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PRODUCTION AND PHYSICO-CHEMICAL CHARACTERISTICS OF CHERRY TOMATOES ACCORDING TO THE NUMBER OF STEMS AND POT VOLUME

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ABSTRACT - The production of tomatoes (*Solanum lycopersicum* L.) is growing all over Brazil, thanks to technologies and management that make it possible to produce larger volumes, such as using protected systems, with more profitable cultivation and a higher-quality end product. This study aimed to analyze the production and quality of tomato fruit as a function of stem management and pot volume per plant. The experiment was conducted from April to October 2022 in a protected environment at Piccolo Dulce tomatoes®, in São Miguel do Iguaçu-PR. The experimental design used was randomized blocks in a 2 x 4 factorial scheme containing 4 repetitions, with 3 pots per repetition. The first factor consisted of the volume of the pot (5 and 8 L). The second factor corresponded to the number of tomato stems (1, 2, 3, and 4). For the morphometric characteristics of the plant and fruit, plant height (m), number of normal fruits, number of non-commercial fruits, longitudinal fruit diameter (cm), transverse fruit diameter (cm), and yield (kg) per plant were evaluated. Soluble solids (SS), pH, titratable acidity (TA), and ratio were determined to analyze the fruit's chemical characteristics. The size of the pot and the number of stems did not influence the characteristics of the cherry tomato fruit, and 5-liter pots with 4 stems per plant are recommended.
Keywords: *Solanum lycopersicum* L. var. *cerasiform*, management, production.

CARACTERÍSTICAS PRODUTIVAS E FÍSICO-QUÍMICAS DE TOMATE CEREJA, EM FUNÇÃO DO NÚMERO DE HASTES E VOLUME DO VASO

RESUMO - A produção de tomate (*Solanum lycopersicum* L.) cresce em todo o Brasil, por meio de tecnologias e manejos, que possibilitam maiores volumes, como por exemplo, o uso de sistema protegido, com cultivo mais rentável e produto final com mais qualidade. Este estudo tem como objetivo analisar a produção e qualidade de frutos de tomate, em função dos manejos de hastes e volume do vaso por planta. O experimento foi realizado no período de abril a outubro de 2022, em ambiente protegido, na empresa Piccolo Dulce tomates®, em São Miguel do Iguaçu-PR. O delineamento experimental utilizado foi blocos ao acaso, em esquema fatorial 2 x 4, contendo 4 repetições, com 3 vasos por repetição. O primeiro fator consistiu no volume do vaso (5 e 8 L). O segundo fator correspondeu ao número de hastes de tomateiro (1, 2, 3 e 4 hastes). Para as características morfométricas da planta e fruto, foram avaliados a altura de planta (m), número de frutos normais, número de frutos não comerciais, diâmetro longitudinal do fruto (cm), diâmetro transversal do fruto (cm) e produção (kg) por planta. Para as análises de características químicas do fruto, foram determinadas os sólidos solúveis (SS), pH, acidez titulável (AT) e ratio. O tamanho do vaso e o número de hastes não influenciaram as características dos frutos de tomate cereja, recomendando-se vasos de 5 L, com 4 hastes por planta.
Palavras-chave: *Solanum lycopersicum* L. var. *cerasiforme*, manejo, produção.

INTRODUCTION

Tomatoes (*Solanum lycopersicum* L.) have been cultivated since the 1800s and are probably native to Peru and northern Chile. The cultivars currently on the market were developed in Israel by the country's research institutes. The cherry tomato (*S. lycopersicum* var. *cerasiform*) is a smaller tomato with a slightly sweeter flavor than the common tomato (SANTIAGO et al., 2018). Brazil is the world's ninth largest producer of tomatoes, including Santa Cruz, Long Life, Italian, Khaki, and Small Tomatoes, also known as cherry tomatoes. The state that stands out as the largest tomato producer is Goiás, followed by São Paulo, Minas Gerais, Bahia, and Paraná (IBGE, 2021).

