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

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ABSTRACT

Grafted Tomatoes were grown on a fine sandy soil using drip irrigation and plastic mulch to evaluate the effects of irrigation scheduling on water requirements and vegetative parameters under typical Massa greenhouses growing conditions. Capacitive sensors were used to automatically schedule irrigations. The result of this study shows that irrigation dose and frequency does not affect stem diameter in grafted tomato plant, no significant effect on leaves number has been observed. But irrigation scheduling have a large effect on root's development, The root containers results indicated that a water stress equivalent to 50%ETc and 20% frequency can lead to deep root system; that makes possible to sustain a suitable vegetative canopy if doses and frequencies are well managed in a daily scale; It was possible save 50% of irrigation water.

***Keywords*:** Tomato, greenhouse, irrigation scheduling, dose, frequency, roots.

I. INTRODUCTION

It is expected that in the next decade several countries in the arid and semiarid areas of the globe will be under water scarcity or stress [1]. However, world population is predicted to double in the next 50 years, so greater yields should be extracted from the current agricultural areas [1]. Tomato (*Lycopersicon esculentum Mill*) is one of the most popular and versatile vegetable all over the world both for the fresh fruit market and the processed food industries, it plays a vital role in providing a substantial quantity vitamin C and A in human diet [2,8]. 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 [3]. Water plays an important role in plant life and determining the tomato yield [9]. Water scarcity reduces yield because of nutrients and water 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. Draying soil later in the growing season adversely affects the fruit quality even though total yields may not be affected [4]. However, Water stress conditions encourage tomato to develop deeper roots a natural moisture searching especially on sandy soils [5]. Moreover, 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. Any Decrease of root system volume leads to a drop in shoot dry weight [6]. The challenge of water use at the crop level is to match the best time and quantity for applying irrigation by moderating plant requirements and increasing water holding into the soil [7]. However, plant water status controls the physiological process and conditions, which determine the quality and quantity of its growth [10].

The objectives of this study was to confirm relationship between irrigation frequency and root development, then find the appropriate irrigation frequency and timing which can sustain crop yield but increase water use efficiency.

II. EXPERIMENTAL METHODS

1.1 Experimental site and plant material

The trial was hold under unheated greenhouse in the Technology Transfer Center of Massa Region.

1.2 Plant Material

The materials selected for trial were commercial Tomato cultivar Calvi (*Lycopersicon esculentum*

Mill.) that were grafted on "Beaufort". The crop was planted on August at a spacing of 0.4x3m to match a density of 10600 plants with two branches per hectare.

1.3 Irrigation system

The irrigation was applied using simple 2l/h dripper line with a 40 cm emitters spacing (Table 1). Concerning Deficit Irrigation (DI) treatments, switching was allowed throw small valves controller. Irrigation and fertilization management were made within a fertigation electro-valves. Daily reference evapo-transpiration ETo was calculated using the Penmann monteith formula [11].

Three values of the equation's factor f = f * DNM (HCC-HPFP) * Z * PSH were applied: 10% = f1, 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

water supply was restricted using 50%, 75% and 100% of the calculated initial ETc (Kci= 0.7), leading to different Kc (values : 0.35-0.53-0.7).

Treatments were based on random combination of doses and frequencies compared to the Control (T12).

Two treatments where irrigated according to remote soil capacitance sensors by setting thresholds values of the measured volumetric soil moisture.

A control (T12) treatment is the conventional method based on the naked eye observations of the plant/climate.

1.4 Experimental Protocol

The aim was to test the combination of two factors (dose and frequency) so we have 9 treatments in addition to those based on soil data and the control. The greenhouse was divided into four blocs with 4 repetitions, or 48 experimental units (Figure 1).

Table 1: Details of irrigation treatments applied in the greenhouse and the used Kc

T	*Code*	*Combination*	*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

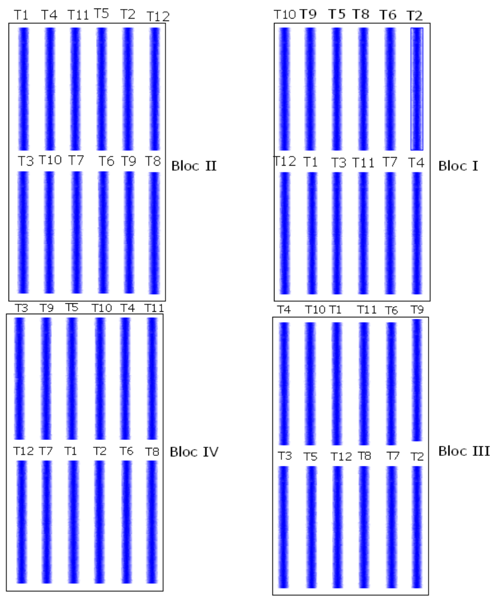

Figure 1. The figure show the experimental design used in this experiment

1.5 Measuring tools

The measuring tools used in the experimental were:

- ✓ A complete weather station with GPRS transmission;
- ✓ Soil moisture probes (AquaCheck, C-prob, Easy AG, Hydra-prob);
- ✓ Drip flow sensors.

