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DEVELOPMENT OF LACTUCA SATIVA L. COM APPLICATION OF VEGETABLE ASH IN CLAY SOIL

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ABSTRACT

The by-products generated by agroindustries have a great potential for reuse due to their high nutritional contents. Organic fertilization alternatives are being sought, especially aimed at the use of waste from local industrial activity, such as vegetable ash, which is a solid waste with considerable potential as a fertilizer. The objective of this study was to evaluate the development of lettuce (Lactuca sativa L.) in clay soil under different doses of vegetable ash. The lettuce seedlings were transplanted in beds inside a tube arch greenhouse, with four treatments and five replications in a completely randomized design. The treatments included T1 - control, without addition of vegetable ash, T2 - 1.7 kg m², T3 - 3.3 kg m² and T4 - 6.7 kg m². After harvest, biometric parameters of the plants were evaluated, such as fresh and dry mass of the root and shoot (commercial and non-commercial), stem diameter and height, and root length. In addition, the pH and the amount of nutrients in the soil were analyzed. The results indicated that vegetable ash, when incorporated into the soil, works as an effective organic fertilizer in lettuce production. The dose of 1.7 kg m² proved to be the most efficient, providing positive results in the biometric parameters, in addition to improving soil quality. This dose corrected soil acidity, increased pH, increased cation exchange capacity (CEC) and base saturation (SB), reduced aluminum levels (Al^{3+}), and increased macro and micronutrients.

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INTRODUCTION

Lettuce (*Lactuca sativa* L.), originally from the Mediterranean region, is considered the most important leafy vegetable in the world from a socioeconomic point of view, being the most commercialized and consumed in Brazil (ABCSEM, 2017). Its popularity is due to the possibility of production throughout the year, its peculiar culinary characteristics, and its great cultural acceptance, being consumed mainly in nature, in the form of salads (Yuri *et al.*., 2017).

Paraná is the second-largest producer of lettuce in Brazil (CONAB, 2021). In the 2021/2022 harvest, the state produced 128.7 thousand tons of vegetables, consolidating itself as one of the main producing regions in the country and demonstrating the relevance of the crop for the local and national economy (CONAB, 2023).

In lettuce cultivation, it is common to use cattle manure, poultry litter, sawdust, or rice straw to maintain soil fertility (Bezerra *et al.*., 2019). Other alternatives for organic fertilization are being sought, especially those arising from the use of waste from local industrial activity (Terra *et al.*., 2014).

According to Jerônimo and Silva (2012), agro-industrial residues are excellent raw materials for the production of organic fertilizers and substrates, being relevant not only from an agronomic point of view but also from a social and economic point of view. Also according to the authors, the use of these materials improves food quality and can contribute to increasing agricultural productivity, promoting a more balanced agriculture that is less dependent on synthetic inputs.

An agro-industrial residue that has been used is vegetable ash, which has considerable potential as an agricultural fertilizer, as it contains essential nutrients for plant growth, such as calcium, magnesium, and phosphorus, performing vital functions in plant metabolism (Silva *et al.*., 2020). In addition, vegetable ash provides micronutrients such as copper (Cu), zinc (Zn), manganese (Mn), iron (Fe), and boron (B), essential elements for plant physiology and agricultural productivity (Rigau, 1960; Detroit; Osaki, 1989).

Research shows that the application of vegetable ash improves soil conditions and favors plant development, as observed in crops such as *Brachiaria decumbens* cv. Basilisk, bell pepper (*Capsicum annuum* L.), and peanut (*Arachis hypogaea*) (Reis *et al.*., 2020; Rezende *et al.*., 2021; Silva *et al.*., 2020). However, some studies indicate that the addition of ash may not result in significant gains for certain vegetables, such as watercress

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(*Barbarea verna*) and arugula (*Eruca sativa*), underscoring the need for additional research (Bezerra *et al.*., 2019).

