Revista Brasileira de
Engenharia Agrícola e Ambiental
v.17, n.9, p.926–931, 2013
Campina Grande, PB, UAEA/UFCG – http://www.agriambi.com.br
Protocolo 142.11 – 30/06/2011 • Aprovado em 21/06/2013

Growth analysis and yield of tomato crop under different irrigation depths[1]

José A. Monte[2], Daniel F. de Carvalho[3], Leonardo O. Medici[4], Leonardo D. B. da Silva[3] & Carlos Pimentel[2]

ABSTRACT

The influence of irrigation depth was evaluated on tomato crop hybrid Debora plus for salad in a field experiment in split-block design with five treatments (irrigation depth of 40, 60, 80, 100 and 120% of crop evapotranspiration - ETc) and four replications. During the experiment, ten plant samples were collected to determine phytomass and leaf area to estimate plant growth parameters for different depths of irrigation. Results showed maximal growth between 70 and 80 days after transplanting in all treatments. Increase in irrigation depth above 80% of ETc increased crop growth rate (CGR), leaf area index (LAI) and total production of tomato fruits, although same commercial fruit yield was obtained with the lower depths. Therefore, an increase in depth of irrigation above 80% of ETc promotes higher water and energy consumption, without providing an increase in commercial yield of tomato fruits.

Key words: *Solanum lycopersicon*, growth analysis, drip irrigation

Análise de crescimento e produtividade da cultura do tomateiro sob diferentes lâminas de irrigação

RESUMO

A influência da lâmina de irrigação no crescimento e na produção de frutos do tomateiro híbrido, Débora plus tipo longa vida para mesa, foi avaliada em experimento de campo no setor de horticultura, da Universidade Federal Rural do Rio de Janeiro, em Seropédica,RJ, utilizando-se delineamento em faixas, com cinco tratamentos (lâminas de irrigação correspondentes a 40, 60, 80, 100 e 120% da evapotranspiração da cultura - ETc) e quatro repetições. Para cada tratamento foram realizadas dez coletas de plantas visando à determinação da fitomassa e da área foliar. Foi possível constatar que o acúmulo máximo de fitomassa ocorreu entre 70 e 80 dias após o transplante, em todos os tratamentos. O aumento na quantidade de água aplicada acima de 80% da ETc resultou em maior crescimento vegetativo do tomateiro e causou incremento na produção total de frutos, porém com a mesma produção comercial de frutos obtida nos tratamentos com menores lâminas aplicadas. Conclui-se que o aumento na quantidade de água aplicada via irrigação, acima de 80% da ETc, promove maior consumo de água e energia sem, no entanto, proporcionar aumento na produção comercial de frutos do tomateiro.

Palavras-chave: *Solanum lycopersicon*, taxa de crescimento, irrigação localizada

[1] Parte da Tese do primeiro autor, no curso de Fitotecnia da UFRRJ. Projeto financiado pelo CNPq
[2] Depto. de Fitotecnia/Instituto de Agronomia/UFRRJ. BR 465, km 7, CEP 23890-000, Seropédica, RJ. Fone: (21) 3787-3755. E-mail: jam1agr@yahoo.com.br; greenman@amcham.com.br (Bolsista do CNPq)
[3] Depto. de Engenharia/Instituto de Tecnologia/UFRRJ. Fone: (21) 2682-1864. E-mail: carvalho@ufrrj.br (Bolsista do CNPq), irriga@ig.com.br
[4] Depto. de Ciências Fisiológicas/Instituto de Biologia/UFRRJ. Fone: (21) 2682-3222. E-mail: lmedici@gmail.com

Introduction

Tomato (*Lycopersicon esculentum* Mill) is one of the most important and has the highest acreage of any vegetable crop in the world (Jensen et al., 2010). In 2010, its global production was approximately 145.6 million tons of fresh fruit and Brazil ranks ninth, with 2.7% of the world production (Matos et al., 2012).

Tomato growing is considered a high risk activity due to the great variety of environments and systems in which it is grown, high susceptibility to pests and diseases, and high demand for inputs and services, which lead to high financial investment per unit area. Furthermore, Lopes et al. (2005) remark that good productivity requires availability of water throughout the cycle, as the tomato plant is very sensitive to water stress. The commercial value of the table tomato is defined by the characteristics and quality of the fruit (Ferreira et al., 2004).

