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CIÊNCIA e NATURA

ISSN 2179-460X
OPEN ACCESS

Ci. e Nat., Santa Maria, v. 48, e91499, 2026 • https://doi.org/10.5902/2179460X91499
Submitted: 10/04/2025 • Approved: 12/14/2025 • Published: 10/13/2026

Botanical-Biology

Evaluation of hydrogel use on the initial development of *Anadenanthera colubrina (Vell.) Brenan*, a native tree species of Caatinga

Avaliação do uso de hidrogel no desenvolvimento inicial de *Anadenanthera colubrina (Vell.) Brenan*, espécie arbórea nativa da Caatinga

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ABSTRACT

Planting hydrogel (potassium polyacrylate) is a compound that retains moisture in the soil and gradually makes it available to plants, reducing water loss in situations of water scarcity. In this study, the effect of planting hydrogel on the production of angico (*Anadenanthera colubrina*) seedlings was evaluated. The substrate was prepared with Acqua Gel for Planting (Danson Technology®) in three different proportions of hydrogel(g)/substrate (kg) per treatment: H0 = without hydrogel, H1 = with 0.625 g/kg, and H2 = with 2.5 g/kg. The hydrogel was incorporated into the dry substrate, being hydrated for the first time only on the day of sowing, and subjected to two irrigation frequencies, once or twice a week. After 32 days, no seedlings died, showing good tolerance to the hydrogel at low doses. The H0 and H1 doses provided better development of the aerial part of the seedlings, while the H1 and H2 doses contributed to the greatest benefit of the root area. The seedlings subjected to different irrigation frequencies did not present significant differences. The best dose was the H1 treatment, which provided better results in three aspects of the newly germinated *Anadenanthera colubrina* seedlings. The tolerance to hydrogel, the increase in the initial development of the angico seedlings and the practicality of irrigation demonstrate that planting hydrogel is an agricultural technology that has great potential to strengthen the production of native seedlings for reforestation of the Caatinga.

Keywords: Semi-arid; Seedling development; Water-absorbent polymer; Water deficit

RESUMO

O hidrogel (poliacrilato de potássio) é um composto que retém a umidade no solo e a disponibiliza gradualmente às plantas atenuando a perda de água em situações de escassez hídrica. Neste estudo, avaliou-se o efeito do hidrogel de plantio na produção de mudas de *Anadenanthera colubrina* (angico). O

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substrato foi preparado com Acqua Gel para Plantio (Danson Technology®) em três proporções diferentes de hidrogel(g)/substrato(kg) por tratamento: H0 = sem hidrogel, H1 = com 0,625g/kg, e H2 = recebeu 2,5g/kg. O hidrogel foi incorporado ao substrato seco, sendo hidratado pela primeira vez somente no dia da semeadura, e submetido a duas frequências de irrigação, uma vez ou duas por semana. Após 32 dias não foi observada mortalidade nas mudas, havendo boa tolerância ao hidrogel em baixas dosagens. As dosagens de H0 e H1 proporcionaram melhor desenvolvimento da parte aérea das mudas, enquanto as dosagens de H1 e H2 contribuíram para o maior benefício da área radicular. As mudas submetidas a diferentes frequências de irrigação não apresentam diferenças. A melhor dosagem foi o tratamento H1, que proporcionou os melhores resultados em três aspectos das mudas de *Anadenanthera colubrina*. Com boa tolerância ao hidrogel, algum incremento no desenvolvimento inicial das mudas de angico, e a praticidade na irrigação demonstram que o hidrogel é uma tecnologia agrícola que tem grande potencial de fortalecer a produção de mudas nativas para o reflorestamento da Caatinga.

Palavras-chave:: Semiárido; Desenvolvimento de mudas; polímero hidroabsorvente; Déficit hídrico

1 INTRODUCTION

The Caatinga Biome has been suffering unbridled degradation, given the lack of understanding of its importance (Tabarelli *et al*., 2018), resulting in the extinction of endemic species of flora and fauna. The intensification of Global Warming is speeding up the degradation of such already fragile biome (Tabarelli *et al*., 2017). Given this scenario, reforestation stands out as an important action to address the accelerated decline of the Caatinga (Justino *et al*., 2025).

One of the main challenges of reforestation in the Caatinga, or semi-arid region, is due to its main characteristic: the low amount of rainfall during long months of drought. This prolonged lack of water damages the natural vegetation and any agricultural production that is attempted to be established.

One solution found in agricultural production is the use of planting hydrogels into the soil to mitigate the rapid loss of water from the roots (Ma *et al*., 2023). There is great potential in the use of planting hydrogels also in the production of native tree seedlings under environmental conditions of the semi-arid region itself, strengthening and speeding up this reforestation process (Da Silva *et al*., 2021). The production of viable seedlings would allow the production of seedlings already acclimated to the Caatinga and close to the planting sites even during periods of drought.

For decades, farmers in semi-arid regions have been using superabsorbent polymers, better known as planting hydrogel, to increase the resilience of their crops during periods of drought (Freitas *et al*., 2002., Monteiro Neto *et al*., 2017). In the same way that it works in agricultural production, this polymer can be an alternative to help reforestation, especially in adverse irrigation conditions (Da Silva *et al*., 2021).

Initiatives using planting hydrogel in the recovery of the Caatinga are mainly linked to the in loco recovery of semi-arid biomes (Silva *et al*., 2014., Da Silva *et al*., 2021., De Macedo *et al*., 2024). Despite its potential in the production of seedlings of any type of plant, only a few recent studies applied to the development of native Caatinga species were found (Antas *et al*., 2024., Silverio *et al*., 2024).

The native tree species chosen to test the effects of the planting gel on seedling development was the *Anadenanthera colubrina* (Fabaceae). This species is resistant to nutrient-poor soils and easily adapts to extreme environmental conditions, in addition to rapid growth (Leite, 2016). These characteristics make it a good candidate to make up for the species used in reforestation of the Caatinga (Brazildry, 2016).

Thus, the aim of the present work was to evaluate the influence of planting hydrogel under different irrigation regimes on the production of angico (*Anadenanthera colubrina*) seedlings under the environmental conditions of the Caatinga.