Given this context and the need to search for sustainable sources for soil fertilization in plant development, the objective of this study was to evaluate the development of lettuce (*Lactuca sativa* L.) in clay soil under different doses of vegetable ash.

METHODOLOGY

The experiment was carried out in a tube arch greenhouse in the rural area of the municipality of Jandaia do Sul - Paraná. The geographical coordinates of the place are Latitude 23°42'38.90" and Longitude 51°40'48.25", with an elevation of 794 meters. The climate of the region, according to the classification of Köppen (1936), is predominantly humid mesothermal subtropical.

The vegetable ash used in the experiment came from the burning of eucalyptus (*Eucalyptus* spp.) and was supplied by a company in the North of Paraná that operates with furnaces and silos for drying and storage of grains. After receipt, the ash was taken to a laboratory in the region for analysis of its chemical composition, as shown in Table 1.

Table 1. Chemical composition of vegetable ash used as organic fertilizer in lettuce cultivation.

N	P	K	Ca	Mg	Ass	Fe	Mn	Zn
---------------------%----------------								
0,11	2,27	4,82	2,91	0,30	0,03	2,08	0,38	0,05

Source: LABORFORT – Chemical Analysis.

Soil samples were collected in a layer of 0 to 20 cm depth in the experimental beds. These samples were homogenized, and a single sample was taken and sent to a soil analysis laboratory in the region for chemical (Table 2) and physical (Table 3) characterization, classifying the soil as clayey.

Table 2. Chemical characteristics of the soil used in the experiment.

ph	P	M.O	Ca	K	Mg	CTC	V	Al3+
mg.dm3 %			---------cmolc.dm-3---------			%		comic.dm3
4,1	15,2	3,6	5,2	0,7	1,5	18,1	40,9	0,9

Source: LABORFORT – Chemical Analysis.

Table 3. Granulometric analysis of the soil used in the experiment.

Sand	Silt	Clay
---------------%--------------		
12,5	12,5	75

Source: LABORFORT – Chemical Analysis.

The experiment was conducted using a completely randomized design (DIC) with four treatments and five replications, totaling 20 experimental units. In each experimental unit, seven lettuce seedlings were transplanted. The treatments evaluated were: T1 - control, without addition of ash; T2 - 1.7 kg of ash m²; T3 – 3.3 kg of ash m²; and T4 – 6.7 kg of gray m².

Two beds were prepared, 40 cm high, 9 m long, 1 m wide, and 0.50 m wide The vegetable ash was incorporated into the soil at different doses of each treatment, being incubated for 10 days before planting.

Curly lettuce seedlings, cultivar Valentina, were used. Transplanting took place 25 days after sowing, following the 30 x 30 cm spacing. Irrigation was carried out daily and weed control was done by manual weeding. Throughout the experiment, there was no incidence of pests or diseases.

The harvest was carried out 49 days after transplanting and the plants were taken to the agronomic analysis laboratory of the higher education institution for evaluation of the following physiological parameters: fresh and dry weight of the aerial part, fresh and dry weight of the root, diameter and length of the stem and root, in addition to the count of marketable and non-marketable leaves.

The collected data were submitted to linear and quadratic regression tests at 5% probability, using the statistical program Sisvar (Ferreira, 2008). These tests were applied to determine the dependence relationship between the effect of ash from plant biomass, used as organic fertilizer, and the variables of interest analyzed.

RESULTS AND DISCUSSION

For all the variables analyzed, both for the aerial part and for the root system of the plants, it was observed that at least one of the treatments evaluated presented a significant difference from the others, at a level of 5% probability, based on the linear and quadratic regression tests (Table 4).