In the state of Rio de Janeiro, Brazil, tomato growing is more common in winter, as temperatures are milder (Filgueira, 2008). Nevertheless, low rainfall makes crop dependent on irrigation, as lack of water greatly affect the quality and quantity of production (Pires et al., 2009).

Among the different irrigation systems used in tomato growing, drip irrigation has become a viable option in Brazil (Marouelli et al., 2011) for its many advantages, such as the possibility to grow in areas of low water availability, high levels of efficiency (Bernardo et al., 2008), and lower incidence of diseases of plant aerial parts, leading to high yield and fruit quality. Although drip irrigation requires a high initial capital investment, it is one of the best techniques to use in applying water to vegetables and orchards (Cetin & Uygan, 2008).

When compared to sprinkler irrigation, drip irrigation can distribute water uniformly, increases plants yield, reduces evapotranspiration, and decreases the use of water and fertilizer (Ozbahce & Tari, 2010). Furthermore, its pumping requires less energy, it potentially minimizes negative irrigation impacts on soil, and facilitates the use of fertigation (Nascimento et al., 2009). Nonetheless, a study of the basic principles of water and fertilizer management is essential for sustainable irrigated agriculture (Bernardo et al., 2008), as well as the amount of water required for best efficiency (Harmanto et al., 2005).

When water is a limiting factor for agricultural production, irrigation with water deficit index provides greater economic return than total irrigation (Zegbe-Domíngues et al., 2003). Deficit irrigation management is possible when crop production function is estimated. When properly applied, the technique shows great potential to increase water use efficiency (Meric et al., 2011), especially in areas of low water availability (Lorite et al., 2007). The deficit irrigation could be used for tomato without reduction in yield and also with increase in fruit quality parameters, such as the content of sugar and antioxidants moieties (Favati et al., 2009).

The amount of water applied to crop, along with other production factors, allows changes in growth. Such quantitative analysis is based on the assessment of data from sequential collections, in order to describe changes in production of dry matter depending on time, by calculating growth rates. In addition, it allows identifying plant traits linked to environmental conditions, as well as yield potential under optimal growth conditions. According to Pereira & Machado (1987), the technique provides expressive information about plant growth, requiring data obtained without any sophisticated equipment.

Based on the above, this study was developed in order to evaluate the growth and yield of tomato, for the winter crop, under different irrigation depths in Seropédica, RJ, Brazil, applied by a drip irrigation system.

Material and Methods

The trial was carried out at the Department of Plant Science of the Federal Rural University of Rio de Janeiro, Brazil, from June 30 to November 3, 2006 in an Ultisol, with 86.6% sand, 10.5% silt, and 2.9% clay, in the first 0.20 m depth. Chemical analysis of soil showed the following traits: 202 mg L^{-1} P, 67 mg L^{-1} K, 2.2 $cmol_c$ dm^{-3} Ca, 1.0 $cmol_c$ dm^{-3} Mg, 0.1 $cmol_c$ dm^{-3} Al, pH (in water) 7.0 and 58 % base saturation.

Each plot was 2.4 m wide x 9.0 m long with two rows of 18 plants each, for data collection and yield assessment. Tomato seedlings hybrid Débora plus were transplanted 35 days after seeding (DAS) in lines 1.2 m apart and 0.5 m between plants, one stem per plant. When plants developed 6 trusses, growing tips were broken off and plants were tied to a stake with plastic ribbons (Wamser et al., 2007). Weed control was carried out manually.

Irrigation management was based on daily crop evapotranspiration (ETc), estimated from Class A pan evaporation using the pan (kp) and crop (kc) coefficients proposed by Carvalho et al. (2006) and Allen et al. (1998), respectively. The Class A pan was installed in a meteorological station located near the experimental area. Every two days (Monte et al., 2009), the depth of irrigation was applied through polyethylene drip tubes, with emitters placed 0.3 m from each other and discharge of 1.14 L h^{-1}.

The experiment was conducted in split-plot design with five treatments and four replications. Treatments corresponded to different irrigation depths applied based on the percentage of ETc, so named: T_{40} (40%); T_{60} (60%); T_{80} (80%); T_{100} (100%) and T_{120} (120%), according to Lima et al. (2009).

