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GROWTH, YIELD, AND QUALITY OF GREENHOUSE TOMATAO IN RESPONSE TO DIFFERENT IRRIGATION LEVELS USING BURIED DIFFUSER (BD) AND SURFACE DRIP (SD) IRRIGATION METHODS UNDER ARID CONDITIONS

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ABSTRACT

A net greenhouse experiment was conducted on tomato to test the performance of two drip irrigation methods; buried diffuser (BD) versus surface drip (SD) under three irrigation levels, namely 100% (recommended irrigation), 75 and 50% of the full irrigation. The effects of irrigation methods were inconsistent during the two seasons because results were assessed significant only in the 2016/2017 season. In this season buried diffuser (BD) has significantly increased plant length, stem diameter (girth), fruit weight, fruit clusters (bunches), and fruit number but significantly decreased number of plant leaves, and total soluble solids (TSS). The increase in plant length and diameter of the stem (girth) was 16.7% and 14.3%, respectively, but number of plant leaves decreased by 4.3%. The fruit weight, fruit clusters (bunches), and fruit number increased by 45.8, 18.6, and 34.8%, respectively while TSS decreased by 12%. The highest reduction in crop yield was recorded with 50% of recommended irrigation due to decrease in plant length, girth, number of leaves, fruit cluster and fruit number by 13.9, 11.7, 10.9, 14.8 and 19.1%, respectively which were evaluated significant as well whereas the 75% irrigation level proved better than 50% level. The combinations of the two factors did not indicate any assessable impact on crop growth, yield or quality. In the 2017/18, all the treatment effects remained as non-significant.

Keywords: irrigation methods and levels, subsurface buried diffuser, net greenhouse tomato, yield growth, and quality.

INTRODUCTION

Water shortage is a global issue, which limits the agriculture development in arid and semi-arid regions. A report of the United Nations stated that one-fifth of the world's population lives in areas characterized by physical water scarcity (Xu *et al.*, 2018). The water deficiency may worsen under changing climatic conditions. Qatar is a peculiar example of water scarce countries because of which the policymakers have been calling for the strategic water resource management, especially for agriculture. The Qatari Ministry of Municipality and Environment (MME) is made responsible for food security, agriculture, and natural resource conservation and development under the National Vision 2030 of the country. Therefore, plans and projects of the Food Security Program must be planned and executed. The agricultural strategy of Qatar focuses on increasing the production of food items, such as vegetables, red meat, poultry, eggs, and fish, through optimal utilization of natural resources. Hence, ambitious steps were taken by the Qatari agricultural sector to meet the requirements of the local market and raise the self-sufficiency in the plant, animal and fish sectors.

Over 92% of Qatar agriculture is based on the total abstracted saline groundwater while desalinated seawater is used in greenhouse crops. Water productivity reflection for this sector, as reported by the of Ministry of Development Planning and Statistics (MDPS, 2014), showed that 534.32 liters of water were needed to produce 1 Q.R of GDP and one liter of water contributed to roughly QR 0.002 of GDP (MDPS, 2017). In the recent years, there has seen a significant increase in the cultivated area of greenhouses that was 120 hectares in 2010 and is more than 300 hectares in 2018. Tomato production from both open-field and protected agriculture systems in Qatar reached 14562 tons during 2017 (MDPS, 2017), which is 26.2% of the total vegetable crops produced in the country (55579 tons) and making just 16.4% of total consumption. The country has recently become able to produce locally a considerable portion of its food. Tomato, one of the highest water-demanding crops, is an annual horticultural plant with world distribution and enormous economic value, while its high content in antioxidant compounds offers a few health benefits to the consumer (Bilton *et al*., 2001). Greenhouse tomato production in is on the increase, providing tomato during those times of the year when field-grown tomato is not readily available. It was indicated that water and soil water dynamics influence plant growth yield and fruit quality of tomato (May and Gonzales, 1994; Obreza *et al*., 1996; Ho, 1999; Sen and Sevgican, 1999).

