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Growth-Stage-Specific K_c of Greenhouse Tomato Plants Grown in Semi-Arid Mediterranean Region

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Abstract

Growth stage specific crop coefficient for greenhouse tomatoes grown in the semi arid Mediterranean was evaluated. The evaluation consisted of two simultaneous field trails: 1) Data accumulation of the water consumption of round and cherry tomato plants with the use of drainage lysimeters. 2) Irrigation of tomatoes planted in local sandy soil with either reduced or excess irrigation water doses using the lysimeter water consumption data as the reference criteria. Crop coefficients of between 0.3-1 for the time period from seedling establishment until first fruit harvest and 0.8 for the fruit harvest period were recorded for the winter season round tomato crop. During the summer season, coefficients of between 0.2-0.9 for the time period from seedling establishment until first fruit harvest and 0.8 for the fruit harvest period were measured for the round tomato crop. The cherry cluster cultivar showed a slightly different pattern of water consumption with a peak in crop coefficient at the middle of the fruit harvest stage and a continuous reduction in water consumption until the end of the growth period. Excess irrigation rates damaged the post harvest quality of the fruit of one of the tested cultivars. Reduced irrigation rates caused a reduction in the mean weight of the fruit.

Keywords: irrigation, tomato, crop coefficient, growth stage, greenhouse, semi-arid Mediterranean, drainage lysimeters

1. Introduction

Highly efficient irrigation of tomato (*Solanum lycopersicum* L.) grown in greenhouses and nethouses is an important goal, especially when considering the fact that water is an essential but increasingly limited and expensive resource. In addition to lowering production costs and reducing negative environmental effects, accurate estimation of the crop water requirement in protected cultivation can decrease heat load during the hot season by maximizing the transpiration fluxes from the plant canopy (Baille, 1999). Although several methods were considered in order to evaluate the irrigation needs of crops, the concept of crop coefficient (Jensen, 1968), is widely used by irrigation practitioners. The crop coefficient (K_c) is the ratio of the actual crop evapotranspiration (ET_c) to reference crop evapotranspiration (ET_0) (Lazzara & Rana, 2010). Using the crop coefficient provides a simple and inexpensive tool that enables us to implement practical knowledge regarding the water requirements of a variety of crops. The crop coefficient is affected by several factors such as, irrigation methods, climatic conditions, soil characteristics and agronomic techniques (Lazzara & Rana, 2010). Crop coefficient values can be derived from soil water balance trials, using lysimeters and well watered crops. These trials should be conducted locally in order to integrate the climatic, soil and agronomic techniques of a specific growth region where the K_c values are to be implemented. The second component that is needed when using the crop coefficient is the reference evapotranspiration (ET_0) that in many cases is calculated using the Penman-Monteith equation which is based on meteorological data and a hypothetical reference crop (Allen et al. 1998).

In the semi arid northern part of the Negev desert, close to the coastal plane of Israel, approximately 15,000 square meters (1500 Ha) of net houses and greenhouses are cultivated for tomato crops all year around. As in other production regions around the Mediterranean basin, the structures used for tomato cultivation in this region can be described as Mediterranean greenhouses (Wittwer & Castilla, 1995). These are low cost structures covered with 50 mesh insect proof netting during the summer and plastic sheets during the winter. They have no active climate control measures.

The tomato plants in these net houses and green houses are planted in the local sandy soils, irrigated with drip irrigation and compound mineral fertilizers. The tomato varieties grown are indeterminate varieties vertically supported by the high wire support system.

The first aim of this work was to evaluate K_c values of greenhouse tomato plants grown in the semi arid Mediterranean region. The K_c values derived from the experiment were assigned to each plant phenological stage, as described by Ko et al. (2009) and Piccinni et al. (2009), Thus the use of K_c data is more accessible to farmers and extension workers. The second aim was to evaluate the influence of deficit or excess irrigation rates on the yield, both amount and quality of tomatoes, grown in the semi arid Mediterranean region under covered cultivation conditions. For this second aim, the lysimeter water consumption data were used as reference criteria i.e. the water requirements of the plants in the lysimeter were considered to be 100% of the potential water requirements in the given growth conditions.

2. Method

3.1 Growth environment and Plant Cultivation

The experiment was conducted at the Negev R&D Center located in the northern part of the Negev desert and the southern part of the Israeli coastal plain (34°23′N, 31°16′E, 104 m above sea level). The climate in the region is semi-arid Mediterranean with rainy winters (October-April, 216 mm mean annual precipitation) and prolonged dry hot summers. The irrigation water used was drinking water from a supply system sourced from a mixture of desalinated and well water. Water quality is shown in Table 1.

