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Impact of Drip Irrigation Scheduling on Yield Parameters in Tomato Plant (*Lycopersicon esculentum Mill.*) Under Unheated Greenhouse

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Abstract: Tomatoes (Lycopersicon esculentum Mill.) were grown on a fine sandy soil using drip irrigation and polyethylene mulch to evaluate the effects of irrigation scheduling on yield parameters. Under typical Souss Massa production conditions. Capacitive sensors were used to automatically schedule irrigations. And twelve irrigation treatments have been applied with a combination between three doses (50%, 75% and 100% ETC) and frequencies (f=0.10, f=15% and f=20%).
The result of this study shows that irrigation dose and frequency doesn't affect fruits number in grafted tomato plant (medium number =4.25 fruits/cluster); no significant effect on medium fruit size has been observed, unlike each separate fruit size. However, irrigation have a moderate effect on total yield (reducing dose by 50%ETC generate a loss of 7% of yield). The effect of Irrigation frequency on yield doesn't exceed 2%. Although, we can achieve the same performance with two completely different irrigation frequencies, this is explained by the regulation of soil water content which is limiting the effect of irrigation frequencies. According to our study we can confirm that irrigation scheduling can also control the size of marketable fruits.
Keywords: Tomato, green house, irrigation scheduling, dose, frequency, Yield.

Introduction

World population is predicted to double in the next 50 years, so greater yields must be extracted from the current agricultural areas along with more marginal areas[1]. Tomatoes are one of the most widely produced and consumed 'vegetables' in the world, both for the fresh fruit market and the processed food industries[2] , it plays a vital role in providing a substantial quantity vitamin C and A in human diet[3].

Optimum production of tomato requires intensive management practices that conserve and manage soil nutrients needed for maintaining soil and water quality and for sustaining tomato production.[4] Water plays an important role in plant life and in determining the yield of tomato.[5]

Water deficit results in reduced yield due to water and nutrients deficiency. Moreover, proper time of irrigation is essential to the production quality of the most vegetables. If water shortages occur early in the crop development, maturity may be delayed which may reduce yields. The moisture shortage later in the growing season adversely affects the quality of product even though total yields may not be affected[6]. However, Water stress conditions encourage tomato to develop its root system at deeper soil layers to retain more water.[7]

By the way, Irrigation frequencies and timings have large effect on root development, tomato yield, water distribution and water use efficiency. Increasing irrigation interval decreases roots dry weight. Decreasing in root system due to water stress resulted in a reduction in shoot dry weights.[8]

The challenge of water management at the crop level is to link the time course of irrigation resources by increasing the resources, moderating plant requirements and/or increase soil water extraction.[9] Tomato plants are sensitive to water stress and show high correlation between evapo-transpiration (ET) and crop yield.[10] Thus yield reductions can be expected if ET is reduced due to insufficient soil moisture. Though, growth is impaired due to water stress [11,12], fruit quality parameters like color or total soluble solids are usually improved[13].

The objective of this work was to study the relationship between irrigation frequency and fruit development, then to find the appropriate irrigation frequency and timing which can maximize crop production and water use efficiency in tomato.

Materials and Methods

Experimental site and plant material

The trial was conducted in October in the transfer technology center of Souss Massa region. It was conducted under unheated greenhouse to improve irrigation scheduling by testing targets and frequencies of drip irrigation water.

Plant Material

The materials selected for trial were commercial Tomato (Lycopersicon esculentum Mill.) Calvi variety that were grafted on “Beaufort”. The crop was trained over tow hands and was planted starting August at 0.4x3m spacing (density of 10600 plants per hectare).

