



## DOSES OF N IN THE MORPHOLOGICAL AND PHYSIOLOGICAL CHARACTERISTICS OF AFRICAN MAHOGANY SEEDLING

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### ABSTRACT

**Purpose:** To analyse the growth of African mahogany (*Khaya senegalensis*) seedlings, regarding their morphology and physiology, in soil fertilized with different doses of N, from the application of ammonium sulphate.

**Theoretical framework:** Based on scientific articles found on search engines and books in the area of soil fertility and plant nutrition. To support the explanation of how the physiological characteristics of seedlings are related to the nutrition they receive from fertilization. Therefore, the application of different doses to the soil can provide different physiological responses, resulting in greater or lesser growth and dry mass production of plants.

**Method:** The experiment was carried out in a completely randomized design with five doses of N and five replications, using ammonium sulphate as the source. The doses tested were: T0 – without fertilization; T1 – 50 mg dm<sup>-3</sup>; T2 – 100 mg dm<sup>-3</sup>; T3 – 150 mg dm<sup>-3</sup>; T4 – 200 mg dm<sup>-3</sup>. The seedlings were produced and then transplanted to the definitive container, when it received nitrogen fertilization. These seedlings went through an adaptation process and, at the end of 90 days, the morphological characteristics were evaluated: height, diameter, leaf dry mass, stem dry mass, root dry mass and; physiological characteristics: net photosynthetic rate, transpiration rate, stomatal conductance, intercellular CO<sub>2</sub> concentration, vapor pressure deficit and transpiration rate.

**Results and conclusion:** Nitrogen fertilization influenced the morphological and physiological characteristics of African mahogany seedlings. The greatest growth and production of dry mass was observed at doses of 100 and 150 mg dm<sup>-3</sup> of N. These results were related to the increase in the net photosynthetic rate, stomatal conductance, transpiration and CO<sub>2</sub> concentration. Recommending the most economical dose of 100 mg dm<sup>-3</sup> of N.

**Research implications:** These results indicate that nitrogen fertilization is essential for the quality growth of African mahogany seedlings, and the dose to be applied is essential for this to happen, since values lower than this dose may not allow the plant to perform at its maximum. growth potential. Meanwhile, higher doses do not guarantee greater growth and will result in unnecessary expenses and, probably, loss of growth due to toxicity.

**Originality/value:** Using nitrogen fertilizers, in the correct dose for the species, increases its growth potential and guarantees the production of quality seedlings within the nursery.

**Keywords:** *Khaya senegalensis*, Seedlings Production, Nitrogen Fertilizer, Plants Morphology, Plants Physiology.

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## DOSES DE N NAS CARACTERÍSTICAS MORFOLÓGICAS E FISIOLÓGICAS DE MUDAS DE MOGNO AFRICANO

### RESUMO

**Objetivo:** Analisar o crescimento das mudas de mogno africano (*Khaya senegalensis*) quanto a sua morfologia e fisiologia, em solo adubado com diferentes doses de N, a partir da aplicação de sulfato de amônio.

**Referencial teórico:** Baseado em artigos científicos encontrados em sites de buscas e em livros da área de fertilidade do solo e de nutrição de plantas. Para embasar a explicação de como as características fisiológicas das mudas estão relacionadas com a nutrição que recebem a partir da fertilização. Portanto, a aplicação de diferentes doses ao solo, pode proporcionar diferentes respostas fisiológicas tendo como consequência, o maior ou menor crescimento e produção de massa seca das plantas.

**Método:** O experimento foi realizado em delineamento inteiramente casualizado com cinco doses de N e cinco repetições, tendo como fonte o sulfato de amônio. As doses testadas foram: T0 – sem adubação; T1 – 50 mg dm<sup>-3</sup>; T2 – 100 mg dm<sup>-3</sup>; T3 – 150 mg dm<sup>-3</sup>; T4 – 200 mg dm<sup>-3</sup>. As mudas foram produzidas e, em seguida, transplantadas para o recipiente definitivo, quando recebeu a adubação nitrogenada. Em seguida, passaram por processo de adaptação e, ao final de 90 dias, foram avaliadas as características morfológicas: altura, diâmetro, massa seca foliar, massa seca de caule, massa seca radicular e; as características fisiológicas: taxa fotossintética líquida, taxa transpiratória, condutância estomática, concentração intercelular de CO<sub>2</sub>, déficit de pressão de vapor e taxa de transpiração.

**Resultados e conclusão:** A adubação nitrogenada influenciou nas características morfológicas e fisiológicas das mudas de mogno africano. O maior crescimento e produção de massa seca das mudas foi observado nas doses de 100 e de 150 mg dm<sup>-3</sup> de N. Esses resultados se relacionaram com o aumento na taxa líquida fotossintética, da condutância estomática, da transpiração e da concentração de CO<sub>2</sub>. Recomendando-se a dose mais econômica de 100 mg dm<sup>-3</sup> de N.

**Implicações da pesquisa:** Esses resultados indicam que a adubação nitrogenada é fundamental para o crescimento com qualidade das mudas de mogno africano, sendo a dose a ser aplicada fundamental para que isso aconteça, já que, valores inferiores a essa dose podem não permitir que a planta apresente o seu máximo potencial de crescimento. Ao passo que, doses superiores não garantem crescimento maior e implicarão em gastos desnecessários e, provavelmente, perdas de crescimento por toxidez.

**Originalidade/valor:** Utilização de adubos nitrogenados, na dose correta para a espécie, aumenta seu potencial de crescimento e garante produção de mudas de qualidade dentro do viveiro.

**Palavras-chave:** *Khaya senegalensis*, Produção de Mudas, Adubo Nitrogenado, Morfologia de plantas, Fisiologia de Planta.

## DOSIS DE N EN LAS CARACTERÍSTICAS MORFOLÓGICAS Y FISIOLÓGICAS DE LAS PLÁNTULAS DE CAOBA AFRICANA

### RESUMEN

**Propósito:** Analizar el crecimiento de plántulas de caoba africana (*Khaya senegalensis*), respecto a su morfología y fisiología, en suelo fertilizado con diferentes dosis de N, a partir de la aplicación de sulfato de amonio.

**Marco teórico:** Basado en artículos científicos encontrados en motores de búsqueda y libros en el área de fertilidad del suelo y nutrición vegetal. Apoyar la explicación de cómo las características fisiológicas de las plántulas están relacionadas con la nutrición que reciben de la fertilización. Por lo tanto, la aplicación de diferentes dosis al suelo puede proporcionar diferentes respuestas fisiológicas, lo que resulta en un mayor o menor crecimiento y producción en masa seca de las plantas.

