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Impact of Drip Irrigation Scheduling On Fruit Quality Parameters and Water Use Efficiency On Tomato Plant (Lycopersicon esculentum Mill.) Under Unheated Greenhouse

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Abstract

To evaluate the effects of irrigation scheduling on fruit quality parameters and water use efficiency. Tomatoes (*Lycopersicon esculentum Mill.)* were grown on a fine sandy soil using drip irrigation and polyethylene mulch. Under typical Sous 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% maximal evapotranspiration (ETM) and frequencies (f=0.10, f=15% and f=20%). The result of this study shows that irrigation dose and frequency doesn't affect fruit quality in terms of fruit size. In fact, it was between 73 and 74 mm for all used treatments. But they can have a slight effect on total yield. So, we can save a lot of water, between 25 and 50%, with tolerable loss of tomato yield. The rate of unmarketable fruit is affected by irrigation dose and a perfect correlation with exponential equation was found between water use efficiency and irrigation dose.

Keywords: Tomato, greenhouse, irrigation, water use efficiency.

1. Introduction

Agriculture is often associated with the image of inefficiency, being less profitable than other sectors. This mostly derives from a frequent low irrigation water use efficiency, calculated from the ratio between the irrigation water used by the crop and the amount of water actually applied with irrigation. Indeed, irrigated agriculture is a major consumer of water and accounts for about two thirds of the total fresh water assigned to human uses [1]. Therefore, Water use efficiency can be optimized by the adoption of more efficient irrigation practices [2]. Tomato is a high water demanding crop, thus requiring irrigation throughout growing season in arid and semiarid areas, where rainfall from may to august are very rare. In these last, the application of deficit irrigation strategies to this crop may greatly contribute to save irrigation water [3]. Since tomato (*Solanumlycopersicum L.*) is one of the most important horticultural crops in the world and since consumers demand more varieties of higher quality, strategies focused on increasing fruit quality continue to be of great interest [4,5]. The appearance of the tomato fruit is generally considered to be an index of quality and often determines consumer choice. Great efforts have recently been focused in producing a good appearance and quality tomato through the utilization of inexpensive and environmentally friendly resources. Production of quality fruits is controlled by the interaction of genetic, environmental and cultural factors, including plant nutrients [4]. Fruit quality is defined as a combination of visual stimuli, like size, shape and color, and sensory properties, like sweetness, acidity and aroma [6]. More studies revealed that irrigation at a reduced rate (50% ETc) exerts beneficial effects upon fruit quality, mostly in terms of total solids and total soluble solids, with interesting implications for industrial purposes. In fact, a high total solids content of the fruit improves the efficiency throughout the industrial process (for paste or concentrated juice) since tomatoes higher in total solids content may require less energy to evaporate water from fruit [7,8]. So far, there are lots of reports about the effect of partial root-zone irrigation on physiology, growth, fruit yield and quality and water use efficiency of horticultural crops [9-12], where reported that water deficit can improve yield and tomato fruit quality [13].

The objective of this work was to study the relationship between irrigation frequency and fruit quality, then to find the appropriate irrigation frequency and timing which can optimize quality of tomato fruits with optimum water use efficiency.

2. Materials and methods

2.1. Experimental site and plant material

The trial was conducted from october to june on 2011-2012, in the transfer technology center of APEFEL located in Khmiss Ait Amira Souss Massa region. It was conducted under unheated greenhouse to improve irrigation scheduling by testing targets and frequencies of drip irrigation water. The materials selected for trial were commercial tomato (*Lycopersicon esculentum Mill*.) Calvi variety that were grafted on "Beaufort". The crop was planted on august with a spacing of 0.4 m between plants and 3 m between lines, that gives a density of 10600 plants per hectare that have been conducted on two buds.

