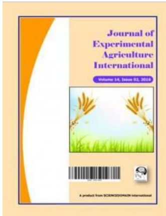

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Alternative Substrates for Production of Cherry Tomato Seedlings

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Authors' contributions

This work was carried out in collaboration between all authors. Author JS participated in the idea and management of the experiment, besides writing the article. Author JST was responsible for collecting, tabulating and analyzing the data. Author MTS participated in the management of the experiment from the implantation to the data collection. Author DFS participated in the handling of the experiment and writing the article. The authors ABSJ and APVC participated in the management and data collection of the experiment, as well as in the bibliographic review. Author KDSC guided the research. All authors read and approved the final manuscript.

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ABSTRACT

The cherry tomato crop has a high production cost, which can be reduced in part using alternative substrates. The objective of this study was to evaluate the different alternative substrates for production of cherry tomato seedlings. The experiment was performed in a completely randomized design with five treatments (T1: Bioplant® commercial substrate (control treatment); T2: Earthworm humus; T3: Soil; T4: Mixture of 50% soil + 50% earthworm humus; T5: Mixture of 75% soil + 25% earthworm humus) in four replicates. Seedlings were collected and evaluated at 28 days after sowing. There was significant effect of the substrates in relation to the traits plant height, leaf

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number, fresh matter of aerial part and dry matter of aerial part. Based on the dry matter of aerial part, the treatments T1, T2, T4, and T5 presented the best plant development due to the accumulation of photoassimilates. Most of the alternative substrates had similar behavior to the commercial substrate, being reflected in the plant vigor and yield. Finally, we concluded that there are alternative substrates capable of replacing the commercial substrate. The T5 treatment is the most indicated, since it did not differ from the commercial substrate in relation to the agronomic traits and presented a production cost of only 24% in relation to the commercial substrate cost.

Keywords: Initial development; production cost; tomato seedlings; organic compounds; cherry tomato.

1. INTRODUCTION

The tomato (*Solanum lycopersicum* Lam.) is a species originated from the Andean region that covers part of Chile, Colombia, Ecuador, Bolivia, and Peru [1]. Tomatoes are cultivated and consumed almost all over the world due to its organoleptic and nutritional characteristics. Its composition is rich in lycopene, vitamins of complex A and B and important minerals such as phosphorus and potassium, as well as folic acid, calcium and fructose [2].

The world's largest tomato producer is China with 52 million tons, followed by India, United States, and Egypt respectively with 18, 14, and 8 million tons. Brazil ranks ninth in the ranking of the world's largest tomato producers with 4 million tons [3].

There are five main groups of tomato in the country: Santa Cruz, Salad or Saladette, Cherry, Italian and Agroindustrial [4]. Among them, the cherry group has superior quality and better taste than traditional table tomatoes. Nowadays, the search for healthier and higher quality food has given more prominence to the cherry group. However, only a small portion of society has access to this tomato group due to its production cost, culminating in a high cost product for the consumer [5].

In this sense, the most advantageous production system of horticultural seedlings is in trays, which has exhibited superior performance in several aspects, since the economy with substrate reduction and the reduced area required in the greenhouse. In addition, it presents the advantage of lower cost for pests and diseases control, increased quality of produced seedlings, high survival index of seedlings after transplanting, lower labor utilization, reduction of the amount of seeds used, improvement of phytosanitary control, and earlier harvest [6].

These substrates should be formed from materials of mineral sources, organic or synthetic, only one material, or the mixture of two or more materials, being indispensable that the substrate exhibits desirable chemical, physical and biological characteristics [7]. For the production of alternative substrates, the use of materials easily available in the region and with low cost is necessary, besides providing favorable conditions to the root system development, seedling nutrition, and reduced possibility of contamination by phytopathogens [8].

The success of this system depends mainly on the quality of the substrate used, which will reflect in the final production. The commercial substrates are the most used, which add a higher cost to the final product when compared to alternative substrates made by the farmers themselves. However, there are few studies with cherry tomatoes regarding the substrate that will imply in better seedling development and the cost of the substrate [6].

Several authors confirmed that the substrate type interferes directly with the seedling quality components, such as [9,10,11] and [12], who respectively evaluated the development of seedlings of basil (*Ocimum basilicum* L.), eggplant (*Solanum melongena* L.), cabbage (*Brassica oleracea* L.), and cucumber (*Cucumis sativus* L.). The literature also mentions that the substrate price is a factor of great relevance for choosing the substrate to be used, since it influences the final cost of the seedling [13] and [10]. However, for cherry tomatoes this information still needs to be studied because little is known of the crop for these factors.

