



## USE OF AGRO-INDUSTRIAL WASTE FOR THE DEVELOPMENT OF *THEOBROMA GRANDIFLORUM* SEEDLINGS

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### ABSTRACT

**Objective:** The aim of this study was to evaluate the behavior of cupuaçu tree (*Theobroma grandiflorum*) seedlings as a function of agro-industrial waste.

**Method:** The influence of agro-industrial waste on the development of cupuaçuzeiro seedlings was evaluated. Treatments included different proportions of organic waste (açaí ash, dendê compost and cattle manure) in proportions of 5%, 10%, 15% and 20% in relation to 3 kg of soil. Finally, morphological and physiological variables were determined.

**Result and Conclusion:** The experimental data was analyzed using analysis of variance. Significant means were then compared using the Tukey test, with a significance level of 5%. From the results obtained, it was observed that one of the agro-industrial residues has the potential to act as an alternative substrate in the production of *Theobroma grandiflorum* seedlings.

**Research implications:** The *Theobroma grandiflorum* species stands out as being extremely important, since its products and by-products are widely accepted in domestic and foreign markets, as well as contributing to Agroforestry Systems. In addition, there is a need to study alternative substrates, especially those generated on a large scale, considering the need to promote proper disposal with sustainable use.

**Originality/value:** In the current scenario, with regard to the destination and final disposal of solid waste, there is a need to look for sustainable alternatives aimed at reusing this waste, especially in agriculture.

**Keywords:** *Theobroma Grandiflorum*, Alternative Substrate, Seedling Development, Agro-Industrial Waste.

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## USO DE RESÍDUOS AGROINDUSTRIAIS PARA O DESENVOLVIMENTO DE MUDAS DE THEOBROMA GRANDIFLORUM

### RESUMO

**Objetivo:** objetivou-se, com a realização do trabalho, avaliar o comportamento de mudas de cupuaçuzeiro (*Theobroma grandiflorum*) em função de resíduos agroindustriais.

**Método:** Avaliou-se a influência dos resíduos agroindustriais para o desenvolvimento de mudas de cupuaçuzeiro. Foram realizados tratamentos que incluíram diferentes proporções de resíduos orgânicos (cinza de açaí, composto de dendê e esterco bovino) com proporções de 5%, 10%, 15% e 20% em relação a quantidade de 3 kg de solo. Por fim, foram determinadas as variáveis morfológicas e fisiológicas.

**Resultado e conclusão:** Os dados experimentais foram analisados por meio da análise de variância. As médias significativas foram posteriormente comparadas utilizando o teste de Tukey, com um nível de significância de 5%. A partir dos resultados obtidos, observou-se que um dos resíduos agroindustriais possuem potencial de atuar como substrato alternativo na produção de mudas de *Theobroma grandiflorum*.

**Implicações da pesquisa:** A espécie *Theobroma grandiflorum* destaca-se como sendo de extrema importância uma vez que seus produtos e subprodutos possuem ampla aceitabilidade no mercado interno e externo, além de contribuir em Sistemas Agroflorestais, junto a isso há necessidade de estudar substratos alternativos, principalmente aqueles gerados em larga escala, considerando a exigência de promover uma destinação adequada com uso sustentável.

**Originalidade/valor:** No cenário atual, no que diz respeito à destinação e disposição final dos resíduos sólidos, há a necessidade de buscar alternativas sustentáveis que visem ao reaproveitamento desses resíduos, sobretudo na agricultura.

**Palavras-chave:** *Theobroma grandiflorum*, Substrato Alternativo, Desenvolvimento de Mudas, Resíduos Agroindustriais.

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## 1 INTRODUCTION

The cupuaçu tree (*Theobroma grandiflorum*) is one of the main fruit trees native to the Amazon, belonging to the Malvaceae family. It originates in regions of the Amazon and is one of the most commercially important fruits in this region due to the favorable conditions regarding the aroma and flavor of its pulp. The fruit of the cupuaçu tree is suitable for industrial use (Alves, 2013; Nascimento, 2018).

The crop has been gaining ground among the various crops grown in Brazil's tropical regions, both because of the acceptability of the product and by-products and because of its important contribution to the establishment of agroforestry systems, and the expansion of cultivation to other Brazilian regions (Matias et al., 2022). In order to meet the demand for expanding cultivation, it is essential to provide seedlings adapted to the region's soil and climate conditions, since in the north of Brazil, cultivation is predominantly carried out on soils with low fertility (Silva et al., 2020).

Characterizing the most appropriate conditions for seedling production generates better conditions for initial growth in the field, as well as helping to increase homogeneity, health and reduce planting mortality. The quality of the substrate is influenced by its composition, as it



plays an important role in providing physical support for the root system and creating suitable conditions to meet the seedling's nutritional and water needs (Siqueira et al., 2018).

