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Composting of household organic waste and its effects on growth and mineral composition of cherry tomato

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ABSTRACT

Composting is an alternative for recycling biodegradable organic waste, transforming it into organic fertilizer that can be used as agricultural nutrients, avoiding its disposal in landfills. This study evaluated the composting of household organic waste as a substitution for cattle manure, with a view to its application in the fertilization of cherry tomatoes (*Solanum lycopersicum* Mill., Var. Cesariforme). Thus, compost piles were set up using 30% organic waste (carbon source) and 70% tree-pruning residues (filling material). Two sources of organic waste were tested: household food waste (FW) and cattle manure (CM), at five proportions (15% FW + 15% CM, 10% FW + 20% CM, 20% FW + 10% CM and the controls 30% CM and 30% FW). After 90 days, the mature compost from each pile was mixed with coconut fibre in a 1:1 ratio and used as substrate filled in 15 L plastic pots, where the cherry tomato plants were grown. The experiment was conducted under greenhouse conditions in a randomized block design, with five treatments and five replicates. Assessments of growth and leaf mineral composition were performed for the cherry tomato plants. The results indicate that cattle manure can be replaced by household food waste as the organic material used in compost piles. Fertilization with organic compost from household food waste positively influenced the growth and nutrient assimilation in the leaf tissue of cherry tomato.

Keywords: biodegradable waste, organic fertilizer, *Solanum lycopersicum* Mill.

Compostagem de resíduo orgânico doméstico e seus efeitos no crescimento e composição mineral do tomateiro cereja

RESUMO

A compostagem é uma alternativa para reciclagem de resíduos orgânicos biodegradáveis, transformando-os em adubo orgânico que podem ser utilizados como aporte de nutrientes para fins agrícolas, evitando sua deposição em aterros sanitários. O objetivo do presente estudo foi avaliar a compostagem de resíduo orgânico doméstico em substituição ao esterco de bovino, com vista a sua aplicação na adubação do tomateiro cereja (*Solanum lycopersicum* Mill., var. cesariforme). Nesse sentido, foram construídas pilhas de compostagem com 30% de resíduos orgânicos (fonte de carbono) e 70% resíduos de podas de árvores (material de enchimento). Foram testadas duas fontes de resíduo orgânico: resíduos alimentares de origem doméstica (FW) e esterco bovino (CM), em cinco proporções (15% FW + 15% CM, 10% FW + 20% CM, 20% FW + 10% CM e os controles 30% CM e 30% FW). Após 90 dias, o composto maturado de cada pilha foi misturado com substrato de fibra de coco na proporção de 1:1 e acondicionado em vasos plásticos de 15 L, onde as plantas de tomateiro cereja foram cultivadas. O experimento foi conduzido em casa de vegetação utilizando o delineamento experimental de blocos casualizados, com cinco tratamentos e cinco repetições. Foram realizadas avaliações de crescimento e composição mineral do tecido foliar do tomateiro cereja. Os resultados indicam que o esterco bovino pode ser substituído por resíduos alimentares como material orgânico para construção das pilhas de compostos. A adubação com composto orgânico oriundo de resíduos alimentares influenciou positivamente no crescimento e assimilação dos nutrientes no tecido foliar do tomateiro cereja.

Palavras-chave: adubação orgânica, resíduo biodegradável, *Solanum lycopersicum* Mill.

1. INTRODUCTION

The management of municipal solid wastes is a problem faced by all developing countries. The rapid pace of growth of population, economic activity, urbanization and industrialization is associated with accelerated waste generation (Srivastava et al., 2015; Kumar et al., 2017; Butu and Mshelia, 2014). Therefore, inadequate waste management is a serious environmental problem, which is even more pronounced when it comes to biodegradable municipal solid wastes.

Biodegradable solid wastes are usually incinerated (Agarwal et al., 2005; Taylan et al., 2008) or dumped in open areas, which may cause health and environmental issues. In addition, the incineration of biodegradable wastes with a high moisture content results in the release of dioxins (Katami et al., 2004), highly toxic and persistent pollutants that pose a threat to humans and the environment (Paritosh et al., 2017).

