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Environment

Water deficit in the germination and initial development of *Handroanthus chrysotrichus* (Mart. ex DC.) Mattos

Déficit hídrico na germinação e desenvolvimento inicial de Handroanthus chrysotrichus (Mart. ex DC.) Mattos

Julia Savegnago Binotto [I], **Gabriela Neves Righi Corrêa**[I], [I] **Raquel Stefanello**[I], **Silvane Vestena**[II]

[I] Universidade Federal de Santa Maria, Santa Maria, Rio Grande do Sul, RS, Brasil
[II] Universidade Federal do Pampa, São Gabriel, Rio Grande do Sul, RS, Brasil

ABSTRACT

Water shortage is one of the most important factors affecting the growth, development, and survival of plants, with numerous effects on metabolic processes. The aim of this study was to evaluate the effect of water stress on germination and initial development of *Handroanthus chrysotrichus* (Mart. ex DC.) Mattos. Two experiments were performed using different concentrations of polyethylene glycol (PEG-6000) at different osmotic potentials to induce water stress. On experiment 1, the following solutions were used: -0.1; -0.2; -0.4; -0.8 and -1.0 MPa, and on experiment 2: -0.05; -0.1; -0.15; -0.2 MPa and distilled water as control treatment (0.0 MPa). After ten days, the first count (%), length (cm) and dry mass (mg) of the root and shoot were checked, and on the 14th day, the germination percentage was determined. It was found that *H. chrysotrichus* can withstand water potentials between -0.05 and -0.2 MPa for the evaluated parameters, and at more negative water potentials from -0.4 to -1.0 MPa, the physiological processes of seed germination and initial development were inhibited. Water potentials between -0.05 and -2.0 MPa led to a reduction in the percentage of germination, the length of both vegetative structures, and the dry mass of the shoot, showing that this species is sensitive to water shortage and that it may have strategies to tolerate a lack of water in the environments where it is distributed.

Keywords: *Handroanthus chrysotrichus*; Germination; PEG-6000; Water stress

RESUMO

A falta de água é um dos fatores que mais afetam o crescimento, desenvolvimento e sobrevivência das plantas com inúmeros impactos nos processos metabólicos. O objetivo deste trabalho foi avaliar o efeito do estresse hídrico na germinação e no desenvolvimento inicial de *Handroanthus chrysotrichus*

(Mart. ex DC.) Mattos. Realizou-se dois experimentos com diferentes concentrações de polietilenoglicol (PEG-6000) em diferentes potenciais osmóticos induzindo estresse hídrico. Experimento 1: utilizou-se as seguintes soluções: -0,1; -0,2; -0,4; -0,8 e -1,0 MPa e o experimento 2: -0,05; -0,1; -0,15; -0,2 MPa e água destilada como tratamento de controle (0,0 MPa). Depois de dez dias, verificou-se a primeira contagem (%), comprimento (cm) e massa seca (mg) da raiz e da parte aérea e, no 14º dia se obteve o percentual de germinação. Constatou-se que, para os parâmetros avaliados, *H. chrysotrichus* suporta potencial hídrico entre -0,05 a -0,2 MPa, sendo que em potenciais hídricos mais negativos, de -0,4 a -1,0 MPa, os processos fisiológicos de germinação das sementes e do desenvolvimento inicial foram inibidos. Potenciais hídricos entre -0,05 a -2,0 MPa proporcionaram redução no percentual de germinação, comprimento das duas estruturas vegetativas e massa seca da parte aérea, evidenciando que esta espécie é sensível a falta de água e que possivelmente apresenta estratégias para tolerar a falta de água nos ambientes de sua distribuição.

Palavras-chave: *Handroanthus chrysotrichus*; Germinação; PEG-6000; Estresse hídrico

1 INTRODUCTION

The ideal growth conditions for a given plant can be defined as those that allow it to achieve maximum growth and reproductive potential, as assessed by dry mass, height, and number of seeds, which together make up the total biomass of the plant. Stress can be defined as any environmental condition that prevents the plant from reaching its full genetic potential, i.e., completing its life cycle. Several studies analyzed abiotic stresses such as drought, flooding, toxic metals, extreme temperature variations (cold or heat), and salinity. These studies also examined the effects of agents that mitigate these stresses have the potential to remediate water, and are biocompatible for biological applications (Nunes et al., 2024; Puntel et al., 2025; Salles et al., 2022; Stefanello et al., 2023, 2024a; Viana et al., 2022). For example, a decrease in water availability can adversely affect growth by inducing stomatal closure, reducing the overall photosynthetic process, and suppressing everything from seed production and germination to plant development (Gurevitch et al., 2009; Lamers et al., 2020; Taiz et al., 2024).