The agricultural sector of the country made huge leaps in implementing modern irrigation systems on the Qatari farms, increasing from 45 percent in 2010 to exceed 80 percent of the total cultivated area in 2018. Thus, improving water productivity is urgently needed in such water-scarce conditions to face the challenge of increasing water supply to agriculture. Maintaining current high yields of greenhouse vegetables may pose an environmental threat due to continued overuse of water. Therefore, focusing on high water productivity of greenhouse vegetables, utilizing appropriate irrigation methods is of high priority research. This will allow efficient water-saving (Rahman, 1996) and confirms the country's strategy for adopting advanced irrigation technology. Accordingly, drip irrigation was target of investigation in this study, since it the most efficient in terms of water use in irrigated tomato (Zhai *et al*., 2010), pepper (Gupta *et al*., 2010) and squash (Amer, 2011). On-farm adoption of surface drip irrigation (SD) is one measure widely believed to conserve water. It is known to reduce water losses through deep percolation or surface runoff, conserving about 30% of water as compared with surface irrigation (Cetin *et al*., 2002) because it allows the small but frequent application of water with minimum losses.

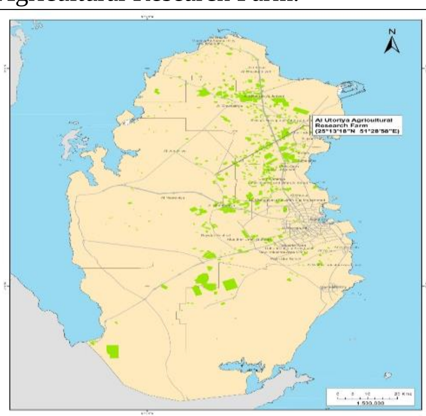
Buried diffuser (BD) is also a modern drip irrigation system which may further add to water conservation by reducing water loss trough surface evaporation as well. It was also concluded by Elshamly *et al*. (2017) that integral drip irrigation, a type of buried drip, has improved water consumption and caused significant increases in tomato yield and water use efficiency. For an efficient greenhouse tomato crop must consist of the optimization water use, irrigation scheduling, water-saving, higher yield, and better fruit quality. Fruit yield and healthy fruits were favored by amount, timing or irrigation interval and high irrigation frequency (Dumas *et al*., 1994; Prieto, 1996; Matos *et al*., 2011). The purpose of this study was to investigate the effects of irrigation method and strategy on growth, yield and fruit quality of net greenhouse tomato as well as saving water and comparing the current irrigation practice (full irrigation, 100%) with the 75% and 50% under drip irrigations (Buried diffuser "BD" versus surface drip "SD" irrigation).

MATERIALS AND METHODS

Experiment Design

The experimental site was Al-Utouriya Agricultural Research Farm (Fig.1) devoted to protected agriculture (25°13′18″N 51°28′58″E). The entire small peninsula of the Arabian Gulf is characterized by a hyper arid climate. Rainfall is scarce, and the average temperature is 30 degrees Celsius from May to September, reaching 40 degrees frequently and can drop to 10 degrees during cool winter nights.

Fig. 1. Location of Al-Utouriya Agricultural Research Farm.



Experiments were conducted in a 39m long, 9m wide netting greenhouse units during two successive winter seasons over the years 2016 to 2018. Hence, two net greenhouses were used to accommodate the two main plots and six net greenhouses to provide for the three replicates.

A split-plot design was implemented with two irrigation methods as main plots; three irrigation levels as sub-plots treatments within each irrigation method. There were three replications of each treatment, each replication was assigned to a devoted net-green house. Irrigation methods were buried diffuser (BD) and surface drip irrigation (SD), as demonstrated in Fig.2. Water applied to impose irrigation level treatments were equivalent to 100, 75, and 50% based on the usually applied amount of water practiced in Qatar. After laying the irrigation systems in the six net greenhouses, tomato plants were transferred from a pre-prepared nursery and planted on soil beds. Paired row system of planting was followed.