Table 1. Analysis results of the water used for irrigation

Mg	$CaCO_3$	Ca	Cl	EC	PH
		(mg/l)		(ds/m)	
7.31	110	32	68	0.5	7.2

The trial took place in a naturally ventilated, north to south oriented green-house with a gutter height of 4m, a ridge height of 4.5 m and a double slope roof. The structure was covered (roof and walls) with 50 mesh insect proof net during the dry summer season. During the winter the roof was covered with transparent polyethylene sheeting and the side walls with polyethylene sheeting from the ground up to one third of the height of the gutter, and with 50 mesh insect proof netting for the remaining two thirds of the height, to the gutter. The trial consisted of two parts:

1) The investigation of tomato plant water consumption levels through the use of drainage lysimeters that were placed in the greenhouse. This part of the study was carried out with the use of two types of tomato varieties: Round tomato (cv. 1402 during the winter and cv. 1125 during the summer) and a cherry cluster strain (cv. Shiran-1335 during the summer).

2) A quantitative irrigation experiment using round tomatoes (cv. 1125 for the summer trial and cv. 1402 for the winter trial), planted in the local soil (local sand (87%), silt (7%) and clay (6%)). In this part, the experimental design consisted of three irrigation treatments, in a completely randomized design with three replications.

1) 100% of the daily water requirement (as assessed by the lysimeters);

2) 120% of the daily water allowance;

3) 70% (80% during 2011-12 winter seasons) of the daily water allowance.

The irrigation was carried out as is customary in this area with a trickle irrigation system (1.6 l/h emmiters), two irrigation lines per planted row and fertigated with a compound fertilizer. Plant density was 2.2 plants/m^2).

3.2 Lysimeter Construction and Operation

The lysimeter plot was constructed from two sets of five polypropylene planting troughs filled with a high drainage capacity growth bedding medium composed of fine texture M 0-8 tuff (Marom Golan, Israel) and 15% (v/v) compost (50% organic material, 2% nitrogen, 1.5% phosphorus and 3% potassium) for each set of tomato cultivars (1125 and 1402 round tomato or 1335 (Shiran) cherry bunch). The troughs were 0.5 m wide, 0.3 m high and 10.4 m long. The surface area of each set of troughs was 26 m^2 and the volume was 7.8 m^3. Plant density in the lysimeter was identical to that recommended for tomato planting in soil; (2.2 plants per m^2 round tomato and 2 plants per m^2 for cherry tomatoes hung with two stems trained seperately). Irrigation was consistent and done in such a way as to ensure constant water saturation in the bedding mixture. (Detailed in Appendix 1).

The drainage water from each variety was collected by gravitational flow into a collection vessel which had at its base a sensor which constantly measured its content by volume. Quantitative calculation of irrigation and drainage water enabled the calculation of the evapotanspiration (ET_c) values for these particular tomato varieties.

3.3 Water Consumption Data Collection and Analysis

The plants' water consumption (ET_c) data from the lysimeters was collected according to the description in section 3.2 and Appendix 1. Reference evapotranspiration (ET_0) was calculated using the Penman-Monteith equation as adopted by FAO-56 (Allen et al., 1998). The crop coefficient was calculated according to the equation by Allen et al. (1998):

$$K_c = ET_c/ET_0 \tag{1}$$

3*.4. Fruit Quality and Post Harvest Tests*

Throughout the experiment, data was collected with regard to the fruit yield quality including blossom end root, cracks and fruit size. Those parameters were used to define market quality yield. Post harvest tests were made immediately after fruit picking using market quality tomatos. Fruit was refrigerated in accordance with simulated commercial storage protocol, 5 days at 12 °C, 96% RH and then for 3 days at 20 °C. At the end of the storage period the fruit was examined for the following parameters: Cracked, firm, flexible, soft, rotten and irregular color. Total Soluble solids (TSS) were determined in fruit extract using digital refrectometer (REF-85 MRC, Israel).

3.4 statistical Analysis

The data was analyzed using the one way ANOVA. The differences in variance between the treatments were tested by the Tukey test with a significance of $p < 0.05$. The analyses were conducted using the statistical package JMP 8 (SAS Institute Inc., Cary, USA).

