



MORPHOPHYSIOLOGICAL ASPECTS IN AFRICAN MAHOGANY (*Khaya senegalensis*) SEEDLINGS UNDER BOVINE MANURE DOSES

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ABSTRACT

Objective: To evaluate the morphophysiological characteristics of *Khaya senegalensis* seedlings, after being grown in substrates with bovine manure.

Theoretical framework: Based on scientific articles found on search engines and books in the field of physiology and forestry. This were the research used to support the explanation of how the physiological characteristics of the seedlings were influenced by the type of substrate and how they may have contributed to the morphological characteristics of these plants.

Method: The experiment was conducted in a greenhouse for 90 days. During this period, the seedlings were subjected to doses of 0, 5, 10, 15, 20 and 25 grams of bovine manure. At the end, the net photosynthetic rate, transpiration rate, transpiration rate, vapor pressure deficit, stomatal conductance and intercellular CO₂ concentration were evaluated. Then, height, diameter and biomass measurements were taken.

Results and conclusion: The dose of 25 grams of bovine manure provided the best conditions when analysing the photosynthetic rate, stomatal conductance, intercellular CO₂ concentration, vapor pressure deficit and transpiration rate. This resulted in greater growth in height and diameter, and greater production of aerial and root dry mass of *K. senegalensis* seedlings.

Implications of the research: These results allow us to verify that, for seedlings to grow in a substrate containing bovine manure, first, improvements occur in the physiological conditions of the plants, which are reflected in faster growth. Therefore, there is a need to study the type of manure and the dose applied, before recommending a type of substrate.

Originality/value: Use of organic waste for the seedlings production, which is an environmentally correct destination.

Keywords: Seedling Production, Organic Residues, Plant Physiology, Morphological Characteristics.

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ASPECTOS MORFOFISIOLÓGICOS EM MUDAS DE MOGNO AFRICANO (*Khaya senegalensis*) SOB DOSES DE ESTERCO BOVINO

RESUMO

Objetivo: Avaliar as características morfofisiológicas de mudas de *Khaya senegalensis*, após serem cultivadas em substratos com esterco bovino.

Referencial teórico: Baseado em artigos científicos encontrados em sites de buscas e em livros da área de fisiologia e silvicultura. Esses foram os recursos para embasar a explicação de como as características fisiológicas das mudas foram influenciadas pelo tipo de substrato e como podem ter contribuído para as características morfológicas dessas plantas.

Método: O experimento foi conduzido em casa de vegetação por 90 dias. Durante esse período, as mudas foram submetidas as doses de 0, 5, 10, 15, 20 e 25 gramas de esterco bovino. Ao final, foram avaliadas quanto a taxa líquida fotossintética, taxa transpiratória, taxa de transpiração, déficit de pressão de vapor, condutância estomática e concentração intercelular de CO₂. Em seguida, foram realizadas as medições em altura, diâmetro e biomassa.

Resultados e conclusão: A dose de 25 gramas de esterco bovino proporcionou as melhores condições ao analisar a taxa fotossintética, a condutância estomática, a concentração intercelular de CO₂, o déficit de pressão de vapor e a taxa de transpiração. O que implicou em maior crescimento em altura e diâmetro, e maior produção de massa seca aérea e radicular das mudas da *K. senegalensis*.

Implicações da pesquisa: Esses resultados permitem verificar que, para que ocorra o crescimento das mudas em substrato contendo esterco bovino, primeiramente, acontecem melhorias nas condições fisiológicas das plantas, que se refletem em crescimento mais rápido. Existindo, portanto, a necessidade de estudar o tipo de esterco e a dose aplicada, antes de recomendar um tipo de substrato.

Originalidade/valor: Utilização de resíduos orgânicos para a produção de mudas, sendo esta, uma destinação ambientalmente correta.

Palavras-chave: Produção de Mudas, Resíduos Orgânicos, Fisiologia de Plantas, Características Morfológicas.

ASPECTOS MORFOFISIOLÓGICOS EN PLÁNTULAS DE CAOBA AFRICANA (*Khaya senegalensis*) EN DOSIS DE ESTIÉRCOL BOVINO

RESUMEN

Objetivo: Evaluar las características morfofisiológicas de las plántulas de *Khaya senegalensis*, después de ser cultivadas en sustratos con estiércol bovino.

Marco teórico: Basado en artículos científicos encontrados en motores de búsqueda y libros en el campo de la fisiología y la silvicultura. Esta fue la investigación utilizada para apoyar la explicación de cómo las características fisiológicas de las plántulas fueron influenciadas por el tipo de sustrato y cómo pueden haber contribuido a las características morfológicas de estas plantas.

Método: El experimento se llevó a cabo en un invernadero durante 90 días. Durante este período, las plántulas fueron sometidas a dosis de 0, 5, 10, 15, 20 y 25 gramos de estiércol bovino. Al final, se evaluó la tasa fotosintética neta, la tasa de transpiración, la tasa de transpiración, el déficit de presión de vapor, la conductancia estomática y la concentración intercelular de CO₂. Luego, se tomaron medidas de altura, diámetro y biomasa.

