Yield and quality of tomato produced on substrates and with application of humic acids

Antonio A de Lima; Marco Antonio R Alvarenga; Leandro Rodrigues; Admilson B Chitarra

1IFE, C. Postal 51, Colorado do Oeste-RO; anilimaunfa@hotmail.com; 2UFLA-Dep. Agricultura, C. Postal 3037, 37200-000 Lavras-MG; 3UFLA-Dep. Ciências dos Alimentos

ABSTRACT

The aim of this work was to evaluate the yield and quality of tomato fruits, hybrid “Vênus”, produced on substrates and with application of nutrient solution and humic acids (AH). Four doses of AH were evaluated (0, 20, 40 and 80 L ha⁻¹) and 4 substrates: S1 (coconut fiber (CF)), S2 (FC + carbonized coffee husk (CC) in the ratio 1:3), S3 (CF + CC in the ratio 2:3) and S4 (CC), were evaluated following the randomized blocks design in factorial 4x4 scheme with four replications. The 35-day old seedlings were transplanted into plastic bags of 7 L. The humic acids were applied four times in eight-day intervals, and the first application was carried out eight days after transplanting. There was no significant effect of AH on the yield and quality of fruit, except in relation to soluble solids (SS)/titratable acidity (AT). Doses of up to 36 L ha⁻¹, increase the AT, above that amount favored increase of SS. The carbonized coffee husk in treatments S2, S3 and S4, did not alter the production of small fruits, medium, non-commercial, moisture, pH, SS, AT and SS/AT, however, significantly reduced the total production, commercial and large size fruit. The production of fruits in S1 was significantly higher compared to the other treatments, with an average of 142.6 t ha⁻¹, showing average increase in yield of 24.4%, 29.3% and 36.1% compared to plant of treatments S2, S3 and S4, respectively.

Keywords: Lycopersicon esculentum, production, fruit quality, soluble solids.

Palavras-chave: Lycopersicon esculentum, produção, qualidade de fruto, sólidos solúveis.

(Received for publication on 23 de fevereiro de 2010; accepted on July 7, 2011)

Plasticulture has been used for horticulture since the 1970s. Protected cultivation enabled the environment to be adjusted to plants and consequently the production period could be extended to seasons of the year, even in regions before unsuitable for agriculture (Andriolo, 1999). However, when cultivating in a protected environment, directly in the soil and without substrates, Moraes & Furlani (1999) reported that various problems occur of contamination by bacteria, phytopathogenic fungi and nematodes and salinity.

The choice of substrate is important because it allows increase in tomato growth and yield. Therefore its physical and chemical properties should be considered, such as particle distribution by size, density, good water retention and nutrients, oxygen availability, high-capacity for cation exchange and low C/N ratio (Martínez, 2002). Several types of organic substrates are used in cultivation without soil, such as coconut fiber, turf, wood residues, pine bark and partially carbonized, or not, rice husks or inorganic materials such as sand, volcanic rocks, perlite, fiberglass and phenolic foam, used alone or in combinations (Carrijo et al., 2004; Fontes et al., 2004).

Inert material substrates should be selected that are long lasting, cheap, easy to use and have low electric conductivity. In this sense coconut fiber has been used with excellent results in tomato production but the
The experiment was carried out in a 2.78 plant/m² density, with a spacing of 1.0 x 0.8 x 0.4 m, respectively, distributed in 1.0 L plastic bags and watered for 15 m³ with a pressure of 1.0 L h⁻¹ and a duration time of three minutes every two hours, from 8 a.m. to 7 p.m. They were irrigated daily by misting from the release of bioactive molecules with action similar to that of auxin (Canellas et al., 2002) and the effect of enzymes on various metabolic pathways (Vaughan & Malcolm, 1985), on sugars and organic acids that improve tomato quality.

