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Residual compost from the production of *Bactris gasipaes* Kunth and *Pleurotus ostreatus* as soil conditioners for *Lactuca sativa* 'Veronica'

Composto residual da produção de *Bactris gasipaes* Kunth e *Pleurotus ostreatus* como condicionador de solo no cultivo de *Lactuca sativa* 'Verônica'

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Abstract

This study evaluated the residual compost from the production of *Bactris gasipaes* Kunth (pupunha heart of palm) (R_P) and the mushroom *Pleurotus ostreatus* (R_M). The residuals were used as soil conditioners for *Lactuca sativa* 'Veronica' crops. After adding R_P and R_M to the soil, all treatments exhibited similar behaviors and soils in each treatment were classified as eutrophic. Soil treatments involving increased application of residual compost resulted in the production of lettuce with greater widths because of an increase in the angle between the stem and leaf, resulting from a lack of nitrogen available to the plant. Soil treatments with 5% of R_P and R_M resulted in a 1.7 and 1.2 times (44% and 22%, respectively) decrease in dry weight of lettuce, as compared to the soil without residual compost addition. The addition of R_P and R_M as soil substrate reduced the growth of lettuce compared to the soil without residual compost. In general, the possibility of replacing chemical fertilizers (NPK) with R_P or R_M without previous composting was found to be inefficient. The resultant dry weight parameters were below the commercial level, and a complete period of composting R_P and R_M was deemed necessary for incorporating nitrogen into the soil. Lignocellulosic mushrooms such as *Pleurotus* spp. present highly fibrous residual compost with low nitrogen content, thus requiring a full period of composting before subsequent use in soil enrichment for various crops.
Key words: Lignocellulosic mushrooms. Soil fertility. Pupunha heart of palm.

Resumo

Uma avaliação do composto residual da produção de *Bactris gasipaes* Kunth (pupunha) (R_P) e da produção de cogumelos *Pleurotus ostreatu*s (R_C) foram realizadas, estas foram utilizadas como condicionadores de solo no cultivo de *Lactuca sativa* 'Verônica'. Após a adição de R_P e R_C no solo, todos os tratamentos se comportaram de maneira semelhante, classificados como solo eutrófico em cada tratamento. Os tratamentos com maior adição de composto residual apresentaram maiores valores para largura da alface

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devido ao aumento do ângulo entre caule e folha resultante da falta de nitrogênio disponível para a planta. Os tratamentos com 5% de R_P e R_C, proporcionaram, respectivamente, uma diminuição no peso seco aéreo de 1,7 e 1,2 vezes, 44% e 22% respectivamente, em relação ao solo sem adição de composto residual. A adição de R_P e R_C como substrato no solo tende a diminuir o crescimento de alface em comparação ao solo sem composto residual. De maneira geral, quanto à possibilidade de substituição de fertilizantes químicos (NPK) por fertilização com R_P e R_C sem compostagem prévia, verificou-se que a sua adição não foi capaz de substituir a adubação NPK, obtendo-se parâmetros de peso seco da alface abaixo do nível comercial, com um período completo de compostagem de R_P e R_C considerado necessário para a incorporação de nitrogênio no solo. Cogumelos lignocelulíticos, como o *Pleurotus* spp., apresentam composto residual muito fibroso e baixo conteúdo em nitrogênio, requerendo um período completo de compostagem, para posterior utilização no enriquecimento de solo para diversas culturas agrícolas.
Palavras-chave: Cogumelos lignocelulolíticos. Fertilidade de solo. Pupunha.

Introduction

Organic waste can be utilized to develop profitable and viable products. Of particular interest is the process of lignocellulosic waste bioconversion by *Pleurotus* spp. (MANDEEL et al., 2005; OKINO et al., 2015; ABDULLAH et al., 2015). However, its use as a fertilizer and soil conditioner, particularly in horticulture and floriculture, is one of its most viable potential uses (MAHER et al., 2000). This has been implemented by producers in several countries, primarily in Europe. Nevertheless, research on waste recovery has often obtained results that were contradictory, incomplete, or inconclusive.

Little research has been conducted by producers or public authorities on the processing or use of residual compost from the palm heart industry, with the residual becoming an environmental problem and a public health issue in some locations. It is estimated that on average, 80% of the pupunha production results in residue (sheath, stem, and leaves). As such, a small factory that produces approximately 3000 "heads" (peach palm) per day generates approximately 5.5 t day^{-1} of residue. Assuming 24 business days, approximately 131 t month^{-1} of residue is created. The residual pupunha compost has low density (300 kg m^{-3}) and high water content (70% w w^{-1}). It is generally a uniform substrate and consists of stabilized organic matter. The composting process, when performed, promotes adsorption of nutrients, such as calcium, magnesium, and potassium, the fraction of organic matter compost, while avoiding excessive leaching of nutrients. The remaining nutrients are available to roots of plants in larger amounts and for longer periods. The compost generally has a high pH (depending on the type of fungus grown) ranging between 7 and 8 and when incorporated into the soil, the compost increases the pH, as well as its cation exchange capacity (MAFF, 2004). Each kilogram of mushroom produced generates an average of 5 kg of residual compost, which corresponds to approximately 40 million tons each year (WILLIAMS et al., 2001). Approximately 70–80% of this compost is estimated to be discarded as garbage, resulting in environmental problems because of inappropriate disposal (SEMPLE et al., 1998).