Resultados y conclusión: La dosis de 25 gramos de estiércol bovino proporcionó las mejores condiciones al analizar la tasa fotosintética, la conductancia estomática, la concentración intercelular de CO₂, el déficit de presión de vapor y la tasa de transpiración. Esto resultó en un mayor crecimiento en altura y diámetro, y una mayor producción de masa seca aérea y radicular de plántulas de *K. senegalensis*.

Implicaciones de la investigación: Estos resultados nos permiten comprobar que, para que las plántulas crezcan en un sustrato que contiene estiércol bovino, en primer lugar, se producen mejoras en las condiciones fisiológicas



de las plantas, que se reflejan en un crecimiento más rápido. Por lo tanto, es necesario estudiar el tipo de estiércol y la dosis aplicada, antes de recomendar un tipo de sustrato.

Originalidad/valor: Uso de residuos orgánicos para la producción de plántulas, que es un destino ambientalmente correcto.

Palabras Clave: Producción de Plántulas, Residuos Orgánicos, Fisiología Vegetal, Características Morfológicas.

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1 INTRODUCTION

African mahogany (*Khaya senegalensis*) is an arboreal species of African origin, belonging to the family Meliaceae, the same as native mahogany (*Swietenia macrophylla*), andiroba (*Carapa guianensis*) and cedar (*Cedrela fissilis*) (Pinheiro et al., 2011). This species was introduced into Brazil to replace Brazilian mahogany because it is resistant to the Brazilian mahogany plague. It now plays an important role, due to its high economic power and rapid growth, with wood as its main product.

However, *K. senegalensis* meets not only the demand for timber products, but also for medicinal substances, especially antifungal, anti-inflammatory, preventive against malaria and insecticides compounds (Zhang et al., 2009). These characteristics help one to understand why the plantations of this species have increased, however, in order to obtain high productivity plantations, there is the need to produce seedlings of quality. In view of this, there is a need to understand more about the obtaining of seedlings and/or to establish more suitable and quicker ways for this.

One of the factors that should be taken into consideration in the production of seedlings is the substrate, since its chemical and physical composition will have a direct influence on the quality of these seedlings. The diversity of substrates is great, and several types can be found ready for use, which can be pure or mixed, with characteristics of price and quality. Cruz et al. (2016), the type of substrate, in addition to these factors, influences the final cost of molting. That is why it is interesting that the formulation of the substrates involves the materials available in a region, making the product cheaper. This justifies the use of organic waste in this way, besides, environmentally, giving it an appropriate destination (Ribeiro et al., 2018).

Bovine manure is one of the most commonly used residues as an organic source in the composition of substrates (Brugnara, 2015). In addition to the supply of nutrients, it can



contribute to microbiological processes, aeration, structuring, water retention capacity and temperature regulation of the medium and the final substrate (Delarmelina et al., 2015). Weinärtner et al. (2006) further highlight its fiber richness, which helps to develop organisms that are antagonists of fungi that cause soil diseases.

Some studies have proven that the addition of bovine manure is an interesting alternative in the composition of seedlings of forest species. Cruz et al. (2016) found that substrates containing tanned bovine manure provided increment of up to 19.37 cm at the height of *Spondias tuberosa* seedlings. Camargo et al. (2011) studying substrates for the production of *Jatropha curcas* seedlings concluded that these must consist of 60% bovine manure, worm humus or chicken bed. Meanwhile, Gonçalves et al. (2014) recommended adding at least 20% of the volume of the substrate for the production of *Glaziovian Athelia* seedlings.

However, the addition of dung for substrate formation can alter the chemical composition of the final product and thus promote physiological changes in the plants to be produced, which may or may not be beneficial. According to Mondini et al. (2019), functional changes in plants by the application of different fertilizers (such as organic ones) can be investigated by means of non-destructive tools involved directly or indirectly in the photosynthetic process.

In view of this, the study aimed to analyze the morphophysiological aspects of African mahogany (*K. senegalensis*) seedlings grown on substrates made up of different doses of bovine manure.

2 THEORETICAL FRAME

The theoretical benchmark was based on scientific articles and books published in the areas of Physiology and Forestry. For better understanding, this article is divided into a few items, one of them is characterizing the species studied; another explains the properties that the substrates need to present to be used in the production of seedlings, with emphasis on organic residues and; a final item, highlighting the use of bovine manure in the production of seedlings.

2.1 *Khaya senegalensis*

Khaya senegalensis (African mahogany) is a species native to Côte d'Ivoire, Ghana, Benin, Nigeria and southern Cameroon; occurring from 0 to 450 m (2010). When it reaches



arboreal size, it can measure from 15 to 20 m in height and, 100 cm in diameter to the breast height (DAP) (Lamprecht, 1990).

The implantation of African mahogany in Brazilian forest systems is an economically viable practice and presents environmental benefits (Castro, 2008). In Brazil, according to information from the Brazilian Association of African Mahogany Planters, there are more than 10,000 hectares planted, aged 1 to 7 years, whose main objective is timber production (Abpma, 2016).

According to Silva (2018) this species can be used in carpentry, joinery, furniture manufacture, ship building and decorative laminates. It is also suitable for constructions, floors, interior decoration, vehicle bodies, toys, innovations, railway sleepers, lathe works and pulp pulp. However, depending on the quality of the wood, it can be used as firewood or for coal production (Mathias, 2013).

