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Growth and production of tomato fertilized with ash and castor cake and under varying water depths, cultivated in organic potponics

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ABSTRACT. Two experiments were performed to evaluate the effect of ash (40, 80, and 120 g per plant), castor cake (140 and 280 g per plant) and water depth (135, 165, 191, and 213 mm) on the growth and production of organic tomato cultivated in pots in a greenhouse. The experimental design was randomized blocks, and the irrigation was managed using an automatic irrigation device. The following variables were evaluated: plant heights, numbers of leaves, bunches, flowers and fruits, total mass of fruits, mass of marketable fruits, mass of fruits with blossom-end rot, total diameter of fruits, and diameter of marketable fruits. Most of the growth variables showed gains with the application of 140 g of ash and 280 g of cake. The dose of 280 g of castor cake was responsible for the greatest mass of marketable fruits (1.78 kg per plant), regardless of the ash dose. The water deficit reduced values of most of the variables of growth and production. The irrigation depth of 213 mm was responsible for the greatest mass of marketable fruits (4.04 kg per plant). The highest water use efficiencies, 37.00 and 37.93 kg m^{-3}, were observed at irrigation depths of 191 and 213 mm, respectively.

Keywords: *Solanum lycopersicum* L., organic agriculture, water management.

Crescimento e produção do tomateiro adubado com cinza e torta de mamona e sob lâminas de irrigação, cultivado em vasoponia orgânica

RESUMO. Foram realizados dois experimentos com objetivo de avaliar o efeito da cinza (40, 80 e 120 g por planta), da torta de mamona (140 e 280 g por planta) e de lâminas de irrigação (135, 165, 191 e 213 mm) no crescimento e produção do tomateiro orgânico, cultivado em vaso e ambiente protegido. O delineamento experimental foi em blocos casualizados e o manejo da irrigação realizado pelo acionador automático para irrigação. Foram avaliadas a altura das plantas, os números de folhas, cachos, flores e frutos, as massas de fruto total, comercial e com podridão apical, e os diâmetros de fruto total e comercial. A maioria das variáveis de crescimento obtiveram ganhos com a aplicação de 140 g de cinza e 280 g de torta. A dose de 280 g de torta proporcionou maior massa fresca comercial (1,78 kg por planta), independente da dose de cinza. O déficit hídrico reduziu os valores da maioria das variáveis de crescimento e de produção. A lâmina de 213 mm foi a responsável pela maior massa fresca comercial (4,04 kg por planta). As maiores eficiências de uso de água, 37,00 e 37,93 kg m^{-3}, foram encontradas para as lâminas de 191 e 213 mm, respectivamente.

Palavras-chave: *Solanum lycopersicum* L., agricultura orgânica, manejo da irrigação.

Introduction

Organic agriculture is a production system based on sustainability and has less harmful effects on the environment than conventional agriculture (Lee, Choe, & Park, 2015), which relies on larger amounts of external inputs (Gomiero, Paoletti, & Pimentel, 2008). Organic potponics is a new cultivation system within organic agriculture, using residual materials as a source of nutrients associated with adequate irrigation management, performed by a low-cost automatic device. This new system aims to apply water and nutrients independently, as opposed to hydroponics and fertigation systems, which require, respectively, the disposal of part of the nutrient solution and the application of a leaching fraction to avoid an imbalance of nutrients or salinization of the substrate (Choi, Lee, & Park, 2015).

Although many studies present different residual materials as a source of nutrients to plants, the use of wood ash and castor cake for tomato crops (*Solanum lycopersicum* L.) is still novel. Ash is a residue from burning wood (Nabeela et al., 2015), and depending on its origin, it may have high contents of K, P, Ca, and Mg (Oburger et al., 2016), which allows its use as a fertilizer or to correct soil acidity (Kuba, Tscholl, Partl, Meyer, & Insam, 2008). Castor cake is a byproduct of the extraction of castor oil (Magriotis et al., 2014). It contains 4.15, 0.61, and 0.96% of N, P, and K, respectively, and a C/N ratio of approximately 11.6 (Zapata, Vargas, Reyes, & Belmar, 2012). Castor cake is considered a high-quality fertilizer (Lima et al., 2011).