In this context, there is a need to prioritize the management of biodegradable solid wastes, which can be undertaken by responsible governmental authorities as well as non-governmental entities (associations, cooperatives and companies). However, recycling these wastes is not a common practice in Brazil. No treatment or proper disposal is carried out, and landfills are usually their main destination. Thus, further research is necessary in order to evaluate alternative techniques, such as composting, for recycling organic solid wastes from domestic sources.

Composting has several advantages over incineration and landfilling, and it is an effective solution to recycle such wastes. This is because it has lower operating costs, reduces environmental impacts and, most importantly, the final product can be used as fertilizer (Li et al., 2013). This technique not only reduces the amount of waste sent to landfills, but also contributes to social, ecological and economic improvement, being the best alternative for the management and transformation of organic waste.

In Brazil, there are highly populated urban areas where the production of a large amount of household compost which could be used as fertilizer in nearby agricultural fields would be possible (Vich et al., 2017). From a sustainability point of view, household organic waste must be efficiently reused in the economic and productive cycle before its final disposal (Ferreira et al., 2018).

From this perspective, this paper assessed the growth and mineral composition of cherry tomato plants fertilized with organic compost from household organic waste as a substitute for cattle manure.

2. MATERIAL AND METHODS

The research was conducted in two stages in Mossoró, Rio Grande do Norte, Brazil (Lat. 514 S, Long. 37189 W and Alt. 18 m). In the first stage, the compost piles were set up using different proportions of household organic waste and cattle manure. In the second stage, the mature compost obtained from each proportion tested was evaluated as a fertilizer source for the growth of cherry tomato plants (*Solanum lycopersicum* Mill., var. cesariforme).

2.1. Stage 1 description

Five compost piles were set up in a courtyard of the Associação Comunitária Reciclando para a Vida (ACREVI), in Mossoró, Rio Grande do Norte, Brazil. Three proportions of household food waste (FW) and cattle manure (CM) (T_1 = 15% FW + 15% CM, T_2 = 10% FW + 20% CM and T_3 = 20% FW + 10% CM) and two controls (T_4 = 30% CM and T_5 = 30% FW) were used. The piles consisted of 30% organic waste (carbon source) and 70% tree pruning residues (filling material). The household food waste was collected in a popular restaurant and urban dwellings, whereas the filling material was obtained from the public cleaning service.

Conical-shaped piles 1.60 m high and 2.00 m wide were spaced parallel to each other to facilitate handling of the compost. The piles were irrigated daily with tap water and manually turned every three days during the first week, then every ten days.

During the maturation process, the piles were monitored weekly by measuring temperature, humidity and pH. The physical-chemical properties of the mature composts were determined by the standard method (Embrapa, 2009), including: OM, C:N ratio, N, P, K, Ca, Mg, S, Fe, Cu, Zn, B, Mn and Na.

In the evaluation of the temperature of the piles during the composting process, high initial temperatures were observed, from 35 to 50°C, reaching a maximum temperature of 65°C during the thermophilic phase, while in the final phase the temperatures were 30 to 35°C.

2.2. Stage 2 description

After 90 days of maturation, the organic compost (OC) from each treatment of Stage 1 was mixed with coconut fibre in a 1:1 ratio and used as substrate in 15 L plastic pots, where the cherry tomato plants were grown. The pots were drilled and had a 3 cm layer of gravel and a 2 mm nylon mesh placed at the bottom to facilitate drainage. The experiment was conducted under greenhouse conditions at the Department of Environmental and Technological Sciences of the Universidade Federal Rural do Semi-Árido (Mossoró, Rio Grande do Norte).

The treatments consisted of the organic composts produced in the first stage, where OC_1, OC_2, OC_3, OC_4 and OC_5 were obtained from the maturation of the compost piles T_1, T_2, T_3, T_4 and T_5, respectively. A randomized block design with five treatments, five replicates and six plants per plot was used, totalling 25 experimental plots and 150 plants. From each plot, only the four inner plants were considered as useful plants. Pots and rows were spaced by 0.35 and 1.0 m, respectively.

The cherry tomato was sown in polystyrene trays with 128 cells, where each of them was filled with earthworm humus and received three to four seeds. Seedlings were irrigated manually twice a day using tap water, in the morning (7:30 a.m.) and in the late afternoon (4:30 p.m.). At 10 days after sowing, the seedlings were thinned to one plant per cell. Plants were transplanted to the pots after showing four expanded leaves.