African mahogany also has medicinal uses, since it has antifungal, anti-inflammatory, preventive against malaria and insecticides compounds (Zhang et al., 2009). Mathias (2013) also indicates it for stomach problems, diarrhea, dysentery and anemia; as an analgesic, in cases of rheumatism and headaches. Its roots can be used against jaundice, edema, and amenorrhea. The oil extracted from the seeds, on the other hand, can be used in the treatment against rheumatism, influenza and syphilis, besides being used in the production of cosmetics and in the food cooking process.

2.2 THE SUBSTRATE IN THE PRODUCTION OF SEEDLINGS

In order to be successful in the implementation of a forest planting, regardless of the species, it is necessary to pay attention to the quality of the seedlings produced (Reis et al., 2019). Within the seedling production phase, the choice of substrate, its dose and/or quantity are important requirements for achieving this quality (Barbosa et al., 2014). Besides influencing the final cost of molting (Cruz et al., 2016).

According to Silva Júnior et al. (2018) the substrates are a factor of high influence on the plant's development capacity because it is responsible for providing physical support to the root system and conditions to adequately supply the water and nutritional demand of the seedling (Siqueira et al., 2018).

There is no perfect substrate for all conditions and species. It is advisable to use components of a substrate in the form of a mixture, as they may present characteristics not suitable for the plant, when used alone (Caldeira et al., 2011). For Pagliarini et al. (2012) the



ideal substrate should have: uniformity in composition, being free from pests, pathogens and weeds. They should also provide good aeration, to allow oxygen diffusion to the roots; good water storage capacity; low resistance to root penetration; and good resistance to structure loss (Menezes Júnior et al., 2000).

Among the types of compounds used, organic waste contributes significantly to aeration, water retention capacity and the formation of a physical structure suitable for root development (Santos et al., 2010). Pereira et al. (2010) also emphasize the development of mycorrhizae and bufonic reactions that prevent changes in pH, in addition to being able to suppress certain pathogens.

Ideally, this substrate formulation should involve the products available in the region, to make the final material cheaper and thus justify the use of this product on the basis of the substrates, as well as, environmentally, providing a suitable destination for different types of waste (Ribeiro et al., 2018).

2.3 BOVINE MANURE FOR THE PRODUCTION OF FOREST SEEDLINGS

Bovine manure can be a viable alternative for the production of seedlings, since, besides showing low cost, it can be prepared from material available on the rural properties. However, this use should be done with caution, because when applied in large proportions, it can bring more harm than benefits to the production of seedlings (Lisboa et al., 2018). Whereas, its proper application, from a good quality product, can supply the needs of the plants in some macronutrients, such as P and K available (Santos et al., 2006). According to Malavolta et al. (2002), organic fertilization with bovine manure, besides improving the drainage and aeration of the substrate, increases the water storage capacity and nutrient levels to the plant, stimulating root development.

Some research has shown positive responses from the growth of forest seedlings in substrate enriched with bovine manure. In a study with substrate composition for the production of seedlings of *Hymenaea courbaril*, Silva et al. (2023) found that the use of bovine manure provided a positive response, in contrast, the excess in the middle caused a reduction in the growth of the seedlings. In this case, the recommended dose of bovine manure was between 20 and 30% of manure per liter of substrate.

Similar to that established by Brito et al. (2021), while studying the production of *Tetona grandis* seedlings. The authors concluded that the bovine manure can be used as a viable alternative to make up the substrate, since, when using it, there was an increase in the



performance shown by the seedlings, in height and diameter of the collection, up to 120 days of development. Combinations with 30% bovine manure are recommended.

In addition to that recommended by Maekawa et al. (2020) for the production of *Ficus gomelleira* seedlings. For this species, the authors recommended a substrate with 25% bovine manure. By Gonçalves et al. (2014), which indicated the addition of tanned bovine dung in proportion to at least 20% of the volume of the substrate for the production of *Glaziovian Athelia* seedlings. Por Lisboa et al. (2018), which recommended the use of bovine manure in proportions between 21 and 28% for seedlings of *Handroanthus heptaphyllus* e; by Delarmelina et al. (2015), which indicated 25% commercial substrate + 35% bovine manure + 40% subsoil land for the substrate composition, for the production of *Chamaecrista devauxii* seedlings.

Whereas, Camargo et al. (2011) studying the composition of substrates for the production of *Jatropha curcas* seedlings, recommended a higher percentage than these. According to them, the best substrates for the production of these seedlings must be made up of 60% of bovine manure, worm humus or chicken bed in the total composition of the substrate.

Passos et al. (2022) established a recommendation in $t\ ha^{-1}$ for the production of saplings of *Enterolobium barnebianum*, and found that doses of $20\ t\ ha^{-1}$ positively influenced the total dry matter of the plants, recommending it for the composition of the substrate used for the production of seedlings of the species.

3 METHOD

The experiment was carried out at the plant house of the Faculty of Agronomy of the University of Cuiabá (UNIC), campus Beira Rio I, in Cuiabá - Mato Grosso, located at the coordinates 15°37'28" S and 56°05'11" O. The predominant climate of the region is the tropical savanna, according to Köppen classification.