In order to study tomato growth based on the different irrigation depths applied, ten samples were collected during the experiment (0, 14, 28, 42, 56, 70, 84, 98, 112 and 126 days after transplant - DAT), one plant per plot in each assessment. The samples used to determine growth rate were previously and randomly collected from each plot, as canopy changes over time. In each assessment, samples were brought to the laboratory and separated in stems, leaves, and fruits. Each part was packed and taken to the forced ventilation oven at the 80 ^{0}C until reaching constant dry matter. Fruits were sliced and pre-dried in the sun, in order to reduce water content. Leaf area was estimated with a 20 disc sampling, 1.5393 cm^2 of leaf area per plant, dried and weighed separately. A relationship between disk dry matter and disk area was applied to total leaf dry matter to find total leaf area.

Exponential polynomials were used to adjust growth data over time, then a mathematical model was adjusted and data were calculated. Coefficient of determination (r^2) was the parameter chosen to select the polynomial function, a second degree polynomial equation as seen below (Eq. 1).

$$Y = e^{\left(a+bx+cx^2\right)} \quad (1)$$

in which:

Y - value of the variable under study: total dry matter (TDM) and leaf area (LA)

x - days after transplant (DAT)

a, b, and c - constants to adjust the second degree polynomial

Net assimilation rates (NAR) and crop growth rate (CGR) were derived from these equations by implicitly assuming that crop growth is a function of time (Pereira & Machado, 1987).

The NAR was measured in grams of phytomass per m^2 of leaves per day and represents the balance between the material produced by photosynthesis and the one lost by respiration (Pereira & Machado, 1987). Rates were obtained by dividing the instantaneous values of total dry matter (TDM) production by the leaf area (LA), according to Eq. 2.

$$NAR = \frac{\left\{[b+2cx]/[e^{\left(a+bx+cx^2\right)}]\right\}}{[e^{\left(a'+b'x+c'x^2\right)}]} \quad (2)$$

in which:

a, b, and c - constants to adjust the second degree polynomial of the neperian logarithm of TDM

a,' b,' and c' - constants to adjust the polynomial regression of second degree of the neperian logarithm of LA

x - days after transplant (DAT)

Leaf Area Index (LAI) was obtained by dividing the mean leaf area of one plant (LA), in m^2, by the surface area occupied by the plant (SA) in m^2. According to Pimentel (1998), LAI is an expression for plant density per area under cultivation, given by the relationship between plant leaf area and surface area for this plant (spacing).

Crop Growth Rate (CGR), expressed in grams per m^2 of ground per day, is a physiological variable that indicates the quantity of phytomass accumulated per unit of area under cultivation during a period of time. It was obtained through the derivative to the adjusted equation of dry matter curve per unit of surface area in relation to time, which determined the instantaneous values according to Eq. 3.

$$CGR = NAR \times LAI \quad (3)$$

Quantification of production was based on values obtained from the mean yield of ten plants, and fruit grades followed guidelines of Luego et al. (1999). The following grades were considered: PC (commercial production of large, medium, and small fruit), PG (production of large fruit, diameter ≥ 60 mm), PM (production of medium fruit, diameter 50-60 mm), PP (production of small fruit, diameter 40-50 mm), PA (production of fruit showing apical rotting), PMo (production of fruit showing soft rot), PR (production of cracked fruit), PB (production of fruit infested with hornworms) and PDf (production of deformed fruit).

The analysis of variance was performed in split-plot design to evaluate the effect of treatments and interaction between treatments and collections. Regression analysis and the Scott-Knott test at the 0.05 significance level were also carried out to compare fruit production in all treatments. Data were analysed through the SISVAR 5.0 program of statistical analysis.

Results and Discussion

During the experiment, the accumulated precipitation and ETc reached 279 and 405 mm, respectively, which shows the need for irrigation to increase water availability, thus increasing crop yield. According to Jensen et al. (2010), total water needs 75-120 days after transplant for growing tomato are 400-600 mm. Therefore, the irrigation practice is recommended (Bernardo et al., 2008) in order to not significantly affect the quality of tomato fruit grown at this time of the year.