3. Results

4.1 Climate Data

Ambient temperature and radiation levels data throughout the period of the experiment from outside the growth structures are shown in figure 1. The months of April and May were characterized by extremely high temperatures, reaching over 40 °C. At the beginning of the season the relatively low nighttime temperature of 12 °C was recorded (1a). Apart from a peak day time temperature of 22 °C in the third week of December, average daily temperatures hovered between 12 °C and 18 °C (1b). The minimum night time temperatures ranged from 5 °C to 13 °C and the radiation values were typical of the spring and summer seasons in the region.

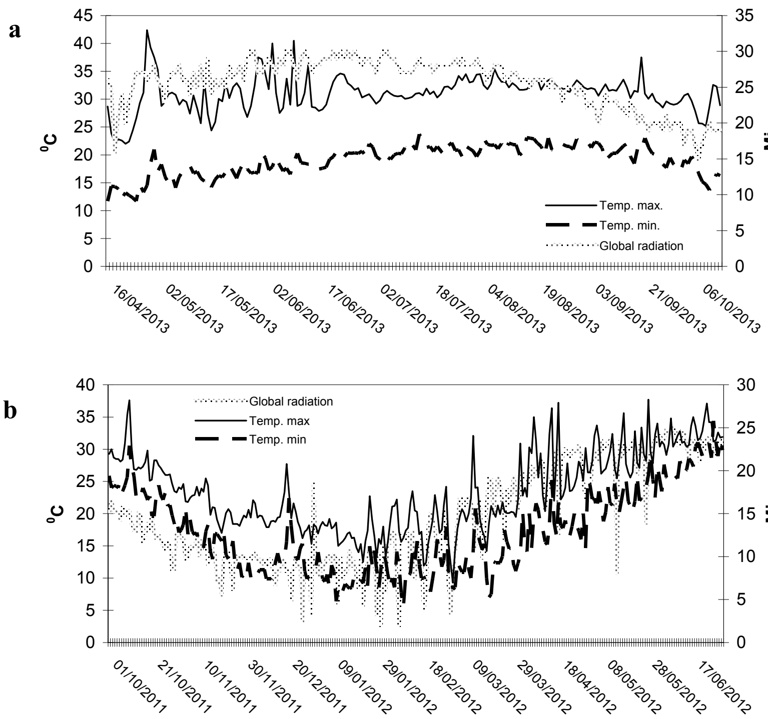

Figure 1. Climate data collected throughout the study from outside the green houses. a) Daily winter temperatures (°C) and radiation levels (Megajoules). b) Daily summer temperatures (°C) and radiation levels (Megajoules)

4.2 Water Consumption and the Growth Coefficient - Winter Season

The winter growth coefficient (K_c) of round tomatoes, ET_c and ET_0 are presented in Figure 2. A sharp rise in the growth coefficient K_c during first blooming (indicated by the letter A) and fruit maturation of the first and second clusters can be detected in figure 2a. This period is characterized by the seedling, establishment, leaf and root development, flowering and then fruit set. At around 70 days after planting, fruit picking commences (indicated by the letter B). The growth coefficient slowly and steadily decreases here until 140 days after planting when the leaf removal process begins, preparing the plant for lowering in order to expedite fruit harvest (marked by the letter C). A ten day stage of reduction in water consumption after leaf pruning is observed. Fourth order polynomial equations that describe the relationship between plant age and K_c and R^2 value are represented in the figure (Figure 2a).

