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EFEITO DO ESTRESSE HÍDRICO NO DESENVOLVIMENTO INICIAL DE *Inga marginata* WILLDENOW

EFFECT OF WATER STRESS ON THE EARLY DEVELOPMENT OF *Inga marginata* WILLDENOW

EFECTO DEL ESTRÉS HÍDRICO EN EL DESARROLLO INICIAL DE *Inga marginata* WILLDENOW

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Resumo

Inga marginata Willd. (Fabaceae), popularmente conhecida como ingá-feijão, é uma espécie arbórea nativa do Brasil, amplamente distribuída em todo o território nacional. Compreender sua resposta à restrição hídrica durante o desenvolvimento inicial é essencial para a produção de mudas e a restauração ecológica. Este estudo avaliou o crescimento inicial de mudas de *I. marginata* submetidas a diferentes regimes de rega. Trinta mudas foram cultivadas em sacos plásticos de 1,5 L e distribuídas em três tratamentos de acordo com o fornecimento de água: T1, três regas de 200 mL planta^{-1} dia^{-1}; T2, uma rega de 200 mL planta^{-1} dia^{-1}; e T3, uma rega de 200 mL planta^{-1} a cada 48 h. O experimento teve duração de 30 dias, durante os quais foram mensuradas a altura, o diâmetro da base do caule e o número de folhas para o cálculo do crescimento absoluto. Ao final do experimento, a biomassa seca foi determinada e a qualidade das mudas foi avaliada por meio do

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Índice de Qualidade de Dickson. As mudas regadas diariamente (T1 e T2) apresentaram maior incremento em altura e maior massa seca foliar em comparação àquelas irrigadas a cada 48 h (T3). Não foi observada mortalidade em nenhum dos tratamentos. Os resultados indicam que as mudas de *I. marginata* apresentam tolerância inicial ao déficit hídrico moderado, em parte por meio da redução na produção de folhas, o que é relevante para o manejo em viveiros e programas de restauração.

Palavras-chave: déficit hídrico; espécie arbórea nativa; qualidade de mudas; ingá-feijão.

Abstract

Inga marginata Willd. (Fabaceae), commonly known as ingá-feijão, is a native Brazilian tree species widely distributed across the country. Understanding its response to water limitation during early development is essential for seedling production and ecological restoration. This study evaluated the initial growth of *I. marginata* seedlings subjected to different irrigation regimes. Thirty seedlings were cultivated in 1.5-L plastic bags and assigned to three treatments according to water availability: T1, three irrigations of 200 mL plant^{-1} day^{-1}; T2, one irrigation of 200 mL plant^{-1} day^{-1}; and T3, one irrigation of 200 mL plant^{-1} every 48 h. The experiment lasted 30 days, during which height, stem base diameter, and number of leaves were measured to calculate absolute growth. At harvest, dry biomass was determined and seedling quality was assessed using the Dickson Quality Index. Seedlings irrigated daily (T1 and T2) showed greater height increment and leaf dry mass than those irrigated every 48 h (T3). No mortality was observed in any treatment. The results indicate that *I. marginata* seedlings exhibit initial tolerance to moderate water deficit, partly through reductions in leaf production, which is relevant for nursery management and restoration programs.

Keywords: water deficit; native tree species; seedling quality; ingá-feijão.

Resumen

Inga marginata Willd. (Fabaceae), comúnmente conocida como ingá-feijão, es una especie arbórea nativa de Brasil, ampliamente distribuida en todo el territorio nacional. Comprender su respuesta a la limitación hídrica durante el desarrollo inicial es esencial para la producción de plántulas y la restauración ecológica. Este estudio evaluó el crecimiento inicial de plántulas de *I. marginata* sometidas a diferentes regímenes de riego. Treinta plántulas se cultivaron en bolsas plásticas de 1,5 L y se asignaron a tres tratamientos según la disponibilidad de agua: T1, tres riegos de 200 mL planta^{-1} día^{-1}; T2, un riego de 200 mL planta^{-1} día^{-1}; y T3, un riego de 200 mL planta^{-1} cada 48 h. El experimento tuvo una duración de 30 días, durante los cuales se midieron la altura, el diámetro basal del tallo y el número de hojas para el cálculo del crecimiento absoluto. Al final del experimento, se determinó la biomasa seca y la calidad de las plántulas se evaluó mediante el Índice de Calidad de Dickson. Las plántulas irrigadas diariamente (T1 y T2) mostraron un mayor incremento en altura y mayor masa seca foliar en comparación con aquellas irrigadas cada 48 h (T3). No se observó mortalidad en ninguno de los tratamientos. Los resultados indican que las plántulas de *I. marginata* presentan una tolerancia inicial al déficit hídrico moderado, en parte mediante la reducción en la producción de hojas, lo cual es relevante para el manejo en viveros y los programas de restauración.

Palabras clave: déficit hídrico; especie arbórea nativa; calidad de plántulas; ingá-feijão..