Adequate irrigation management (Wang, Kang, Du, Li, & Qiu, 2011) is vital to avoid the leaching of nutrients, especially in tomato production systems, which demand substantial amounts of N fertilizers (Zotarelli, Dukes, Sholberg, Muñoz-Carpena, & Icerman, 2009).

Higher values of water use efficiency can be obtained by irrigation management with water deficit (Cantore et al., 2016), especially in the cultivation of tomatoes, which are sensitive or moderately tolerant to water deficit (Zheng et al., 2013). However, irrigation is one of the most complex techniques in agriculture because many factors are involved in its management (Escarabajal-Henarejos, Molina-Martínez, Fernández-Pacheco, & García-Mateos, 2015). Irrigation automation systems can be used to apply water deficit to the crops and help farmers to perform adequate irrigation management. Automatic device for irrigation (Gomes, Carvalho, Almeida, Medici, & Guerra, 2014; Medici, Rocha, Carvalho, Pimentel, & Azevedo, 2010) are available that control irrigation based on soil water tension (Medici et al., 2010) using low-cost materials, compared to other controllers available in the market (Gonçalves et al., 2014).

This study aimed to evaluate the effects of wood ash, castor cake, and varying irrigation depths on the growth and productivity of tomato cultivated in an organic potponic system.

Material and methods

Two experiments were conducted in a greenhouse in the Campus of the Federal Rural University of Rio de Janeiro (UFRRJ), Seropédica, Rio de Janeiro State, Brazil (22°48'S; 43°41'W; 33 m), in 2014 (experiment I) and 2015 (experiment II). Tomato seedlings, cv. 'Dominador', were transplanted to 8-L pots filled with soil collected from the A horizon of a Planosol, whose chemical analysis showed the following results: Experiment I – $pH_{(H2O)}$: 5.5, Al: 0 $mmol_c$ dm^{-3}, Ca: 18 $mmol_c$ dm^{-3}, Mg: 5 $mmol_c$ dm^{-3}, Na: 1 $mmol_c$ dm^{-3}, P: 18.0 mg dm^{-3}, and K: 24.0 mg dm^{-3}; Experiment II – $pH_{(H2O)}$: 6.6, Al: 0 $mmol_c$ dm^{-3}, Ca: 10 $mmol_c$ dm^{-3}, Mg: 2 $mmol_c$ dm^{-3}, Na: 0 $mmol_c$ dm^{-3}, P: 33.0 mg dm^{-3}, and K: 50.0 mg dm^{-3}.

The temperature and relative air humidity inside the greenhouse were monitored using a thermo-hygrograph (IMPAC/IP-747RH). The means of the maximum daily temperatures were 39.4°C (2014) and 40.4°C (2015), which are considered above the recommended level for the development of tomato plants (Filgueira, 2008). However, no damage was observed in fruiting and fruit set. The average daily minimum and mean temperatures were 17.7 and 26.0°C (2014) and 18.2 and 25.5°C (2015), respectively. The relative air humidities were 65.9% (2014) and 71.4% (2015), which are considered adequate for tomato cultivation (Guimarães, Caliman, Silva, Flores, & Elsayed, 2007).

Tomatoes were planted in on polystyrene trays of 128 cells, filled with organic substrate, and transplanted at 32 days after sowing, on April 17, 2014, and on June 22, 2015. Weed control and disbudding were performed manually, starting at 15 days after transplanting (DAT). Staking started at 20 DAT, and tomato plants were trained using one single stake with a plastic ribbon. After three leaves were formed from the 6th bunch, the tomato plants were pruned (the main stem was cut). At 95 (experiment I) and 30 (experiment II) DAT, the control of tomato diseases was initiated, using weekly applications of Bordeaux or lime-sulfur mixtures. Fruit harvest occurred from 78 (2014) and 71 (2015) DAT to 127 (2014) and 112 (2015) DAT.

The experimental design included randomized blocks totaling 240 pots spaced 1.0 x 0.5 m apart. Each experimental plot consisted of 10 plants that were arranged in a row.