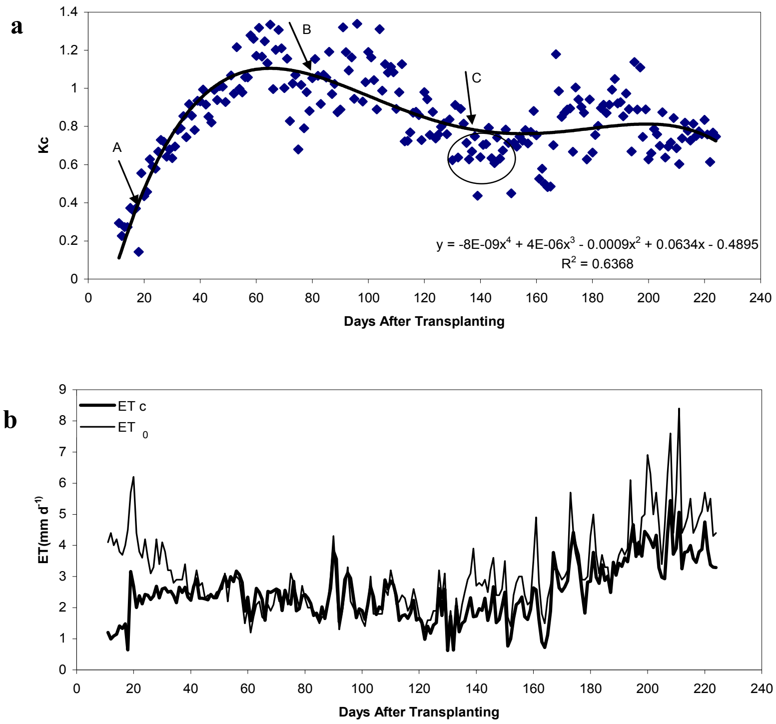

Figure 2. (a) Correlation between plant age and growth coefficient values of round tomato during winter. Developmental stages marked along time line: A- blooming, B-first fruit pick, C-leaf pruning. (b) Calculated reference ET (ET_0) and water requirements of plants grown in lysimeters (ETc) during winter season

Figure 2b represents ET_0 and ET_c values expressed as mm per day at different growth development stages. The ET_0 or evapotranspirational rate at soil saturation point is marked by the narrow line. ET_c or the evapotranspirational rate of the crop is marked by a thick line. The first few days show a noticeable difference in water requirements, a difference of 6mm per day or a 50% higher value for ET_0. From then on the relationship between the equations alters and the water requirements remain parallel with each other until day 120 when they diverge again with ET_0 rising above ET_c steadily until the gap is at its greatest at 220 days. This shadowing of the two values during most of the growth period shows that the lysimeter used in this study could give a reliable indication of tomato plant irrigation requirements for those that are grown in the same climatic conditions but planted in the soil.

4.3 Water Consumption and the Growth Coefficient - Summer Season

Figure 3a presents the growth coefficient (K_c) of the summer growing season of 2011, as a function of days after planting for the 1125 variety (round tomato).The graph initially runs parallel to that of the winter season. The fruit harvest however (as shown by the arrow marked B) starts earlier than in the winter and the plant "exhausts" itself earlier with diminishing yield leading to the culmination of the crop and the removal of the plants at day 200 as opposed to day 250 in the winter. The stage after leaf pruning when a water consumption decline is highlighted by the letter C and an accompanying circle. A third order polynomial equation that describes the relationship between plant age and K_c and the R^2 value is represented in the figure.

Figure 3b portrays values of ET_c for round tomato plants from the lysimeter and ET_0 calculated using the Penman-Monteith equation the summer 2011 season. The heat of summer raises the ET_0 values which remain higher than ET_c for the entire season. Thus we see that even though the water requirements of the plant rise, the monitoring and control mechanism of the influx and drainage water maintain a level at which the plant can reach its optimal growth potential.

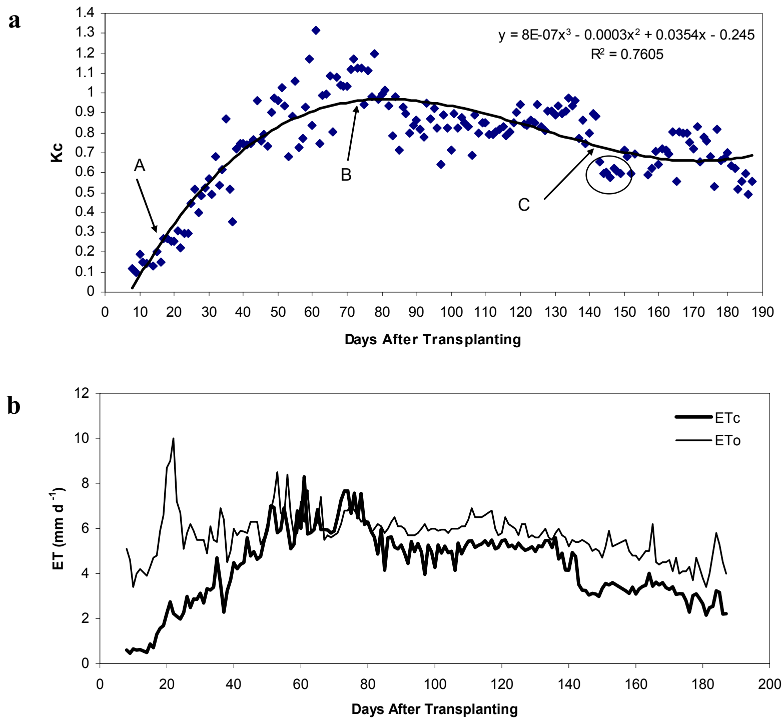

Figure 3. (a) Correlation between plant age and growth coefficient values of round tomato during summer season. Developmental stages marked along time line: A- blooming, B-first fruit pick, C-leaf pruning. (b) Calculated reference ET (ET_0) and water requirements of plants grown in lysimeters (ET_c) during summer season