All measurements are recorded four times per houre and then transferred to the basestation for data processing.

1.6 Measured Parameters

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

Many parameters have been measured from the beginning of January to monitor the plants growth at each treatment: length of internodes, basal and apical stem diameter, Number of leaves, root's section.

The root profile enables visualize spatial root distribution in the soil, depending on the distance from trunk and the emitters. It also allows us to compare the final scheme of roots distribution with the initial condition. To make counting operation easy, we used Mesh square (1m per side), composed of cells unit of 10cmx10cm, after classification of root's diameter.

1.7. Fertilization management

We decided to adopt a fertilization strategy with a changing salinity and amount of the fixed concentrate according to the plant stage and requirements. So treatments received different fertilises amount conresponding to water requirements. The Table 2 shows fertilization scheduling according to the plant stage during the training where the equilibrium is calculated by dividing unites of fertilizer into unites of nitrogen.

Table 2: Detail of fertilization scheduling based on plant stage.

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.

III. RESULTS AND DISCUSSION

2 Climatic conditions

Climate conditions were used to calculate the reference evapo-transpiration (ETo) for irrigation management. Figure 2 shows the difference between the calculated ETo* and the used ETo** (mm/day).

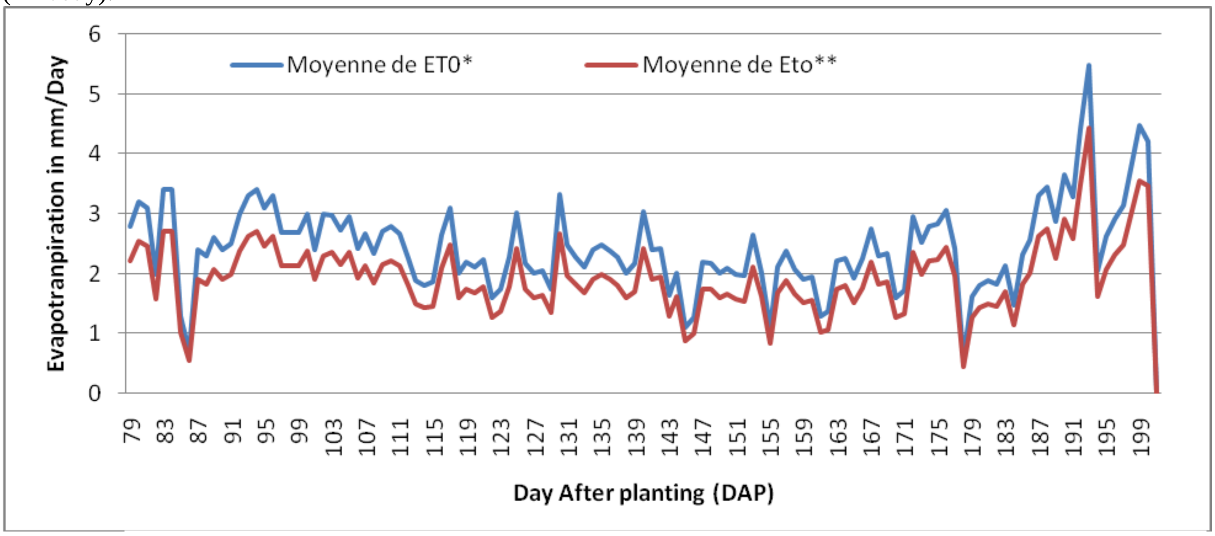

Figure 2: development of reference evapo-transpiration calculated (ET0 *) and real evapo-transpiration reference (ET0 **) in mm / day.

The **Figure 2** shows that daily mean values of ETo fluctuated, increasing from the beginning of the measurement period. A difference was observed between calculated ETo* and real 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.

3 Irrigation water

Irrigation requirements were calculated from real needs of each treatment based on the last 24 hours ETo, Kc and DNM. The result is a fixed-dose and a variable number of irrigation by day and for each treatment. Automatic calculations were designed to facilitate the work. The following figure 3 gives the total quantity of water from 83 DAP until 326DAP.