An automatic drip irrigation system, with a timer to control the irrigation depth, was programmed for two daily irrigations. The system had self-compensating drippers with a flow rate of 2.0 L h^{-1}. After reaching 60 cm height, the plants were grown as a single stem and staked to avoid the contact of branches, flowers and fruits with the soil. Staking was performed using a ribbon which was fixed to two wires.

Plant growth was assessed biweekly, from 15 to 90 days after transplanting (DAT), by the following variables: shoot height, stem diameter and leaf number. Shoot height (SH) was obtained using a metric tape, whereas stem diameter was measured with a digital caliper, always at 1.0 cm above of substrate. Leaf number was counted using only leaves of the main branch.

Shoot fresh and dry weight were recorded at the end of the experiment (DAT) using leaves of one plant per plot. In the laboratory, the leaves were weighed, washed in distilled water, packed in Kraft paper bags and dried in a forced-air oven at 65ºC. After drying, they were weighed again in order to determine the fresh weight:dry weight ratio.

The same samples from assessment of the fresh weight were used to determine the mineral composition of the leaf tissue. After drying, they were ground and stored in plastic containers for later assessment of the total nitrogen and other nutrients (P, K, Ca, Mg, S, Fe, Cu, Zn, B, Mn and Na).

The results were subjected to analysis of variance using the F test at 5% probability with the aid of the statistical program ASSISTAT 7.7 (Silva and Azevedo, 2016). The Tukey test ($p < 0.05$) was used to compare the mean values.

3. RESULTS AND DISCUSSION

3.1. Growth of cherry tomato plants

Based on the analysis of variance, no significant effect was observed for shoot height (SH), stem diameter (SD) and root length (RL), whereas leaf number (LN), shoot fresh weight (SFW) and leaf area (LA) showed a significant effect ($p < 0.01$). For shoot dry weight (SDW), there was an effect at the 5% level (Table 1).

Table 1. Analysis of variance for the shoot height (SH), stem diameter (SD), root length (RL), leaf number (LN), shoot fresh weight (SFW), shoot dry weight (SDW) and leaf area (LA) of cherry tomato fertilized with organic composts produced using different proportions of cattle manure and household food waste.

		QM						
SV	DF	SH	SD	RL	LN	SFW	SDW	LA
Blocks	4	44.8^{ns}	0.9^{ns}	26.1^{ns}	1792.2^{ns}	436.1^{ns}	50.4^{ns}	3500007.3^{ns}
Treatments	4	290.4^{ns}	3.1^{ns}	78.5^{ns}	11398.1^{**}	5008.6^{**}	204.9^{*}	13175450.4^{**}
Error	16	100.4	1.85	55.31	1653.2	849.8	43.1	2633513.5
Total	24							
CV%		7.8	10.5	16.8	22.5	23.5	28.3	29.4

According to the F-test: ** significant at the 1% level ($p < 0.01$); * significant at the 5% level ($0.01 \leq p < 0.05$); ns not significant ($p \geq 0.05$). SV = source of variation; DF = degrees of freedom; CV = coefficient of variation.

Tomato plants fertilized with OC_5 (30% FW) showed the highest LN at the end of the cycle, although they did not differ from those fertilized with OC_1 (15% FW + 15% CM) and OC_2 (10% FW + 20% CM). On the other hand, the lowest LN was recorded in plants fertilized with OC_3 (20% FW + 10% CM), which was statistically similar to that observed after fertilization with OC_4 (30% CM) (Figure 1A).

Regarding LA (Figure 1B), the best results were observed with OC_5 fertilization, and were statistically similar to those obtained for plants treated with OC_4, OC_1 and OC_2. The OC_3

treatment resulted in the lowest LA. According to Reis et al. (2013) and Gonzalez-Sanpedro et al. (2008), leaf area is an important variable for modelling plant growth and development and, therefore, total crop yield. These authors stress that the increment in leaf area provides an increase in the ability of the plant to use solar energy in order to carry out photosynthesis, and thus can be used to evaluate yield.

Figure 1 also shows that LA influence SFW (Figure 1C) and SDW (Figure 1D). The treatments showing the most significant results for LA were the same ones that led to increased shoot fresh weight and shoot dry weight (OC_5, OC_1, OC_2 and OC_4, respectively), which indicates that these variables are correlated.