In view of the foregoing, objective of this study was to evaluate the different alternative substrates for production of cherry tomato seedlings.

2. MATERIALS AND METHODS

2.1 Site Location and Sowing Date

The experiment was carried out in a greenhouse at the Agricultural Sciences Center of the Federal

University of Alagoas (CECA/UFAL) located in the municipality of Rio Largo-AL (09° 28' 02" S; 35° 49' 43" W; 127 m) in February 2016.

2.2 Treatments and Experimental Design

Five substrates were evaluated and constituted as follows: T1: Bioplant® commercial substrate (control treatment); T2: Earthworm humus; T3: Soil; T4: Mixture of 50% soil + 50% earthworm humus; T5: Mixture of 75% soil + 25% earthworm humus, which chemical compositions are presented in Table 1.

The experimental design was completely randomized with five treatments and four replications. The sowing procedure was performed in trays with 98 cells. The experimental plot consisted of the 98 cell seedlings and the useful area was the 40 central seedlings of the tray. Before sowing, the cells of the trays were filled with the substrates corresponding to the treatments. Subsequently, a hole with 1 cm of depth was made to deposit the seed of the Carolina cultivar. The seedlings were irrigated once a day until 28 days after emergence.

2.3 Evaluated Parameters

The following traits were evaluated: plant height (AP) in cm; leaf number (NF) in units; fresh matter of aerial part (MFPA) in g; dry matter of aerial part (MSPA) in g; lap diameter (DC) in mm; root length (CR) in cm; seedling emergence (E) in %; emergence speed index (IVE), dimensionless; mean emergence time (TME) in days/seeds; production cost of substrates (CPS) in R$.$t^{-1}$ and US$.$t^{-1}$, adopting the average price of the region; relative cost (CR) in %, cost of the alternative substrates in comparison to the commercial substrate [14].

For AP, a millimeter ruler was used, measuring from the surface of the substrate until the last leaf insertion. The DC was measured using a digital caliper, at the lap height of the seedling. For MFPA, the seedlings were cut and then weighed in analytical balance. Likewise for MSPA, the seedlings were cut and placed in paper bags and transferred into forced ventilation oven at 65℃ for 72 hours and then weighed on analytical balance. The NF was counted per unit and CR was measured at the root of longer length with millimeter ruler. The variables E, IVE and TME were calculated according to [15], following the respective formulas below:

$E = \frac{N}{A} \times 100$, wherein:

N - Total number of germinated seeds;
A - Total number of sown seeds;

$IVE = \frac{E1}{N1} + \frac{E2}{N2} + \cdots + \frac{En}{Nn}$, wherein:

E1, E2, ..., En - Number of normal seedlings emerged in the first, second until the last count;

N1, N2, ..., Nn - Number of days of sowing to first, second until the last count;

$TME = \frac{\sum ni \times ti}{\sum ni}$, wherein:

ni - Number of seeds emerged per day;
ti - Incubation time (days);

Table 1. Chemical composition of the five substrates used in the production of tomato seedlings of the cherry group. Rio Largo-AL, UFAL, 2016

Parameters	Substrates*				
	T1	T2	T3	T4	T5
pH (CaCl)	5.00	7.40	5.10	6.30	5.70
H+Al (cmol.dm^{-3})	3.70	1.70	4.00	2.90	3.40
Al (cmol.dm^{-3})	0.01	0.01	0.04	0.02	0.03
OM (g.dm^{-3})	21.80	30.10	16.70	23.40	20.10
Ca (mmol.dm^{-3})	22.00	56.00	26.00	41.00	33.50
Mg (mmol.dm^{-3})	12.00	46.00	18.00	32.00	25.00
K (mmol.dm^{-3})	16.30	6.50	2.10	4.30	3.20
P (mmol.dm^{-3})	5.90	8.00	0.30	4.20	2.20
BS (mmol.dm^{-3})	50.00	108.50	48.00	78.30	63.10
CEC (mmol.dm^{-3})	87.00	125.50	88.00	106.80	97.40
V (%)	58.00	86.50	54.40	70.40	62.40
Mn (mg.dm^{-3})	4.70	140.20	11.40	75.80	43.60
Fe (mg.dm^{-3})	113.10	76.10	236.00	156.10	196.00
Cu (mg.dm^{-3})	21.20	1.00	0.40	0.70	0.50
Zn (mg.dm^{-3})	28.20	71.00	1.80	36.40	19.10

** T1: Bioplant® commercial substrate (control treatment); T2: Earthworm humus; T3: Soil; T4: Mixture of 50% soil + 50% earthworm humus; T5: Mixture of 75% soil + 25% earthworm humus*

2.4 Statistical Analysis

The results of the experiment were submitted to analysis of variance. When the F test was significant, the Tukey test was applied at (P = 0.05), using the computational software Minitab 17 [16].