2 LITERATURE REVIEW

2.1 The use of native species in the reforestation of degraded areas of the Caatinga

The name Caatinga comes from Tupi-Guarani and means “white forest”, as this vegetation loses its leaves during the dry season, revealing its stems. This biome covers about 10% of the country’s territory and has unique species in its fauna and flora. It is located in a semi-arid climate region and takes on a new appearance during the rainy season, turning green again and showing that this rich ecosystem adapts to the most varied seasons (Silva, Leal and Tabarelli, 2017).

Silva and collaborators (2021) state that Brazil has been suffering from deforestation in this biome, which is one of the least preserved. Silva, Leal and Tabarelli (2017) show that improperly exploited Caatinga resources have accelerated the desertification process with the increase in dry seasons and the decrease in rainfall. For Alves, Araújo and Nascimento (2009), economic activities not properly regulated by the government in the Caatinga are making the biome fragile and compromising water resources, compacting the soil, causing erosion and reducing biological diversity.

Therefore, it is clear that protective measures need to be taken to preserve this flora. Kill (2011) even reinforces that some species are already on the IBAMA's extinction list. Some tree species, such as the umbuzeiro (*Spondias tuberosa* Arruda) and the aroeira (*Myracrodruon urundeuva* M. Allemão), are already protected by forestry legislation, to prevent these species from being used as a source of energy (Brasil, 2017., IBAMA 06-N/1992). Despite these measures, 70% of the Caatinga has already suffered human action and only 0.28% is being protected by conservation parks (Kill, 2011) and the destruction of the Caatinga has not slowed down (Sarmento & De Andrade Neto, 2024).

It is important that reforestation be carried out with native vegetation from that biome, even if exotic species may seem easier to manage at first. This is because exotic species also cause negative impacts on the Caatinga, reducing the chances of survival of this biome by spreading easily and quickly, reducing the opportunity for natural vegetation to develop.

In this sense, Medeiros & Oliveira (2019) advocate the restoration of degraded areas with the faveleira, which is associated with several other species, favoring the reestablishment and quality of the area. The result is an ecosystem with better conditions to shelter the local fauna, preventing the migration of species or their extinction. Another resistant species is the trapiá, which, in addition to facing arid climate situations, is indicated for direct sowing in saline soils (Rodrigues, 2020).

A successful Caatinga reforestation initiative can be seen in the municipality of Açu, Rio Grande do Norte. A pioneering experiment carried out by researchers from the Federal University of Rio Grande do Norte (UFRN), called "BrazilDry", sought to develop new reforestation techniques to recover degraded dry tropical forests and combat desertification. Through this experiment, it was possible to recover a 3.3-hectare area of Caatinga that had been degraded and used for farming, demonstrating that it is possible to promote the reforestation of native forests (BrazilDry, 2016).

In this and several other successful Caatinga reforestation actions, the water issue often arises as an initial difficulty, since several factors of plant development are influenced by the amount of water in the soil (Rodrigues Maia, 2023., Crispim, 2019). Faced with this challenge, it is urgent to seek alternatives that favor the availability of water, especially for newly planted seeds and seedlings, with the superabsorbent polymer being a promising alternative.

2.2 Superabsorbent polymers and their use in planting native Caatinga seedlings

Superabsorbent polymer (SAP), better known as hydrogel, is a polymeric compound sold in the form of powder, grains or portions similar to pieces of malleable plastic. When hydrated, it absorbs water and acquires a gelatinous consistency (Ma *et al*., 2023., Kumar *et al*., 2020). It has numerous applications (Ma *et al*., 2023) including maintaining water in crop soil (Kumar *et al*., 2020) since it is a non-toxic, biodegradable material that is harmless to both people and the environment (SOCO Chemical, 2021).

When added to the soil and the crop is hydrated, either by rain or irrigation, this material absorbs the liquid and gradually releases it as the plant needs it (Vasconcelos, 2016). Kumar *et al*. (2020) present an extensive review of the use of hydrogels in arid and semi-arid areas. After decades of agronomic and biological studies on the use of planting hydrogel (Ma *et al*., 2023), many plant species of commercial interest have been studied, and indicate good performance in improving the physical and chemical

characteristics of the substrate, in addition to prolonged maintenance of soil moisture (Navroski, *et al*., 2016., Mews *et al*., 2015., Mandulão *et al*., 2017., Dranski *et al*., 2013).

A study carried out in Rio Grande do Norte with xerophytic plants from the Caatinga indicated that seedlings of mulungu, cumaru and other species, planted in holes with planting hydrogel, showed improved survival (Costa, 2020). In the state of Ceará, Crispim (2019) highlights that this polymer, when applied to Fabaceae species (*Vigna unguiculata, Canavalia ensiformis and Vigna radiata*) resulted in excellent development.

A type of Fabaceae that is quite common in several regions of Brazil, such as the Caatinga, Cerrado, and Atlantic Forest, is the angico. In general, they are large and grow quickly, reaching up to 30 meters in height. The species found in the Caatinga is *Anadenanthera colubrina* (Vell.) Brenan, a resistant species whose trunk can reach more than one meter in diameter and has a bark that is relatively smooth (Leite, 2016). Its use in reforestation is considered promising in the recovery of degraded areas of the Caatinga (Brazildry, 2016). Thus, the species *Anadenanthera colubrina* (Fabaceae) was chosen for the present experiment.

3 METHODOLOGY

The experiment was conducted at the Industrial-School Unit (DIGUIE) of the Federal Institute of Education, Science and Technology of Rio Grande do Norte (IFRN), Campus Macau. The climate of the municipality of Macau/RN is hot and semi-arid, reaching average annual temperatures of 27°C, maximum of 32°C and minimum of 23°C, with regular annual rainfall of around 471.61 mm and a rainy season between March and May (Souza, 2017). The effect of the planting hydrogel on the angico seedlings was tested in the dry season, that is, regular watering provided all the moisture available to the seedlings.

3.1 Preparing the experiment

The seeds were obtained through donation from the Center for Ecology and Environmental Monitoring - NEMA/UNIVASF. The experiments were carried out from November 1st to December 7th, 2022. The seedlings were placed in a fish farming greenhouse without cover, under the direct influence of local climatic conditions.