Therefore, the residual compost of both the pupunha palm and mushrooms industries could be a fertilizer with interesting agronomic traits, primarily because of high-quality organic matter and high amounts of nitrogen, potassium, phosphorus, calcium and other trace elements, in particular iron (CHONG; RINKER, 1994; GERRITS, 1994; FERNANDES et al., 2015). When incorporated into the soil, it should increase the soil's capacity to retain water, raise the pH, and result in greater aggregation (MAFF, 2004), in addition to providing macronutrients (N and P) for plant nutrition (MAHER et al., 2000).

Lettuce is the most common commercially produced leafy vegetable in Brazil. It is a good source of vitamins and minerals, and is particularly high in vitamin A. It adapts to mild climates, producing the greatest yields when grown in winter. The limiting factor for summer cultivation is the production of a low-quality product, which results in higher prices (PINTO et al., 2014). The Veronica (garden) cultivar leads the market, accounting for 70% of all lettuce production, whereas the iceberg variety accounts for only 15% (RODRIGUES et al., 2014). This vegetable requires ideal medium-textured soil, rich in organic material, with good nutrient availability. To obtain higher productivity, the application of substances that improve the physical, chemical, and biological conditions of the soil is necessary. Greater yields are obtained by improving the chemical and physical-chemical characteristics of the soil, which can be obtained by adding increasing amounts of organic compost. The objective of our study was to evaluate of the use of residual compost from *Bactris gasipaes* Kunth (pupunha heart of palm) and *Pleurotus ostreatus* mushroom production in the fertilization of the soil for lettuce crops.

Materials and Methods

Collection and preparation of pupunha palm waste and residue from the cultivation of Pleurotus ostreatus

Experimental pupunha palm residue was collected along 12 km of Alexandra-Matinhos Road, in the Municipality of Paranaguá (Paraná State, Brazil), between the coordinates 25°09′19.2″S and 48º35′15.0″W. The relief was flat and the soil was of the Haplic Cambisol class with medium texture. The climate was Af Tropical Superwet with no water deficit, with average temperatures higher than 22°C during the hottest month, and temperatures exceeding 18°C in the coldest month. The average relative humidity was above 85%, and rainfall was approximately 2,500–3,000 mm annually (EMBRAPA, 1999).

The residue originated from stripping (the sheath) the pupunha palm stems (R_p) to obtain palm cream and was purchased from a palm heart preserve industry. The residue was ground in a mill into pieces of approximately 5 cm and then dried at 55°C for 72 h (BELLETTINI et al., 2015). *Pleurotus ostreatus* mushrooms (R_M) were grown in the sheath of pupunha as the mycelium substrate. The residue was collected immediately after completion of the second fruiting cycle of the mushrooms, and mushrooms were cultivated under specific conditions (SINGH; SINGH, 2012; KOUTROTSIOS et al., 2014) at the Federal University of Paraná – Food Engineering Laboratory.

Utilized soil

The soil was collected in the municipality of Paranaguá, in the same location that the pupunha palm was obtained. This type of soil belongs to the class Haplic Cambisol, having a medium texture (EMBRAPA, 1999). Prepared compost, of the brand "Salto," was also utilized for the minimum prior enrichment of the soil used in the initial mixture. The collected soil was sieved (mesh: 0.5 cm) for homogenization and separated from larger fragments of organic matter.

Experimental planning

The proportion of residue (R) added to the soil in the relevant treatments were established by percentage, as described by Ribas et al. (2009), taking into account the dry weight of R_P oven dried at 55 °C, and the wet weight of the R_M, relative to the volume of soil used for cultivation. Six treatments were defined (T2–T7), plus the control (T1), with 20 repetitions for each treatment, totaling 140 experimental units. The treatments accounted for the different types of R as substrate, in which the development of *Lactuca sativa* seedlings was assessed. The substrate was placed in 1-L plastic pots; specifically, 700 g of soil or soil R^{-1} was added to each pot, according to Table 1.

After mixing the soil with different ratios of R for soil homogenization, according to each treatment, the mixture was left to stand for 40 days (RIBAS et al., 2009) with frequent watering and increasing humidity of the substrate for the composting period, which further stabilized the material.

Table 1. Treatments utilized in soil enrichment with pupunha palm (R_P) and *Pleurotus ostreatus* mushroom (R_M) residual compost.

Treatments	Component amount/pot	% Equivalent
T1	500 g of earth 200 g of prepared compound	Soil
T2	465 g of earth 35 g of sheath of peach palm 200 g of prepared compound	Soil + 5% of R_P^a
T3	430 g of earth 70 g of sheath of peach palm 200 g of prepared compound	Soil + 10% of R_P^a
T4	395 g of earth 105 g of sheath of peach palm 200 g of prepared compound	Soil + 15% of R_P^a
T5	465 g of earth 35 g of residue from *Pleurotus ostreatus* mushroom 200 g of prepared compound	Soil + 5% of R_M^b
T6	430 g of earth 70 g of residue from *Pleurotus ostreatus* mushroom 200 g of prepared compound	Soil + 10% of R_M^b
T7	395 g of earth 105 g of residue from *Pleurotus ostreatus* mushroom 200 g of prepared compound	Soil + 15% of R_M^b

[a] Dry weight percentage of R_P in relation to the soil. [b] Wet weight percentage of R_M in relation to the soil.

