



USE OF SEWAGE TREATMENT PLANT (STP) SLUDGE FOR FERTILIZATION OF RUBBER TREES (*HEVEA BRASILIENSIS*)

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ABSTRACT

Objectives: To evaluate the effect of sanitized sewage sludge from Wastewater Treatment Plants (WWTP) on the growth of rubber tree (*Hevea brasiliensis*), comparing it with conventional organic and chemical fertilization.

Theoretical Framework: The disposal of WWTP sludge poses technical, economic, and environmental challenges. Its agricultural use emerges as a sustainable alternative, providing essential nutrients for plants, reducing the amount of waste sent to landfills, and aligning with circular economy principles.

Method: The experiment was conducted in a randomized block design with nine treatments and two replications, spaced 6 × 3 m, three years after planting. Increasing doses of nitrogen from sanitized sludge were applied, as well as bovine manure, urea, and a control without fertilization. Growth variables measured were total plant height and diameter at breast height (DBH).

Results and Discussion: Higher nitrogen doses from sludge promoted greater growth, especially in DBH, a variable related to latex production. The 70 g N/plant dose showed performance comparable to conventional fertilization, while higher doses enhanced vegetative development. These findings confirm the feasibility of sludge as an agricultural input and reinforce its contribution to soil fertility.

Research Implications: The study demonstrates that sanitized sludge can replace or complement traditional fertilizers in rubber tree cultivation, reducing costs and environmental impacts, while offering a sustainable solution for WWTP sludge management.

Originality/Value: This research expands knowledge on the agricultural use of sludge in perennial crops of economic interest, such as rubber tree, which are still little explored in the literature, highlighting its potential to strengthen sustainable agricultural practices.

Keywords: Biosolid, Solid Waste, Organic Fertilization, Plant Nutrition.

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UTILIZAÇÃO DO LODO DE ESTAÇÃO DE TRATAMENTO DE ESGOTO (ETE) PARA ADUBAÇÃO DA SERINGUEIRA (*HEVEA BRASILIENSIS*)

RESUMO

Objetivos: Avaliar o efeito do lodo higienizado proveniente ETE no crescimento da seringueira (*Hevea brasiliensis*), comparando-o com adubações orgânica e química convencionais.

Referencial Teórico: A destinação do lodo de ETE representa desafio técnico, econômico e ambiental. Seu uso agrícola surge como alternativa sustentável, por fornecer nutrientes essenciais às plantas, reduzir o volume de resíduos destinados a aterros e alinhar-se aos princípios da economia circular.

Método: O experimento foi conduzido em delineamento de blocos casualizados, com nove tratamentos e duas repetições, em espaçamento de 6 × 3 m, três anos após o plantio. Foram aplicadas doses crescentes de nitrogênio via lodo higienizado, além de tratamentos com esterco bovino, ureia e controle sem adubação. As variáveis analisadas foram altura total da planta e diâmetro à altura do peito (DAP).

Resultados e Discussão: Doses mais elevadas de nitrogênio oriundas do lodo promoveram maior crescimento, especialmente no DAP, variável relacionada à produção de látex. A dose de 70 g N/planta apresentou desempenho semelhante às adubações convencionais, enquanto doses superiores potencializaram o desenvolvimento vegetativo. Esses resultados confirmam a viabilidade do lodo como insumo agrícola e reforçam sua contribuição para a fertilidade do solo.

Implicações da Pesquisa: O estudo evidencia que o lodo higienizado pode substituir ou complementar fertilizantes tradicionais na cultura da seringueira, reduzindo custos e impactos ambientais, além de oferecer alternativa sustentável para a gestão de resíduos de ETE.

Originalidade/Valor: A pesquisa amplia o conhecimento sobre o uso agrícola do lodo em culturas perenes de interesse econômico, como a seringueira, ainda pouco exploradas na literatura, destacando seu potencial para fortalecer práticas de manejo agrícola sustentáveis.

Palavras-chave: Biossólido, Resíduos Sólidos, Adubação Orgânica, Nutrição de Plantas.