Tomatoes are a low-calorie vegetable, rich in vitamins (A and C), sodium, potassium, calcium, phosphorus, and iron. In addition to these, the quality parameters in the fruit's compositional analysis are important for its value, such as acidity, soluble solids, sugar content, lycopene, appearance, firmness, flavor, size, color, and brightness (COUTINHO et al., 2020a).

One alternative to meeting the demand for good-quality, high-yielding fruit is to grow tomato plants in pots in a protected environment. The size of the pots can influence the quality of the root system and the quantity of

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the roots, which are responsible for transporting nutrients to the aerial part of the plant and, consequently, to the development and quality of the fruit (SILVA et al., 2020).

In addition to the substrate volume, which indirectly alters fruit quality, growing in a protected environment provides adequate management for the number of stems, which alters the source/drain ratio, as sunlight is better distributed throughout the crop canopy (COUTINHO et al., 2020b). In this way, it is possible to achieve an appropriate balance between the vegetative and reproductive parts of the plants, reducing self-shading and altering the yield, quality, and quantity of pigments in the plant and/or fruit (ECHER et al., 2020). According to Dalastra et al. (2018), the effects of increasing or decreasing planting density on the productivity of Italian tomato crops are related to the plant's physiology. In this sense, increasing the number of stems per plant and reducing and redistributing the number of bundles on the stems can improve the distribution of light in the plant, alter the rate of gas exchange, increase productivity, and improve fruit production.

Given the importance of the cherry tomato crop to the national economy, it is necessary to understand the effects of differences in the number of stems per plant, pot volume, and the impact on fruit quality and productivity. However, these factors interfere with the plant's physiology, so management practices must be devised to improve them. This will guarantee fruit quality with a good level of productivity and at a lower cost. This study aimed to verify the morphometric characteristics of the plant and fruit and the quality of cherry tomato fruit, influenced by pot volume and the number of stems per plant.

MATERIAL AND METHODS

The study was carried out from April to October 2022 at the Piccolo Dulce Tomates® company, located in the municipality of São Miguel do Iguaçu-PR, at latitude 25º 33' 28" S, longitude 54º 26' 15" W, and altitude 420 m. The experiment was set up in a protected environment under a galvanized iron structure with an arched roof covered with a low-density polyethylene film (150 µm thick).

The experimental design used was randomized blocks in a 2 x 4 factorial scheme with 4 repetitions. Each experimental plot consisted of three pots arranged in a single row for each block. The first factor was the pot's volume (5 and 8 L). The second factor corresponded to the number of stems per plant: T1 = just one stem per plant, T2 = two stems per plant, led parallel to each other on opposite sides of the pot, T3 = three stems per plant, with two stems on the right and one stem on the left, and T4 = four stems per plant, with two stems on each side, spaced 0.45 m apart.

The plastic pots were filled with coconut fiber substrate, which has excellent fertilizer absorption and drainage, and placed at a spacing of 1.75 m between rows and 0.30 m between plants. Before planting in pots, the seedlings were grown in a greenhouse on Piccolo Dulce Tomates® and then transplanted when they had 3-4 permanent leaves. The plants were guided vertically using 2.5m high polyethylene ribbons attached to a wire stretched horizontally over the tomato rows. Throughout the crop cycle, shoots were cut to maintain the number of stems in each treatment. Each plant was grown with 20 bunches and pruned in the apical region after the third leaf above the twentieth bunch. The bunches were distributed as evenly as possible on the stems for the different treatments: T1 with 20 bunches per stem, T2 with 10 bunches on each of the two stems, T3 with 7 bunches on each of the two stems and 6 bunches on one stem and T4 with 5 bunches on each of the four stems.

Defoliation was carried out weekly, from the beginning of the first to the fifth bunch, removing only 4 leaves per week from each stem. After the fifth bunch, 9 leaves were left per stem to enhance the plant's vegetative growth. The leaves were only removed when the bunch was fully formed, at the ripening stage, so as not to interfere with the development of the plant and fruit, thus avoiding diseases and the expense of treatments since these leaves are removed.