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Tomato plants were twined along the plastic twine. Separate plastic twine was provided to each branch so that branches do not break up. Single and two stems were trained by removing the rest of the branches Tying of plants to the plastic twine started from the fourth week after transplanting and it was done at weekly intervals along with pruning operation. De-leafing the older leaves were carried out periodically starting from 70-80 days after transplanting. Leaves were retained in the stem to a height of about 150 cm from the growing tip.

Fig. 2. The Buried diffuser and its installation in the net greenhouse.

Buried Diffuser (BD)

Installation of BD

Weekly harvesting of tomato fruits started at 70-80 days and continued until 160 -200 days after transplanting. Fruits were harvested at the color breaking stage. Measurements of the parameters to monitor crop growth, yield, and fruit quality were recorded. Most of these measurements were made at successive stages of crop growth. Five randomly selected plants were labeled in each treatment/subplot for these measurements. The average values were calculated, tabulated and used for split-plot design ANOVA calculations.

Growth parameters: Five labeled plants were used to record readings of these parameters and an average was calculated.

Plant height (cm): The plant height was recorded at 180 days after transplanting (DAT). The height of plants was recorded by measuring with the meter-scale from the base to its growing tip. The mean value was recorded and expressed in centimeters.

The number of leaves per plant (Nos.): The total number of leaves on primary and secondary branches was counted before the final harvesting.

The diameter of the stem (girth) (cm): Stem girth of selected plants was recorded at the base, the middle and top portion of the stem, at the end of the cropping period with the Vernier caliper.

Fruit Yield parameters

The number of fruit cluster (bunches) per plant: It was recorded from the time of initiation of the first fruit cluster to the end of the crop**.**

The number of fruits per plant: The total number of fruits was recorded treatment wise from individual plants after harvesting at weekly intervals till the end of the cropping period.

Fruit weight per plant (kg): It was calculated treatment wise by totaling the weight of the fruits recorded at different harvests during the experiment and was expressed in kilograms.

Fruit quality parameters

Total Soluble Solids (TSS): The tomato fruits were cut, and the juice was placed on hand refractometer device. The total soluble solids of each sample were observed and expressed in degree Brix.

pH & Conductivity: pH and conductivity of tomato fruit juice were estimated by using a handheld pH/EC meter by piercing out tomato juice from different treatments.

Nitrates (NO_3): Mixed chops of fruit by a food processor were used for estimating nitrate content in samples. Nitrate content expressed as mg nitrate per kg on a fresh weight basis (mg $NO3^-$/kg Fresh weight) was determined calorimetrically in filtered supernatant by a flow injection analysis system using a green test device.

Statistical analysis:

The data collected in respect of various parameters on growth, yield and quality attributes were analyzed statistically using a Vassar stat ANOVA computation. Critical Values for the Tukey HSD Test values were calculated at 1% P<=0.01) and 5% (P<=0.05) probability levels, where the F test was found significant.

RESULTS AND DISCUSSION

Plant Growth

A wide variation between the two experimental seasons has been observed because most of the data for the first season (October 2016 to April 2017) remained significant while for the second season (October 2017 to April 2018), the recorded data were assessed as non-significant. The reason is the very high difference in average rainfall received during these two growing periods. The mean for the first season was even below 20cm while for the second season it was more than 40cm (World Weather Online, 2019). Hence, the greater variation in rainfall over masked the treatment difference of Irrigation method as well as Irrigation levels because more water became available to plants than targeted through irrigations. It may be noted that the experiment was conducted in Net greenhouse which could not control the effect of rainfall. Therefore, this explanation must be considered by the readers for all non-significant results of the second growing season.

Table 1. Greenhouse tomato plant growth traits (means) as affected by irrigation method.