Figure 1 shows the values of NAR (net assimilation rate) for tomato crop. A distinct pattern was observed from the 1st to the 60th DAT in all treatments, whereas a similar pattern appeared in the second half the cycle. NAR values reached over 10 g m^{-2} d^{-1} in the treatment using 40 and 120% of ETc at 55 DAT. Such rates were higher than the ones found by Monte et al. (2009) in the same tomato hybrid in summer growing, when mean temperatures ranged from 20 to 37 °C. During the experiment, mean values of maximum, minimum and medium temperature were 29, 17 and 22 °C, respectively.

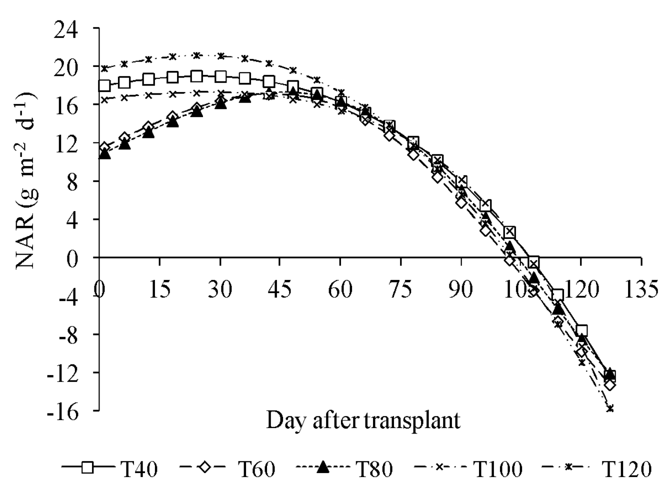

Figure 1. Net Assimilation Rate (NAR) of tomato plants for treatments under different irrigation depths applied according to crop evapotranspiration (T) percentage

According to Filgueira (2008), optimal temperatures for tomato range within 21 - 28 °C in daytime and 15 to 20 °C at night, and varied according to plant age and cultivar. The tomato is therefore sensitive to high temperatures, such as the ones usually observed in the experimental region in summer. Temperatures above the optimal range reduce photosynthesis and increase mitochondrial respiration, thus altering carbon balance and decreasing biomass (phytomass) (Pimentel, 1998).

Figure 2 shows LAI (leaf area index) values throughout the experiment. All treatments show an initial increase of LAI, until reaching maximum values around 90 DAT (days after transplant), then LAI decreases. At the maximum LAI peak, values were lower than those obtained by Fayad et al. (2001) with Santa Clara cultivar. Nonetheless, treatments with larger irrigation depths showed maximum values of LAI higher than those obtained by Monte et al. (2009) in a summer growing using the same genotype at the same transplant time. LAI levels found in this study were similar to those obtained by Reis et al. (2009) after growing persimmon tomato in protected environment.

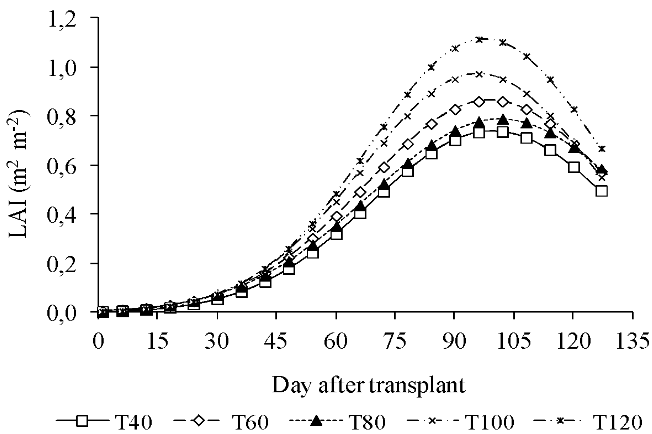

Figure 2. Leaf Area Index (LAI) of the tomato crop submitted to different irrigation depths applied according to crop evapotranspiration (T) percentage

As verified for NAR (Figure 1), LAI values (Figure 2) confirm the higher productivity of phytomass in tomato winter crop under irrigation (Filgueira, 2008) when compared with those obtained in the summer crop (Monte et al., 2009). Therefore, the treatments with higher irrigation depths reached values of LAI above 1.0. Mean temperatures were suitable for tomato crop during this experiment, which allowed high photosynthetic efficiency and consequent higher leaf area and LAI, as spacing is the same.