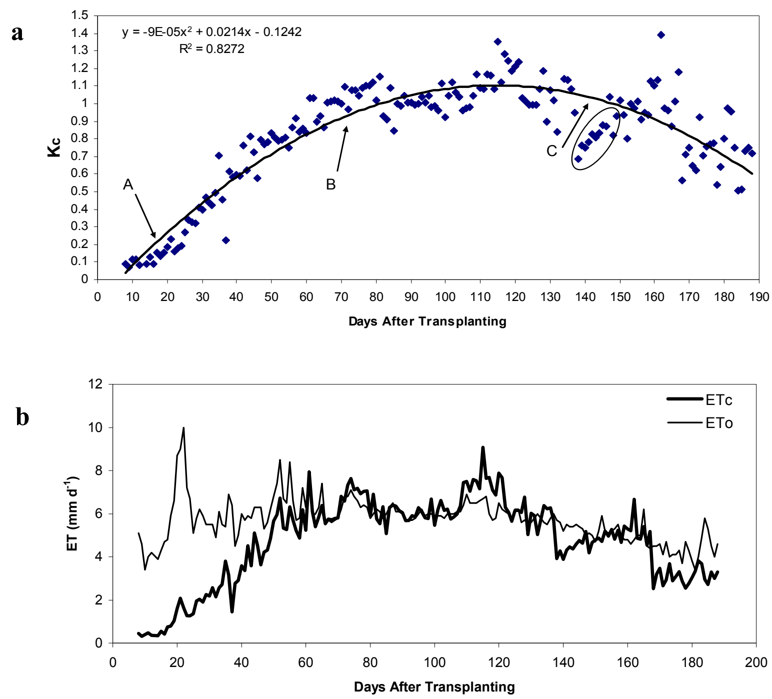

Figure 4. (a) Correlation between plant age and growth coefficient values of cherry tomatoes during summer season. Developmental stages marked along time line: A- blooming, B-first fruit pick, C-leaf pruning. (b) Calculated reference ET (ET_0) and water requirements of plants grown in lysimeters (ET_c) during summer season

Figures 4a and 4b represent the growth coefficient (K_c), (ET_0) and (ET_c) at all the ages of cherry tomato plant.

For the cherry tomato water consumption data was collected only during the summer season. Figure 4a illustrates the growth coefficient of the cherry tomato as a function of plant age and developmental stage. It highlights the differences between the growth coefficient K_c of the cherry strain and that of the round one. The crop coefficient value at day 150 for the cherry tomato was recorded at 0.9 whereas the value for the round tomato was 0.6. 40 days later a different situation emerged and the cherry tomatoes K_c was significantly lower whereas that of the round tomato remained steady. Second order polynomial equation and regression coefficient are presented in the figure.

Figure 4b demonstrates that ET_0 is higher than ET_c for the first 40 days during the seedling establishment, flowering and fruit set stage. We can therefore assume that the plants' water requirements have been more than adequately supplied. Both values consequently converge throughout the harvest period remaining similar until the end of the growing season.

Tables 2 and 3 show mean K_c values calculated for each growth stage according to the data presented in Figure 3 and 4.

Table 2. Crop coefficient for round tomatoes grown in a plastic covered greenhouse during the winter season. DAT-Days after transplanting

		Round Tomato
Growth stage	DAT	K_c
Seedlings establishment	7-20	0.30
Blooming and initial fruit set	21-35	0.57
Fruit development of 1st and 2nd clusters	36-90	1
Fruit pick	91-250	0.83

Table 3. Crop coefficient for round and cherry cluster tomatoes grown in a net house covered with 50 mesh insect proof net during the summer season. DAT-Days after transplanting

		Round Tomato	Cherry cluster
Growth stage	DAT	K_c	
Seedlings establishment	7-20	0.18	0.15
Blooming and initial fruit set	21-35	0.47	0.35
Fruit development of 1st and 2nd clusters	36-69	0.9	0.8
Fruit pick	70-200	0.81	0.97
Yield extinguishing	135-200	-	0.85

Summer growth statistics reveal that the growth coefficient reveals differences in the growth patterns of round and cherry tomatoes. The values for the seedling establishment and root development stages are slightly lower for the cherry tomato plant and the values for the flowering and fruit set period substantially lower. Comparisons of the fruit development stage show that the cherry tomato has an initial 20% higher value over the round variety but this is not maintained as the plant ages.

