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Management of Irrigation Water for Cucumber Crop by Using Drip Irrigation Systems Under Greenhouse Conditions

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Abstract: This study aimed to examine the consequences of three regimes for irrigation on cucumber crops and their growth indication, production, and water productivity under greenhouse cultivation. Cucumber seedlings were planted in May 2018 under a greenhouse condition. Three regimes of drip irrigation were examined, first 100%, 80%, and 50% of ETc namely T1, T2, and T3, respectively. The second regime was systems of drip irrigation (surface and sub-surface irrigation). Finally, the third was dripper discharge which used (2 l/h and 4 l/h). Results indicated clearly that the best production was under 80% ETc regime by 2 l/h dripper for surface and subsurface that was 10.1 and 11.2 ton/greenhouse respectively with IR 172 m^3/season and the best regime by using 4 l/h was 50% ETc for surface and sub-surface respectively which was 11 and 11.5 ton/greenhouse with IR 216 m^3/season which saved about half a quantity of irrigation water. On the other hand, the very best water productivity value (WP) was under 80% ETc was 58.7 and 65.4 kg/m^3 under surface (S) and sub-surface (SS) drip irrigation respectively by 2 l/h dripper flow rate.

1 Introduction

Water-saving in the agricultural sector is a crucial factor in many countries with limited water resources and growing populations. Recently, cultivating vegetables under greenhouses in Egypt has been expanding rapidly. The number of greenhouses reached about twenty thousand, where about 12000 (60%) are used for cucumber production (EL-Aidy et al 2007).

Under greenhouses cucumber crop is one of the most popular and best vegetables grown in the Arab Republic of Egypt. Irrigation scheduling has a significant effect on growing cucumber crops by supplying irrigating water under different growth stages (Mao et al 2003). It gives more production under greenhouse cultivation than the open field (Maklad et al 2012).

Usually, drip irrigation systems used under greenhouse causes save water by increasing fruit yield and improving WP due to the consumption of less water (Berihun 2011). Any degree of water deficits may produce deleterious effects on the growth and yield of the crop (Saif et al 2003).

Water scheduling application is an effective way to drip irrigation system efficiency, by reducing irrigation amount, while the causes of water stress are inadequate irrigation (Deng et al 2006, Zaman et al 2001).

This study aimed to search out technologies for water-saving by maximizing production by employing drip irrigation regimes for irrigating cucumber crops under greenhouse conditions.

2 Materials and Methods

2.1 Materials

2.1.1 Soil and water characteristics

The soil of the experimental greenhouse is assessed as silty clay texture by mechanical analysis of homogeneous soil of the experiment at 40 cm depth which is suitable for cucumber growing roots; details are shown in **Table 1**. The irrigation well was 40 m in depth with a 10 m diameter and irrigation groundwater characteristics are detailed in **Table 2**.

2.1.2 Climate data

The climatic data were obtained from a meteorological station located next to the field of experiment and accustomed estimate the ETo data because the microclimate may be a major think of this study, the following data were recorded at Central Laboratory for Agriculture Climate (CLAC) during growth season showed in **Table 3**.

2.1.3 The greenhouse experiment

A field study was at an experimental greenhouse of the Agriculture Research Centre, located at Dokii, Egypt, (Latitude 30ºN and longitude 30ºN. The water source was groundwater from a well situated within the experimental area, an arch there is not any heating and air ventilation inside the chosen greenhouse, manufactured from wooden frames covered with transparent plastic roof polyethylene (PE) 120µm thickness plastic film protected with meshes of 20 x 10 threads/cm^2. The greenhouse used for this experiment was classified as low technology greenhouse, each 3.2 m high, 40 m long, and 16 m wide 640 m^2 area shown in **Fig 1**.

2.1.4 Drip irrigation system

The components of the system are described below:

1- Control head: It was at the water supplement source, a centrifugal pump 4"/3", driven by an electric engine 15 HP. The pump discharge is 35 m^3/h and 30 m lift, at width 1900 rpm screen filter 3" (120 mesh), backflow prevention device, pressure gauges, pressure regulator, control valves to control the desired pressure at different parts of the system, flowmeter, and chemical injection.
2- Fertilizer unit for injecting fertilizers into the irrigation system.
3- Main line: 75 mm diameter PVC pipes, and sub-main line: PVC pipes of 50 mm diameter.
4- Laterals: PE tubes 16 mm in diameter at the spacing of 50 cm distance, built-in16 mm PE surface and sub-surface drip line with 2 l/h and 4 l/h emitter discharge at 1 bar operating pressure. The spacing was 50 cm. The irrigation network is described in **Fig 2.**

2.1.5 Cucumber plant

Seedling cultivation for cucumber (*Cucumis sativus L.*) was transplanted in May 2018 and harvested in August 2018 ending as a summer cycle, with a distance (0.5 m) between each cucumber seed, the length of season was 14 weeks. Cucumbers *(Cucumis sativus L.*), Joyance variety at 10 days with stalk length 7-10 cm, were planted at a rate of 960 saplings per 640 square meters, Treatments had the identical recommended amount of fertilizers.

