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GERMINATION AND INITIAL DEVELOPMENT OF *Hymenaea stigonocarpa* Mart. ex Hayne IN DIFFERENT SUBSTRATES AND IRRIGATION RATES

Aline Santos Sousa [1]
Ricardo Santana do Carmo [2]
Esthefany Oliveira Torres [3]
Wesley Moura Lima [4]
Cristiane Matos da Silva [5]
Wilson Araújo da Silva[6]

ABSTRACT

Objective: The aim of this study was to evaluate the effect of different types of plant substrates and irrigation rates on the initial growth and quality of *Hymenaea stigonocarpa* (jatobá-do-cerrado) seedlings, with a view to optimising production practices in the state of Maranhão.

Theoretical Framework: The research is based on concepts of plant physiology and nursery management, considering the importance of substrates and irrigation in the development of seedlings of native species.

Method: Four types of substrate were tested (S1: 100% commercial; S2: commercial + sand; S3: sand + coconut fibre; S4: 100% coconut fibre) and three irrigation rates (L1: 100% of evapotranspiration; L2: 150%; L3: 200%). Plant height, neck diameter, fresh and dry mass of the aerial part and roots, as well as the Dickson index were evaluated.

Results and Discussion: The emergence rate was high (91.11%). Substrate S1 showed the best results in all variables, followed by S3. Among the leaf blades, L1 favoured height and aerial mass, while L3 had the best overall performance. The results highlight the significant influence of the variables tested on seedling development.

Research Implications: The findings help in the choice of substrates and irrigation strategies for efficient seedling production, contributing to reforestation and cerrado recovery projects.

Originality/Value: The research is relevant because it deals with a native species that has been little studied in Maranhão, offering data applicable to sustainable management in forest nurseries.

Keywords: Forest Seedlings, Irrigation Management, Cerrado, Seedling Production.

[1]Universidade Estadual da Região Tocantina do Maranhão, Imperatriz, Maranhão, Brazil.
E-mail: alinesousa.20200009792@uemasul.edu.br Orcid: https://orcid.org/0009-0000-2256-7356
[2] Universidade Estadual da Região Tocantina do Maranhão, Imperatriz, Maranhão, Brazil
E-mail: ricardocarmo.20200009952@uemasul.edu.br Orcid: https://orcid.org/0009-0000-0741-5944
[3] Universidade Estadual da Região Tocantina do Maranhão, Imperatriz, Maranhão, Brazil.
E-mail: esthefanytorres.20200003313@uemasul.edu.br Orcid: https://orcid.org/0009-0008-2761-9774
[4]Universidade Estadual da Região Tocantina do Maranhão, Imperatriz, Maranhão, Brazil.
E-mail: wesleylima.20200003378@uemasul.edu.br Orcid: https://orcid.org/0009-0009-5980-7312
[5] Universidade Estadual da Região Tocantina do Maranhão, Imperatriz, Maranhão, Brazil
E-mail: cristiane.silva@uemasul.edu.br Orcid: https://orcid.org/0000-0002-6416-4413
[6] Universidade Estadual da Região Tocantina do Maranhão, Imperatriz, Maranhão, Brazil.
E-mail: wilson@uemasul.edu.br Orcid: https://orcid.org/0000-0003-4549-6815

GERMINAÇÃO E DESENVOLVIMENTO INICIAL DE MUDAS *Hymenaea stigonocarpa* Mart. ex Hayne EM DIFERENTES SUBSTRATOS E LÂMINAS DE IRRIGAÇÃO

RESUMO

Objetivo: Este estudo teve como objetivo avaliar o efeito de diferentes tipos de substratos vegetais e lâminas de irrigação no crescimento inicial e na qualidade de mudas de *Hymenaea stigonocarpa* (jatobá-do-cerrado), visando otimizar práticas de produção no Estado do Maranhão.

Referencial Teórico: A pesquisa fundamenta-se em conceitos de fisiologia vegetal e manejo de viveiros, considerando a importância dos substratos e da irrigação no desenvolvimento de mudas de espécies nativas.