USO DEL LODO DE LA ESTACIÓN DE TRATAMIENTO DE AGUAS RESIDUALES (ETAR) PARA LA FERTILIZACIÓN DEL ÁRBOL DEL CAUCHO (*HEVEA BRASILIENSIS*)

RESUMEN

Objetivos: Evaluar el efecto del lodo higienizado proveniente de Estaciones de Tratamiento de Aguas Residuales (ETAR) en el crecimiento del árbol de caucho (*Hevea brasiliensis*), comparándolo con fertilización orgánica y química convencional.

Marco Teórico: La disposición del lodo de ETAR representa un desafío técnico, económico y ambiental. Su uso agrícola surge como una alternativa sostenible, al proporcionar nutrientes esenciales para las plantas, reducir el volumen de residuos enviados a rellenos sanitarios y alinearse con los principios de la economía circular.

Método: El experimento se realizó en un diseño de bloques al azar, con nueve tratamientos y dos repeticiones, en un espaciamiento de 6 × 3 m, tres años después de la plantación. Se aplicaron dosis crecientes de nitrógeno provenientes del lodo higienizado, además de estiércol bovino, urea y un control sin fertilización. Las variables analizadas fueron la altura total de la planta y el diámetro a la altura del pecho (DAP).

Resultados y Discusión: Las dosis más altas de nitrógeno del lodo promovieron un mayor crecimiento, especialmente en el DAP, variable relacionada con la producción de látex. La dosis de 70 g N/planta mostró un desempeño comparable a la fertilización convencional, mientras que dosis superiores potenciaron el desarrollo vegetativo. Estos resultados confirman la viabilidad del lodo como insumo agrícola y refuerzan su aporte a la fertilidad del suelo.



Implicaciones de la Investigación: El estudio demuestra que el lodo higienizado puede reemplazar o complementar los fertilizantes tradicionales en el cultivo del caucho, reduciendo costos e impactos ambientales, y ofreciendo una solución sostenible para la gestión de lodos de ETAR.

Originalidad/Valor: La investigación amplía el conocimiento sobre el uso agrícola del lodo en cultivos perennes de interés económico, como el caucho, aún poco explorados en la literatura, destacando su potencial para fortalecer prácticas agrícolas sostenibles.

Palabras clave: Biosólido, Residuos Sólidos, Fertilización Orgánica, Nutrición Vegetal.

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1 INTRODUCTION

Population growth and urban sprawl increase the pressure on water resources, making it essential to install Sewage Treatment Plants (STP) to reduce the environmental impacts resulting from the release of effluents without adequate treatment. However, the operation of WWTPs generates large volumes of sludge, whose destination represents a technical, economic and environmental challenge (Paganini *et al.*, 2024).

Currently, about 52.2% of the sewage generated in Brazil is treated, according to the Instituto Trata Brasil (2024). Despite this progress, this percentage is still far from the target of 90% treatment by 2033, established by the Legal Framework for Sanitation (Law No. 14,026 / 2020), which updated national legislation and set goals for the universalisation of water and sewage services (BRAZIL, 2020). With the expansion of sewage coverage, sludge production is also growing, estimated at hundreds of thousands of tons per year, which reinforces the need for safe and sustainable solutions for its disposal (Mendonça *et al.*, 2025).

In the state of Espírito Santo, the disposal of sludge has evolved with initiatives aimed at agricultural reuse. Projects conducted by Incaper and Cesan have tested the use of sludge as fertiliser in conilon coffee and black pepper crops, especially in the municipality of Nova Venécia (Costa; Costa, 2011). The material is classified as Class B by CONAMA Resolution No. 498/2020, being submitted to rigorous chemical and biological analyses before application. Almeida *et al.* (2023) highlight that the sludge generated in Nova Venécia and Pinheiros WWTPs has potential for agricultural use, being applied in degraded areas and commercial crops, with positive results even in regions with water restriction and tropical soils poor in organic matter.

