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CROP PRODUCTION

Trough and pot crop systems with leaching recirculation and defoliation levels for mini tomatoes

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ABSTRACT. The use of raw rice husk as substrate allows the use of crop systems that promote the recirculation of leachate in long crop cycles. Mini tomatoes present relatively low demand for photoassimilates. Thus, partial defoliation of the sympodium could benefit the crop without damage to the production or quality of the fruits. The objective of this work was to evaluate the plant growth, fruit yield and fruit quality of Cherry Hybrid Wanda and Grape Hybrid Dolcetto mini tomatoes cultivated in two recirculation crop systems (pots and troughs), using raw rice husk as substrate, under three defoliation conditions (without defoliation, removal of one and two leaves of the sympodium). The Cherry cultivar showed higher plant growth, fruit yield and mean fruit size. The Grape cultivar produced fruits with higher sugar concentration. For the Grape cultivar, the removal of one sympodium leaf did not affect the plant responses. However, for the Cherry cultivar, it was necessary to maintain the complete sympodium. The trough cultivation system improved plant growth and yield, whereas the pot system increased fruit sugar concentration.

Keywords: cherry, grape, growth, *Solanum lycopersicum*, rice husk, substrate.

Sistemas de cultivo em calhas x vasos com recirculação do lixiviado e níveis de desfolha para minitomates

RESUMO. O emprego de casca de arroz *in natura* como substrato permite empregar sistemas de cultivo que promovam a reutilização do lixiviado em ciclos longos de produção, sendo importante estudar o manejo fitotécnico da cultura nesta condição. Os minitomates apresentam demanda de fotoassimilados relativamente pequena. Assim, a desfolha parcial do simpódio poderia beneficiar a cultura sem prejuízos à produção e qualidade dos frutos. O objetivo do trabalho foi avaliar o crescimento, o comportamento produtivo e a qualidade de frutos de minitomateiro Cereja Híbrido Wanda e Grape Híbrido Dolcetto em dois sistemas fechados de cultivo (vasos e calhas), empregando casca de arroz *in natura* como substrato, sob três condições de desfolha (sem desfolha, retirada de uma e duas folhas do simpódio). A cultivar Cereja apresentou maior crescimento da planta, produção e tamanho médio de frutos. A cultivar Grape apresentou frutos com maior concentração de açúcares. Para cultivar Grape, a retirada de uma folha do simpódio não afetou as respostas produtivas. Entretanto, para cultivar Cereja é necessária a manutenção do simpódio completo. O sistema de cultivo em calhas melhora o crescimento e eleva as respostas produtivas, enquanto que o sistema de vasos aumenta a concentração de açúcares dos frutos.

Palavras-chave: cereja, grape, crescimento, *Solanum lycopersicum*, casca de arroz, substrato.

Introduction

Vegetables are generally present in the cuisine of a population, as they are rich in vitamins, minerals, fibre and antioxidant compounds that are essential to good health. With infinitude of colors, types, sizes and formats, some vegetable species also have medicinal and spice properties.

Tomato (*Solanum lycopersicum*), the most consumed fruit vegetable in Brazil, has guaranteed the income of many farmers, especially in family agriculture, because it presents a high yield. Among tomato groups, mini tomatoes have gained market share in recent years, due to their unique flavour, high total soluble solids content and wide culinary versatility (Beckles, 2012). Despite producing small fruits, mini tomato plants are highly productive, reaching yields of up to 22 kg plant^{-1} (Mello, 2016) in crop cycles of up to one year. In addition to high fruit yield per square metre, this specialty tomato reaches high prices, being at least 20% higher than conventional tomatoes (Caron, Tessmer, Mello, & Jacomino, 2013).

