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Composting of fresh vegetable residues and its application in lettuce cultivation

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ABSTRACT

A considerable part of fresh plant-based food has been discarded as waste, although it could be used to make organic compost for growing plants, retaining nutrient that would be discarded without any control in the environment. The aim of this study was to produce an organic compost using fresh vegetable food discarded from restaurants and mowed grass and to evaluate it for production of lettuce. The compost was produced and mixed with the commercial substrate Tropstrato HT Hortaliças® to occupy 0, 5, 10, 15, 20 or 25% of the volume of the mixture, which was used to grow Imperial and Imperial Roxa cultivars in the first experiment, and Camila and Red Star lettuce cultivars in the second one. The experiments were conducted under protected environment, organized in a 6x2 factorial scheme, following completely randomized design with three replicates. Chemical analyses of the substrate and compost and measurements of plant size and mass were carried out. The addition of compost caused an increase in all measurements of the plant traits, with the maximum estimated increase ranging from 1.7 to 9.0 times that estimated for the absence of compost in the plant growth substrate. Maximum estimated values for size and mass were observed with compost concentrations ranging from 20.1 to 26.7% of the mixture volume. The production of organic compost and its mixture with a commercial substrate proved to be an alternative for lettuce production, giving a better destination to the organic residues and promoting a reduction in the use of industrial inputs.

Keywords: *Lactuca sativa*, cultivation on substrate, recycling, fertilizer, organic compost.

RESUMO

Compostagem de resíduos vegetais frescos e sua aplicação no cultivo de alface

Uma parte considerável dos alimentos vegetais frescos ainda é descartada como resíduo, embora possa ser aproveitada para confecção de composto orgânico e este usado para o cultivo de plantas, retendo nutrientes que seriam dispostos sem controle no ambiente. O objetivo deste trabalho foi produzir um composto orgânico com descarte de alimentos vegetais frescos de restaurante e poda de grama e avaliá-lo para cultivo de alface. O composto foi produzido e misturado ao substrato comercial Tropstrato HT Hortaliças® de modo a ocupar 0, 5, 10, 15, 20 ou 25% do volume da mistura e ela usada para cultivo das cultivares Imperial e Imperial Roxa num primeiro experimento, e Camila e Red Star num segundo experimento. Os experimentos foram realizados em cultivo protegido em esquema fatorial 6x2, em delineamento inteiramente casualizado com três repetições. Foram realizadas análises químicas do substrato e do composto e medições de tamanho e massa das plantas. A adição de composto provocou aumento de todas as características de planta medidas, sendo que o aumento máximo estimado variou de 1,7 a 9,0 vezes aquele estimado para a ausência de composto no substrato de crescimento das plantas. Os valores máximos estimados destas características de tamanho e massa foram observados com concentrações de composto entre 20,1 e 26,7% do volume da mistura. A produção de composto orgânico e sua mistura a um substrato comercial mostrou-se uma alternativa para produção de alface, proporcionando destino adequado aos resíduos orgânicos e promovendo redução do uso de insumos industriais.

Palavras-chave: *Lactuca sativa*, cultivo em substrato, reciclagem, adubação, composto orgânico.

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Urban organic residues are still one of the largest soil and water pollutants. The inappropriate discard is the main cause of environmental contamination and public health problems (Fratta *et al*., 2019). On the other hand, part of these residues has been treated using several technologies to generate value, such as nutrient recovery through vermicomposting (Biruntha *et al*., 2020) and electricity generation through burning and steam generation (Maccarini *et al*., 2020), for agriculture and industrial purposes. In this sense, organic waste composting is a good solution for the urban environment and agriculture problems, providing organic matter to soil and nutrients to plants, avoiding the accumulation of these waste in dumps and landfills.

Organic residues contain a significant amount of nutrients for plants and can be used as soil fertilizer, replacing totally or partially, fertilizers of industrial origin, which are conventionally used for cultivation and are responsible for increasing the production cost of crops. An example of the use of such residues for fertilization occurred in the production of petunia seedlings and flower pots (*Petunia X hybrida*) using compost of mowed grass and cattle manure as substrate, which allowed the plants to complete their life cycle without mineral deficiency symptoms (Zanello & Cardoso, 2016). In addition to nutrients, plant residues naturally contain carbon compounds, which contribute to maintain or increase the soil organic matter content. These materials can be agronomically used, therefore, to supply nutrients to the plants and to condition the soil and improve its chemical, physical and biological attributes (Chenu *et al*., 2019).