Irrigation system

The irrigation was applied using simple dripper line with 40 cm spaced emitters that gave a flow of 2 l/h/emitter. Concerning Deficit Irrigation (DI) treatments, switching was allowed throw small valves that are placed in the beginning of each line. Irrigation and fertilization management were made within a fertigation station throw electro-valves. Daily reference evapo-transpiration ETo was calculated using the Penmann monteith formula.[14]

a. Irrigation frequencies (f values):

Three values of the factor of the equation f = f * DNM (HCC-HPFP) * Z * PSH were applied: f1=10%, f2= 15%, and f3 = 20%

DNM1 = 0.10 * 70 * 0.22 * 0.26 = 0.4 mm

DNM2 = 0.15 * 70 * 0.22 * 0.26 = 0.6 mm

DNM3 = 0.20 * 70 * 0.22 * 0.26 = 0.8 mm

b. Irrigation target

Restrictions of water supply were applied for tomato cultivation using 50%, 75% and 100% of the calculated initial ETc (Kci= 0.7). The result is three different Kc of 0.35, 0.53 and 0.7.

c. Soil strategy

There were two treatments where irrigation management was conducted according to soil data by setting two threshold values (maximum and minimum) value of the volumetric soil moisture using capacitive probes.

Unfortunately, monitoring of these two treatments was not as expected because no dendrometer was available to track the status of the plants. For this we will limit the comparison of 9 doses and frequencies combinations with the Control (T).

d. control

A control treatment was conducted according to a conventional method based on the farmer naked eye.

Experimental Protocol

It was therefore to test the combination of two factors (dose and frequency) so 9 combinations (treatments). In addition to treatment based on soil data and the control treatment. The greenhouse was divided into four blocs with four repetitions, or 48 experimental units. The detail of all treatments is presented in the Table 1.

Table 1 Detail of the applied irrigation treatments and used Kc

Treatment	Code	Combination	Used Kc
1	1050	Dose 50% frequency 10%	0,35
2	1075	Dose 75% frequency 10%	0,53
3	10100	Dose 100% frequency 10%	0,7
4	1550	Dose 50% frequency 15%	0,35
5	1575	Dose 75% frequency 15%	0,53
6	15100	Dose 100% frequency 15%	0,7
7	2050	Dose 50% frequency 20%	0,35
8	2075	Dose 75% frequency 20%	0,53
9	20100	Dose 100% frequency 20%	0,7
10	SS	Sol Strategy	SS
11	SS	Plant- Sol Strategy	SSP
12	T	Local Treatment	T

Experimental Design

The **Figure 1** illustrate the adopted experimental design.

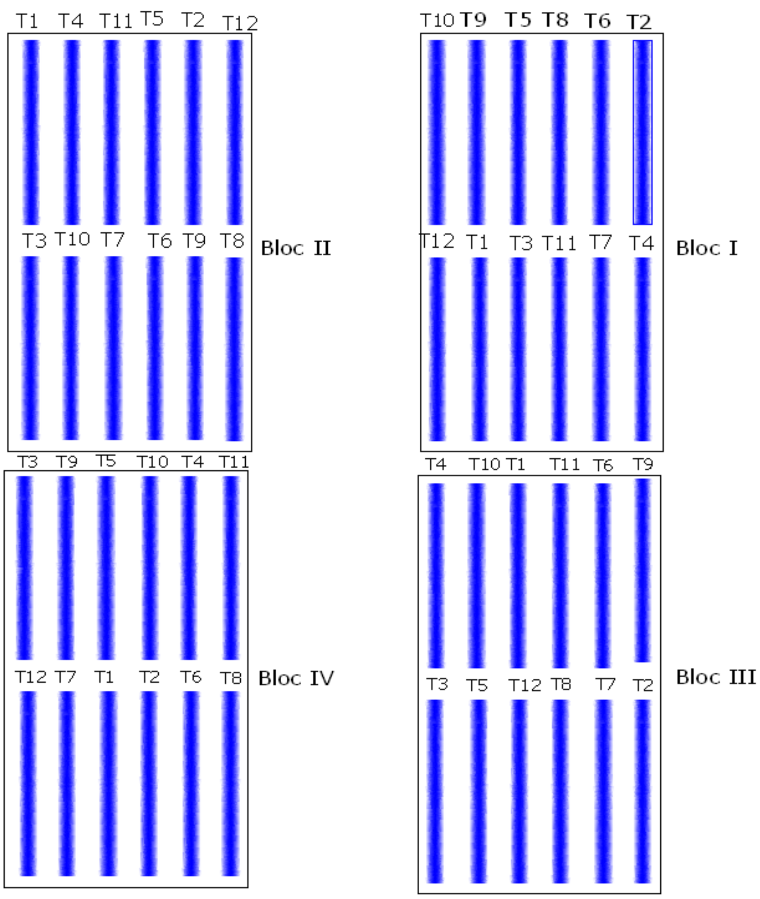

Figure 1: Experimental design used in the study

Fertilization management

It was decided to give a nutrition solution from the same tank. We change only the dose of each fertilizer. Then, salinity of the concentrated solution is always fixed but the amount of used fertilizers changes according to the plant requirement for each treatment.