2.2 Methods

2.2.1 Experimental design

The greenhouse was designed in a splits plot with three replications where irrigation regimes (T1:100%, T2:80% and T3:50%) of estimated evapotranspiration, the greenhouse divided into 6 plots of 2 m × 40 m area with 0.5 m spacing between them this description showed in **Fig 3**. Each plot has two built-in SDI (surface drip irrigation) and SSDI (sub-surface drip irrigation) with two different emitters, 2 l/h and 4 l/h to examine every irrigation regime which is the best as shown in **Fig 4**. Irrigation was scheduled based on a water balance, calculated by El-Gindy (2007).

2.2.2 Evapotranspiration

ETc, estimated from the potential evapotranspiration (ETo), and using the crop coefficient (Kc) proposed this equation,

$$ETc = ETo * Kc \qquad \ldots\ldots\ldots\ldots (1)$$

ETc: crop evapotranspiration localized irrigation system, mm/day,
Eto: reference crop evapotranspiration, mm/day and Kc: crop coefficient.

Table 1. Physical properties of homogeneous soil of the experiment analyzed before cultivation

Depth	Soil particle size distribution %			Texture	F.C% At 33 KPa	P.W.P At 1500KPa
	Sand	Clay	Silt			
(0-50) cm	8.1 sand	48.8 clay	43.1 silt	Silty clay	36	17

Where: F.C: field capacity % and P.W.P: permanent wilting point were determined as percentages in weight %.

Table 2. Irrigation water's chemical analysis

pH	EC ppm	Soluble anions and cations (meq/l)							
		Ca^{++}	Mg^{++}	Na^{++}	K^{+}	CO_3^{-}	HCO_3^{-}	SO_4^{-}	Cl^{-}
7.30	500	1.2	0.1	3.31	0.41	0.00	0.5	1.4	3.12

Table 3. Average rooting depth and crop coefficient for cucumber crop (FAO 2011)

Growth stage	Days no.	Kc	Date
Initial Stage	8	0.45	2 May :10 May 2018
Development Stage	40	0.70	11 May: 20 June 2018
Mid-Season	30	0.90	21 June: 20 July 2018
Late-Season	25	0.75	21 July: 15 August 2018