**Método:** El experimento se llevó a cabo en un diseño completamente aleatorizado con cinco dosis de N y cinco repeticiones, utilizando sulfato de amonio como fuente. Las dosis analizadas fueron: T0 – sin fertilización; T1 – 50 mg dm<sup>-3</sup>; T2 – 100 mg dm<sup>-3</sup>; T3 – 150 mg dm<sup>-3</sup>; T4 – 200 mg dm<sup>-3</sup>. Las plántulas se produjeron y luego se trasladaron al recipiente definitivo, cuando recibió fertilización nitrogenada. Estas plántulas pasaron por un



proceso de adaptación y, al final de 90 días, se evaluaron las características morfológicas: altura, diámetro, masa seca de la hoja, masa seca del tallo, masa seca de la raíz y; características fisiológicas: tasa fotosintética neta, tasa de transpiración, conductancia estomática, concentración intercelular de CO<sub>2</sub>, déficit de presión de vapor y tasa de transpiración.

**Resultados y conclusión:** La fertilización nitrogenada influyó en las características morfológicas y fisiológicas de las plántulas de caoba africana. El mayor crecimiento y producción de masa seca se observó a dosis de 100 y 150 mg dm<sup>-3</sup> de N. Estos resultados se relacionaron con el aumento de la tasa fotosintética neta, la conductancia estomática, la transpiración y la concentración de CO<sub>2</sub>. Recomendar la dosis más económica de 100 mg dm<sup>-3</sup> de N.

**Implicaciones de la investigación:** Estos resultados indican que la fertilización nitrogenada es esencial para el crecimiento de calidad de las plántulas de caoba africana, y la dosis a aplicar es esencial para que esto suceda, ya que los valores inferiores a esta dosis pueden no permitir que la planta se desempeñe en su máximo potencial de crecimiento. Mientras tanto, las dosis más altas no garantizan un mayor crecimiento y resultarán en gastos innecesarios y, probablemente, pérdida de crecimiento debido a la toxicidad.

**Originalidad/valor:** El uso de fertilizantes nitrogenados, en la dosis correcta para la especie, aumenta su potencial de crecimiento y garantiza la producción de plántulas de calidad dentro del vivero.

**Palabras clave:** *Khaya senegalensis*, Producción de Plántulas, Fertilizante Nitrogenado, Morfología Vegetal, Fisiología Vegetal.

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## 1 INTRODUCTION

African mahogany (*Khaya senegalensis*) is a tree species belonging to the botanical family Meliaceae, the same as cedar, andiroba and Brazilian mahogany. Its main product is wood, because it is considered noble, having potential to be commercialized both in the domestic and external market (Pinheiro et al., 2011). When processed, this wood can be used in the furniture industry, naval, for the manufacture of panels and laminates, civil construction and in the medical area, as in the case of treatments against malaria (Pinheiro et al., 2011; Tepongning et al., 2011).

In Brazil, commercial reforestation with African mahogany has increased in area in the last few years. In 2018, this area was 37 thousand hectares, which made Brazil the largest producer of the genus (Reis et al., 2019). Therefore, it is necessary to produce knowledge about the production of seedlings of this species, mainly as to their nutrition. This means starting with the study of the characteristics of the substrate used during this production.

According to what is reported by Freitas et al. (2017), among the substrates used for the production of seedlings of tree species, subsoil land stands out, which is still used by nurseries. However, most Brazilian soils have high acidity and low availability of nutrients under natural



conditions. Hence the importance of fertilizing during the production of the seedlings in the nursery.

According to Dutra et al. (2015) one of the ways of producing quality seedlings that have a chance of survival after transplantation is through balanced nutrition, using mineral fertilizers. Another characteristic that should be considered to designate whether a given substrate is of quality is its ability to alter the physiological characteristics of plants. According to Mondini et al. (2019), functional changes in plants by the application of different fertilizers can be investigated by means of non-destructive tools directly or indirectly involved in the photosynthetic process.

The proper development of seedlings will occur when the soil is fertile and presents adequate concentrations of nutrients, mainly N, P and K, whose requirements for plants are generally greater than the capacity of the soil supply (Cardoso et al., 2016). Thus, one of the most important stages of forestry is the definition of the ideal fertilizer for each species in the various stages of its development (Ciriello et al., 2014).

Of these elements, generally, N is the most absorbed by plants, since large quantities are required, mainly in the initial phase of its development, because the element is part of cell components and participates in processes such as ionic absorption, photosynthesis, respiration, multiplication and cellular differentiation (Taiz; Zeiger, 2013).

Some research has contributed to demonstrating the importance of N in the growth of plants during the process of the production of seedlings. Belapart et al. (2013) recommended doses of 224 and 448 mg dm<sup>-3</sup> of N for *Calophyllum brasiliense* seedlings. Falcão Neto et al. (2014) recommended 75 mg dm<sup>-3</sup> of N for seedlings of *Dipteryx lacunifera*. Goulart et al. (2017) recommended 100 mg dm<sup>-3</sup> of N for *Tabebuia serratifolia* seedlings. Besides these, other authors have also observed the importance of nitrogenous fertilization for the production of forest seedlings, such as Guedes et al. (2011) Ciriello et al. (2014) Moretti et al. (2015) and Cardoso et al. (2016).

Therefore, the present study was developed to analyze the growth of African mahogany (*Khaya senegalensis*) seedlings, as to their morphology and physiology, in fertilized soil with different doses of N (source - ammonium sulfate).

## 2 THEORETICAL FRAME

The theoretical benchmark was based on scientific articles and books published in the areas of Soil Fertility and Plant Nutrition. For better understanding, this theoretical reference



was divided into a few items: *Khaya senegalensis*; Nitrogen effects in the production of quality seedlings; Nitrogenous fertilization in the production of seedlings of forest species.

## 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 stem is gray or reddish brown in color and the crown is rounded and dense. The leaves are composed of 3 to 6 pairs of leaflets, 7 to 11 cm long and 3 to 5 cm wide, with bright green on the top and gray on the bottom. The flowering period runs from December to April and the flowers are small, white and unisexual (Nikiema; Pasternak, 2008).