The fertilization scheduling is shown in Table 2 according to the different stages where the equilibrium was calculated by dividing unit of fertilizer used by the unit of nitrogen.

Table 2 Detail of irrigation fertilization scheduling for development stage of plant.

Stage of plant	Electrical conductivity dS/m	Unite of Nitrogen per hectare per day	balance N/N-P2O5/N-K2O/N-MgO/N
Plantation - 27 DAP	2,5	3,1	1-0,63-2,17-0,22
28 DAP - 67 DAP	2,5	3,1	1-0,81-2,10-0,33
68 DAP - 109 DAP	2,7	3,1	1-0,70-2,80-0,40
110 DAP - 145 DAP	3	3,1	1-0,70-2,80-0,40
146 DAP - 261 DAP	2,6	3	1-0,70-2,80-0,40

- **DAP: Day After Planting , N: nitrogen, P2O5: Phosphorus, K2O: Potassium, MgO: Magnesium.**

Measuring tools

The measuring tools used in the experiment were:

✓ A complete telemetric weather station;

✓ Soil moisture probes (C-prob, Easy AG, Hydra-prob, AquaCheck);

✓ Drip sensors to control water supply.

All measurements are automatically recorded every 15 minutes and then transmitted to a base station for computer data processing.

Measured Parameters

✓ **Climatic parameters:**

- Outside Greenhouse: temperature, relative humidity, radiation, wind speed and direction, rainfall
- Inside Greenhouse: Temperature, relative humidity, PAR, leaf wetness.
- Soil parameters: Temperature and soil moisture.

✓ **Agronomic parameters:**

Many parameters have been followed to monitor the fruit growth of each treatment from the beginning of January :

✓ Number of fruits per treatment;

✓ Yield by plant compared to irrigation frequency;

✓ Yield by plant compared to irrigation dose ;

✓ Size of fruits;

✓ Percentage of non commercial fruits.

Results and Discussion

Climatic conditions

All climate conditions were used to calculate evapo-transpiration of reference that is used for irrigation management for each treatment. Figure 3 shows the trend of the calculated reference evapo-transpiration (ETo *) and real reference évapo-transpiration (ETo **) in mm/day.

The **Figure 3** shows that daily mean ETo values fluctuated, and increased from the beginning of the measurement period. A difference was observed between calculated evapo-transpiration ETo* and real evapo-transpiration of reference (ETo **) all over the period of trial. The maximum value of ETo* and ETo** has been observed at the **191th day** after planting with respectively **5.5mm/day** and **4.5mm/day**.

Effect of irrigation scheduling on Total harvested yield per plant

The first parameter studied to evaluate the irrigation supply and frequency effect on yield was the total weight of harvested fruit.

From the **Figure 4** and statistical analysis of the total yield per plant and per treatment, show that the best yield is obtained for the treatment **T9 (ETc 100%, f = 20%)** with **28.6 Kg** / plant, followed by T1 treatment **(50% SEM, 10%) with 28.3Kg/plant**. This result matches with what was reported by[15,8]. Irrigation has a complex effect in increasing yield; One of the main effects was the increased number of marketable fruits per hectare. Stronger and healthier plants can produce higher rates of flowering, fruit set, and ripened fruits.

We can therefore, conclude that reducing the frequency to **10%** and dose to **50%** can give almost equal yield and a light loss of **1%** compared **100% ETc**.

This result is generalized for all treatments; where the dose decreases, the frequency must be increased to maintain optimum yield performance.

Number of fruit per cluster

To better understand the impact of dose and frequency on yield, the number of fruits per cluster was studied and reported in **Figure 5**.