Método: Foram testados quatro tipos de substratos (S1: 100% comercial; S2: comercial + areia; S3: areia + fibra de coco; S4: 100% fibra de coco) e três lâminas de irrigação (L1: 100% da evapotranspiração; L2: 150%; L3: 200%). Avaliaram-se altura da planta, diâmetro do colo, massas fresca e seca da parte aérea e das raízes, além do índice de Dickson.

Resultados e Discussão: A taxa de emergência foi alta (91,11%). O substrato S1 apresentou os melhores resultados em todas as variáveis, seguido do S3. Entre as lâminas, L1 favoreceu altura e massa aérea, enquanto L3 teve melhor desempenho geral. Os resultados destacam a influência significativa das variáveis testadas no desenvolvimento das mudas.

Implicações da Pesquisa: Os achados auxiliam na escolha de substratos e estratégias de irrigação para produção eficiente de mudas, contribuindo para projetos de reflorestamento e recuperação do cerrado.

Originalidade/Valor: A pesquisa é relevante por abordar uma espécie nativa pouco estudada no Maranhão, oferecendo dados aplicáveis ao manejo sustentável em viveiros florestais.

Palavras-chave: Mudas Florestais, Manejo de Irrigação, Cerrado, Produção de Mudas.

GERMINACIÓN Y DESARROLLO INICIAL DE *Hymenaea stigonocarpa* Mart. ex Hayne EN DIFERENTES SUSTRATOS Y DOSIS DE RIEGO

RESUMEN

Objetivo: El objetivo de este estudio fue evaluar el efecto de diferentes tipos de sustratos vegetales y tasas de irrigación sobre el crecimiento inicial y la calidad de las plántulas de *Hymenaea stigonocarpa* (jatobá-do-cerrado), con vistas a optimizar las prácticas de producción en el estado de Maranhão.

Marco teórico: La investigación se basa en conceptos de fisiología vegetal y manejo de viveros, considerando la importancia de los sustratos y de la irrigación en el desarrollo de plántulas de especies nativas.

Método: Se ensayaron cuatro tipos de sustrato (S1: 100% comercial; S2: comercial + arena; S3: arena + fibra de coco; S4: 100% fibra de coco) y tres tasas de irrigación (L1: 100% de la evapotranspiración; L2: 150%; L3: 200%). Se evaluaron la altura de la planta, el diámetro del cuello, la masa fresca y seca de la parte aérea y las raíces, así como el índice de Dickson.

Resultados y discusión: La tasa de emergencia fue elevada (91,11%). El sustrato S1 mostró los mejores resultados en todas las variables, seguido de S3. Entre las láminas foliares, L1 favoreció la altura y la masa aérea, mientras que L3 tuvo el mejor rendimiento global. Los resultados ponen de manifiesto la influencia significativa de las variables ensayadas en el desarrollo de las plántulas.

Implicaciones de la investigación: Los resultados ayudan en la elección de sustratos y estrategias de riego para la producción eficiente de plántulas, contribuyendo a los proyectos de reforestación y recuperación del cerrado.

Originalidad/Valor: La investigación es relevante porque trata de una especie nativa poco estudiada en Maranhão, ofreciendo datos aplicables al manejo sostenible en viveros forestales.

Palabras clave: Plántulas Forestales, Manejo del Riego, Cerrado, Producción de Plántulas.

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1 INTRODUCTION

Hymenaea stigonocarpa Mart. ex Hayne , popularly known as jatobá-do-cerrado, is a heliophilic species, that is, it depends on high incidence of sunlight to grow and develop properly, in addition to having low tolerance to cold temperatures. This tree has a wide geographic distribution, occurring from southern Mexico to much of South America (Costa *et al.*, 2011). Its generic name, *Hymenaea* , comes from the Greek " hymen ", in reference to the god of marriage, alluding to the two paired leaflets that make up its leaves. According to the Cronquist classification system , the taxonomic position of the species is: Division: Magnoliophyta ; Class: Magnoliopsida ; Order: Fabales ; Family: Caesalpiniaceae ; Genus: *Hymenaea* ; Species: *H. stigonocarpa* Mart. ex Hayne (Carvalho, 2007).