Organic residues such as mowed grass have been produced in large scale due to the increase in landscaping areas and often discarded in inappropriate places (Zanello & Cardoso, 2016). In addition, other important organic residues such as non-consumable parts or foods leftovers from residences and restaurants are mostly discarded almost entirely in common trash, without a technological and sustainable destination. Current estimates show that around 0.67 kg *per capita* of solid waste is generated daily in India (Biruntha *et al*., 2020). In Brazil, the city of São Paulo (SP) produces about 18 thousand tons of garbage daily, being 10 thousand tons of this trash coming from residences, and 50% of it is organic trash (Cidade de São Paulo, 2022). In the state of São Paulo, solid waste production ranges from 0.7 to 1.1 kg/day per capita (CETESB, 2022). Latin America presents alarming solid waste data, because, besides the increase in the amount generated, only 10% are designated for recycling or another reuse technique (ONU, 2018). Previous surveys data showed losses of 20 types of fruit and vegetable products, with an average of 14.3% of losses during commercialization (Cristofoli *et al*., 2014). Other surveys showed losses of up to 40% of the production in post-harvest, processing, and distribution of different food (Gustavsson *et al*., 2011), being high temperatures one of the most important accelerating factors of reactions that lead to food loss.

Organic composted materials have shown immense potential for agricultural applications, reducing the urban waste, inappropriately discarded, and promoting benefits to crops cultivation (Biruntha *et al*., 2020). However, the duality of offering great nutrient availability and economic viability in order to replace conventional fertilizers, are still an obstacle to the expansion of its application. One of the main issues is whether a compost based on discards of fresh plant foods can support the cultivation of horticultural species and how much compost is necessary to meet plant demand.

Based on the aforementioned, this study aimed i) to transform two of the main vegetable residues generated in urban areas, fresh plant food waste and mowed grass into an organic compost and ii) to cultivate lettuce (*Lactuca sativa*), a model vegetable, with the compost produced from the first objective. This compost was tested by mixing different proportions of the organic matter composted and a commercial substrate aiming to evaluate the technical feasibility of producing lettuce, which is a fast-growing species of great economic importance.

MATERIAL AND METHODS

The composting was made with two important plant residues generated daily at Centro de Ciências Agrárias at Universidade Federal de São Carlos (CCA/UFSCar). These residues are actually the same ones largely generated in Brazilian cities, fresh plant food discards, from the University Restaurant (RU) of the CCA/UFSCar, and mowed grass, resulting from the maintenance of the gardens on the university campus. Only parts that are not used for consumption, such as peels and seeds of vegetables and fruits, or parts presenting a non-preferential aspect for consumption (vegetable leaves for salad) were used. These parts represent over 50% of the discard generated in this restaurant currently. Leftovers were not used, to reduce the risk of biological contamination. The discards were chopped (4-5-cm long) before composting. The residue mowed grass consisted of bahiagrass straw (*Paspalum notatum*), 1-10-cm long, not older than 7 days since it was cut.

A composting pile measuring 1.0 m high X 1.0 m wide was made mixing the two materials. The quantity of each one in the mixture was calculated to obtain an initial carbon/nitrogen ratio (C/N) of 30/1. We considered the concentration of C and N of each material, in dry mass-based material. To make the measurement of quantity of material for making the pile easy, the dry mass material was transformed into volume of fresh material, considering the moisture and density of the fresh materials. Four liters of mowed grass for each liter of food residue were used. After installation, the pile was turned over and the moisture was adjusted every four days on the two first weeks and each seven days on the following weeks, making it 45 days of composting.