Irrigation was carried out via drip, with estimated water consumption, using a benchtop measuring buckets and watering shifts, as shown in Figure 1. Irrigation was carried out according to the crop's needs, using a flexible tape (flow rate 1.6 L h^{-1}), applying around 1-2.5 L of water per day, and keeping the soil humidity above 80%. Three pots were on the benchtop, interspersed with a basin, which was used to store the drained water.

The plants were initially fertilized when they had around 10 leaves, with a 1:38 ratio of the following components: 27 kg of magnesium, 50 kg of calcium, 18 kg of MKP (Monopotassium Phosphate), 17 kg of NK (Nitrogen and Potassium), 6 kg of SK (Sulfur and Potassium), 300 g of Bo (Boron), 60 g of Zn (Zinc), and 900 g of micronutrients, with the concentration later diluted in 400 L of water. After the vegetative phase, a 1:83 ratio of the components was used: 45 kg of magnesium, 65 kg of calcium, 30 kg of MKP, 25 kg of NK, 13 kg of SK, 500 g of Bo, 100 g of Zn, and 1.5 kg of micronutrients. The concentration was then diluted in 400 L of water. The formulation was applied after the fruit had formed until its final cycle. Although this change occurred during the vegetative and reproductive phase, we still applied the mineral foliar fertilizer EfetiveR® once a week, consisting of manganese and zinc, which are essential for plant development. The foliar fertilizer UpCell® contains calcium as a stable and safe formulation for absorption by the leaves. Two applications of Sperto® were necessary to control whiteflies *(Bemisia tabaci* B.) during the fruit ripening phase.

The fruits were collected when they were 90% red. The plant height, number of normal fruits, non-commercial fruits, longitudinal diameter (cm) of the fruit, transverse diameter (cm), and production per plant were evaluated. Fruits were classified as non-commercial when they showed any apparent physical defect such as deformation, spots, wilting, and sagging, among other visual defects. Plant height (m) was measured with a tape measure and diameters with a digital caliper. A precision scale with two places after the comma was used for the production.

For the chemical analysis, the fruit from bunches 10 and 11 were collected in the morning using plastic boxes and then taken to the laboratory at the Engineering Center of the Uniguaçu College. The fruit was then frozen to analyze soluble solids (ºBrix) and pH, which was determined by directly reading the juice extract obtained after pressing the tomatoes using a benchtop digital peagameter. Acidity was determined using the titrimetric method, according to the methodology proposed by the Adolfo Lutz Institute (IAL, 2008). After the chemical analysis, the ratio of soluble solids to acidity, known as the *ratio*, was determined.

FIGURE 1 - Partial view of the tomato growing area, showing the benchtop layout with measuring buckets and the drainage solution collection system.

The data obtained was subjected to the Shapiro-Wilk normality test ($p \leq 0.05$). When normal, an analysis of variance was carried out, and the means were submitted to the Tukey test ($p \leq 0.05$) using the Sisvar statistical software (FERREIRA, 2019).

RESULTS AND DISCUSSION

Temperatures above 35ºC were recorded at the start of the cycle, which caused the flowers of some plants to abort in the first two bunches. The initial phase of the formation of the first flowers is very sensitive to high temperatures (COUTINHO et al., 2020b), so this phase should be given attention. As tomatoes are climacteric fruits, variations in temperature cause losses for the producer, especially at high temperatures during the vegetative, productive, and post-harvest periods, phases in which a series of transformations occur as the exposure temperature increases (SILVA; CARON, 2022).

For the plant and fruit morphometric variables, there was no significant interaction between the pot's volume and the number of stems, which were evaluated separately (Table 1). Although this study did not show any difference in the pot's volume, according to Silva et al. (2020), the pot with a capacity of 5 L showed greater production efficiency with fertigation. They also reported that pruning did not influence the production and quality of the fruit.

Concerning the number of stems criterion, significant differences were observed for plant height, number of normal fruits, number of non-commercial fruits, and longitudinal fruit diameter, with no significant difference observed for transverse fruit diameter and production per plant.