In the central region of Brazil, the species is characteristic of the Cerrado biome, occurring especially in physiognomies such as cerradão and cerrado sensu stricto (Ribeiro and De Freitas, 2017). In Brazil, it can be found from Piauí to northern Paraná, reaching heights between 10 and 30 meters (Silva *et al.*, 2016). As for germination, its seeds present dormancy due to the integumentary impermeability to water and oxygen, making it necessary to overcome this barrier to enable seedling production (Ferreira *et al.*, 2021).

The Jatobá-do-Cerrado stands out for its economic value, being used both in the timber industry and in folk medicine. However, disorderly exploitation has led to the reduction of the species' natural populations (Gariglio *et al* ., 2010). Historically, Brazilian forests have been a primary source of wood for domestic consumption and export (Hoffmann *et al.*, 2011). Given this scenario, the production of native forest seedlings becomes essential, as Scalon points out. *et al.* (2011), mainly to meet the growing demand for environmental restoration projects.

H. stigonocarpa seedlings in different substrates, there are still significant gaps in the understanding of the combined effects between types of substrates and irrigation depths, especially in the context of the State of Maranhão. In this sense, this work aimed to evaluate the effects of different irrigation depths and types of substrates on the initial development of *H. stigonocarpa seedlings* . Aiming to contribute with relevant scientific data that guide adequate seedling production practices, promoting the conservation of the species and the success of reforestation programs, especially in the Tocantina region of Maranhão.

2 THEORETICAL FRAMEWORK

2.1 *Hymenaea* SEEDLINGS *stigonocarpa* (CERRADO JATOBA)

The production of seedlings of native species, such as the Jatobá-do-Cerrado (*Hymenaea stigonocarpa*), is a fundamental step for forest restoration, especially in the context of the requirements of Law 12.727, of October 17, 2012 — the Brazilian Forest Code — which reinforces the importance of ecological restoration (Marcuzzo , Vieira and Salin , 2020; Sampaio *et al* ., 2021). This species, with slow growth and large seeds, is part of the group of late secondary species (Carvalho, 2007), and presents epigeal germination , characterized by the elevation of the cotyledons above the ground, resulting from the elongation of the hypocotyl.

However, the propagation of Jatobá-do-Cerrado faces a significant obstacle: tegumentary dormancy, which hinders the absorption of water and oxygen by the seeds, becoming a limiting factor in seedling production, especially in legumes (Freitas *et al.*, 2013; Oliveira *et al.*, 2003). The choice of appropriate techniques to overcome dormancy depends on factors such as the species, type and degree of dormancy, in addition to the age of the seed and the time of collection (Santos *et al* ., 2013).

The production of forest species seedlings requires consistent technical and scientific foundations that consider the best conditions for germination and initial growth. This step is strategic for programs to regenerate degraded areas, especially in Brazil, which has millions of hectares compromised in various ecosystems (Bueno, 2020).

2.2 IRRIGATION SUBSTRATES AND DECKS

Among the main factors that influence the quality of seedlings in forest nurseries, the type and quality of the substrate stand out (Wendling *et al.*, 2002). The appropriate choice of substrate is essential, as it directly affects the development of the root system, the availability of nutrients and, consequently, the growth of the plant (Vale *et al* ., 2004; Oliveira *et al.*, 2012).

There is a wide variety of materials used as substrates — such as coconut fiber, sand, soil, sawdust, rice husk and vermiculite —, which requires comparative studies to understand their effects on different species and combinations (Blom, 1983; Chen *et al* ., 1988; Gabriels *et al.*, 1986). The combined use of these materials can be beneficial, as long as it provides ideal conditions for the formation of vigorous seedlings.

In addition to the substrate, irrigation is another determining factor for the success of seedling production. Correct application of water contributes to uniform seed germination, reduces labor and management costs, and prevents losses due to water stress (Martins *et al* ., 2012; Marcos Filho, 2005). The irrigation depth directly influences seedling growth and its efficiency depends on factors such as the species, size and growth habit of the plant, characteristics of the substrate, cultivation container and microclimate of the nursery (Monteiro *et al* ., 2016). In the case of forest species, the estimate of crop evapotranspiration (ETc), based on reference evapotranspiration (ETo) and crop coefficient (Kc), can be an efficient strategy to rationalize water use in seedling production (Carvalho *et al* ., 2011).