Irrigation method	A Plant length (cm)		The stem girth (cm)		The Number of plant leaves	
	2016/17	2017/18	2016/17	2017/18	2016/17	2017/18
	S	**NS**	**S**	**S**	**S**	**NS**
Buried Diffuser (BD)	371	339	12.8	11.9	43	41
Surface Drip (SD)	318	306	11.2	10	45	39
Critical Values for the Tukey HSD Test						
1%	28.24	-	1.05	2.6	2.96	-
5%	20.13	-	0.75	1.85	2.11	-

S = Significant at the P = 0.01 or P = 0.05 level. NS = Non-significant.

Irrigation water reductions/deficits usually cause negative action on vegetative growth. In the present study as well, the irrigation levels affected the growth parameters (Plant length and number of leaves) significantly in the first season (2016-17) but non-significantly in the second season (2017-18). However, the plant girth affected significantly in both the experimental seasons (Table 2). The values of all the three parameters were higher where irrigation level was 100%, but 75% and 50% levels decreased these growth characters, the difference between the latter two were relatively narrow. Reducing irrigation level from 100% to 75% resulted in decrease of plant length, girth and number of leaves by 9.5%, 7%, and 4.3%, respectively whereas reducing irrigation level from 75% to 50% resulted in decreased plant length, girth and number of leaves by 5%, 5%, and 6.8%, respectively. A similar trend of decreases in vegetative characteristics as irrigation level is reduced were also reported on basil plant (Mahmoud *et al*., 2017) and on cubage (Metwaly and El-Shatoury, 2017).

Table 2. Greenhouse tomato plant growth traits (means) as affected by irrigation level.						
Irrigation Level	A Plant length (cm)		The stem girth (cm)		The Number of plant leaves	
	2016/17	2017/18	2016/17	2017/18	2016/17	2017/18
	S	**NS**	**S**	**NS**	**S**	**NS**
100% (Full)	374	319	12.8	11.5	46	40
75% (reduced	339	326	11.9	11.3	44	40
50% (reduced	322	322	11.3	10.1	41	40
Critical Values for the Tukey HSD Test						
1%	40.43	-	1.51	-	4.24	-
5%	30.24	-	1.13	-	3.17	-
S = Significant at the P = 0.01 or P = 0.05 level. NS = Non-significant.						

In 2016/17 season plant length, stem girth and the number of plant leaves were all significantly affected (at p=01 level) by irrigation method as a sole factor (Table 1). Buried diffuser irrigation method has 16.7% and 14.3% more plant length and girth, respectively in comparison with surface drip irrigation method. On the contrary, number of plants and leaves significantly decreased (at p=05 level) by 4.4%. This was found to be in partial agreement with results of (Esmailpour and Akbari (2016). During 2017/18 season, the buried diffuser caused significant increase by 19% (at p=05 level) on plant girth only, while the other two growth parameters did not show significant effects. The enhanced crop growth under surface drip irrigation may be attributed to the favorable microclimate that prevails under the shade house conditions of higher evaporation rate which is anticipated to increase the rate of plant metabolic processes like photosynthesis, respiration and their better acclimatization.

All the interactions of irrigation methods (BD and SD) and irrigation levels (100%, 75%, and 50%) were evaluated as nonsignificant in both the years of experimentation (Table 3). Reducing irrigation level from 100% to 50% resulted in decreased plant length, girth and number of leaves in case of buried diffuser by 13.9%, 11.7%, and 10.9%, respectively in comparison with surface drip irrigation. These could be attributed to the relative drier soil surface experienced with the buried diffuser irrigation method in comparison to the surface drip irrigation method, thus leading to limited early growth. The phenomenon is especially true considering planting beds of light-textured soil composition which may unavoidably restrict upward movement of soil water leading to poor crop growth at this stage. Elevated temperatures usually associated with the dry conditions may cause growth inhibition.