The ecological performance of each species depends on genotype-environment interactions, which directly influence plant growth and development (Ferreira et al., 2015; Ji et al., 2022; Pour-Aboughadareh et al., 2019). Among the environmental factors, the amount of water greatly affects the germination and early development of various plant including tree species (Valdovinos et al., 2021), limiting their growth and productivity. When plant cells are subjected to lack of water, there are numerous impacts on the plant metabolic processes, including a decrease in cell turgor, as well as morphological, physiological, and biochemical changes, with losses in the translocation of photoassimilates and the transport and absorption of water and/or mineral nutrients (Oliveira et al., 2022; Taiz et al., 2024; Yang et al., 2021). These effects occur due to a direct influence on the plant's metabolism that causes various responses, such as the production of reactive oxygen species (ROS) capable of damaging cells, causing stomatal closure and limiting the entry of carbon dioxide (CO_2) into the leaves, which inhibits photosynthesis and, consequently, the production of photoassimilates that will affect productivity (reduction of the shoot, acceleration of senescence and leaf abscission) (Andrade et al., 2020; Ferrari et al., 2015; Taiz et al., 2024), as well as seed growing (Taiz et al., 2024; Thiesen et al., 2021).

When plants are exposed to adverse conditions, biochemical pathways homeostatically adjust to minimize the negative effects of stress and maintain metabolic balance; these mechanisms include the ability to accumulate metabolites and protective proteins, in addition to regulate growth, morphogenesis, photosynthesis, membrane transport, stomatal opening, and resource allocation (Kerbauy, 2019; Ramos et al., 2022; Silva et al., 2024; Taiz et al., 2024). The effects of these and other changes serve to achieve cellular homeostasis so that the plant life cycle can be completed under the new environmental regime; however, depending on the characteristics of the stressors, the response is not always one of resistance to stress, but rather of susceptibility, and studies that seek to evaluate these effects on metabolic processes (germination and initial development) are welcome (Silva et al., 2024; Silverio et al., 2024; Taiz et al., 2024). There has been a great deal of research on the effects of biotic and abiotic stresses on agricultural species, but there are few studies on native tree species, such as *Handroanthus chrysotrichus* (Mart. ex DC.) Mattos.

H. chrysotrichus (Bignoniaceae) is a species native to Brazil found in the Cerrado, Atlantic Forest, and Pampa biomes (Campos et al., 2024). This species can be seen from the state of Espírito Santo to Rio Grande do Sul (Martins et al., 2009; Rabaiolli et al., 2017). *H. chrysotrichus* has economic, ecological, ornamental, and medicinal value (Oliveira et al., 2008), as it can be used for reforestation and restoration of degraded areas, as well as for beautification of urban areas and places with high pollution rates. It can be grown in integrated systems, such as crop-livestock-forest integration, and assimilated with other species in agroforestry systems (Campos et al., 2024). Its wide latitudinal distribution means that the species is exposed to a wide range of climatic micro conditions (Moura et al., 2017), which implies adaptations to biotic and abiotic stresses.

In recent years, climate change has caused physiological stresses that often suppress germination and plant development. Of all the resources plants need to develop, water is both the most abundant and the most limiting (Kerbab et al., 2021; Taiz et al., 2024). Water is a key resource that limits agricultural and natural ecosystems' productivity. Its availability leads to marked differences in vegetation along with precipitation gradients (Kerbauy, 2019; Taiz et al., 2024). Furthermore, extensive research has been conducted on the sensitivity of most species currently cultivated for economic and agricultural purposes to multiple environmental constraints (Stefanello et al., 2024b; Puntel et al., 2025). Studies on *H. chrysotrichus* are incipient, and more research is needed to understand how the species behaves in situations of water shortage given its wide distribution and adaptability to different brazilian regions.