In protected cultivation, the production of mini tomatoes has been carried out, commonly, using culture in pots filled with substrate. However, costs of pots are high, since many of them cannot be reused from one cycle to another. As an alternative, some growers are using trough crop systems where the substrate is placed directly into crop troughs, eliminating the costs of pots. In the potting system, the root system is confined to a reduced space, with substrate volume of approximately 6-8 litres plant^{-1} being used, which usually represents a substrate height from 0.20 to 0.25 m. In the trough system, the roots of the plants extend along the trough and intertwine, with the substrate height being approximately 0.08 m. These variations in the substrate arrangement and the root system can cause changes in water and nutrient availability as well as root growth and, consequently, fruit yield and quality.

However, both types of systems adopted by tomato growers have been characterized as "open", which means the leached nutrient solution is lost to the environment, with serious consequences concerning the high waste of water and fertilizers as well as environmental contamination.

The production of mini tomatoes in a substrate recirculating system, in which the collection and reuse of the drained nutrient solution is promoted, reduces the occurrence of environmental damage, such as contamination of the soil and groundwater, in addition to saving water and fertilizer. However, the technique requires a substrate with low chemical activity (low cation exchange capacity) to avoid salinization of the root medium. In the southern region of Brazil, an important rice producer, rice husk is abundant, as it is the residue of the grain processing industries. Raw rice husk has high aeration space and low chemical activity and can be successfully used as an isolated substrate in recirculating systems for mini tomatoes (Peil, Albuquerque Neto, & Rombaldi, 2014) as well as for other cultivated vegetable fruits such as melon (Duarte, Peil, Bacchis, & Strassburguer, 2008) and zucchini (Strassburger, Peil, Fonseca, Aumonde, & Mauch, 2011).

Generally, indeterminate growth tomato plant shave been used in protected cultivation, which can reach elevated heights under suitable conditions that allow the prolongation of the crop season. Long-season crops in greenhouse cultivation are a common practice in countries such as the Netherlands. The crop season is extended for up to one year, with the leaves and racemes underneath the harvested bunches removed and the plants lowered to follow their growth for an undetermined time. In Brazil, long-season crops are still not common, but some growers are adopting them due to the elimination of costs from new seedlings and non-interruption of the harvest.

In this case, it is necessary to adopt differentiated plant management in relation to short-season crops. The practice of defoliation and lowering of the basal portion of the stem, as occurs in the harvest of the clusters, is mandatory, thus favoring canopy ventilation and an adequate plant sink/source ratio. However, for mini tomato plants, whose fruits have low sink demand, the defoliation management can be differentiated in relation to that usually adopted for salad tomato plants. Possibly, besides the defoliation in the basal part of the stem, the number of leaves of the sympodium, which is composed of two leaves below and one leaf above the cluster (Chamarro, 1995), could be reduced without prejudice to the growth of fruits and with benefits regarding canopy ventilation and pest and disease management.

However, genotypic characteristics may have a significant influence on plant responses, since cultivars of different groups of mini tomato plants may differ in root growth, fruit size and leaf area, which would imply differences in water and nutrient absorption, in the sink:source ratio and, consequently, in the responses to different cropping systems and defoliation intensities.

Therefore, the objective of this work was to evaluate the plant growth, fruit yield and quality of Grape and Cherry mini tomato cultivars grown in two recirculating systems, pots and troughs, with raw rice husk substrate under three different defoliation intensities.

Material and methods

The experiment was conducted from August 31st, 2015 to May 31st, 2016, in the Didactic and Experimental Field of the “Departamento de Fitotecnia” of the “Faculdade de Agronomia Eliseu Maciel” at the Campus of the “Universidade Federal de Pelotas” (31°52S - 52°21'W) located in the municipality of Capão do Leão, Rio Grande do Sul State, Brazil. This region's climate is characterized by being subtropical humid or temperate.

The experiment was conducted in a symmetric roof structure metallic greenhouse, encompassing an area of 210 m² (10 x 21 m), 4.5 m maximum height and 3.5 m middle height disposed in north-south orientation and covered with low-density polyethylene film (150 μm thick). The soil was levelled and covered with double-sided (white/black) polyethylene film 150 μm in thickness with the white face exposed.