The season buried diffuser compared to surface drip irrigation, produced less reduction in plant length and diameter of stem (girth), when irrigation level was reduced from 75% to 50% and from 100% to 50%. However, reductions produced were very close on both growth parameters upon reducing irrigation level from 100% to 75%. This indicates that reducing irrigation level to 75% cause minimal growth reduction for greenhouse tomato production under net greenhouse, meanwhile, further reduction of irrigation level would have to be at the expense of the establishment of the crop stand. The reverse was true in the case of reduction in the number of plant leaves where the surface drip irrigation method enhanced the number of plant leaves. Better crop vigor with less scorching of the twigs and leaves, along with less visual symptoms of sunburn, leaves senescence and discoloration were documented. Almost the same results were evidenced by several studies, which showed that reducing irrigation water decreased crop growth and canopy development (Ibrahim *et al*., 2011; Nyatuame *et al*., 2013 and XU and Leskovar, 2014). Based on the previous discussion it can be inferred that the Buried diffuser irrigation method (BD), generally seems to better sustain vegetative growth of greenhouse tomato under 75% reduced irrigation water conditions.

Crop Yield

The effect of irrigation methods and irrigation levels on the yield parameters (Fruit weight, Number of Fruit clusters, and Number of Fruit) of greenhouse tomato has been indicated in the Tables 4, 5 and 6. In 2016/17 season, fruit weight, fruit clusters and fruit number were all significantly (at p = 01 level) affected by irrigation method as a sole factor (Table 4) while the differences in the second season were non-significant. Buried diffuser irrigation, in comparison with surface drip irrigation, has increased fruit weight, fruit clusters and fruit number by 45.8 %, 18.6%, and 34.8%, respectively, which clearly revealed that the former (BD) is superior method than the latter (SD). More number of bunches brought a greater number of fruits, which contributed to more fruit weight. Several earlier studies (Al-Ghobari and Dewidar, 2018; Kong *et al*, 2012; Hanson *et al*. 1997; Gencoglan *et al*. 2006) also indicated similar trends. However, a dissimilar result which indicated inferiority of subsurface irrigation compared to surface drip irrigation method has also been reported by Çolak *et al*. (2018). The important considerations regarding the effectiveness of irrigation methods are rainfall pattern and soil texture. Where the rainfall is higher or the soil texture is not very sandy, both the methods may remain similar because rainy water may fulfil requirements of plants while upward movement of moisture from subsurface irrigation in loamy and clay soils may make the water available to plants.

Table 3. Greenhouse tomato plant growth traits (means) as affected by the interaction between Irrigation Methods and Irrigation Levels (IL).

Irrigation Method X Irrigation level (IL)	A Plant length (cm)		The stem girth (cm)		The Number of plant leaves	
	2016/17	2017/18	2016/17	2017/18	2016/17	2017/18
	NS	**NS**	**NS**	**NS**	**NS**	**NS**
BD x 100% IL	399	326	13.6	12.3	46	40
BD x 75% IL	364	348	12.7	11.7	43	42
Bd x 50% IL	351	342	12.18	11.7	40	42
SD x 100% IL	348	312	12.0	10.7	47	40
SD x 75% IL	315	304	11.2	10.8	45	38+
SD x 50% IL	393	302	10.4	10.5	43	39

NS = Non-significant at the P = 0.01 or P = 0.05 level.

Table 4. Greenhouse tomato yield and associated traits (means) as affected by irrigation method.

Irrigation Methods	Fruit weight (Kgs)		Number of Fruit clusters/bunches		Number of Fruit	
	2016/17	2017/18	2016/17	2017/18	2016/17	2017/18
	S	**NS**	**S**	**NS**	**S**	**NS**
Buried Diffuser (BD)	145.3	107.1	3.31	3.37	1492	1246
Surface Drip (SD)	99.7	82.7	2.79	3.29	1107	1082
Critical Values for the Tukey HSD Test						
1%	32.023	-	0.24	-	229.53	-
5%	22.828	-	0.17	-	163.62	-

S = significant at the P = 0.01 or P = 0.05 level. NS = non-significant.