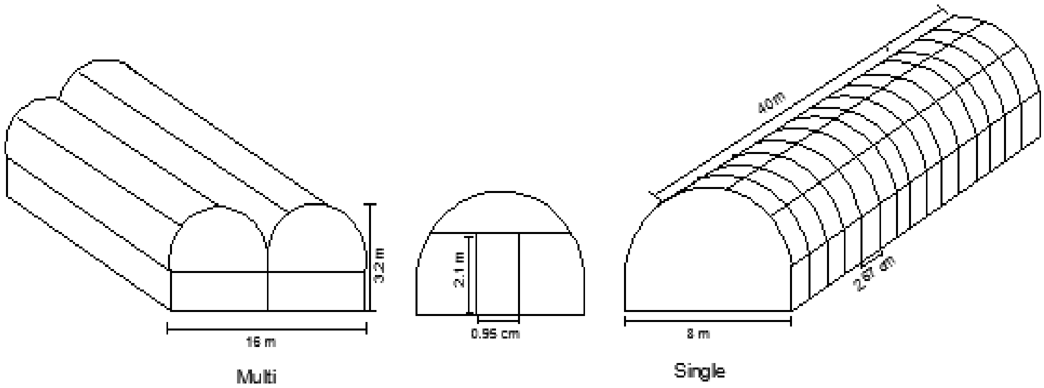

Fig 1. Greenhouse dimensions

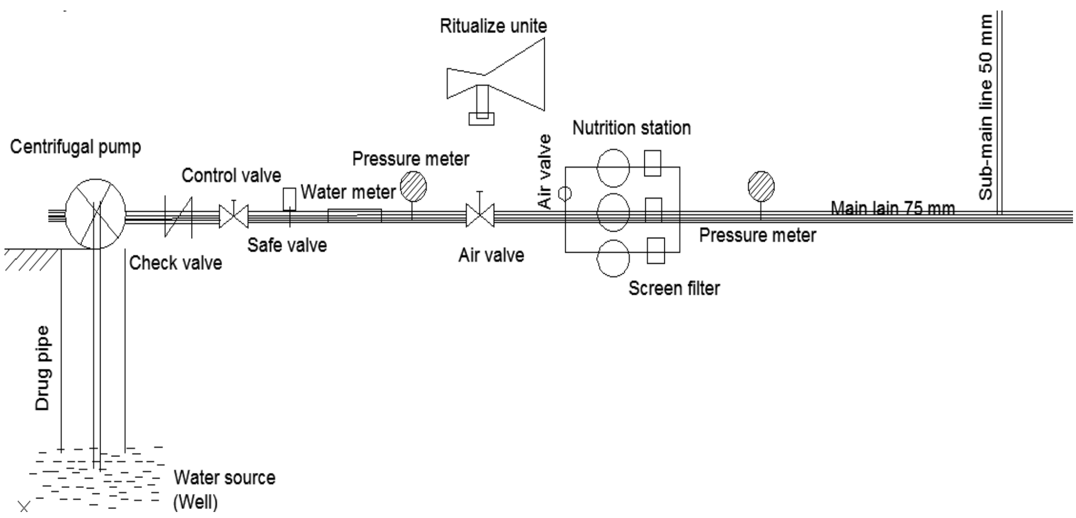

Fig 2. The layout of drip irrigation system component

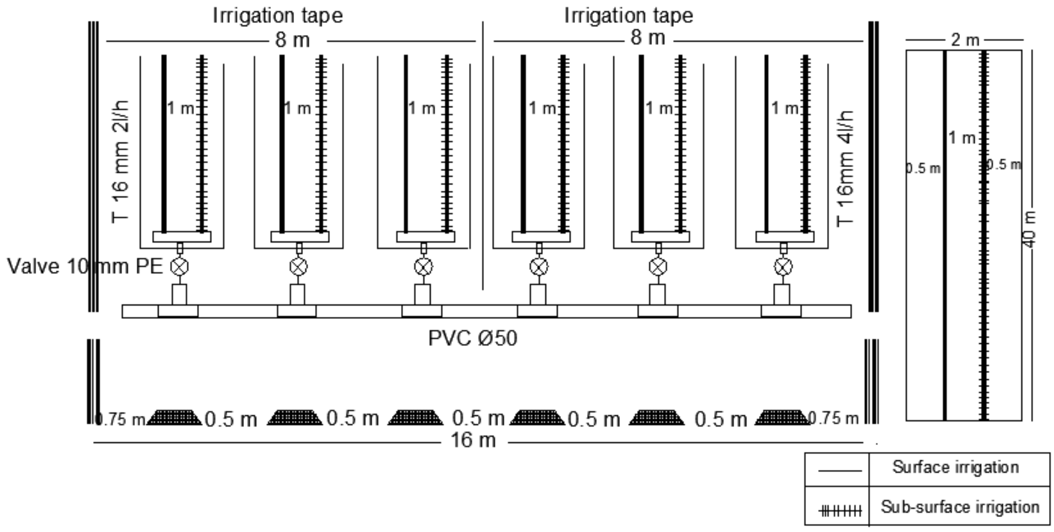

Fig 3. The layout of growing beds

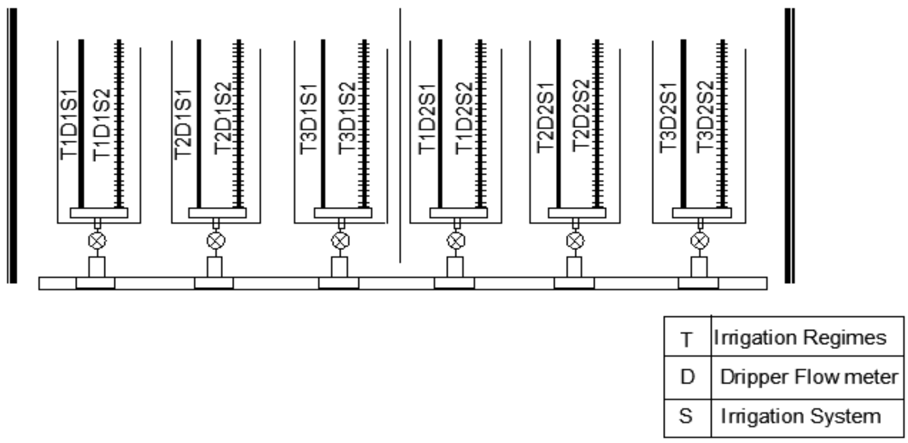

Fig 4. Irrigation treatments under greenhouse

2.2.3 Irrigation requirement

The water applied quantity for each treatment was calculated by the following equation (Howell 2003)

$$IR = \frac{Eto.Kc.A}{\Sigma a} * 0.7 \qquad \text{............. (2)}$$

Where:
IR: irrigation requirement (l/greenhouse/day); ETo: reference crop evapotranspiration (mm/day); Kc: crop coefficient; A: greenhouse area (m^2) and Σa: water application efficiency (Clark et al 2007).

By using the following equation, total irrigation requirements m^3/season under cultivating greenhouse could be estimated as shown in **Table 4**.

Calculating the amount of irrigation water which already been added to the cultivating greenhouse by following the equation:

$$T = \frac{IR\ .\ A}{Q} * 60 \qquad \text{................ (3)}$$

T: time of irrigation (minute); IR: irrigation requirements for the plot (mm); A: the area of the plot (m^2); Q: discharge of lateral in the greenhouse (l/h)

Table 5 shows the quantity of water which already applied under different irrigation treatments under greenhouse cultivation.

