POTENTIAL OF TANNERY SLUDGE AND COFFEE MILL IN SUBSTRATES FOR CAMBUCI PEPPER PRODUCTION

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ABSTRACT: The objective of this study was to evaluate the fruit production, development and quality of cambuci pepper seedlings produced in a substrate formulated by mixing dehydrated tannery sludge with composted coffee grinds. The proportions (v/v) of 5, 10, 15, 20, 50 and 100% tannery sludge mixed with coffee grinds were tested and compared with those of the commercial substrate Provaso®. The experiment was implemented in two stages in a greenhouse using a randomized block design. In the first stage, 480 plants were subjected to the treatments, and the emergence, biometric, physiological and quality characteristics of the plants were evaluated. In the second stage, 96 of these seedlings were planted on the ground, after which their survival and fruit production were evaluated. The Scott–Knott and Dunnett tests ($p < 0.05$) were applied, in addition to correlation analysis comparing the stages. Tannery sludge/coffee mill proportions of 10/90%, 15/85% and 20/80% had the greatest effects on seedling development and quality. The correlation analysis between the stages did not show significant results. The substrate with 20% tannery sludge presented the highest averages in the second stage.

Keywords: seedling quality, waste utilization, physiological performance.

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ABSTRACT: The objective of this study was to evaluate fruit production and the development and quality of cambuci pepper seedlings produced in a substrate formulated by mixing dehydrated tannery sludge with composted coffee moinha. The proportions (v/v) of 5, 10, 15, 20, 50 and 100% tannery sludge mixed with coffee moinha were tested and compared with those of the commercial substrate Provaso®. The experiment was implemented in two stages in a greenhouse using a randomized block design. In the first stage, 480 plants were subjected to the treatments, and the emergence, biometric, physiological and quality characteristics of the plants were evaluated. In the second stage, 96 of these seedlings were planted in the soil, after which their survival and fruit production were evaluated. Scott–Knott and Dunnett tests ($p < 0.05$) were applied, in addition to correlation analysis comparing the steps. Tannery sludge/coffee moinha proportions of 10/90%, 15/85% and 20/80% presented the highest values of development and seedling quality. The correlation analysis between the steps did not show significant results. The substrate with 20% tannery sludge had the highest average yield in the second stage.

Keywords: seedling quality; waste recovery; cost savings.

1 INTRODUÇÃO

Vegetable farming in Brazil is developed predominantly by family farming, and the use of seeds and substrates increases the production cost in propagation nurseries (CLEMENTE, 2015; MENEGHELLI *et al*., 2018). Commercial substrates account for 16.31% of the production of vegetable seedlings (SOUZA; GARCIA, 2013). The production of agricultural substrates from waste has been studied in different studies with the aim of developing an alternative substrate from waste to reduce production costs (BERILLI *et al*., 2019).

Among the residues that can be used in the development of substrates, tannery sludge stands out as an organic residue formed by the physical-chemical and biological treatment of effluent from the animal skin tanning process (HOEHNE *et al*., 2017; FUNDAÇÃO ESTADUAL DO ENVIRONMENT, 2018). This residue has a high content of organic matter and mineral elements essential to plants (BERILLI *et al*., 2018a), in addition to total N, Ca, Mg and Na (SILVA *et al*., 2015).

Tannery sludge combined with other organic waste provided superior or similar quality to commercial substrates in the production of vegetable seedlings such as eggplant (Berilli *et al*., 2021), chili pepper (BERILLI *et al*., 2020), peppers (BERILLI *et al.)*. ., 2019), biquinho pepper (ALMEIDA *et al*., 2017), arugula (HOEHNE *et al*., 2017) and lettuce (BASTOS; MERIZIO; ARAÚJO, 2011), indicating their potential as biofertilizers and substrate ingredients (BERILLI *et al*., 2018a).

A residue that can complement the benefits of tannery sludge is coffee grinds due to the high concentrations of nitrogen, phosphorus and potassium. The coffee mill is generated by the mechanical drying of coffee beans, which are formed by plant remains from the coffee plant (Meneghelli *et al*., 2018), and tests on the use of this mill as a substrate have shown advantages for the production of cabbage (MENEGHELLI *et al*., 2018; OLIVEIRA *et al*., 2018), cucumber (GUISOLFI *et al*., 2018), eggplant (MENEGHELLI *et al*., 2017) and tomato (KRAUSE *et al*., 2017) plants.