Plant height was a characteristic assessed and used to demonstrate the total length each plant can obtain with 20 bunches per plant, indicating the difficulty of management when plants grow with 1 or 2 stems. In addition to being taller and more difficult to manage, plants grown with one stem use more light and absorb more light, which can speed up their development and the transfer of nutrients since, physiologically, this factor is not shared with other stems. In this way, growing in a protected environment helped to manage the number of stems per plant, thus allowing a change in the source/drain ratio since well-distributed light in the crop canopy can increase production per plant (DALASTRA et al., 2018). This interference can be seen in the number of normal fruits, where the treatment with the lowest number of stems had the highest number of normal fruits.

With the growth of new stems, the plant has to subdivide the nutrients appropriately for each stem. However, one may have a greater number of bunches, which can make the redistribution of photo assimilates even more difficult, thus increasing competition per stem and damaging the cell wall of the fruit (DALASTRA et al., 2018; COUTINHO et al., 2020a; COUTINHO et al., 2020b; COUTINHO et al., 2020c; ECHER et al., 2020). In this way, it is possible to achieve an adequate balance between the vegetative and reproductive parts of the plants, reducing self-shading and altering the yield and quality of the plant or fruit (COUTINHO et al., 2020b; ECHER et al., 2020).

The plants grown with 3-4 stems had the highest number of non-commercial fruits. Proper management can reduce the number of these types of fruit, as the plants need an architecture that improves exposure to light, thus aiding photosynthesis, which can alter the number of commercial fruits (COUTINHO et al., 2020b; COUTINHO et al., 2020c).

TABLE 1 - Plant height (PH), number of normal fruits (NFN), number of non-commercial fruits (NFNC), longitudinal diameter (LD), transverse diameter (TD), and yield per plant, concerning pot volume and number of stems.

Pots' volume	PA (m)	NFN	NFNC	LD (cm)	TD (cm)	PROD (kg)
8 L	2.24 a*	8.95 a	1.05 a	15.28 a	7.26 a	2.73 a
5 L	2.26 a	9.00 a	1.00 a	15.20 a	7.34 a	2.78 a
CV(%)	3.28	1.51	13.26	4.7	2.47	5.24
DMS	0.05	0.03	0.03	0.53	0.13	0.11
Number of stems						
1	4.25 a	9.49 a	0.51c	15.39 ab	7.21 a	2.68 a
2	2.20 b	9.18 b	0.82 b	15.68 a	7.33 a	2.77 a
3	1.52 c	8.60 c	1.40 a	14.58 b	7.33 a	2.79 a
4	1.04 d	8.64 c	1.36 a	15.29 ab	7.32 a	2.79 a
CV(%)	3.28	1.51	13.26	4.7	2.47	5.24
DMS	0.10	0.19	0.19	1.00	0.25	0.20

*Averages in the column followed by the same letter do not differ according to Tukey's test at a 5% error probability.

For the longitudinal diameter of the fruit, there was a significant difference in the number of stems. This change between treatments was probably caused by redistributing water and nutrients to the fruit. Although there were differences, all the values observed were very close and showed the same longitudinal pattern of the fruit. There was no significant difference between the treatments regarding the transverse diameter of the fruit and the yield per plant. The fruit was oblong, with a longer longitudinal diameter than the transverse diameter (QUESADA et al., 2020).

According to a study by Luz et al. (2016), cherry tomato genetic materials show differences between formats, as this variation can occur depending on the cultivar being worked with. Studies carried out by Dalastra et al. (2018), working with the management of Italian tomato stems, found increased production when the plants were managed by keeping 4 stems.

The yield per plant was similar in all treatments. Therefore, if the producer is looking for savings, using smaller pots (containers) and managing the plant with some stems compatible with the crop on the property would be more profitable.

Table 2 shows that the chemical variables analyzed, which were studied separately, did not interact with the pot's volume and the number of tomato stems. This reaffirms that, regardless of the pot's volume and the number of stems used in crop management, the chemical characteristics of cherry tomato fruit remain similar. In agreement, Silva et al. (2020), working with the management of cherry tomato hybrids, obtained a higher fruit production in 5 L pots.