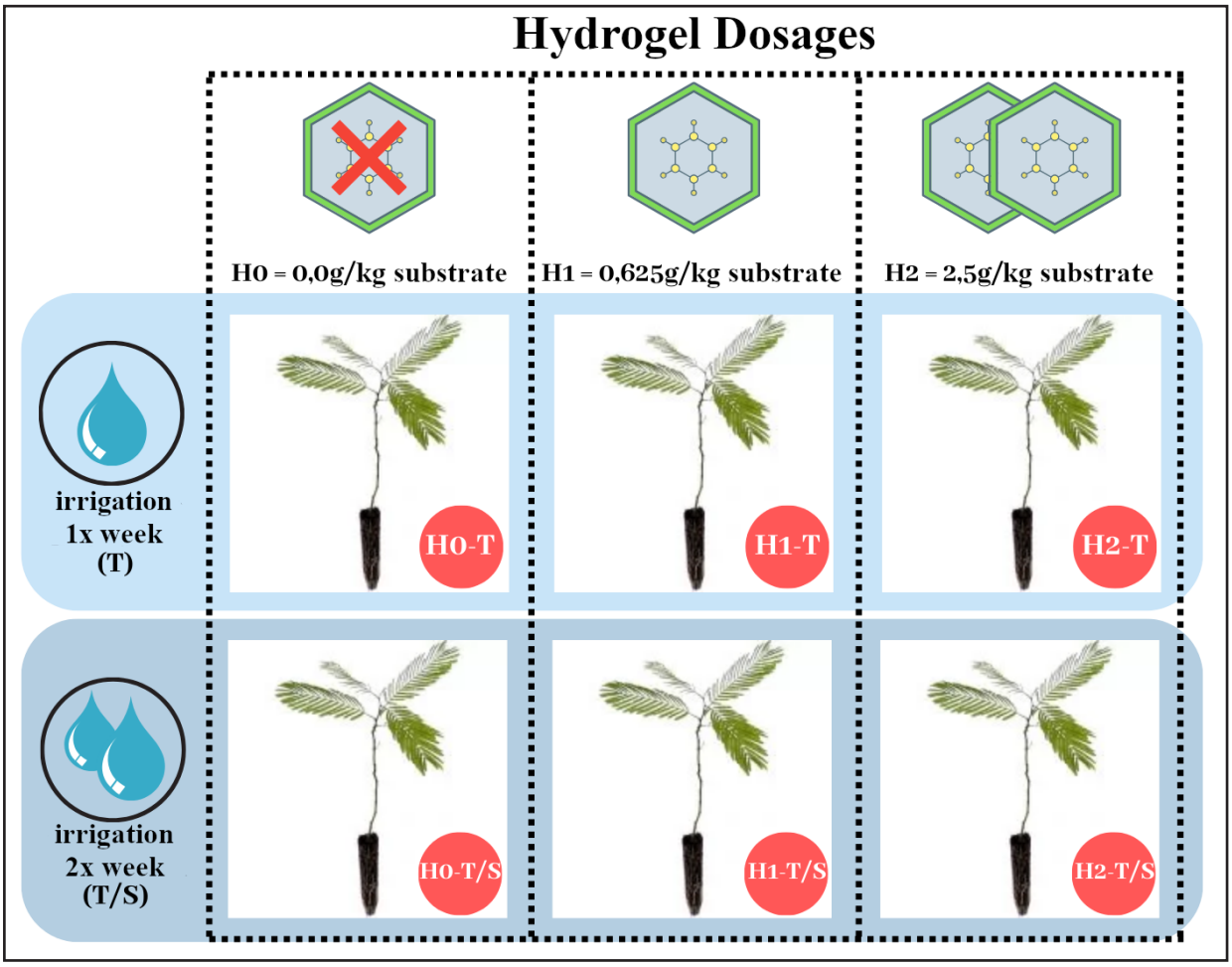
The substrate used for planting consisted of equal parts of sifted soil from IFRN (clayey consistency), washed construction sand and fertilizer from the Soil Study Group of the Jundiaí Agricultural School (GESOLO). Acqua Gel branded hydrogel (Danson Technology®) was added to this substrate according to three seedling treatments: H0 = no hydrogel/kg of substrate., H1 = 0.625 g of hydrogel/kg of substrate., and H2 = 2.5 g of hydrogel/kg of substrate.

The hydrogel was incorporated into the dry substrate according to each treatment and 800g was placed in each seedling bag. Three randomly selected angico seeds (*Anadenanthera colubrina*) were planted in each bag, and the substrate was then hydrated with 200 mL of distilled water. The seedlings were organized into three trays, so that the treatments were separate. One week after planting, 2 of the 3 seedlings in each bag were thinned, leaving only the most vigorous one.

3.2 Experimental design and experiment conduction

The experimental design adopted was organized with two irrigation regimes and three hydrogel dosages (Figure 1). The irrigation regime was: half of the seedlings were watered only on Tuesdays (T) while the other half of the seedlings were watered on Tuesdays and Fridays (T/S). Each condition consisted of 10 seedlings submitted, totaling 60 seedlings. After 32 days of monitoring the development of the seedlings, they were separated from the substrate and development measurements were performed.

Figure 1 – Experimental design: each group has 10 seedlings of *Anadenanthera colubrina* making up 60 seedlings



Source: Authors' private collection (December 2022)

Subtitle: Each irrigation regime (T and T/S) was performed with all hydrogel dosages (H0, H1 and H2). The treatments are: H0-T = no hydrogel - Tuesday., H1-T = 0.625 g of hydrogel/kg - Tuesday; H2-T = 2.5 g of hydrogel – Tuesday; H0-T/S = no hydrogel - Tuesday/Friday; H1-T/S = 0.625 g of hydrogel/kg - Tuesday/Friday; H2-T/S = 2.5 g of hydrogel – Tuesday/Friday

3.3 Measuring the parameters to assess seedling development

The measurements of the aerial part were (Table 1): aerial part height (APA), measuring from the cotyledon mark to the apical meristem, with a 30 cm ruler., stem diameter (DC), measured with the aid of an analog caliper with an accuracy of 0.05 mm at the cotyledon mark., and number of leaves (NF), obtained by counting the compound leaves.