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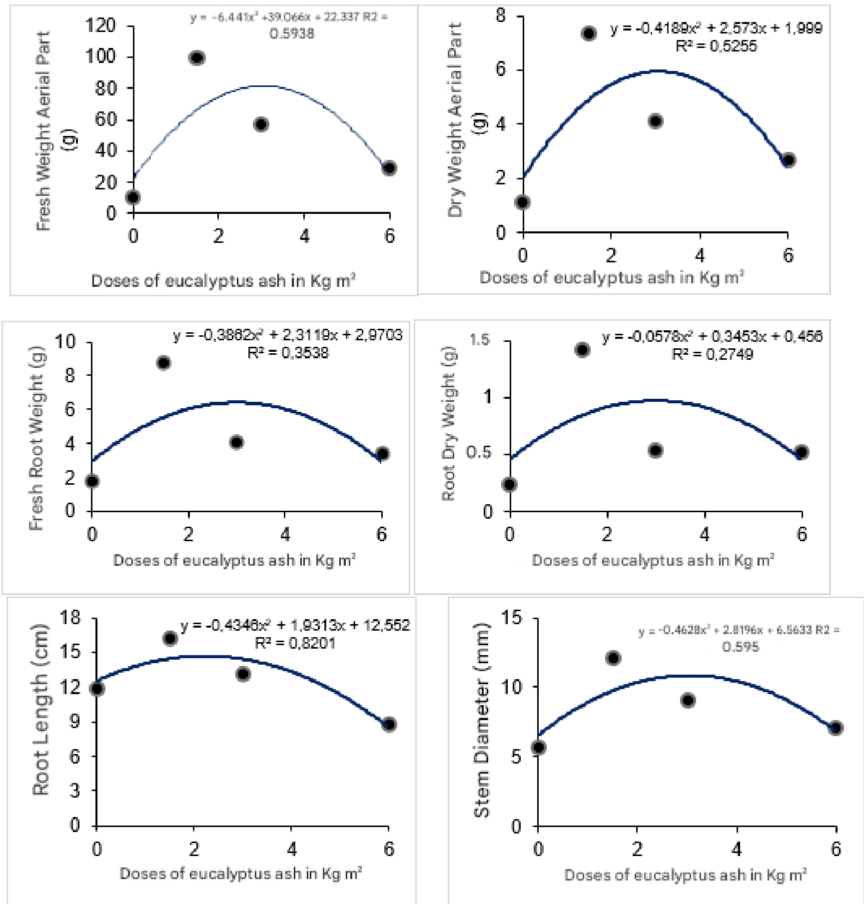
Table 4. Linear and quadratic regression tests for the variables related to shoot fresh weight (PFA), root fresh weight (PFR), shoot dry weight (PSA), root dry weight (PSR), stem diameter (DC), root length (CR), number of commercial leaves (NFC) and number of non-commercial leaves (NFNC) by different assays of ash evaluated.

FV	GL	PFA	PFR	PSA	PSR	Anno Domini	CR	NFC	NFNC
Doses	3	7461,57*	45,42*	35,51*	1,31	38,44*	48,18*	42,45*	2,18*
b1 (Linear)	1	52.66ns	0.00ns	0.57ns	0.00ns	0.43ns	40.08ns	0.09ns	6,25*
b2 (Quadratic)	1	17135,24*	73,84*	74,61*	1,79*	88,16*	95,27*	92,45*	0.05ns
Repetitions	5	-	-	-	-	-	-	-	-
Error	12	-	-	-	-	-	-	-	-
Average	-	48,80	4,48	3,80	0,68	8,50	12,49	8,25	2,35

Regarding the agronomic variables studied, there were significant differences (P>0.05) in shoot fresh weight, shoot dry weight, root fresh weight, root dry weight, stem diameter, root length, and number of marketable leaves of lettuce plants, where the quadratic regression model was adopted due to its higher degree of significance (Table 4 and Figure 1).

Figure 1: Quadratic Regression Analysis for shoot fresh weight, root fresh weight, root dry weight, stem diameter, root length by different ash dosages.