2.2. 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 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 evapotranspiration (ETo) was calculated using the penmann monteith formula [14]. Three values of the factor of the equation f = f x DNM (HCC-HPFP) x Z x PSH were applied:

f1=10%, f2= 15%, and f3 = 20% (Where DNM is the maximal net dose)
DNM1 = 0.10 x 70 x 0.22 x 0.26 = 0.4 mm
DNM2 = 0.15 x 70 x 0.22 x 0.26 = 0.6 mm
DNM3 = 0.20 x 70 x 0.22 x 0.26 = 0.8 mm

*Where: DNM is de the net maximal dose
Z: root depth
PSH: percentage of the wetted zone
HCC: humidity at field capacity
HPFP: humidity at permanent wilting point

Restrictions water supply for tomato cultivation was exercised by using 50%, 75% and 100% of the calculated initial maximal evapotranspiration ETM (Kci= 0.7). The result of combination is three different cultural coefficients (Kc): 0.35, 0.53 and 0.7.
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 indicated by capacitive sensors.
Unfortunately, monitoring of these two treatments was not as expected because of the absence dendrometers to track the status of the plants. For this we will limit the comparison of 9 doses and frequencies combinations with the Control (T) irrigated with conventional method. A control treatment was conducted according to a conventional method based on the climate and observation on the field.

2.3. Experimental protocol

During this test a combination of three doses and three frequencies was used. So, 9 combinations (treatments) were obtained. Three other treatments have been added for comparison: soil strategy (SS), plant-soil strategy (SSP) and eventually the local treatment (T). The experimental device was mounted by dividing greenhouse into four completely randomized blocs, which means four repetitions. By the way, we got a number of 48 experimental units with 16 plants per experimental unit. The Table 1 shows the detail of irrigation treatments applied in the greenhouse and equivalent Kc.

Table 1: Detail of irrigation treatments applied in the greenhouse and equivalent Kc

Treatment	**Combination**	**Kc**
T1	Dose 50% frequency 10%	0.35
T2	Dose 75% frequency 10%	0.53
T3	Dose 100% frequency 10%	0.70
T4	Dose 50% frequency 15%	0.35
T5	Dose 75% frequency 15%	0.53
T6	Dose 100% frequency 15%	0.70
T7	Dose 50% frequency 20%	0.35
T8	Dose 75% frequency 20%	0.53
T9	Dose 100% frequency 20%	0.70
T10	Soil Strategy	SS
T11	Plant- Soil Strategy	SSP
T12	Local Treatment	T

2.4. Fertilization management

For fertilization, we decided to use many trays with simple fertilizer each one, with a concentrate solution. And for supply, we changed only the injection rate of each fertilizer. So for each treatment the salinity of the concentrate solution is always fixed but the amount of used fertilizers is changed according the plant requirement by stage. The table 2 shows fertilization supply according to the stage of plant during the training. Where the equilibrium was calculated by dividing unites of used fertilizer by unites of used nitrogen.

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

Stage of plant	**Electrical conductivity dS/m**	**Unite of Nitrogen per hectare per day**	**Balance N/N-P_2O_5/N-K_2O/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	3.0	3.1	1-0.70-2.80-0.40
146 DAP - 261 DAP	2.6	3.0	1-0.70-2.80-0.40

- DAP: Day After Planting
- N: nitrogen, P_2O_5: Phosphorus, K_2O: Potassium, MgO: Magnesium.

2.5. Measuring tools used for study

The measuring tools used in the experiment were a complete weather station with GPRS communication; soil moisture probes (C-prob, Easy AG, Hydra-prob, AquaCheck); drip sensors to control supply. All measurements are automatically recorded every 15 minutes and then transferred to a base station connected to a computer for data processing.

The climatic parameters search in the greenhouse outside and inside were temperature, relative humidity, radiation wind speed and direction, rainfall and soil moisture.

A set of agronomic parameters has been followed from the beginning of january to monitor the growth of fruit of each treatment. This was followed the following parameters: number of fruits per treatment; yield by plant with respect to frequency irrigation and dose irrigation; size of fruits and percentage of unmarketable fruits.

3. Results and discussion

3.1. Climatic conditions

All climate parameters were used to calculate reference evapotranspiration that used for irrigation management for each treatment. Figure 1 shows daily changing of the reference evapotranspiration calculated (ET0 *) and real evapotranspiration (ET0 **) in mm/day.