2.2.4 Water productivity (WP)

By authors describing, is the ratio of crop yield or crop value, to a selected measure of water consumed, applied, or evaporated in the process of growing a crop. according to the following equation (Molden et al 2010, Zwart and Bastiaanssen 2004).

$$WP = \frac{\text{crop yield (ton/ha)}}{\text{Applied water (m3/}ha\text{)}} \qquad \text{............ (4)}$$

Table 4. Estimated irrigation requirement for greenhouse/season

Growing stage	Days	Month	ETo mm/day	Kc	Σa	IR m^3/growing stage		
						100%	80%	50%
Initial. Stage (8 days)	8	May	4.5	0.45	95%	9.4	7.2	4.6
Development. (40 days)	30	June	5	0.70		80	64	40
	10	July	5.1					
Mid-Season (30 days)	20	July	5.1	0.90		76	60	38
	10	August	4.6					
Late-Season (25 days)	20	August	4.6	0.75		48	38	22
	5	September	3.6					
Σ days	103	IR m^3/season				213.4	168	104.6

Table 5. Applied water irrigation requirement for irrigation treatment under greenhouse

<table>
<tr><th rowspan="3">Growing stage</th><th rowspan="3">Month</th><th rowspan="3">Irrigation Time</th><th colspan="2">Line flow rate (m³/h)</th><th colspan="6">IR m³/growing stage</th></tr>
<tr><th colspan="2"></th><th colspan="2">100%</th><th colspan="2">80%</th><th colspan="2">50%</th></tr>
<tr><th>2l/h</th><th>4l/h</th><th>2</th><th>4</th><th>2</th><th>4</th><th>2</th><th>4</th></tr>
<tr><td>Initial Stage</td><td>May</td><td rowspan="8">40 mint.</td><td rowspan="8">0.16</td><td rowspan="8">0.32</td><td>17</td><td>34</td><td>13.6</td><td>26</td><td>8.4</td><td>17</td></tr>
<tr><td rowspan="2">Development Stage</td><td>June</td><td rowspan="2">84</td><td rowspan="2">168</td><td rowspan="2">66</td><td rowspan="2">132</td><td rowspan="2">42</td><td rowspan="2">84</td></tr>
<tr><td rowspan="2">July</td></tr>
<tr><td rowspan="2">Mid-Season</td><td rowspan="2">64</td><td rowspan="2">128</td><td rowspan="2">50</td><td rowspan="2">102</td><td rowspan="2">32</td><td rowspan="2">64</td></tr>
<tr><td rowspan="2">August</td></tr>
<tr><td rowspan="2">Late-Season</td><td rowspan="2">52</td><td rowspan="2">104</td><td rowspan="2">40</td><td rowspan="2">80</td><td rowspan="2">26</td><td rowspan="2">52</td></tr>
<tr><td>September</td></tr>
<tr><td colspan="2">Total Irrigation</td><td>216</td><td>432</td><td>172</td><td>344</td><td>108</td><td>216</td></tr>
</table>

2.2.5 Soil and plant measurements

There are numerous techniques for evaluating soil moisture. (Digital Mini Moisture) The meter was used for estimating soil moisture at 15 –50 cm profile soil depth at least that of the root penetration.

The data of growing plants were measured during the cucumber crop growth period to evaluate the whole yield, the height of the plant by using the meter to measure the height from the beginning of the stalk to its end, and the fruit number harvested per plant.

3 Results and Discussion

3.1 Irrigation requirements

Results showed adding irrigation water requirements by using 2 l/h dripper discharge equals the estimated quantity of irrigation water requirement which is supported by climatic factors approximately. Water applied under 50% ETc treatment by 4 l/h dripper discharge equals the same quantity of water applied under 100% ETc treatment by 2 l/h dripper discharge, as shown in **Table 4**. The results of irrigation regimes estimation agree with Howell (2003). Thus, it is often used 2 l/h dripper rather than 4 l/h under 100% ETc irrigation or 4 l/h dripper under 50% ETc irrigation level which saved 50% of total irrigation water.

3.2 Soil moisture

The average soil moisture content at (0-50) within the profile, the values as percentage in weight under different irrigation treatments for two sorts of irrigation systems SDI and SSDI with 2 l/h and 4l/h dripper flow. Water content for the soil was readings between two consecutive irrigations, the typical readings for every growing stage for the transplanted crop (initial stage, development, midseason, and harvest stage of cucumber).

Moisture within the profile initially showed higher moisture altogether the treatments because of the quantity of applied water before transplanting to replenish the profile to field capacity and the treatments at different growth stages received different quantities of water by different drippers 2 and 4 l/h which were 100%, 80%, and 50% of ETc as irrigation water levels after transplanting.

Under 2 l/h, after irrigation the soil moisture in the root zone area was lower than field capacity (F.C) but it didn't return to (PWP) value under 50% irrigation regime. However, under other regimes the soil moisture was equal field capacity (F.C) value and then retched to (the PWP) value after 48 hours from irrigation as shown in **Fig 5**.