The seedlings were transplanted 35 days after sowing to 7 L plastic bags and distributed in 1.0 x 0.8 x 0.4 m spacing (between double rows, single rows and plants in the same row, respectively) with a 2.78 plant/m² population density. The experiment was carried out in a chapel model protected environment, 30 m long, 10 m wide and 1.8 m tall, covered with low density 150 micras polyethylene.

A randomized block design was used in a 4x4 factorial scheme consisting of four levels of humic acid (0, 20, 40 and 80 L ha⁻¹) and four substrates: S₁ = coconut fiber (CF); S₂ (CF + carbonized coffee husks (CC) at a 1:3 ratio, based on volume); S₃ (CF + CC, at a 2:3 ratio, based on volume); and S₄ (CC) (Table 1). Codahumus 20 was used as HA source, applied every eight days in four installments, that is, one quarter of the doses established (0, 20, 40 and 80 L ha⁻¹), starting on the eighth day after transplant (Table 1). The plots consisted of nine plants and the samples were removed from five central plants in each plot.

The nutrients were supplied by daily fertirrigation, according to the development stage of the crop and the doses were based on recommendations by Castellane & Araújo (1995). In the initial growth phase: 12.5 N; 1.5 P; 7.0 K; 4.0 Ca; 2.0 Mg; 2.0 S (mmol L⁻¹); and further, 20 Fe; 15 Mn; 5 Zn; 30 B; 0.8 Cu; 0.5 Mo (µmol L⁻¹). In the growth and fructification phase: 14.0 N; 2.0 P; 11.2 K; 5.2 Ca; 1.6 Mg; 5.7 S (mmol L⁻¹); and 25 Fe; 15 Mn; 5 Zn; 30 B; 0.8 Cu; 0.5 Mo (µmol L⁻¹).

To tutor the tomato plant, a secondary stem was selected from a vigorous branch just below the first florescence cluster and the other branches were removed, 15 days after transplant. From then onwards there was no further pruning so that the plants developed with four to six stems. Spray irrigation was applied using multiple exit sprays and a mean 1.0 L h⁻¹ flow. Irrigation time was determined by measuring the interval between the start of applying the water and the beginning of drainage from the plastic bags, and the frequency was adjusted daily, according to the crop development stage and the climatic conditions.

Ripe tomatoes or tomatoes at the maximum physiological development stage were harvested every five days in a total of 11 harvests. The tomatoes were weighed and classified according to the equatorial diameter (caliber) as small (40<50 mm), medium (50<60 mm) and large (>60 mm) and those that presented blossom end rot were also separated. With the results obtained, the production was determined of small, medium, large, noncommercial tomatoes (tomatoes with blossom end rot and insect attack were included in this class), total (consisting of the sum of the commercial and noncommercial tomatoes) and commercial tomatoes. The commercial tomatoes production was obtained from the sum of the large, medium and small classes (caliber).

At the second harvest, five fruits were selected per plot with orangy-red coloring to determine the fresh fruit matter (FFM), dry fruit matter (DFM), moisture, pH, soluble solids and titratable acidity (AT). The FFM was determined in tomatoes with a diameter ≥50 mm. The fresh tomatoes were weighed, cut and dried in a forced air circulation chamber at 70°C for 72 hours and then weighed to determine the DFM and moisture. The SS, pH and AT contents were determined according to the norms described by the Adolfo Lutz Institute (1985). The SS/AT ratio was also determined that expresses the tomato flavor.

The data were submitted to analysis of variance and the substrate means were compared by the Tukey test at 5% probability and the humic acid dose by regression using the Sisvar software (Ferreira, 2000).

**RESULTS AND DISCUSSION**

There was no significant effect of the humic acid (HA) applied to the substrates, except in the SS/AT ratio (Figure 1). This probably occurred due to lixiviation of the humic substances (SH) produced by the high irrigation frequencies (10 to 14 times per day) and the capacity of the substrates to gradually make HS available from 3.0 to 6.2 g kg⁻¹ (Table 1). However, the substrates presented significant effect on large, total and commercial fruit production (Table 2) and on the mean fresh fruit and dry fruit matter contents (Table 3).