The soil used was the dystrophic Red Latosol with a sandy loam texture, collected in an area of Cerrado native to the Federal Institute of Mato Grosso, campus of São Vicente da Serra. After collection, a sample of this soil was taken, air dried, sieved in a two mm mesh and submitted to chemical and particle size characterization (Table 1).



Table 1

Chemical and particle size characterization of the dystrophic Red Latosol used in the experiment, before the application of residue

pH	K	P	H+Al	Al	Ca	Mg	SB
CaCl ₂	mg dm ⁻³		cmole dm ⁻³				
4.50	70.20	1.43	6.25	0.25	1.92	0.67	2.77
CTCT	t effective	V	m	MO	Sand	Silt	Clay
cmole dm ⁻³		%		g kg ⁻¹			
9.02	3.02	30.71	8.28	34.61	538	54.30	407.70

pH in CaCl₂ - ratio 1:2,5; P and K - in Mehlich; H+Al - in calcium acetate pH7,0; Al, Ca and Mg - in KCl 1N; SB - sum of bases; CTCT - total capacity for exchange of cations; t effective - effective capacity for exchange of cations; V - saturation by bases; m - saturation by aluminum; MO - organic matter; Sand, silt and clay - density meter method.

Source: Prepared by the authors (2022).

The bovine manure was collected at the Experimental Farm of the Federal University of Mato Grosso (UFMT) in the breeding area, in the beef sector, with the cattle excrement as a constitution, which were removed and taken to the UNIC for tanning process for five months. During this period, the material remained uncovered, inside a container, in which it was turned over every two days and irrigated to maintain the activities of the microorganisms.

The seedlings of *K. senegalensis* were produced from commercially acquired seeds, from the accredited nursery Seeds Caiçara. According to the supplier, these seeds were obtained in the 2019 crop, being marketed with guarantee of 99.8% purity, and germination rate of 84%.

The seeds were submitted to overcoming dormancy, from immersion in water at room temperature, for 24 hours, as recommended by the seller. After overcoming dormancy, they were left to germinate in pots with a capacity of 240 cm³, filled with soil, the same used for the experiment. After 20 days, the cuttings were about 10 cm high and were transplanted for the treatments tested in the experiment, in plastic bags of 30x40 cm, with a capacity for two kilos of soil.

The treatments tested in this experiment consisted of doses of bovine manure, being: control (without addition of manure); 5 g (10 g kg⁻¹); 10 g (20 g kg⁻¹); 15 g (30 g kg⁻¹); 20 g (40 g kg⁻¹) and 25 g (50 g kg⁻¹) of manure. The six treatments were arranged in an entirely casualized design, with six repetitions, totaling 36 sample units. Samples of the prepared mixtures were characterized for their chemical composition and results can be observed in Table 2.



Table 2

Chemical characterization of the substrate, after addition of doses of bovine manure, depending on the applied dose

Features	Dose (g)				
	5	10	15	20	25
pH (CaCl ₂)	5.20	5.20	5.30	5.60	5.60
P (mg dm ⁻³)	15.4	20.4	33.7	37.6	42.5
K (mg dm ⁻³)	99.0	122.2	144.4	159.6	174.8
Ca (cmole dm ⁻³)	3.	3.20	3.25	3.40	3.55
Mg (cmole dm ⁻³)	1.	1.20	1.21	1.25	1.29
Ca+Mg (cmole dm ⁻³)	4.10	4.40	4.46	4.65	4.84
Al (cmole dm ⁻³)	0.00	0.00	0.00	0.00	0.00
H (cmole dm ⁻³)	4.30	4.58	4.35	4.22	4.09
SB (cmole dm ⁻³)	4.36	4.72	4.84	5.06	5.29
CTCT (cmole dm ⁻³)	8.66	9.29	9.19	9.29	9.38
effective t (cmole dm ⁻³)	4.36	4.72	4.84	5.06	5.29
V (%)	50.4	50.8	52.7	54.5	56.4
m (%)	0.00	0.00	0.00	0.00	0.00
MO (g dm ⁻³)	32.3	33.7	33.5	33.6	33.9

pH in CaCl₂ - ratio 1:2,5; P and K - in Mehlich; H+Al - in calcium acetate pH7,0; Al, Ca and Mg - in KCl 1N; SB - sum of bases; CTCpH7,0 - total cation exchange capacity; t effective - effective cation exchange capacity; V - saturation by bases; m - saturation by aluminum; MO - organic matter.

Source: Prepared by the authors (2022).

At the end of 90 days, the physiological characteristics of the cuttings were analyzed, using the portable photosynthetic measuring system, model LI-6400 XP (LI-COR, Lincoln, NE, USA). The characteristics analyzed were: net photosynthetic rate (A , in $\mu\text{mol m}^{-2} \text{s}^{-1}$), transpiratory rate (E , $\text{mmol m}^{-2} \text{s}^{-1}$), transpiration rate (Tr , in $\text{mmol (adapted) m}^{-2} \text{s}^{-1}$), vapor pressure deficit ($VpdL$, in kPa), stomatic conductance (gs , in $\mu\text{mol m}^{-2} \text{s}^{-1}$) and intercellular CO₂ concentration (Ci , in $\text{mmol m}^{-2} \text{s}^{-1}$). For this characterization, two cuttings were analyzed and measurements were carried out at the beginning of the day, until 9:00 am, to avoid possible climatic interference.