Under 4 l/h, it was equal to the field capacity (F.C) then lowed to retch to the (PWP) under the 50% irrigation regime but under other regimes the soil moisture was higher than the field capacity (F.C) and then retched to be lower than P.W.P shown in **Fig 6.**

Soil moisture content under 100% ETc and 80% ETc had the same results by 2 l/h and 4 l/h.

The results proved that using 2 l/h dripper discharge to irrigate the greenhouse under 80% ETc treatment had significant differences with other treatments on the soil moisture content under subsurface irrigated lines. Sub-surface drip irrigation (SSDI) had the highest value of soil moisture content under all irrigation regimes.

3.3 Cucumber total production

The yield depended directly on the length of the harvest period. Yields range from about 1 to 3 Kg per plant per week during the highest harvest period. A stand harvest period of 14 weeks within the managed crop can yield a complete of 20 to 25 Kg per plant. Most cultivar trails show similar but somewhat lower yields from mini cucumber when put next to strength forward as shown in **Figs 7 and 8.**

The 80% ETc irrigation level had the very best yield production in comparison with other levels of irrigation under 2 l/h discharge of dripper, but under using 4 l/h 50% Etc was the best. The rate of reduction was 0.05% between 4 l/h and 2 l/h dripper discharge under sub-surface drip irrigation.

3.4 Water productivity

The differences in WP under irrigation treatments cause the quantity of crop yield. Results proved that the yield was preserved under the 80% ETc irrigation requirement. Although T1 had higher WP than that under 50% Etc. These results indicators are in agreement with Condon et al (2002), and Hashem et al (2011).

There was a clear interaction between irrigation type and irrigation water level treatments for WP. The WP values ranged from 34.2 Kg m^{-3} to 65.4 Kg m^{-3} depending on the interaction treatments, dripper flow rate and irrigation system. The very best WP value is 65.4 Kg m^{-3} for SSDI under (80% ETc) irrigation level by using 2l/h dripper discharge. Generally, WP increases with SSDI and 2 l/h drippers compared to SDI system irrigation water applied as shown in **Fig 9**.

3.5 Growth indicators

Plant height (m)

The irrigation regime's effect on the height of the plant is compared statistically within treatments as presented in **Fig 10.** Results showed that the regime achieved higher height under 100% ETc and 80% ETc regime compared with 50% ETc. Finally, 80% ETc achieved the highest height of plants using a 2 l/h dripper flow rate under sub-surface irrigation (SSDI). So, the idea about adding irrigation water quantity that was over or low had a relation with the plant height cucumber crop.

These results agree with Hashem et al (2011) and Ngouajio et al (2007) who stated that the cucumber vegetative parameters were increased with the irrigation level of 80% ETc followed by 100% and 50% irrigation levels during the Spring-Summer seasons. The increase of vegetative parameters under 100% ETc irrigation level was attributed to the suitable irrigation quantity, especially in the early stages of crop growth which enhanced a deeper and more extensive root system.

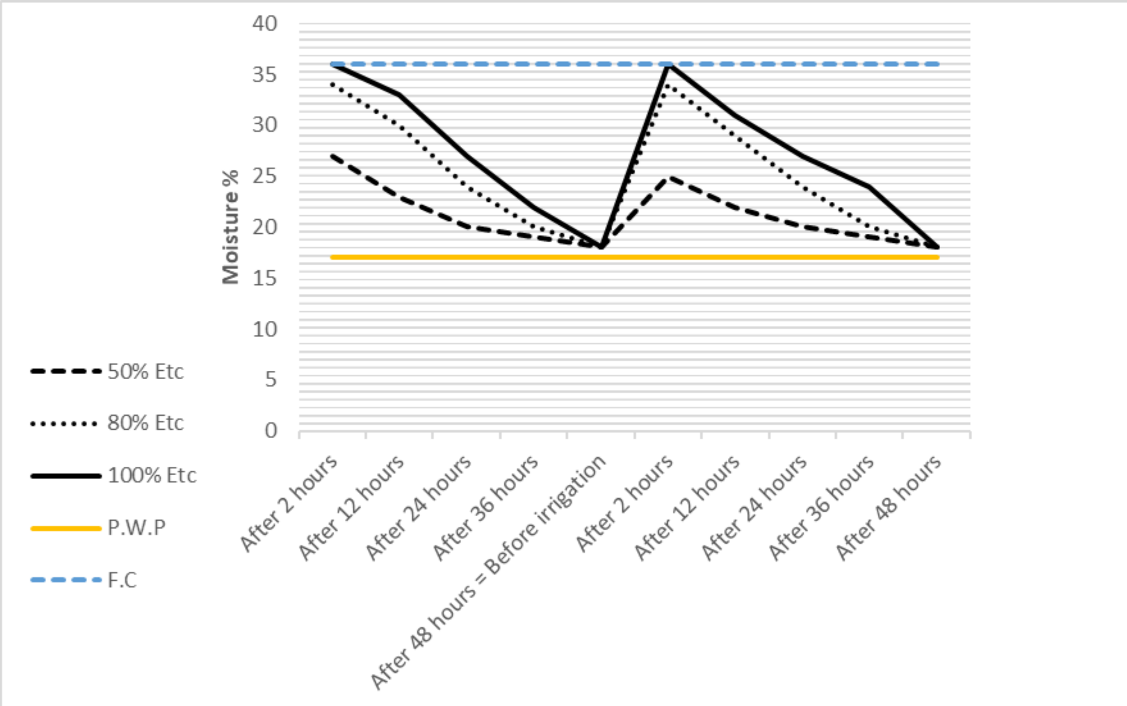

Fig 5. Average soil moisture content values as percentage in weight under three irrigation regimes for 2l/h flow rate dripper during the growth stage of cucumber crop