Studies indicate that sanitised sludge provides macronutrients such as nitrogen and



phosphorus, as well as essential micronutrients, contributing to the improvement of soil fertility, structure and water retention (Silva *et al.*, 2023; Paganini *et al.*, 2024). In developed countries, the agricultural use of sludge is consolidated, provided that the chemical and microbiological standards are respected. In Brazil, the practice has been evaluated in different cultures, with promising results.

In the case of rubber tree (*Hevea brasiliensis*), a species of great economic relevance for Brazil, studies on the use of sewage sludge as a source of nutrients are still scarce. Considering the potential benefits and the need for sustainable alternatives for the management of this waste, this study evaluated the effect of sanitised sewage sludge on the growth of rubber trees, compared to traditional organic and chemical fertilisers

2 THEORETICAL FRAMEWORK

2.1 USE OF SLUDGE IN AGRICULTURE

Abstract: The generation of urban organic waste has increased significantly on a global scale, following the population growth and the intensification of consumption. In this context, the agricultural reuse of sewage sludge emerges as an alternative of great relevance, aligned with the principles of circular economy and environmental sustainability goals (Paganini *et al.*, 2024). The sewage sludge, when properly sanitised, is rich in organic matter, nitrogen, phosphorus and micronutrients, and can be used as a low-cost agricultural input, with the potential to replace or complement conventional sources of mineral and organic fertiliser (Silva *et al.*, 2023).

Recent studies have reinforced the agronomic viability of this input. Silva *et al.* (2024) demonstrated that the agricultural use of sanitised sludge significantly increased soil fertility and water retention capacity in tropical areas. Similarly, Maryani *et al.* (2023) identified gains in vegetative growth and biomass of rubber tree seedlings fertilised with treated industrial sludge, without evidence of heavy metal contamination. Marin *et al.* (2023), evaluating the application in crops such as soybean and wheat, also reported increased productivity associated with nutrient cycling promoted by sludge.

In addition to the supply of nutrients, sludge has additional advantages such as improved soil structure, stimulating microbial activity and moisture retention capacity, essential aspects in tropical soils that often have high acidity and low natural fertility (Silva *et al.*, 2023; Mendonça *et al.*, 2025). These effects contribute to agricultural sustainability, since they reduce



dependence on high-cost chemical inputs and reduce the environmental liability of sanitation systems.

2.2 ARRANGEMENT OF SLUDGE IN AGRICULTURE

The final disposal of sewage sludge should be evaluated under multiple dimensions: technical, sanitary, economic and environmental. Its use in agriculture, although promising, demands rigorous criteria for monitoring to guarantee the safety of the soil, of the crops, and of human health. Recent research indicates that composting and sludge hygiene significantly reduce the presence of pathogens and antimicrobial resistance genes, without compromising the chemical and biological quality of the soil (Mendonça *et al.*, 2025).

Silva *et al.* (2024) highlight that the application of sanitised sludge in tropical soils promotes not only gains in fertility, but also improvement in physical and biological attributes, resulting in higher agricultural productivity. These results corroborate the understanding that agricultural use is the most sustainable form of final disposal, by promoting the reuse of nutrients and reducing the pressure on landfills.

However, challenges still remain related to the variability of the chemical composition of the sludge, the need for monitoring heavy metals and the development of regulations that guarantee the safety of the process in different regions and agricultural crops (Marin *et al.*, 2023; Paganini *et al.*, 2024). Despite these limitations, the use of sewage sludge represents a strategic alternative for the Brazilian agricultural sector, especially in regions with low natural fertility soils, such as Espírito Santo.

Therefore, the agricultural disposal of sewage sludge, when performed based on technical criteria and supported by appropriate public policies, is a practice capable of uniting agronomic efficiency and environmental sustainability, presenting itself as a viable solution for the management of urban waste and for the nutrition of crops of economic interest, such as rubber.

3 METHODOLOGY

The experiment was conducted in an experimental area for the cultivation of rubber tree (*Hevea brasiliensis*), with spacing of 6 × 3 metres between plants. The experimental design was a randomised block, consisting of nine treatments and two replications each, totalling 18 plots.



The experiment took place three years after planting seedlings, a sufficient period for initial evaluation of the vegetative growth of the crop.