The implantation of African mahogany in forest systems in Brazil is an economically viable practice and presents environmental benefits (Castro, 2008). This is attributed to its various characteristics, such as favorable climatic conditions, resistance to the drill of the hands and the non-existence of the pest *Hypsipyla grandella* (which attacks Brazilian mahogany) in its area of natural occurrence (Silva et al., 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. 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 anti-malaria compounds and insecticides (Agbedahunsi et al., 2004; 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 EFFECTS OF NITROGEN ON THE PRODUCTION OF QUALITY SEEDLINGS

Most of the organic components of plants contain N, which is absorbed by the roots in the form of nitrate ( $\text{NO}_3^-$ ) or ammonium ( $\text{NH}_4^+$  ammonium) ions (Malavolta et al., 1997). N acts in several physiological functions, as it is a constituent of cellular elements such as amino acids, proteins, nucleic acids, chlorophylls and coenzymes. Therefore, it participates in processes such as ion absorption, cell division, photosynthesis and respiration (Taiz; Zeiger, 2013; Raven et al., 2016). According to Malavolta (2006) because it is an element directly related to vegetative growth, its effects are also reflected in the size of the leaf area, in the production of vegetative buds, in the profiling and in the protein content of the grains.

This macronutrient is the most abundant in the plant, as well as the most demanded, depending on the functions mentioned above (Malavolta et al., 1996) and, among the main sources of N for fertilization, via soil, used in Brazil, are urea ( $\text{CO}(\text{NH}_2)_2$ ) and ammonium sulfate ( $(\text{NH}_4)_2\text{SO}_4$ ) (Malavolta et al., 2002).

For this reason, in the N deficiency in plants, Vieceli (2017) points out, as main symptoms, the reduction of plant growth, which occurs due to cellular components having N in their constitution. In addition, yellowing of the leaves; slow growth of stems; lower number, size and thickness of the leaves; and early defoliation.

An example is the study by Barroso et al. (2005), reporting the growth of teak seedlings (*Tetona grandis*) in nutritional solution. These authors observed the greatest reduction in seedling growth after the omission of N. The plants showed symptoms such as generalized chlorosis, paralysis of emission of new roots and rotting of secondary roots. The omission of N resulted in one of the smallest accumulations of dry mass, with a fall, on average, of 90%, in relation to the cuttings submitted to the treatment with a complete nutritional solution.

When studying the omission of nutrients in paricá cuttings (*Schizolobium amazonicum*), Marques et al. (2004) noted morphological changes due to the lack of nutrients, mainly in the deficiency of N, which was the one that most limited the plant's growth. These effects began to be observed at 10 days after transfer to the nutrient solution. The seedlings showed reduced size, fewer leaves, a less developed root system and a dark color.

It is worth mentioning that, the nutritional state reflects the internal quality of the plant, therefore, the adequate nutritional content in the plant tissue will bring about better development, resistance to pathogens and better capacity to adapt to the new place, after planting (DelQui et al., 2004). However, according to Furtini Neto et al. (2000), the demand for nutrients varies



according to the species, climatic season, stage of growth, and is more intense in the initial phase of plant growth.

An example is the study conducted by Duboc (2005); when researching the initial development and nutrition of several native tree species under fertilization, the author observed a difference in the nutritional requirements of each species, even as a function of the successive stages of growth. For the N, for example, the pioneer species showed a high nutritional requirement, in the dense Cerrado and in the Gallery Forest. However, secondary species had low nutritional requirements for N at both sites.

### 2.3 NITROGENOUS FERTILIZER FOR THE PRODUCTION OF FOREST SEEDLINGS

When assessing the growth of saplings of umburana (*Amburana cearensis*), Dutra et al. (2015) developed further when applying N and P to the substrate. This results in higher height, height-to-neck diameter ratio, dry root mass and better seedling quality indices, after the applications of 193, 245, 250 and 167 mg dm<sup>-3</sup> of N, respectively.

Positive results were also found by Goulart et al. (2017), when analyzing the production of yellow ipê seedlings (*Tabebuia serratifolia*) in response to nitrogenous fertilization, with ammonium sulfate, in five doses (0, 75, 150, 225 and 300 mg dm<sup>-3</sup>). The authors saw greater gains in growth and quality, with the application of N, when this was between 90 and 110 mg dm<sup>-3</sup>.

Guedes et. al (2011) analyzed the effects of nitrogenous fertilization on the growth of andiroba seedlings (*Carapa guianensis*). In this case, the highest mean for height growth was observed after application of 0.65g per plant and, for neck diameter, the best dose was 0.91 g per plant.

When studying the effect of nitrogenous fertilization on the production of seven-shelled seedlings (*Samanea inopinata*), Cruz et al. (2006) observed influence on almost all morphological parameters evaluated, except for the relationship between air dry mass/dry root mass and cervical height/diameter. It is recommended to apply 0,91 g of ammonium sulfate per molt, combined with organic compound.

Another characteristic that should be studied, with respect to fertilization, is the overdose. According to Scholberg et al. (2000) an overdose of N may promote excessive growth of plant parts; prolongation of the vegetative cycle; and increased occurrence of fruit with defects, which remain small and slowly mature at a late age.



In the same sense, Leite et al. (2010) noted that nitrogenous fertilizing using urea as a source increased the production of jambolan seedlings (*Syzygium cumini*). However, doses above 2,106 mg dm<sup>-3</sup> caused a depressive effect on seedlings. Agreeing with the study of Bezerra et al. (2018), who evaluated sources and doses of N, in the *production of Euterpe oleracea* (milling) *seedlings* and found that high doses of N, regardless of the source, resulted in the formation of poor-quality seedlings.

Another example is the study by Tucci et al. (2009). These authors evaluated the effects of increasing doses of N on the production of mahogany seedlings (*Swietenia macrophylla*) and found that, increasing doses of N (40; 80; and 120 g N ton<sup>-1</sup>), contributed to increase growth in stem diameter, dry mass of leaves, total dry mass and content of N, P and Ca in seedlings leaves. However, these results decreased at doses of 160; 200; and 240 g N ton<sup>-1</sup>. Given that, at the maximum dose used (240 g N ton<sup>-1</sup>), there was a negative effect on the diameter of the stalk and the air dry mass, impairing the quality of the cuttings.

### 3 METHOD

The study was carried out from an experiment installed in a vegetation house of the Faculty of Agronomy of the University of Cuiabá, located on the campus Beira Rio I, in Cuiabá - MT, 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 African mahogany seeds were collected from mother trees and acquired commercially from nursery located in Campo Grande - MS, having their guarantee certified origin. These seeds were left in water (room temperature) for 24 hours to overcome dormancy, as indicated in the product recommendations by the supplier. They were then placed to germinate in pots with a capacity of 240 cm<sup>3</sup> filled with soil. When the seedlings reached 10 cm in height, they were transplanted into the final recipients.