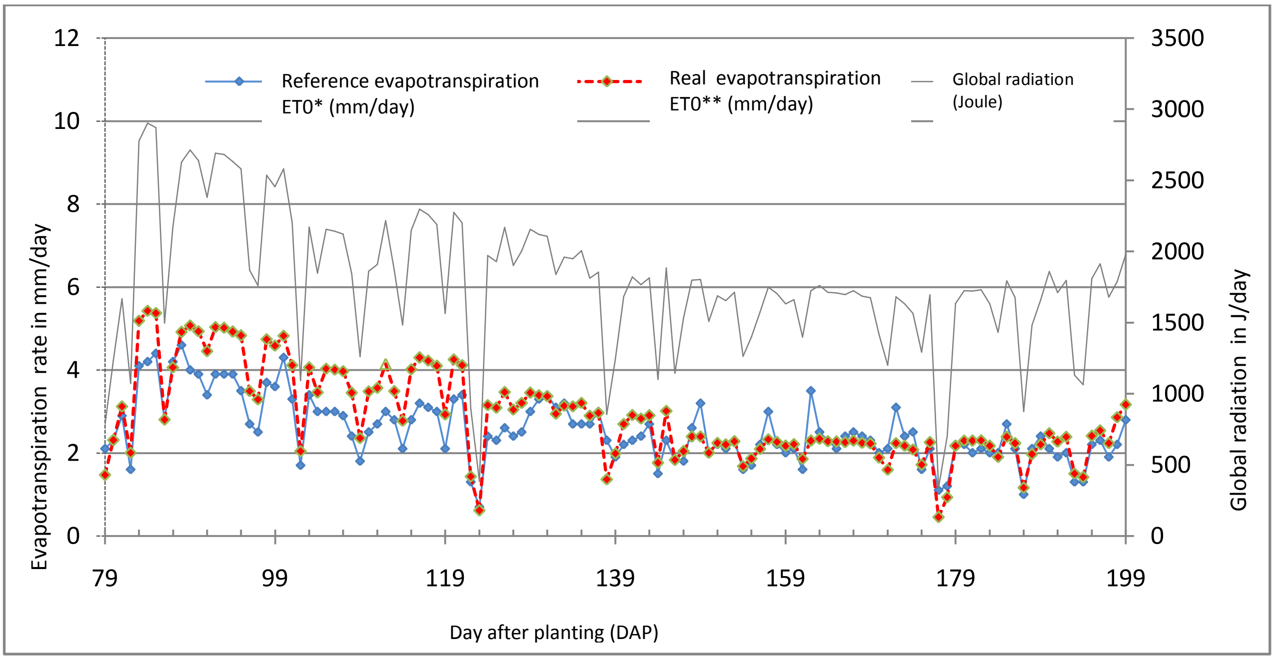

Figure 1: Daily changing of calculated reference evapotranspiration (ETo*) and real evapo-transpiration (ETo**) in mm / day.

The **Figure 1** shows that daily mean ETo values fluctuated, decreasing from the beginning of the measurement period. A difference was observed between ETo* and (ETo**) all over the period of trial. The maximum value of ETo* and ET0** has been observed at the **84th and 88th day** after planting with respectively **5.4mm/day** and **4.9mm/day**. The (ETo**) values ranged between 0.5 mm d^{-1} on 177th DAP and 5.4 mm d^{-1} on 84th DAP (sunny day). High ETo** values were measured as a considerable amount of water is stored in the soil for ETo** at the end of the rainy season, plant have root systems deeper than 0.6m. Additionally, water stress conditions are interpreted to occur seldom as a result of the shallow groundwater table. The ETo values measured in this study could therefore approximate of this vegetation. For comparative purposes, ETo calculated with the Penman-Monteith equation was also displayed in Figure 3. The ETo ranged between 4.9 mm/day (84th DAP) and 1.2 mm d^{-1} (187th DAP). The average ratio of ETo*/ETo** for the measurement period was 0.85 with a standard deviation of 0.21. These results are similar to those reported by [15, 16].

3.2. Effect of dose and frequency on fruit yield

To evaluate the separate effect of irrigation dose and frequency a statistical analysis was made (Figure 2).