During the experiment period, the greenhouse environment was managed only by natural ventilation, with daily opening of the side windows and doors at 8 o'clock and the closing time varying according to the temperature condition prevailing in that day, occurring at approximately 7 pm on high temperature days and at 2 pm on low temperature days. On days when there was precipitation and/or very strong winds or high relative humidity of the air outside, it was partially or totally closed.

A nutrient solution adapted from Rocha, Peil, and Cogo (2010) was used with the following composition of macronutrients (in mmol liter^{-1}): 12.2 of NO_3^-, 1.5 of $H_2PO_4^-$, 2.25 of SO_4^{-2}, 1.2 of NH_4^+, 6.0 of K^+, 3.5 of Ca^{+2}, 2.0 of Mg^{+2}, and micronutrients (in mg liter^{-1}): 3.0 of Fe, 0.5 of Mn, 0.05 of Zn, 0.15 of B, 0.02 of Cu, and 0.01 of Mo. Rainwater was used to prepare the nutrient solution (EC = 0.0 dS m^{-1}). After the preparation, the electrical conductivity (EC) of the solution was measured, obtaining a value of 1.82 dS m^{-1}.

Seeds of Cherry Hybrid Wanda ISLA® and Grape Hybrid Dolcetto ISLA® cultivars were used, being referred to from here on as "Cherry" and "Grape", respectively. On July 20th, 2015, sowing was carried out in polystyrene trays of 128 cells containing commercial substrate. The trays were arranged in a floating system for fertigation. In the seedling production phase, the same nutrient solution as described above was used at 50% concentration, maintaining a solution film depth of approximately 5.0 cm high.

When the seedlings presented four leaves, the main stem was topped to break the apical dominance and stimulate the growth of the side shoots, which would be selected in sequence. Transplantation was performed seven days after apical pruning, on August 31st, 2015, considered the start date of the experiment.

The base for the installation of the two substrate cultivation systems was composed of 12 wooden gullies (7.50 m long and 0.30 m wide) internally covered with double face (black-white) plastic channels to collect and recirculate the drain solution. The gullies were arranged in 6 pairs of double rows sloping 3%. The pairs of double rows were 1.20 m apart with 0.50 m between-row distance. The drained nutrient solution was collected and returned to a nutrient solution catchment tank placed at the final part of the gullies.

Pot cultivation was the first crop system used, with one plant transplanted in each pot filled with 7 litres of substrate at a height of 0.22 m. The pots were arranged on the gullies in the amount of 19 pots per gully. Trough cultivation was the second crop system used, the substrate being arranged directly in the gullies in a layer 7.5 m in length, 0.27 m in width and 0.08 m in height, resulting in 8.5 litres of substrate for each plant. Raw rice husk from the rice husking process performed by the industry was employed as substrate in both systems. The physical and chemical characteristics of the raw rice husk were determined through laboratory analysis (Table 1).

Prior to transplantation, the substrate was abundantly irrigated with water to wash it. After transplantation, this first drained volume was discarded, replenishing the reservoirs with nutrient solution. Fertigation was performed using drip tapes with a flow rate of 1.6 L hour^{-1} and a spacing of 0.40 m. The nutrient solution was supplied intermittently according to the crop demand and climatic condition variation, with 30 min of supply every one or two hours, from 7 am to 7 pm. During the night, 15-minute irrigation was performed at 1 am only.

The nutrient solution was monitored daily through measurements of EC (using a digital conductivity meter) and pH (using a digital pH meter), which was maintained from 5.5 to 6.5 by adding a correction solution based on sulfuric acid (H_2SO_4 1N) or sodium hydroxide (NaOH 1N). The replacement of nutrients or water was accomplished through the addition of concentrated stock solutions or stored rainwater, maintaining the EC value at 1.8 dS m^{-1}.

Table 1. Physical and chemical characteristics of the raw rice husk used in the cultivation of mini tomato plants in pots and troughs.