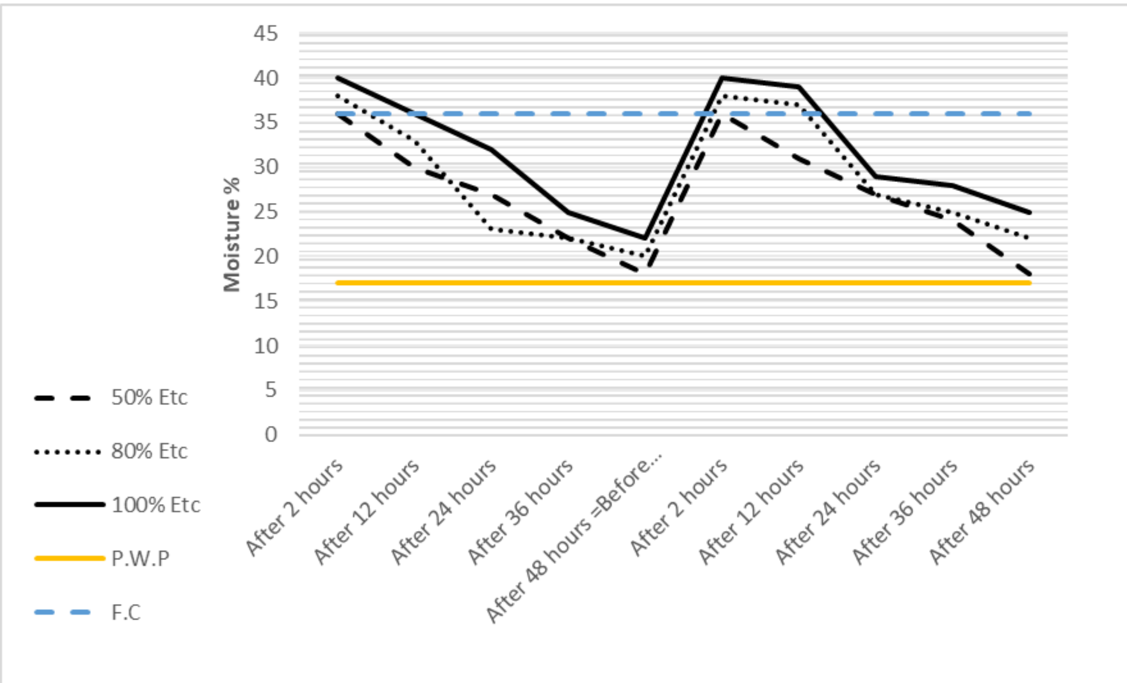

Fig 6. Average soil moisture content values as a percentage in weight under three irrigation regimes for a 4l/h flow rate dripper during the growth stage of cucumber crop