The plants cultivated in the substrates containing coconut fiber (S₁) presented the following tomato distribution by size class, among small, medium, large and...
Table 1. Physico-chemical properties of substrates (características físico-químicas dos substratos). Lavras, UFLA. 2008.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>S₁</th>
<th>S₂</th>
<th>S₃</th>
<th>S₄</th>
<th>AH*</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH in H₂O</td>
<td>5.8</td>
<td>7.2</td>
<td>7.3</td>
<td>7.8</td>
<td>-</td>
</tr>
<tr>
<td>N-total (g kg⁻¹)</td>
<td>9.2</td>
<td>8.7</td>
<td>9.7</td>
<td>8.2</td>
<td>4.0</td>
</tr>
<tr>
<td>P (g kg⁻¹)</td>
<td>2.0</td>
<td>2.4</td>
<td>2.5</td>
<td>2.5</td>
<td>33.4</td>
</tr>
<tr>
<td>K (g kg⁻¹)</td>
<td>8.2</td>
<td>17.7</td>
<td>22.0</td>
<td>30.5</td>
<td>37.1</td>
</tr>
<tr>
<td>Ca (g kg⁻¹)</td>
<td>4.2</td>
<td>10.2</td>
<td>8.2</td>
<td>9.1</td>
<td>1.7</td>
</tr>
<tr>
<td>Mg (g kg⁻¹)</td>
<td>1.5</td>
<td>2.8</td>
<td>2.5</td>
<td>2.3</td>
<td>0.3</td>
</tr>
<tr>
<td>S (g kg⁻¹)</td>
<td>2.3</td>
<td>2.5</td>
<td>2.7</td>
<td>2.4</td>
<td>7.5</td>
</tr>
<tr>
<td>B (mg kg⁻¹)</td>
<td>29.5</td>
<td>19.6</td>
<td>21.4</td>
<td>21.2</td>
<td>-</td>
</tr>
<tr>
<td>Cu (mg kg⁻¹)</td>
<td>85.2</td>
<td>57.7</td>
<td>61.8</td>
<td>45.0</td>
<td>-</td>
</tr>
<tr>
<td>Mn (mg kg⁻¹)</td>
<td>77.8</td>
<td>182.0</td>
<td>157.1</td>
<td>164.2</td>
<td>7.1</td>
</tr>
<tr>
<td>Zn (mg kg⁻¹)</td>
<td>84.2</td>
<td>52.9</td>
<td>55.0</td>
<td>29.7</td>
<td>16.2</td>
</tr>
<tr>
<td>Fe (mg kg⁻¹)</td>
<td>716.3</td>
<td>1256.1</td>
<td>1265.1</td>
<td>1188.9</td>
<td>102.1</td>
</tr>
<tr>
<td>Umidity (%)</td>
<td>78.8</td>
<td>77.3</td>
<td>76.4</td>
<td>71.9</td>
<td>-</td>
</tr>
<tr>
<td>Density (g dm⁻³)</td>
<td>89.0</td>
<td>100.0</td>
<td>240.0</td>
<td>210.0</td>
<td>1230.0</td>
</tr>
<tr>
<td>CE (mS cm⁻¹)</td>
<td>3.8</td>
<td>3.8</td>
<td>4.8</td>
<td>5.6</td>
<td>-</td>
</tr>
<tr>
<td>C total (dag kg⁻¹)</td>
<td>40.6</td>
<td>40.6</td>
<td>36.9</td>
<td>41.0</td>
<td>9.9</td>
</tr>
<tr>
<td>C/N</td>
<td>44.1</td>
<td>46.7</td>
<td>38.0</td>
<td>50.0</td>
<td>24.9</td>
</tr>
<tr>
<td>Humic acid (g kg⁻¹)</td>
<td>2.0</td>
<td>2.5</td>
<td>1.4</td>
<td>2.5</td>
<td>100.0</td>
</tr>
<tr>
<td>Fulvic acid (g kg⁻¹)</td>
<td>3.2</td>
<td>2.4</td>
<td>1.6</td>
<td>3.7</td>
<td>102.0</td>
</tr>
</tbody>
</table>