The soil used in the experiment was the dystrophic Red Latosol with a sandy loam texture, collected in an area of native Cerrado, belonging to the Federal Institute of Mato Grosso, campus of São Vicente da Serra. After collection, a soil sample was taken, dried in the air, sieved in a two mm mesh and sent to the laboratory for its chemical and physical characterization, which is presented in Table 1. This soil was used to fill the plastic bags of 30x40 cm, with a capacity for two kilos, for which the cuttings were transplanted.

**Table 1**

*Chemical and particle size characterization of the dystrophic Red Latosol used in the experiment, prior to the application of N doses*

| pH                     | K                   | P     | H+Al | Al    | Ca                     | Mg    | SB     |
|------------------------|---------------------|-------|------|-------|------------------------|-------|--------|
| CaCl <sub>2</sub>      | mg dm <sup>-3</sup> |       |      |       | cmole dm <sup>-3</sup> |       |        |
| 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 <sup>-3</sup> |                     |       | %    |       | g kg <sup>-1</sup>     |       |        |
| 9.02                   | 3.02                | 30.71 | 8.28 | 34.61 | 538                    | 54.30 | 407.70 |

pH in CaCl<sub>2</sub> - 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 (2024).

The soil was calcareated with dolomitic limestone, 79% PRNT, prior to the addition of nitrogenous fertilizers, and kept in incubation for seven days, under daily irrigation. The amount of limestone applied was calculated based on soil analysis, following the method of increasing saturation by bases to 50%. Other characteristics of the limestone used are: % CaO = 24,0; % MgO = 17,1; % Neutralization power (PN) = 84,4; % residual action = 15.

After incubation, the seedlings were transplanted into the plastic bags with previously prepared soil, where they remained for 10 days during the adaptation period. After these 10 days, solutions containing macronutrients (except N) were applied: 300 mg.dm<sup>-3</sup> of P using KH<sub>2</sub>PO<sub>4</sub>; 140 mg.dm<sup>-3</sup> of K using KCl and K<sub>2</sub>SO<sub>4</sub> (100 mg.dm<sup>-3</sup> of KCl and 40 mg.dm<sup>-3</sup> of K<sub>2</sub>), in solution, according to Passos (1994). And solutions containing micronutrients (Alvarez, 1974): 0,81 mg.dm<sup>-3</sup> of B, 3,66 mg.dm<sup>-3</sup> of Mn, 4,0 mg.dm<sup>-3</sup> of Zn, 1,33 mg.dm<sup>-3</sup> of Cu and 0,15 mg.dm<sup>-3</sup> of Mo, as sources H<sub>3</sub>Government, MnCl<sub>2</sub>.4H<sub>2</sub>O, ZnSO<sub>4</sub>.7H<sub>2</sub>O, Cu SO<sub>4</sub>.5H<sub>2</sub>O and (NH<sub>4</sub>)<sub>6</sub>Mo<sub>7</sub>O<sub>24</sub>.4H<sub>2</sub>O, respectively.

After the applications of the nutrient solutions, doses of N were applied, being: T0 - without addition of N; T1 - 50 mg dm<sup>-3</sup> N; T2 - 100 mg dm<sup>-3</sup> N; T3 - 150 mg dm<sup>-3</sup> N; T4 - 200 mg dm<sup>-3</sup> N. These doses were tested using ammonium sulfate (21% N) as a source, in entirely casualized design, with five repetitions.

At the end of 90 days, the physiological characteristics were evaluated, from three plants still alive from each treatment, being: the net photosynthetic rate (A), the transpiratory rate (E), the stomatic conductance (gs), the intercellular concentration of CO<sub>2</sub> (Ci), the vapor pressure deficit (VpdL) and the transpiration rate (Trmmol). These characteristics were measured with the help of a portable photosynthesis measurement system, model LI-6400 XP (LI-COR, Lincoln, NE, USA). For the measurements, the apparatus was adjusted to a temperature of 28°C,



a relative humidity of 60% and a photosynthetically active flux density of  $1000 \mu\text{mol m}^{-2} \text{s}^{-1}$ . They were carried out on the first or second fully expanded leaf, from the kaolin apex (usually the fourth or fifth leaf), exposed to solar radiation and without phytosanitary impairment. And, they occurred in the daytime period, between 07:00 and 11:00 (local time), with the values being recorded only after the stability of the gs.

Whereas, morphological characteristics were evaluated from all the plants of the experiment, being: height of the aerial part (H), with graduated ruler, measuring from the base of the soil to the last leaf of the plant; diameter of collar (DC), measuring with digital caliper; and dry mass. For dry mass analysis, the seedlings were sectioned into leaves (MSF), stalks (MSC) and roots (MSR), placed in an oven for the forced circulation of air at  $65^{\circ}\text{C}$  until a constant weight, and weighed in a semi-analytical balance.

The data were interpreted by means of linear regression analysis, then the graphs were obtained, using the statistical program R, after verification of their normality. The analysis of variance was obtained and the means compared using the Tukey test at 5% probability.

## 4 RESULTS AND DISCUSSIONS

### 4.1 MORPHOLOGICAL CHARACTERISTICS OF AFRICAN MAHOGANY SEEDLINGS SUBMITTED TO DIFFERENT DOSES OF N

Analyzing the growth and development of African mahogany in fertilized soil with different doses of N, it was found that there was no statistical difference (Table 2) for growth in neck diameter and dry mass of leaves.

**Table 2**

*Statistical analysis for height (H in cm), diameter (DC in mm), dry mass of leaves (MSF in g), dry mass of stem (MSC in g) and dry mass of root (MSR in g) of African mahogany seedlings after submission to different doses of N*

| Dose (mg $\text{dm}^{-3}$ ) | H        | DC     | MSF     | MSC     | MSR     |
|-----------------------------|----------|--------|---------|---------|---------|
| 0                           | 35.02 b  | 3.57a  | 3.84a   | 4.18 b  | 5.02 to |
| 50                          | 61.40 to | 3.58a  | 4.84a   | 4.98 ab | 2.45 b  |
| 100                         | 64.54a   | 3.93 a | 5.11a   | 5.27a   | 3.25 b  |
| 150                         | 58.96 to | 4.24a  | 5.11a   | 4.99 ab | 3.49b   |
| 200                         | 58.50 to | 3.70a  | 4.47 to | 4.33 ab | 2.62 b  |
| CV (%)                      | 8.7      | 17.4   | 15.0    | 11.     | 16.4    |