After the measurements of the physiological characteristics, the morphological analyzes of the cuttings were carried out, being: height (H), with a graduated ruler, from the surface of the substrate to the last leaf, with measurement in centimeters; and neck diameter (DC), with digital caliper, in the region of insertion between the aerial part and the root part, with measurement in millimeters. Next, the cuttings were collected, sectioned in part from the air and part from the roots, washed in running water for the removal of excess soil. These plants were taken into the circulation oven at 65°C and as soon as they presented a constant weight, they were weighed in an analytical balance with a precision of 0.01 g, to obtain the dry mass of the air part ($MSPA$) and the dry mass of the root part ($MSPR$), with a measurement in grams.

To analyze the development of seedlings in relation to the doses of manure, the data were adjusted by means of a linear regression model, containing as an independent variable the



doses of the residue and, as dependent variables, the morphological and physiological characteristics. The statistical analyzes were carried out using the R software and the Tukey test was used to compare averages at 5% probability.

4 RESULTS AND DISCUSSIONS

4.1 BOVINE MANURE IN THE MORPHOLOGICAL CHARACTERISTICS OF *K. senegalensis* SEEDLINGS

The effects of the applications of different doses of bovine manure on the morphological characteristics of *K. senegalensis* seedlings are presented in Table 3, where it can be observed that the means for height (H), neck diameter (DC), dry mass of the air part (MSPA) and dry mass of the root part (MSPR) were statistically different, being the highest observed in soil with addition of manure. Proving that this addition was beneficial for the growth of seedlings of this species.

Table 3

Comparison test of means for height (H), neck diameter (DC), dry weight of the upper part (MSPA) and dry weight of the root part (MSPR) of African mahogany seedlings submitted to different doses of bovine manure

Doses (g)	Variables			
	H (cm)	DC (mm)	MSPA (g)	MSPR (g)
0	31.01 b	4.41 b	4.78cd	2.94 bc
5	54.73 to	4.25 b	4.53cd	1.72 d
10	56.83 to	4.78 b	4.51 d	2.13cd
15	57.48 to	5.43 ab	5.56 bc	2.56bc
20	49.43 to	5.54 ab	6.36 ab	3.49b
25	47.25 ab	7.04 to	6.8 a	4.59a
pa	0.0039**	0.0003**	0.0037**	0.0011**
CV(%)	13.27	16.75	9.68	18.45

** Significance less than 1% probability of error;

Vertical averages followed by the same lower-case letter do not differ statistically, by Tukey's test at the 5% probability level of error.

Source: Prepared by the authors (2022).

For growth at height, no difference was observed between the cuttings submitted to the doses of bovine manure of 5 g to 20 g, and in these treatments were obtained the highest averages. In these cases, growth in height was 43.3% higher at the 5 g dose; 45.4% at the 10 g dose; 46.1% at the 15 g dose; and 37.2% at the 20 g dose, compared to growth in seedlings at the control treatment. So even the smallest doses of dung were enough to increase growth in



height. This indicates that there has been an improvement in the soil conditions. However, doses greater than 20 g would already promote growth in height less prominently.

Comparatively, this growth in height was higher than that observed in Da Ros et al. (2018) when studying the growth of African mahogany (*K. ivorensis*) seedlings submitted to substrates containing wastewater from pig farming, as these authors observed an average of 23.7 cm, after 128 days of sowing. In addition to being superior to that obtained by Cruz et al. (2016) which, when analyzing the substrates with tanned bovine dung, obtained an increase of up to 19.37 cm in the height of *Spondias tuberosa* plants, when compared to those that did not have dung in their composition.

For the sample diameter variable, the highest mean was observed at a dose of 25 g (37% higher growth than observed in the control treatment). However, the performance may also be satisfactory at the 15 g and 20 g doses and a lower dose is not recommended. Accordingly, the effects of the bovine manure on the growth in diameter of the seedlings of *K. senegalensis* were better from the dose of 15 g. Corroborating that this addition can improve the conditions for growth, thus being able to obtain seedlings of a higher quality and suitable for planting. According to Smiderle et al. (2018) research work with forest species has found that seedlings with greater height and larger stem diameter have presented greater initial growth potential in the field.

The height of the upper part and the diameter of the neck are the two morphological characteristics most used to qualify seedlings to be planted in the field. According to Gomes & Paiva (2011), the height is quick and easy to determine, since it is a non-destructive analysis; and the diameter is related to the capacity of formation and growth of new roots. This morphological characteristic accounts for 70 to 80% of the differences in the weight of dry matter of the cuttings (Souza et al., 2006).

These averages were compatible with the recommendations made by Gomes & Paiva (2011) that qualify a seedling for planting in the field when they show values greater than 2 mm in neck diameter. In this case, all the seedlings would be fit, regardless of the treatment tested. However, if one considers that, possibly, the cuttings submitted to the treatments with the addition of manure to the soil, have reached this level of adequacy, previously the cuttings submitted to the treatment without manure, it is found that the application of the residue is the best option for the production of cuttings of *K. senegalensis*.