The substrate plays a crucial role not only in providing the essential nutrients for seedling development, but also in ensuring adequate adherence by the roots when the seedling is removed from the container before planting, in order to protect it from impacts and desiccation (Silva et al., 2019; Rodrigues et al., 2021).

Currently, increased environmental awareness has motivated industries to seek alternative options for dealing with the waste resulting from their industrial activities (Freitas et al., 2010). At the same time, the inadequate management of urban waste has emerged as a significant challenge, both from a social and environmental point of view (Abreu Jr. et al., 2005), requiring the exploration of alternatives to ensure its proper disposal.

Progress in agro-industry has resulted in the significant and diversified production of waste, causing serious environmental concerns, and with the rising costs of fertilizers, the use of this waste in agriculture as a substrate is emerging as an advantageous alternative both from an environmental and economic point of view (Vendruscolo et al., 2016).

Thus, it can be seen that there is a scarcity of studies in the literature related to the development of *Theobroma grandiflorum* seedlings from agro-industrial waste. With this in mind, the aim of this study was to analyze the influence of agro-industrial waste generated on a large scale in the state of Pará, such as açai ash, palm oil compost and cattle manure on the production of cupuaçu seedlings.

## 2 LITERARY REVISION

### 2.1 *Theobroma grandiflorum* (cupuaçuzeiro)

Originally from the Amazon Region, the Cupuaçu (*Theobroma grandiflorum* Wild ex Spreng Schum) is naturally found in the forest areas of the south and northeast of the Eastern Amazon, as well as in the northeast of Maranhão. Its commercial exploitation occurs mainly in the northern region of Brazil, extending to other areas, such as the south of Bahia. Although it is not exclusive to Brazil, as its presence extends throughout the Amazon Basin, the Cupuaçu is also identified in neighboring countries, such as Colombia, Peru, Venezuela, Ecuador, Suriname, among others (Müller et al., 1995).

The Amazon region is rich in biodiversity and is home to a great diversity of plant species that produce fruit and oilseeds. Products derived from cupuaçu pulp are commonly consumed in the form of juices, ice creams, jellies, sweets and other processed foods, as well as in natura, demonstrating exceptional performance in boosting the domestic and foreign markets (Silva; Farias, 2018; Mota et al., 2020).

Cupuaçuzeiro seedlings are used in Agroforestry Systems, which are an alternative to conventional production systems of great importance in terms of sustainable development, as they allow space to be used in a similar way to ecological patterns by maintaining natural resources in the long term, linked to the systemic development of agricultural activities, in addition to principles based on sustainability (Veiga, 2009; Martins et al., 2022).

### 2.2 Use of agro-industrial waste

In the Brazilian context, the issue of organic waste is worrying, as indicated by data from the Municipal Association of Municipal Sanitation Services (ASSEMAE), showing that only 1% of the 37 million tons of organic waste generated is reused (ASSEMAE, 2019). Thus, research into viable and sustainable options, aimed at reducing production costs and the



economic viability of the crop for producers, requires studies applied to the use of organic waste (CONAB, 2020).

According to the National Solid Waste Policy law 12.305/2010, solid waste is classified as: household, urban cleaning, commercial establishments and service providers, industrial, health services, construction and mining. Organic solid waste consists of all non-inert waste of identified origin from living beings, whether animal or vegetable, such as fruit, vegetables, leaves, seeds, animal manure, egg shells, meat scraps, among others (Bento et al., 2013).

Among the agro-industrial waste applied, bovine manure stands out, which has been increasingly used both in the formulation of the substrate during the initial growth phase of seedlings in nurseries and in improving soil conditions for the development of these seedlings in the field (De Assis Carneiro, 2020). Its conditioning action and function as a source of nutrients can favor cation exchange capacity, porosity and water retention, as well as being related to an increase in the accumulation of dry matter, the development of biometric characteristics and an increase in chlorophyll levels (Aguar et al., 2017; Gonçalves et al., 2014; Silva et al., 2016).