4.4 Yield and Fruit Size

No significant difference was found in total yield, market quality yield (Figure 5a) or mean fruit weight (Figure 5b) when comparing the winter season trial treatments (1402 round tomato cultivar).

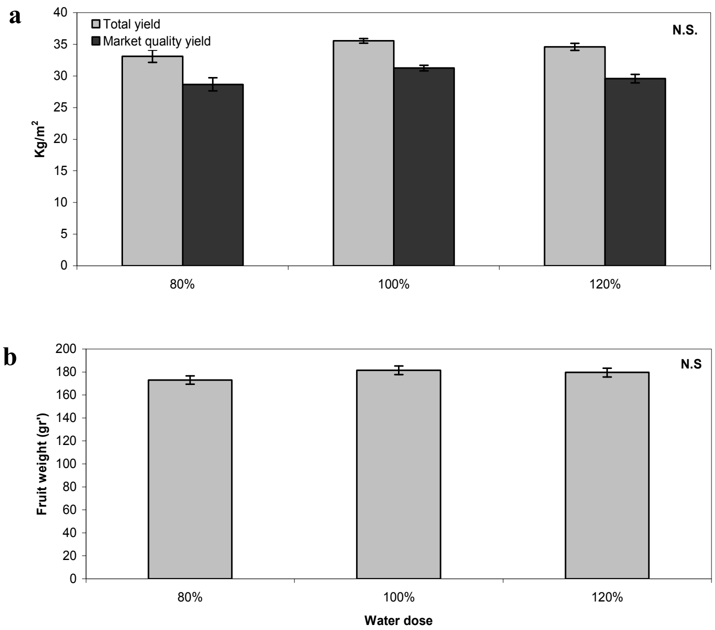

Figure 5. (a) Total yield (Kg/m^2) and (b) Mean fruit weight for round tomato in the winter season of 2011-12

During the summer growing season the yield levels of 1125 round tomato cultivar in the 70% treatment was reduced by about 10 % in comparison to the 100% and 120% treatments (Figure 6a) however this change was not significant. The decrease in the mean fruit size of the 70% treatment was statistically significant ($p = 0.0024$, $f = 6.68$) relative to the mean fruit size of the other two treatments (Figure 6b) and may explain the decrease in total fruit yield weight.

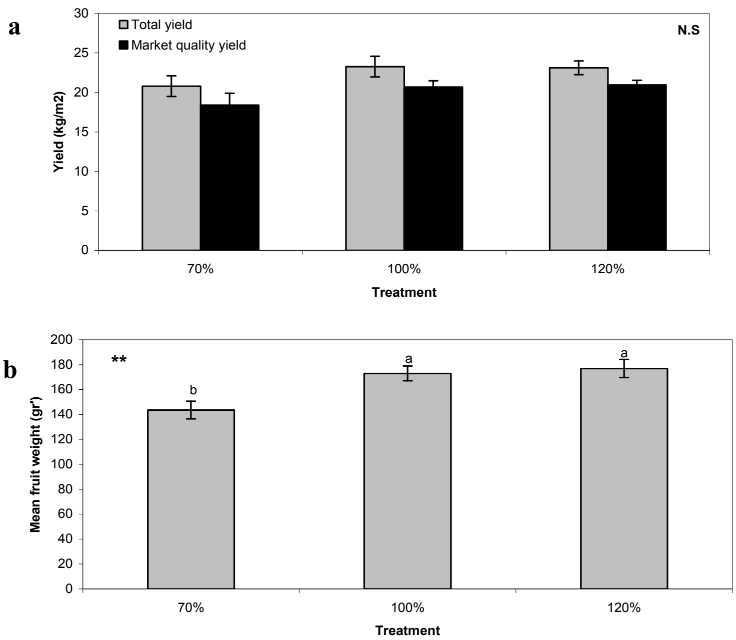

Figure 6. (a) Total yield (kg/m) and (b)Mean fruit weight for round tomato in the 2013 summer growing season