Experiment I used a factorial scheme with 3 doses of ash and 2 doses of castor cake, with 4 replications, using the following treatments: T1 – 40 g of ash and 140 g of castor cake per plant; T2 – 80 g of ash and 140 g of castor cake per plant; T3 – 120 g of ash and 140 g of castor cake per plant; T4 – 40 g of ash and 280 g of castor cake per plant; T5 – 80 g of ash and 280 g of castor cake per plant; and T6 – 120 g of ash and 280 g of castor cake per plant. The doses of ash are equivalent to 0.8 t ha^{-1}(30 kg ha^{-1} of K), 1.6 t ha^{-1}(60 kg ha^{-1} of K), and 2.4 t ha^{-1} (90 kg ha^{-1} of K), respectively, whereas the doses of castor cake are equivalent to 2.8 t ha^{-1} (140 kg ha^{-1} of N) and 5.6 t ha^{-1} (280 kg ha^{-1} of N), respectively. In addition, 50 g of reactive natural phosphate were added once to each pot at the time of planting. The castor cake was applied at planting and at 30 DAT.

The ash used was obtained from the burning of Eucalyptus wood, and the castor cake was obtained at the market. The chemical analyses of these materials showed the following results: ash – pH $_{(H2O)}$: 10.4, P: 17.0 g kg^{-1}, K: 37.8 g kg^{-1}, Ca: 2.1 cmolc dm^{-3}, and Mg: 1.3 cmolc dm^{-3}; and castor cake – N: 49.8 g kg^{-1}, P: 4.7 g kg^{-1}, K: 1.7 g kg^{-1}, Ca: 8.5 g kg^{-1}, and Mg: 14.5 g kg^{-1}.

In experiment II, 4 irrigation depths were tested, with 6 replications: L4 – the volume applied with irrigation management performed using the automatic device for irrigation, promoted a soil water tension of approximately 12 kPa; and L3, L2, and L1 – fractions corresponding to 90, 77, and 63% of the volume applied in L4, respectively. Based on the results obtained in experiment I, fertilization for experiment II contained 280 g of castor cake, 25 g of potassium sulfate, 50 g of reactive natural phosphate, and 8 g of calcitic limestone (RNV 88 and 45% of Ca). The doses of potassium sulfate, reactive natural phosphate, and limestone were applied at planting, while the castor cake was applied as in experiment I.

A drip irrigation system was used in both experiments. Experiment I used drippers (Supertif/John Deere Water), and experiment II used spaghetti tubing (nominal diameter of 0.7 mm, Plasnova). Micro tubes of different lengths were used to allow the application of the different irrigation depths: L1 – 2 micro tubes with a length of 36 cm (2.5 L h^{-1}); L2 – 2 micro tubes with a length of 42 cm (3.0 L h^{-1}); L3 – 2 micro tubes with a length of 52 cm (3.5 L h^{-1}); and L4 – 2 micro tubes with a length of 65 cm (3.9 L h^{-1}), at a pressure of 24.5 kPa. In both cultivation years, tests were performed in each experimental plot to quantify the water distribution uniformity, and a Christiansen's uniformity coefficient of 97% was obtained in both experiments.

For irrigation management, two automatic devices for irrigation were installed in one of the four plots (replicates) representing each treatment (one in each pot), totaling 12 devices for experiment I. In experiment II, the automatic device for irrigation was installed only in one plot (replicate) representing treatment T4, one in each pot. The applied volume was recorded daily through the readings of hydrometers installed at the beginning of each irrigation line (block). Thus, it was possible to calculate the water depth applied by emitters (localized form) in each treatment from the ratio between the applied water volume and the area of the pot (from 1 to 30 DAT) or the area shaded by the plant (from 31 to 126 [2014] or to 112 [2015] DAT).

Additionally, in experiment II, the soil water tension was monitored using tensiometers connected to pressure transducers, which were linked through cables to 3 data acquisition systems (data loggers), referring to each evaluated block. The data loggers were programed to record soil water tension every hour when the irrigation system was off and every 10 seconds when the irrigation system was on.

Non-destructive growth analysis was performed by measuring plant height and the numbers of leaves, bunches, flowers, and fruits. The four most representative plants of each plot were evaluated, and the measurements were performed biweekly.

The following data were collected: total mass of fruits, mass of marketable fruits, mass of fruits with blossom-end rot, total diameter of fruits, and diameter of marketable fruits. Unmarketable fruits were considered those with equatorial diameter smaller than 40 mm and/or defects such as rot, overripe fruits, blossom-end rot, sunburned fruits, empty fruits, fruits with open locule, yellowish fruits, cracked fruits, and fruits with deep damages.