Soil fertility evaluation before and after Lactuca sativa cultivation

The routine analysis of soil in the seven treatments was performed at the Department of Soil Science and Agricultural Engineering (DSEA) of Federal University of Paraná-UFPR. The following elements were evaluated: pH in a $CaCl_2$ 0.025 M solution (ratio 1:2.5) – active acidity, available phosphorus and potassium extracted by H_2SO_4 0.025 N + HCl 0.05 N; organic carbon, calcium, magnesium, and exchangeable aluminum extracted by KCl 1 N; hydrogen + exchangeable aluminum (potential acidity) in accordance with the methodology described by EMBRAPA (1999), and total nitrogen using the Dumas method. For the calculation of the estimated organic matter (OM), we used the amount of organic carbon multiplied by 1.724.

Lactuca sativa and obtaining seedlings

The type of *Lactuca sativa* utilized in the experiments was “Veronica.” This type was selected based on the temperatures during the experimental period (autumn-winter), and because it was a standard and the market leader, with large plants with pale green leaves, being highly resistant to bolting, and having black seeds. The seedlings were purchased from Agro-Horta Agricultural Products, Ltd. (Colombo, Paraná State, Brazil). The seedlings were kept in trays with 200 cells containing commercial substrate (Plantmax® HT) vermiculite. Irrigation with commercial nutrient solution was intermittent for 15 min every 60 min during the day and once at night.

Management and monitoring

The experiment began at the end of May 2013 and was conducted during autumn-winter. During the experiment, daily watering was conducted until the maximum water retention of each substrate was reached. The pots were maintained in a greenhouse for 63 days after the seedlings were transplanted (20 to 25 days, with 2 to 3 leaves, and approximately 4 to 6 cm high). This is a suitable time for lettuce to reach its maximum development (FIGUEIRA, 1982). The evaluation of the parameters related to plant development was performed following removal of the seedlings at 63 days of growth following transplantation.

Evaluation of Lactuca sativa development cultivated in R_P and R_M supplemented soil

Developmental parameters evaluated in *Lactuca sativa* specimens were total wet material per treatment, wet mass of shoots and roots, total dry matter per treatment, dry matter of shoots and roots, number of leaves per plant, and height and width of the aerial plant and root length (SANTOS et al., 2013). The determine the fresh weight of the plants, plants were individually weighed using a semi-analytical scale. To determine the number of leaves, all leaves larger than 0.03 m were detached from the plant and counted. After which, the height and width of each plant was determined with a ruler. To obtain dry mass, plants were placed in an oven with forced circulation at 65 °C for 72 h and subsequently weighed.

Results and Discussion

The pH values ranged between 6.0 and 6.3 for the pre-cultivation soil for treatments T1–T7 and were suitable according to Olenik et al. (2004). Aluminum (Al^{+3}) is a toxic element because it restricts root growth of plants, being associated with exchangeable acidity. In the samples analyzed, there was no Al^{+3}, and the soil could be classified as having very low potential acidity. The calcium (Ca^{+2}) content was classified as average (between 2.41 and 4.80 $cmol_c$ dm^{-3}) and high (over 4.80 $cmol_c$ dm^{-3}) for the different treatments, being classified as good and very good, respectively, according to Ribeiro et al. (1999). Thus, it was suitable for the functioning of meristems, cell reproduction, and the formation of the cell wall the middle lamella, which is composed mainly of calcium pectate. Magnesium (Mg^{+2}) had a value higher than 0.90 $cmol_c$ dm^{-3}, and was suitable for the photosynthesis process, increased chlorophyll, and activation of enzymes for carbohydrate metabolism. The soil is classified as having a high amount of magnesium (RIBEIRO et al., 1999). Potassium (K^+) had a value higher than 0.3 $cmol_c$ dm^{-3} in all treatments, and was rated as very high, enabling the deployment of sugars for respiration, starch and protein synthesis, and oxidative and photosynthetic phosphorylation. The sum of bases (SB), which is the sum of Ca^{+2} + Mg^{+2} + K^+, was higher than 3.6, which was classified as good/very good for all treatments (RIBEIRO et al., 1999). The concentration of nutrients from the soil analysis is shown in Tables 2 and 3.

The cation exchange capacity of the soil (T) was classified as good for all treatments, enabling a greater storage potential of cationic nutrients in the exchangeable form (COSTA, 2008). The amount of phosphorus (P), according Olenik et al. (2004), was very high in the treatments, being available for biochemical and enzymatic metabolism of carbohydrates, allowing the lettuce to breathe. The organic carbon (C) was higher than 14.1 g dm^{-3} and was rated high by Olenik et al. (2004). The carbon was converted into organic matter (OM), and based on the classification proposed by Ribeiro et al. (1999), it was considered a very good soil with regard to organic matter in all treatments. The base saturation percentage (V) was over 50%, classifying the soil as eutrophic ($V \geq 50\%$) or fertile in all treatments, with high amount of cations (50–80%), enabling high productivity. The aluminum saturation (m) percentage was zero for all treatments, indicating a productive, nutrient-rich soil, not requiring correction of acidity and allowing root growth (COSTA, 2008).