3 METHODOLOGY

The work he was accomplished in the greenhouse of the Science Center Agricultural University State of the Region Tocantina do Maranhão CCA/UEMASUL, with coordinates (5°33' 45”S and 47°27' 18”W), which presents area of approximately 140.00 m² covered with a shade screen with 50% shading , from December 2023 to March 2024 , as per presented in the Figure 1.

Figure 1

Greenhouse used to conduct the experiment .



During the experiment, maximum and minimum temperatures were monitored. minimums and relative humidity, using a digital hygrograph for this purpose. The seeds of *H. stigonorcarpa* , acquired of producers specialized, passed put process of scarification with sandpaper and were disinfected by immersion in sodium hypochlorite solution at a concentration of 2% for 3 minutes. Then 2 seeds were planted inpolyethylene pots with a volume of 1.7 liters containing different types of plant substrate, totaling 90 seeds .

The experimental design was in a factorial scheme composed of two factors with 3 levels each and 5 repetitions (3x3x5), totaling 45 experimental units. Factor 1 consisted of 3 different types of substrate, namely: S1 = 100% commercial substrate; S2 = 50% clayey soil + 50% palm bark; S3 = 50% washed sand + 50% palm bark. Factor 2 consisted of three different irrigation depths, being: L1 = 100% of ET0; L2 = 150% of ET0 and L3 = 200% of ET0. The irrigation depths were calculated using Equation 1, presented below :

$$ETC = ET0 * Kc \quad (1)$$

where :

ETC= crop evapotranspiration (mm.day-¹)
ET0 = evapotranspiration of the reference crop (mm.day-¹)
Kc = crop coefficient (admensional)

In this study, the Jatobá crop coefficient (Kc) of 0.55 was adopted, according to (Silva *et al.*, 2017). At the beginning of each month, the slides were updated, according to the monthly average of ETo shown in Table 1, the reference months used were from December to March.

Table 1

Average of ET0 from 2005-2018 in Imperatriz – MA (mm.day-¹).

Jan	Feb	Sea	Apr	May	June	Jul	Aug	Set	Out	Nov	Ten
4.42	4.18	4.44	4.46	5.03	5.53	6.73	7.9	8.86	7.32	5.26	4.41
					Average = 5.71						

Source: SANTANA, JS *et al.* Irrigation diagnosis in the family farming of Imperatriz - MA. Rev. Sustinere , Rio de Janeiro, v. 8, n. 2, p. 515-538, Jul-Dec , 2020b.

Before planting, the pots were irrigated until the substrate moisture reached field capacity. After this stage, the corresponding levels of factor 2 were applied daily, based on the evapotranspiration of the reference crop (ET 0). The average temperatures and average relative humidity values were monitored during the execution of the experiment using a digital hygrograph. The seeds were planted in the pots to monitor the germination percentage, emergence speed index, average germination time, average germination speed, germination synchrony and evaluation of the morphological parameters of seedling growth (number of leaves, plant height, collar diameter, fresh mass of the aerial part, dry mass of the root, dry mass of the aerial part and Dickson quality index). As shown in Figures 2 and 3:

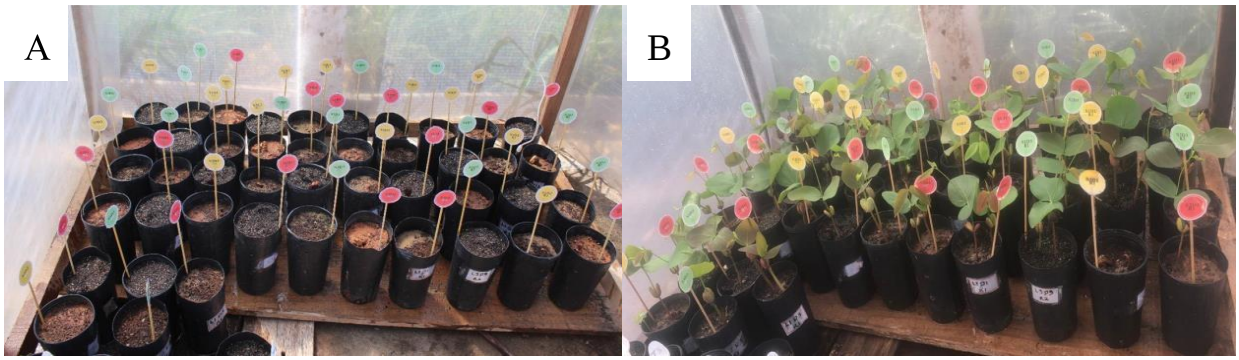
Figure 2

Characteristics of substrate types



Figure 3

Arrangement of pots in the greenhouse . (A) Planting of seeds ; (B) Development of seedlings



To obtain the response variables, seed germination and seedling growth were monitored daily for 100 days, recording the number of seeds germinated per day in each treatment for a period of 30 days after the first germination, thus allowing to obtain the germination percentage and the emergence speed index, according to Equations 2, 3, 4, 5 and 6 presented below :

$$G = \frac{N}{A} * 100 \qquad (2)$$

where:

N = number of seeds germinated at the end of the test

A= total sample number

Unit = %

$$IVG = \frac{ni}{ti} \qquad (3)$$

where:

ni = number of seeds germinated in time "I"

ti = time after test installation ;

i = 1 → x days . Unit : dimensionless .

$$TMG = \frac{\sum ni/ti}{\sum ni} \qquad (4)$$

where:

ni = number of seeds germinated in time "I"

ti = time after test installation ;

i = 1 → x days . Unit : dimensionless .

$$VMG = \frac{1}{T} \qquad (5)$$

where:

ni = number of seeds germinated in time "I"

ti = time after test installation

i = 1 → x days . Unit : dimensionless .

$$Z = \sum C\ ni * \frac{2}{n} \qquad (6)$$

where:

ni = number of seeds germinated in time "I"

ti = time after test installation ;

i = 1 → x days . Unit : dimensionless .

To study the effects of different plant substrates and irrigation levels on the initial growth of seedlings, the following morphological characteristics were measured: number of leaves, plant height, collar diameter, fresh root mass (MFR), fresh shoot mass (MFPA), root dry mass (MSR) and shoot dry mass (MSPA), total dry mass (MST) and Dickson quality index (IDQ) in each treatment. The number of leaves was obtained by direct counting, using a pen and field clipboard, the plant height was measured using a metal tape measure and the collar diameter was obtained with a digital caliper. Fresh Root Mass (MFR) and Fresh Shoot Mass (MFPA) were weighed on an analytical balance with a precision of 0.0001 g, immediately after

separation between these parts, using a scalpel; Root Dry Mass (RSM) and Shoot Dry Mass (SPM) obtained on a precision scale after constant weight in a forced circulation oven at a temperature of 60° C. Total Dry Mass (TSM) in grams corresponds to the sum of RSM + SPM. Dickson's quality index (QDI) calculated according to Equation 7 proposed by Dickson *et al.* (1960) apud Goulart *et al.* (2017) is presented below:

$$IDQ = \frac{MST(g)}{\frac{H(cm)}{DC(mm)} + \frac{MSPA(g)}{MSR(g)}} \qquad (7)$$

where:

ni = number of seeds germinated in time "I"

ti = time after test installation ;

i = 1 → x days . Unit : dimensionless .

The values of the means obtained from the morphological characteristic response variables as a function of the variations caused by the different plant substrates and different irrigation depths and their possible interactions were subjected to normality tests and analysis of variance and, if significant, paired mean studies were carried out using the Tukey test at 5% probability (P≤5%), using the ASSISTAT 7.7 computational package.