3. RESULTS AND DISCUSSION

There was significant effect at P=0.01 and P=0.05 by the F test between the substrates respectively for the traits NF and AP and MFPA and MSPA (Table 2). The coefficient of variation for these traits was between 12.94 % and 18.28 %, being considered regular according to Ferreira [17].

Regardless of the proportion, the substrates formulated with earthworm humus (T2, T4, and T5) provided greater plant heights. Therefore, they differed statistically from the substrates T1 and T3, which presented lower plant heights. These substrates were important for this trait, since they were superior when compared to the commercial substrate T1 (control treatment). This fact is related to the amount of organic matter present in these materials, where several authors attribute its final seedling quality [18]. All the substrates provided higher AP when compared to the substrates studied by Rodrigues et al. [19]. These authors evaluated the tomato seedling production using trays of different cell volumes and substrates based on soil and organic compost, obtaining the maximum AP value of 5.61 cm, which is lower than the values found in the present study, evidencing the potential of the studied substrates.

For NF, only the substrate T3 differed from the others, providing the lowest leaf emission. Lower NF is not desirable because the tendency is that the plant synthesizes fewer photoassimilates with less leaves, which will reflect in less vigor and final production. Rocha [2] also mentioned the leaf importance, which is the main dry matter storage organ in the tomato crop. The difference of the T3 substrate with the others regarding NF trait can be explained by its chemical composition (Table 1), where the low P content is remarkable. The nutrient P participates in several metabolic processes in plants, such as energy transfer, synthesis of nucleic acids, glucose, respiration, synthesis and membrane stability. Moreover, it is responsible for leaf emission, since this element is used for the ATP synthesis and NADPH, which in turn are used for the synthesis of sugars in the fixation and reduction reactions of CO_2 [20]. Melo [21], who observed higher NF for treatments that received greater P amounts, also shares this statement. However, attention is required because very high P doses can cause toxicity to the plant.

In the evaluation of fresh matter of aerial part (MFPA), the substrates T2, T3, T4, and T5 did not differ among themselves and differed with the commercial substrate. This evidences that there are economically viable alternatives for replacing the commercial substrate, which leads to a decrease in the seedling cost. The alternative substrates differed from T1, which provided the smallest fresh matter of aerial part. This fact can be explained by analyzing the foliar tissue, where several authors concluded that the decreasing order of absorption is Ca>N>K and it can be observed in the chemical composition of the substrates (Table 1). The T1 substrate presents the lowest values of Ca and K and these elements may be the factors that led T1 to have the lowest MFPA [22].

Table 2. Mean results of plant height (AP), leaf number (NF), fresh matter of aerial part (MFPA) and dry matter of aerial part (MSPA) in tomato seedlings of the cherry group cultivated in trays with alternative substrates. Rio Largo-AL, UFAL, 2016

Substrates[1]	AP (cm)	NF (un.)	MFPA (g)	MSPA (g)
T1	9.70 b[2]	17.35 ab	0.70 b	0.11 ab
T2	13.49 a	22.60 a	1.34 a	0.15 a
T3	8.40 b	14.75 b	1.23 a	0.06 b
T4	13.18 a	21.67 ab	1.32 a	0.15 a
T5	13.87 a	22.62 a	1.33 a	0.15 a
QM	24.7470**	50.8400*	0.2966**	0.0067**
P	0.0003	0.0196	0.0002	0.0001
CV (%)	12.94	17.82	13.83	18.28

*[1/] T1: Bioplant® commercial substrate (control treatment); T2: Earthworm humus; T3: Soil; T4: Mixture of 50% soil + 50% earthworm humus; T5: Mixture of 75% soil + 25% earthworm humus. [2/] Means followed by the same letter in the column do not differ by Tukey test at P=0.05. ** Significant at P=0.01 by F test. * Significant at P=0.05 by F test*

Regarding the dry matter of aerial part (MSPA), the substrates T1, T2, T4, and T5 presented the greater plant development due to the accumulation of photoassimilates, which were statistically similar. Most of the alternative substrates had similar behavior to the commercial substrate for MSPA, which is a trait that influences plant vigor and yield. On the other hand, the T3 substrate had the lower result for MSPA, differing from the others. With the exception of T3, the other treatments (T1, T2, T4, and T5) presented MSPA greater than those found by Costa et al. [8], demonstrating the possibility of replacing the commercial substrate with another alternative, without loss of the seedling agronomic quality.