Considering the above, the aim of this study was to evaluate the effect of water stress on germination and initial development of *Handroanthus chrysotrichus* (Mart. ex DC.) Mattos.

2 MATERIAL AND METHODS

The experiment was carried out at the Seed and Plant Tissue Culture Laboratory of the Universidade Federal de Santa Maria (UFSM), RS. *H. chrysotrichus* seeds were manually collected from matrices at UFSM and stored in paper bags in a refrigerator at 7 ºC until the start of the studies, without treatment with fungicide or similar detergent; contaminated and dark seeds were excluded.

Two experiments were conducted using different concentrations of polyethylene glycol (PEG-6000) at different osmotic potentials to induce water stress. Experiment 1: The following solutions were used: -0.1; -0.2; -0.4; -0.8; and -1.0 MPa, Experiment 2: -0.05; -0.1; -0.15; -0.2 MPa, and distilled water as the control treatment (0.0 MPa). The seeds were placed on germitest paper moistened with distilled water or osmotic solutions; the amount of distilled water or each solution used was 2.5 times the mass of the dry paper (Brasil, 2009). Four replicates of 50 seeds were used for each treatment, placed in airtight plastic bags, and placed in a growth chamber with a 16-hour photoperiod and a temperature of 25 ± 2 °C for 14 days.

After 10 days of the experiment, the initial count (%), initial length (cm) and dry mass (mg) of the seedlings' shoots and roots were evaluated. For the analysis of length and dry mass, 10 seedlings were used per replicate of each treatment (Krzyzanowski et al., 2020), and on day 14, the percentage of germination of seeds in the different treatments was evaluated. Seedlings considered normal were classified as germinated (Brasil, 2009).

A completely randomized experimental design was used and the data were analyzed using ANOVA, comparing the means with the Scott Knott test at a 5% probability level.

3 RESULTS AND DISCUSSIONS

Seed germination and initial development of *Handroanthus chrysotrichus* were significantly affected ($p < 0.05$) when subjected to PEG 6000 simulating water stress in both experiments. Table 1 shows the results of the first experiment, where *H. chrysotrichus* seeds were susceptible to stress and showed a maximum tolerance limit of -0.2 MPa.

Table 1 – First count (FC) and germination percentage (G), shoot length (SL), and root length (RL) and shoot dry mass (SDM) and root dry mass (RDM) of *Handroanthus chrysotrichus* (Mart. ex DC.) Mattos, submitted to different water potentials

Treat. (MPa)	**FC (%)***	**G (%)***	**SL(cm)***	**RL (cm)***	**SDM (mg)***	**RDM (mg)***
0	80 a	85 a	1.44 a	4.24 a	1.14 a	1.28 a
-0.2	22 b	59 b	0.81 b	3.53 b	0.47 b	1.0 b
-0.4	0 c	0 c	0 c	0 c	0 c	0 c
-0.6	0 c	0 c	0 c	0 c	0 c	0 c
-0.8	0 c	0 c	0 c	0 c	0 c	0 c
-1.0	0 c	0 c	0 c	0 c	0 c	0 c
CV (%)	16.43	6.98	19.10	11.54	21.21	6.92

*significant ($p < 0.05$).