S₁: coconut fiber (FC); S₂: FC + carbonized coffee husk (CC) in the ratio 1:3; S₃: FC + CC in the ratio 2:3; S₄: CC; C.E.: electrical conductivity; *Coda 20: Codahumus 20. humic acid (S₁: fibra de coco (FC); S₂: FC + casca de café carbonizada (CC) na proporção 1:3; S₃: FC + CC na proporção 2:3; S₄: CC; C.E.: condutividade elétrica; *Coda 20: Codahumus 20. ácido húmico).

Table 2. Average yield of Italian tomato fruits, hybrid Venus, small (FP), medium (FM), large (FG), non-commercial (FNC), total (PT), commercial (PC) (produção média de frutos de tomate italiano, híbrido Vênus, pequenos (FP), médios (FM), grandes (FG), não-comerciais (FNC), total (PT), comercial (PC).) Lavras, UFLA. 2008.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>FP (t ha⁻¹)</th>
<th>FM (t ha⁻¹)</th>
<th>FG (t ha⁻¹)</th>
<th>FNC (t ha⁻¹)</th>
<th>PT (t ha⁻¹)</th>
<th>PC (t ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S₁</td>
<td>13.7</td>
<td>55.6</td>
<td>73.2</td>
<td>4.2</td>
<td>146.8</td>
<td>142.6</td>
</tr>
<tr>
<td>S₂</td>
<td>15.0</td>
<td>51.4</td>
<td>41.4</td>
<td>4.3</td>
<td>111.8</td>
<td>107.5</td>
</tr>
<tr>
<td>S₃</td>
<td>16.0</td>
<td>52.3</td>
<td>32.5</td>
<td>4.0</td>
<td>105.7</td>
<td>101.6</td>
</tr>
<tr>
<td>S₄</td>
<td>17.2</td>
<td>53.9</td>
<td>20.1</td>
<td>4.8</td>
<td>95.1</td>
<td>90.4</td>
</tr>
<tr>
<td>Average</td>
<td>15.5</td>
<td>53.3</td>
<td>41.8</td>
<td>4.3</td>
<td>114.8</td>
<td>110.5</td>
</tr>
<tr>
<td>CV (%)</td>
<td>25.3</td>
<td>16.6</td>
<td>24.3</td>
<td>35.2</td>
<td>9.4</td>
<td>10.7</td>
</tr>
</tbody>
</table>

Means followed by the same letter in the column do not differ according to Tukey’s test at the 5% level of probability (na coluna, médias seguidas pela mesma letra não diferem entre si pelo teste de Tukey, ao nível de 5% de probabilidade). S₁: coconut fiber (FC); S₂: FC + carbonized coffee husk (CC) in the ratio 1:3; S₃: FC + CC in the ratio 2:3; S₄: CC (S₁: fibra de coco (FC); S₂: FC + casca de café carbonizada (CC) na proporção 1:3; S₃: FC + CC na proporção 2:3; S₄: CC).

According to Alvarenga et al. (2004), 2.5 mS cm⁻¹ is the maximum salinity limit expressed by the electric conductivity of the soil for the tomato and there is a 10% yield decrease for every 1.0 mS cm⁻¹ increase above the tolerance limit. Carrijo et al. (2004) observed greater mean fruit matter in the crops with green coconut fiber and carbonized rice husks that may have been related to the greater capacity of these substrates to make water and nutrients available.