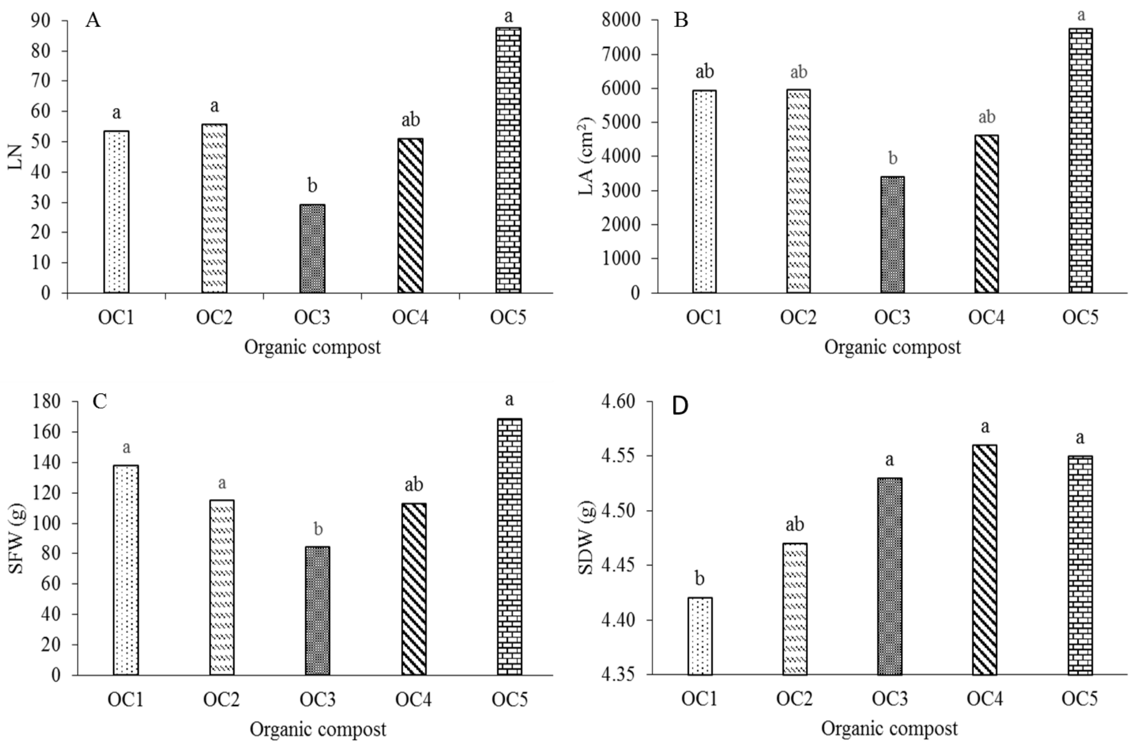

Figure 1. Mean values of leaf number (LN) (A), leaf area (LA) (B), shoot fresh weight (SFW) (C) and shoot dry weight (SDW) (D) of cherry tomato fertilized with organic composts produced using different proportions of cattle manure and household food waste.
Means followed by the same letter do not differ significantly at the 5% level (Tukey Test).

Quantifying the biomass production is relevant because it indicates the photosynthetic efficiency of a crop and serves as an indicator of its final yield. According to Figueiredo et al. (2010), the speed with which biomass is accumulated after germination may be used as an indicator of the yield and economic life of a crop. For Rocha (2009), the main storage organ of dry matter in the tomato crop is the leaf. Although leaves are a source of photoassimilates, they are also characterized as the main drains, followed by the stem and fruits.

For SH, SD and RL, treatments had no significant effect at the end of the cycle. Several authors have reported that the use of organic fertilizers do not show a significant effect on the shoot height and stem diameter of tomato plants. Araújo et al. (2011) observed that the cherry tomato showed better development after treatment with organic fertilizers. However, the statistical analysis proved that there was no significant effect on SH, LN and SD. These results are consistent with those found by Matos et al. (2015), who studied the use of organic fertilizers as a replacement for chemical fertilization in cherry tomato grown under different irrigation levels. The authors reported that plants treated with humus did not show a significant increase in shoot height and stem diameter.