Analysis	Results
Wet density (g L^{-1})	236
Dry matter (g 100g^{-1})	38
Dry density (g L^{-1})	90
Total porosity (m^3 m^{-3})	0.72
Aeration space (m^3 m^{-3})	0.58
Water available (m^3 m^{-3})	0.04
Buffer water (m^3 m^{-3})	0.00
WRC* 10 cm (m^3 m^{-3})	0.14
WRC 50 cm (m^3 m^{-3})	0.10
EC** (dS m^{-1})	0.07
pH (H_2O)	5.29

*WRC: Water Retention Capacity. **EC: Electrical Conductivity.

Spacing plants at 0.40 m within-row distance imposed plant density of 2.9 plants m^{-2}, totalling 19 plants per gully regardless of the system used. The plant training was done through an 8-m long plastic stake wrapped in hanging hooks approximately 3.0 m above the crop line and supported by the greenhouse structure.

After the emission of the first truss, the practice of defoliation was started, and this was done periodically throughout the growing cycle immediately after the emission of each new truss (Figure 1).

Defoliation was performed at three different levels: 0 - without defoliation, maintaining the complete sympodium (two leaves below and one leaf above the truss); 1 - removing one leaf per sympodium by withdrawing the second leaf below the inflorescence and retaining the leaves immediately below and above the truss; and 2 - removing two leaves per sympodium by removing the second leaf below the inflorescence and the leaf immediately above it, leaving only the leaf immediately below the truss. After harvesting the fruit of each cluster, the leaves below the cluster in question were also removed. Other crop management practices and pest and disease control treatments were carried out as they became necessary.

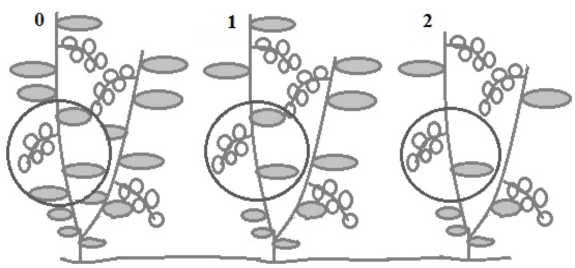

Figure 1. Defoliation levels applied in the mini tomato crop: 0) Without defoliation. 1) One leaf removed per sympodium. 2) Two leaves removed per sympodium.

Harvesting started at 81 days after setting (DAS), on November 20th, 2015, and ended at 270 DAS. The fruits were harvested weekly, counted, weighed to obtain the fresh matter and later dried in an oven to obtain the dry matter. The total soluble solids content (TSS) of the fruits was also evaluated using a refractometer. The leaves from the defoliation were counted, weighed to obtain the fresh matter, passed through foliar area measuring equipment (LI-31000C) to obtain the leaf area index (LAI) and then dried in an oven to obtain the dry matter. At the end of the experiment, the plants were removed and separated into fractions of fruit, leaves and stem. Stem length was obtained by means of linear measurement of the same with the use of a tape measure.

Randomized block experimental design with subdivided plots and three replications was used. The crop systems (pots and troughs) were allocated in the plot, a set of two cultivation gullies being considered, totalling 38 plants. The cultivars (Cherry and Grape) were allocated in a subplot with 19 plants, and the defoliation levels (without defoliation, removal of one and two leaves of the sympodium) were allocated in a sub-subplot with 6 plants. The far end plants were considered border plants. The data were submitted to analysis of variance and comparison of means by Tukey's test at 5% probability using the GENES software (Cruz, 2013).

Results and discussion

For the number of clusters, number of fruits per plant, TSS, final stem length, and dry matter partitioning among fruits, leaves and stem, there were no significant interactions among the system, cultivar or defoliation. In these cases, the results were interpreted separately for each of the factors (Table 2).

The trough system, compared to cultivation in pots, did not change the number of clusters produced, but it resulted in a higher number of fruits and, consequently, increased the dry matter partition of the fruits to the detriment of the proportion of dry matter destined to the leaves. In addition, the stem length of plants grown in troughs was 34 cm higher than that of plants grown in the pot system. However, there was no effect of the system on the dry matter partition to the stem. The fruits from the pot system had higher TSS content (Table 2).