Imperial Roxa (purple leaves) (IR) and Imperial (green leaves) (IM) lettuce cultivars were chosen to be grown as they are tolerant to mildew and premature bolting (Agristar, 2018), typical problems, concerning lettuce cultivation, during summer in São Paulo. The plants show an average cycle of 60 days, average weight of 450 g/plant. The leaves are generally thin, peaked and long. The commercial seeds of these two cultivars (Agristar®) were germinated in 120-cell polystyrene trays, with an average of two seeds per cell. After 40 days of sowing, the plants were transplanted into 1.4-L plastic pots, 15-cm wide and 17-cm high, filled with a mixture of compost obtained from the composting and commercial substrate Tropstrato HT Hortaliças® (ground pine bark, peat, and charcoal). The compost was mixed with the commercial substrate to achieve 0, 5, 10, 15, 20 or 25% of the mixture volume. No mineral material or complementary fertilizer was added to the compost-commercial substrate mixture in any of the treatments. Samples of the compost and commercial substrate were collected and analyzed for chemical composition following the method of solid residues analysis (Andrade & Abreu, 2006). Plants were cultivated in a greenhouse, protected on the upper surface with a 150-micron agricultural plastic diffuser and on the lateral surfaces with a white anti-aphid screen. No pesticides were sprayed during the experimental period, with the purpose of keeping principles of sustainable agriculture and without synthetic residues potentially dangerous to human and other animals' health and the environment.

The experiment was conducted in 6x2 factorial scheme, considering six proportions of the compost in the mixture (0, 5, 10, 15, 20 and 25% of the volume) and two lettuce cultivars in a completely randomized design, with three replicates, totalizing 36 plots. Each plot consisted of four pots with one lettuce plant each. At 49 days of growing in the pots, we measured the height and the diameter of the plants and the length and diameter of the largest leaf with the aid of a ruler and a caliper. The number of leaves was counted. We also measured shoot fresh mass of the plants, using a digital balance accurate to 1 g. The measurements were done in all plants and the average of four plants from each plot composed the plot data. Variance analysis, linear regressions and average test were used for the statistical data analysis. In the variance analysis, significant interactions between the lettuce cultivars and the proportion of compost in the mixture were unfolded and studied using linear regression and Tukey test. First and second-degree polynomials were adjusted to the data and the second-degree polynomial was chosen when all the coefficients of polynomials were significant, at least 5% for F test. When no significant interaction was noticed, the simple effect of "proportion of compost in mixture" was evaluated based on linear regression. The compost proportion in the mixture to reach the maximum value of each plant trait measured was calculated using the first derivative of the respective second-degree polynomial. The analyses were conducted using Assistat software version 7.7.

The experiment was repeated using other two lettuce cultivars, Camila and Red Star, also from the company Agristar® do Brasil. The compost used in the second experiment was the same used in the first experiment. The compost was kept in a plastic bag, in a shade environment, at 20-25°C, to keep its characteristics. As the results of this second experiment were similar to the results of the first experiment, we decided to present only the results of the first one. Both lettuce cultivations were conducted in spring/summer in the state of São Paulo.

RESULTS AND DISCUSSION

The value of all traits evaluated of lettuce plants increased due to increase of the compost concentrations mixed with the commercial substrate (Figures 1 and 2). A significant interaction between cultivar and compost concentration was observed for length and diameter of the largest leaf and plant fresh mass. In contrast, no interaction for height and diameter of the plant and number of leaves per plant was verified (Figure 2). For these variables, the effect of the compost concentration did not depend on the cultivar, thus the regression analysis considered the simple effect of the compost concentration in the mixture in the two cultivars together. Except for the plant fresh mass, which showed a constant increase proportion along to the compost concentration, the increase of other variables reached a maximum value. The compost concentration in the mixture in which the plants reached this maximum value was 22.0% for plant height, 20.5% for plant diameter, 26.7% for number of leaves per plant, 21.9% for the length of the largest leaf for the cultivar IR and 21.6% for the cultivar IM, and 21.7% for the diameter of the largest leaf for the cultivar IR and 20.1% for the cultivar IM.

The estimated maximum increases provided by the compost ranged from 1.7 times for the length of the largest leaf up to 6 times for plant fresh mass of the cultivar IM and 9 times for plant fresh mass of the cultivar IR. These positive results may be attributed to the multiple physicochemical and microbiological characteristics of the compost and properties conditioned by it, as its lower acidity (pH 7.1) in relation to the commercial substrate (5.3) (Table 1), its higher concentration of Ca (+98.1%), Mg (+47.6%), Fe (+114.3%) and Zn (+39.1%), presence of humic substances that are biostimulants and diversity of microorganisms, in addition to increase in water retention and cation exchange capacity (CTC). Together, the produced compost promotes a more favorable environment for the development of lettuce.