3.1 TREATMENTS

The treatments consisted of six increasing doses of nitrogen provided by sanitised sludge from Sewage Treatment Plant (STP), in addition to a treatment with bovine manure, a chemical fertiliser based on urea, and a control without application of fertilisers. Nitrogen doses per plant were defined based on the recommendation of 70 g N/plant, adjusted according to the total nitrogen content in the sludge (1.2%), according to Prezotti *et al.* (2007).

Table 1 presents the detailed description of the treatments and the respective nitrogen doses applied.

Table 1

Experiment treatments with the amount of nitrogen per plant

Treatment (T)	N dose/plant (g)
1 – BOVINE MANURE	70
2 – CHEMICAL/UREA	70
3 – CONTROL	0
4 – SLUDGE	35
5 – SLUDGE	70
6 – SLUDGE	105
7 – SLUDGE	140
8 – SLUDGE	175
9 – SLUDGE	140

3.2 APPLICATION OF FERTILISERS

The application of fertilisers was performed in coverage, directly around the base of the plants, with uniform distribution on the soil. The sludge used was previously sanitised with virgin lime, in proportion to 30% of the dry weight, according to the guidelines of the Manual of Agricultural Use and Disposition of Sewage Sludge for Espírito Santo (Costa; Costa, 2011), ensuring the reduction of pathogens present.



3.3 ASSESSMENT OF GROWTH

After three years of planting, the variables total plant height (m) and diameter at breast height (DBH) were measured at 1.30 metres from the ground, using tape measure and digital calliper, respectively. Measurements were performed on all plants of each experimental plot.

3.4 STATISTICAL ANALYSIS

The collected data were submitted to analysis of variance (ANOVA) to verify the existence of statistical differences between treatments, using a significance level of 5% ($p < 0.05$). When significant, the multiple comparison test of means was performed by the Tukey method. The analyses were performed using the statistical software R, version 4.2.0.

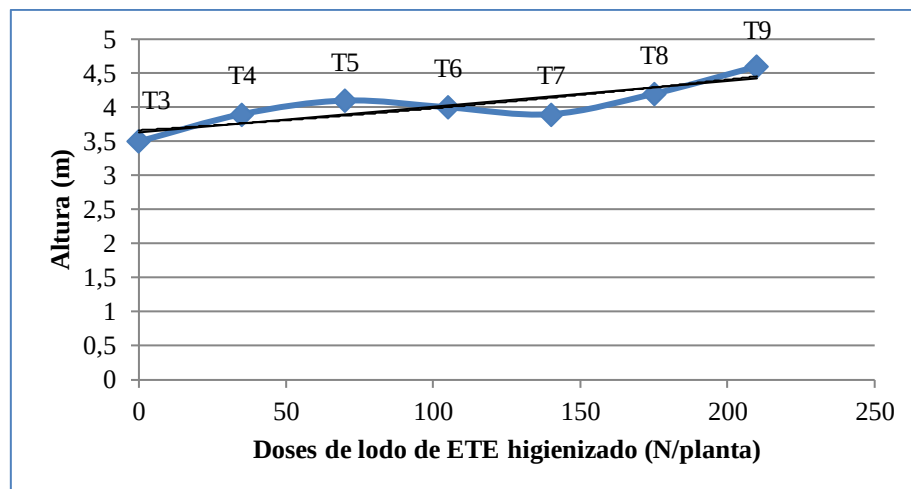
4 RESULTSS AND DISCUSSÕES

The analysis of the collected data showed significant differences in the growth of rubber tree plants according to the different treatments evaluated. As illustrated in Figure 1, treatment T9 (140 g N/plant via sanitised sludge) presented the highest average plant height, significantly surpassing the control (T3 – 0 g N/plant). On the other hand, the lower dose of sludge (T4 - 35 g N / plant) resulted in lower height than control, indicating that inadequate doses may not meet the nutritional demand of the crop.