4.5 Post Harvest

Table 5 shows the results of the post harvest evaluation data after a period of simulated storage for the fruit picked during the summer growth season. The additional water allowance in the 120% treatment increased the percentage of soft and rotten fruit after a storage period. Color pigmentation and TSS (total soluble solids) levels were not affected by the different treatments. However when comparing the market yield it can be seen that the 120% of the water requirement irrigation rate causes a rise in the number of unmarketable fruit. That is to say rotten, soft or abnormally pigmented fruit. However contrary to the results from the summer, post harvest quality of the winter season fruit was not affected by the irrigation treatments. A possible explanation for this difference could be due to a higher sensitivity of the 1125 tomato variety used in the summer season, to excess irrigation rates which is not the case with the winter season variety (1402). This sensitivity might negatively affect fruit shelf life and stored fruit quality.

Table 4. Post harvest test results, winter growth season

Treatment	Firm	soft	Rotten	Irregular color	TSS
			%		
80%	30	61.5	3	5.5	5.1
100%	25.5	69.3	1	7	4.9
120%	25	69	1	5	5.2

Table 5. Post harvest test results, summer growth season

Treatment	Firm	Soft	Rotten	Irregular color	TSS
			%		
70%	42.3	14.4	5.1	38.2	5.2
100%	36.8	29.1	9.8	24.2	5.2
120%	25.2	44.5	20.2	10.1	5.4

4. Discussion

Low cost drainage lysimeters were used in order to valuate the K_c values for greenhouse and net house tomato crops, planted in sandy soils and grown in a semi-arid Mediterranean region. The water consumption data was analyzed according to the relevant plant growth stages in order to create an accessible and simple crop coefficient data base. Crop coefficients of between 0.3-1 for the period from seedling establishment till fruit harvest stage and 0.8 for the fruit harvest period were measured for the winter season round tomato crop. During the summer season growth, round tomato crop coefficients of between 0.2-0.9 for the period from seedling establishment till fruit harvest stage and 0.8 for the fruit harvest period were measured. Those values are close to previously measured crop coefficients for field grown tomatoes in regions with a Mediterranean climate (Hamidat et al., 2003; Vazquez et al., 2005).The cherry cluster cultivar showed a slightly different pattern of water consumption with a peak in the crop coefficient in the middle of the fruit picking stage and a continuous reduction in water consumption throughout the growth period.

Fruit weight and post harvest quality were affected by reduced or excessive amount of irrigation, but only during the summer growth season. Mean fruit weight was reduced by 20% under deficit irrigation treatment. Similar effect of deficit irrigation on fruit weight of glasshouse tomato was observed by Pulupol et al. (1996). Fruit sugar content (expressed as TSS) was not effected by the reduced watering treatments in contrast to several previous findings (Beckles 2012) where water limitation increased fruit sugar content in tomato. When water dose exceeded the maximum plant water consumption (120% treatment) more fruits were found soft or rotten at the end of the storage period. Fruit softness is a known phenomenon that was demonstrated regarding several fruit types grown under high irrigation regimes (Hofman, 1998).

The lysimeters that were used in these experiments were comprised of a container filled with a growth medium suitable for growing plants with a limited root volume .They maintain optimal water content and regulated drainage that can be used as a tool for evaluating maximal water consumption of plants grown in certain conditions (Danielson & Feldhake, 1981; Del-Campo, 2007; Parisi et al., 2009). Using such apparatus together with an irrigation trial as described above can provide an accurate indication of water crop requirements with relatively simple, low cost, commercially available equipment. These experiment results emphasized the importance of accurate irrigation of greenhouse tomatoes when high quality yield together with reduced costs are important goals.

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References

Allen, R. G., Pereira, L. S., Raes, D., & Smith, M. (1998). Crop evapotranspiration. Guidelines for computing crop water requirements. *Irrigation and Drainage* (Paper 56, p. 300). Food and Agric. Organization of the United Nations, Rome, Italy.

Baille, A. (1999). Overview of greenhouse climate control in the Mediterranean regions. *Cahiers Op. 1999*. Retrieved from http://om.ciheam.org/om/pdf/c31/CI020831.pdf

Beckles, D. M. (2012). Factors affecting the postharvest soluble solids and sugar content of tomato (*Solanum lycopersicum* L.) fruit. *Postharvest Biology and Technology, 63*(1), 129-140. http://dx.doi.org/10.1016/j.postharvbio.2011.05.016

Danielson, & Feldhake. (1981). Urban lawn irrigation and management practices for water saving with minimum effect on lawn quality. C*ompletion Report No. 106*.Colorado State University.