In addition, Gomes et al. (2019) observed that when growing mini watermelon in coconut husk fiber, plants grown with two stems and a density of one plant per pot had higher yields without compromising fruit quality. This suggests that specific management practices, such as choosing the right number of stems and planting density, can positively influence yield without negatively affecting the product's final quality.

Table 2 also shows that the SS fluctuated between 5.91 and 6.11°Brix for both pot volume and number of stems/plants. Although there was no significant difference, soluble solids directly influence the fruit's quality and acceptability, and it is essential to evaluate them to guarantee market expectations. Roque et al. (2022), working with cherry tomatoes irrigated with saline water, found an increase in fruit SS to 7.98°Brix, which is normally 6.00°Brix for this type of fruit. Silva et al. (2020) also found a variation in SS between the cherry tomato varieties studied, with higher levels in fruit from pruned plants grown in 5L pots and an increase in the *ratio* directly linked to an increase in SS.

Given the importance of pH control in tomato production, pH values greater than 2.6 offer greater security for fruit production, thus hindering the development and spread of diseases. This makes it more difficult for diseases to develop and spread and directly interferes with the distribution of nutrients in the plant and other factors that may interfere with its nutritional and commercial value (COUTINHO et al., 2020c; SILVA et al., 2020).

The fruit showed pH values between 4.2 and 4.3. For titratable acidity, 0.08% citric acid was present (Table 2), thus demonstrating that both analyses showed no significant difference in the quality of cherry tomato fruit. However, the pH values were acceptable, thus offering greater health safety and palatable fruit quality to the end consumer. The pH indicates the intensity of acidity, and TA quantifies the acid content present. Acidity directly influences the taste of *fresh fruit*, with sweeter or more acidic cultivars present depending on the cultivation region (SILVA et al., 2020).

From the SS/TA ratio, there is the *ratio* which showed no significant difference, either for the volume of the pots or for the number of stems, demonstrating that the plant's source/drain ratio was balanced, considering the fruit viable for marketing, tasty and with quality (DALASTRA et al., 2018; COUTINHO et al., 2020c; SILVA et al., 2020). Growing in a protected environment allows one to manage the number of stems per plant, thus altering the source/drain ratio since sunlight is better distributed throughout the crop canopy. In this way, an adequate balance between the vegetative and reproductive parts of the plant can be achieved, reducing the high shading that can alter the productivity and quality of the fruit (ECHER et al., 2020).

TABLE 2 - Soluble solids (SS), pH, titratable acidity (TA), and *ratio* obtained from cherry tomato fruit concerning pot volume and number of stems of plants kept in a protected environment.

Pots' volume	SS	pH	TA	*Ratio*
8 L	6.06 a*	4.29 a	0.08 a	9.87 a
5 L	6.04 a	4.25 a	0.08 a	10.11 a
CV(%)	5.43	1.84	12.89	13.08
DMS	0.24	0.06	0.01	0.96
Number of stems				
1	6.13 a	4.27 a	0.08 a	10.56 a
2	5.91 a	4.29 a	0.08 a	9.14 a
3	6.11 a	4.28 a	0.08 a	9.94 a
4	6.04 a	4.25 a	0.08 a	10.33 a
CV(%)	5.43	1.84	12.89	13.08
DMS	0.46	0.11	0.01	1.82

*Averages in the column followed by the same letter do not differ according to Tukey's test at a 5% error probability.

However, the results obtained in this study did not show any statistical difference in the chemical characteristics of cherry tomato fruit depending on the pot volume and the type of stem. Future work is still needed based on other factors such as other seasons, species, management, and the volume of pots, as this crop still represents a high cost for its implementation and management, which can alter the quality of the fruit.

The pot's volume and the stem type did not influence the quality of the cherry tomato fruit. Therefore, if the producer is looking for savings, it would be more profitable to use smaller containers and, for the number of stems, to find out which would best suit the management implemented on the property.

CONCLUSIONS

The interaction between pot size and number of stems did not influence cherry tomatoes' morphometric and fruit quality characteristics. Therefore, for the best results, it is recommended to use 5-liter pots with 4 stems per plant.

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