The Cherry cultivar showed a higher number of clusters per plant, resulting in a higher number of fruits and a higher partition of dry matter to these organs than in the Grape cultivar (Table 2). The Grape cultivar presented a 14 % higher TSS value (7.38) than that measured in the fruits of the Cherry cultivar (6.34). Both values can be considered adequate according to the results obtained by Peil et al. (2014) for Cherry-type fruits and Takahashi and Cardoso (2015) for Grape-type fruits. The largest final stem length and the largest dry matter partition for this organ were observed for the Grape cultivar, which on the other hand presented lower dry matter partition to leaves (Table 2).

Regarding the effect of defoliation, in relation to plants with a complete sympodium, the number of clusters, the number of fruits, the length of the stem and the dry matter partition to this organ were unaffected when only one leaf was removed; nevertheless, they were reduced when two leaves per sympodium were removed (Table 2). However, as predicted, the dry matter partition to the leaves was gradually reduced, with benefits for the proportion of dry matter allocated to the fruits, the main assimilation sinks of the plant (Guimarães, Silva, Peternelli, & Fontes, 2009), as the defoliation intensity increased. Still, the TSS content was not affected by defoliation (Table 2).

Table 2. Main effects of crop system, mini tomato cultivar and defoliation experimental factors on the number of clusters and fruits, total soluble solids content (TSS), final stem length and dry matter partitioning to the different above-ground organs of the plant.

Factors	Nº clusters	Nº fruits plant^{-1}	TSS	Stem length (m)	Dry matter partitioning (%)		
					Fruits	Leaves	Stem
System							
Troughs	62^{ns}	864 A	6.78 B	8.29 A	57.9 A	17.2 B	24.9^{ns}
Pots	61	769 B	6.94 A	7.95 B	56.2 B	18.1 A	25.7
Cultivar							
Cherry	67 A	842 A	6.34 B	7.91 B	58.1 A	18.4 A	23.5 B
Grape	57 B	790 B	7.38 A	8.33 A	56.1 B	16.9 B	27.0 A
Defoliation							
0	64 A	888 A	6.93^{ns}	8.42 A	54.6 C	19.5 A	25.9 A
1	62 AB	827 A	6.88	8.17 A	56.6 B	17.9 B	25.5 AB
2	60 B	734 B	6.80	7.77 B	60.0 A	15.6 C	24.4 B
Mean	61.83	816	6.87	8.12	57	18	25
CV%	3.4	7.71	2.64	3.29	3.25	4.41	5.29

Means followed by the same letter in the column do not differ, at 5% probability, by the Tukey test. ns: not significant by the F test at 5% probability. Defoliation: 0, 1 and 2, respectively, without defoliation, one leaf and two leaves removed per sympodium.

For the Cherry cultivar, as the number of leaves removed per sympodium rose from zero to two leaves, the results for stem, leaf, fruit and total aerial dry matter, LAI and fruit production decreased progressively (Table 3). For the Grape cultivar, however, the plants without defoliation and those with one leaf removed did not differ statistically from each other regarding the same variables mentioned above, except for the dry matter of leaves. This differentiated behaviour between the cultivars with respect to defoliation is possibly related to the plant architecture of each cultivar. Cherry-type plants are larger, as indicated by the higher values of LAI and leaf, stem, fruit and total aerial dry matter production with complete sympodium (respectively, 3.98, 331.7, 385.2, and 1622.7 g plant^{-1}) compared to Grape-type plants (2.27, 187.9, 283.9, and 1015.4 g plant^{-1}).

The stem length was affected by the removal of two leaves, possibly due to the high restriction on photoassimilate production in this condition, which reduced the dry matter distribution to this organ, as indicated by the lower stem dry matter/total plant dry matter ratio (Table 2).

Table 3 shows the results for the cultivar x defoliation interaction for leaf, stem, fruit and total aerial plant parts dry matter production; LAI; yield per plant; and mean fruit weight. There were no significant interactions between the factors cultivar x system or between cultivar x system x defoliation for these variables.