Table 2. Routine analysis for soil fertility evaluation with R_P and R_M addition after 40 days of composting, pre-cultivation. Exchangeable acidity (Al^{+3}) and titratable acidity ($H^+ + Al^{+3}$), potassium (K^+), secondary macronutrients (Ca^{+2} and Mg^{+2}), and sum of bases (Ca^{+2}, Mg^{+2}, and K^+).

Treatment	pH	Al^{+3}	$H^+ + Al^{+3}$	Ca^{+2}	Mg^{+2}	K^+	SB
	$CaCl_2$	cmol$_c$ dm^{-3}					
T1	6.30	0.00	3.00	5.30	2.70	0.98	8.98
T2	6.20	0.00	3.00	2.80	2.80	0.93	6.53
T3	6.30	0.00	2.70	4.00	2.60	1.15	7.75
T4	6.30	0.00	2.50	4.00	2.60	1.18	7.78
T5	6.00	0.00	4.40	4.60	2.90	1.21	8.71
T6	6.00	0.00	3.40	4.50	3.10	1.50	9.10
T7	6.10	0.00	2.50	4.10	2.90	1.33	8.33

Where: (T1) = Soil, (T2) = Soil + 5% of R_P, (T3) = Soil + 10% of R_P, (T4) = Soil + 15% of R_P, (T5) = Soil + 5% of R_M, (T6) = Soil + 10% of R_M, and (T7) = Soil + 15% of R_M.

Table 3. Routine analysis for soil fertility evaluation for values of cation exchange capacity (T), phosphorus (P), carbon (C), organic matter (OM), percent base saturation (V), and aluminum (m) in soil with addition of R_P and R_M 40 days after composting.

Treatment	T	P	C	OM	V	M	Ca/Mg
	cmol$_c$ dm^{-3}		g dm^{-3}		%		
T1	11.98	210.30	18.20	31.38	75	0	1.96
T2	9.53	65.00	18.20	31.38	69	0	1.00
T3	10.45	56.70	17.20	29.66	74	0	1.54
T4	10.28	47.40	17.20	29.66	76	0	1.54
T5	12.11	51.10	16.20	27.93	72	0	1.59
T6	12.50	52.80	18.20	31.68	73	0	1.45
T7	10.83	49.50	19.20	33.10	77	0	1.41

Where: (T1) = Soil, (T2) = Soil + 5% of R_P, (T3) = Soil + 10% of R_P, (T4) = Soil + 15% of R_P, (T5) = Soil + 5% of R_M, (T6) = Soil + 10% of R_M, and (T7) = Soil + 15% of R_M.

After the initial soil analysis, the soils were deemed fertile and were used as substrate for lettuce cultivation for 63 days. After harvest, the soil was analyzed once more, and the results are shown in Tables 4 and 5. Post-cultivation soils retained very similar characteristics to the pre-cultivation soil (composted for 40 days), with a slight increase in the carbon and organic matter quantity because of the composting process and a decrease in phosphorus because of leaching from the soil.

After 23 days of cultivation, the treatments with a 5% R addition to the soil (T2 and T5) had statistically similar results regarding height and width of the lettuce, but were lower in regards to the treatment without R_P and R_M addition (T1). Some treatments attracted flies to the surface of the soil in the pots, and the treatments containing R_M had growth of small basidiomata on the soil, indicating that the compost was not thoroughly processed. This was particularly true for pots containing R_P and R_M at higher concentrations (T4 and T7), which resulted in inadequate plant development (Figure 1).

Table 4. Routine analysis for soil fertility evaluation with R_P and R_M addition after 63 days of cultivation. Exchangeable (Al^{+3}) and titrable ($H^+ + Al^{+3}$) acidity, potassium (K^+), secondary macronutrients (Ca^{+2} and Mg^{+2}), and sum of bases (Ca^{+2}, Mg^{+2}, and K^+).

Treatment	pH	Al^{+3}	$H^+ + Al^{+3}$	Ca^{+2}	Mg^{+2}	K^+	SB
	$CaCl_2$	$cmol_c\ dm^{-3}$					
T1	6.10	0.00	3.20	5.10	3.30	0.52	8.92
T2	6.20	0.00	3.20	5.20	3.10	0.85	9.15
T3	6.40	0.00	2.70	5.30	3.10	1.27	9.67
T4	6.40	0.00	2.50	4.50	2.80	1.07	8.37
T5	6.20	0.00	3.20	5.00	3.00	1.03	9.03
T6	6.40	0.00	3.00	5.00	2.90	1.14	9.04
T7	6.50	0.00	2.70	4.50	2.80	1.29	8.59

Where: (T1) = Soil, (T2) = Soil + 5% of R_P, (T3) = Soil + 10% of R_P, (T4) = Soil + 15% of R_P, (T5) = Soil + 5% of R_M, (T6) = Soil + 10% of R_M, and (T7) = Soil + 15% of R_M.