Wang et al. (2017) conducted a study in a greenhouse to evaluate the impacts of replacing mineral fertilizer with organic fertilizers for one full growing period on soil fertility, tomato yield and quality using soils with different tomato planting history. The authors found that vermicompost and chicken manure compost more effectively promoted plant growth, including stem diameter and plant height compared with other fertilizer treatments, in all three types of soil.

As reported by Reis et al. (2013), the principles and practices of growth analysis aim to describe and interpret the performance of a given species in a natural or controlled environment. In general, the highest results of LN, LA, SFW and SDW were observed in tomato plants fertilized with OC_5 (organic compost containing 30% FW). Plants fertilized with OC_3 (compost containing 20% FW + 10% CM) showed the lowest values for these growth variables.

3.2. Leaf mineral composition

Table 2 shows the analysis of variance for the macro and micronutrient content in leaves of tomato plants grown under different organic composts. A significant effect was observed on copper (Cu) and manganese (Mn) at the 5% level. Moreover, there was a significant effect on the phosphorus (P) and iron (Fe) content at the 1% level.

Table 2. Analysis of variance for the mineral composition of the leaf tissue of cherry tomato fertilized with organic composts with different proportions of cattle manure and household food waste.

		Nutrients								
SV	DF	N	P	K	Ca	Mg	Cu	Mn	Fe	Zn
Blocks	4	3.74^{ns}	0.48^{ns}	0.64^{ns}	4.30^{ns}	0.31^{ns}	10.68^{ns}	134.21^{ns}	49888.46^{ns}	44.51^{ns}
Treatments	4	5.37^{ns}	6.59^{**}	2.41^{ns}	58.77^{ns}	0.51^{ns}	21.76^{*}	356.49^{*}	828926.86^{**}	71.89^{ns}
Error	16	3.49	0.22	1.63	25.18	0.26	7.13	78.33	171367.3	83.85
Total	24									
CV (%)		14.54	19.28	21.11	16.84	7.12	21.4	13.94	24.32	26.24

According to the F-test: ** significant at the 1% level ($p < 0.01$); * significant at the 5% level ($0.01 \leq p < 0.05$); ns not significant ($p \geq 0.05$). SV = source of variation; DF = degrees of freedom; CV = coefficient of variation.

As for nutrient uptake, calcium was the most-absorbed macronutrient in the leaf tissue of tomato plants under all treatments, a very important fact, because according to Nurzynski and Jaros (2012) calcium is fundamental for a tomato crop, because when it is deficient blossom end rot disease occurs on the fruit. Nitrogen was the second most commonly found macronutrient, followed by magnesium, potassium and phosphorus (Table 3).

It can therefore be inferred that the order of nutrient concentration in the leaf tissue was Ca>N>Mg>K>P. Similar results were observed in the leaf tissue of tomato plants grown under a protected environment and subjected to various biofertilizer doses and irrigation depths (Sales, 2014). On the other hand, Moreira (2012) studied the nutrition and development of tomatoes fertilized with biofertilizers and verified the following order Ca>N>K>P>Mg. According to the author, the differences regarding this order of nutrient concentration in the leaf tissue might be a consequence of the growth stage, which influences the content of virtually all macro- and micronutrients.

With respect to the effect of the organic composts on macronutrients (Table 3), only the phosphorus levels were influenced by the different proportions of household food waste and cattle manure. The phosphorus content in tomato leaves was higher when plants were grown in the plots fertilized with composts containing cattle manure, which are represented by the OC_1, OC_2, OC_3 and OC_4 treatments. The highest phosphorus levels were observed under OC_3 fertilization, which had a lower proportion of cattle manure.

Table 3. Mean values of macronutrients in the leaf tissue of cherry tomato fertilized with organic composts with different proportions of cattle manure and household food waste.

Treatments	Macronutrients (g Kg^{-1})				
	N	P	K	Ca	Mg
OC_1	12.51a	5.24a	5.69a	29.25a	7.52a
OC_2	11.81a	5.68a	7.07a	30.22a	7.22a
OC_3	12.08a	6.07a	6.24a	31.61a	6.71a
OC_4	13.56a	4.31ab	5.2a	24.4a	7.28a
OC_5	14.26a	3.22b	6.03a	33.56a	6.9a
Dms	3.62	1.84	2.48	9.74	0.98

Means followed by the same letter do not differ significantly at the 5% level (Tukey test).