For almost all the results, the Cherry cultivar presented higher values than the Grape cultivar at the three levels of defoliation adopted, except for variables LAI and stem dry matter, for which there were no differences between cultivars in the condition of removal of two leaves of the sympodium (Table 3).

Table 3. Dry matter production of stem, leaves, fruits and total aerial plant parts; leaf area index; fruit yield and mean weight of fruits of two mini tomato cultivars as a function of defoliation levels in recirculating substrate systems.

Cultivar	Defoliation		
	0	1	2
	Leaf dry matter (g plant^{-1})		
Cherry	331.7 Aa	247.9 Ba	152.9 Ca
Grape	187.9 Ab	151.4 Bb	110.2 Cb
CV (%)	9.1		
	Stem dry matter (g plant^{-1})		
Cherry	385.2 Aa	310.3 Ba	221.3 Ca
Grape	283.9 Ab	243.8 Ab	187.9 Ba
CV (%)	8.8		
	Fruit dry matter (g plant^{-1})		
Cherry	877.6 Aa	724.6 Ba	567.8 Ca
Grape	522.9 Ab	486.7 Ab	412.4 Bb
CV (%)	6.7		
	Total aerial plant dry matter (g plant^{-1})		
Cherry	1622.7 Aa	1309.6 Ba	958.0 Ca
Grape	1015.4 Ab	899.8 Ab	728.0 Bb
CV (%)	6.6		
	Leaf area index		
Cherry	3.98 Aa	2.91 Ba	1.83 Ca
Grape	2.27 Ab	1.88 Ab	1.33 Ba
CV (%)	11.9		
	Fruit yield (kg plant^{-1})		
Cherry	10.97 Aa	9.18 Ba	7.12 Ca
Grape	5.84 Ab	5.49 ABb	4.62 Bb
CV (%)	7.0		
	Mean weight of fruits (g)		
Cherry	11.6 Aa	10.9 Aa	9.7 Ba
Grape	7.1 Ab	6.8 Ab	6.4 Ab
CV (%)	4.8		

Means followed by the same capital letter in a row, or lower case in a column, do not differ at 5% probability by the Tukey test.

Due to the greater dry matter of the plant (Table 3), the demand for photoassimilates is higher in the Cherry cultivar. Thus, the removal of one single leaf of the sympodium has already caused damage to the dry matter production of all aerial organs of the plant and, consequently, to the fruit yield (Table 3). However, in the Grape cultivar, whose plants presented less dry matter (Table 3), the demand for photoassimilates is lower. Thus, a negative effect of the removal of only one leaf per sympodium on the variables related to crop growth was observed only for leaf dry matter production in this cultivar.

Meanwhile, when two leaves of the sympodium were removed, the growth variables were all negatively affected, indicating that in this condition, the sink:source ratio was increased to the point of damaging the production and supply of photoassimilates to all the aerial organs and, consequently, the fruit yield (Table 3).

The fruit yield values observed for the Cherry cultivar were 10.97; 9.18, and 7.12 kg plant^{-1} for defoliation levels 0, 1, and 2, respectively, and were 54 to 88% higher than those obtained with the Grape cultivar (5.84, 5.49, and 4.62 kg plant^{-1}, respectively).

For the Cherry cultivar, the fruit yield of plants that underwent defoliation of one and two leaves per sympodium was, respectively, 1.79 kg plant^{-1} (16%) and 3.85 kg plant^{-1} (35%) lower than that of plants with complete sympodium. However, for the Grape cultivar, a significant reduction of fruit yield was observed only between the absence of defoliation and the defoliation of two leaves per sympodium, being 1.22 kg plant^{-1} (21%). Even though both cultivars produced small sized fruits, the intensification of the defoliation before the formation of the fruits impaired fruit yield, but this effect was more pronounced for the Cherry cultivar, whose mean fruit size was significantly higher than that of the Grape cultivar regardless of the defoliation level adopted. Marcano (1995) observed the same effect of reducing fruit yield for salad tomatoes, but other authors, including Hachmann, Echer, Dalastra, Vasconcelos, and Guimarães (2014), emphasize that defoliation in salad tomato type can favor the production of the culture.