Del-Campo, M. G. (2007). Effect of water supply on leaf area development, stomatal activity, transpiration, and dry matter production and distribution in young olive trees. *Australian Journal of Agricultural Research, 58*, 1-7.

Hofman, P. J. (1998). Production factors influence fruit quality and response to postharvest treatments. *Aciar Proceedings* (Vol. 81, pp. 6-18). Australian Centre for International Agricultural Research.

Jensen M. E. (1968). *Water Consumption by Agricultural Plants, Water Deficits and Plant Growth* (Vol. II, pp. 1-22). In T. T. Kozlowsky (Ed.). Academic Press, New York.

Lazzara, P., & Rana, G. (2010). The crop coefficient (k_c) values of the major crops grown under Mediterranean climate. *Mediterranean Dialogue on Integrated Water Management, FP6 INCO-MED Funded Project*.

Ko, J., Piccinni, G., Marek, T., & Howell, T. (2009). Determination of growth-stage-specific crop coefficients (Kc) of cotton and wheat. *Agricultural Water Management, 96*(12), 1691-1697. http://dx.doi.org/10.1016/j.agwat.2009.06.023

Wittwer, S. H., & Castilla, N. (1995). Protected cultivation of horticultural crops worldwide. *HortTechnology, 5*(1), 6-23.

Hamidat, A., Benyoucef, B., & Hartani, T. (2003). Small-scale irrigation with photovoltaic water pumping system in Sahara regions. *Renewable Energy, 28*(7), 1081-1096. http://dx.doi.org/10.1016/S0960-1481(02)00058-7

Parisi, S., Martani, L., Cola., G., & Maggiora, T. (2009) Mini lysimeters evapotranspiration measurements on suburban environment. *Italian Journal of Agro meteorology, 3*, 13-1.

Piccinni, G., Ko, J., Marek, T., & Howell, T. (2009). Determination of growth-stage-specific crop coefficients (K_c) of maize and sorghum. *Agricultural Water Management, 96*(12), 1698-1704. http://dx.doi.org/10.1016/j.agwat.2009.06.024

Pulupol, L. U., Behboudian, M. H., & Fisher, K. J. (1996). Growth, yield, and postharvest attributes of glasshouse tomatoes produced under deficit irrigation. *HortScience, 31*(6), 926-929.

Vázquez, N., Pardo, A., Suso, M. L., & Quemada, M. (2006). Drainage and nitrate leaching under processing tomato growth with drip irrigation and plastic mulching. *Agriculture, Ecosystems & Environment, 112*(4), 313-323. http://dx.doi.org/10.1016/j.agee.2005.07.009

Appendix

Technical details and operation of the drainage lysimeters

The lysimeters contained growth medium of a high drainage capacity (see section 3.2) and an automatic irrigation regime which ensured optimal water availability during the growing season.

The lysimeters were irrigated by a double row of dripper irrigation pipe (0.6 l/s) with a 15 cm spacing between the emmiters. Watering was consistent and done in such a way as to ensure constant saturation. The drainage water from each treatment was collected by gravitational flow into a collection vessel which had at its base a sensor constantly measuring its content volume. In addition a pump was submerged which emptied the water and a gauge that measured the amount being emptied. The irrigation schedule was based on an algorithm assimilated in the irrigation controller (Irrinet, Motorola, Israel).The algorithm was based on water level data in the drainage collection vessel. The rate of the change in the water level of the vessel following plot irrigation was a function of the time measured from the previous irrigation. This function slope represented the drainage rate. The rate of the water level rise (and the function slope) was reduced when the drainage amount lessened. This drainage stage ended when the calculated derivative of the slope reached 0. At this point two actions were taken by the irrigation controller:

1. The amount of drainage water was measured by the height at the level of the cut off point in the collection container.

2. Determination of the time interval before subsequent watering (based on the amount of drainage recorded in stage 1).

A large drainage value indicates a low water requirement and thus prescribed a longer interval between irrigations. When the drainage amount is smaller the following irrigation is scheduled sooner.

The algorithm function is constructed in order to define the watering time intervals plotted against drainage amounts. Subsequently the monitoring system initiates the evacuation of the collection vessel.Once this has finished, the cycle of irrigation and water collection resumes. Quantitative calculations of irrigation and drainage water enable a calculation of the evapotanspirational value over certain time periods which in turn allow an evaluation of the total daily amount.