In relation to CGR, Figure 3 shows that treatments receiving large amounts of irrigation water, thus showing high values of LAI (Figure 2), also reached higher values of phytomass accumulation per unit of soil area (higher CGR).

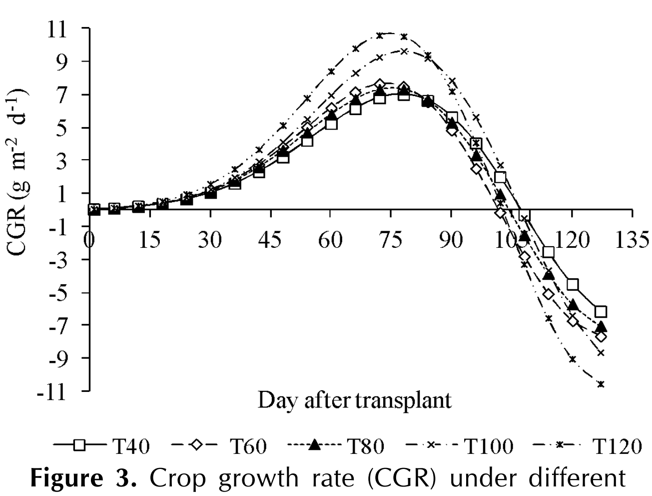

Figure 3. Crop growth rate (CGR) under different irrigation depths applied according to crop evapotranspiration (T) percentage

All treatments showed the same growth pattern of tomato plants. Growth started slowly, then accelerated until reaching the maximum value around 75 DAT and decreased until the end of the cycle. This growth pattern was similar to results found by Monte et al. (2009), although showing lower values of CGR in summer crops. As plants grow, biomass and leaf area increase, thus increasing photosynthesis capacity. As the tomato genotype under study shows indeterminate growth, it tends to keep growing and compete with the fruit reproductive growth. Thus, the final height growth is determined by crop management when the apical yolk is eliminated, because growth should not continue after a determined height to avoid competition between vegetative and reproductive organs. Moreover, harvesting would be harder. Thus, the treatments irrigated with depths corresponding to 100 and 120% of ETc had greater production of phytomass around 75 DAT (Figure 3), leading to higher LAI by 90 DAT (Figure 2).

Phytomass production decreased in all treatments after 75 DAT. In the treatments corresponding to 40, 60, and 80% of ETc production decreased less, whereas the ones irrigated with 100 and 120% of ETc showed larger decrease. Due to high LAI levels in these treatments, the beginning of senescence and consequent reduction of photosynthesis provided higher consumption of carbohydrates in maintenance respiration, which is high at the end of the cycle (Pimentel, 1998).

Treatments irrigated with larger depths showed higher values of LAI and CGR at 60 DAT (Figures 2 and 3), proving that tomato plants respond to irrigation depths which provide high vegetative growth. Nonetheless, by 100 DAT until the end of the cycle, biomass accumulation was negative due to senescence of vegetative organs (Pereira & Machado, 1987), as observed in the negative NAR values (Figure 1). Such phytomass accumulation at the end of the cycle was less negative than in the treatments which produced less phytomass earlier, i.e., the ones irrigated with 40, 60, and 80% of ETc (Figure 3).

Table 1 shows the size and defects of fruit according to the different irrigation depths applied. In general there was a greater production of medium size fruit, followed by large and small size ones. In all treatments, defective fruit was mainly infested with hornworms, followed by fruit with apical rotting, cracked fruit, fruit showing soft rot, and deformed fruit.