As for dry mass, the dose of 25 g was also outstanding. In the case of the aerial part, the production of dry mass was 29.4% higher than that observed in the control treatment. While the root part was 37% higher. Corroborating that the addition of the highest dose of bovine manure



avored the growth and development of *K. senegalensis* seedlings, as it possibly increased the levels of nutrients available to the plants, favoring their physiological characteristics.

According to Gomes & Paiva (2011), the production of air dry mass indicates the rusticity of the seedling, with the highest values representing the most lignified and rustic, with the highest production potential in environments with adverse conditions. Therefore, it is one of the best characteristics to evaluate the quality of the seedlings, although destructive, as it reflects the plant's liquid photosynthesis (Fernandes et al., 2019). Furthermore, regarding the root part, Gomes & Paiva (2011) recommend that the more abundant the root system, the greater the chance of survival of the seedling in the field. Since this distribution will be related to the capacity of the plants to absorb water and nutrients.

Lisbon et al. (2018) testing the addition of bovine manure for the production of *Handroanthus heptaphyllus* seedlings, found greater growth in height and diameter and greater production of dry mass in seedlings that grew in substrate containing manure. This was also observed by Camara et al. (2017), for *Colubrina glandulosa* seedlings.

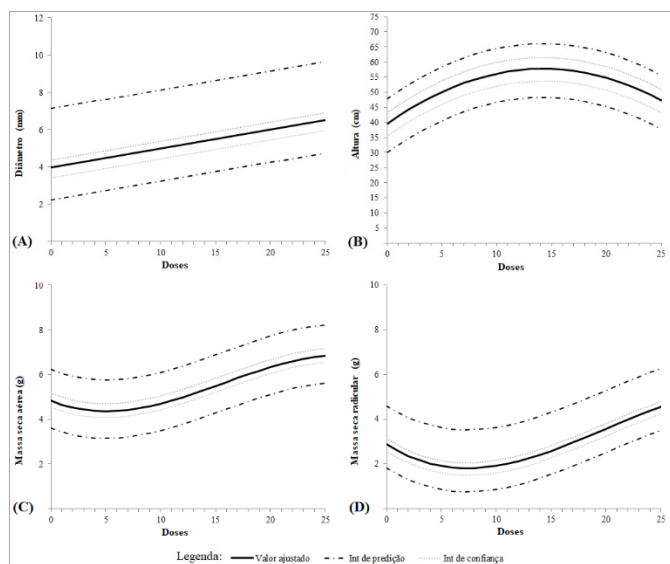
For Dias et al. (2008) one possible explanation for this behavior is that organic fertilizer improves soil structure, allowing better development of the root system. In study, Silva et al. (2012) observed that the substrates with higher total porosity promote higher quality of the root system and consequently gave rise to clonal *Eucalyptus* seedlings with higher dry mass of the aerial and root part.

Considering the growth adjustment (Figure 1), it was found that the mean growth in diameter were increasing according to the doses tested, indicating that for this characteristic the maximum dose of bovine manure for *K. senegalensis* was not yet obtained.



Figure 1

Growth curves for morphological variables of African mahogany cuttings as a function of bovine manure doses. (A) diameter; (B) height; (C) dry mass of the uppermost part and (D) dry mass of the root part.



Source: Prepared by the authors (2022).

For height, data were increasing up to the 15 g dose, representing that doses greater than 20 g of bovine manure would no longer produce the same effects and may cause a reduction of this characteristic. For both the dry mass of the air part (MSPA) and the dry mass of the root part (MSPR), the means were low in the lowest doses of manure, increasing from the dose of 10 or 15 g. Proving the need to supplement the initial nutritional conditions of the soil and that this can be done by the addition of doses of bovine manure.

4.2 BOVINE MANURE IN THE PHYSIOLOGICAL CHARACTERISTICS OF *K. senegalensis* SEEDLINGS

The effects of the applications of different doses of bovine manure when studying physiological characteristics, such as photosynthetic liquid rate, stomatic conductance, intercellular concentration of CO₂, transpiratory rate, vapor pressure deficit and transpiration rate, were greater in *K. senegalensis* seedlings that grew in soil containing 25 g of this manure. This can be analyzed in Table 4 and Figure 2.



Table 4

Mean comparison test for photosynthetic liquid rate (A), stomatic conductance (Gs), intracellular CO₂ concentration (Ci), transpiratory rate (E), vapor pressure deficit (VpdL) and transpiration rate (Tr) of African mahogany seedlings submitted to different doses of bovine manure

Doses (g)	Variables		
	A ($\mu\text{mol m}^{-2} \text{s}^{-1}$)	Gs ($\mu\text{mol m}^{-2} \text{s}^{-1}$)	Ci ($\text{mmol m}^{-2} \text{s}^{-1}$)
0	6.10 d	0.04 d	177.3 d
5	6.62cd	0.05 d	179.6 d
10	7.15bc	0.05 d	193.7c
15	7.55 b	0.12 c	246.2 b
20	9.91 to	0.14 b	262.9 b
25	10.21 to	0.17a	272.4 to
pa	<0.0001**	0.0001**	0.0001**
CV (%)	6.36	12.41	1.24
Doses (g)	Variables		
	E ($\text{mmol m}^{-2} \text{s}^{-1}$)	VpdL (kPa)	Trmmol ($\text{mmol m}^{-2} \text{s}^{-1}$)
0	1.11 d	1.83 d	25.83 d
5	1.16 d	2.12 c	28.11 c
10	1.22 d	2.15 c	28.56 c
15	2.59c	2.16 c	29.56 b
20	3.04 b	2.32 b	31.25a
25	4.23a	2.66 to	33.85 to
pa	0.0001**	0.0001**	0.0001**
CV (%)	9.62	3.41	2.86

** Significance less than 1% probability of error;

Vertical averages followed by the same lower-case letter do not differ statistically, by Tukey's test at the 5% probability level of error. Source: Prepared by the authors (2022).