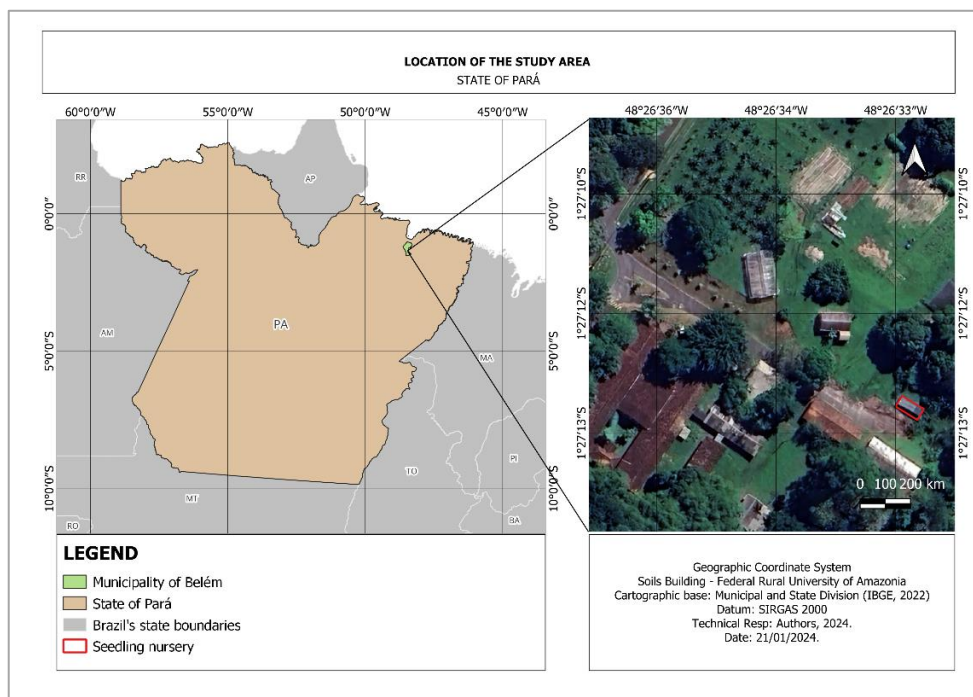
The state of Pará is the country's main producer of açai and palm oil and generates a large amount of waste that is generally not properly disposed of. The use of açai pits as an organic substrate for seedling production stands out as a promising alternative, because when properly prepared, it has the potential not only to act as a soil conditioner, but also to provide plants with nutrients (IBGE, 2022; De Oliveira Bastos; Dos Santos; Shibata, 2023). The use of oil palm compost as a substrate can help to obtain quality seedlings as it has nutrients in its chemical composition that can neutralize soil acidity (Botelho, 2020).

In this context, this study is extremely important, since in the state of Pará the final disposal of organic waste from agro-industrial activities is inadequate, and one possible way of using these materials in search of sustainable alternatives is to use them as a substrate for seedling production.

### 3 MATERIAL AND METHOD

#### 3.1 Study área

The experiment was carried out from September 2022 to August 2023 in a seedling nursery located in the experimental area of the Institute of Agrarian Sciences-ICA, in the area of soil science, of the Federal Rural University of Amazonia, with the geographical coordinates: 48° 23' longitude West of Greenwich and 1° 31' latitude South of the Equator. The highest rainfall rates are recorded between March and August, exceeding 1500 mm per year. The average annual temperature reaches 28.1°C, with September being identified as the hottest month of the year, while March represents the month with the lowest temperature, with an average of 25.6°C (Figure 1).



**Figure 1** – Map of the experimental area (Soils Building - Federal University of Amazonia)

**Source:** Authors, 2023.

### 3.2 Soil analysis

The soil was collected from an area of fallow land, with a history of 20 years of non-production, at a depth of 0-20 cm. The soil in the experimental region was identified as dystrophic Yellow Latossolo, following the guidelines of the Brazilian Soil Classification System (EMBRAPA, 2006). The soil collected was delivered to the UFRA laboratory in order to determine its chemical needs, according to the methodology suggested by Embrapa (2011), with the chemical composition of the soil in the experimental area shown in Table 1.

The soil was then laid out in full sun to dry. After drying, the soil's acidity was corrected by applying dolomitic limestone (PRNT 92%) based on the liming calculation. After 30 days, a pH analysis was carried out to determine the active acidity, which was found to be 6.10.

**Table 1** - Chemical attributes of the soil used in the experiment, collected at a depth of 0-20 cm in the soil profile.

| pH               |      | Corg                      | M.O   | P <sup>(1)</sup>    | K <sup>+(1)</sup> | Ca <sup>2+ (2)</sup>   | Mg <sup>2+ (2)</sup> | Al <sup>3+ (3)</sup> | H+Al |
|------------------|------|---------------------------|-------|---------------------|-------------------|------------------------|----------------------|----------------------|------|
| H <sub>2</sub> O | KCl  | ---g kg <sup>-1</sup> --- |       | mg dm <sup>-3</sup> |                   | cmolc dm <sup>-3</sup> |                      |                      |      |
| 4,55             | 3,23 | 9,29                      | 16,02 | 23,69               | 0,02              | 0,5                    | 1,00                 | 0,94                 | 6,08 |

(1) Mehlich-1 extraction; (2) KCl 1.00 mol L<sup>-1</sup> extraction; (3) calcium acetate 0.05 mol L<sup>-1</sup> extraction. pH: hydrogenion potential; Corg: organic carbon; M.O: organic matter content; P: available phosphorus; K: available potassium; Ca<sup>2+</sup>: exchangeable calcium; Mg<sup>2+</sup>: exchangeable magnesium; Al<sup>3+</sup>: exchangeable aluminum; H+Al: potential acidity.