It can be seen that this parameter is not affected by the dose neither by frequency. The statistical analysis revealed that there was no significant difference between the numbers of fruits obtained for each twelve treatments. Indeed, the average number of fruits per cluster is close to 4.25 fruit/cluster. Usually, irrigation has a greater effect on the average fruit weight than on fruit number because of the limited number of tomatoes flowers [16].

Effect of dose and frequency on fruit size

Fruit size is very important in the process of accessing the dose and frequency impact on tomato production. Medium size of fruit per treatment has been studied and shown in **Figure 6**.

The statistical analysis revealed that there was no significant difference between the sizes of fruits obtained for each twelve treatments. Indeed, the average size of fruits per plant is close to 73.83mm per fruit. Therefore, the yield was affected by bigger fruits[16].

To compare the impact of irrigation scheduling on the size of tomato fruit, we consider 3 commercial fruit sizes (C1: Big, C2: medium, C3: Small).

The **Figure7** illustrates the result of this study. The first conclusion to be taken from this trend is that the dominant size is the medium (C2) with 66% of fruit, while the other ones C1 and C3 (Large and Medium) are minorities with 16 to 18% of fruits.

Drip irrigation scheduling affects fruit size of tomato; It seems that the size C1 (Large) and C3 (Small) are favored by moderate doses 75% ETc and low frequency (f = 20%), while the medium size (C2) is favored by high doses (100 %ETc) and low frequency (f = 20%). the average fruit weight for 1-day irrigation frequency was higher than that of 3-days frequency.[8]

Effect of dose on yield

To evaluate the separate effect of irrigation dose and frequency, a statistical analysis was made (see **Figure 8**), it is clear that the yield of tomato is slightly affected by the irrigation doses even if soil water potential had no significant effects on tomato yields.[17] In fact, the best performance is obtained by an irrigation dose of **100% ETc**, while the lowest yield was obtained by the irrigation dose of **50%ETc**.

The consequent reduction in the yield is **-7%** in the case of dose **50%ETC** and **-3%** in the case of irrigation dose of **100% ETc**.

So, we can really save water, between 25 and 50%, with very slight and tolerable loss of tomato yield.

Effect of frequency on yield

To check the effect of drip irrigation on the yield of tomato frequencies, we examined separately the relationship between irrigation frequency and yield. The **Figure 9** illustrates the obtained results.

When doses are separately examined, the effect of irrigation frequencies on tomato yield is very moderate; it does not exceed 2% in daily basis. For week basis[8], some authors fined that irrigation frequency of **3-days** increases the average of yield by **10%**; We can therefore achieve the same performance with two completely different irrigation frequencies. This is explained by the regulation effect of soil water that attenuated the effect of irrigation frequencies.