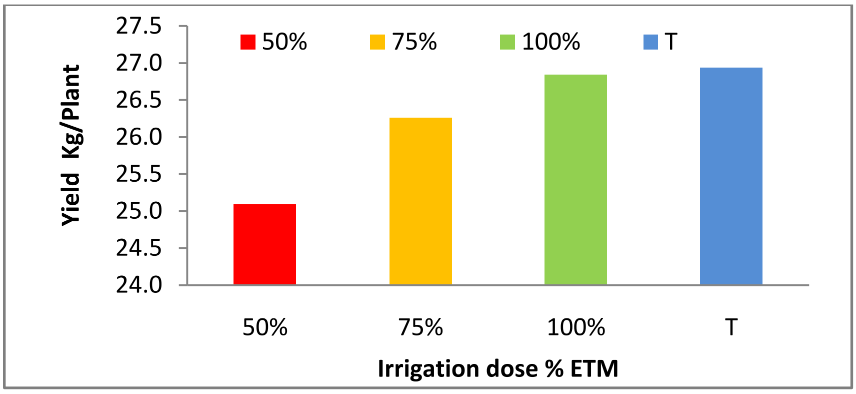

Figure 2: Effect of drip irrigation doses on the yield of tomato plant.

According to the analysis of Figure 2, it is clear that the yield of tomato is slightly affected by the irrigation doses showed that soil water potential had no significant effects on tomato yields. In fact, commercial yield was higher for the treatment, where in the quantity of water applied was the greatest (**100% ETM**) maximal evapotranspiration **[**17, 18**]**, while the lowest yield was obtained by the irrigation dose of **50%ETM**. The same behavior was reported by [19] for surface drip irrigation. The consequent reduction in the yield is **7%** in the case of dose **50%ETM** and **-3%** in the case of irrigation dose of **100% ETM**. So, we can save a lot of water, between 25 and 50%, with tolerable lose of tomato yield.

To put in evidence the effect of irrigation frequency on yield, we have study the separate effect of frequency on the obtained yield (Figure **3**).

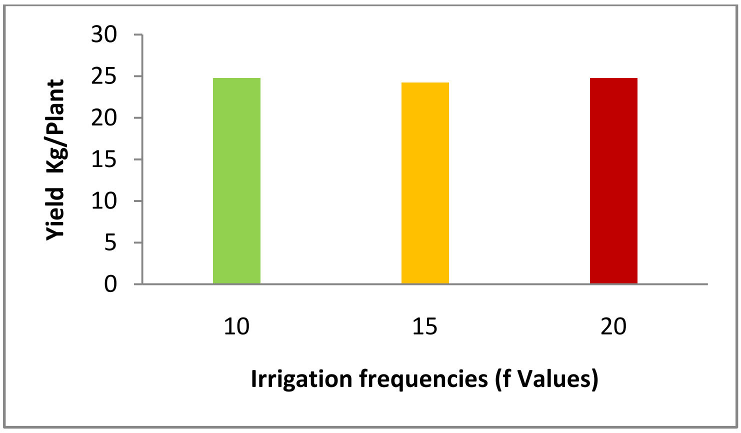

Figure 3: Effect of drip irrigation frequency on the yield of tomato plant.

Statistical analysis of the effect of irrigation frequency on yield watches that are a significant difference between treatments. However, the frequency of 15% seems give less yield compared to other used irrigation frequencies. Use of high frequency irrigation (10%) resulted in reduced deep percolation and increased use of water from shallow ground water when crops were grown in high water table areas [20].

3.3. Effect of irrigation scheduling on quality

3.3.1. Effect of irrigation scheduling Fruit size

The first agronomic parameter that is used to judge fruits quality is size. The Figure 4 shows the effect of treatments on fruit size of tomato plant found result.

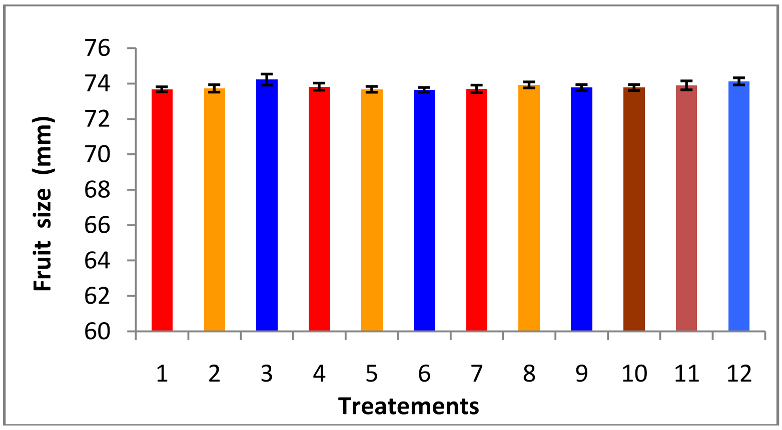

Figure 4: Effect of treatments on fruit size of tomato plant.