**Source:** Authors, 2023.



### 3.3 Experimental design and data collection

The experimental design chosen consisted of randomized blocks, in which the treatments included different proportions of organic waste (açai ash, dendê compost and cattle manure), varying between 5%, 10%, 15% and 20% in relation to the amount of soil. This arrangement resulted in 12 treatments with 4 replications, totaling 48 experimental units.

The experiment began when the seedlings were planted in 3dm<sup>3</sup> polyethylene bags, filled with soil and a certain percentage of residue, for an experimental period of 5 months. The variables analyzed were: plant height (AP), stem diameter (DC), number of leaves (NF), aerial dry mass (MSPA), root dry mass (MSR) and chlorophyll content (Soil Plant Analysis Development). The phytometric variables were measured at 30, 60, 90, 120 and 150 days after transplanting, while the leaf chlorophyll content (SPAD) was measured at 90 and 150 days using a portable chlorophyll meter (model SPAD 502).

The height of the seedlings was measured using a graduated ruler. The number of leaves was determined by counting the final leaves on each plant. The stem diameter was obtained using a digital caliper (Marberg model 15MM6') and measured at the base of the stem.

MSR and MSPA were obtained through destructive analysis, by separating the root and aerial parts, weighing the green mass of the root and aerial part and packing them in paper bags. They were then submitted to an oven for drying at a temperature of 65°C to obtain the constant weight of the dry mass of the root and aerial part, which was then weighed using a high-precision analytical balance (0.001g).

### 3.4 Analysis of statistical data

The data from the experiments was subjected to analysis of variance using the SISVAR computer software (Ferreira, 2019). Significant means were compared using the Tukey test with a significance level of 5%.

## 4 RESULTS AND DISCUSSION

No significant effects were observed for the variable plant height (AP) in relation to treatment, either in isolation or in their interactions. For root dry mass (MSR) and dry mass of the aerial part (MSPA), the effects were significantly influenced by the treatments and proportions. For the number of leaves (NF) and chlorophyll index (SPAD), significant effects were observed in relation to the treatments, while the stem diameter (DC) showed significant effects only for the proportions (Table 2).

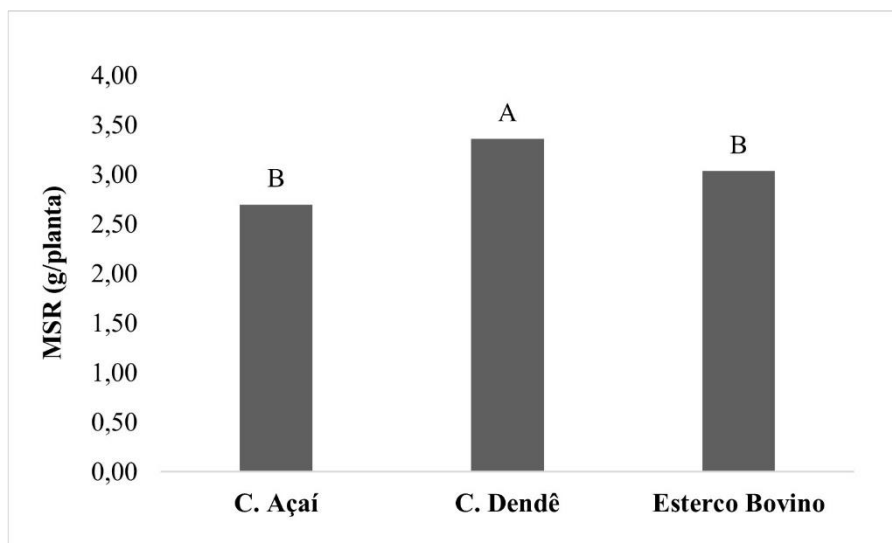
**Table 2** - Summary of the analysis of variance for plant height (AP), stem diameter (DC), number of leaves (NF), root dry mass (MSR), shoot dry mass (MSPA) and chlorophyll content (SPAD).

| FV              | GL | AP    | DC        | NF     | MSR   | MSPA   | SPAD    |
|-----------------|----|-------|-----------|--------|-------|--------|---------|
| TREATMENT       | 2  | NS    | NS        | 25,18* | 1,93* | 58,52* | 304,48* |
| PROPORTIONS     | 3  | NS    | 0,004583* | NS     | 1,64* | 4,06*  | NS      |
| TREATMENT *PROP | 6  | NS    | NS        | NS     | NS    | NS     | NS      |
| CV(%) =         | -  | 11,60 | 14,89     | 17,13  | 20,81 | 28,15  | 9,84    |

GL - degree of freedom; CV - coefficient of variation; NS= not significant; \*= significant at 5% probability.  
Source: Authors, 2023.