Root measurements were performed after separating the seedlings from the substrate (Table 1). The roots were gently removed from the substrate with running water to prevent damage to the root part of the angico. A sieve was used to avoid loss of root fragments. The plants were then placed on trays for drying and the aerial part was separated from the root part. Each part was weighed on a Shimadzu ATY224 analytical balance to determine the fresh mass (MFPA, MFR, and MFT).

To obtain the dry weight (Mews et al. 2015), the plants were placed in the Lucadema model LUCA 82/480 forced air circulation greenhouse at 70 °C for 22 hours. After this period, they were weighed again on the analytical balance, where the dry mass (MSPA, MSR, and MST) was obtained.

Table 1 – List of variables obtained from *Anadenanthera colubrina* seedlings

Acronym	Variable	Unit of measurement	How it was measured/ calculated
APA	aerial part height	cm	cotyledon to apical meristem
DC	stem diameter	mm	cotyledon height
NF	number of leaves	-	counting of compound leaves
MFPA	aerial part fresh mass	g	weighing on analytical balance
MFR	root fresh mass	g	weighing on analytical balance
MFT	total fresh mass	g	MFPA + MFR
MSPA	aerial part dry mass	g	weighing on analytical balance
MSR	root dry mass	g	weighing on analytical balance
MST	total dry mass	g	MSPA + MSR
AgPA	aerial part water	g	MFPA – MSPA
AgR	root water	g	MFR – MSR
AgT	total water	g	MFT – MST
RELMF	fresh water ratio	g	MFPA / MFR
RELMS	dry mass ratio	g	MSPA / MSR

Source: Authors' private collection (December 2022)

3.4 Statistical analysis

Statistical analysis was performed using the IBM SPSS Statistics program. The variables described in the table were compared between treatments (H0-T, H1-T, H2-T, H0-T/S, H1-T/S and H2-T/S), between dosages (H0, H1 and H2) and between irrigation frequencies (T and T/S). The Shapiro-Wilk test was applied to assess normality, and the Levene's Test was applied to assess homogeneity of variances.

For normal and homogeneous variables, we used ANOVA tests (Tukey post-hoc) to compare treatments and hydrogel dosages., and the T-test for independent samples to compare irrigation frequencies (T or T/S). For nonparametric variables, these tests were replaced by Kruskall-Wallis and Mann-Whitney. Values for which $p \leq 0.05$ were considered significant.

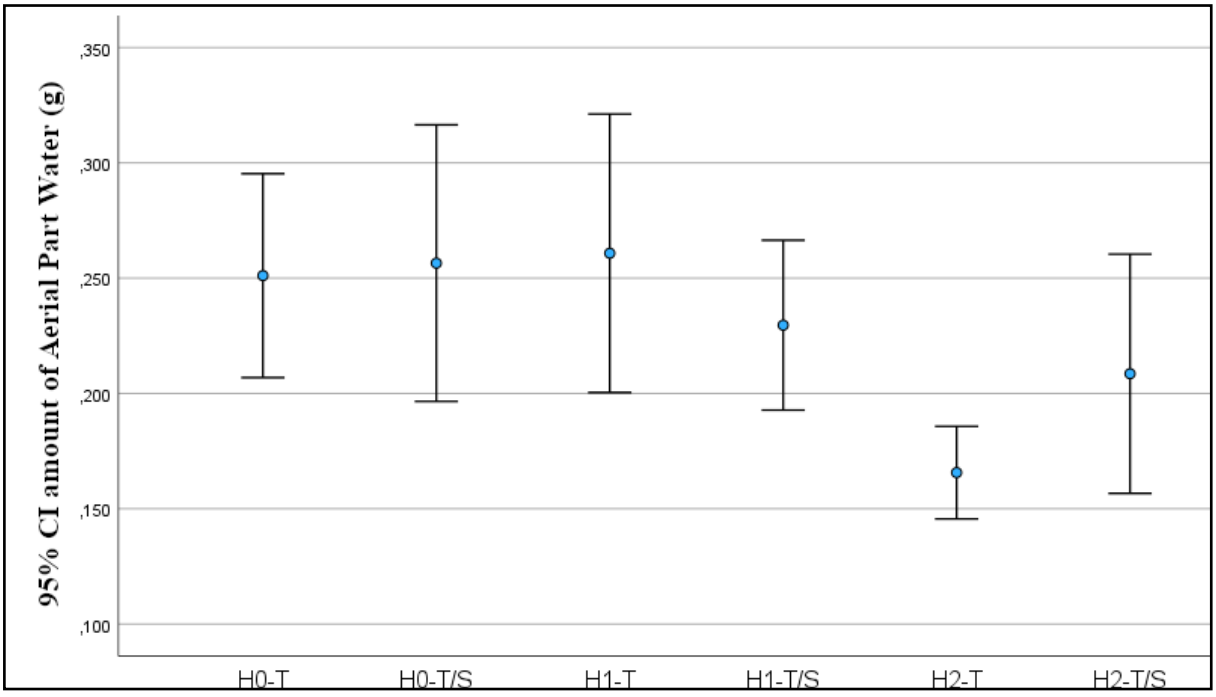
4 RESULTS AND DISCUSSION

All seedlings survived. Unlike what was found by Sousa et al. (2013), there were no seedling deaths with the two hydrogel dosages used, H1 and H2. Although apparently contradictory, this difference in results can be explained by the difference between the experimental designs and the location where the two studies were tested. While Sousa et al. (2013) carried out the experiments in a location with a greater thermal amplitude and monitored the seedlings for a longer time, transplanting the already germinated seedlings to another container, the present study was carried out in a location with a lower thermal amplitude, monitored the seedlings for a shorter time and did not replant. Therefore, our results indicate the absence of a deleterious effect of the use of hydrogel in the initial phase of *Anadenanthera colubrina* seedling production under the environmental conditions faced in the Caatinga of the Costa Branca of Rio Grande do Norte: prolonged drought, high temperatures and smaller thermal amplitude.