Table 5. Routine analysis for soil fertility evaluation for cation exchange capacity values (T), phosphorus (P), carbon (C), organic matter (OM), percent base saturation (V), and aluminum (m) in the soil with R_P e R_M addition, from treatment, after 63 days of cultivation.

Treatment	T	P	C	OM	V	M	Ca/Mg
	$cmol_c\ dm^{-3}$		$g\ dm^{-3}$		%		
T1	12.12	40.80	23.20	40.00	74	0	1.55
T2	12.35	34.00	26.40	45.51	74	0	1.68
T3	12.37	46.00	23.20	40.00	78	0	1.71
T4	10.87	32.60	23.20	40.00	77	0	1.61
T5	12.23	39.10	19.20	33.10	74	0	1.67
T6	12.04	32.20	17.20	29.65	75	0	1.72
T7	11.29	33.10	21.20	36.55	76	0	1.61

Where: (T1) = Soil, (T2) = Soil + 5% of R_P, (T3) = Soil + 10% of R_P, (T4) = Soil + 15% of R_P, (T5) = Soil + 5% of R_M, (T6) = Soil + 10% of R_M, and (T7) = Soil + 15% of R_M.

Microbial attack on the organic matter results in the release of important chemicals, such as nitrogen, calcium, phosphorus, and magnesium, which produce the immobilized form (large chains) that become nutrients (mineral water) available to plants and other microorganisms. The addition of pupunha palm residue with or without mushroom mycelium (R_P and R_M, respectively) resulted in a greater inhibition of plant growth. According to the physiology of the plants, competition for nutrients was observed between the plant and the native soil microbiota, which used nitrogen from R_P organic matter and fungal mycelium (R_M) to perform the composting process. Thus, the composting was not yet been complete, and the elements, which were deficit in the soil, were not available to the plant, as shown in Table 6. This resulted in decreased productivity (Figure 2 and 3) and a lower average weight of lettuce.

Figure 1. Growth of lettuce (cm) in terms of height and width at 23 days after being planted for each treatment. Mean values followed by the same letter do not differ statistically through ANOVA and Tukey test ($p < 0.05$), based on 20 replicates. Where: (T1) = Soil, (T2) = Soil + 5% of R_P, (T3) = Soil + 10% of R_P, (T4) = Soil + 15% of R_P, (T5) = Soil + 5% of R_M, (T6) = Soil + 10% of R_M, and (T7) = Soil + 15% of R_M.

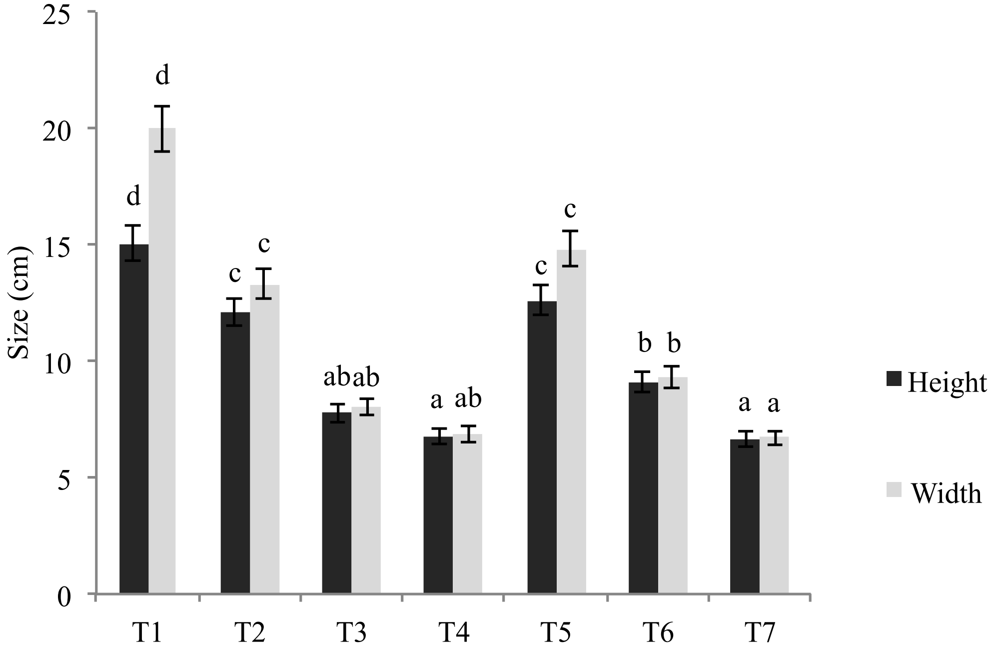


Table 6. Nitrogen (N_2) amount the soil for the different treatments (T1–T7) 63 days after planting lettuce.