The highest root dry mass values were observed for the oil palm compost treatments, followed by the cattle manure treatments (Figure 2).

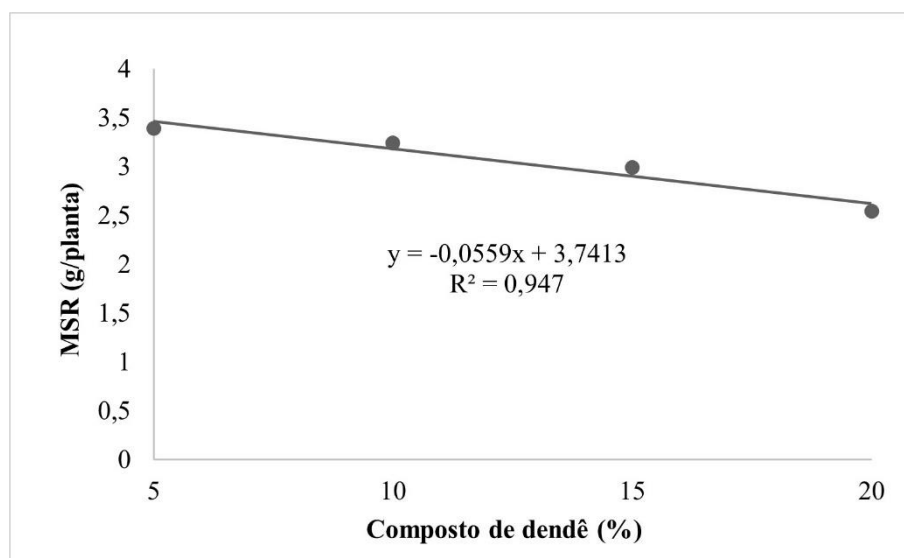


**Figure 2** - Average root dry mass production as a function of treatment. MSR (root dry mass); C. Açaí (acai ash); C. Dendê (dendê compost); Esterco bovino (cattle manure).

**Source:** Authors, 2023.

Dos Santos et al. (2010), when evaluating the effects of oil palm cake on banana seedlings (*Musa* spp.), observed an increase in DMR in the treatments. According to Botelho (2020), the greater development of MSR in the treatments submitted to oil palm compost may justify the results obtained in this variable, since this compost can act as a soil conditioner, improving physical characteristics, chemical and biological processes, as well as making nutrients available.

With regard to the proportions of palm compost applied, the effects were significant for the root dry mass variable and fitted the decreasing linear regression model with a maximum percentage of 3% and maximum production of 3.40 g per cupuaçuzeiro seedling, where it can be seen that the production of RSM decreases as the proportions of palm compost increase (Figure 3).

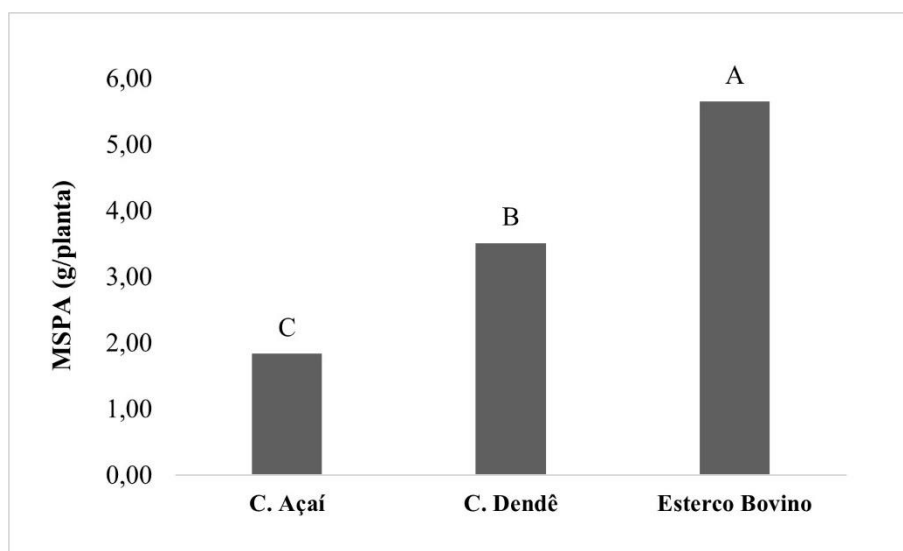


**Figure 3** - Root dry mass as a function of palm compost proportions. MSR (root dry mass); Composto de dendê (dendê compost).



Source: Authors, 2023.

The yields with the highest dry mass values for the aerial part were observed in the cattle manure treatments (Figure 4).