Peppers of the Capsicum genus are cultivated throughout the national territory, enriching Brazilian culture and biodiversity. Cambuci peppers, which are less spicy and even sweet, are widely used in stews and preserves, in addition to being sold in supermarkets and even exported (RIBEIRO, 2008). There are no studies on mixing tannery sludge with coffee grinds to produce cambuci pepper seedlings, which justified this experiment.

Furthermore, the composition of the substrate can directly influence the nutritional and productive performance of vegetables in the field (BHARATHI; RAVISHANKAR, 2018; OLIVEIRA *et al*., 2018). Following this logic, the present study aimed to evaluate the development and quality of cambuci pepper plants produced with tannery sludge mixed with coffee grinds in comparison with those produced with commercial Provaso® substrate and to measure the fruit production of these plants in the field.

2 MATERIALS AND METHODS

The experiment was implemented at the Federal Institute of Education, Science and Technology of Espírito Santo – Campus de Alegre, in the Municipality of Alegre/ES, and lasted six months (Jul./2020 – Jan./2021). The work was divided into two stages in a greenhouse with sprinkler-irrigated benches, which followed a randomized block design (DBC). The first had eight treatments, six replications and 10 seedlings per experimental unit, totaling 80 seedlings per replication and a total of 480. The second stage included four replications, each consisting of 24 plants (three plants per experimental unit), for a total of 96 useful plants. Seven proportions of tannery sludge (LC)/coffee mill (MC) and a commercial substrate (SC) were tested as controls (Table 1).

Table 1. Discrimination of treatments with different proportions (v/v) of organic residues in the substrate and commercial substrate (control)

Component	Proportion (%)							
	TSC	TMO100	TLC05	TLC10	TLC15	TLC20	TLC50	TLC100
Subst. Commercial*	100	0	0	0	0	0	0	0
Tannery sludge	0	0	5	10	15	20	50	100
coffee grinder	0	100	95	90	85	80	50	0

Source: the authors
Note: ***Provaso**® commercial substrate

Bovine LC, anaerobically decomposed and dehydrated, was obtained from the company Capixaba Couros LTDA, located in the Municipality of Baixo Guandu/ES. The MC, obtained from coffee dryers around Alegre/ES, was composted with garden grass using a rotated windrow. The commercial substrate used was the organic compound fertilizer class A "Provaso", batch 11/2019, which was bottled in November 2019 and stored for 12 months (Map Registration n° 10586 10.000-5, EP-ES 10.586-4). This substrate is composed of sugarcane bagasse, filter cake from a sugarcane factory, manure, poultry litter and ash. The chemical attributes of the waste are described in Table 2.

Table 2. Chemical characteristics of LC, MC and SC used in the evaluated treatments.

Det.	**MO**	**Corg**	**N**	**P**	**K**	**Ca**	**Mg**	**S**	**Na**	**Fe**	**Cr**	**pH**	**CTC**	**MOC**	**C/N**	**CTC/C**
Unid	---------------------- % ----------------------										mg/kg	-	mmol/kg	%	-	-
LC*	36	18	1	1	0,2	14	1	3	0,1	0,4	196	7,5	70	31,7	15/1	4/1
Class	-	-	B	M	A	A	M	A	-	-	-	Bom	-	-	Bom	-
MC*	58	28	3	0,6	2	2	0,4	0,5	0,04	1,7	16	6,4	915	50	11/1	33/1
Class	Good	-	B	M	A	M	B	M	-	-	-	Good	-	-	excellent	-
SC**	-	15	1	-	-	-	-	-	-	-	-	6.5	195	-	15/1	13

Source: * Transcription of the results of analyses carried out by the Labominas Agronomic Laboratory, methodology recommended by the Ministry of Agriculture; ** manufacturer - information on the product label; humidity - 50%
Note: Comp: component; LC: tannery sludge; MC: coffee grinder; SC: commercial substrate; MO: organic matter; N: nitrogen; P: phosphorus; K: potassium; Ca: calcium; Mg: magnesium; S: sulfur; Na: sodium; Fe: iron; Cr: chromium; pH: hydrogen potential; CTC: cation exchange capacity; MOC: compostable organic matter; C/N: carbon/nitrogen ratio; CTC/C: CTC/carbon ratio. Det: determination; Unit: unit; Val: value; class: interpretation classes (B: low; M: medium, A: high), according to analyses carried out by the Labominas Agronomic Laboratory based on Kiehl (1985)

Cambuci pepper seeds (*Capsicum baccatum* L.), manufacturer Topseed, expiration date: Nov./2021, were used, with 80% germination and 99% purity. Sowing was carried out with three seeds per cell. The propagation stage analyses were based on works by Oliveira *et al*. (2014), Crispim *et al* . (2015) and Almeida *et al* . (2017).