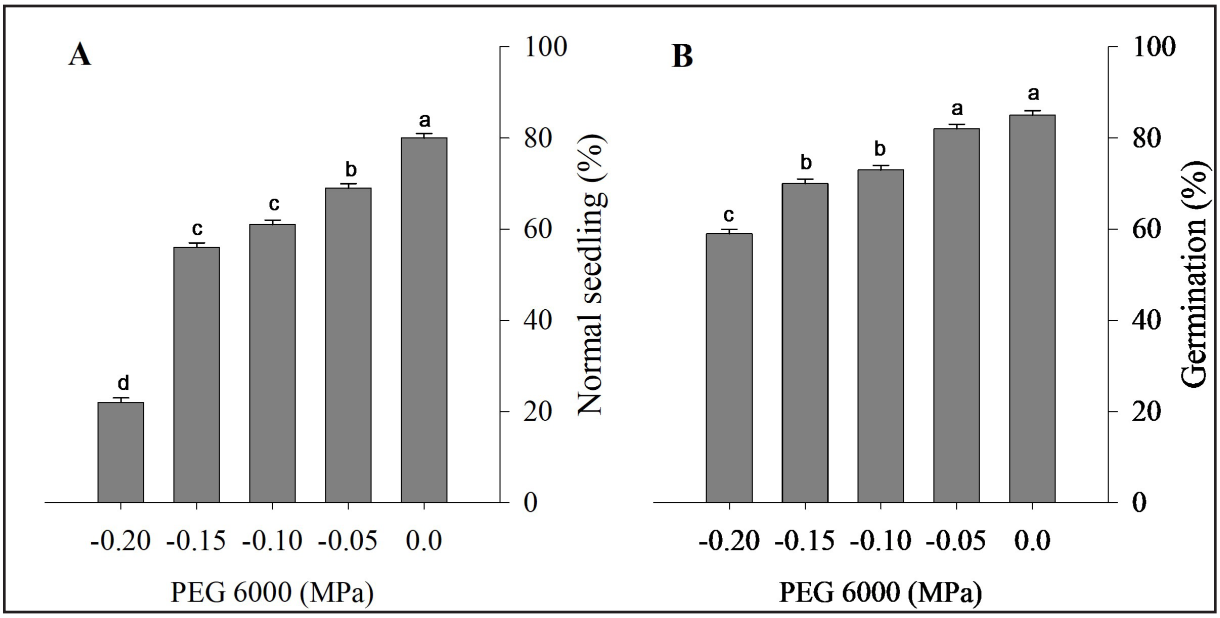
Source: Authors (2024)

It is noteworthy that this species is sensitive to water shortage, since it was significantly affected even at a potential of -0.2 MPa, and from this water potential, -0.4 to -1.0 MPa, no germination and seedling development were observed, with inhibition in these processes (Table 1). The results obtained with *H. chrysotrichus* seeds, exposed to PEG concentrations from -0.2 to -1.0 MPa, clearly show the difficulty imposed by higher potentials, with inhibition of the germination process from -0.4 MPa (Table 1).

With the data of this first experiment, another test was carried out with different water potentials up to -0.2 MPa (-0.05; -1.0; -0.15; and -0.2 MPa) to verify the behavior of this species under the effect of water deficit on germination and initial development. Analysis of the data indicated that the water deficit simulated by PEG 6000 had a significant effect ($p < 0.05$) on seed germination, length of the two vegetative structures, and dry mass of the aerial part of *H. chrysotrichus* seedlings (Figures 1, 2 and 3).

After 14 days of treatment, germination was reduced with decreasing water potential of the solutions, from 85% in the control to 59% at a water potential of -0.2 MPa, a reduction of 26% (Figure 1B). In addition, both the percentage of normal seedlings and germination were affected by different water potentials starting from -0.05 and -0.1 MPa, respectively (Figures 1A and 1B).

Figure 1 – (A) First count and (B) germination of seeds of *Handroanthus chrysotrichus* (Mart. ex DC.) Mattos subjected to water stress (0.0 to -0.2 MPa)