Figure 1. Development of lettuce cultivar Imperial (green leaves) in a mixture of commercial substrate Tropstrato HT Hortaliças® with organic compost obtained from fresh vegetable residues, with the organic compost occupying 0, 5, 10, 15, 20 and 25% of the mixture volume. Araras, UFSCar, 2016.

Considering that the main recommendation of the commercial substrate Tropstrato Hortaliças is to produce vegetable seedlings, it was expected that it would not sustain a sufficient development of the lettuce plants until obtaining commercial standard plants (Figure 1). The commercial substrate presented good load of macro and micronutrients (Table 1), however, its acidity (pH 5.3) and high concentration of exchangeable Al^{3+} (25 $mmol_c/dm^3$) may have limited the cultivation and development of lettuce plants, which is a sensitive species

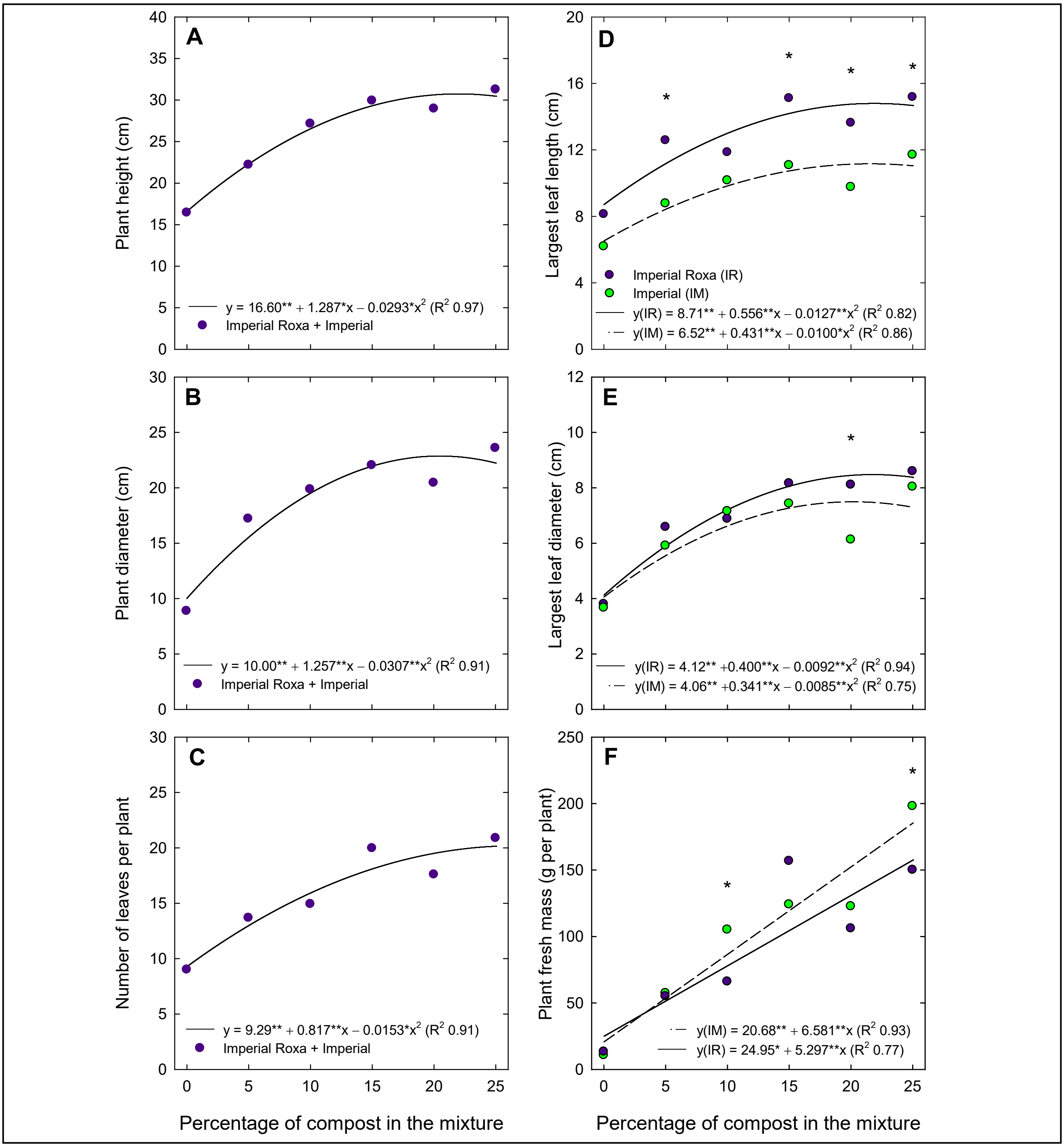

Figure 2. Relationships between plant height (A), plant diameter (B) number of leaves per plant (C), length (D) and diameter of the largest leaf (E) and plant fresh mass (F) of two lettuce cultivars, Imperial Roxa (IR) and Imperial (IM), and percentages of organic compost obtained from fresh vegetable residues composting in the mixture volume with commercial substrate Tropstrato HT Hortaliças® (organic compost occupying 0, 5, 10, 15, 20 and 25% of the mixture volume). Asterisks in equation coefficients indicate significant at 1% (**) or 5% (*) by the F test. Individual asterisks above circles in panels D, E, F indicate significant difference between cultivars in that percentage of compost in the mixture by Tukey test at 5% probability. Araras, UFSCar, 2016.

to acidity and Al toxicity. Thus, the addition of the compost to the substrate contributed to decrease the acidity and, consequently, the availability of Al and to increase the availability of some nutrients in the environment. Zanello & Cardoso (2016) also observed limited development of petunias in pots using the same commercial substrate, whereas the use of the compost containing mowed grass and cattle manure as cultivation substrate proved to be more adequate.

The positive effects of the compost can also be attributed to biostimulant effects of humic substances, such as growth stimulation and disease suppression (Guo *et al.*, 2019) and, as already registered for lettuce, reduction of lifecycle time and increase in productivity (Canellas *et al.*, 2015). These humic substances are formed and have their concentration increased by up to two times during the composting of organic residues, when compared to that of fresh residues (Inbar *et al.