The percentage of emergence (EMER) was evaluated 17 days after sowing (DAS), followed by thinning, leaving one seedling per cell (more vigorous). Afterwards, the number of expanded leaves (NF), plant height (AP), in cm, and collar diameter (DC), in mm, were evaluated using a ruler and digital caliper. The relative chlorophyll content was determined using a portable chlorophyll meter (model SPAD-502, Minolta brand) at approximately 7:00 am based on the average of three measurements on different leaves of all the seedlings.

During this period, the nitrogen balance indices (NBI-G and NBI-R), total chlorophyll content (SFR-G and SFR-R), anthocyanin content (ANT-RG and ANT-RB) and flavonoid content (FLAV) were estimated with the aid of a fluorometer with multiple light excitation sources (ultraviolet, blue, green and red) (Model Multiplex®, brand Force A). This analysis took place between 8 and 11 am, with the equipment pointed at the canopy, from top to bottom, at an angle of approximately 45 degrees, on the adaxial side of the leaves (BERILLI *et al*., 2018b).

Destructive evaluations were performed at 45 DAS using six plants from each experimental unit at the IFES Phytotechnics Laboratory. The seedlings were washed under running water, and the aerial parts were separated from the root system. The leaf area (FA), in cm², was obtained using a bench leaf area meter (model LI-3100C, brand LI-COR®). The fresh shoot mass (MFPA) and fresh root mass (MFR) were evaluated on an electronic scale (with an accuracy of 0.001 g).

The root variables—length (CR), in cm; projected area (PAR); surface area (ASR), in cm²; average diameter (DMR), in mm; and volume (VR), in cm³—were measured using a digitizer (model STD4800, Epson® brand) and software (WinRHIZO®, Regent Instruments). Then, the aerial part dry mass (MSPA) and root dry mass (MSR) were evaluated (in g) using an electronic scale (accuracy of 0.001 g). After remaining for 72 hours in an oven with forced air circulation at 65°C, the plants were packed separately in identified paper bags.

The chlorophyll a and b contents (mmol m^{-2}) were also determined by extractions obtained from 5 mm diameter leaf discs taken from three seedlings from each treatment using dimethyl sulfoxide (DMSO) (10 mL/sample). The samples were heated in a water bath for 25 min (65°C), and the absorbance of chlorophyll was measured at 480 nm (A480), 649 nm (A649) and 665 nm (A665) using a spectrophotometer (model SP-2000, Spectrum brand) (HISCOX; ISRAELSTAM, 1979; WELLBURN, 1994).

The quality of the seedlings was assessed using the Dickson Quality Index (DQI), an indicator that compares the effects of production practices in nurseries in assessing the relative quality of the seedlings over a certain period. The IQD is obtained from the values of MST = total dry mass (g); AP (cm); DC (mm); MSPA (g); and MSR (g) through the following expression (DICKSON; LEAF; HOSNER, 1960):

$$IQD = \left[\frac{MST}{\frac{AP}{DC} + \frac{MSPA}{MSR}} \right] \quad (1)$$

After evaluation of the propagation phase, suitable seedlings were transplanted into the soil. This phase followed the recommendations of Ribeiro (2008). The harvest began 115 days after sowing (DAS) and lasted 50 days, with five harvests starting 48 days after transplanting (Sept./2020 and Jan./2021). The pepper fruit used in the experiment was flat in shape and not suitable for harvest (Ribeiro, 2008); therefore, the harvest point was defined based on the periods of 110 and 120 DAS (indication of the seed producer), on the color green and measuring 4 x 5 cm (length x dia). The soil attributes of the crops are shown in Table 3.

Table 3. Soil attributes in the seedling cultivation area.