When analyzing Figure 1, it can be seen that the application of 1.7 kg of vegetable ash per m² presented the best performance in all the variables evaluated. At this dose, the maximum fresh weight of the shoot reached 98.97 g, corresponding to an increase of 89.75% from the control. The maximum dry weight of the shoot was also obtained with the same dosage, reaching 7.34 g, representing an increase of 85.15% in production compared to the control. In studies conducted by Pereira *et al.*element. (2010) and Sousa *et al.*element. (2017), it was evidenced that vegetable ash showed a greater capacity to promote an increase in fresh and dry matter yield in both papaya and oats when compared to other nutritional sources.

For the stem diameter variable, the application of the dose of 1.7 Kg m2 of vegetable ash (T2) also provided better results, with a diameter of 12.08 mm, presenting a productive increase of 52.90% about the control. Results similar to those observed in this study, for stem diameter, were also evidenced by Bonfim-Silva *et al.*element. (2013) with the pigeon pea crop and the use of vegetable ash as a source of fertilization, where they observed an average of 2.97 mm of stem diameter when applied to the dose of 15 g dm-3 of vegetable ash, promoting an increase in production of 23.57% when compared to the treatment in which the residue was not used.

The highest root fresh mass was also observed with the application of 1.5 Kg m² of vegetable ash, resulting in 8.77 g and an increase of 79.82% in fresh weight about the control, which did not receive fertilization with plant biomass ash. Similar results were obtained for the root dry weight, reaching 1.42 g and promoting an increase of 83.10%, and in the root length where the length of 16.21 cm was observed, promoting a productive increase of 26.59% when compared to the treatment where fertilization with plant biomass ash was not performed. Furthermore, according to Graph 1, it is possible to verify that as the doses of ashes applied increase, the length variable also presents a considerable reduction.

Maeda *et al.* (2007) state that plant biomass ash is an important organic compound, capable of providing macronutrients such as calcium and magnesium, contributing to the reduction of aluminum content in the soil, thus promoting the neutralization of acidity and helping in the availability of nutrients for plants, resulting in better root development.

For the variables number of marketable and non-marketable leaves of lettuce plants, as shown in Figure 2, the quadratic regression and linear regression models were applied, respectively.