4.1 Comparison between all treatments

In the general comparison between all six treatments (Figure 1), only the Aerial Part Water (AgPA) showed a significant difference (Kruskal-Wallis test, p = 0.008, Figure 2). Despite the greater water availability provided by the greater amount of hydrogel in the roots of the seedlings in H2-T and H2-T/S, these presented lower AgPA (Figure 2). A similar and more intense result was found by Sousa et al. (2013) with *Anadenanthera peregrina*, who tested higher doses of hydrogel and monitored the development of the plants for a longer time.

Figure 2 – Graph of 95% confidence intervals of the amount of Aerial Part Water (AgPA) of *Anadenanthera colubrina* of the six treatments



Source: Authors' private collection (December 2022)

Subtitle: Graph of 95% confidence intervals of the amount of Aerial Part Water (AgPA) of *Anadenanthera colubrina* of the six treatments: H0-T = no hydrogel / Irrigation once a week; H0-T/S = no hydrogel / Irrigation twice a week; H1-T = 0.625g/kg of hydrogel / Irrigation once a week; H1-T/S = 0.625g/kg of hydrogel / Irrigation twice a week; H2-T = 2.5g/kg of hydrogel / Irrigation once a week; H2-T/S = 2.5g/kg of hydrogel / Irrigation twice a week

Considering the paper of Sousa *et al*. (2013) and our results, we confirm that there is a negative effect in the use of higher doses, as is

the case with H2, which would probably intensify if the seedlings were monitored for a longer period.

4.2 Comparison between hydrogel dosages

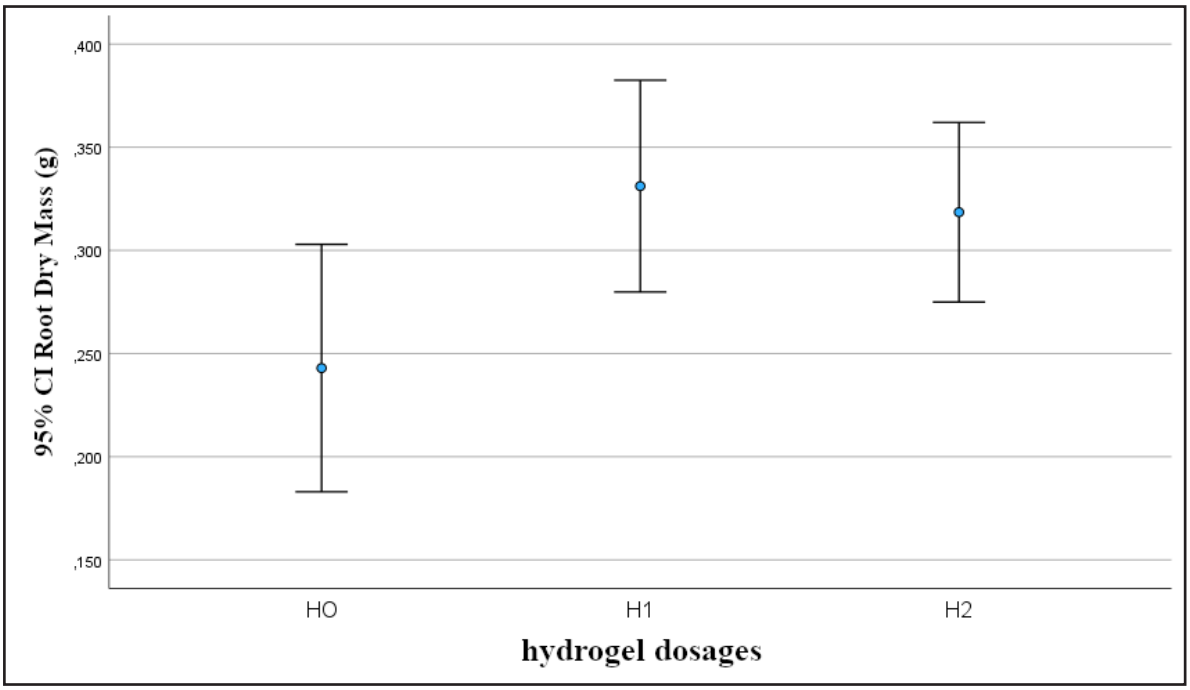
When we analyzed the effect of hydrogel dosages (Table 2), we obtained significant differences in the comparison of some variables. The Root Dry Mass (RSM), according to the ANOVA test (p = 0.031., Tukey post hoc), was lower in the seedlings of group H0, in which there was no application of the hydrogel, as shown in Figure 3.

Table 2 – Mean values of the variables listed in Table 1 by hydrogel dosage obtained after 32 days of monitoring the *Anadenanthera colubrina* seedlings, where H0 = no hydrogel, H1 = 0.625 g of hydrogel/kg of substrate, and H2 = 2.5 g of hydrogel/kg of substrate. The variables marked with * presented significant values in the comparison between the dosages. APA = aerial part height, DC = stem diameter, NF = number of leaves, MFPA = aerial part fresh mass, MFR = root fresh mass, MFT = total fresh mass, MSPA = aerial part dry mass, MSR = root dry mass, MST = total dry mass, RELMF = fresh water ratio, RELMS = dry mass ratio, AgPA = aerial part water, AgR = root water, AgT = total water

mean	APA cm	DC mm	NF un.	MFPA g	MFR g	MFT g	MSPA g	MSR* g	MST g	RELMF* g	RELMS* g	AgPA* g	AgR g	AgT* g
H0	3,35	1,44	3,90	0,51	0,47	0,98	0,26	0,24	0,50	1,45	1,34	0,25	0,22	0,48
H1	2,75	1,48	3,95	0,54	0,60	1,15	0,30	0,33	0,63	1,02	0,97	0,25	0,27	0,52
H2	3,39	1,44	4,00	0,45	0,50	0,94	0,28	0,33	0,61	0,92	0,86	0,17	0,17	0,34

Source: Authors' private collection (December 2022)

Figure 3 – Graph of 95% confidence intervals of Root Dry Mass (MSR) of *Anadenanthera colubrina* at different hydrogel dosages