Det.	**M.0.**	**pH**	**P¹**	**K**	**Ca**	**Mg**	**Al**	**H+Al**	**SB**	**CTC**	**t**	**T**
Unid.	Dag/ dm³	Água	-- mg/dm³ --		------------------------- cmol$_c$/dm³ -------------------------							
Val.	1,0	6,2	83,5	247	3,4	0,9	0,0	0,7	4,9	5,6	5,6	4,9
Class.	B	B	M	A	M	M	B	B	M	M	M	M
Det.	m	V	P rem	At	s	B	Zn	Mn	Ass	Faith	Sand + silt	Clay
Items.	----- % -----		mg/L	--------------------- mg/dm $^{-3}$ -----------------------							g/kg	
Val.	0.0	88.0	35.5	ns	59	0.2	3.6	23	1.3	52	740	260
Class.	B	A	TM	-	A	B	A	A	M	A	two	two

Source: Transcription of the results of analyses carried out by the Labominas Agronomic Laboratory. Class. : Interpretation classes, according to Prezotti *et al* . (2007)

Note: Det: determination; Unit: unit; Val: value; class. : interpretation classes (B: low; Medium, A: high; TM: medium texture); MO: organic matter; pH: hydrogen potential; P: phosphorus; K: potassium, Ca: calcium, Mg: magnesium, Al: aluminum (Acidity Exchangeable cations); H+Al: potential acidity; SB: sum of bases; CTC: cation exchange capacity; T: CTC at pH 7.0; t: effective CTC; m: aluminum saturation; V: base saturation; P rem: remaining phosphorus; Na: sodium; S: sulfur; B: boron; Zn: zinc; Mn: manganese; Cu: copper; Fe: iron. Type 2 soil, according to Normative Instruction No. 2/2008, from the Ministry of Agriculture

At this stage, variables related to the fruit and average productivity were analyzed. The length and diameter of the fruit (cm) were evaluated with a digital caliper, and the mass (g and kg) was measured with an analytical balance (accuracy of 0.0001 g). The average productivity was obtained as follows: the sum of the weight of fruits/plant was multiplied by the number of plants per treatment. Then, both the number of fruits and the weight were calculated for a planting area of 1 ha (20 thousand plants/ha).

Statistical analyses were performed using R and RStudio software. The data obtained were checked for normality of errors (Shapiro–Wilk test) and homogeneity of variance (Bartlet test). Analysis of variance was performed, and if significant differences were found, the means were compared with each other using the Scott–Knott test ($p < 0.05$) with the “Expdes” package. The Dunnett test ($p < 0.05$) using the “Asbio” package was used to compare the waste mixtures with the commercial substrate. Pearson's correlation analysis was used to compare the variables from the first and second stages using the “color” function.

RESULTS AND DISCUSSION

For NF, the substrates composed of 10, 15, 20 and 50% LC provided higher averages than did the other treatments, including the commercial substrate. The highest AP was achieved at a proportion of 10% LC. Substrates with percentages of 10, 15 and 20% obtained the highest values for AF, with TLC20 being 141% greater than that of the commercial substrate (Table 4).

In an experiment on the production of chili pepper seedlings, the analyzed variables had effects similar to those in the present study, with mixtures of LC with Bioplant® and the commercial substrate Provaso® tested (BERILLI *et al*., 2020). In the present study, treatments with positive effects on growth characteristics probably combined the chemical qualities of the two residues while reducing the negative effects presented by treatments with greater quantities of residues.

Table 4. Average values for emergence percentage (EMER), number of leaves (NF), plant height (AP), stem diameter (DC) and leaf area (AF) of cambuci pepper plants.

Treat.	**EMER (%)**	**NF (und)**	**AP (cm)**	**DC (mm)**	**AF (cm²)**
TSC	66,4 a	3,9 c	3,8 d	1,0 a	2,4 c
TMO100	70,4 a	4,1 c	4,8 c*	1,0 a	4,5 b*
TLC05	71,3 a	4,6 b*	5,2 b*	1,0 a	4,9 b*
TLC10	61,7 a	5,2 a*	5,5 a*	1,0 a	5,8 a*
TLC15	64,3 a	5,1 a*	5,1 b*	1,0 a	5,8 a*
TLC20	70,3 a	4,9 a*	5,0 c*	1,0 a	5,8 a*
TLC50	68,8 a	5,4 a*	4,5 c*	0,9 a	4,6 b*
TLC100	66,6 a	4,4 b*	3,5 d	0,8 a	3,2 c
Média	67,5	4,7	4.7	1.0	4.6
CV (%)	14.0	6.5	4.7	13.6	14.6

Source: prepared by the authors

Note: Treat. : treatments, TSC: 100% commercial substrate, TMO100: 100% MC, TLC05: 5% LC, TLC10: 10% LC, TLC15: 15% LC, TLC20: 20% LC, TLC50: 50% of LC, TLC100: 100% of LC, MG: general average, CV: coefficient of variation. Means followed by the same letters in the same column do not differ from each other according to the Scott–Knott test at the level of $p < 0.05$. Means followed by * differ from the treatment with commercial substrate (TSC) at the level of $p < 0.05$ according to Dunnett's test.