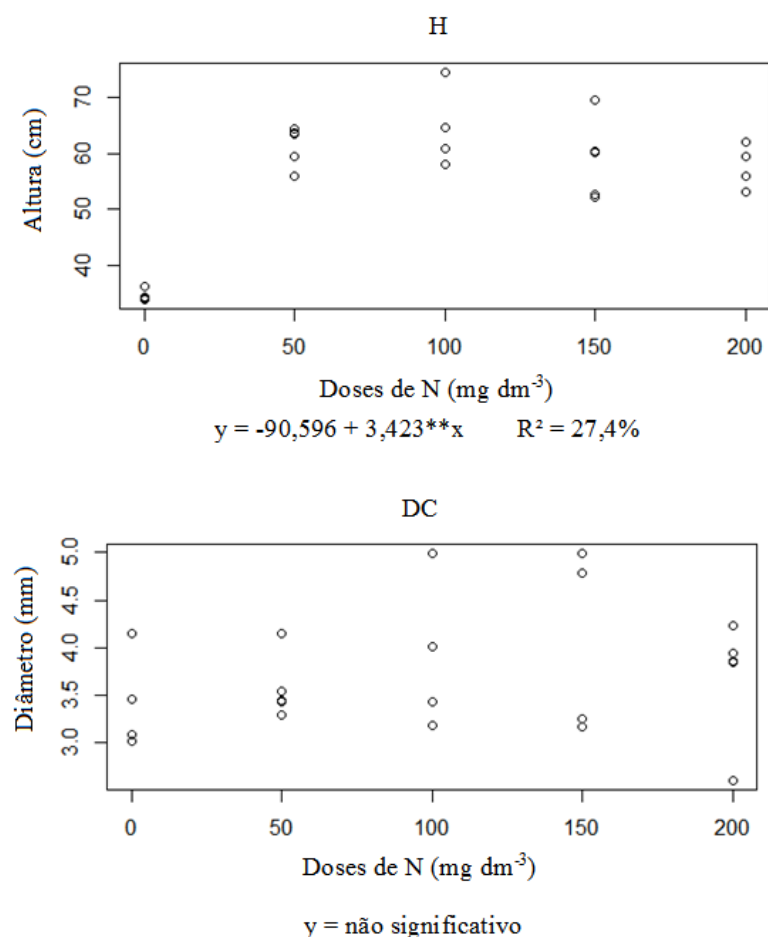
Averages followed by the same letter do not differ from each other by the Tukey test at 5% probability.  
Source: Prepared by the authors (2024).



As for height growth (Table 2), the cuttings presented averages ranging from 35.02 cm for those submitted to the witness treatment and 64.4 cm for those of the treatment with dose of  $100 \text{ mg dm}^{-3}$  (increase of 45.6%). This mean growth at the dose of  $100 \text{ mg dm}^{-3}$  was similar to that observed at the dose of  $50 \text{ mg dm}^{-3}$  (61.4 cm). In all treatments with applications of N, growth in height was higher than that observed for seedlings in the treatment of the witness. However, at doses higher than  $100 \text{ mg dm}^{-3}$ , there was a reduction in growth in height (Figure 1), comparing treatments with N addition. This allows to understand the importance of the application of N, through fertilization, for the initial growth of African mahogany seedlings.

**Figure 1**

*Height (H in cm) and neck diameter (DC in mm) of African mahogany seedlings after submission to different doses of N.*



Source: Prepared by the authors (2024).

This is because N has structural function as part of cellular components and therefore participate in important processes such as photosynthesis, respiration, cellular differentiation and ionic absorption (Taiz; Zeiger, 2013). Furthermore, height is one of the most analyzed



morphological characteristics, along with diameter, to indicate the quality of the seedlings, being a non-destructive and easy to obtain characteristic, which, according to Gomes e Paiva (2013) correlates positively with growth in the field. This implies saying that the seedlings submitted to treatment with nitrogenous fertilization are more suitable for planting in the field or even that they will be suitable as from a shorter time in the nursery. This is a favorable situation, mainly if one thinks of a nursery with a commercial stamp.

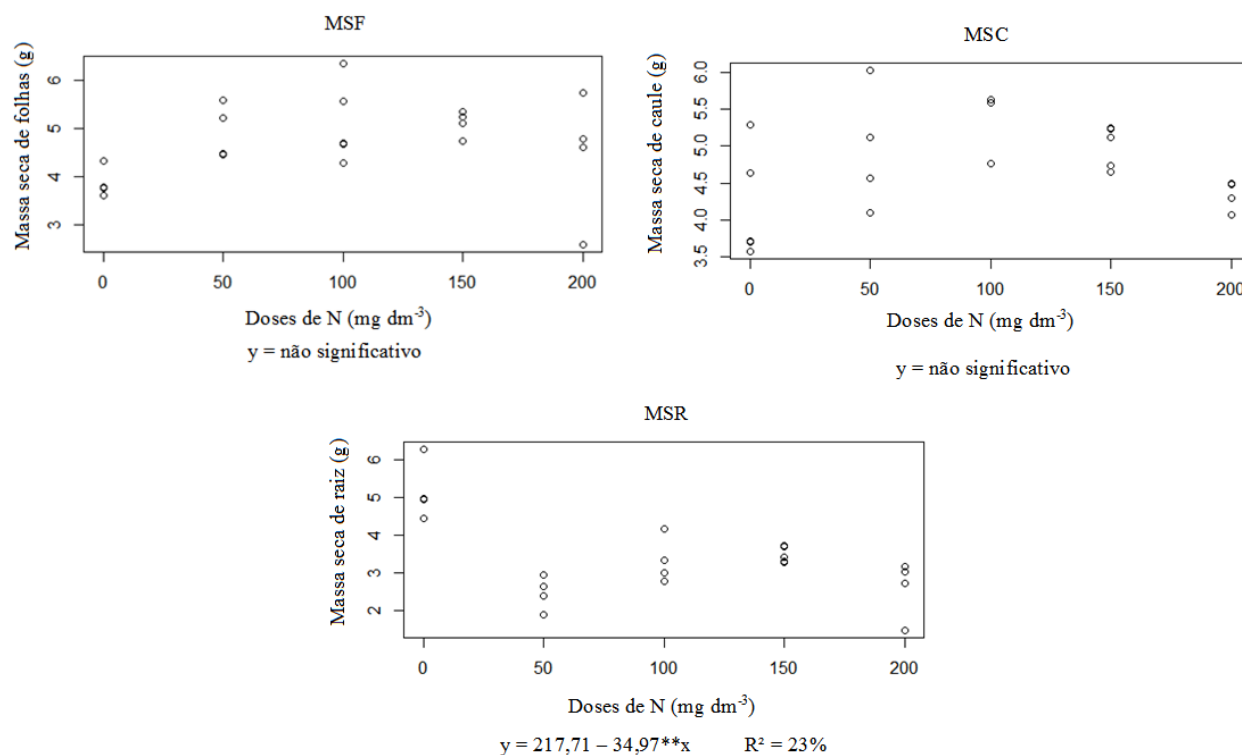
For the diameter (Table 2), no difference was observed between the means, only growth trend for the cuttings at the dose of  $150 \text{ mg dm}^{-3}$  (4.24 mm), with an increase of 7.3% in relation to the cuttings of the control treatment (mean of 3.6 mm), and it was not possible to adjust linear regression equation (Figure 1). In this case, the dose of  $150 \text{ mg dm}^{-3}$  was the only one to provide growth in diameter, greater than 4 mm. Therefore, it is important to point out that the seedlings submitted to treatment with nitrogenous fertilization reached the height and diameter recommended for planting in the field, possibly in less time, a result that is sought in a forest nursery.