**Figure 4** - Average dry mass production of the aerial part as a function of the treatments. MSP (dry mass of the aerial part); C. Açaí (acai ash); C. Dendê (dendê compost); Esterco bovino (cattle manure).

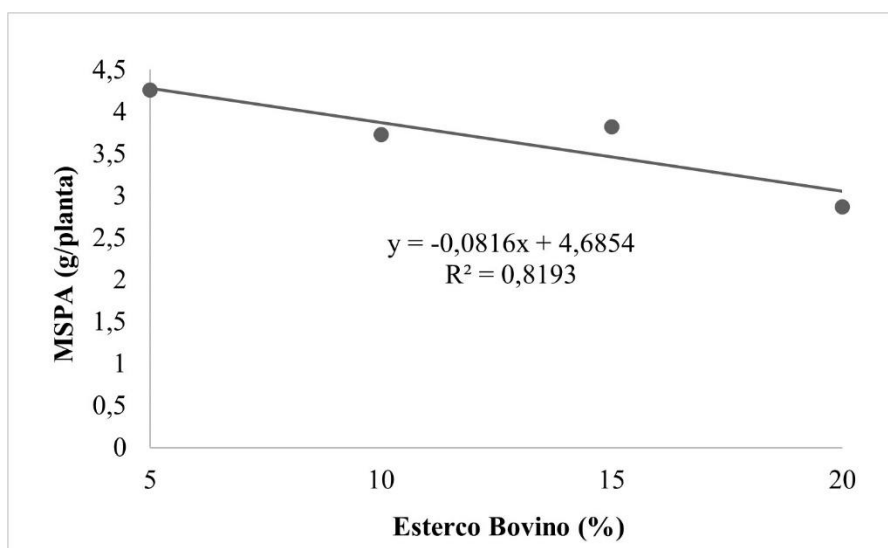
Source: Authors, 2023.

Nascimento et al. (2018), when evaluating the production of *Theobroma grandiflorum* seedlings, also analyzed the better performance of cattle manure on MSPA when compared to other biofertilizers. N'Dafá (2022), when working with the production of *Theobroma cacao* seedlings, also observed an increase in the dry mass of the aerial part from the application of cattle manure, noting that the use of manure promoted an increase in the productivity of cacao seedlings.

According to Barbosa (2004), the better performance of MSPA in the treatments submitted to cattle manure may be related to the high content of exchangeable  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$  and P present in its composition, directly influencing the productivity of the dry mass of the aerial part. In general, seedlings that show high growth in the aerial part have the ability to capture solar energy more efficiently, resulting in the maintenance of appropriate photosynthetic rates which favor the production of biomass in the plants (Smiderle; Souza, 2016).

The higher production can be explained by the more substantial amount of organic matter present in these fertilizations, favoring a balanced availability of nutrients for the plants (Moreira et al., 2011). When examined from a chemical perspective, the use of organic fertilizers, such as cattle and poultry manure, preserves or raises the levels of organic matter in the soil and is effective in meeting the nutritional needs of plants (Batista et al., 2012).

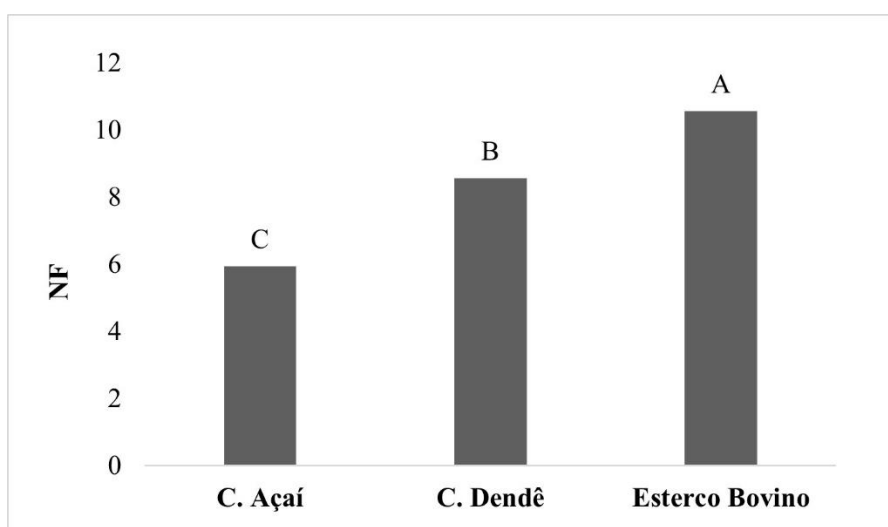
Braos et al. (2015) observed an increase in the levels of available phosphorus in soils that received bovine manure. As such, the adoption of this organic fertilizer in agriculture is recommended, highlighting its benefits of lower environmental impact in the agricultural scenario and its contribution to the economic stability of producers, considering it a natural resource available on farms. In relation to the proportions of cattle manure applied, MSPA was adjusted to a decreasing linear regression model with a maximum percentage of 2.9% and a maximum production of 4.20 g per cupuaçuzeiro seedling, showing that the production of this variable decreases as the proportions of cattle manure increase (Figure 5).