According to Fan et al. (2018), phosphorus is an important nutrient for root growth and plays a critical role in plant metabolism. Maia et al. (2013) investigated the effect of organic fertilization on cherry tomato plants and found higher phosphorus levels in plants treated with a mix of soil and cattle manure. Similarly, the highest phosphorus concentration was observed under the lower manure proportion.

Also regarding the assimilation of macronutrients, Figure 2 shows that plants grown under OC_1, OC_2, and OC_3 fertilization absorbed mainly magnesium, potassium and phosphorus, respectively. As for plants fertilized with OC_5 (30% FW), there was a higher accumulation of calcium, followed by nitrogen. In contrast, OC_4 fertilization (30% CM) did not induce significant macronutrient content when compared to the other treatments. This is likely to be a consequence of the lack of diversity of material used in the compost pile that produced this organic fertilizer.

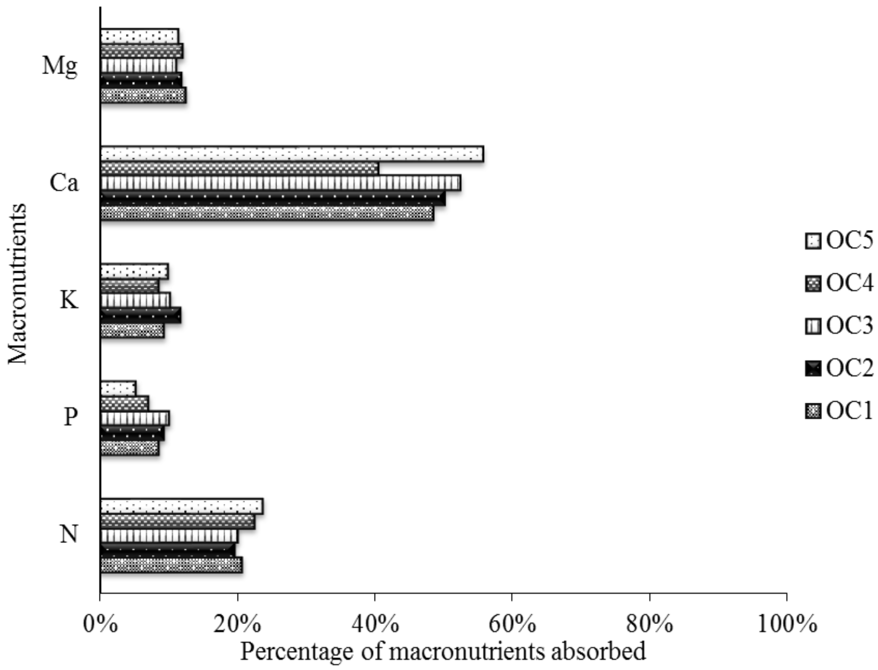

Figure 2. Percentage of macronutrients absorbed in the leaf tissue of cherry tomato fertilized with organic composts produced using different proportions of cattle manure and household food waste.

Related to the mineral composition of the leaf tissue, the P, Ca and Mg levels might be considered as appropriate for the tomato crop (Embrapa, 2009). Although the N and K levels are relatively low, the reference values are based on a different sampling period. This may have led to the disparity in the levels of these nutrients.

Several authors have reported the influence of organic fertilization on the mineral composition of tomato leaves. Maia et al. (2013) found that the macro- and micronutrient contents in cherry tomato leaves under different doses of cattle manure compared to the chemical fertilization were influenced by the addition of the organic fertilizer to the contents of N, P, K, Ca, Mg, S, Mn and Zn.

Regarding the micronutrient content (Table 4), iron (Fe) was the most absorbed in all treatments, followed by manganese (Mn), zinc (Zn) and copper (Cu). The predominant Fe content might be a consequence of the high concentrations of this micronutrient in the organic composts.

Nevertheless, only the Cu, Mn and Fe content in the leaf tissue were influenced by the diversity of organic materials used in the piles that originated the different composts. For the Cu content, even though a significant effect was observed at the 5% level according to the F test, the mean values of all treatments was found to be statistically similar (Table 4). The highest Mn content was observed in the OC_4 treatment. In contrast, the lowest concentrations of this micronutrient were observed in plants grown under OC_1 and OC_2 fertilization, which were statistically similar, although they did not differ from those observed under the OC_3 and OC_5 treatments.