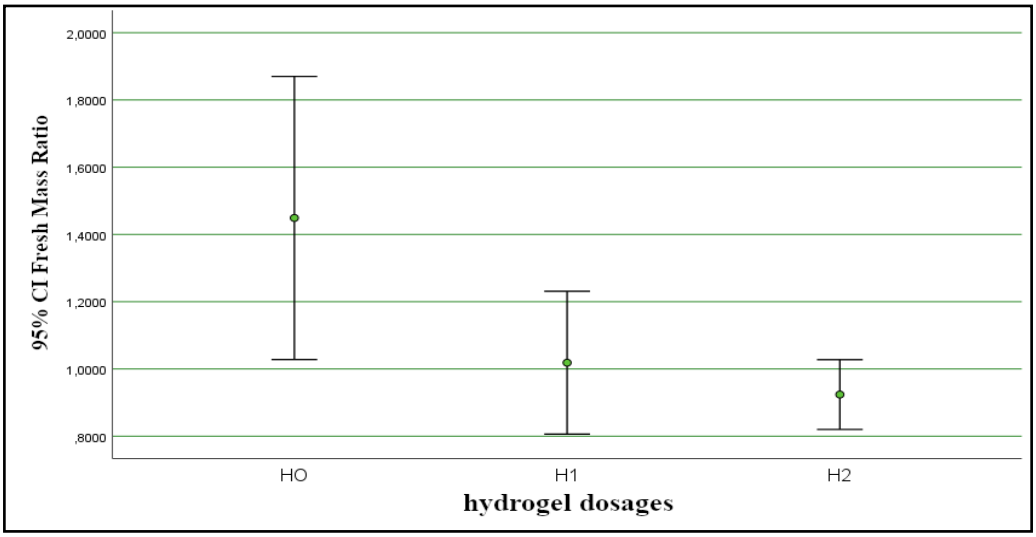
Source: Authors' private collection (December 2022)

Subtitle: Graph of 95% confidence intervals of Root Dry Mass (MSR) of *Anadenanthera colubrina* in different hydrogel dosages: H0 = no hydrogel; H1 = 0.625g of hydrogel; H2 = 2.5g of hydrogel

The greater availability of water generated by the application of hydrogel appears to have favored the accumulation of nutrients in the roots of groups H1 and H2 of angicos, which visibly presented more developed xylopodia (Silva do Ó, 2016). The result is consistent with the expectation that roots are especially prone to being affected by the nutritional environment in which they are inserted (soil) (Epstein & Bloom, 2006).

The different hydrogel dosages in the present study, in turn, did not show significant differences. A possible explanation is that the H1 dosage (0.625 g of hydrogel/kg of substrate) already represents a sufficient water surplus to trigger the development of the xylopodium in angicos, while the higher H2 dosage only maintains the effect, without a significant increase in the roots.

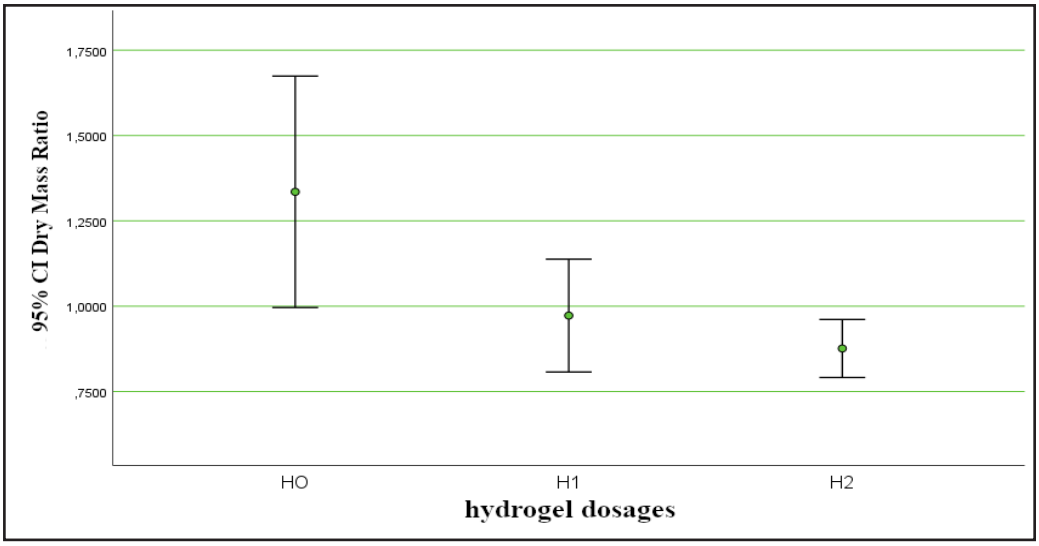
Figure 4 – Graph of 95% confidence interval plot of Fresh Mass Ratio (FMR) of *Anadenanthera colubrina* at different hydrogel dosages



Source: Authors' private collection (December 2022)

Subtitle: Graph of 95% confidence interval plot of Fresh Mass Ratio (FMR) of *Anadenanthera colubrina* in different hydrogel dosages: H0 = no hydrogel; H1 = 0.625g of hydrogel/kg substrate; H2 = 2.5g of hydrogel/kg substrate

Figure 5 – 95% confidence interval plot of Dry Mass Ratio (RELMS) of *Anadenanthera colubrina* at different hydrogel dosages



Source: Authors' private collection (December 2022)

Subtitle: Graph of 95% confidence interval graph of Dry Mass Ratio (RELMS) of *Anadenanthera colubrina* in different hydrogel dosages: H0 = no hydrogel; H1 = 0.625g hydrogel/kg substrate; H2 = 2.5g hydrogel/kg substrate

The variables Fresh Mass Ratio (RELMF) (Kruskall-Walis, p = 0.016) and Dry Mass Ratio (RELMS) (Kruskall-Walis, p = 0.013) also showed significant differences between the different hydrogel dosages (Figures 4 and 5).