Figure 1

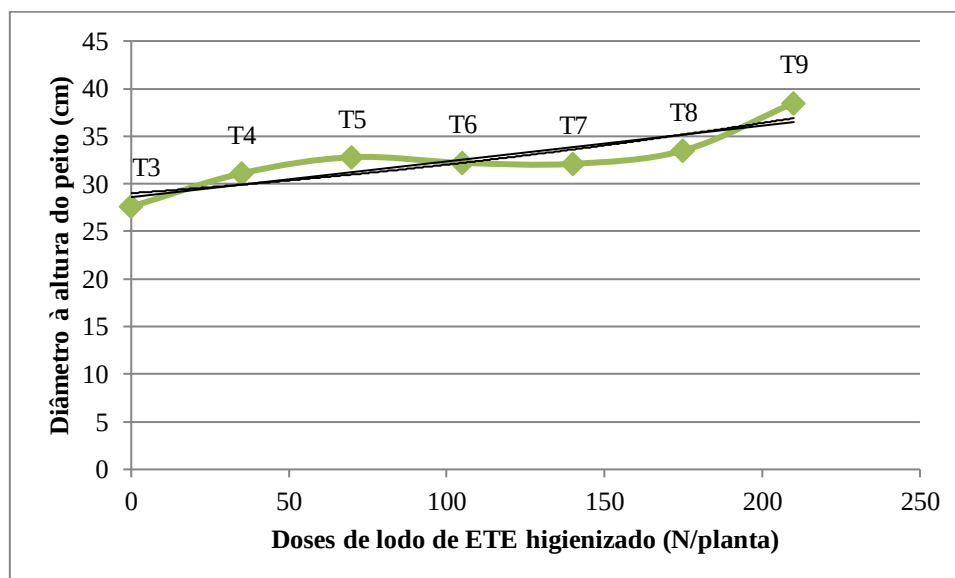
Average height of plants in different treatments.



In relation to the diameter at breast height (DBH), an important variable and correlated to the productivity of the rubber tree, the T9 treatment also obtained the highest values, as shown in Figure 2. Similarly to height, higher doses of nitrogen via sludge provided greater DAP development, while low doses did not differ significantly from control.

Figure 2

Mean diameter at breast height (DBH) of plants in different treatments.



When comparing the treatments that applied the recommended dose of 70 g N / plant, it was verified that the sanitised sludge (T5) presented superior performance for both height and DBH in relation to bovine manure (T1) and urea (T2), as shown in Figures 3 and 4. This



superiority can be attributed to the slow mineralisation of the sanitised sludge, which keeps the supply of nitrogen available for a longer period, favouring the continuous vegetative development of the plant.

Figure 3

Plant height for treatments with 70 g N/plant.