Water use efficiency (WUE) was obtained by the ratio between the produced mass of marketable fruits and the applied irrigation depth (Lovelli, Perniola, Ferrara, & Tommaso, 2007).

Analysis of variance was performed for all the data, and when significance was observed using an F test, the data were subjected to regression analysis.

Results and discussion

Experiment I (2014) – Effects of ash and castor cake

There was no significant interaction between the factors ash and castor cake on any of the growth variables. The dose of 280 g of castor cake promoted increments in plant height and in the number of leaves, bunches, flowers, and fruits (Table 1) in relation to the dose of 140 g. This residue has been studied to meet the nutritional needs of other crops, such as castor, and increments in plant height and number of inflorescences have been observed with increases in its dosage (Oliveira Filho, Oliveira, Medeiros, Mesquita, & Zonta, 2010). Similar results were found by Vignolo, Araújo, Kunde, Silveira, and Antunes (2011) in the number of strawberry fruits and by Martins, Suguino, Dias, and Perdoná (2011) in the number of leaves of banana seedlings.

The ash doses promoted effects on all variables, except on the number of flowers. The dose of 120 g led to increments in plant height (18 and 12% at 60 and 75 DAT, respectively) (Figure 1a) and in the numbers of leaves (13 and 12% at 45 and 60 DAT, respectively) (Figure 1b), bunches (14 and 19% at 45 and 60 DAT, respectively) (Figure 1c), and fruits (27% at 75 DAT) (Figure 1d), in relation to the dose of 40 g. In a study conducted by Nabeela et al. (2015), there was a positive increase in the height of canola (*Brassica napus* L.) seedlings in response to increasing doses of ash. For the grape crop, Piva, Botelho, Ortolan, Müller, and Kawakami (2013) obtained a positive increment in leaf area index with the increase in ash doses associated with bovine manure.

Table 1. Growth variables for the doses of castor cake, evaluated at 1 and at 15, 30, 45, 60, 75, 90, 105, and 120 days after transplanting (DAT).

Doses	Days after transplanting (DAT)								
	1	15	30	45	60	75	90	105	120
(g)	Plant height (cm)								
140	17.8a	37.3a	74.3a	99.8b	123.5b	151.1b	171.6a	174.4a	173.4a
280	17.8a	37.2a	77.0a	111.7a	139.0a	162.5a	176.1a	181.4a	179.7a
	Number of leaves								
140	5.38a	10.0a	10.9b	12.0b	16.9b	20.0b	22.2b	21.9a	21.6a
280	5.33a	10.2a	12.0a	14.2a	19.6a	22.3a	23.5a	22.2a	22.0a
	Number of bunches								
140	-	-	1.5b	2.9b	4.3b	5.2b	6.1a	6.0a	-
280	-	-	2.3a	3.7a	5.5a	5.9a	6.6a	6.2a	-
	Number of flowers								
140	-	-	3.5a	6.4a	0.7b	3.8b	4.2a	1.5a	-
280	-	-	3.7a	6.7a	2.0a	5.5a	4.8a	1.8a	-
	Number of fruits								
140	-	-	0.3b	3.1b	7.9b	10.7b	13.1b	11.7b	-
280	-	-	0.7a	5.0a	12.8a	15.9a	17.5a	16.0a	-

The – symbol indicates that the variable was not evaluated. Means followed by the same letter in the columns do not differ significantly by an F test at the 0.05 probability level.