Table 1 shows an increase of cracked fruit and fruit infested with hornworms in treatments that received 100 and 120% of ETc when compared with the treatments irrigated with depths below 80% ETc, indicating that increase in the amount of irrigation water may increase the incidence of such defects. These results agree with those found by Marouelli & Silva (2006), who stated that the higher vegetative growth of the aerial part lead to higher humidity inside the plant canopy, favoring the emergence of diseases and injuries caused by insects. Sá et al. (2005) demonstrated that very low or high soil water tensions increase the incidence of defective fruit. Commercial tomato production was not affected by the irrigation depths applied, disagreeing with the values obtained by Macêdo &

Table 1. Analysis of grades of tomato fruits (t ha^{-1}), according to the different irrigation depths

Treat	Production of defect-free fruit				Production of defective fruit			
%ET_c	PC*	PG	PM	PP	PA	PR	PB	PDf
T_{40}	28.93 a**	7.36 a	20.03 a	1.53 a	2.92 a	0.34 b	3.84 b	0.90 a
T_{60}	28.26 a	6.10 a	20.30 a	1.86 a	3.45 a	0.23 b	3.51 b	0.97 a
T_{80}	33.15 a	7.73 a	23.43 a	1.97 a	2.44 a	0.37 b	4.23 b	0.92 a
T_{100}	36.53 a	11.73 a	23.51 a	1.29 b	3.76 a	0.96 a	6.24 a	1.11 a
T_{120}	33.99 a	11.10 a	21.91 a	0.99 b	4.50 a	1.55 a	6.17 a	1.24 a
CV	13.33	35.18	11.72	27.16	39.23	33.25	33.25	38.69

* PC: commercial production of large, medium, and small fruit; PG: production of large fruit; PM: production of medium fruit; PP: production of small fruit; PA: production of fruit showing apical rotting; PMo: production of fruit showing soft rot; PR: production of cracked fruit; PB: production of fruit infested with hornworms; PDf: production of deformed fruit

**Means followed by a same letter in a column are statistically similar (Scott-Knott test, $p < 0.05$)

Alvarenga (2005), in which the number of commercial tomato fruits increased with the irrigation depth applied to the crop.

Treatments T_{100} and T_{120} showed higher total fruit production, although the number of defective fruits was higher (Figure 4), showing more cracked and infested fruits (Table 1) than treatments using less than 80% of ETc.

In a study on irrigation under regulated water deficit, Zegbe-Domíngues et al. (2003) found that treatments with 50% of ETc deficit showed less amount of fresh tomato pulp for industrial processing. Nonetheless, the fruit dry mass was identical and showed higher content of total soluble solids when compared with the control treatment, which was irrigated with 100% of ETc. In this case, the treatment receiving half irrigation depth showed lower fruit water content and better commercial fruit for industrial processing, as less energy would be spent to evaporate water.

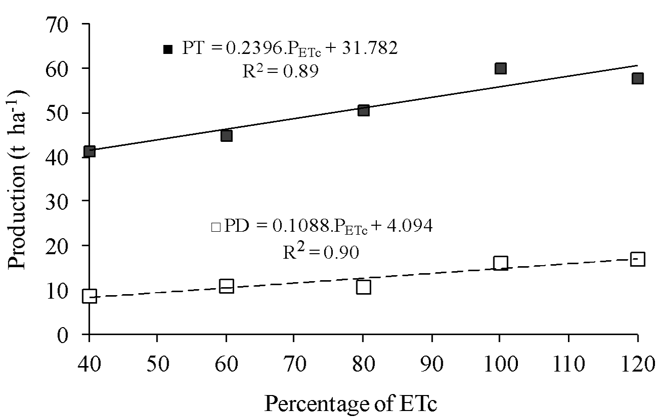

Figure 4. Mean values and curves adjusted for the analysed variables of total fruit production (PT) and total production of defective fruit (PD)

According to Kirda et al. (2004), irrigation with 30 and 50% regulated deficit showed no expressive production decrease when compared with the control treatment, which received 100% of the water required. Harmanto et al. (2005) achieved higher tomato yield when 75% of ETc was replaced by irrigation. This shows that regulated deficit irrigation has been a viable practice which could be used in water-short areas.

As there was no significant difference in commercial production of tomato between the different treatments (Table 1), the smallest irrigation depths applied provided more cost-effective commercial production. These results agree with Sá et al. (2005), who demonstrated that efficient use of water showed a linear increase as the soil water tension increased, also agreeing with the results achieved by Kirda et al. (2004), in which the 30 and 50% irrigation deficit showed higher efficiency in water use.