Plants fertilized with OC_1 (15% FW + 15% CM) and OC_3 (20% FW + 10% CM) showed higher and lower Fe content, respectively. Nevertheless, the latter did not differ from the OC_4 control (30% CM) and the OC_2 treatment (10% FW + 20% CM).

Table 4. Mean values of micronutrients in the leaf tissue of cherry tomato plants fertilized with organic composts with different proportions of cattle manure and household food waste.

Treatments	Micronutrients mg Kg^{-1}			
	Cu	Mn	Fe	Zn
OC_1	13.33a	54.46b	2255.00a	38.47a
OC_2	14.06a	55.77b	1629.40ab	38.39a
OC_3	14.15a	68.45ab	1142.40b	32.28a
OC_4	11.64a	74.39a	1607.60ab	35.49a
OC_5	9.21a	64.29ab	1875.20ab	29.86a
Dms	5.18	17.18	803.47	17.77

Means followed by the same letter do not differ significantly at the 5% level (Tukey test).

According to Malavolta et al. (1989), the Cu, Mn and Zn concentrations in the leaf tissue are considered to be at appropriate levels. However, the Fe content showed values higher than those quoted as appropriate for the tomato crop. The order of micronutrient concentration for the cherry tomato at 90 DAT was Fe>Mn>Zn>Cu.

Figure 3 shows that the concentration of Zn, Mn and Cu in the leaf tissue was similar, whereas the iron content was significant increased. This was probably due to the excess of this nutrient in the organic composts, considering the fact that iron is an immobile element and high levels are usually shown in the upper parts of the plant. In spite of this, the Fe concentration was not sufficient to cause phytotoxicity, given that plant growth was not compromised.

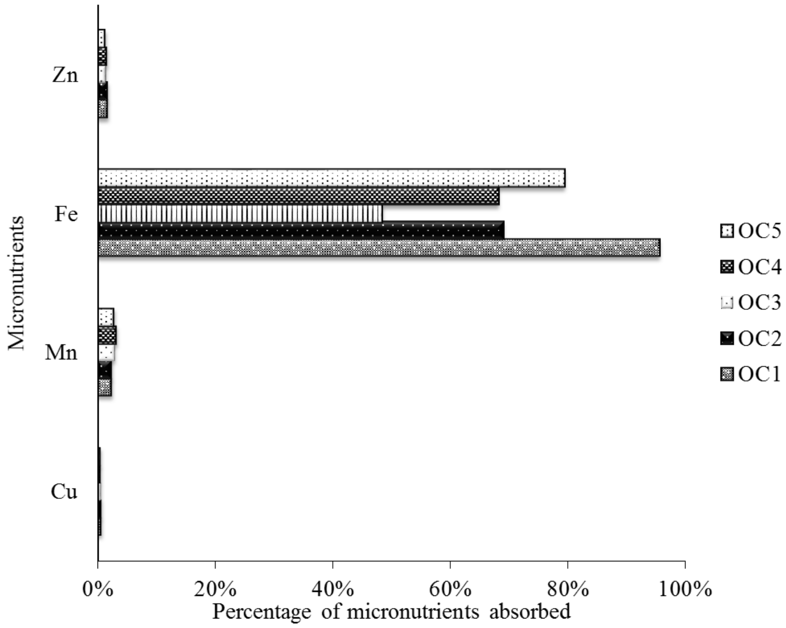

Figure 3. Percentage of micronutrients absorbed in the leaf tissue of cherry tomato fertilized with organic composts with different proportions of cattle manure and household food waste.

The mineral composition of the leaf tissue depends on several factors, including soil and climatic conditions, genetics of the cultivar, growth stage and the bioavailability of nutrients from organic fertilizers, which may vary with the chemical composition and diversity of the material. In this study, the factor that most influenced nutrient concentration was the diversity of the material used to produce the organic composts.

4. CONCLUSIONS

Cattle manure can be replaced by household food waste as the organic material used in compost piles without compromising cherry tomato growth;

Fertilization with organic compost from household food waste positively influenced nutrient assimilation in the leaf tissue of cherry tomato;

There was no nutritional deficiency in tomato plants grown under any of the proportions of organic waste studied;

In general, composting from household food waste and tree pruning residues was the most satisfactory due to the production of a compost that significantly increased plant biomass, and can be considered an effective technique for recycling this organic waste.

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