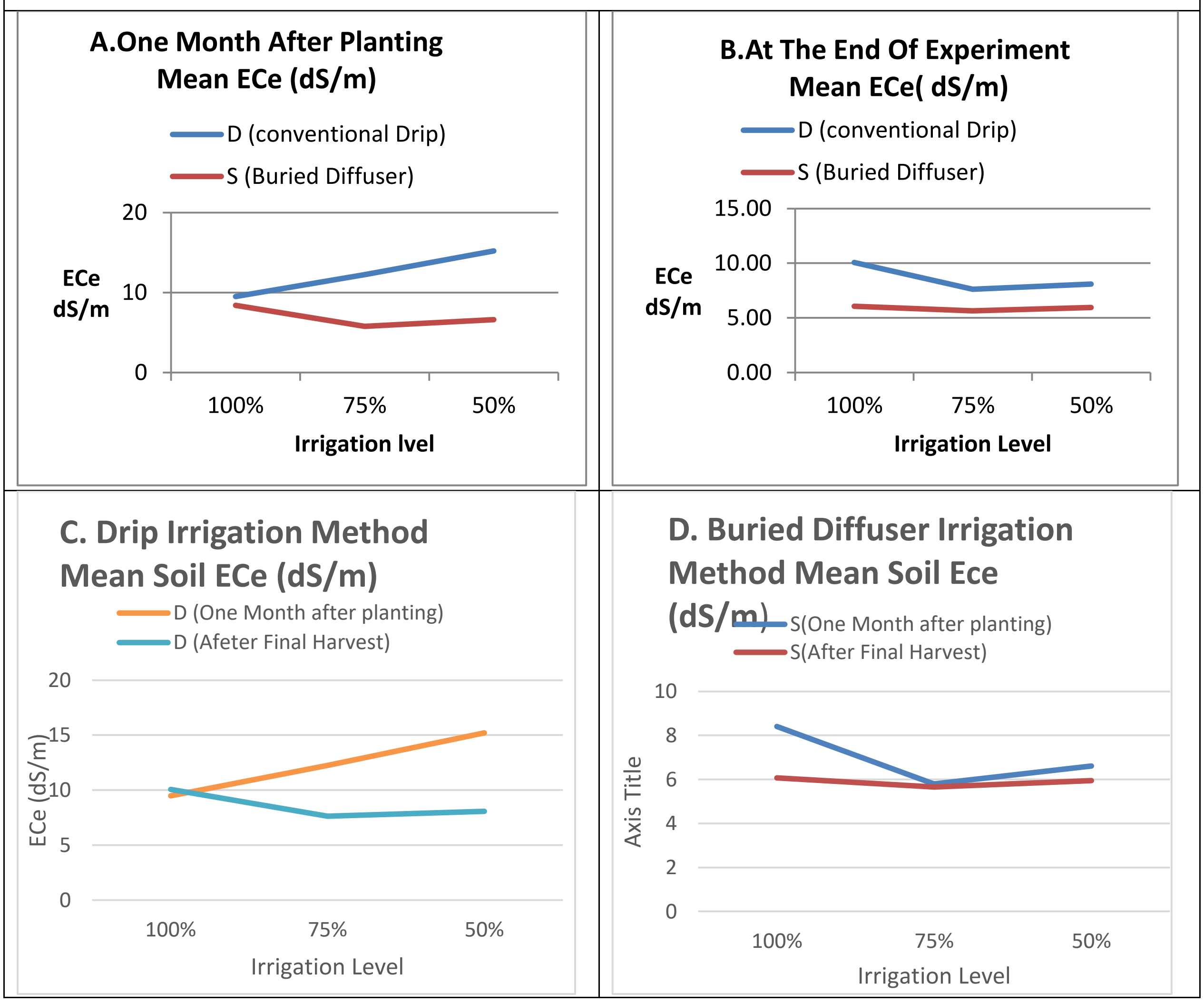
Pair Comparison	Standard Error (S_d^{-a}) (dS/m)	LSD	Significance
Two main-plot means(averaged over all subplot treatments)	2.12	9.11	ns
Two subplot means(averaged over all main-plot treatments)	0.49	1.36	s
Two subplot means at the same main-plot treatment	0.85	2.36	s
Two main-plot means at the same or different subplot treatments	2.23	6.18	s

Table 4. **At the End of Experiment(after harvest)**: Mean ECe (dS/m) of soils under the two irrigations Methods & at the three irrigation levels.

Irrigation method	Mean ECe (dS/m)			Average
	irrigation levels			
	100%	75%	50%	
D	10.06	7.64	8.09	8.60
S	6.07	5.66	5.95	5.89
Average	8.07	6.65	7.02	7.25

Pair Comparison	Standard Error (S_d^{-a}) (dS/m)	LSD	Significance
Two main-plot means(averaged over all subplot treatments)	1.04	4.47	ns
Two subplot means(averaged over all main-plot treatments)	0.80	2.21	ns
Two subplot means at the same main-plot treatment	1.13	3.13	ns
Two main-plot means at the same or different subplot treatments	1.39	3.86	s

Fig. 4. Mean Measured ECe(dS/m)of soils under two irrigation Methods & at three irrigation levels.