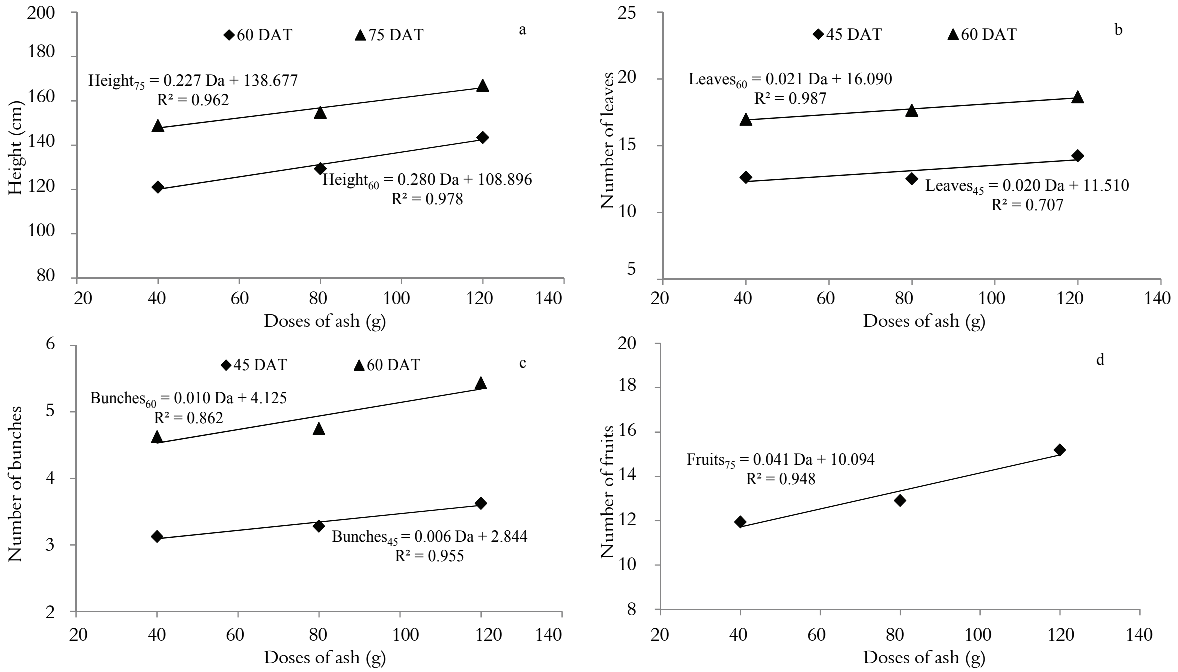

Figure 1. Plant height (a) and number of leaves (b), bunches (c), and fruits (d) at different doses of ash.

The increase in the dose of castor cake resulted in positive increments in all the tested growth variables, and this effect was observed in most of the evaluations performed. To a lesser degree, the increase in ash doses caused significant effects only on the variables plant height (observed at 60 and 75 DAT) and numbers of leaves and fruits, observed only at 45, 60, and 75 DAT. The increase in the doses of castor cake on the growth variables was more pronounced than the effect of the ash doses and resulted in mean increments of 85.3 and 79.2%, respectively, in the total mass of fruits and mass of marketable fruits (Table 2). Additionally, the increase in the total diameter of fruits and diameter of marketable fruits was 5.9%. The effect of ash doses on the growth variables was not sufficient to promote increments in the total mass fruits and mass of marketable fruits or in the total diameter of fruits and diameter of marketable fruits, which can be partially explained by the fact that the K doses (30, 60, and 90 kg ha^{-1}), applied in the form of ash, are not sufficient to promote increments in the tomato fruit production.

The beneficial effects on growth variables, and consequently, on the production variables obtained in the present study, are due to the increase in N provided to the plants through the castor cake, corroborating Ferreira, Ferreira, and Fontes (2010), who reported that an increment in the level of N generated increased plant height, number of leaves, flowering, and fruiting, resulting in greater production of tomato fruits. Mueller, Wamser, Suzuki, and Becker (2013) obtained positive increments in the total yield of tomato with the increase in the doses of N in the form of poultry litter.

Table 2. Total mass of fruits (TMF), mass of marketable fruits (MMF), total diameter of fruits (TDF), and diameter of marketable fruits (DMF) for the doses of castor cake.

Dose	TMF	MNF	TDF	DMF
(g)	(kg per plant)		(mm)	
140	1.02b	0.99b	52.80b	53.49b
280	1.89a	1.78a	55.93a	56.59a

Means followed by the same letter in the columns do not differ significantly based on an F test at 0.05 probability level.

In response to crop development in the different treatments, the irrigation depths applied through the automatic device for irrigation management were equal to 132, 177, 177, 175, 195, and 191 mm for T1, T2, T3, T4, T5, and T6, respectively, which shows that as the lowest doses of ash and castor cake (40 and 140 g, respectively) were applied, the lowest irrigation depth was obtained in response to the lower growth of the plants. When higher doses of ash (80 and 120 g) and castor cake (280 g) were applied, the greatest irrigation depths (195 and 191 mm) were obtained in response to the greater growth of the plants, in agreement with the results found in the present study.