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1. Introduction

Inga marginata Willd. (Fabaceae), popularly known as “ingá-bainha”, “ingá-feijão”, and “ingá-peludo”, is a tree species that can reach up to 20 m in height and occurs naturally throughout most of the Brazilian territory (Carvalho, 2006). The species presents compound, paripinnate leaves and produces indehiscent legumes containing seeds surrounded by an edible pulp (Carvalho, 2006). Due to its wide ecological amplitude, *I. marginata* is capable of growing in soils with different textures and drainage conditions, including acidic and poorly drained soils (Carvalho, 2006), which makes it suitable for reforestation and restoration initiatives (Fonseca et al., 2016).

In addition to its ecological relevance, *I. marginata* has been reported to contain bioactive compounds with antioxidant capacity in its bark, pulp, and seeds (Flores, 2020), and it serves as a food resource for several animal species, especially birds (Antunes et al., 2019). These characteristics reinforce the importance of the species for biodiversity conservation and ecosystem functioning, as it establishes well, promotes biodiversity, and contributes to ecological balance (Fonseca et al., 2016), possibly due to its resilience under stress conditions.

Plant stress occurs when environmental conditions deviate substantially from the optimum required for growth and water availability is among environmental factors most limiting (Larcher, 2000). Water deficit occurs when water supply does not meet plant demand, triggering morphological and physiological adjustments that may reduce growth and biomass accumulation (Santos & Carlesso, 1998). Understanding species-specific responses to water limitation is therefore essential for defining irrigation practices in nurseries and for predicting plant performance in restoration areas subjected to irregular rainfall.

Despite the wide distribution of *I. marginata*, information on its response to water deficit during the early seedling stage remains limited. Thus, this study aimed to evaluate the initial growth and quality of *I. marginata* seedlings subjected to different irrigation regimes, focusing on morphological traits and biomass allocation.

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2. Methodology

The experiment was conducted in September 2025 in Ivinhema, Mato Grosso do Sul, Brazil. Thirty Inga marginata seedlings were grown individually in 1.5-L plastic bags filled with a soil-based substrate classified as a dystrophic Red Latosol with medium texture and maintained outdoors under full sunlight. Each irrigation treatment was applied to an independent and randomly assigned set of 10 seedlings, with each seedling considered an experimental unit and an independent replicate. Therefore, inferences are restricted to comparisons among irrigation treatments under the specific experimental conditions tested.

Three irrigation regimes were applied using 200 mL of water per plant at different frequencies: T1, three irrigations per day (07:00, 12:00, and 17:00), totaling 600 mL plant^{-1} day^{-1}; T2, one irrigation per day (12:00), totaling 200 mL plant^{-1} day^{-1}; and T3, one irrigation every 48 h (12:00), corresponding to an average of 100 mL plant^{-1} day^{-1}. Irrigation volumes were fixed per event and applied uniformly to all plants within each treatment; however, substrate water content was not directly measured during the experimental period. These regimes were designed to simulate common nursery irrigation practices.

Seedling height, stem base diameter, and number of leaves were measured at the beginning and end of the 30-day experimental period. Absolute growth was calculated as the difference between final and initial measurements. At the end of the experiment, five seedlings per irrigation treatment were randomly selected and taken to the laboratory at the State University of Mato Grosso do Sul – Ivinhema Unit for biomass determination. This subsampling was adopted due to logistical constraints associated with sample processing and drying capacity and aimed to provide an exploratory assessment of biomass allocation patterns during early development. Seedlings were separated into roots, stems, and leaves and oven-dried at 105 °C for 24 h, as no subsequent chemical analyses were performed.

Seedling quality was evaluated using the Dickson Quality Index - DQI (Dickson et al., 1960):

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$$DQI = \frac{Total\ dry\ mass\ (g)}{\frac{Height(cm)}{Stem\ diameter(mm)} + \frac{Shoot\ dry\ mass(g)}{Root\ dry\ mass(g)}}$$

Data were tested for normality using the Lilliefors test and analyzed by ANOVA or Kruskal–Wallis tests, followed by Tukey's or Dunn's tests, respectively, using BioEstat 5.0 software (Ayres et al., 2007). Statistical significance was set at $p \leq 0.05$.

3. Results and Discussion

All seedlings survived throughout the experimental period. No significant differences were observed among treatments for the evaluated parameters at the beginning of the experiment. Seedlings irrigated at least once per day (T1 and T2) showed significantly greater height increment than those irrigated every 48 h (T3) ($F = 8.3507$; $p = 0.0018$), whereas stem diameter increment did not differ among treatments ($H = 1.6218$; $p = 0.4445$). Leaf number increment also did not differ significantly among irrigation treatments ($p > 0.05$), indicating that variations in irrigation frequency did not substantially affect leaf production during the 30-day evaluation period (Table 1).

Table 1. Mean absolute growth (final measurement – initial measurement) of *I. marginata* seedlings under different irrigation regimes.