Irrigation levels, as a sole factor, has only caused significant difference (at p = 05 level) on the parameters of fruit cluster and fruit number in the year 2016-2017 (Table 5). Although differences in fruit yield could not be evaluated as significant, yet the maximum tomato yield (137.3 Kg) was recorded in case of 100% irrigation level and minimum was seen in 50% irrigation level (107.4 Kg) whereas intermediate yield (122.8 Kg) was noticed in the treatment of 75% irrigation level. The results showed that reducing irrigation level from 100% to 75% resulted in decrease of fruit weight, fruit cluster, and fruit number by 10.6%, 12.5%, 5.9%, and 4.9%, respectively. Reducing irrigation level from 75% to 50% resulted in decrease of fruit yield, fruit cluster and fruit number by 12.5%, 8.5% and 13.6%, respectively. Reducing irrigation level from 100% to 50% caused a cut of fruit weight, fruit cluster and fruit number by 21.8%, 14.8% and 19.1%, respectively. These results suggested that on average, a water saving of 25% would be possible with the loss in the fruit yield of only 10.6% in growing tomato inside the net greenhouse which was also regarded as non-significant in statistical terms. All the yield parameters in the season 2017-2018 showed insignificant effects due to the investigated three irrigation level treatments. Similar water management strategies have also been found in some previous studies as a valuable alternative of economizing water use under open field as well as protected conditions, particularly in arid and semi-arid regions (Fereres and Soriano, 2007; Geerts and Raes, 2009), where water is the most limiting factor for crop cultivation.

No significant interactions were found in all combinations of the two factors (Table 6). The buried diffuser irrigation method compared to surface drip (SD) irrigation method resulted in comparatively less reduction in fruit weight, number of fruit bunches and number of fruits. It is also quite possible that reducing irrigation quantities could have the advantage of less nutrient loss through leaching from the root zone induced in the sandy soil.

Table 5. Greenhouse tomato yield and associated traits (means) as affected by irrigation level.						
Irrigation levels	Fruit weight (Kgs)		Number of Fruit clusters/bunches		Number of Fruit	
	2016/17	2017/18	2016/17	2017/18	2016/17	2017/18
	NS	**NS**	**S**	**NS**	**S**	**NS**
100% (Full)	137.3	90.2	3.25	3.27	1396	1182
75% (reduction 1)	122.8	99.7	3.07	3.41	1331	1159
50% (reduction 2)	107.4	94.6	2.83	3.31	1172	1151
Critical Values for the Tukey HSD Test						
1%	-	-	0.34	-	328.6	-
5%	-	-	0.26	-	245.75	-
S = Significant NS = Non-significant at the P = 0.01 or P = 05 levels						

Crop Fruit quality

The effects of two experimental factors; irrigation methods, irrigation levels, and the interaction between irrigation methods and irrigation levels on the quality parameters of greenhouse tomato have been tabulated (Tables 7, 8 and 9). Most of the variation in tomato flavor can be related to differences in the sugars measured as total dissolved solids (TSS) and acids contents of the fruits. These are commonly considered as fruit quality determining attributes in tomato. The TSS values of tomatoes determined for various experimental treatments are mostly acceptable for fresh tomato having °Brix values within the range (°Brix = 3.5-5.5), but processing requires a minimum °Brix of 4.5, so mostly these cannot be processed. Acidity is inferred from pH values which are falling within the normal range (pH= 4-4.5). Results of pH together with TSS indicated good flavor/taste of these net greenhouse fruit tomatoes with no regard to the method of irrigation and/or level of irrigation which were all non-significant as well as their interactions (Table 7, 8 and 9).

Table 6. Greenhouse tomato yield and associated traits (means) as affected by the interaction between irrigation method and irrigation levels.						
Irrigation Method x Irrigation level	Fruit weight (Kgs)		Number of Fruit clusters/bunches		Number of Fruit	
	2016/17	2017/18	2016/17	2017/18	2016/17	2017/18
	NS	**NS**	**NS**	**NS**	**NS**	**NS**
BD x 100%	157626	99991	3.42	3.33	1585	1190
BD x 75%	144818	109234	3.3	3.43	1513	1251
BD x 50%	133474	111920	3.21	3.33	1378	1296
SD x 100%	116905	80491	3.08	3.2	1207	1173
SD x 75%	100776	90120	2.83	3.39	1149	1067
SD x 50%	81389	77364	2.45	3.28	966	1006