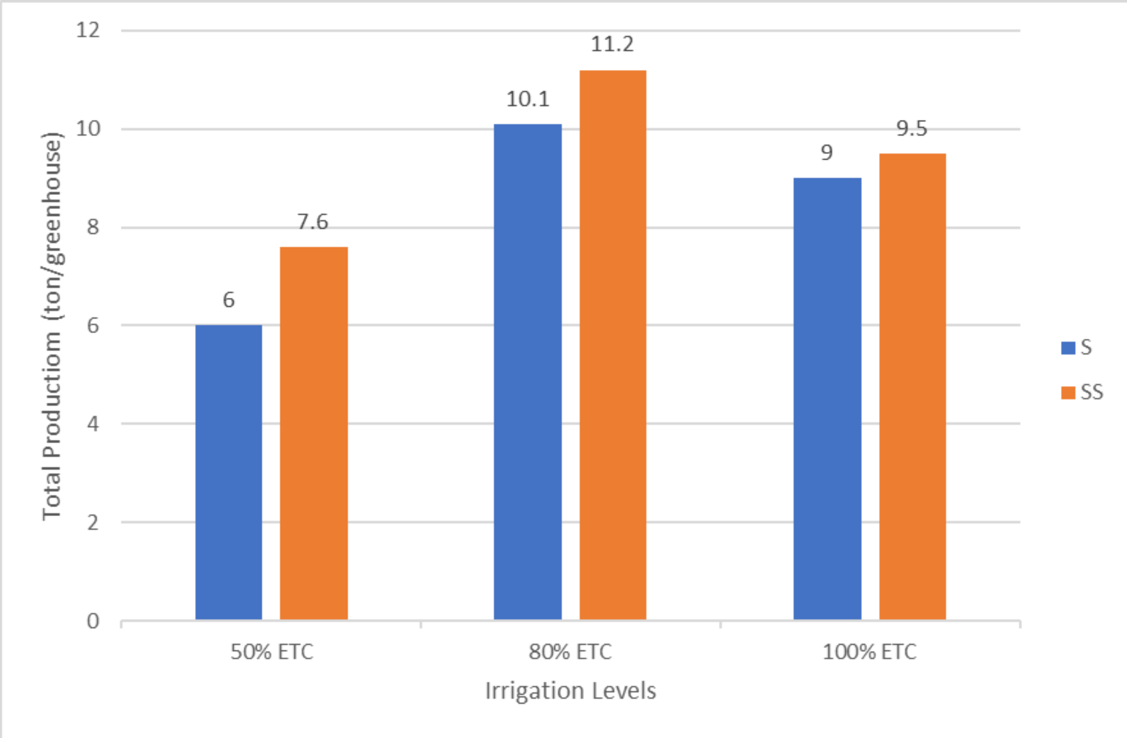

Fig 7. Total cucumber production under three irrigation levels for surface (S) and sub-surface (SS) drip irrigation system by using a 2 l/h dripper

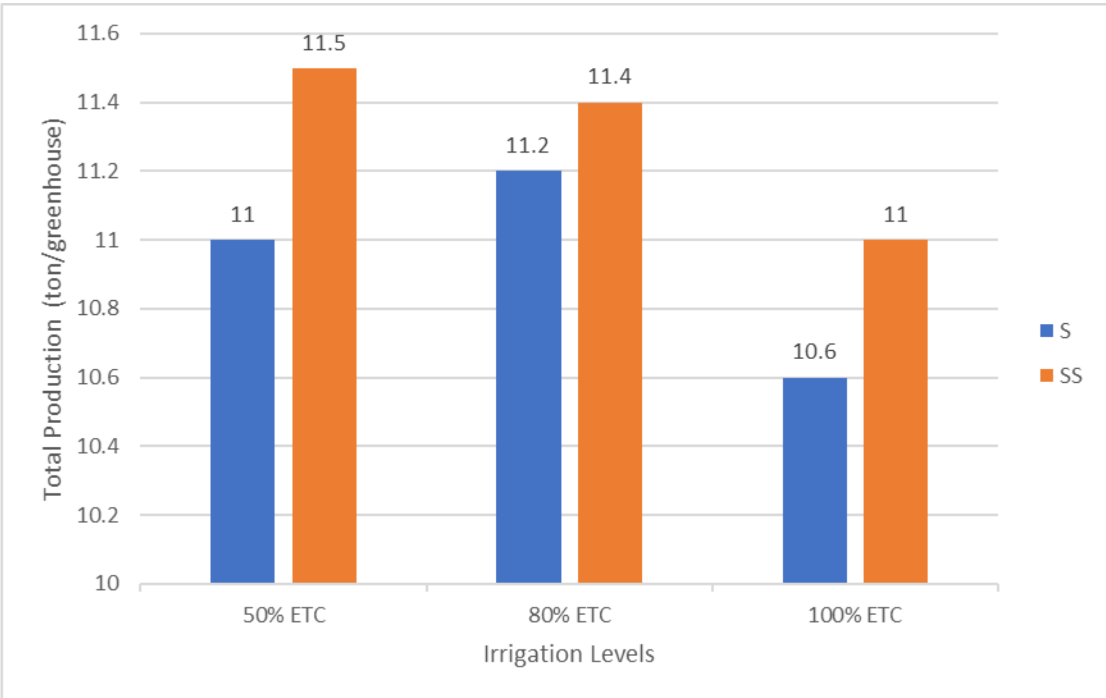

Fig 8. Total cucumber production under three irrigation levels for surface (S) and sub-surface (SS) drip irrigation system by using a 4 l/h dripper