Thus, in the Grape cultivar, it would be possible to remove one leaf per sympodium without damage to the fruit yield to improve the ventilation of the crop canopy and to reduce the occurrence of disease. However, for the adoption of this practice, it is also necessary to consider the high labor demand, and additional studies are necessary to establish the benefit-cost relationship of sympodium defoliation.

Considering the long-season crop and the factors studied in this experiment, no data from a similar crop season were found for comparison purposes. Therefore, for an approximate comparison of the fruit yield data regarding their suitability, the average results obtained from the plants without defoliation in the first 45, 60, and 105 days of harvest were considered and were, respectively, 3.71, 5.42, and 6.64 kg plant^{-1} for the Cherry cultivar, and 2.45, 3.15, and 4.05 kg plant^{-1} for the Grape cultivar. Some experiments have been carried out under greenhouse and soilless cultivation conditions similar to those of the present study. For Cherry-type mini tomatoes, Rocha et al. (2010) obtained 2.09 kg plant^{-1} in a 45-day harvest period; Menezes et al. (2012) in a 60-day harvest obtained 5.76 kg plant^{-1}. Likewise, for Grape-type mini tomatoes, Takahashi and Cardoso (2015) obtained 2.50 kg plant^{-1} in 60 days of harvest; Cunha, Sandri, Vieira, Cortez, and Oliveira (2014) obtained 4.23 kg plant^{-1} in 105 days. Maciel, Fernandes, Melo, and Oliveira (2016) obtained yields from 2.77 to 5.64 kg plant^{-1} in the evaluation of mini tomato hybrids in a harvest of approximately 120 days. In this way, the fruit yield results obtained in the present study agree with other scientific works.

Cherry cultivar yield varied from 206 to 318 Mg ha^{-1} and Grape cultivar from 134 to 169 Mg ha^{-1}, respectively, between the removal of two leaves per sympodium and without defoliation. These values are considered above average, even when compared to salad-type tomato cultivars, as observed by Reis, Azevedo, Albuquerque, and Junior (2013) who obtained average yield of 123 Mg ha^{-1} and by Shirahige, Melo, Purquerio, Carvalho, and Melo (2010) who obtained from 80.7 to 140.5 Mg ha^{-1} with different Santa Cruz and Italian type tomato cultivars.

The mean weight of the fruits was not affected by the removal of one leaf, but it decreased by 16% with the removal of two leaves from the Cherry cultivar. The removal of one or two leaves from the Grape cultivar did not result in a significant reduction of mean fruit weight. Considering that the number of fruits was significantly reduced from the removal of two leaves per sympodium for both cultivars (Table 2), it can be inferred that the reduction of fruit yield observed with this practice is mainly due to a higher rate of flower and/or fruit abortion, which can be attributed to the degree of leaf area reduction (Table 3) and, consequently, to the decreased photo assimilate production caused by different levels of defoliation.

Considering the mean weight of fruits obtained in the plants without defoliation, the results are approximately 4 and 3 g lower than the description provided by the Cherry and Grape cultivar seed production companies, respectively. According to the classification recommended by Fernandes, Corá, and Braz (2007) for Cherry tomatoes, fruits from plants without defoliation are in the middle class (10 to 15 g, >25 ≤30 mm in diameter); and fruits from plants with one and two leaves removed are in the small class (5 to 10 g, >20 ≤25 mm in diameter). For Grape-type fruits, there are no classification references in the available literature, but it is believed that these are within the standard considered adequate by the Brazilian market.

The crop cultivation systems did not have a significant effect on leaf or stem dry matter production, LAI or mean fruit weight. However, the system x defoliation interaction was statistically significant for the variables fruit and total aerial plant dry matter production and fruit yield (Table 4). The trough system presented better results than the pot system in relation to the three variables for plants with complete sympodium, whereas for plants with one or two leaves removed, there were no significant differences between the systems. Therefore, from the moment the leaves are removed from the sympodium, the defoliation factor has a dominant effect on plant responses, effectively cancelling the system effect.