*, 1990). Humic substances such as humic and fulvic acids are present in compost and vermicompost and can cause structural and physiological changes in roots and shoots related to the absorption, distribution and assimilation of nutrients, and changes in secondary metabolism for greater tolerance to abiotic stresses (Canellas *et al.*, 2015).

The results found in the experiment with cultivars Camila and Red Star confirmed the positive effects of the organic compost in cultivars IR and IM. The largest plant diameters, 17.5 cm for Camila and 20.2 cm for Red Star, occurred in the mixture presenting proportion of 20% of the compost and 80% of commercial substrate (data not shown). These values of diameter are close to the ones described by the company that provides the seeds, fresh plants with 25 cm diameter and 150 g (Agristar®, 2018). The same did not occur for cultivar Imperial, which has average of 450 g/plant fresh mass and 38 cm of diameter (Agristar®, 2018). This cultivar reached the maximum value of 200 g/plant and 23 cm diameter in concentration of 25% of the compost in the volume of the mixture. Apart from the information provided by the seed company, no references were found regarding productivity and other characteristics of this cultivar, especially for the adopted cultivation system. In a trial using Mimosa lettuce cultivars, Nodari *et al.* (2013) observed fresh mass ranging from 79 to 289 g/plant, showing that the value of 200 g is within the averages observed for other cultivars of the same group.

The results point out the importance of genotype-production system for lettuce cultivation and reveal cultivars more adapted for cultivation using only organic compost as nutrient source (without mineral fertilization), such as the cultivar Red Star. Although many commercial substrates are available in the market, few can proportionate good plant growth (Trani *et al.*, 2007). Besides supplying nutrients, the substrate shall provide an adequate supply of air and water to the plant root system and a favorable environment for the growth of root symbiotic microorganisms. Other authors also observed in organic system, using crispy head lettuce (Verônica) and looseleaf type (Elisa), fresh mass between 68 and 257 g/plant (Mógor & Câmara, 2007) and between 174 g (without mulch) and 308 g/plant (white and black plastic film mulch) for cultivar Babá de Verão (butterhead lettuce) using 20 t/ha of cattle manure (Farias *et al.*, 2017).