In the absence of hydrogel (H0), seedling development was primarily in the aerial part (Table 3), unlike what was described by Nascimento (2021) for *Mimosa caesalpiniaefolia*. According to the author, the bifurcations and root tips are larger in the group without hydrogel to ensure their survival. On the other hand, Azevêdo (2014), comparing tree species with different wood densities in two contexts of water availability, describes a greater investment in the aerial part in the development of species with high wood density, such as angico. Possibly, the slightly lower wood density of *Mimosa caesalpiniaefolia* in relation to *Anadenanthera colubrina* may explain the difference in the allocation of resources to different parts of the developing seedling according to water availability (Azevêdo, 2014).

Table 3 – Differences in grams between the Root Fresh Mass and the Aerial Part, and the Root Dry Mass and the Aerial Part by hydrogel dosage obtained after 32 days of monitoring the *Anadenanthera colubrina* seedlings, where H0 = no hydrogel, H1 = 0.625 g of hydrogel/kg of substrate, and H2 = 2.5 g of hydrogel/kg of substrate. Negative values of H0 indicate that the Aerial Part has a greater mass than the Root.

Difference	**MFR-MFPA (g)**	**MSR-MSPA (g)**
H0	-0,05	-0,01
H1	0,06	0,03
H2	0,05	0,05

Source: Authors' private collection (December 2022)

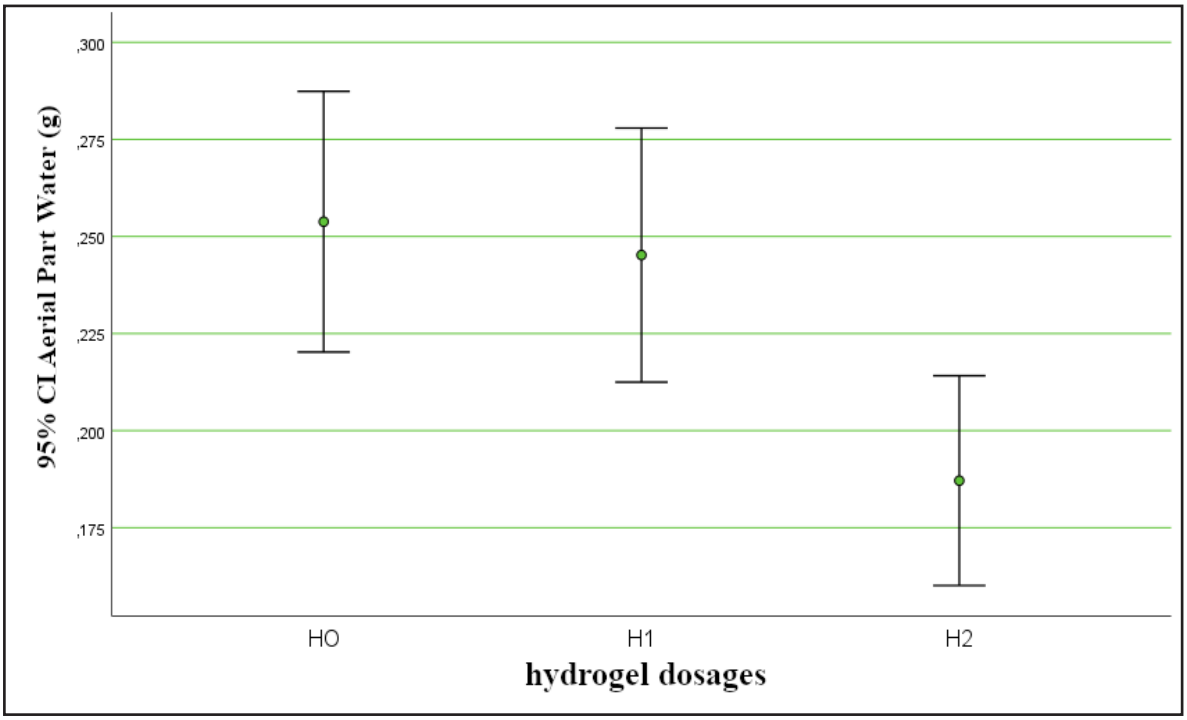
Treatment H1, in which a dosage of 0.625 g of hydrogel was used, showed greater root investment, but with very similar values, presenting RELMS and RELMF with values close to 1 (Figures 4 and 5). Similar results were found in the study by Nascimento (2021)

with seedlings of *Mimosa caesalpiniaefolia* Benth. Seedlings in treatment H2, with 2.5 g of hydrogel, also showed slightly greater root development (Figures 4, 5 and Table 3), as was the case for seedlings of *M. caesalpiniaefolia* (Nascimento, 2021).

However, unlike H1, in H2 this difference in Fresh Mass was maintained in Dry Mass, indicating that H1 seedlings retained proportionally more water in the roots, whereas in H2 the water content remained similar between plant parts (Table 3). The fact that these seedlings did not develop the aerial part equally proportionally may be the result of excessive soil moisture caused by the high concentration of hydrogel, which may have compromised the physiology of the plant, as highlighted by Sousa et al. (2013).

The variables Aerial Part Water (AgPA) and Total Water (AgT) also showed significant differences between the different hydrogel dosages (Kruskall-Walis, p = 0.003 and p = 0.036, respectively), as can be seen in figures 6 and 7.