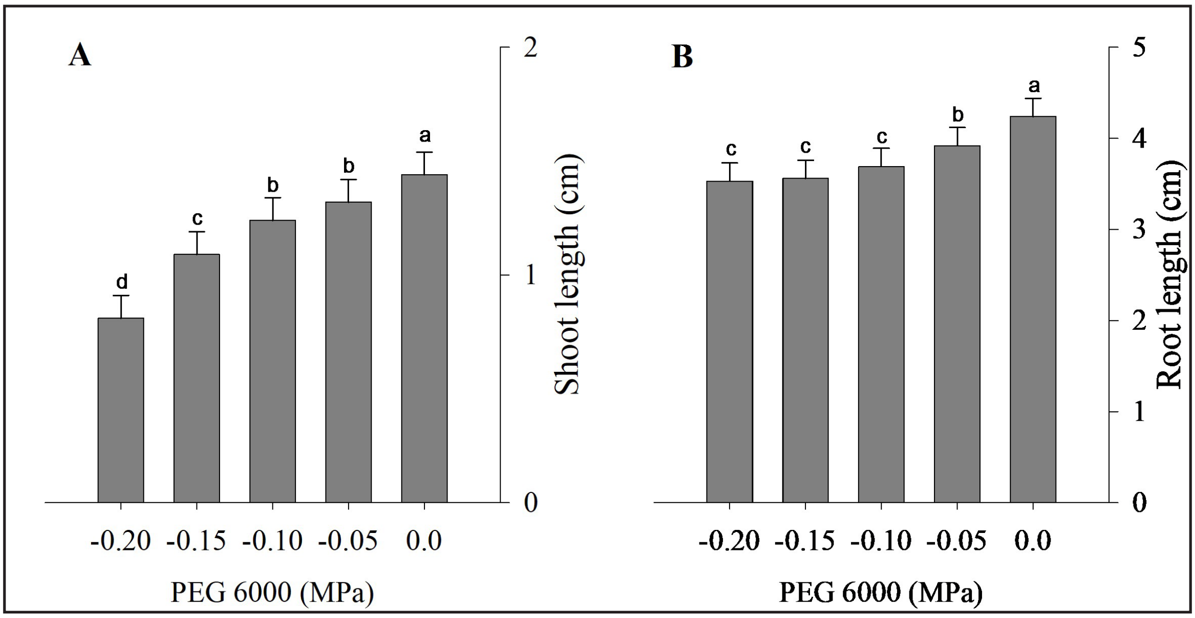


* Lowercase letters indicate significant differences ($p < 0.05$) between the different water potentials of the solutions.
Source: Authors (2024)

In the imbibition process, an event that occurs when water enters the seed (hydration) due to differences in water potential mediated by the matrix component of the seed, water plays an essential role in reactivating the metabolic activities of the embryo, including the production of phytohormones such as gibberellins, auxins, and cytokinins, as well as the remobilization of metabolism with the digestion of reserves into solutes such as simple carbohydrates, amino acids, and fatty acids necessary for anaerobic and aerobic cellular respiration and, as a consequence, the germination and growth of the embryo into a seedling (Kerbauy, 2019; Vieira & Carvalho, 2023; Taiz et al., 2024).

H. chrysotrichus seeds, at the end of the desiccation period, have a water content of about 12% (Goulart et al., 2017), which means that the substrate does not have a negative water potential that prevents the seed from imbibing to continue the germination process with the remobilization of reserves and the activation of the germinative metabolism. However, based on the results obtained, it is possible to verify that this species is susceptible to water stress during the germination process, which triggers negative effects in the post-germination processes, such as the initial development of the seedlings, as shown in Figures 2A and 2B.

Figure 2 – (A) Length of shoot and (B) root of *Handroanthus chrysotrichus* (Mart. ex DC.) Mattos subjected to water stress (0.0 to -0.2 MPa)



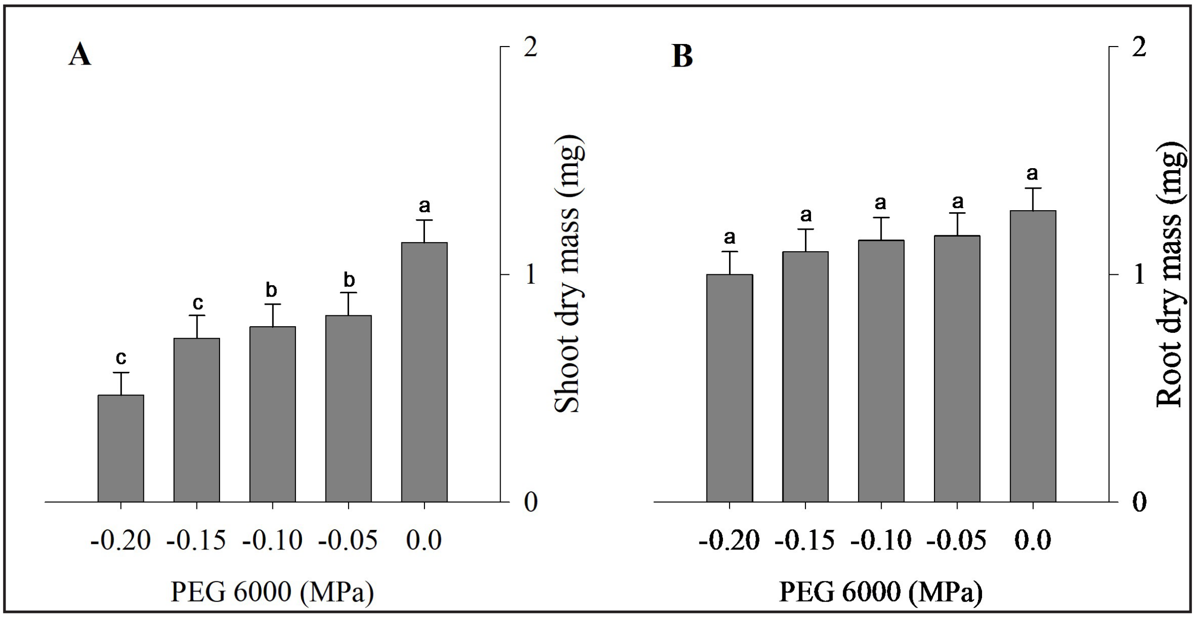
* Lowercase letters indicate significant differences ($p < 0.05$) between the different water potentials of the solutions.