Despite to the aforementioned fact, it was noticed that the conventional drip irrigation method (D) was associated with higher soil salinity (higher ECe values), compared to buried diffuser irrigation method(S) (Fig. 4 A, B, C and D). On one hand, at early stages of plant growth under the two methods of irrigation, the buried diffuser at 75 and 50% levels of irrigation showed a similar reduction in soil salinity. On the other hand, the drip irrigation method (D) showed the contrary, where it increasingly raised soil salinity at 75 and 50% levels of irrigation (Fig. 4.A). It could be concluded that the buried diffuser method of irrigation at this early stage of plant growth has provided with better plant growing conditions. At the End of the Experiment, soil salinity was almost the same for the three levels of irrigation under buried diffuser, but the drip irrigation method exhibited lesser soil salinity by 24.1 and 19.6% for the 75 and 50% levels of irrigation, respectively (Fig. 4B). The journey of plant growth from the point of one month after planting to the end of the experiment showed some other important observations too. Under 100% level of irrigation, (Fig.4C and D), the buried diffuser irrigation method was more effective in reducing soil salinity. Soil salinity significantly became 27.74 % lesser at 100% level of irrigation, meanwhile, this method of irrigation did not significantly reduce soil salinity at 75 and 50% levels of irrigation. Drip irrigation method, on the contrary to the buried irrigation method, reduced soil salinity but insignificantly by 37.68 and 47.76% at the 75 and 50% levels of irrigation, respectively. This could be attributed to the overall shallow soil depth in the planting bed, coupled with the buried diffuser also caused a reduction in the soil depth, by being positioned at about 5-10 cm deep from the exact ground surface. A condition that actually creating a dry thin layer above the buried diffusers and also seemed to lead to salt-spread over a relatively lesser soil volume, compared to the top surface positioned drippers.

Acknowledgement: The author would like to thank the Department of Agricultural Research of the ministry of municipal Affairs, Qatar for supporting this work.

REFERENCES

Abdrabbo A. Abou Kheira (2009). Comparison of Different Irrigation Systems for Deficit- Irrigated Corn in the Nile Valley. Agricultural Engineering International: the CIGR. *E Journal*. Manuscript LW 08 010. Vol. XI.

Ayars, J.E., C.J. Phene, R.B. Hutmacher, K.R. Davis, R.A. Schoneman, S.S. Vail and R.M. Mead (1999). Subsurface drip irrigation of row crops: A review of 15 years of research at the Water Management Research Laboratory. *Agric. Water Manag*., 42 (1): 1-27.

Bainbridge, D. A. (2001). Buried clay pot irrigation: A little known but very efficient traditional method of irrigation. *Agric. Water Manag*., 48(2): 79–88.

Camp, C. R. (1998): Subsurface drip irrigation: A review. *Trans. ASAE*, 41(5): 1353–1367.

Chahbani Bellachheb (2012): http://www.solutionsforwater.org/wp content/uploads/2012/03/Buried-diffuser-report-February-2012.pdf

El Mokh F., K. Nagaz, Mahmoud M. and N. B. Mechlia (2014). Effects of surface and subsurface drip irrigation regimes with saline water on yield and water use efficiency of potato in arid conditions of Tunisia. *Journal of Agriculture and Environment for International Development*, 108(2):

Fujimaki, H. et al (2012). http://www.alrc.tottori u.ac.jp/fujimaki/download/WASH_2D/SSSA.pdf

Gideon, O. et al. (1999). *Agricultural Water Management*, 39 (1): 19-33.

Gil, M., L. Rodríguez-Sinobas, R. Sánchez and L. Juana (2011). Procedures for determining maximum emitter discharge in subsurface drip irrigation. *J. Irrig. Drain. Eng*., 10.1061/(ASCE)IR.1943-4774 .0000299, 287–294.

Lazarovitch, N., U. Shani, T. Thompson and A. Warrick (2006). Soil hydraulic properties affecting discharge uniformity of gravity-fed subsurface drip irrigation systems. *J. Irrig. Drain Eng*., 10.1061/(ASCE) 0733-9437(2006)132:6(531), 531–536

Oron G., Y. DeMalach L. Gillerman, I. David and V.P. Rao (1999). Improved saline-water use under subsurface drip irrigation. *Agric. Water Manage.*, 39: 19-33.

Phene, C. J., K.R. Davis, R.B. Hutmacher and R. L. McCormick (1987). Advantages of subsurface irrigation for processing tomatoes. *Acta Hortic.*, 200: 101–114.

Provenzano, G. (2007). Using HYDRUS-2D simulation model to evaluate wetted soil volume in subsurface drip irrigation systems. *J. Irrig. Drain Eng.*, 10.1061/(ASCE)0733-9437(2007)133:4(342), 342–349.

Rodríguez-Sinobas, L., M. Gil, L. Juana and R. Sánchez (2009a). Water distribution in laterals and units of subsurface drip irrigation. I: Simulation. *J. Irrig. Drain Eng.*, 10.1061/(ASCE)IR.1943-4774.0000058,721–728.

Shalhevet J. (1994). Irrigation with saline water. Pp.263-276 In: *Arid Zone Irrigation* (B.Yaron, E. Danfors and Y. Vaadin, eds.). Springer-Veriag, Heidelberg, West Germany.

Sun S.M., P.L. Yang, Q.X. An, R. Xu, B.L. Yao, F.Y. Li, and X.X. Zhang (2016). Investigation into surface and subsurface drip irrigation for jujube trees grown in saline soil under extremely arid climate. *Eur.J.Hortic.Sci*., 81(3): 165-174.

(*Accepted for publication May 2018*)