Treatment	N_2	Equivalence
	g kg^{-1}	%
T1	2.19	-
T2	2.16	-1.36
T3	2.44	10.24
T4	2.62	16.41
T5	2.58	15.12
T6	2.59	15.44
T7	2.52	13.10

Where: (T1) = Soil, (T2) = Soil + 5% of R_P, (T3) = Soil + 10% of R_P, (T4) = Soil + 15% of R_P, (T5) = Soil + 5% of R_M, (T6) = Soil + 10% of R_M, and (T7) = Soil + 15% of R_M.

Figure 2. Growth of lettuce (cm) in terms of height and width at 63 days after being planted for each treatment. Mean values are followed by the same letter do not differ statistically through ANOVA and Tukey test ($p < 0.05$), based on 20 replicates. Where: (T1) = Soil, (T2) = Soil + 5% of R_P, (T3) = Soil + 10% of R_P, (T4) = Soil + 15% of R_P, (T5) = Soil + 5% of R_M, (T6) = Soil + 10% of R_M, and (T7) = Soil + 15% of R_M.

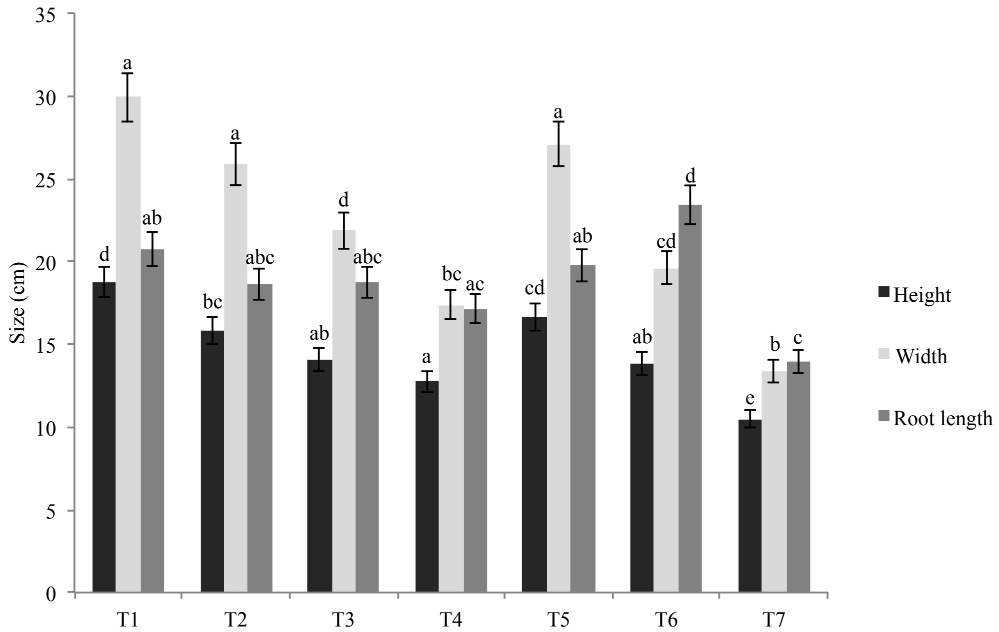
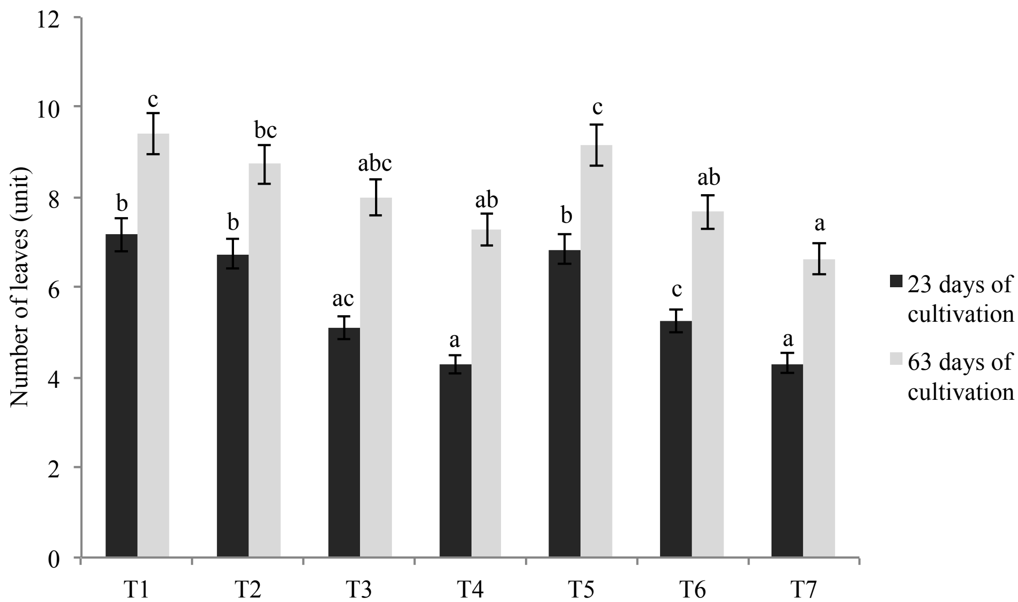


Figure 3. Growth of lettuce (cm) in terms of height and width at 23 and 63 after being planted for each treatment. Mean values are followed by the same letter do not differ statistically through ANOVA and Tukey test ($p < 0.05$), based on 20 replicates. Where: (T1) = Soil, (T2) = Soil + 5% of R_P, (T3) = Soil + 10% of R_P, (T4) = Soil + 15% of R_P, (T5) = Soil + 5% of R_M, (T6) = Soil + 10% of R_M, and (T7) = Soil + 15% of R_M.