Experiment II (2015) – Effect of water deficit

The applied irrigation depths were equal to 135, 165, 191, and 213 mm, respectively, for L1, L2, L3, and L4. Aiming for a greater yield of tomato plants in a protected environment, Santana, Vieira, Barreto, and Cruz (2010) and Macêdo and Alvarenga (2005) applied irrigation depths varying from 372 to 802 mm and from 158.1 to 399.2 mm, respectively. Also in a protected environment and producing tomatoes in pots, Silva et al. (2013) applied irrigation depths ranging from 180 to 828 mm. In the present study, the lower values of applied irrigation depth are essentially due to the cultivation system in pots and in a protected environment and due to the irrigation method, in which water is locally applied, associated with the adequate management of the irrigation system with an automatic device for irrigation. All these factors contributed to the lower water consumption during the productive process.

With a reduction of 37% in irrigation depth (213 to 135 mm) or increase in soil water tension for the activation of irrigation (11.6 to 47.2 kPa), there was a reduction in plant height (11, 12, 7, 8, 7, and 7% at 45, 60, 75, 90, 105, and 111 DAT, respectively) and in the numbers of leaves (11% at 45 DAT) and fruits (32 and 20% at 60 and 75 DAT, respectively) (Figure 2). Similar results were found for plant height by Soares, Lima, Brito, Sá, and Araújo (2011), Macêdo and Alvarenga (2005) and Santana et al. (2010), for number of leaves by Soares et al. (2011), and for fruits by Silva et al. (2013) and Macêdo and Alvarenga (2005). The numbers of bunches and flowers were not influenced by the irrigation depths, which is consistent with the result found by Cantore et al. (2016) in a study of water deficit in tomato crops.

The irrigation depth of 213 mm (11.6 kPa) promoted the highest values of the evaluated growth variables, resulting in greater total mass of fruits, mass of marketable fruits, and total diameter of fruits (Figures 3a and 4, respectively). This result demonstrates that yield was directly proportional to the irrigation depth, corroborating the results found by Mukherjee, Kundu, and Sarkar (2010) and Zheng et al. (2013). The diameter of marketable fruits was not influenced by the irrigation depths.

The mass of fruits with blossom-end rot (Figure 3b) varied from 1.34 to 0.83 kg per plant with the increment in irrigation depth, showing that even when plants were not subjected to water deficit (100% of automatic device for irrigation; 213 mm and 11.6 kPa), the incidence of fruits with blossom-end rot was high. That pattern can be explained by the high K:Ca ratio of 2.7. According to Jones Júnior (2005), excess K fertilizers in the nutrient solution reduce the absorption of Ca because K is preferentially absorbed and transported in the plant. Fanasca et al. (2006) observed increases in the mass of fruits with blossom-end rot from 0.34 to 0.98 kg per plant with variation of 0.23 to 4.4 in the K:Ca ratio.

The mass of marketable fruits declined by 45% with the variation in irrigation depth from 213 to 135 mm as a result of the effect of water deficit that caused losses in the production through fruits with blossom-end rot. As in the present study, Cantuário, Luz, Pereira, Salomão, and Rebouças (2014) observed increases in the incidence of fruits with blossom-end rot as the soil water tension increased for bell peppers. It is possible that there was a reduction in the transport of water in the xylem to the shoots, leading to a lower transport of Ca, especially to the apex of the fruit, due to the imposition of water deficit (Adams & Ho, 1993; Ho, Belda, Brown, Andrews, & Adams, 1993), and this Ca limitation could promote the formation of small fruits and a larger amount of fruits with rot (Madrid, Barba, Sánchez, & Garcia, 2009; Wang et al., 2011).