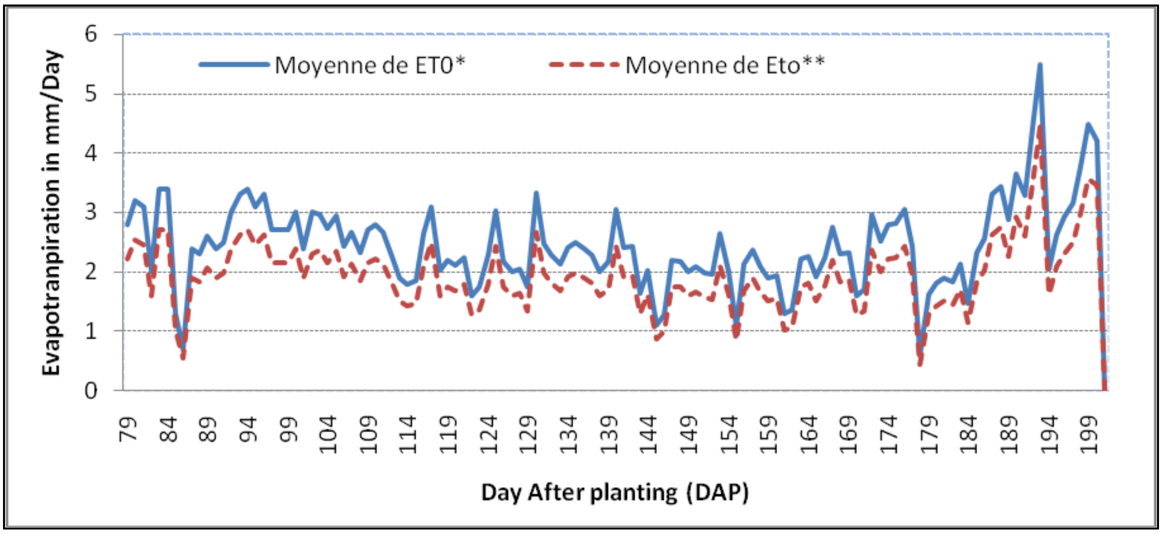

Figure 3: Calculated reference evapo-transpiration (ETo*) and real evapo-transpiration reference(ETo **) in mm / day.

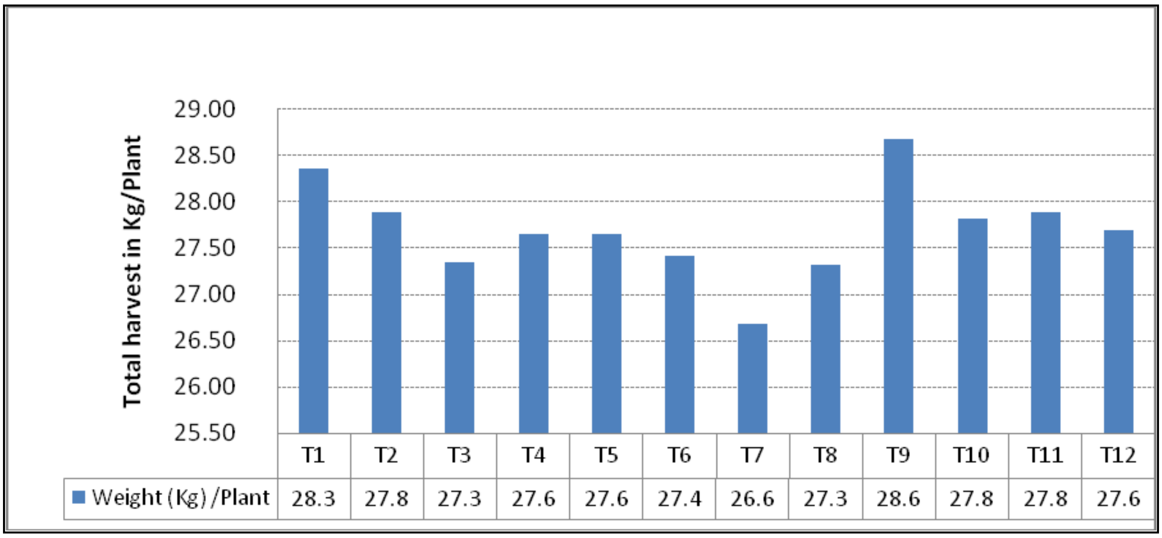

Figure 4: Total harvested fruits for each treatment in Kg/plant.

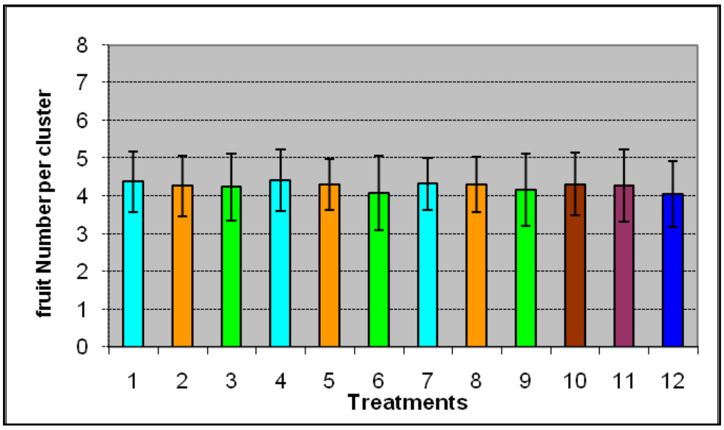

Figure 5: Fruits number per cluster obtained for each treatment.