The higher values of the growth variables in relation to the commercial substrate seemed to be related to the nutrients in the residues tested, such as nitrogen, which had a greater content than the commercial substrate. Nitrogen is part of the chlorophyll molecule (PAGLIARINI; CASTILHO; MARIANO, 2014) and is directly linked to photosynthetic efficiency, which positively affects plant growth (MAIA JÚNIOR *et al*., 2017). This advantage can be seen in the NF, AP and AF results.

The nutritional composition of LC, mainly Ca, Mg, N, P and S, seems to favor the development of seedlings (BERILLI *et al*., 2014, 2018a, 2020). Magnesium is an important component of the chlorophyll structure (TAIZ *et al*., 2017), and the Mg content in LC, which is more than double that of mills, may also increase the aforementioned growth of the seedlings.

The higher AF values may be attributed to phosphorus in greater quantities in the LC than in the MC. Phosphorus, such as ATP, is a component of the nucleotides used in plant energy metabolism. The accumulation of biomass and plant growth are related to the increase in photosynthesis and the formation of sucrose and starch. Thus, AF is an important structure in plants for the production and accumulation of biomass through the photosynthetic process (TAIZ *et al*., 2017).

Lopes *et al* . (2019) demonstrated the positive association between the availability of N and K contained in manure and leaf expansion, in which the height of radish plants showed quadratic relationships depending on the application of this manure. Similarly, the relevance of the N and K contents present in the LC and MC for the growth variables analyzed was evident in the treatments, with averages above the commercial substrate.

Treatments with more than 10% LC promoted inferior results for AP. Residue analysis (Table 2) revealed that, compared with LC, MC had greater amounts of organic matter (OM) and organic carbon (Corg) and a greater carbon-nitrogen (C/N) ratio. Furthermore, the density of MC was lower than that of LC, which probably provided greater porosity to the substrate and a more favorable environment for root development.

On the other hand, the sodium concentration of the LC (0.08%) used was twice that of the MC (0.04%), and experiments with MC indicate that its salinity causes harm to plants with an increase in its concentration in the substrate (KRAUSE *et al*., 2017; ALMEIDA *et al*., 2018; MENEGHELLI *et al*., 2018). Research with LC also indicated that increasing the proportion of this residue in the substrate causes losses to seedlings (BERILLI *et al*., 2018b; QUARTEZANI *et al*., 2018). The lower proportions of LC in the substrate indicate that the nutrient content of this residue is associated with the chemical and physical advantages of the mill, reducing the negative effects of the higher salinity presented by the LC.

The mixture of 10% LC + 90% MC presented the greatest average fresh and dry matter of the seedlings, including seedling quality. The commercial substrate provided lower averages for the MFPA, MFRA, MSPA and MSRA variables. The highest IQD values occurred in the TLC10 (10% LC + 90% MC) and TLC20 (20% LC + 80% MC) treatments (Table 5). These results may be related to the calcium (14.3%) and sulfur (3.24%) contents of the LC, which are classified as having high concentrations for organic fertilizers, while the values of 1.6% and 0.47% of the MC are interpreted as being in the medium class for this type of fertilizer (Table 2).

Table 5. Average values of fresh shoot matter (MFPA), fresh root matter (MFR), shoot dry matter (MSPA), root dry matter (MSRA) and the Dickson quality index (DQI) of cambuci pepper plants grown on different substrates.

Treat.	**MFPA**	**MFRA**	**MSPA**	**MSRA**	**IQD $^{-3}$**
	---------- g $^{-2}$ ----------		**---------- g $^{-3}$ ----------**		**Index**
TSC	10.7d	4.5c	17.8c	5.3c	5.2b
TMO100	17,6 b*	6,6 b	26,2 b	7,0 b*	5,8 b
TLC05	19,3 b*	8,4 a*	27,7 b*	7,6 b*	6,6 b
TLC10	22,6 a*	9,5 a*	37,5 a*	8,4 a*	7,1 a
TLC15	20,1 b*	9,4 a*	35,6 a*	9,0 a*	8,3 a*
TLC20	20,4 b*	9,7 a*	36,8 a*	8,5 a*	8,2 a*
TLC50	15,0 c*	7.7a*	30.6a*	8.2a*	6.2b
TLC100	9.9 d	6.3b	21.1c	5.4c	5.7 b
Average	17.0	7.7	29.2	7.4	6.6
CV (%)	11.6	19.6	17.5	17.2	21.4

Source: prepared by the authors

Note: Treat. : treatments, TSC: 100% commercial substrate, TMO100: 100% MC, TLC05: 5% LC, TLC10: 10% LC, TLC15: 15% LC, TLC20: 20% LC, TLC50: 50% of LC, TLC100: 100% of LC, MG: general average, CV: coefficient of variation. Means followed by the same letters in the same column do not differ from each other according to the Scott–Knott test at the level of $p < 0.05$. Means followed by * differ from the treatment with commercial substrate (TSC) at the level of $p < 0.05$ according to Dunnett's test.