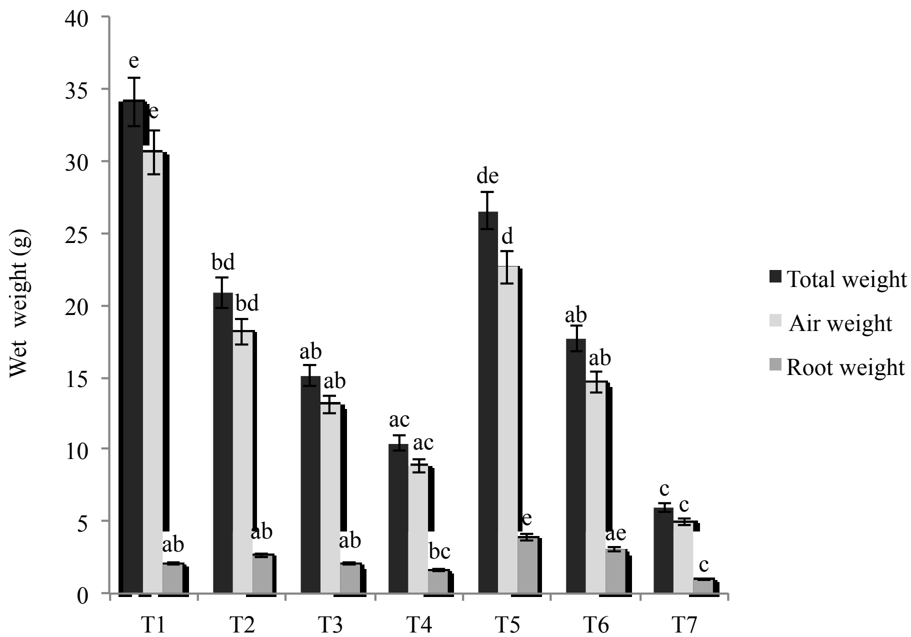


After 63 days of cultivation, the lettuce was harvested and the treatment with a 5% addition of R_P and R_M (T2 and T5, respectively) were similar (Figure 2 and 3). However, only the treatment that contained the fungal mycelium (T5) exhibited lettuce development that was statistically similar to that of the control treatment, without addition of R (T1). The sheath of peach palm is highly fibrous, tough, and has low nitrogen content, rendering the composting process more difficult. Because treatment T5 had a smaller amount of pupunha palm sheath and contained *Pleurotus ostreatus* mycelium, the development of the lettuce was more similar to T1 when compared to the T2 treatment.

The addition of R_P and R_M to the soil resulted in no significant increase in available nitrogen attributable to the addition of the residual substrate (Table 6) used for composting waste. The nitrogen content in pupunha palm fibers is very low, and the *Pleurotus ostreatus* mycelium continued to grow and exhibited basidiocarp after 23 days of lettuce cultivation. It was verified that after 63 days of culture the addition of mycelium slightly increased the amount of nitrogen in the soil.

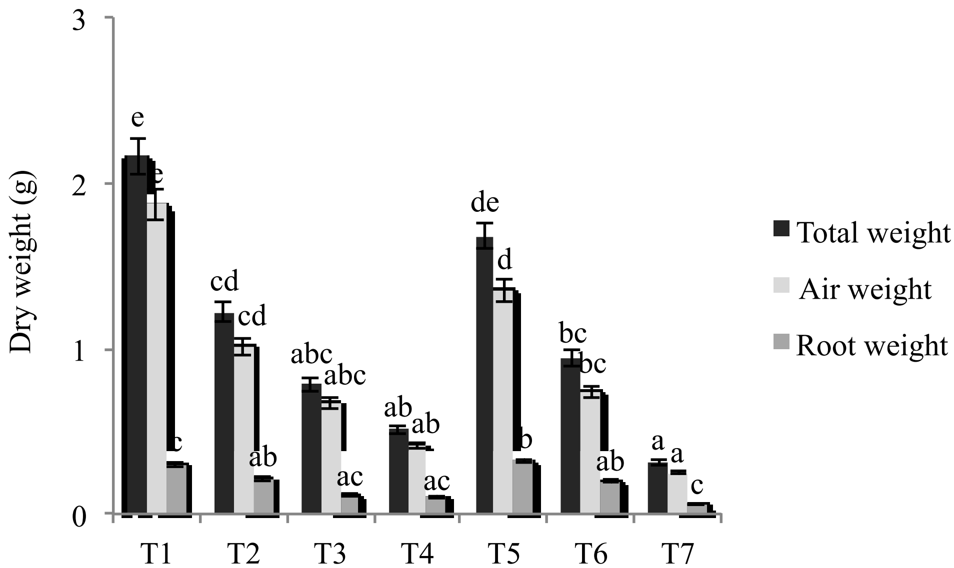
The treatments with a greater amount of residual compost added, for both R_P and R_M, showed higher values for width because of the increased angle between the stem and leaf that resulted from a lack of nitrogen available to the plant. Variations in total, weight of root, and aerial *Lactuca sativa* specimens were observed as a function of the dose of R that was added in relation to the amount of soil with time, as is shown in Figures 4 and 5. In terms of development of plants in treatments with R, a lower dry weight of all parameters was observed compared with the control group. With a greater addition of R, plant growth decreased. Treatments with 5% R mixed with the soil, for R_P and R_M, caused a reduction in dry weight of 1.7 and 1.2 times, or 44% and 22%, respectively, compared with the control group (T1). This result demonstrated that higher levels of both R_P and R_M damaged plant development in terms of all parameters.

