

Development of tomato plants under different water tensions in soil during the productive stage

Desarrollo de tomates sometidos a diferentes tensiones de agua en suelo durante el estado productivo

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ABSTRACT

Tomato (*Solanum lycopersicum* L.) is one of the most cultivated and consumed fruit in the world. Water availability is one of the most important factors affecting tomato productivity, as fruit production is limited by water deficit and excess. Our objective was to evaluate the influence of five soil water tensions (15, 20, 30, 45 and 60 kPa) during the productive stages of tomato plants grown in a greenhouse. The largest plants were obtained under the tension of 23.64 kPa. For variables such as the numbers of fruits produced per plant, productivity, mass, and fruit diameter, the highest results were obtained with 15 kPa tension. The productivity under 15 kPa tension was 6.11 kg/plant, while that under 60 kPa was 3.45 kg/plant, which corresponded to 43.5% more productivity than the lowest tension applied in the study. Therefore, soil water tensions can directly influence the productive development stage of tomato, with better results obtained under 15 kPa tension.

Key words: Irrigation management, tensiometer, table tomato, fruit production.

RESUMEN

El tomate (*Solanum lycopersicum* L.) es una de las hortalizas más cultivadas y consumidas en el mundo. La disponibilidad hídrica puede ser considerada uno de los factores más importantes que afectan la productividad del tomate, pues la producción de frutos está limitada por el déficit y exceso de agua. Este trabajo tuvo como objetivo evaluar la influencia de cinco tensiones de agua en el suelo (15, 20, 30, 45 y 60 kPa) durante el estadio productivo del tomate cultivado en casa vegetación. Las mayores plantas fueron obtenidas utilizando la tensión de 23,64 kPa. Para las variables número de frutos producidos por planta, productividad, masa y diámetro de frutos, los mayores resultados fueron obtenidos en la tensión de 15 kPa. La productividad en la tensión de 15 kPa fue de 6,11 kg por planta, mientras que a 60 kPa fue de 3,45 kg por planta, lo que corresponde al 43,5% más en productividad utilizando la menor tensión estudiada. Por lo tanto, diferentes tensiones de agua en el suelo pueden influenciar directamente el estadio de desarrollo productivo del tomate, con mejores resultados en la tensión de 15 kPa.

Palabras clave: Manejo de la irrigación, tensiómetro, tomate de mesa, producción de frutos.

Introduction

Tomato (*Solanum lycopersicum* L.) is one of the most cultivated and consumed fruits in the world. Its productivity and quality are closely linked to the appropriate use of water as well as the genetics, nutrition pattern, and the sanity of plants (Alvarenga, 2004; Santana and Vieira, 2010). Among these factors, the water supply directly affects the fruit production (Santana & Vieira, 2010) in tomato plants,

which makes the use of irrigation indispensable for its cultivation.

Although the localized irrigation system is more efficient for the application of water compared to other systems, in order to reduce wastage, it is necessary to manage water by using an appropriate amount of water at the right time depending on the crop type (Carvalho & Oliveira, 2012). The maximum demand of water by tomato occurs during its flowering and fruit growth stages (Alvarenga, 2004). During the

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fruiting stage, processing tomatoes have maximum productivity when irrigated at a tension of nearly 10 kPa; however, a reduction in productivity occurs when the soil water tension decreases, probably due to the lack of aeration in the root zone (Marouelli & Silva, 2006).

The water supply to processing tomatoes should be managed according to the physiological stages, recommending the use of the tensions 35, 12 and 15 kPa in the vegetative, fruiting and maturation stages, respectively (Marouelli & Silva, 2007). Therefore, irrigation management based on the physiological stages can serve as a tool to increase crop productivity as well as to become an efficient method of using water. However, for table tomatoes, few studies have suggested that water tension maximizes productivity. The objective of this work was thus to evaluate the influence of five different soil water tensions on table tomato crop at the productive stage under greenhouse conditions.