4 RESULTS AND DISCUSSIONS

You results showed that they did not there was differences statistics significant for the different types of substrates on the speed of seed germination . The emergence of jatobá seedlings had start to the tenth day and extended to 30 days after sowing , reaching a total of 91.11% emergence with 82 seeds germinated from 90. In an environment with an average temperature between 25 °C and 31 °C the wound daily with digital thermo-hygrograph . It was possible check Germination (G), Germination Speed Index (GSI), Mean Germination Time (MTG) , Speed mean germination rate (VMG), and germination synchrony (Z) (Table 2) .

Table 2

Results of Germination Rate (G), Germination Speed Index (GSI), Mean Germination Time (MTT) , Speed mean germination rate (VMG) and germination synchrony (Z) after 30 days under different types of substrates

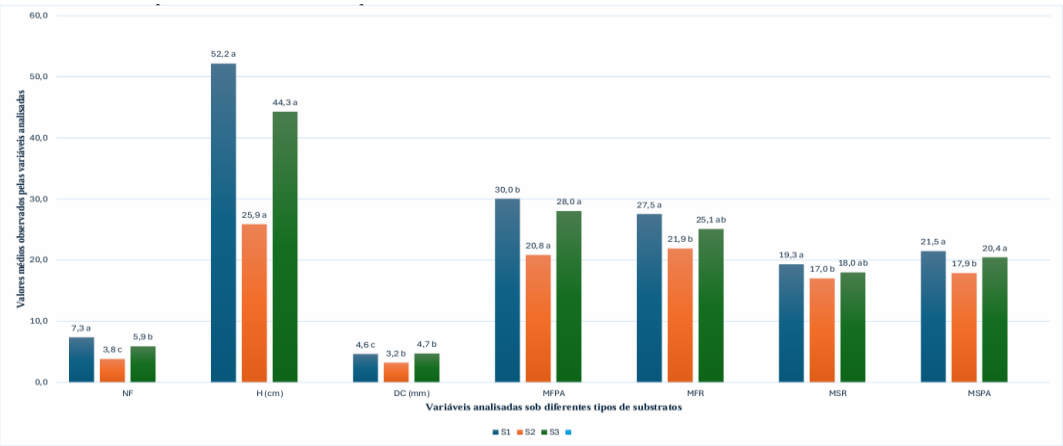
Treatments	G	IVG (dimensionless)	TMG (days)	VMG (seeds.day-1)	Z (dimensionless)
S1	90%	1.82	15.10	0.066	0.016
S2	90%	1.84	15.04	0.067	0.014
S3	93.33%	2.00	14.78	0.068	0.011
GENERAL	91.11%	5.66	4.10	0.244	0.126

Legend: S1 = 100% commercial substrate; S2 = 50% clay soil + 50% palm bark; S3 = 50% washed sand + 50% palm bark.

You results of Analysis of Variance (ANOVA) and means test paired by Tukey's test (5% probability) (H), (DC), (MFR), (MFPA), (MSR), (MSPA) and Dickson quality index (Figure 4 and Figure 5). No presented interaction between the factors F1 (soil types) and F2 (water depths) , as well he was accomplished analysis of each factor separately using means test paired , to check if the interaction between the factors .