Araujo et al. (2020) studying the growth of African mahogany (*K. ivorensis*) under doses of N and P obtained seedlings with average height growth of 32.2 cm (at the dose of  $0 \text{ mg dm}^{-3}$  of N) to 55.2 cm (at the dose of  $100 \text{ mg dm}^{-3}$  of N), therefore similar in almost all treatments tested in this experiment, except for the dose of  $200 \text{ mg dm}^{-3}$  where the average was 61.04 cm. However, as for diameter, they were higher, as the authors observed averages of 10.2 mm ( $0 \text{ mg dm}^{-3}$  dose of N) to 14.2 mm ( $50 \text{ mg}$  dose and  $100 \text{ mg dm}^{-3}$  of N).

When analyzing dry mass, we observe the trend of increase in the mass production of seedlings in treatments with applications of N, however, without significantly different averages for dry mass of leaves (Table 2). Since, both for the production of dry mass of the leaves and the stalk, it was not possible to obtain a regression equation that was representative (Figure 2).

**Figure 2**

*Dry mass of leaves (MSF in g), dry mass of stem (MSC in g) and dry mass of root (MSR in g) of African mahogany seedlings after submission to different doses of N.*



Source: Prepared by the authors (2024).

Dry mass of the leaves tended to increase after N at doses of 100 and 150 mg dm<sup>-3</sup> of N, averaging 5.11 g, compared to 3.84 g in the control treatment, corresponding to an increase of 24.8%. While, for the production of dried stem mass, the mean dose of 100 mg dm<sup>-3</sup> was 5.27 g, which corresponded to a 20.7% increase compared to 4.18 g in the control treatment. This trend of increase in dry mass production for seedlings in fertilization treatments may be related to the fact that N is part of compounds in plants, such as amino acids, nucleic acids and chlorophyll (Taiz; Zeiger, 2013). Being favorable results because the production of biomass is one of the best characteristics for assessing the quality of the seedlings, in spite of being destructive, since it reflects the plant's liquid photosynthesis.

While, for the production of dry mass of the root, there was a reduction with the application of N via fertilization. The highest mean (5.0 g) in the control treatment is observed. This characteristic may be related to the species itself and/or, with the improvement in the nutritional condition of the soil, which made possible a greater increase in the air dry mass than in the dry mass of the root. Among fertilization treatments, both at the dose of 100 mg dm<sup>-3</sup> and at the dose of 150 mg dm<sup>-3</sup>, the mean dry root mass was greater than 3 g. According to Gomes and



Paiva (2013), root production also has a major influence on the survival and initial growth of seedlings in the field, so the more abundant the root system, the greater survival.

#### 4.2 PHYSIOLOGICAL CHARACTERISTICS OF AFRICAN MAHOGANY SEEDLINGS SUBMITTED TO DIFFERENT DOSES OF N

The results obtained for the physiological characteristics of the seedlings after being submitted to different doses of N, are shown in Table 3 and Figures 3 and 4. It was observed that it was possible to adjust equations for all the characteristics studied and all presented significantly different means. This indicates the influence of N doses on plant physiology and that this influence possibly has consequences for the growth and development of African mahogany seedlings.

**Table 3**

*Statistical analysis for net photosynthetic rate (A, in  $\mu\text{mol m}^{-2} \text{s}^{-1}$ ), stomatic conductance (gs, in  $\mu\text{mol m}^{-2} \text{s}^{-1}$ ), intercellular CO<sub>2</sub> concentration (Ci, in  $\text{mmol m}^{-2} \text{s}^{-1}$ ), transpiratory rate (E, in  $\text{mmol m}^{-2} \text{s}^{-1}$ ), vapor pressure deficit (VpdL, in kPa) and transpiration rate (Trmmol, in  $\text{mmol m}^{-2} \text{s}^{-1}$ ) African mahogany cuttings after submission to different doses of N*