Material and Methods

Study site and soil preparation

The experiment was conducted between April and July 2014 in a greenhouse located in the experimental area of the Centro de Ciências Agrárias e Engenharias of the Universidade Federal do Espírito Santo (CCAUE-UFES) in Alegre, ES, Brazil. The climate of the study region is of type "Aw" with dry season in the winter, according to the classification of Köppen (Koeppen, 1948), presenting with a temperature and average annual rainfall of 23°C and 1200 mm, respectively.

The soil used in the experiment was classified as red-yellow latosol. Soil samples were collected in the experimental area of the CCAUE-UFES from depths of 0–30 m. The soil was unstructured; it was sieved through a 4-mm sieve and homogenized. Soil correction was performed at 25 days before transplanting of the seedlings, according to the

chemical analysis given in Table 1. After liming of the soil, 600 g of chicken bed was incorporated for every 50 kg of soil. The chemical fertilization of planting was performed directly in the pots, according to the methodology proposed by Novais *et al.* (1991) for controlled environment. During the experiment, additional fertilization was performed based on the Manual of Recommendation of Liming and Fertilization for the Espírito Santo State, 5th approach (Prezotti *et al.*, 2007).

Experimental design

The experiment was conducted in a completely randomized design, with five treatments and five replications. The experimental units were 50-L pots containing soil with tomato plants ('Alambra' cv.). The pots were arranged on the ground with a spacing of 1.0 x 0.5 m between rows and among plants, respectively.

The vegetative stage was considered as the period from the transplantation of the seedlings until the 33rd day after transplanting (DAT). All experimental plots were also irrigated, maintaining the soil matric potential between the field capacity (10 kPa) and the tension of 25 kPa.

During the productive stage of tomato from the 34th DAT to the 90th DAT, the treatments were applied, which consisted of five soil water tensions (15, 20, 30, 45 and 60 kPa). The experimental plots were irrigated to maintain the matric potential between the field capacity (10 kPa) and the tension required for each treatment. Thus, when the water tension in the soil reached the pre-established tension level, the irrigation was triggered. After the time required for the soil to return to the field capacity was reached, irrigation was suspended.

Irrigation management

Water was supplied through a drip irrigation system with a flow rate of 2 L/h. Two tensiometers

Table 1. Chemical attributes of the red-yellow latosol used as substrate for planting tomato.

pH	P	K	Ca	Mg	Al	H+Al	CEC	T	V
	mg.dm ⁻³		cmol _c .dm ⁻³		%				
5,3	3,0	69,0	1,2	0,8	0,1	4,5	6,7	2,3	32,7

Extraction and determination: pH in water (1:2,5); P, K: Mehlich 1; Ca, Mg, Al: KCl (1M); H=Al: Calcium acetate (0,5M), CEC at pH 7.

were installed per treatment at a depth of 0.2 m, and the irrigation moment was determined by the mean of the tensiometers. To enable the use of tensiometers, the water retention curve was obtained according to Embrapa (2011). The curve was adjusted to the soil according to the model proposed by van Genuchten (1980). The volumetric moisture and the water replacement slide for each treatment were also determined. The irrigation time for the soil to return to the field capacity was determined by calculating the ratio of water replacement slide and the dripper flow rate, assuming 90% application efficiency (Bernarndo *et al.*, 2009). The physical-water characteristics of the soil are described in Table 2.

Table 2. Physical-water characteristics of the soil. Field capacity (FC), wilting point (WP), available water (AW) and soil density (Ds).

FC	WP	AW	Ds	Sand	Silt	Clay
m ³ .m ⁻³	m ³ .m ⁻³	m ³ .m ⁻³	g.cm ⁻³	g.kg ⁻¹	g.kg ⁻¹	g.kg ⁻¹
0,270	0,176	0,094	1,116	302,56	63,4	634,04

Cultivation

The tomato seedlings were tutored at 15 days after transplanting in a Mexican system (Wamser *et al.*, 2007), with two stems per plant. Cleaning and pruning were performed once a week. Pruning of the apical bud was performed at 55 days after the transplanting of the seedlings, at the time when the plants presented 8–10 clusters.

The control of invasive plants was done manually when necessary. The phytosanitary control was performed preventively using the recommended products for the tomato crop according to the Brazilian Ministry of Agriculture, Livestock and Supply (MAPA).