**Figure 5** - Shoot dry mass as a function of bovine manure proportions. MSP (dry mass of the aerial part); Esterco bovino (cattle manure).

**Source:** Authors, 2023.

The number of leaves showed differences in average production between the treatments, with the highest average values observed in the cattle manure treatments (Figure 6).



**Figure 6** - Average number of leaves as a function of treatment. NF (number of leaves); C. Açai (acai ash); C. Dendê (dendê compost); Esterco bovino (cattle manure).

**Source:** Authors, 2023.

When compared with the study conducted by Silva et al. (2007) on the production of *Theobroma grandiflorum* seedlings, which recorded an average of 5 leaves per cupuaçu seedling, the result presented revealed an average of 10 leaves per seedling. When studying the use of cattle manure as an alternative substrate in the production of cupuaçu seedlings, Nascimento et al. (2018) observed that the treatments based on cattle manure showed satisfactory results with regard to the number of leaves, with an average number of 7 leaves per seedling. According to Pereira Filho (2020), the addition of organic compounds from cattle manure improves the chemical, physical and biological characteristics of the soil, through the solubilization and release of macro and micronutrients.

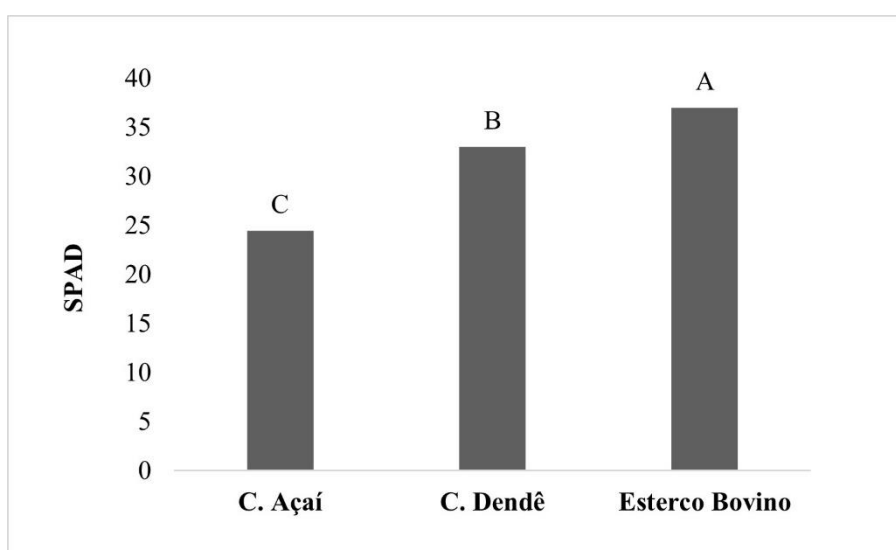
The number of leaves per plant is directly related to the nutrient levels available in the soil and essentially to the morphological characteristics of each cultivar (Bonela et al., 2017).



As pointed out by Silva et al. (2007), an increase in the number of leaves results in greater production of photoassimilates, which are then directed towards growth in height, neck diameter and dry mass formation.

This suggests that the plants grown in this substrate showed a higher photosynthetic capacity, as NF is correlated with the plant's photosynthetic area, and a greater number of leaves results in a larger area for capturing light energy in the photosynthetic process (Bonfim-Silva et al., 2020). In addition, NF has a direct impact on dry matter production (Barbosa et al., 2022), making it a crucial variable to consider.

The chlorophyll index (SPAD) showed higher values in the cattle manure treatments (Figure 7).



**Figure 7** - Average chlorophyll index values as a function of treatment. SPAD (chlorophyll index); C. Açaí (acai ash); C. Dendê (dendê compost); Esterco bovino (cattle manure).

**Source:** Authors, 2023.

Oliveira Júnior et al. (2011) when analyzing the development of *Eucalyptus urophylla* seedlings as a function of different substrates, observed better results in treatments submitted to cattle manure. According to Silva et al. (2011), the intensity of the green color (chlorophyll) is associated with the nitrogen content. Measuring chlorophyll allows the quality of seedlings to be assessed, since a relationship can be established with the nitrogen content in the leaves of the plants, because as chlorophyll levels increase, there is an increase in the amount of nitrogen in the composition of the plants (Miyake, 2017).

The cattle manure treatments had a higher number of leaves and a higher chlorophyll index (SPAD), a result that may be related to the fact that the amounts of cattle manure applied influence the chlorophyll levels in the plants and, consequently, the number of leaves per seedling. These levels indicate that the treatments with the most favorable averages are those that provided more substantial plant growth, since the weight of the plant's dry parts plays a fundamental role in assessing plant growth (Fontes; Dias; Silva, 2005).