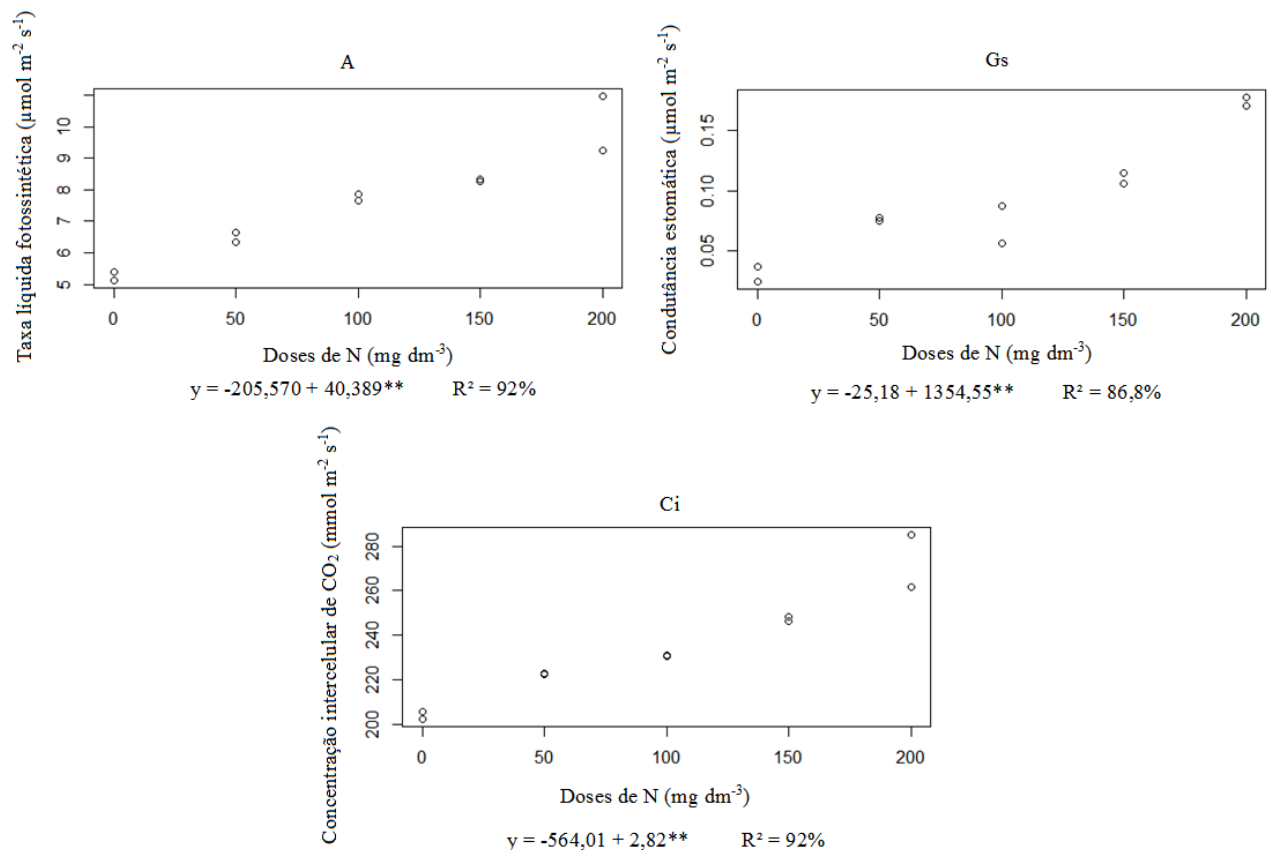
| Dose ( $\text{mg dm}^{-3}$ ) | A        | g      | Ci        | AND    | VpdL     | Trmmol    |
|------------------------------|----------|--------|-----------|--------|----------|-----------|
| 0                            | 5.26 d   | 0.03 d | 203.88 d  | 0.75 d | 1.60 and | 27.04 and |
| 50                           | 6.49 c   | 0.08 c | 222.71 c  | 2.07 c | 1.91 d   | 28.17 d   |
| 100                          | 7.76 b   | 0.08 c | 230.63 c  | 2.37c  | 2.34c    | 29.28 c   |
| 150                          | 8.30 b   | 0.11b  | 247.27b   | 2.75 b | 2.78 b   | 30.15 b   |
| 200                          | 10.10 to | 0.17a  | 273.43 to | 3.22a  | 3.12a    | 31.58a    |
| CV (%)                       | 5.8      | 9.3    | 2.4       | 8.0    | 7.7      | 1.1       |

Averages followed by the same letter do not differ from each other by the Tukey test at 5% probability.

Source: Prepared by the authors (2024).

**Figure 3**

Net photosynthetic rate ( $A$ , in  $\mu\text{mol m}^{-2} \text{s}^{-1}$ ), stomatic conductance ( $g_s$ , in  $\mu\text{mol m}^{-2} \text{s}^{-1}$ ) and intercellular  $\text{CO}_2$  concentration ( $C_i$ , in  $\text{mmol m}^{-2} \text{s}^{-1}$ ) of African mogno cuttings after submission to different N doses.



Source: Prepared by the authors (2024).

For the net photosynthetic rate (Figure 3), increasing mean values were observed for African mahogany cuttings as a function of N fertilization. Thus, the highest mean was observed for cuttings at the dose of 200 mg dm<sup>-3</sup>, with an increase of 47.9% compared to the control treatment, although in all treatments with N addition, the mean was higher than the control. The highest growth and dry mass production was observed in seedlings submitted to N doses mainly at the dose of 100 mg dm<sup>-3</sup>. These results indicate, therefore, that fertilizing with N increases the photosynthetic capacity of the seedlings and this was reflected in their greater growth and mass production. This is related to the functions of the N in the metabolism of the plant, one of these being the functions of structuring the molecule of chlorophyll. Therefore, it can be said that, African mahogany cuttings were responsive to increment with N doses to the soil, however, without the need of the highest dose tested.



Kirschbaum (2011) corroborates 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. In addition, the increase in the mass of leaves, observed in the present case, is a significant factor in plant growth, since the leaf is the organ responsible for photosynthesis (Tatagiba et al., 2015).

One of the physiological characteristics that may have contributed to this higher photosynthetic liquid rate was the stomatic conductance (Figure 3). For this physiological characteristic, an increase was also observed, with the increase in the dose of N, having the highest average in the dose of 200 mg dm<sup>-3</sup> of N. Thus, it is correct to state that fertilization with N and the absorption of this by plants increases the stomatic conductance that will probably be related to the opening of the stomata and the exchange of gases, such as CO<sub>2</sub>, which contributed to the effects observed in the photosynthetic liquid rate. The values observed between the doses of 100 and 150 mg dm<sup>-3</sup> are sufficient for the growth and development of African mahogany seedlings.