The highest averages for the net photosynthetic rate (A) and transpiration rate (Tr) were observed in seedlings submitted to growth in soil increased by 20 g and 25 g of bovine manure. According to Weerasinghe et al. (2014) the highest values of liquid photosynthesis are related to the environment, and for the increase in photosynthetic rate to occur, there is a need to increase the rate of transpiration because once the stomata open, water outflows in the form of vapor, but also, CO₂ intakes, which will be directed to photosynthesis.

This condition has been found to favor growth in height and diameter, as well as increased production of dry mass, usually at a dose of 25 g of bovine manure. Kirschbaum (2011) confirms the importance of photosynthesis for plant growth, when he emphasizes that a 30% increase in the photosynthetic rate can result in a 10% increase in plant growth. This was probably reflected in the higher growth of *K. senegalensis* seedlings, after the addition of bovine dung to the soil.

For the other physiological characteristics, stomatic conductance (Gs), intracellular concentration (Ci) of CO₂, transpiratory rate (E) and vapor pressure deficit (VpdL), the highest means were observed in seedlings in soil with 25 g of bovine manure.



The rate of transpiration (Tr) is influenced by several factors such as climate, soil, plant age and the availability of water in the soil, intensifying with decreasing relative air humidity and increasing temperature. However, the soil increased with cattle manure may have contributed to the greater retention of humidity, which reduced periods of hydric stress for the plant that, less stressed, showed higher rates of transpiration.

Martins et al. (2008) studying *Eucalyptus saligna* observed that this species presented greater transpiration and water consumption and indicated that this was related to the larger leaf area, typical of the species. On the other hand, when studying *Eucalyptus grandis*, they found a reduction in transpiration and in the consumption of water, due to the reduction of the foliar area. Accordingly, it can be concluded that species that show a reduction in transpiration and water consumption, with a smaller foliar area, show greater control in the opening and closure of stomata (Silva et al., 2004). However, in the present case, there was no reduction in the foliar area, depending on the environment in which the plants grew.

Rodrigues et al. (2003) state that stomatic behavior and photosynthesis may be affected by decreased leaf water potential. Thus, the analysis of the stomatic conductance (G_s) was carried out, a mechanism for controlling the plant in relation to the quantity of water available, since the substrate can affect the quantity and the time of availability of water for the plant. However, in this case, the highest mean was observed at the 25 g dose.

Probably because this stomatic conductance contributed to the values observed for photosynthesis at these doses and consequently to the growth and production of dry mass of *K. senegalensis* cuttings. This allows one to infer that this type of dung contributed to maintaining the soil's humidity, reducing the possibility of water deficits in these conditions, and that these were sufficient for the species studied.

The intercellular concentration (C_i) of CO_2 is also related to the stomatic conductance, since the plants need to promote the opening of the stomata for this gas to enter and contribute to the photosynthetic process. To Parihar et al. (2015) increases in intercellular concentration values are responses of increases in stomatic conductance that may result in restrictions on photosynthetic performance. However, this was not observed in the present case, in which the concentration seems to have collaborated with the increase in the photosynthetic rate and, consequently, with the growth of the cuttings, having its highest average dose of 25 g.

Accordingly, the addition of manure favored the maintenance of CO_2 in the plant, as well as its entry and effective use by the plants, and this was, morphologically, translated into growth.



Another feature that contributed to growth was the transpiratory rate (E), which is related to the availability of water in the soil in each treatment. When the plant has a higher transpiratory rate, it demands adequate levels of water in the soil (facilitated by the increase in organic matter when the dung was added), which contributed to photosynthesis, since CO₂ enters while the plant releases water. The seedlings in soil with bovine dung, transpired more therefore the higher transpiratory rate in the dose of 25 g may also have favored the growth and the production of dry mass for the seedlings submitted to this treatment.

Lima et al. (2010) explain that the stomatic behavior determines the transpirative demand to which the leaves are potentially subject, controlling their water loss to the environment, in the form of vapor. In a situation of optimum water availability (field capacity), plants have high transpiratory rates so that, as soil water becomes scarce, the plant begins to reduce its transpiratory rate to decrease water loss and save the water available in the soil (Silva et al., 2015).