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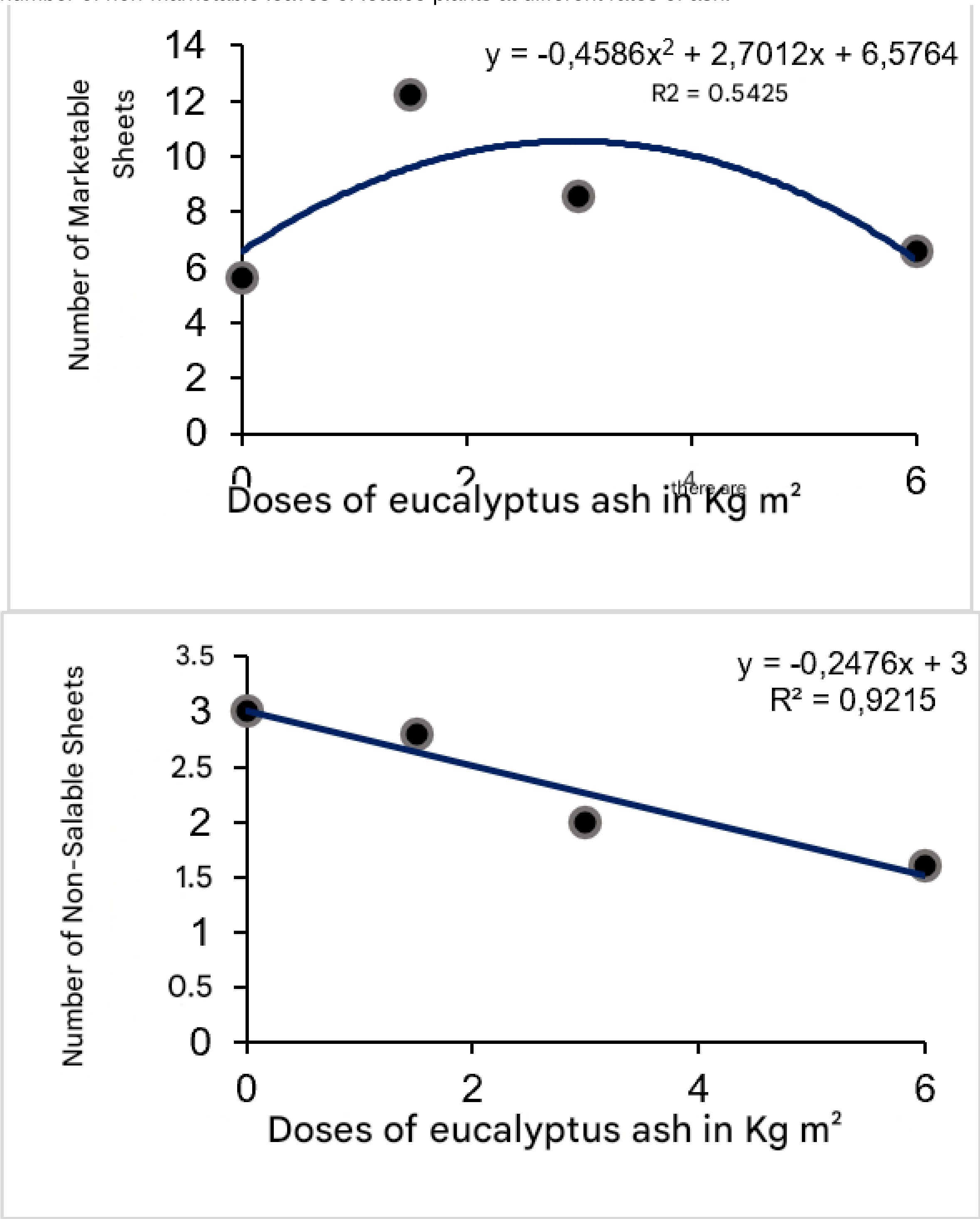
Figure 2: Quadratic regression analysis for the number of marketable leaves and linear regression analysis for the number of non-marketable leaves of lettuce plants at different rates of ash.



As can be seen in the graph above, for the control where no dose of ash was used, in the adult plants, the average was around 3 leaves that were impossible to market. It is also possible to identify that, as the ash rates on the crop are applied and increased, the NFNC variable also decreases. As established in the graph, the average number of leaves

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unsuitable for sale and consumption reduces from 3 to approximately 1.5. The use of ashes as organic fertilizer promotes a reduction in product losses at harvest, enabling greater use of the aerial part of lettuce plants. The number of leaves is a crucial factor for marketing standards, as it determines whether a plant is viable or unviable for consumption in nature, as the leaves are the ones that will be marketed (Brzezinski *et al.*, 2017).

According to Table 5, the soil without ash application (T1) is acidic, with low levels of macronutrients such as calcium, magnesium, phosphorus, and potassium. In addition, it also had low base saturation and the existence of Al3+ and was considered an extremely toxic element for plants. However, as expected, as the incorporation of vegetable ash from eucalyptus burning was carried out, there was a significant increase in the nutrient contents in the soil, as well as a complete reduction in the availability of Al3+. It was also found that, with the addition of ash doses, there was a significant increase in soil pH, from 4.12 to 8.33.

Table 5. Chemical analysis on the effect of applying different dosages of vegetable ash (T1 – Control; T2 – 1.7 Kg m2; T3 – 3.3 Kg m2; T4 – 6.6 Kg m2) in the soil under study.

Parameters	Treatments			
	T1	T2	T3	T4
pH CaCl2	4,12	7,39	7,79	8,33
Al3+	0,92	0	0	0
CTC	8,34	22,0	20,55	19,92
SB	7,42	21,7	19,62	19,30
MO	3,58	2,96	2,88	2,69
P	15,18	49,7	37,92	30,26
K	3,87	8,62	16,64	32,13
Ca	28,73	65,9	51,97	36,6
Mg	8,40	20,0	26,86	28,16
B	0,57	0,36	0,50	1,06
Ass	20,51	0,84	0,64	1,00
Fe	42,4	32,0	32,70	32,94
Mn	69,79	27,0	6,55	0,54
Zn	6,18	2,77	0,97	0,69

Al3+, CTC, SB and Mg (cmolc dm-3; P, K, B, Cu, Fe, Mn and Zn (mg dm-3); Ca and MO (%).
Source: LABORFORT – Chemical Analysis.