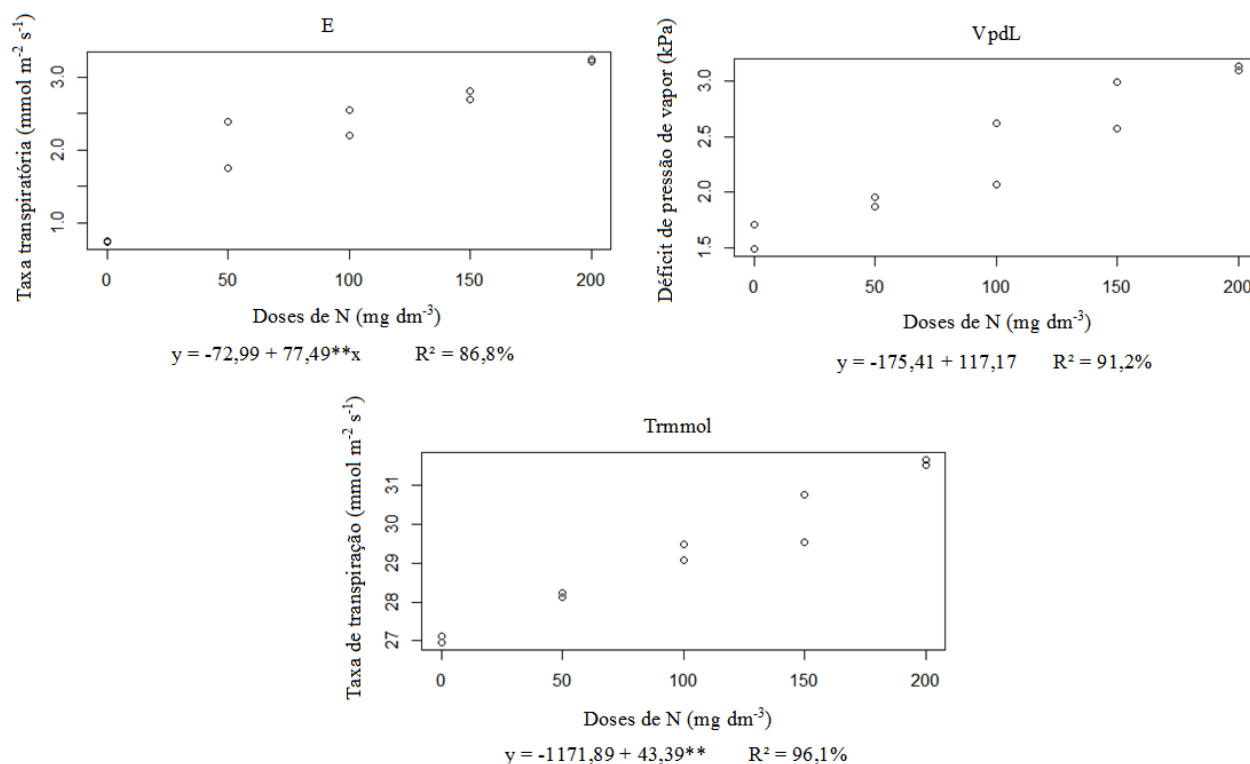
Stomatic opening is the main pathway through which CO<sub>2</sub> is exchanged from the atmosphere to the leaves, being controlled by complex mechanisms in order to maintain a balance between CO<sub>2</sub> absorption and control of water vapor loss (Taiz; Zeiger, 2013). However, these positive results of the study were observed even this functioning of the stomata constituting a physiological impairment, since, when opened, they allow the assimilation of CO<sub>2</sub> and the loss of H<sub>2</sub>O. Closing reduces the CO<sub>2</sub> input to rubisco carboxylation sites within chloroplasts and conserves H<sub>2</sub>O, reducing the risk of dehydration (Tatagiba et al., 2015).

For the intercellular concentration of CO<sub>2</sub> (Figure 3), averages with increasing values were also observed in seedlings submitted to fertilized soil with N, ranging from 203.9 mmol m<sup>-2</sup> s<sup>-1</sup> in the treatment witnesses to 273.4 mmol m<sup>-2</sup> s<sup>-1</sup> at the dose of 200 mg dm<sup>-3</sup>. This mean value presented in the witness does not seem to be sufficient for African mahogany. This physiological characteristic is important because it is directly related to the photosynthetic process, since, with the increase in the content of CO<sub>2</sub> inside the leaf of the plant, an organ in which, in fact, the photosynthetic process occurs, this gas can be put to good use in the chemical phase of photosynthesis, in which the production, mainly, of carbohydrates will occur. These carbohydrates may later be used in the production of energy for the plant.

The increase in CO<sub>2</sub> concentration occurred as a function of increased transpiratory rate (Figure 4), with means ranging from 0.75 mmol m<sup>-2</sup> s<sup>-1</sup> in the control treatment to 3.22 mmol m<sup>-2</sup> s<sup>-1</sup> at a dose of 200 mg dm<sup>-3</sup>.

**Figure 4**

Transpiratory rate ( $E$ , in  $\text{mmol m}^{-2} \text{s}^{-1}$ ), vapor pressure deficit ( $V_{pdL}$ , in  $\text{kPa}$ ) and transpiration rate ( $Tr_{\text{mmol}}$ , in  $\text{mmol m}^{-2} \text{s}^{-1}$ ) of African mahogany cuttings after submission to different doses of N.



Source: Prepared by the authors (2024).

Therefore, accompanying the results observed in the previous characteristics, because, the increase in the transpiratory rate occurs as a function of the opening of the stomata, allowing the outflow of water and the entry of  $\text{CO}_2$ . In this case, the outflow of water was not an unfavorable process, because the seedlings were submitted to a situation without a water deficit and all of them were kept under irrigation and with a similar water slide. However, with the transpiration, the flow of mass occurs, which assists in the absorption of water and nutrients, and, afterwards, the ascent of these to the upper part of the plant, favoring the plant's nutrition and the photosynthetic process. This is how they collaborate with the results verified for the photosynthetic net rate and for the growth and mass production of the seedlings. According to Silva et al. (2015) in a situation of optimum water availability (field capacity), plants usually have high transpiratory rates so that as soil water becomes scarce, it begins to reduce its transpiratory rate to decrease water loss and save available soil water.

This increase in transpiratory rate, stomatic conductance and  $\text{CO}_2$  concentration, occurred in an environment where an increase in vapor pressure deficit was also observed



(Figure 4). The higher the dose of N, the greater was the vapor pressure deficit, which therefore contributed to the previously mentioned results, and which were also driven by the moisture maintained in all the treatments tested.

In this sense, one can highlight what was observed for the transpiration rate (Figure 4), which was also higher for those seedlings submitted to the addition of N doses, having the highest average in the dose of  $200 \text{ mg dm}^{-3}$ . This increase in transpiration rate is related, among other characteristics, to the vapor pressure deficit, as this type of pressure did not affect the transpiration of the plant, contributing to the entry of  $\text{CO}_2$  and consequently to the increase in the photosynthetic process.

## 5 FINAL CONSIDERATIONS

Nitrogenous fertilization, with ammonium sulfate as its source, influences the morphological and physiological characteristics of African mahogany seedlings.

The highest growth and dry mass production were observed at doses of 100 and  $150 \text{ mg dm}^{-3}$  of N. However, the producer may opt for the dose of  $100 \text{ mg dm}^{-3}$  of N, as this is more economical.

The increased development of African mahogany seedlings after soil fertilization with N is related to the increase in net photosynthetic rate, stomatic conductance, transpiration and  $\text{CO}_2$  concentration, under appropriate conditions, for the seedlings of this species.

Results such as these can stimulate the use, more often, of nitrogenous fertilizers to improve the quality of seedlings produced in the nursery. It is known that the quality of the seedling is directly related to its ability to survive in the field and to its first years of post-planting growth. This implies mentioning that it may also be related to the quality of the tree to be produced. In addition, using the right fertilizer at the right dose can make the nurseryman manage to produce more seedlings in less time, which is interesting when it comes to a production with a commercial objective, for example.

Further work should be carried out if the objective is testing with other doses, other sources, or other species. It is important that the correct dose is used for each species and that the same dose is not generalized to all species, as this may lead to losses in the growth capacity of some species and longer nursery time.



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