The statistical analysis of the average size showed that there was no significant difference between treatments. Indeed, the average fruit size is between 73 and 74 mm for all treatments. A slight effect of the blocks has been noticed. The same result is reported by Mitchell & al [21].

3.3.2. Percentage of unmarketable fruits

The second parameter relating to the quality that has been studied is the percentage of unmarketable fruits. For each treatment invalid fruits for market were counted and reported in Figure **5**.

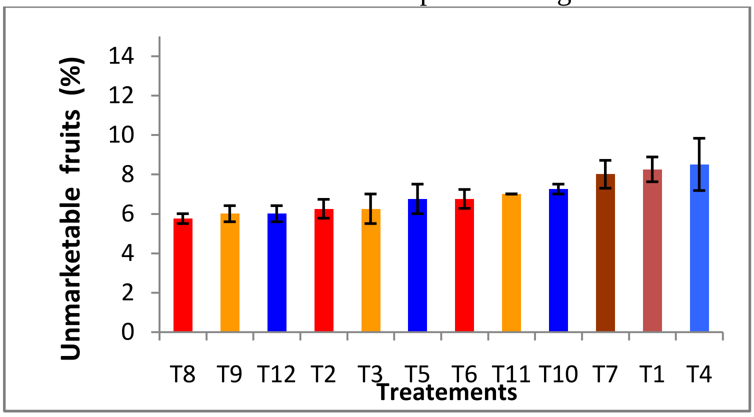

Figure 5: Effect of treatments on percentage of unmarketable fruits of tomato plant.

Statistical analysis of variance (ANOVA) with single criteria (treatment) showed that treatments had a significant effect on the percentage of unmarketable fruits. The deeper analysis with two factors together (dose and frequency) shows that the effect of doses is rather than frequencies. More we decrease the dose further increases the percentage of unmarketable fruits. The supply of 34% of the dose increases the percentage of unmarketable fruits with 2%. However, this increase was only 0.5% for increasing supply between 50% and 69%. That's mean that a moderate irrigation stresses can significantly improve fruit quality of field-grown processing tomatoes without depressing marketable yields [21]. But several conditions of osmotic or water stress can cause blossom-end rot [22].

3.3.3. Effect of irrigation target on quality

To analyze the effect of irrigation dose on fruit quality one separate analysis was made and represented in the **Figure 6**.

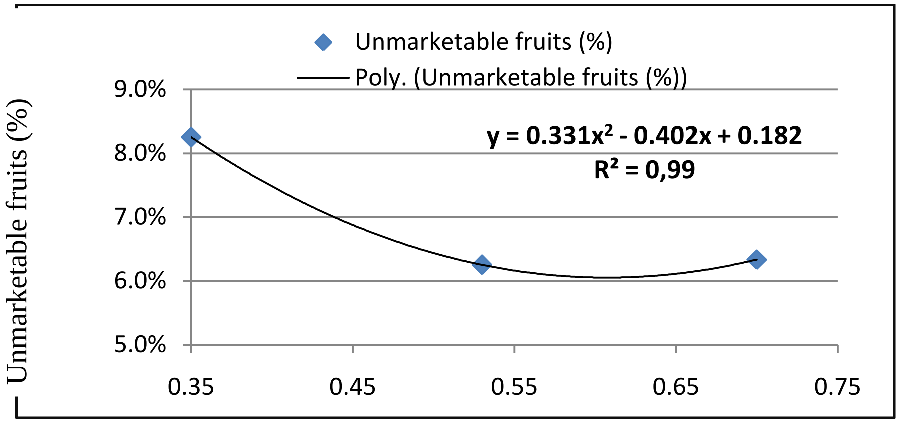

Figure 6: Effect of doses on percentage of unmarketable fruits of tomato plant

When we analyze separately the effect of irrigation dose on the unmarketable fruits, a perfect polynomial correlation between the dose and percentage of unmarketable fruits was found with (R^2=100%). So, we can save 50% of irrigation water with a tolerable loss of 2% in fruits. However, keeping the proper nutrient levels and ratios between all the nutrients in the root environment for each growth stage of a crop should be targeted in order to achieve high yields and high quality products throughout the cropping season [23].