Figure 4. Wet weight (g) of shoot, root, and total lettuce weight at 63 days after planting (harvest lettuce) for each treatment. Mean values followed by the same letter did not differ statistically by ANOVA and Tukey test ($p < 0.05$), based on 20 repetitions. Where: (T1) = Soil, (T2) = Soil + 5% of R_P, (T3) = Soil + 10% of R_P, (T4) = Soil + 15% of R_P, (T5) = Soil + 5% of R_M, (T6) = Soil + 10% of R_M, and (T7) = Soil + 15% of R_M.



Plant growth, with a 5% addition of such residues to the soil, can be related to the increased water retention capacity of the soil, improving its structure and providing P, K, and MO sources. Depending on its concentration, nutrients can be harmful in terms of soil conditioning. Both R_P and R_M exhibited high levels of potassium (K) and phosphorus (P). Maher et al. (2000) studied the average composition of 13 samples of R and found a high level of initial K (among the water-soluble nutrients) and high electrical conductivity (EC), limiting its immediate use for plant growth (CHONG; RINKER, 1994; GUO et al., 2001). This fact is caused by the sensitivity of some plants to high concentrations of salts (BEYER, 2003), as is the case of lettuce; however, in this study the limiting factor for the development of lettuce was the available nitrogen content in the soil. For this reason, several authors recommend a period of maturation of R, before its application, as described by Guo et al. (2001), who stated that the compost should be rested under ambient weather conditions for approximately two years before it is reused. Nevertheless, Chang (1987) recommended a period of 2 to 3 months of maturation in the field before application, whereas Beyer (2003) indicated a period of at least 6 months was necessary.

Figure 5. Dry weight (g) of shoot, root, and total lettuce weight at 63 days after planting (harvest lettuce) for each treatment. Mean values followed by the same letter did not differ statistically by ANOVA and Tukey test ($p < 0.05$), based on 20 repetitions. Where: (T1) = Soil, (T2) = Soil + 5% of R_P, (T3) = Soil + 10% of R_P, (T4) = Soil + 15% of R_P, (T5) = Soil + 5% of R_M, (T6) = Soil + 10% of R_M, and (T7) = Soil + 15% of R_M.



Inadequate amounts of organic compost derived from R in mushroom production for soil fertilization and increased EC in quantities above ideal have been reported. For example, Vavrina et al. (1996), in experiments with pots in the greenhouse, evaluated the effect of concentrations of 5%, 10%, 15%, 25%, and 30% of R ($v\ v^{-1}$) mixed with peat, using peat as the control, in the development of tomatoes. They noted that during the first harvest, there were no major differences among the weight of the plants with added R up to 20%. However, higher additions caused a decrease in plant growth. In another experiment, using rye straw, in the first crop, productivity was greater with R additions equivalent to 50 t ha^{-1}. However, with higher doses there was a reduction in plant growth, likely caused by an increase in EC (MAHER, 1994). Ribas et al. (2009), researching the development of *Lactuca sativa* 'Summer' using R application of *Agaricus brasiliensis* with both the base coat layer on a peat base and soil base, at proportions of 5%, 10%, 25%, and 40% (dry weight), found that applications between 12.5% and 25% favored lettuce development.

Thus, the R_P and R_M proportions to be applied in each culture must be properly defined in order to avoid problems of salinity and especially nitrogen availability. The use of R in agriculture, for example that originated from *A. brasiliensis* culture, is possible because the fungus grows from a previously composted substrate when the necessary means for its development are provided (RIBAS et al., 2009). Lignocellulosic mushrooms, such as *Pleurotus* spp., present a highly fibrous R, which is also low in nitrogen (MEMBRILLO et al., 2008), thus requiring a full period of composting for later use for soil enrichment for several crops. In general, fertilization with R_P or R_M with no previous composting was unable to replace NPK fertilization, because dry weight parameters fell below the commercial level. A complete period of composting R_P and R_M is deemed necessary for incorporating nitrogen into the soil.

Conclusions

The residual mixture composed of both the productions of pupunha palm and *Pleurotus ostreatus* mushroom as a soil substrate, immediately after a production cycle of mushrooms, decreased the growth of lettuce when compared to materials used in standard procedures. Lignocellulosic mushrooms, such as *Pleurotus* spp., produce highly fibrous residual compost, being low in nitrogen content, thus requiring a full period of composting for later use in soil enrichment for several crops.

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