Results showed that increase in total production of tomato fruit in treatments receiving irrigation depths of 100 and 120% of ETc was due to increased production of defective fruit. Nonetheless, high total fruit production with increased number of defective fruits is not economically advantageous, as commercial production is the most important in agribusiness.

Conclusions

1. Water replacement corresponding to 100 and 120% of ETc (405 and 486 mm) during the life cycle of tomato plants effectively enhanced vegetative growth, providing an increase in total fruit yield and number of defective fruits.

2. The irrigation depth of, approximately, 324 mm (80% of ETc) provided the commercial production of tomatoes, for the winter crop, similar to the treatments irrigated with higher depths (T_{100} and T_{120}), but with lower production of defective fruit.

Literature Cited

Allen, R. G.; Pereira, L. S.; Raes, D.; Smith, M. Crop evapotranspiration: Guide-lines for computing crop water requirements. Rome: FAO, 1998. 300p. Irrigation and Drainage Paper No. 56.

Bernardo, S.; Soares, A. A.; Mantovani, E. C. Manual de irrigação. 8.ed. Viçosa: UFV, 2008. 625p.

Carvalho, D. F.; Silva, L. D. B.; Folegatti, M. V.; Costa, J. R.; Cruz, F. A. Evaluation of the reference evapotranspiration in Seropédica, Rio de Janeiro state, Brazil, using weighing lysimeter. Revista Brasileira de Agrometeorologia, v.14, p.108-116, 2006.

Cetin, O.; Uygan, D. The effect of drip line spacing, irrigation regimes and planting geometries of tomato on yield, irrigation water use efficiency and net return. Agricultural Water Management, v.95, p.949-958, 2008.

Favati, F.; Lovelli, S.; Galgano, F.; Miccolis, V.; Di Tommaso, T.; Candido, V.. Processing tomato quality as affected by irrigation scheduling. Scientia Horticulturae, v.122, p.562–571, 2009.

Fayad, J. A.; Fontes, P. C. R.; Cardoso, A. A.; Finge, F. L.; Ferreira, F. A. Crescimento e produção do tomateiro cultivado sob condições de campo e de ambiente protegido. Horticultura Brasileira, v.19, p.232-237, 2001.

Ferreira, S. M. R.; Freitas, R. J. S.; Lazzari, E. N. Identity and quality standards of tomatoes (*Lycopersicon esculentum* Mill.) for fresh consumption. Ciência Rural, v.34, p.329-335. 2004.

Filgueira, F. A. R. Novo manual de olericultura: Agrotecnologia moderna na produção e comercialização de hortaliças. 3.ed. Viçosa: UFV, 2008. 421p.

Harmanto, V. M., Salokhe, B. M. S.; Tantau, H. J. Water requirement of drip irrigated tomatoes grown in greenhouse in tropical environment. Agricultural Water Management, v.71, p.225-242, 2005.

Jensen, C.R.; Battilani, A.; Plauborg, F.; Psarras, G.; Chartzoulakis, K.; Janowiak, F.; Stikic, R.; Jovanovic, Z.; Li, G.; Qi, X.; Liu, F.; Jacobsen, S.; Andersen, M. N. Deficit irrigation based on drought tolerance and root signalling in potatoes and tomatoes. Agricultural Water Management, v.98, p.403-413, 2010.

Kirda, C.; Cetin, M.; Dasgan, Y.; Topcu, S.; Kaman, H.; Ekici, B.; Derici, M. R.; Ozguven, A. I. Yield response of greenhouse grown tomato to partial root drying and conventional deficit irrigation. Agricultural Water Management, v.69, p.191–201, 2004.

Lima, M. E.; Carvalho, D. F.; Souza, A. P.; Guerra, J. G. M.; Ribeiro, R. L. D. Desempenho da alface em cultivo orgânico com e sem cobertura morta e diferentes lâminas d´água. Ciência e Agrotecnologia, v.33, p.1503-1510, 2009.

Lopes, C. A.; Ávila, A. C.; Reis, A.; Inouenagata, A.; Quezado-Duval, A. M.; Henz, G. P.; Charchar, J. M.; Boiteux, L. S.; Giordano, L. B.; Melo, P. C. T. Doenças do tomateiro. 2.ed, Brasília: Embrapa Hortaliças. 2005. 151p.