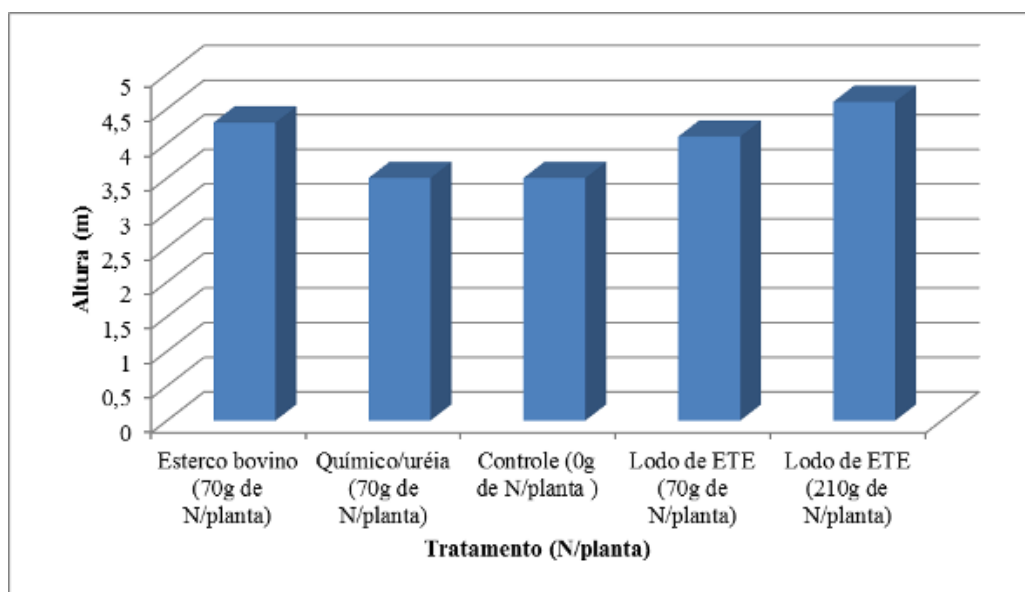
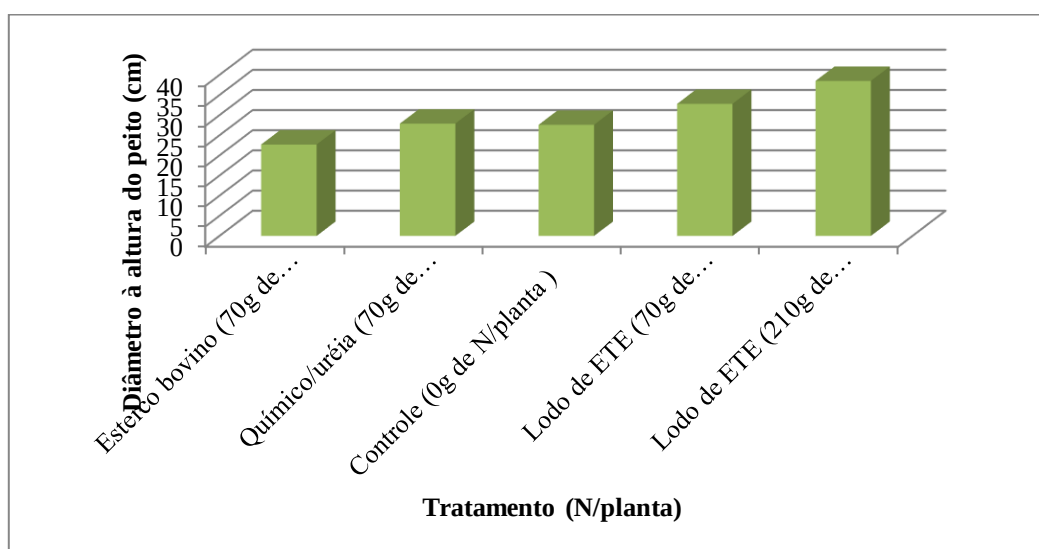


Figure 4

DBH of plants for treatments with 70 g N/plant.



The results corroborate recent studies that show the efficiency of sanitised sludge as a source of nutrients, highlighting its potential to replace or complement conventional fertilisations. In addition to providing nitrogen and phosphorus gradually, the sludge contributes



to the improvement of soil fertility and structure, favouring the development of perennial crops. The improvement in DBH especially suggests the possibility of increased latex production, an aspect of great economic relevance for the rubber tree crop (MARYANI et al., 2023; MENDONÇA; SOUZA; BARBOSA, 2025).

In addition to agronomic aspects, the use of sanitised sludge contributes to the sustainability of waste management, reducing the volume destined to landfills and promoting the recycling of nutrients, aligned with the principles of the circular economy.

5 CONCLUSION

The sanitised sludge from Sewage Treatment Plant proved to be a viable and efficient source of nutrients for the cultivation of rubber tree (*Hevea brasiliensis*). The dose of 70 g of nitrogen per plant, provided by the sludge, presented performance equivalent to the organic (cattle manure) and chemical (urea) fertilisations, both in height and in diameter at breast height (DBH). Higher doses than this potentiated vegetative growth, especially DAP, which is directly related to latex production, indicating additional agronomic benefit.

In addition to gains in plant development, the use of sanitised sludge contributes to environmental sustainability by promoting the reuse of organic waste, reducing the amount destined for landfills and helping to close biogeochemical cycles in the agricultural system. Thus, the use of sewage sludge is presented as a sustainable and economically viable alternative for the nutrition of rubber trees and can be incorporated into the agricultural management practices of the crop.

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