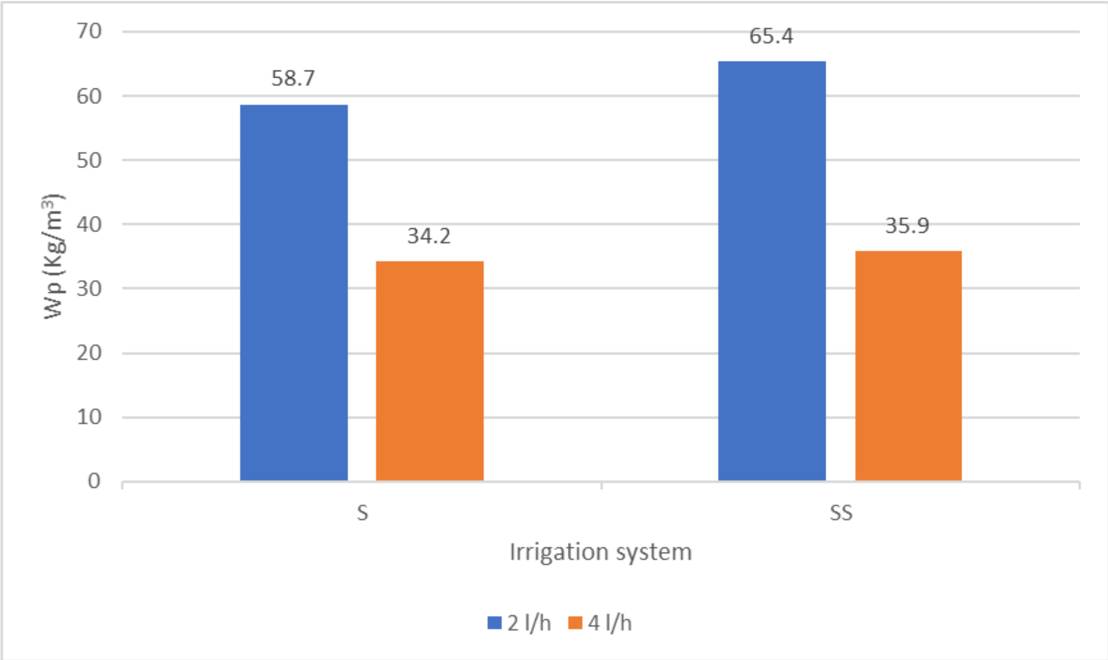

Fig 9. Water productivity (WP) under 80% ETc irrigation level with using 2 l/h and 4l/h flow meter under surface (S) and subsurface (SS) drip irrigation

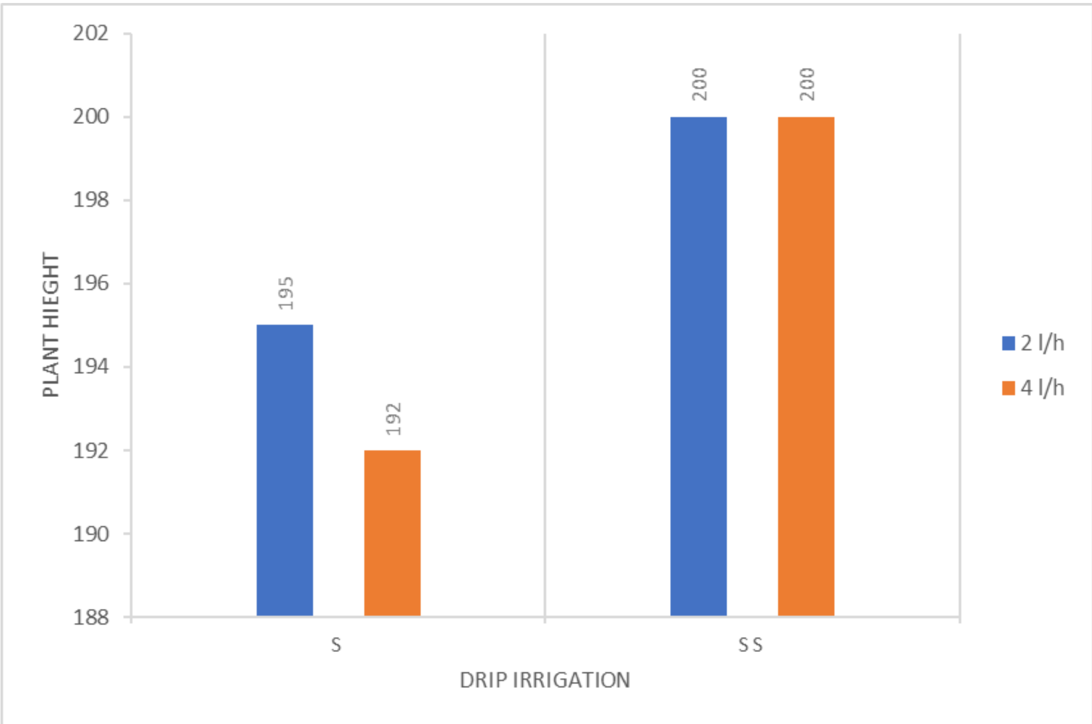

Fig 10. The effect of drip discharge under surface (S), sub-surface (SS) irrigation on plant height (cm) for 80% ETc irrigation level

4 Conclusion

It concluded that under conditions of the greenhouses, could be use 80% ETc irrigation regime which had the highest cucumber yield and water productivity. 2l/h drip emitter discharge at 100% irrigation level gives the same quantity of water which gives with 4l/h drip emitter discharge at 50 % irrigation level. The research recommended using 2l/h emitter discharge than 4 l/h. On another side, the sub-surface drip system reduced the yield production of cucumber by 44%. Study results demonstrated that the growth parameters (plant height, fruit number per plant) were increased by using 80% ETc throughout the cultivation season, which stimulated and encouraged the best growth for the plant.

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