3.4. Water use efficiency

One of the main parameters studied in this trial is the water use efficiency; this parameter has great utility because it informs us water consumption per kilogram of product tomato, as well as the interaction between consumption and water production. Figure 7 illustrates the result of this study.

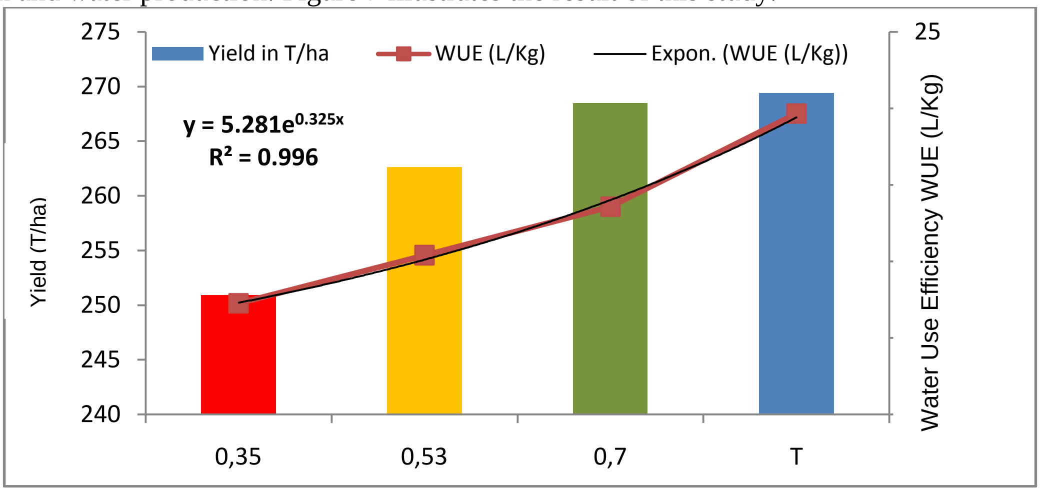

Figure 7: Effect of doses on yield and water use efficiency (WUE) on tomato plant.

The analysis of Figure 7 shows that it is possible to make a significant water-saving with a non-significant loss in yield performance. Indeed, water can be saved and get the same result than that obtained by the conventional method, water saving can be 25% with a slight loss in yield performance that does not exceed 2.2%, or even a gain of 50% in water with losing only 5.6% yield performance. This result is close to the one found by Shrivastava & *al.* [24] revealed that 44% irrigation water can be saved with a good yield performance in a monitored system of drip irrigation. A perfect correlation has been put in evidence between doses and water use efficiency (WUE) with a correlation coefficient equal to (**R^2=0.99)** the equation is as follows:

$$WUE = 5.281e^{(0.325dose)}$$

Where WUE is Water use efficiency in L/Kg of tomato fruit and irrigation dose in mm.

Conclusion

As a conclusion of this work we can say that saving water can be made without a significant loss in yield and fruit quality. While yield of tomato is slightly affected by the irrigation doses commercial yield was higher for the treatment where quantity of water applied was the greatest. However, irrigation frequency and doses didn't have significant effect on fruit quality of tomato plant with respect to fruit size, the average fruit size remained including between 73 and 74 mm for all used treatments. On the other hand, water stress had a significant effect on the percentage of unmarketable fruits due to apparition of blossom–end rot on the fruit of stressed plants. This effect is due the dose of irrigation and not to the frequency, when decreasing water supply rate of unmarketable fruit increase. To save water is possible, with a tolerable loss of yield and quality; water use efficiency can be improved without spending water with dose of 0.53ETM we can obtain a good yield (262T/ha) and good water use efficiency (10.40 L/Kg).

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