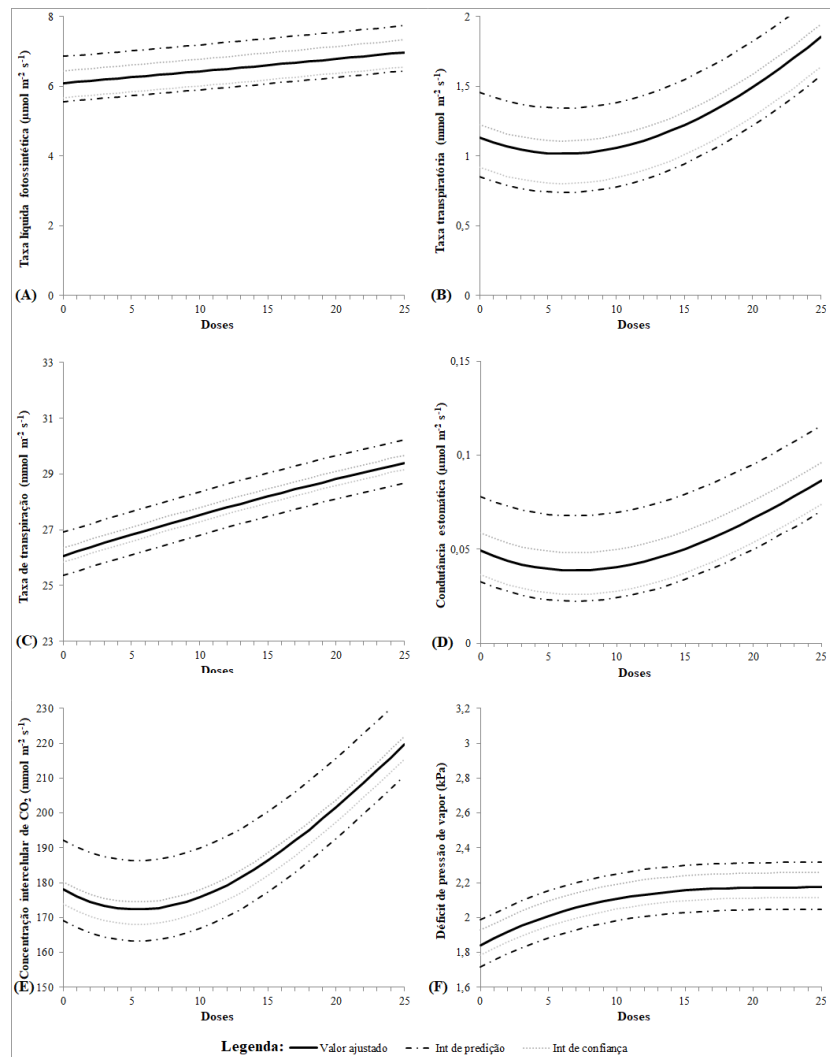
While the vapor pressure deficit (VpdL) is related to temperature. According to Pimentel (2004), when the vapor pressure deficit of the air is high and the absorption of water by the roots does not meet the atmospheric demand, the availability of CO₂ decreases. In the case of *K. senegalensis* the quantity of water available was sufficient to maintain the availability of CO₂, meeting the demand. Thus, even though the vapor pressure deficit was higher at a dose of 25 g, this was still the best physiological treatment for seedlings. This was probably maintained as a function of the addition of manure, which is an organic material with a capacity for favoring the retention of water.

From the data presented in Figure 2 it is observed that for the photosynthetic rate (A) and for the transpiration rate (C) there was an increase according to the applied dose and the addition of the manure was the factor that favored this result. Whereas, for transpiratory rate (B) and for stomatic conductance (D), the increase from the 10 g dose is related to the loss of water from the seedlings via stomata, indicating the need for bovine manure doses higher than 10 g.]



Figure 2

Growth curves for the physiological variables of African mahogany cuttings as a function of bovine manure doses. (A) photosynthetic net rate; (B) transpiratory rate; (C) transpiration rate; (D) stomatic conductance; (E) intercellular concentration of CO₂; (F) vapor pressure deficit.



Source: Prepared by the authors (2022).

Similar behavior was observed for the intercellular concentration of CO₂ (E), in this case the increase was increasing from the dose 10 g, noting that the higher the dung doses, the higher the CO₂ levels, which contributed to the increase of photosynthesis. Meanwhile, the vapor pressure deficit (F) remained stable from the 15 g dose, probably because of the physical characteristics brought about by the addition of organic matter, which allowed for greater water retention.



5 FINAL CONSIDERATIONS

When analyzing the morphophysiological aspects of *K. senegalensis* seedlings grown on substrates consisting of soil and different doses of bovine manure, it was found that the addition of this type of residue influenced the growth and development of plants, because it altered their physiological conditions.

The addition of 25 g of bovine manure to the soil has altered the morphophysiological characteristics of *K. senegalensis* seedlings to favor the production of seedlings of the highest quality.

Results such as these can stimulate the use, more often, of organic waste for the production of seedlings. This would be an (environmentally) correct way of giving a new destination to this waste, with a positive impact on society, since it would be a way of not leaving it outdoors, not allowing it to help in the proliferation of insects; to avoid its deposition in places that may bring about contamination of the soil and water; and to reduce discarding in natura. As well as being a way of reducing costs with the production of seedlings when looking for an alternative form of fertilizing the soil, at the same time as stimulating the production of seedlings of the species studied.

Further work should be carried out if the aim is to test with other doses, other types of waste, or other species. It is important to use waste that is the easiest and cheapest to buy near the place where the seedlings are produced. Accordingly, depending on the place of study, the same doses worked in the present case can be tested, though, with residues that are more common in the area.

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