The mean noncommercial tomato (NCF) production was not affected by the different treatments (Table 2). The NCF production of 4.3 t ha⁻¹, due mainly to calcium deficiency, was within the average values, from 3.8 to 5.8 t ha⁻¹ observed by Sampaio et al. (1999). Blossom end rot probably occurs due to factors such as irrigation management, high relative air humidity in the harvest season and decrease in the transpiratory flow of water and nutrients to the canopy that affected the Ca²⁺ redistribution for the fruits. In nutritive solution, Paiva et al. (1998) verified greater calcium accumulation in tomatoes under low relative humidity conditions (40%) because it increased the transpiratory flow of water and nutrients to the canopy and consequently for the fruits.

Substrate S₁ was significantly different compared to the other treatments in total tomato production (TP), 146.8 t ha⁻¹ (Table 2) while treatments S₂ and S₃ presented mean TP values significantly higher than S₄. The mean commercial tomato production (CP) in S₁ (142.6 t ha⁻¹) was greater than noncommercial tomatoes: 9.4%, 37.9%, 49.9% and 2.9%, respectively. However, in the substrate with carbonized coffee husks (S₄) small tomatoes increased to 18.1%, medium tomatoes to 56.6% and there was a 21.1% decrease in large tomato size.

The average tomato production in the different substrates was not significantly different for small (15.5 t ha⁻¹) and medium (53.3 t ha⁻¹) fruits (Table 2). However, S₁ presented a large tomato production mean of greater than the other substrates, with increases of 43.5%, 55.6% and 72.6% for S₂, S₃ and S₄, respectively. It was observed that as the carbonized coffee husks (CC) content increased in the substrates, there was a significant reduction in large, total and commercial tomato production due to variation in electric conductivity (3.8 to 5.6 mS cm⁻¹) and the pH (5.8 to 7.8) resulting in fewer nutrients available to the plant (Table 1).
the plants in the other treatments but S2 only surpassed significantly substrate S4 (Table 2). The plants in the S1 treatment presented a greater increase in commercial tomatoes (CP) of 24.4%, 29.3% and 36.1% compared to the plants in substrates S2, S3 and S4, respectively. It should be emphasized that the mean CP estimate in the different substrates, of 110.5 t ha⁻¹, was greater than those obtained in NFT hydroponic culture with the UC-82 and Saladinha cultivars, with means of 85.5 to 101.3 t ha⁻¹ (Genúncio et al., 2006) and using coconut fiber and fertirrigation in the TX and Larissa cultivars, means of 104 t ha⁻¹ (Carrijo et al., 2004).

The fresh fruit matter (FFM) with diameter (≥50 mm) in substrate S1 was significantly superior only to S4, with respective means of 169.9 and 159.2 g (Table 3). Carrijo et al. (2004) reported that coconut fiber increased FFM in the TX and Larissa cultivars, mean 128.2 g m⁻², greater than the rock wool (107.4 g m⁻²) and rice husk (110.7 g m⁻²) substrates. It is important to emphasize that in hydroponic culture with substrate, the Carmen cultivar presented FFM very close to those reported in the present experiment, 143.1 to 160.7 g (Fernandes et al., 2002).

The mean fruit moisture was around 94.1% and was not affected by the treatments (Table 3). Fernandes et al. (2002) reported similar values for the Carmen cultivar, conducted in NFT of about 94.3% moisture and Davies & Hobson (1981) reported that tomatoes have 92.5% to 95.0% water and 5.0% to 7.5% dry matter in their composition. The substrates used presented statistically significant differences for tomato dry matter (DFM) with a mean of 6.0% (Table 3). This result was very close to the DFM contents reported by Fernandes et al. (2002) in long life tomatoes, with means of 5.6% and 5.8%.

The soluble solids (SS) are the main components that give flavor to the tomato (sugars and acids) and influence the industrial yield (Giordano et al., 2000). The SS contents did not vary significantly in the treatments and presented a mean average of 4.3°Brix (Table 3). Values from 4 to 6°Brix for SS are considered normal in tomatoes (George et al., 2004). Souza et al. (2001) found significant differences for SS content among tomato genotypes ranging from 4.21° to 5.30°Brix indicating the importance of the factor of genetic control.