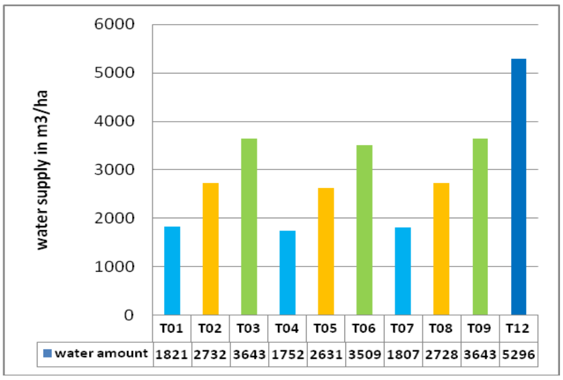

Figure 3: Detail of total irrigation supply per treatment.

Treatments irrigated with a 0.35 Kc received 34% of the supply water compared to the control treatment (T12), the treatments irrigated with a 0.53 Kc received 52% of the amount given to the control. For treatments with 0.7 as the value of Kc were irrigated with 70% of total amount received by the control. The Kc used in this study corresponds to Kc reported by **André & *al*. [12],** The kc values obtained for the different stages of a tomato crop development were: (a) 0.64 for the vegetative growth, (b) 1.03 for the flowering, (c) 1.48 for fruit setting and (d) 0.73 for the final stages. For the local treatment T12, irrigation requirement was similar to the recommendations of **Adeniran & al. [13]** water requirement for tomato plant in normal conditions is 5896m3/ha/year.

4 *Growth parameters*

1 - Length of internodes

Statistical analysis of the treatment effect on this parameter showed a very highly significant effect of blocks, putting into evidence the gradient of heterogeneity in the greenhouse in the north-south direction. Internodes tend to be longer in the northern block (B3 and B4). The figure 4 presents the average length of internodes for each treatment and shows significant differences between treatments.

Treatment 12 (Control), showed the lowest length of the internodes, while, plants of treatment T6 with 75%dose and f=20% had the longer ones.

It seems that treatment corresponding to the soil strategy and Local Treatment give the lowest length of internodes between 7cm and 6.5cm.

Results of (T4, T5, T7 and T8) are similar to those of **Sibomana and Aguyoh** [14]; when they stressed tomato plants 90 DAP until only 22% of water requirements compared to the control treatment. Plants that received 60% ETc had longer internodes compared to those that received 40%ETc.

The internodes can be also affected by water and climate temperature as reported by **Berghage and Heins** [16], whom say that the stem elongation pattern can be characterized by internodes number and length depending on temperature.

4.1 Basal stem diameter

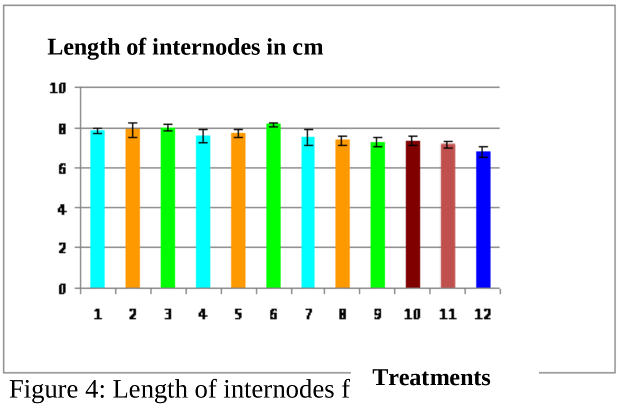

Figure 4: Length of internodes f

The Figure 5 illustrates the changes in the plant height basal stem diameter due to water deficit.

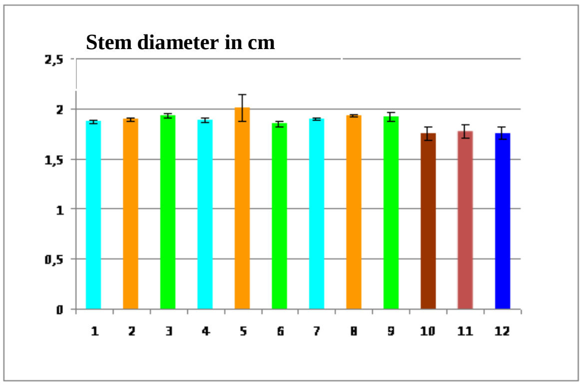

Figure. 5: Effect of treatments on the basal and apical stem diameter of plants.