Concerning the abovementioned variables, defoliation showed a decreasing effect on plants cultivated in the trough system as its level increased, which did not occur in the same way in the pot system (Table 4). In this system, the plants without defoliation and with a leaf removed did not present differences between them in relation to fruit yield. Thus, it can be inferred that the plants in the trough system had their needs for water and nutrients satisfied, which possibly did not occur in the plants of the pot system due to the limited space for root development. It was observed that the plants cultivated in pots with complete sympodium wilted more frequently than the others, indicating that the root system did not always provide water absorption consistent with the high leaf area of these plants. Therefore, it is possible that there was a reduction of transpiration and, consequently, of fruit and total aerial plant part dry matter production as well as of fruit yield; these results are equivalent to those observed for plants with one leaf removed, which presented smaller leaf area.

The trough cultivation system provided better results due to questions related to plant root disposition, the availability of water and mineral nutrients and the height of the substrate layer. In this system, roots were not limited in their growth and expansion, as occurred in pots, in which the space between the walls is limited. In addition, the tension exerted by the walls of the pots on the water is larger, which may have impaired the availability of water for the plants. Associated with this, it was observed that the leaching solution drained at each fertigation was higher in the pot system than in the trough system due to the continuous set of roots/substrate formed by the group of plants in each trough, which held the solution for a longer period compared with the pot system.

Table 4. Dry matter production of fruits and total aerial plant parts and fruit yield of mini tomatoes produced in two recirculating substrate systems as a function of defoliation level.

System	Defoliation		
	0	1	2
	Dry matter of fruits (g plant^{-1})		
Troughs	773.3 Aa	641.2 Ba	504.2 Ca
Pots	627.2 Ab	570.1 Aa	476.1 Ba
CV (%)	6.7		
	Total aerial dry matter (g plant^{-1})		
Troughs	1431.8 Aa	1146.7 Ba	867.3 Ca
Pots	1206.4 Ab	1062.7 Ba	818.7 Ca
CV (%)	6.8		
	Production of fruits (kg plant^{-1})		
Troughs	9.3 Aa	7.7 Ba	6.0 Ca
Pots	7.5 Ab	7.0 Aa	5.7 Ba
CV (%)	7.0		

Means followed by the same capital letter in a row, or lower case in a column, do not differ at 5% probability by the Tukey test.

Another factor to be considered is the substrate height, which was 8 cm in the troughs and 22 cm in the pots (Figure 2).This factor is determinant for more uniform occupation of the substrate profile by the roots, especially in the case of the raw rice husk, in which the water retention capacity decreases significantly as the tension increases from 10 to 50 cm of water column (Table 1). It can be observed in Figure 2 that the roots of the plants occupied only the base of the substrate layer in the pots, whereas in the troughs, practically the whole height of the substrate was occupied. Thus, in practice, the volume of substrate that served as a reserve for water and mineral nutrients and space for root growth in pots was less than the 7 litres of the capacity of the container capacity.

The hypothesis that there was lower water availability in the pot system can be corroborated by the results showing higher concentration of soluble solids in the fruits from this system (Table 2), which is directly related to low water availability in the root medium.

Figure 2. Distribution of the roots of mini tomato plants in raw rice husk substrate removed from the trough (A) and pot (B) cultivation systems.

Conclusion

The Cherry cultivar presented greater plant growth, yield and mean fruit size than the Grape cultivar. However, Grape presented fruits with a higher concentration of sugars.

For the Cherry cultivar, it is necessary to maintain the complete sympodium to ensure greater plant growth and better fruit yield. However, for the Grape-type, the removal of one leaf per sympodium can be performed without affecting the total plant growth or the fruit yield in a significant way.

The trough crop system promotes greater plant and fruit growth as well as increased fruit yield for plants of both varieties maintained with complete sympodium.

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