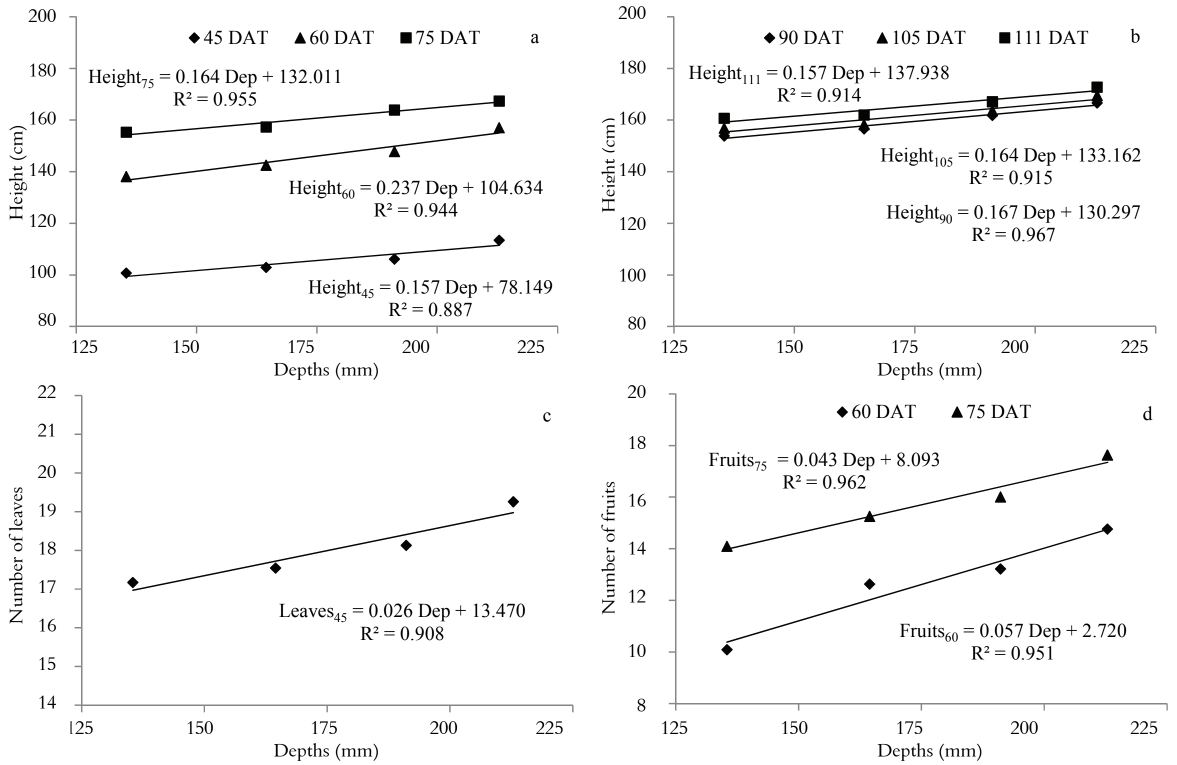

Figure 2. Plant height from 45 to 75 days after transplanting (DAT) (a) and from 90 to 111 DAT (b), number of leaves at 45 DAT (c), and number of fruits at 60 and 75 DAT (d) at different irrigation depths.

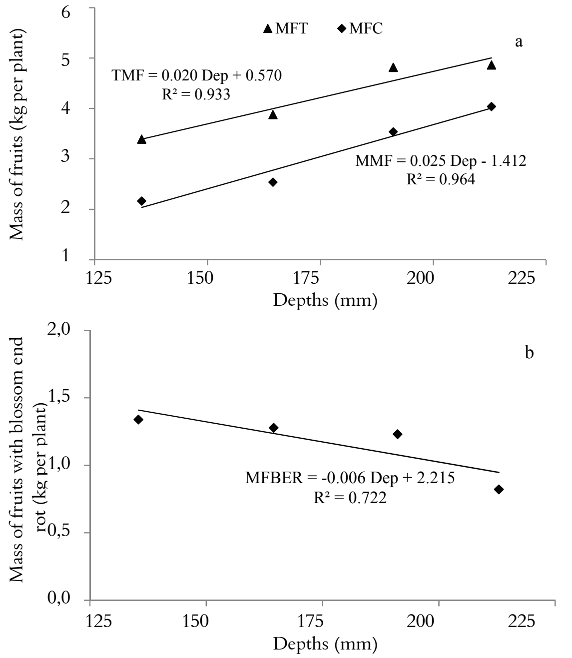

Figure 3. Total mass of fruits (TMF), mass of marketable fruits (MMF) (a), and mass of fruits with blossom-end rot (MFBER) (b) at different irrigation depths.