An association between AP and NF with MSPA was observed, since an increase in AP and NF conferred an increase in MSPA, i.e., these traits are somehow dependent. [22] also cited this relation between AP and NF with MSPA. For the variables DC, CR, E, IVE and TME, there was no significant differences at P=0.05 by the F test (Table 3). For these traits, the seedlings of cherry tomatoes performance is independent of the type of substrate used. Thereby, the alternative substrates had the same agronomic performance as the commercial one.

Results lower than the DC of the present study were observed by Costa et al. [8], which evaluated the effect of different types of substrates and obtained the value of 1.76 mm for the best treatment. The CR is an important parameter to discuss because it is responsible for seedling survival in the transplanting, besides being an indirect measure of the aeration of the substrate. Thus, plants with greater CR allow indicating that the substrate presents low resistance to root penetration and maintains adequate turgescence levels of the cells of the seedlings, which will reflect on vigorous seedlings Sampaio et al. [23]. In this aspect, all the alternative substrates (T2, T3, T4, and T5) exhibited the same result as the commercial substrate and even superior to those found by Klein et al. [24].

For E, IVE and TME, the alternative substrates (T2, T3, T4 and T5) obtained the same performance as the commercial substrate (T1), maintaining the same time of permanence of the seedlings in the nursery, which will promote resistance to conditions of the cultivation environment [8]. These substrates probably have interesting characteristics associated with a good substrate, such as porosity, fertility, and sterility. The great values of E, IVE and TME demonstrated that the substrates used had high water holding capacity, besides allowing the movement of water and air, providing an ideal condition for the emergence and development of the seedlings. Similar values of E, IVE and TME can be observed in the researches of Rios et al. [25].

When analyzing the production cost of the substrates, the price of the ton of the commercial substrate is relatively higher than the other substrates evaluated (Table 4). The price of the commercial substrate (T1) was US$ 9,734.38 per ton, well above the production cost of the alternative substrates, ranging from 21 to 32% of the T1 cost. These values demonstrate how much of the production cost could be reduced by replacing the commercial substrate with an alternative source. This implies a greater economic return to tomato producers and lower price of the product in the commerce, enabling a greater consumption of cherry tomatoes by the population.

Table 3. Mean values for lap diameter (DC), root length (CR), emergence (E), emergence speed index (IVE) and mean emergence time (TME) in tomato seedlings of the cherry group cultivated in trays with alternative substrates. Rio Largo-AL, UFAL, 2016

Substrates[1/]	DC (mm)	CR (cm)	E (%)	IVE (ad.)	TME (dias)
T1	2.64	12.67	85.71	21.76	5.47
T2	3.02	12.00	82.48	21.54	4.10
T3	2.28	12.15	69.05	16.85	6.24
T4	3.12	13.75	79.76	21.17	5.35
T5	2.95	13.08	89.45	20.66	7.08
QM	0.4646^{ns}	2.0230^{ns}	239.8884^{ns}	16.4016^{ns}	2.7956^{ns}
P	0.1200	0.2059	0.4023	0.7344	0.3739
Mean	2.80	12.73	81.29	20.40	5.65
CV (%)	16.45	8.61	18.36	28.00	26.82

[1/] T1: Bioplant® commercial substrate (control treatment); T2: Earthworm humus; T3: Soil; T4: Mixture of 50% soil + 50% earthworm humus; T5: Mixture of 75% soil + 25% earthworm humus. ^{ns} Not significant at P=0.05 by F test

Table 4. Economic analysis of the production of the substrates. Rio Largo-AL, UFAL, 2016

Parameters	Substrates[1/]				
	T1	T2	T3	T4	T5
CPS[2/] (R$.t^{-1})	3125.00	1000.00	667.00	834.00	750.00
CPS (US$.t^{-1})[3/]	9734.38	3115.00	2077.71	2597.91	2336.25
CR[4/] (%)	----	32.00	21.34	26.69	24.00

[1/] T1: Bioplant® commercial substrate (control treatment); T2: earthworm humus; T3: Soil; T4: Mixture of 50% soil + 50% earthworm humus; T5: Mixture of 75% soil + 25% earthworm humus. [2/] CPS: Production cost of the substrates for one ton of the substrate with average prices of the region. [3/] Converted price in dollar by exchange rate of 3.115. [4/] CR: Relative cost of the alternative substrate compared to the commercial substrate

4. CONCLUSION

From the results presented in this study, we concluded that there are alternative substrates that can replace the commercial substrate. The substrates T2, T4 and T5 are recommended because there is no reduction of quality and vigor of the seedlings and the relative cost varies from 24 to 32% in relation to the commercial substrate. This leads to a better financial result for the grower and enables more access of cherry tomatoes to the population.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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