There was a decrease in the average MFPA from the 15% LC proportion, with the lowest value occurring at the 100% proportion. This result may be related to the fact that certain elements, such as sodium, are toxic to plants. A possible increase in the sodium content of the substrates, due to the addition of LC to the mixtures, can stimulate a reduction in the water potential of the substrate (SECCO *et al*., 2010), negatively influencing water absorption by the roots (ALMEIDA *et al*., 2018). This would impair the translocation of water from the roots to the aerial parts of the plants and the accumulation of fresh matter in the aerial parts.

Dietrich *et al* . (2021) noted that proportions greater than 15% of LC mixed with commercial substrate proportionally restricted the development and quality of papaya cv. Golden THB, damage related to toxicity due to the high concentration of salts, mainly sodium.

However, in other experiments, the accumulation of matter in seedlings of other peppers was associated with higher proportions of LC, suggesting the existence of different tolerances or variations in residue composition. In pepper, mixing between 32.7% and 48.2% of the LC in urban waste compost was most appropriate (BERILLI *et al*., 2019). A proportion of 30% LC mixed with the commercial substrate Bioplant® resulted in increased IQD, MFR, MSPA and MSR in biquinho pepper seedlings (ALMEIDA *et al*., 2017).

The best means for the root variables occurred with treatments with 100% MC and 5, 10 and 15% LC, except for ASR and DMR, which did not show significant differences (Scott–Knott test). On average, the TLC20 and TLC50 treatments were superior to the commercial substrate in terms of the CR (Table 6). It is suspected that the decrease in RV, in proportions above 20% of LC, is due to impediments in the absorption of water and solutes by the roots due to a decrease in the osmotic potential of the substrate, triggered by sodium at levels harmful to the seedlings (ALMEIDA *et al*., 2018). The highest CR averages compared to those of pure Bioplant® and Provaso® also occurred in biquinho pepper seedlings when 30% and 70% of the LC was added to Bioplant® (ALMEIDA *et al*., 2017).

Table 6. Mean values of length (CR), area projection (PAR), surface area (ASR), average diameter (DMR) and volume (VR) of roots of Cambuci pepper plants grown on different substrates.

Treat.	**CR cm**	**PAIR cm2**	**ASR cm2**	**DMR mm $^{-2}$**	**VR cm3 $^{(-2)}$**
TSC	70.8b	3.8 b	13.4 to	49.0 to	16.3b
TMO100	89.3 a	4.8 to	15,1 a	48,6 a	19,5 a
TLC05	90,2 a	4,9 a	14,2 a	49,8 a	21,0 a
TLC10	98,0 a	4,6 a	14,3 a	46,4 a	18,7 a
TLC15	93,0 a	4,5 a	14,2 a	48,4 a	17,8 a
TLC20	91,9 a	4,3 b	13,6 a	47,6 a	16,5 b
TLC50	85,5 a	4,2 b	13,1 a	48.5 to	16.3b
TLC100	75.5b	3.8b	12.0 to	46.1 a	13.5b
Average	86.8	4.4	13.7	48.1	17.4
CV (%)	7.7	12.1	12.6	17.0	17.0

Source: prepared by the authors

Note: Treat. : treatments, TSC: 100% commercial substrate, TMO100: 100% MC, TLC05: 5% LC, TLC10: 10% LC, TLC15: 15% LC, TLC20: 20% LC, TLC50: 50% of LC, TLC100: 100% of LC, MG: general average, CV: coefficient of variation. Means followed by the same letters in the same column do not differ from each other according to the Scott–Knott test at the level of $p < 0.05$. Means followed by * differ from the treatment with commercial substrate (TSC) at the level of $p < 0.05$ according to Dunnett's test.

The compound indices obtained using the fluorometer increased as a function of the gradual increase in the amount of LC in the substrate mixtures. The highest values for nitrogen balance (NBI-G and NBI-R) and total chlorophyll index (SFR-G and SFR-R) occurred at the proportion of 100% LC, including values above the commercial substrate. No significant differences were detected for the anthocyanin index ANT_RG (Table 7).