Lorite, I. J.; Mateos, L.; Orgaz, F.; Fereres, E. Assessing deficit irrigation strategies at the level of an irrigation district. Agricultural Water Management, v.91, p.51-60, 2007.

Luego, R. F. A.; Calbo, A. G.; Lana, M. M.; Moretti, C. L.; Henz, G. P. Classificação de hortaliças. Brasília: Embrapa Hortaliças. 1999. 61p.

Macêdo, L. S.; Alvarenga, M. A. R. Efeitos de lâminas de água e fertirrigação potássica sobre o crescimento e qualidade do tomateiro em ambiente protegido. Ciência e Agrotecnologia, v.29, p.296-304, 2005.

Marouelli, W. A.; Medeiros, M. A.; Souza, R. F.; Resende, F. V. Produção de tomateiro orgânico irrigado por aspersão e gotejamento, em cultivo solteiro e consorciado com coentro. Horticultura Brasileira, v.29, p.429-434, 2011.

Marouelli, W. A.; Silva, W. L. C. Irrigação por gotejamento do tomateiro industrial durante o estádio de frutificação, na região de Cerrado. Horticultura Brasileira, v.24, p.342-346, 2006.

Matos, E. S.; Shirahige, F. H.; Melo, P. C. T. Desempenho de híbridos de tomate de crescimento indeterminado em função de sistemas de condução de plantas. Horticultura Brasileira, v.30, p.240-245, 2012.

Meric, M. K.; Tuzel, I. H.; Tuzel, Y.; Oztekin, G. B. Effects of nutrition systems and irrigation programs on tomato in soilless culture. Agricultural Water Management, v.99, p.19-25, 2011.

Monte, J. A.; Pacheco, A. S.; Carvalho, D. F.; Pimentel, C. Influência do turno de rega no crescimento e produção do tomateiro no verão em Seropédica. Horticultura Brasileira, v.27, p.222-227, 2009.

Nascimento, J. M. S.; Lima, L. A.; Cararo, D. C.; Castro, E. M.; Silva, M. V. G. Avaliação da uniformidade de aplicação de água em um sistema de gotejamento para pequenas propriedades. Ciência e Agrotecnologia, v.33, p.1728-1733, 2009.

Ozbahce, A.; Tari, A. F. Effects of different emitter space and water stress on yield and quality of processing tomato under semi-arid climate conditions. Agricultural Water Management, v.97, p.1405–1410, 2010.

Pereira, A. R.; Machado, E. C. Análise quantitativa do crescimento vegetal. Campinas: Instituto Agronômico de Campinas. 1987. 33p. Boletim Técnico, n.114.

Pimentel, C. Metabolismo do carbono na agricultura tropical. Seropédica: Edur, 1998. 150p.

Pires, R. C. M.; Furlani, P. R.; Sakai, E.; Lourenção, A. L.; Silva, E. A.; Torre Neto, A.; Melo, A. M. T. Desenvolvimento e produtividade do tomateiro sob diferentes freqüências de irrigação em estufa. Horticultura Brasileira, v.27, p.228-234, 2009.

Reis, L. S.; Sousa, J. L.; Azevedo, C. A. V. Evapotranspiração e coeficiente de cultivo do tomate caqui cultivado em ambiente protegida. Revista Brasileira de Engenharia Agrícola e Ambiental, v.13, p.289-296, 2009.

Sá, N. S. A.; Pereira, G. M.; Alvarenga, M. A. R.; Mattioli, W.; Carvalho, J. A. Comportamento da cultura do tomateiro sob diferentes tensões de água no solo em ambiente protegido. Revista Brasileira de Engenharia Ambiental, v.9, p.341-347, 2005.

Wamser, A. F.; Mueller, S.; Becker, W. F.; Santos, J. P. Produção do tomateiro em função dos sistemas de condução de plantas. Horticultura Brasileira, v.25, p.238-243, 2007.

Zegbe-Domínguez, J. A.; Behboudian, M. H.; Lang, A.; Clothier, B. E. Deficit irrigation and partial rootzone drying maintain fruit dry mass and enhance fruit quality in "Petoprite" processing tomato (*Lycopersicon esculentum*, Mill.). Scientia Horticulturae, v.98, p.505-510, 2003.