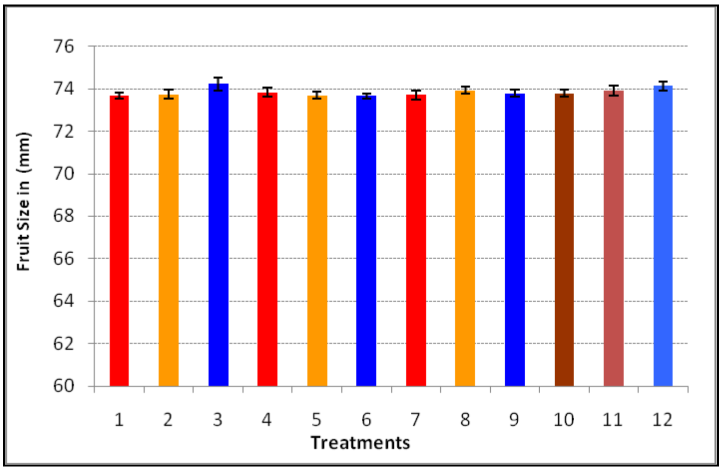

Figure 6: Medium size of fruits obtained for each treatment.

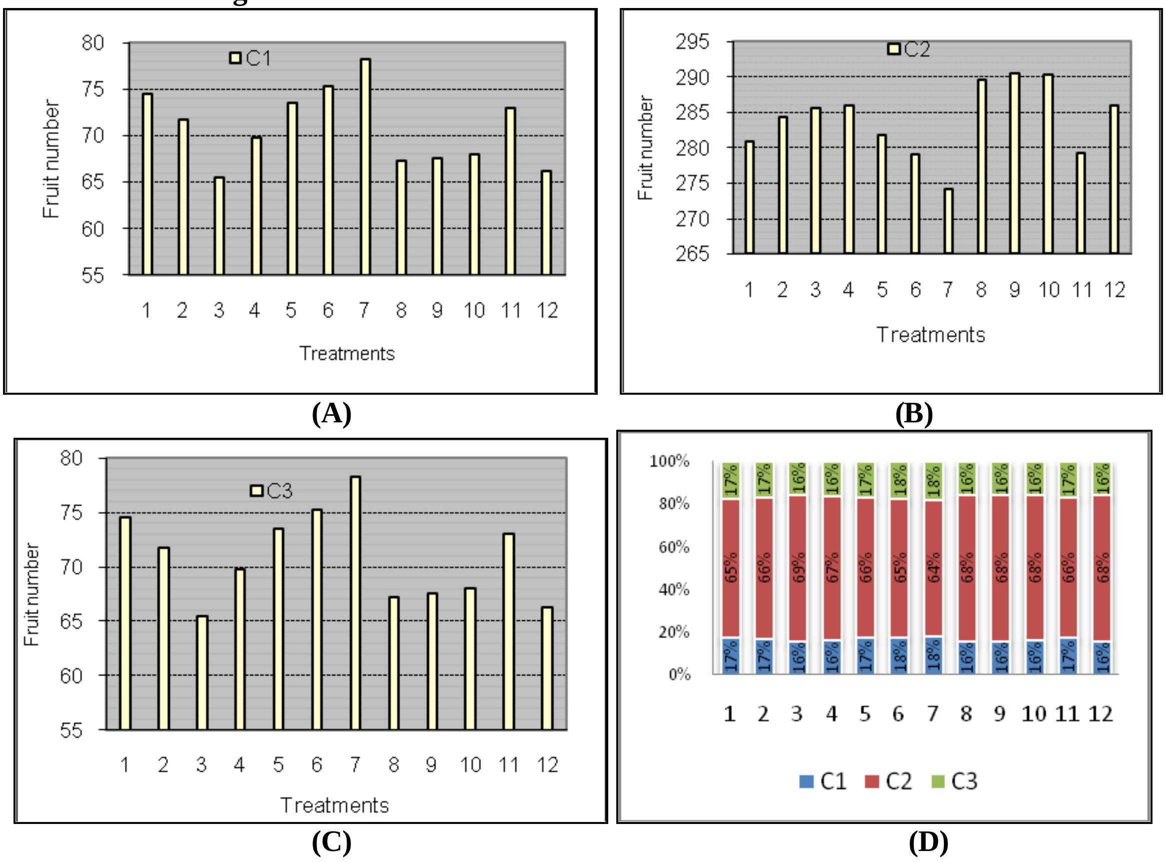

Figure 7: Effect of irrigation scheduling in tomato fruit size:
(A): large, (B): medium, (C): small, (D) Fruit size composition.