Table 7. The average chlorophyll content (SFR-G and SFR-R), flavonoid content (FLAV), anthocyanin content (ANT-RG and ANT-RB) and nitrogen balance (NBI-G and NBI-R) of the leaves of the cambuci pepper plants were determined via a Multiplex® fluorometer.

Treat.	SFR_G	SFR_R	FLAV	ANTH_RG	ANTH_RB	NBI_G $^{-1}$	NBI_R $^{-1}$
TSC	1.4d	1.3d	0.8c	-0.1 to	-0.8 b	1.6 b	2.2b
TMO100	1,4 d	1,3 d	0,8 c	-0,1 a	-0,8 b	1,6 b	2,1 b
TLC05	1,5 c*	1,4 c*	0,8 c	-0,1 a	-0,8 b	1,7 b	2,3 b
TLC10	1,6 c*	1,5 b*	0,8 b*	-0,1 a	-0,8 b	1,6 b	2,2 b
TLC15	1,6 b*	1,5 b*	0,9 b*	-0,1 a	-0,8 b	1,5 b	2,2 b
TLC20	1,6 b*	1,5 b*	0,9 a*	-0,1 a	-0,8 b	1,5 b	2,2 b
TLC50	1,8 a*	1,7 a*	0,9 a*	-0,1 a	-0,7 a*	1,5 b	2,2 b
TLC100	1,7 a*	1,6 a*	0,8 c	-0,1 a	-0,7 a*	2,1 a*	2,7 a*
Média	1,6	1,5	0,8	-0,1	-0,8	1,7	2.2
CV (%)	4.1	4.3	4.4	2.3	2.4	6.6	6.7

Source: prepared by the authors

Note: Treat. : treatments, TSC: 100% commercial substrate, TMO100: 100% MC, TLC05: 5% LC, TLC10: 10% LC, TLC15: 15% LC, TLC20: 20% LC, TLC50: 50% of LC, TLC100: 100% of LC, MG: general average, CV: coefficient of variation. Means followed by the same letters in the same column do not differ from each other according to the Scott–Knott test at $p < 0.05$. Means followed by * differ from the treatment with commercial substrate (TSC) at the level of $p < 0.05$ according to Dunnett's test.

Anthocyanins are flavonoid substances that act in plant defense and leaf expansion, senescence and in response to abiotic stresses; in these cases, they are synthesized in the epidermal layers of leaves (ARAÚJO; DEMINICIS, 2009). Thus, the increase in flavonoid and anthocyanin averages may be related to the imbalance of nutrients in the LC, which act as defense substances against oxidizing substances (SALES *et al*., 2016), for example, chromium and sodium, as mentioned in research by Berilli *et al.* . (2014, 2016).

The average number of photosynthetic pigments obtained by leaf extraction and spectrophotometer readings also increased significantly with the increase in the proportion of LC in the substrates. The treatment composed of 100% LC had the greatest overall average. The proportions of carotenoids in the TLC10, TLC15 and TLC20 treatments were significantly lower than those in the other treatments (Table 8). These results are consistent with the analyses from the multiplex (Table 7), and the P, Mg and S contents of the LC (higher than those of the MC) may have contributed, as the treatments with 50 and 100% of LC obtained the best results.

Table 8. Average levels of photosynthetic pigments (Ca: chlorophyll a; Cb: chlorophyll b; Ct: total chlorophyll; Car: carotenoids) and SPAD indices in the leaves of Cambuci pepper plants.

Treat.	SPAD	Here	Cb	Ct	car
	Items. SPAD	mmol.m $^{-2}$			
TSC	21.4b	36.3b	10.2b	46.6c	84.1 a
TMO100	21.9b	33.3c	13.7b	47.0c	72,3 a
TLC05	21,6 b	32,4 c	16,2 b	48,6 c	66,7 a
TLC10	23,8 a	35,2 b	13,4 b	48,6 c	56,8 b*
TLC15	24,3 a	43,6 b	13,1 b	56,7 c	51,7 b*
TLC20	24,9 a	45,3 b	17,9 b	63,2 b	56,9 b*
TLC50	27,0 a*	42,6 b	23,2 a*	65,8 b*	64,5 a
TLC100	24.8 a	58.0 a*	23.2a*	81.2a*	63.4 to
Average	23.7	40.9	16.4	57.2	64.6
CV (%)	11.3	19.4	22.5	13.5	14.9

Source: prepared by the authors

Note: Treat. : treatments, TSC: 100% commercial substrate, TMO100: 100% MC, TLC05: 5% LC, TLC10: 10% LC, TLC15: 15% LC, TLC20: 20% LC, TLC50: 50% of LC, TLC100: 100% of LC, MG: general average, CV: coefficient of variation. Means followed by the same letters in the same column do not differ from each other according to the Scott–Knott test at the level of $p < 0.05$. Means followed by * differ from the treatment with commercial substrate (TSC) at the level of $p < 0.05$ according to Dunnett's test.