Parameter	Treatment 1	Treatment 2	Treatment 3
Height (cm)	9.5 a	9.2 a	2.2 b
Diameter (mm)	1.15 a	0.93 a	0.78 a
Leaves (nº)	1.4 a	1.3 a	0.7 a

Means followed by the same letter do not differ significantly ($p > 0.05$).

Plant responses to water limitation occur at multiple organizational levels, ranging from molecular regulation to whole-plant growth adjustments. As discussed by Chaves et al. (2003), reductions in water availability often lead to early changes in leaf expansion and biomass allocation as adaptive responses aimed at limiting water loss and maintaining plant function. In this context, the reduced growth observed under lower irrigation frequency in the present study may reflect short-

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term morphological adjustments during early seedling development, rather than severe stress responses.

Dry biomass accumulation varied among irrigation treatments, with significant differences observed only for leaf dry mass (Table 2) (H = 6.08; p = 0.0478). Leaf dry mass was higher in seedlings irrigated once per day (T2) compared to those irrigated every 48 h (T3). Dry matter production and the Dickson Quality Index are considered reliable indicators of seedling quality for field establishment (Gomes & Paiva, 2011).

Table 2: Dry mass and Dickson Quality Index (DQI) of *I. marginata* seedlings after 30 days.

	Treatment 1	Treatment 2	Treatment 3
Root (g)	2.633 a	2.675 a	1.681 a
Stem (g)	1.466 a	1.714 a	0.855 a
Leaf (g)	3.168 a	4.630 a	1.716 b
DQI	0.78 a	0.80 a	0.40 a

Means followed by the same letter do not differ significantly (p > 0.05).

The interpretation of seedling performance based on morphological attributes and integrated quality indices is supported by evidence from other forest species. Guimarães et al. (2024) demonstrated that traits such as height, stem diameter, biomass allocation, and the Dickson Quality Index are closely associated with early field performance of native tree species, highlighting the predictive value of nursery-measured attributes for seedling establishment. In this context, the higher DQI values observed under daily irrigation, combined with greater leaf biomass accumulation, indicate superior seedling quality, even in the absence of statistically significant differences among treatments.

Reduced leaf biomass under lower irrigation frequency suggest a morphological adjustment aimed at limiting transpiration under water deficit conditions, as commonly reported for plants subjected to limited water availability (Santos & Carlesso, 1998). Studies on other *Inga* species have also demonstrated that water availability plays a key role in seedling development and biomass accumulation (Silvério et al., 2025).

Similarly, Barella et al. (2025) reported reductions in both fresh and dry biomass in *Eugenia uniflora* under water deficit, while Morales et al. (2015)

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demonstrated that tomato plants subjected to limited water availability exhibited reduced height, stem diameter, and dry mass, corroborating the growth reduction pattern observed in the present study.

Reductions in irrigation frequency, even when total water input is not directly quantified at the substrate level, may influence plant growth by affecting key physiological processes such as stomatal regulation and photosynthetic carbon assimilation. According to Flexas and Medrano (2002), water limitation in C_3 plants leads to stomatal closure and progressive limitations to photosynthesis, resulting in reduced carbon gain and growth. This physiological framework provides a mechanistic basis for interpreting the lower leaf biomass accumulation observed under reduced irrigation frequency in the present study.

In contrast, Delgado, Silva, and Silva (2017) reported that increased irrigation volumes did not lead to greater shoot height in *Inga vera* Willd. subsp. *affinis* (DC.) T.D. Penn. The authors attributed this response to enhanced nutrient leaching under higher water inputs, given the pioneer nature of the species and its high nutritional demand. Additionally, they observed superior seedling height when irrigation was applied in two daily events rather than four, likely because more frequent applications resulted in superficial wetting of the substrate. Based on these findings, the authors recommended an irrigation regime consisting of a 10 mm water layer applied twice daily, which produced seedlings of greater growth and quality while reducing water use by approximately 29% compared with a 14 mm layer.

These findings highlight that seedling responses to irrigation regimes may vary among species. Even under lower irrigation frequency/volume, *I. marginata* exhibited growth, indicating its capacity to respond and efficiently utilize water in physiological processes. The species also exhibited physiological plasticity under flood stress, with adaptive adjustments that enabled survival under adverse conditions (Bender et al., 2012).

4. Conclusion

Under the conditions evaluated, irrigation frequency influenced early growth and leaf biomass of *Inga marginata* seedlings over a 30-day period. Daily irrigation

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promoted greater height increment e foliar biomass, whereas irrigation every 48h resulted in reduced growth. Despite these differences, there were indications of maintained seedling survival and growth under reduced irrigation frequency over the 30-day nursery development period. These results should be interpreted as preliminary and restricted to short-term responses under nursery conditions and may inform future studies aimed at optimizing irrigation practices for the production of *I. marginata* seedlings used in restoration and reforestation programs.

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