The statistical study on the treatments effect on the basal and apical stem diameter of plants showed no significant differences between treatments. Indeed, the evolution of the trunk diameter was the same for all watched plants. This result is confirmed by **Sibomana and Aguyoh** [14], who found that stem diameter of tomato plants decreases due to water stress. Stress on Control can be explained by a bad irrigation management [15].

4.2 Leaves number

Figure 6 shows the result of leaves number counting and analyze.

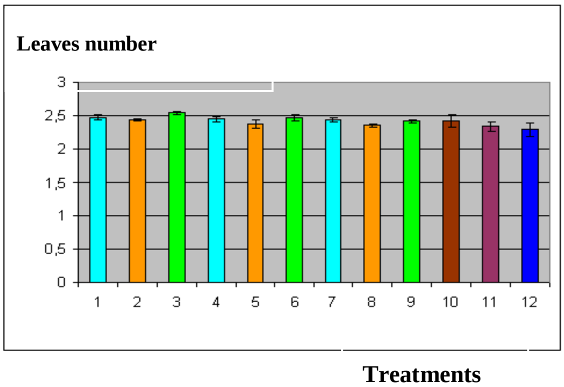

Fig. 6: Average of leaves number between two trusses for each treatment**.**

Monitoring the leaves number between two trusses (11th and 12th truss) with respect to treatment showed no significant differences between the twelve treatments. Water stress has almost no effect on leaves number, but can have impact on biomass, **Pervez** [17]. **Ibrahim and Hsiao** [18, 19] reported similar findings for chickpea where total shoot biomass was reduced mainly because of less branch production.

4.3 Root sections

As it is a destructive operation, roots counting was performed only once at the beginning and the end of our study in June. The table 3 below shows the number of roots by mesh after classification according to their diameter.

Table3: Roots counting per class of diameter.

Ø (mm)	Depth In cm	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
R2-	10	669	720	871	779	812	858	807	834	670	400	754	595
R2+		16	21	39	13	24	19	14	13	10	14	17	16
R2-	20	608	444	326	190	557	715	656	339	239	271	418	462
R2+		14	25	10	3	7	6	7	2	4	4	5	13
R2-	30	125	185	410	50	268	198	212	84	197	183	253	301
R2+		0	14	12	0	1	4	5	2	7	10	0	6
R2-	40	0	85	71	12	250	95	69	25	46	34	37	85
R2+		0	2	0	0	2	4	1	1	0	1	0	1
R2-	50	0	0	0	0	0	0	0	0	7	12	4	41
R2+		0	0	0	0	0	0	0	0	1	1	0	3
R2-	60	0	0	0	0	0	0	0	0	0	0	0	0
R2+		0	0	0	0	0	0	0	0	0	0	0	0
Total		1432	1496	1739	1047	1921	1899	1771	1300	1181	930	1488	1523

It's shows that root density can be very different when comparing between treatments. It seems that plant develop more roots in top layer of the soil (10cm-40cm), especially with less diameter as small as hairy roots. The most developed root system was observed for treatment T5, T6, T7 and T3 corresponding respectively to (75%ETC, f=15%), (100%ETC, f=15%), (50%ETC, f=20%) and (100%ETC, f=10%). This result is similar to the one found by **Saleh and Ismail** [6] The dry weight of shoots/roots for 1-day irrigation frequency was higher than 3 and 5 days frequencies. The root-shoot ratio for 1 and 5 days irrigation frequencies were similar but were look lower than that of 3-days frequency.

The dose of 100%ETc and 20% of frequency seems to develop deeper roots; however, the soil measurements based strategy and Control lead to high density of roots at the bottom and only small and medium roots density at the top layer (930 to 1523). May be increasing irrigation intervals reduced the amount of water supply. In fact, **Ozaw** [5]**, Tayeb Zaki Nejad** [20] and **Badstue** [21]**, Scholand & al.** [22] reported that under water stressed conditions tomato plants develop deeper roots where high soil moisture content was available. However, the roots showed a significant decrease in sever water stress in the soil top layers **Tayeb Zaki Nejad** [20].

IV CONCLUSIONS

Irrigation Dose and frequency does not affect the trunk diameter in grafted tomato plant, it remained the same for all monitored plants.

- We still have a good root system with 50%ETc / 20%frequency; in this case, we can save 50% of water. It seems that when we decrease water dose, the irrigation interval must increase.

Magnification of fruits, then ending with T7 (ETc 75%, f = 20%).

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