S = Significant NS = Non-significant at the P = 0.01 or P = 0.05 level

TSS (total soluble solids) was significantly affected by irrigation method (Table 7) and nitrate content was significantly affected by irrigation level as sole experimental factors (Table 8). TSS was significantly (at p = 01 level) decreased by 12% indicating relatively better flavor fruits under surface drip irrigation. This could be interpreted according to the fact that different irrigation strategies may have an impact on crop water productivity, affecting crop quality as well. This performance of buried diffuser is not in agreement with the better performance revealed for subsurface irrigation reported by Çolak *et al.* (2018) on eggplant. Generally, Deficit irrigation, as a sort of reducing irrigation level, was reported to account for a significant amount of water saving with some improvement in fruit quality such as tomato by Khapte *et al*. (2019). The 75% irrigation level provided the greenhouse tomato fruits with the highest nitrate content (277.24 mg/kg, Table 8).

This irrigation level seems optimum for nutrients, may be due to minimizing leaching and the consequent nutrient loss. The combinations of the two experimental factors together could not affect significantly all the studied parameter of tomato' quality (Table 9). Buried diffusion was associated with relatively less TSS and less pH value.

Table 7. Greenhouse tomato fruit food quality traits (means) as affected by irrigation method and level.				
Irrigation Methods	TSS (Brix)	Conductivity µS/cm	pH	$NO3^-$ -N (mg/kg)
	S	**NS**	**NS**	**NS**
Buried Diffuser (BD)	4.12	1763	4.2	260.0
Surface Drip (SD)	4.79	1538	4.3	259.4
Critical Values for the Tukey HSD Test				
1%	0.53	-	-	-
5%	0.38	-	-	-

NS = Non-significant at the p = 0.01 or p < 0.05 level.

Table 8. Greenhouse tomato fruit food quality traits (means) as affected by irrigation level.				
Irrigation level	TSS (Brix)	Cond. uS/cm	pH	$NO3^-$ -N (mg/kg
	NS	**NS**	**NS**	**S**
100% (Full)	4.29	1654	4.28	260.8
75% (Reduction 1)	4.47	1947	3.99	277.2
50% (Reduction 2)	4.62	1350	4.35	241.1
Critical Values for the Tukey HSD Test				
1%	-	-	-	41.6
5%	-	-	-	31.1

S = Significant NS **=** Non-significant at the P = 0.01 or P = 0.05 level

Table 9. Greenhouse tomato fruit food quality traits (means) as affected by the interaction between irrigation method and level.				
Irrigation Method X Irrigation level	TSS (Brix)	Conductivity µS/cm	pH	$NO3^-$ -N (mg/kg
	NS	**NS**	**NS**	**NS**
BD x 100%	4.04	1590	4.28	257.2
BD x 75%	4.13	2203	3.99	277.2
Bd x 50%	4.2	1495	4.35	245.6
SD x 100%	4.53	1718	4.28	264.4
SD x 75%	4.8	1691	4.32	277.23
SD x 50%	5.05	1205	4.3	236.7

NS = Non-significant at the P = 0.01 and P = 0.05 level

Conclusion

All farmers in arid conditions usually target the adoption of surface drip irrigation while applying irrigation water in amounts somewhat higher than that needed. Net greenhouse experiments were conducted at Agriculture Research Station, Al-Utouriya, Doha, Qatar, from 2016 to 2018 in two successive seasons. The aim was to compare the performance of new Buried Diffuser irrigation method with the surface drip irrigation method, already in use. It can be concluded that buried diffuser as an irrigation method can comparably be introduced to replace surface drip irrigation for providing water to tomato plants continuously without much water losses. Irrigation level at 75% water of the current practice application could be adopted for both irrigation methods to save irrigation water without substantially scarifying crop growth, yield and/or quality. Of course, long-term experimental work will be needed to confirm consistent advantages.

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