According to Ochecová *et al.* (2017) and Silva *et al.* (2020), vegetable ash is an organic fertilizer, rich in nutrients and, due to the presence of calcium, magnesium, and potassium ions, it is capable of increasing the base saturation of the soil. Bonfim-Silva et al., (2019) also pointed out that the incorporation of ash into the soil can promote changes

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in its chemical characteristics, such as an increase in the contents of Ca, Mg, B, Mn, CEC, in pH levels, in addition to increasing base saturation and acting to reduce the levels of $Al3^{+}$ and Fe. These authors mention that the use and application of ashes should be judicious because excessive doses can be toxic to plants.

When very high doses of vegetable ash are used in crops, it can impair the development of plant roots and consequently the development of the crop (Ignatieff and Page, 1959). Nascimento Filho (2015) also points out that the inconvenient use of ashes can also cause damage to the ecosystem, such as soil salinization, nutritional imbalance, accumulation of contaminants and leaching or surface runoff of nutrients and contaminants, compromising, as a whole, crop production and soil and water quality.

By analyzing the values obtained in the chemical analysis of soil for treatment 4, where the highest dose of ash was applied (6.7 Kg $^{m-2}$), it is possible to see that the soil mixed with the highest dose of ash reached an extremely basic condition. Under these conditions, the availability and absorption of certain elements end up being compromised. Therefore, the negative effect of phototoxicity seen in the plants in this treatment may have occurred, mainly due to the excessive amount of ash used.

Similar studies have also evidenced these conditions and results, Darolt *et al.*element. (1993) tested different amounts of ash in lettuce nutrition and found significant gains in yield in the quantities of 10 t $^{ha-1}$ and 15 t $^{ha-1}$. However, at the doses of 20 t $^{ha-1}$ and 30 t $^{ha-1}$, the results were not so satisfactory. According to these researchers, this evident negative effect is directly related to the greater nutritional imbalance provided by the higher doses of ash used. Therefore, it is necessary to conduct new studies testing different amounts of this product, to identify which dose best fits the cultivation of different crops, without bringing negative effects to the plants and the producer.

Bonfim-Silva *et al.* (2020) consider that to make the use of this waste more efficient in agriculture, it is interesting to carry out three different steps: first, the chemical analysis of the vegetable ash must be carried out before its application in the agricultural system as a corrective and/or fertilizer. After applying the ash, it is important to monitor the concentrations of nutrients in the soil, and last but not least, it is valuable to monitor the absorption of nutrients by the plants. All this is necessary to avoid the excessive application of this residue in agricultural systems.

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CONCLUSION

Vegetable ash is an important organic compound that can be used in agriculture, mainly to supply the nutritional needs of lettuce, as it brings benefits to the development and results of the physiological parameters of the plants. The application of ash from plant biomass at a dose of 1.7 Kg $^{m-2}$ provided greater development of lettuce. In addition, the vegetable ash, mixed with the soil in the production of lettuce, brought satisfactory results about the soil quality indices under study, such as the correction of soil acidity through the increase of the pH level; increase in CTC and SB; reduction of Al^{3+} contents and increase in the availability of macro and micronutrients.

The results suggest that vegetable ash, when applied in adequate doses, can be an excellent source of nutrients for lettuce cultivation, significantly improving the development of the shoot and root, as well as the commercial quality of the leaves. However, excessive doses can have adverse effects, highlighting the importance of a balanced application to maximize benefits and minimize the risks of toxicity and nutritional imbalance.

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