Characteristics evaluated

The evaluated variables included plant height, yield, productivity, fresh mass and fruit diameter. The height of the plant was measured from the cervix to the apex by using a measuring tape (graded in centimeters) at 90 DAT. The yield was determined by the direct counting of the fruits on plants at 90 DAT and the value obtained was added to the number of fruits that had been harvested so far in each plant. The productivity

and average fruit mass were determined by direct weighing of the harvested fruits. To obtain the average productivity, the average mass of the fruits harvested from each plant was multiplied by the number of fruits produced by the same plant (yield), to obtain the result in kilograms per plant. The diameter of the fruits was measured by using a digital pachymeter. The classification of fruits was performed according to the system proposed by the Ministry of Agriculture, Livestock and Supply (MAPA, 2000). This system was proposed for the marketing of tomatoes for consumption in natura among MERCOSUR member countries and in the Brazilian domestic market.

Statistical analysis

The data of the evaluated characteristics were submitted to the analysis of variance at the level of 5% significance. The effect of water tensions on the variables was analyzed by regression. Statistical analyzes were performed with the SAEG 9.1 software (SAEG, 2007).

Results and Discussion

All characteristics evaluated in the tomato plants were influenced by soil water tension, indicating that the productive stage of tomato can be affected by the water supply. For the plant height variable, a quadratic behavior was noted, with the highest value (225.22 cm) estimated by the regression curve at 23.64 kPa (Fig. 1). Notably, up to 30 kPa tension, the increase in height was less than 2%. However, the plants submitted to the tension of 60 kPa grew 20.9% less than the plants irrigated at 20 kPa tension. The quadratic response of this variable demonstrates the heightened sensitivity of tomato to excess and deficit of water. Excessive water slides hamper roots aeration as well as favor nutrient loss through leaching (Marouelli & Silva, 2006), which hinder the development of plants. On the other hand, water deficit can cause physiological changes in the plant. One of the first symptoms of water deficit is the reduction of turgescence, which in turn is associated with reduced cell extension and plant growth (Taiz & Zeiger, 2009). These factors may have contributed to the reduction of plant height at tensions above 30 kPa in this study.

Fruit yield was inversely proportional to soil water tension (Fig. 2A). At 15-kPa tension, the highest

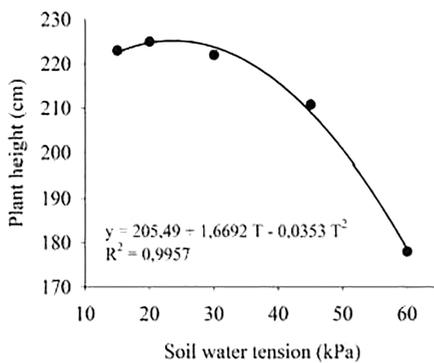


Figure 1. Height of tomato plants (cm) 90 days after transplanting of the seedlings under different soil water tensions (15, 20, 30, 45 and 60 kPa).

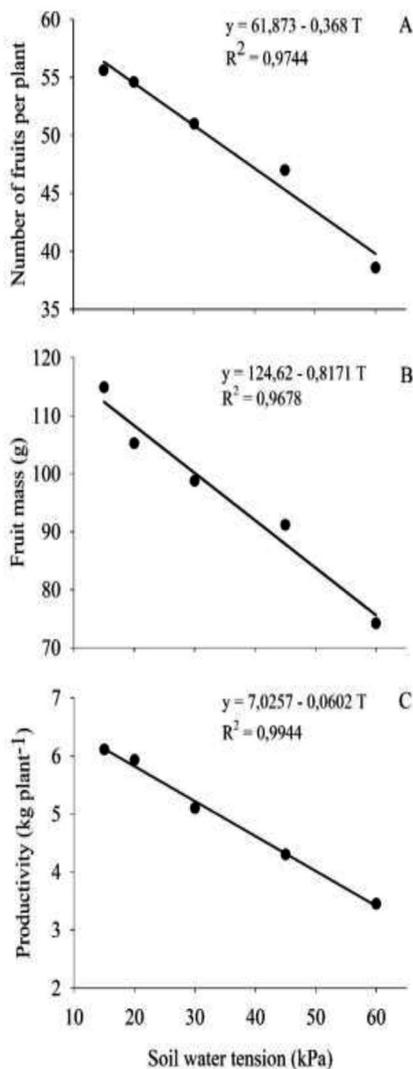


Figure 2. Number of fruits per plant (A), fresh fruit mass (B) and productivity (C) of tomato plants under different soil water tensions (15, 20, 30, 45 and 60 kPa) during the productive stage.