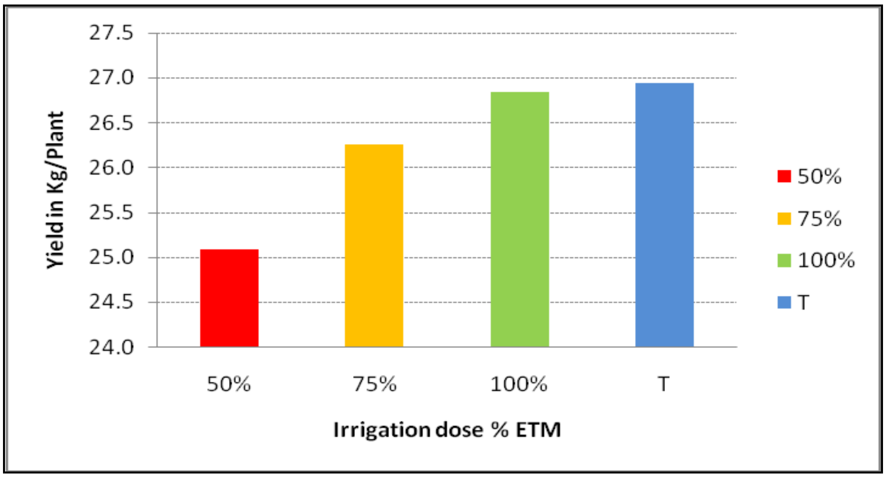

Figure 8: Effect of drip irrigation doses on tomato yield.

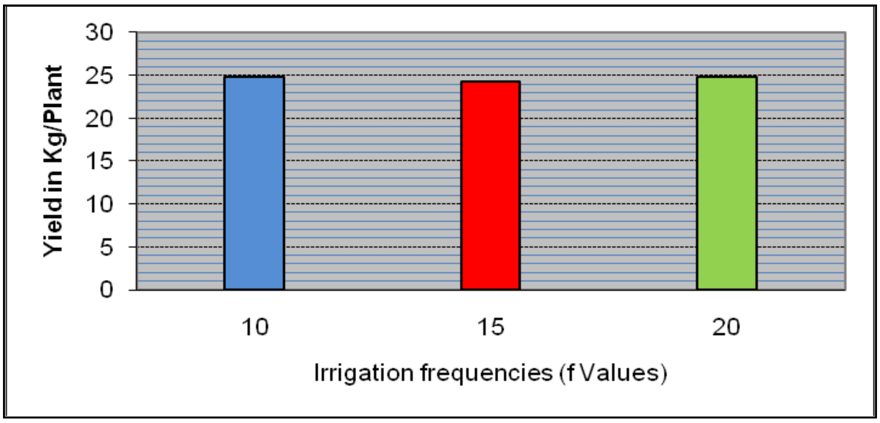

Figure 9: Effect of drip irrigation frequency on tomato production in (Kg/Plant).

Conclusion

At the end of this study it is to say, that we can save water, between **25** and **50%**, with slight and tolerable loss of tomato yield.

Doses can affect significantly the yield; In fact, the best performance is obtained by an irrigation dose of **100% ETc**, while the lowest yield was obtained by the irrigation dose of **50% ETc**. With a reduction in the yield respectively of **-7%** in the case of dose **50%ETc**.

By the way, reducing the frequency to **10%** and dose to **50%** can keep yield almost the same as irrigation with **100% ETc**.

However the number of fruits per cluster and medium fruit size is not affected by the irrigation scheduling.

We can achieve the same performance with two completely different irrigation frequencies thanks to the regulation effect of soil water that might attenuate the effect of irrigation frequencies.

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