There were no significant differences in the seedling setting rate after transplanting. All residue mixtures were superior to the commercial substrate in terms of the number of fruits, with the exception of TLC50. The highest averages for variables related to fruits and productivity were observed in the TLC20 treatment (20% LC + 80% MC), except for fruit diameter and unit mass. Compared with the commercial substrate, the treatment with 100% MC resulted in greater average productivity, with the exception of length (Table 9).

Table 9. The average values of total fruits/plant, average length/fruit, average diameter/fruit, total weight of fruits/plant, average weight/fruit/plant, number of fruits/ha and total weight of fruits/ha of plants of cambuci pepper were calculated.

Treat.	Number of fruits I	Length .	Diamete r	Weight I	Unit Weight	Number of fruits II ha 5	Total weight II ha
	Items.	-------- mm --------		--------- g ---------		Items	Tone
TSC	19.8d	35.6b	47.8b	384.2c	19.2 to	4.0d	7.7c
TMO100	50.4 b*	36.3b	71.6a*	611.9 b*	13,6 c*	10,1 b*	12,2 b*
TLC05	47,2 b*	34,1 c*	47,1 b	540,8 b	11,8 c*	9,4 b*	10,8 b
TLC10	37,1 c*	35,0 b	46,5 b	442,7 c	12,2 c*	7,4 c*	8,9 c
TLC15	34,8 c*	38,7 a*	48,1 b	378,0 c	11,0 c*	7,0 c	7,6 c
TLC20	61,8 a*	38,1 a*	49,8 b	964,3 a*	15,5 b	12,4 a*	19,3 a*
TLC50	30,7 c	36,1 b	48,2 b	347,0 c	11,4 c*	6,1 c	6,9 c
TLC100	35,8 c*	35,1 b	48,1 b	440,2 c	12,3 c*	7,2 c*	8,8 c
MG	39,7	36,1	50,9	513,6	13,4	7,9	10,3
CV (%)	17,1	3.7	4.3	18.2	18.3	19.3	18.2

Source: prepared by the authors

Note: I Accumulated average of harvests. II Estimated productivity. Treatment: treatments, TSC: 100% commercial substrate, TMO100: 100% MC, TLC05: 5% LC, TLC10: 10% LC, TLC15: 15% LC, TLC20: 20% LC, TLC50: 50% LC, TLC100: 100% LC, MG: general average, CV: coefficient of variation. Means followed by the same letters in the same column do not differ from each other according to the Scott–Knott test at the level of $p < 0.05$. Means followed by * differ from the treatment with commercial substrate (TSC) at the level of $p < 0.05$ according to Dunnett's test.

Pearson's correlation analysis revealed that the variables studied in the propagation phase did not influence the fruit production phase. However, the good efficiency of residues on root development may have positively favored the ability of roots to adequately absorb nutrients from the soil (VENDRUSCOLO; MARTINS; SELEGUINI, 2016).

Therefore, the fruit production results did not show the same pattern observed in the seedling production phase, in which the best averages of seedling development and quality characteristics were obtained by the TLC10, TLC15 and TLC20 treatments. However, TLC20 stood out in both phases, presenting a significant difference for the following variables: number of fruits and total weight. Furthermore, all residue treatments produced more fruits than did the commercial substrate. The experiment, in general, predominantly presented coefficients of variation (CVs) below 20% and can be considered as well conducted and, consequently, with good quality results (FERREIRA, 2011).

4 CONCLUSIONS

The substrates containing 10, 15 and 20% LC mixed with 90, 85 and 80% MC obtained the best averages for development characteristics and the seedling quality index. All treatments with residue mixtures provided higher averages than the treatment containing commercial substrate, except for root parameters. The substrate formed by the proportion of 20% LC and 80% MC had the greatest average production and productivity in adult plants, with the exception of the diameter and unit mass of fruits. No correlation was detected between the two stages; that is, the seedling production variables did not influence the fruit production variables.

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