production (55.6 fruits/plant) was obtained, followed by that at 20 kPa tension (54.6). The tension of 60 kPa provided the lowest fruit yield (38.6), which was 30.5% lower than the production obtained at 15 kPa tension. The reduction of yield due to increased soil water tension can be explained by lower plant growth, higher flower drop, and fruit miscarriage in plants submitted to water deficit conditions during the end of the flowering phase and the beginning of the fruiting phase (Marouelli *et al.*, 1991; Prieto *et al.*, 1999).

The average mass of fruits showed a linear behavior decreasing as a function of the increase in the water tension in the soil (Fig. 2B), which varied from 114.8 g under 15 kPa tension to 74.18 g at 60 kPa tension. The productivity of tomato plants depends on the number of fruits produced per plant and the fruit mass, presenting similar behavior to these two variables (Fig. 2C). The highest productivity of the plants was obtained at 15 kPa (6.11 kg/plant), which was 43.5% greater than that at 60 kPa (3.45 kg/plant), where there was a higher water deficit. Marouelli & Silva (2006), in their work with tomatoes for processing, found larger fruit masses and productivity (5.0 kg plant⁻¹) at soil water tension of 10 kPa during the fruiting stage. Marouelli & Silva (2007) obtained higher productivities using the tensions of 35, 12 and 15 kPa in the vegetative, fruiting and maturation stages, respectively. The increase in fruit mass and productivity observed in the lower soil water tensions was justified by the composition of the tomato fruit, which had more than 90% water; therefore, higher water availability results in larger fresh fruit masses (Alvarenga, 2004). In addition, without any water restriction, the vegetable maintains its metabolic activity at adequate levels, capturing CO₂ from the atmosphere and nutrients of the substrate, allowing better productive responses by the adequate production of photoassimilates (Melo *et al.*, 2010).

The largest diameter of fruits was obtained at 15 kPa tension, which decreased due to the increase of water tension in the soil (Fig. 3). It was verified that, in the tension of 15 kPa, the diameter was 63.21 mm, while, at 60 kPa, the diameter corresponded to 52.92 mm. However, according to the standards for the classification of tomato fruits of the Ministério da Agricultura, Pecuária e Abastecimento (MAPA, 2000), all fruits produced were classified as small, with a transverse diameter of 50–65 mm. The reduction in fruit diameter as a function of increased water deficit

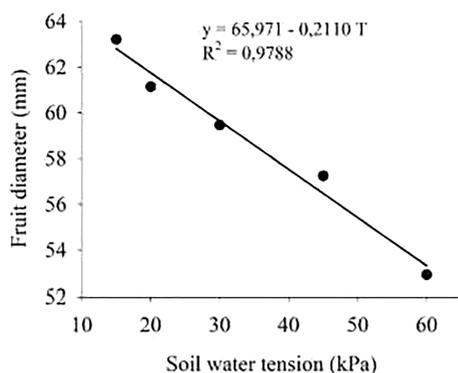


Figure 3. Fruit diameter of tomato plants under different soil water tensions (15, 20, 30, 45 and 60 kPa) during the productive stage.

was also verified by Silva *et al.* (2013) and Koetz *et al.* (2010). According to Koetz *et al.* (2010), the diameter of the fruit can be increased or decreased through the applied water slide. However, slides that provide water deficit can cause reduction in the rate of division and cell elongation (Taiz & Zeiger, 2009), resulting in smaller diameters of fruits.

Conclusions

All characteristics evaluated in the tomato plants were influenced by soil water tension, indicating that the productive stage of tomato can be affected by water supply. The tension of 15 kPa potentiated the number of fruits produced, the productivity, the mass and the diameter of fruits. The greater height of plant was obtained with 23.64 kPa tension.

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