The environment has an important influence on the tomato SS contents. Caliman et al. (2008) observed lower and significant SS values in a protected environment than in the field, 3.60° to 3.68°Brix and 5.20° to 5.95°Brix, respectively. The higher °Brix values for the genotypes produced in the field were related to the sugar synthesis and accumulation in the tomatoes due to the greater luminosity compared to cultivation in a protected environment. Under the conditions of the present experiment, a decrease was observed in luminosity intensity, associated to mistiness and rainfall during the harvest season. In this case, Cintra et al. (2000) reported mean the SS values below 4.0°Brix, probably related to the rainy
Titratable acidity (AT) influences flavor because it measures the quantity of organic acids and indicates tomato adstringency. Citric and malic acids are the main organic acids found in tomatoes, representing 9% and 4% of the dry fruit matter. AT was not influenced by the substrate type and presented a mean of 0.55% (Table 3). The mean AT values were a little above the range considered normal for tomatoes, from 0.3% to 0.4% (George et al., 2004). However, in hydroponic cropping, Fernandes et al. (2002) reported 0.5% to 0.6% AT in the pulp of Carmen hybrid tomatoes. However, using highly saline irrigation water (CE 9.5 dS m⁻¹) the AT values (from 0.91% to 1.01%) were above the levels considered normal in tomatoes (Blanco & Folegatti, 2008). The factors that contributed to increased acidity were probably related to the ionic concentration of the nutritive solution and decrease in solar radiation, common in protected environments that affected the photoassimilate metabolism.

The treatments did not affect the tomato pH and the mean was 4.3 (Table 3). The values found were below the maximum limit established of 4.5 and it was important to prevent microorganism proliferation in the pulp. The pH is a genetic characteristic. Feltrin et al. (2005) reported means ranging from 3.96 to 4.17 in the Sweet Million, Rocio and Densus cultivars.

There was significant effect only among the organic acid factors and the SS/AT variable (p<0.05) (Figure 1). The regression presented a decreasing quadratic response to the 36 L ha⁻¹ humic acid (HA) dose corresponding to the minimum point of the SS/AT ratio, or 7.6. However, starting at this value, the SS/AT ratio increased to 8.1 at the 80 L ha⁻¹ HA dose. The data indicated that there was a small increase in AT up to the 36 L ha⁻¹ dose but above this value the SS content increased, with little reduction in organic acids.

At higher doses, the humic acids increased the SS/AT ratio, probably favoring the process of organic acid conversion to sugars. Abdel-Mawgoud et al. (2007) reported greater SS contents in tomatoes with HA leaf application at the 75 g 100 L⁻¹ dose, indicating a positive relation with the photoassimilate content produced by the plant. This occurred because the humic acid stimulated photosynthesis and there was a greater rate of assimilates in the leaves and exportation to the tomato, that increased the SS content.

High quality tomatoes are characterized by containing more than 0.32% AT, 3% SS and an SS/AT ratio greater than 10 (Mencarelli & Saltveit Junior, 1988). The AT and SS contents presented in the recent study were within the limits established by the referred authors, because they presented average values of 0.55% and 4.3%, respectively. However, the maximum values reported for the SS/AT ratio were below 10. Nevertheless, it was observed that in field cropping the tomatoes were more flavorful, with greater ‘Brix than the tomatoes produced in the protected environment, with means of 12.1 and 16.8 SS/AT (Caliman et al., 2008). This occurred because there was greater solar radiation in the field than in the protected environment. In the present experiment the harvest season coincided with the season of heavier rainfall, low luminosity and high relative humidity that would explain the lower photosynthesis activity and the dilution factor, that is, water accumulation in the tomatoes.

Coconut fiber presented significantly greater results than the other substrates for large, total and commercial tomato production. On the other hand, carbonized coffee husks altered the electric conductivity and pH of the substrate solution that significantly decreased the large, total and commercial tomato size although it did not affect the quality characteristics.

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