Marouelli and Silva (2007) observed maximum marketable yields for a tomato crop using soil water tensions of 12 kPa for the stage of fruit development and 15 kPa for the maturation stage. These values of soil water tension are similar to the mean tension for the treatment with the greatest irrigation depth used in the present study.

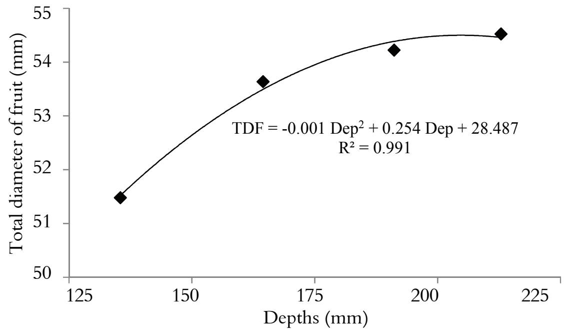

Figure 4. Total diameter of fruits (TDF) at different irrigation depths.

The reduction in irrigation depth promoted a reduction in most of the variables evaluated in the present study, indicating that any degree of water stress can harm the growth and yield of tomatoes (Saif, Maqsood, Farooq, Hussain, & Habib, 2003). Water deficit results in numerous physiological alterations, such as reductions in root matter, leaf area, and number of leaves and, consequently, reductions in plant growth (Mao et al., 2003; Patanè, Tringali, & Sortino, 2011). When the plant is subjected to water stress, almost all of its aspects of growth and development are affected, which can modify its anatomy and morphology as well as interfere with many metabolic reactions (Soares et al., 2011). The lack of water reduces cell turgor pressure and consequently decreases cell elongation and, therefore, plant growth and development (Taiz & Zeiger, 2009).

The highest values of water use efficiency (WUE) were observed for the irrigation depths of 191 mm (37.0 kg m^{-3}) and 213 mm (37.9 kg m^{-3}) (Figure 5) and are above the mean value presented by Doorenbos and Kassam (1994) for a tomato crop (11.0 kg m^{-3}). This pattern occurred because the yield of the crop was close to the mean yield, while the applied irrigation depth was much lower than the range of irrigation depths cited by the previously mentioned authors.

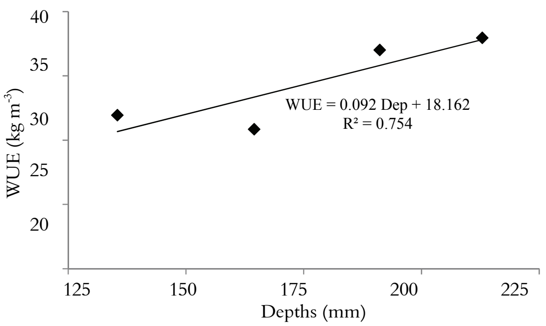

Figure 5. Water use efficiency (WUE) at different irrigation depths.

This results indicate that the cultivation system and the irrigation management were sufficient, leading to a WUE approximately 3.5 times higher than the mean value reported in the literature. Furthermore, the WUE presented by Doorenbos and Kassam (1994) derives from mean values of conditions that are different from those in the present study, only serving as a reference. In more recent studies and under more similar conditions, i.e., tomato cultivation in pots, WUE values higher than those presented by the above-mentioned authors have also been observed, such as in the study of Reina-Sánchez, Romero-Aranda and Cuartero (2005), who obtained a WUE of 25.0 kg m^{-3}.

In general, the irrigation depth that promotes the greatest WUE is lower than the irrigation depth that promotes maximum yield (Nangare, Singh, Kumar, & Minhas, 2016), which justifies the use of deficit irrigation aiming at better WUE. However, this pattern was not observed in the present study because WUE was calculated based on the marketable yield, which was linearly influenced by the irrigation depths due to the losses caused by the incidence of fruits with blossom-end rot. Under the conditions of the present study, water deficit would not be recommended because any level of deficit would lead to a reduction in WUE.

Conclusion

Tomato plants grew larger and produced more when fertilized with 140 g of ash or 280 g of castor cake. With the dose of 280 g of castor cake, the ash did not promote further plant growth.

Water deficit caused reductions in the growth and yield of tomatoes.

Higher values of water use efficiency, 37.0 and 37.9 kg m^{-3}, were observed at the irrigation depths of 191 and 213 mm, respectively.

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