Figure 4

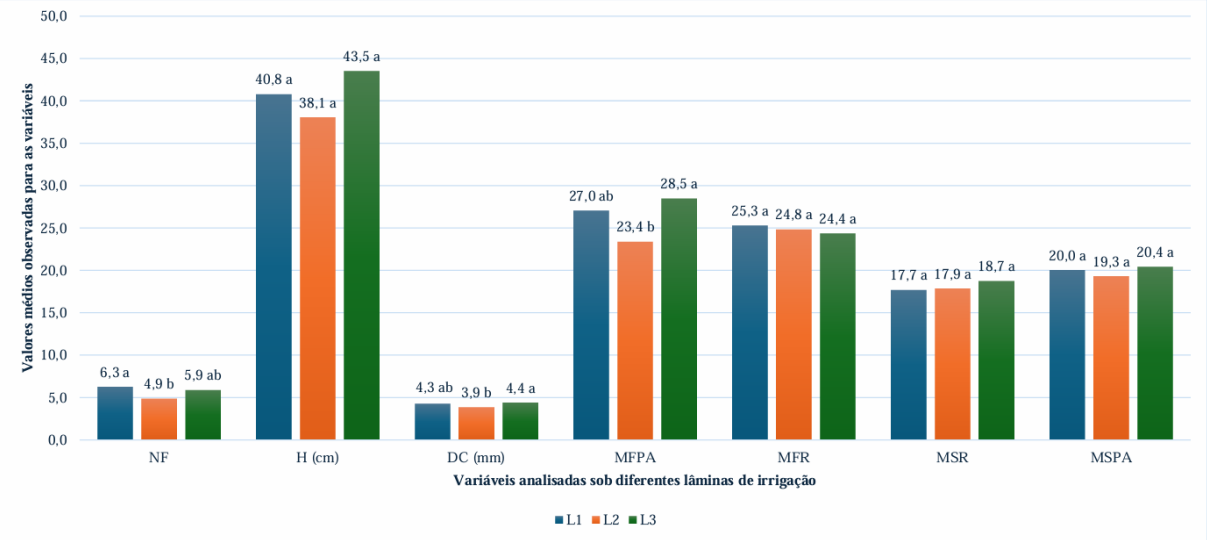
Average values observed for the variables number of leaves (NF), height (H) (in cm), diameter of collect (DC) (in mm), fresh mass of the part aerial mass (MFPA) (in g), fresh root mass (MFR) (in g), fresh dry part aerial (MSPA) (in g), mass dry mass of roots (MSR) (in g) and total drought (MST) (in g) of Jatobá seedlings in response to the different types of substrates.



Legend: S1 = 100% commercial substrate; S2 = 50% clay soil + 50% palm bark; S3 = 50% washed sand + 50% palm bark. Means followed by the same letter in the column do not differ from each other by Turkey 's test at 5% significance .* : significant (P<0.05)

Figure 5

Average values observed for the variables number of leaves (NF), height (H) (in cm), diameter of collect (DC) (in mm), fresh mass of the part aerial mass (MFPA) (in g), fresh root mass (MFR) (in g), fresh dry part aerial (MSPA) (in g), mass dry mass of roots (MSR) (in g) and total drought (MST) (in g) of Jatobá seedlings in response to the different types of substrates.



Legend: L1 = 100% of ET0; L2 = 150% of ET0 and L3 = 200% of ET0. Means followed by the same letter in the column do not differ from each other by Turkey 's test at 5% significance .* : significant (P<0.05)

You results presented in the Table 2 indicates that Jatobá seeds exhibited a high germination rate , which may be associated with temperature variation inside the greenhouse . The seeds respond the these variations due to the mechanisms enzymatic agents that act in different temperatures . According to Da Silva (2021), this feature probably reflects adaptations ecological of the species to the environment . In addition from this , it was observed that the substrate S2 (50% clay soil + 50% palm bark) also presented one response effective in the Germination variables (G), Germination Speed Index (IVG), Average Germination Time (TMG) , Speed Average Germination Rate (VMG) and Germination Synchrony (Z). This highlights the importance of the type of substrate , which can influence significantly improve the quality of the seedlings (Bueno, 2020).

You results obtained in the Figures 4 and 5 reveal differences significant among the substrates and irrigation sheets as to the development of Jatobá seedlings . Analysis of Variance (ANOVA) and the mean test paired by the Tukey test (with 5% probability) for the variables (H), (DC), (MFR), (MFPA), (MSR), (MSPA) and Dickson quality index not revealed interaction significant among the factors F1 (substrate types) and F2 (irrigation depths) . Demonstrating that the absence of interaction between these factors indicates that the impact of

each can be considered independently . This suggests that both types of substrates as for the irrigation blades can be optimized separately to achieve best results in the variables analyzed .

It was observed that the S1 substrates (100% substrate commercial) and S3 (50% sand washed + 50 % palm bark) presented averages significantly largest number of leaves in compared to substrate S2 (50% clay soil + 50% palm bark) . Campello, Chaer and De Resende (2021) highlight that the leaves they are essential for photosynthesis and for adaptation of seedlings after planting , making the evaluation of this variable crucial. The smallest number of leaves on substrate S2 can be related to soil compaction and conditions environmental , such as temperature and luminosity , which can to have impaired plant growth . On the other hand , compaction he can limit the root expansion and oxygen availability , affecting directly the development of leaves (Câmara and Endres, 2008).