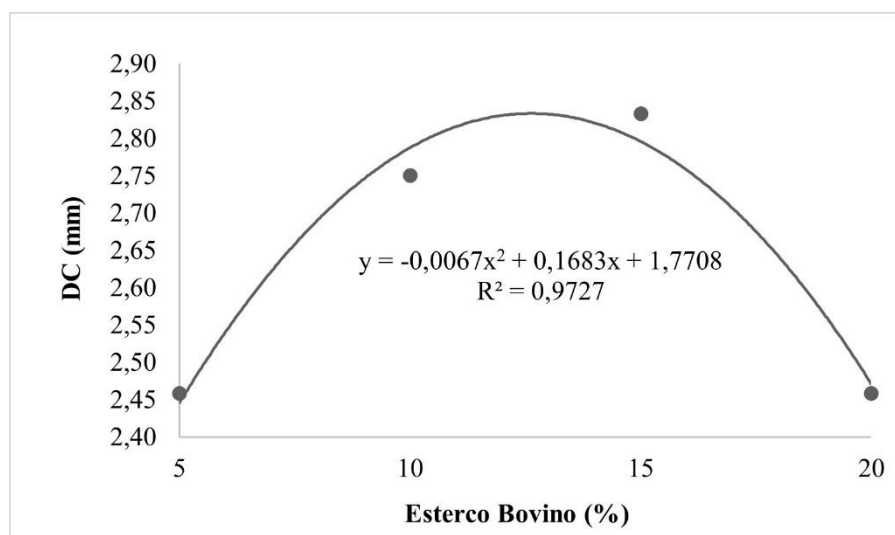
Delarmelina et al. (2015) observed that the favorable growth characteristics of *Chamaecrista desvauxii* seedlings in substrates containing cattle manure can be attributed not only to the nutrient content of this waste, but also to its impact on the substrate. Zandonadi et al. (2014) state that the incorporation of organic matter promotes greater aggregation and water retention in the soil.

As a result, it was observed that the cattle manure treatments had higher average yields in terms of MSPA, NF and SPAD than the açaí ash and oil palm compost treatments. The



seedlings with the highest SPAD indices had the highest aerial dry mass and number of leaves, which may be related to the availability of nutrients provided by the cattle manure.

The diameter of the collar showed significant results in relation to the proportions of cattle manure, adjusted to the quadratic linear regression model with a maximum dose of 12.5% and a maximum diameter of 2.82 mm per cupuaçu seedling (Figure 8).



**Figure 8** - Stem diameter as a function of the proportions of cattle manure. DC (stem diameter); Esterco bovino (cattle manure).

**Source:** Authors, 2023.

Nascimento et al. (2018), examining the use of alternative substrates in the production of *Theobroma grandiflorum* seedlings, observed that the treatments based on cattle manure showed satisfactory results in terms of stem diameter, with an average diameter of 3.62 mm per seedling, as well as the dry mass of the aerial part.

As emphasized by Taiz & Zeiger (2017), plants with a larger stem diameter are more likely to survive due to their increased ability to develop new roots. De Sales et al., 2017, when assessing the stem diameter of *Schinus terebinthifolius* seedlings, also observed better results in the treatments with cattle manure, showing higher values than the other treatments. In the same way as the results found by De Sales et al., 2017, it was clear that the stem diameter was directly related to the height of the plant, because as the diameter increased, the height also showed an increasing behavior.

In general, plants with a high DC tend to stand out in the growing environment, since the increase in the thickness of the coelto is closely linked to the ability to translocate solutes from the root system to the aerial part of the seedlings, which results in more vigorous seedlings (Diniz et al., 2018; Steffen et al., 2019). According to Pinto et al. (2007), seedling vigor is manifested through the variables of plant height, stem diameter and number of leaves. In this way, it can be justified that cattle manure was relevant in relation to stem thickening, contributing to the quality of the seedling.

Paiva Sobrinho et al. (2010) explain that cattle manure acts as organic matter. In the composition of the substrate, the organic source is responsible for retaining moisture and providing part of the nutrients for seedling growth. In this sense, it can be inferred that cattle manure showed positive results in relation to stem thickening, contributing to seedling development by influencing all the significant variables in the experiment.



## 5 CONCLUSION

Among the organic residues used in the experiment, palm compost and cattle manure were the ones that gave positive results in terms of the average development of the cupuaçuzeiro seedlings.

The use of cattle manure proved to be effective in the production of cupuaçuzeiro seedlings, with satisfactory results. Using cattle manure to grow seedlings is a viable option, allowing farmers to use this waste to fertilize the soil, which contributes to environmental sustainability.

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