In studies using organic composts from different origins, several authors observed values of fresh biomass lower than the ones obtained in this study using a compost based on residues of grass and food. Veras *et al.* (2019) observed that fertilization with mineral N-P-K produced higher fresh mass in lettuce plants (92 g/plant) than the treatment using organic compost (56 g/plant). Similarly, the highest fresh mass of crispy head lettuce was 39 g/plant using 20 L of organic compost made with household solid residues (Silva *et al.*, 2019). In studies using food residue compost in lettuce cultivation, Freitas *et al.* (2018) observed higher shoot fresh mass (14 g/plant) using 100% of compost, when compared with different mixtures of soil and compost, showing that this type of residue has potential to be used in composting. A compost of mowed grass with cattle manure showed high potential as substrate for petunia cultivation, showing much superior performance (42 g/plant of fresh mass) when compared with commercial substrates that are used for this same purpose, such as ground pine bark (21 g/plant fresh mass) and coconut powder, being the good results attributed to the higher levels of macro and micronutrients in the compost (Zanello & Cardoso, 2016). Among some advantages of using organic fertilizer are the higher ascorbic acid concentration in plant leaves (26 to 44%) and the lower nitrate content in plant leaves in this system (66.7 mg/kg) than in those with mineral fertilization (113.6 mg/kg) and hydroponics (278.4 mg/kg). These levels are related to high nitrate availability due to the use of soluble mineral fertilizers and may pose risks to human health (Silva *et al.*, 2011).

The results in this study show the viability of using residues and the applicability of the compost produced

Table 1. Chemical characteristics of the commercial substrate Tropstrato HT Hortaliças® and the compost obtained with fresh vegetable residues composting (discard of fresh vegetables food from the restaurant in the University and straw grass) at Centro de Ciências Agrárias at Universidade Federal de São Carlos. Araras, UFSCar, 2016.

Treatments	Acidity	C	N	P	K	Ca	Mg	S	Cu	Fe	Mn	Zn
	(pH)	%							mg/dm^3			
Substrate	5.3	37.6	13.1	0.37	5.90	1.56	0.82	0.58	33	4543	248	46
Compost	7.1	25.9	2.3	0.26	2.32	3.09	1.21	0.23	19	9734	258	64

with them as an organic fertilizer in the production of lettuce, including in organic production system, and suggest alternatives to reduce costs with commercial substrates and fertilizers. Such use reduces the potential impact of discarding these residues into the environment. In addition, it takes advantage of the available nutrients, and it is even possible to estimate the stock of nutrients in plant residues. Considering average losses of 20% of the lettuce plant mass during meal preparation in restaurants and 0.3 g of N per plant [10 g of dry biomass per plant x 3% of N in biomass, Grangeiro *et al*. (2006)] we estimated a loss of 0.06 g N per plant and approximately 0.96 g of N per square meter of seedbed (spacing 25 x 25 cm) or 9.6 kg of N per cultivated ha, corresponding to an average of 27% of total N applied as fertilizer. Considering the lettuce cultivation area in Brazil in the 2017 harvest, which was 39,000 ha (HF Brasil, 2018), the estimated loss of N contained in the vegetable is 374.4 t of N, improperly discarded into the environment and that could be reused, at least in part, by composting and using the compost as organic fertilizer in the cultivation of plants.

Therefore, in addition to reducing losses, composting of non-consumed food parts or even of non-commercialized products, commonly found in fairs and supply centers, is a viable technical alternative to recover nutrients applied to the soil in the form of fertilizers. It is also a way of combining the current problems of urbanization, such as the generation of organic waste in cities, with the high demand of current agriculture for nutrients, which can partially replace mineral fertilizers applied to increase productivity, in particular, of horticultural crops currently produced close to urban centers, in the so-called green belts. In conclusion, the compost produced in this study using fresh vegetable residues (food waste and mowed grass) applied in quantities that occupy between 20% and 27% of the volume of the mixture with commercial substrate is effective for growing lettuce and may replace the use of mineral fertilizers and eventually reduce production costs.

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