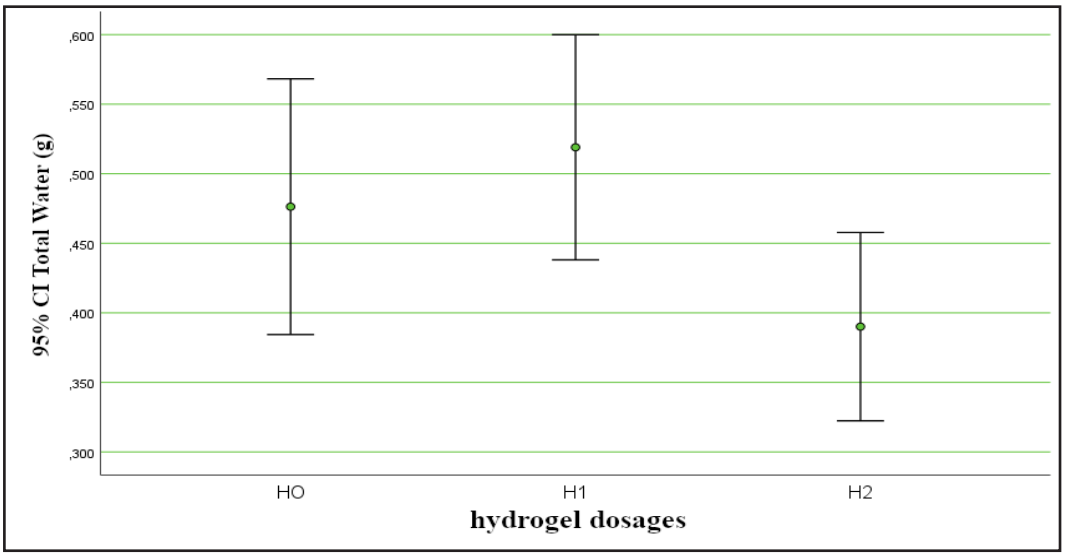
Figure 6 – Graph of the 95% confidence interval of the Aerial Part Water (AgPA) of angico (*Anadenanthera colubrina*) of the different hydrogel dosages



Source: Authors' private collection (December 2022)

Subtitle: Graph of the 95% confidence interval of the Aerial Part Water (AgPA) of angico (*Anadenanthera colubrina*) of the different hydrogel dosages: H0 = no hydrogel; H1 = 0.625g of hydrogel/kg substrate; H2 = 2.5g of hydrogel/kg substrate

Figure 7 – Graph of the 95% confidence interval of Total Water (AgT) of angico (*Anadenanthera colubrina*) from different hydrogel dosages



Source: Authors' private collection (December 2022)

Subtitle: Graph of the 95% confidence interval of Total Water (AgT) of angico (*Anadenanthera colubrina*) of the different hydrogel dosages: H0 = no hydrogel., H1 = 0.625g of hydrogel/kg substrate., H2 = 2.5g of hydrogel/kg substrate

Based on the results obtained, the seedlings subjected to the highest concentration of hydrogel (H2) accumulated less water in their stem and leaves, which was also reflected as a lower accumulation of total water. This result reinforces that the high availability of water in the soil provided by H2 may have some negative effect on the development of the seedlings (Sousa et al. 2013).

4.3 Comparison between irrigation frequencies

When comparing the two different irrigation frequencies (T or T/S), no significant result was found for any of the variables. This particularity may have occurred because the difference between the irrigation frequency intervals was short, and the experiment lasted only 32 days. In the study by Araújo (2022), for the same species of angicos, *Anadenanthera colubrina*, this difference was only evident around 45 days after planting.

Thus, at least for their initial development (first month), irrigating the angico seedlings once or twice a week does not seem to bring significant differences under

the conditions of this study. This fact is interesting when we think about seedling production, since irrigating only once a week means less water consumption and effort on the part of those responsible, or even an advantage in a scenario of intense water scarcity such as the dry season in Macau. However, there is a need to conduct longer studies with other irrigation rates so that this information can be confirmed or even this interval between waterings can be extended even further.

5 FINAL CONSIDERATIONS

The absence of deleterious effects in the use of hydrogel in lower doses than those used by Sousa et al. (2013) and under the conditions of the present study, indicate the possibility of using this agricultural technology in the initial phase of the production of angico (*Anadenanthera colubrina*) seedlings in Costa Branca, Rio Grande do Norte. This result is important because the use of hydrogel reduces the frequency of irrigation required for maintenance of the seedlings, facilitating their production in regions with similar water scarcity.

The absence of hydrogel and the lowest hydrogel dosage (H1) provided better development of the aerial part of *Anadenanthera colubrina* seedlings in relation to the root. As for the H1 and H2 dosages, the root area benefited, at least regarding its mass, both fresh and dry. The accumulation of water in the aerial part was also greater in the H0 and H1 concentrations. Thus, the experiment developed leads us to conclude, so far, that the best dosage was H1, as it provided improvement in three aspects of the *A. colubrina* seedlings.

The findings of this study support the conclusion that the application of planting hydrogel promotes the early development of *Anadenanthera colubrina*, if it is used at low concentrations. The results also indicate that it is possible to extend the irrigation interval combined with a low dosage of planting hydrogel. A longer interval between waterings may mean greater ease of management of the seedlings, especially in the long term. Thus, for future studies, it would be interesting to test a longer time interval

between irrigations, at least 15 days, as well as to extend the days of the experiment, since there were only 32 days of testing in the present study.

Even though the mechanisms involved in the use of hydrogel in the context of the semi-arid region are not fully understood, the full viability of the seedlings is evident, since there was no mortality during the experiment period. Therefore, the reduction in irrigation frequency provided by the hydrogel can facilitate the execution of reforestation actions through water rationing, the possibility of covering large areas with reduced teams and the maintenance of seedlings in hard-to-reach places, reducing costs and promoting the viability of reforestation projects.

The present work, even with punctual and very specific results regarding the experimental conditions, opens new perspectives in the search for new questions about the mechanisms involved in the use of this promising agricultural technology applied in the reforestation of native trees of the Caatinga.

ACKNOWLEDGMENTS

We would like to thank the Center for Ecology and Environmental Monitoring - NEMA/UNIVASF, the Integration Project of the São Francisco River with the Hydrographic Basins of the Northern Northeast - PISF and the Ministry of Regional Development - MDR for donating the seeds used in this work., the Soil Studies Group (GESOLO) of the Jundiaí Agricultural School/UFRN for providing fertilizer for planting., and the Federal Institute of Education, Science and Technology Rio Grande do Norte, Campus Macau, for providing logistical, infrastructural and financial support to the research project that resulted in this work.

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How to quote this article

da Silva, M. G., Leão, A. C., Moura, J. de S., Kawamoto, T. H. Lobato Junior, W. S., & Rocha, L. H. S. Evaluation of hydrogel use on the initial development of *Anadenanthera colubrina* (Vell.) Brenan, a native tree species of caatinga. *Ciência e Natura*, Santa Maria, v. 48, e91499, 2026. DOI 10.5902/2179460X91499. Disponível em: https://doi.org/10.5902/2179460X91499.