You substrates S1 and S3 showed collector diameters significantly greater than S2 . These results they are aligned with studies previous ones indicating that substrates with sand and palm fiber provide better drainage and soil aeration , favoring plant growth (Jeronimi , 2020; Gonzaga et al ., 2016). The addition of palm fiber and sand to the ground improves the substrate structure , promoting growth more robust seedlings .

THE plant height he was significantly bigger us substrates S1 and S3 in comparison with S2. The plant height is an important development indicator (Santos *et al.,* 2023) , and the use of substrates with good aeration and water retention , such as commercial and compost put sand and coconut fiber , resulted in seedlings more vigorous (Monteiro, 2022). Mendes *et al.* (2015) observed that sandy soils they can have lower growth compared to clay soils , but the present study it found best results in substrates sandy mixed with palm fiber .

The substrate commercial and the mixture of sand with palm fiber provided bigger averages for fresh and dry mass of the part aerial and roots . The matter organic present in these substrates improve the soil structure , water retention and nutrient availability , resulting in better seedling development (De Queiroz *et al., 2022; Vieira and Casali,* 1997 ; Almeida and Silva, 2018). However , substrate S2 , with high proportion of clay , can to have presented minor performance due to its minor drainage capacity and greater compression .

The irrigation blades presented variations significant , with 200% of ET0 (L3) and 100% of ET0 (L1) showing best results . The water application in excess or insufficient he can affect the quality of the seedlings and the resource efficiency water . The choice of irrigation blade must be adjusted to avoid waste and reduce the costs associated with water and labor (Silva et al . , 2017).

No there was interaction significant among the factors , but at compare you treatments in isolation , the substrates S1 and S3 showed best quality indices , with S1 getting the best performance . The IQD is an indicator important of the quality of the seedlings , and the substrate commercial provided the best conditions for the development of Jatobá seedlings (Matos, 2023).

It is imperative highlight although , the results highlight the importance of the substrate and irrigation depth in the development of H. *stigonocarpa* seedlings . The substrate commercial and the mixture of sand with palm fiber they were you more effective , while the substrate with high clay proportion presented limitations significant . The choice adequate irrigation blade also plays a crucial role in resource optimization water and in the quality of seedlings .

5 CONCLUSION

No they were found differences statistically significant among the different types of substrates in terms of respect to germination . The high seedling emergence rate (91.11 %) suggests that the species *H. Stigonocarpa* adapts good to the temperature variations , indicating a good germination capacity in different conditions .

The S1 substrate (100% substrate commercial) presented averages superior for all variables evaluated , including (H), (DC), (MFPA), (MFR), (MSPA), (MSR) and (MST), in addition to the Dickson Quality Index (DQI) . This demonstrates the influence positive of the substrate commercial in root development and part aerial of the seedlings .

Substrate S3 (50% sand) washed + 50 % palm bark) presented results similar to those of S1 for the variables studied , evidencing the effectiveness of the mixture in provide good aeration and improve root development and nutrient uptake by the plants .

Substrate S2 (50% clay soil + 50 % palm bark) showed underperformance in comparison with the substrates S1 and S3. The compaction soil potential and low nutrient availability they can to have contributed to the growth reduced seedlings .

Among the irrigation depths , the L1 dose (100% of ET0) presented results satisfactory for (H), (MFPA) and (MSPA). The L3 dose (200% of ET0) had an effect positive in (H) , (DC), (MFPA), (MSPA) and (MST), promoting greater accumulation of biomass and contributing significantly for the growth and development of seedlings .

With that , this study highlighted the importance of both the choice of substrate as for management adequate irrigation to optimize the development of H. *Stigonocarpa* seedlings ,

suggesting *that* both the substrate as for the irrigation blades must be chosen and adjusted carefully to maximize growth efficiency and seedling quality .

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