Source: Authors (2024)

In addition to negatively affecting seed germination, the decrease in water potential had a detrimental effect on both the shoot and root growth of *H. chrysotrichus* seedlings. A reduction was observed from -0.05 MPa, with values ranging from 1.35 to 0.81 cm for the aerial part and from 3.82 to 3.53 cm for the root system, when compared to the control treatment (Figure 2B).

Regarding the dry mass of the vegetative structures in the shoot of *H. chrysotrichus*, significant differences were observed when subjected to water stress starting at a potential of -0.05 MPa, when compared to the control treatment (Figure 3 A).

Figure 3 – (A) Dry mass of shoot and (B) roots of *Handroanthus chrysotrichus* (Mart. ex DC.) Mattos subjected to water stress (0.0 to -0.2 MPa)



* Lowercase letters indicate significant differences ($p < 0.05$) between the different water potentials of the solutions.
Source: Authors (2024)

Although a negative effect was observed in the dry mass values of the shoot, no significant effect of the different treatments was observed for the dry mass of the root compared to the control treatment (Figure 3B). When the water potential becomes more negative, it is because there has been a reduction in the osmotic potential. This reduction in the dry mass of the shoot could be due to an increase in the concentration of osmotically active solutes and ions in the vacuole to maintain the water potential and turgidity of the cell close to the optimal level for maintaining metabolism (Moura et al., 2016; Silverio et al., 2024; Taiz et al., 2024).

The movement of water through the soil-plant-atmosphere continuum is only possible if the water potential decreases along this path. When the water potential of the rhizosphere decreases due to a water deficit or salinity, plants continue to absorb water as long as the water potential is lower (more negative) than in the soil water, and the fact that they accumulate compatible organic solutes capable of reducing the osmotic potential without losing water to the environment favors the continuity of metabolic processes, especially in the root, and is called osmotic adjustment (Moura et al., 2016; Silverio et al., 2024; Taiz et al., 2024).

One of the ways in which osmotic adaptation can occur is through the accumulation of osmotically active solutes in the cytosol (proline, sorbitol, and glycine betaine), and the synthesis of these compatible solutes requires adenosine triphosphate (ATP), as it is an active metabolic process. It should be noted that the synthesis of these organic solutes requires carbon from the photosynthesis produced, and the productivity of the species tends to decrease (Buchanan et al., 2015; Silverio et al., 2024; Taiz et al., 2024), which probably occurred in the study, where both root length and dry mass of this vegetative structure were not affected as much as the aerial part of this species. Corroborating these results, Tasca et al. (2024) also emphasize that with the reduction of soil water availability, there is a greater investment in root biomass accumulation and a reduction in specific leaf area, demonstrating resource conservation strategies. Furthermore, these authors, evaluating the morphological responses of *Hovenia dulcis* Thunberg to water stress, report that the differences observed in growth parameters and biomass accumulation contribute to a deeper understanding of the resource acquisition strategies of *H. dulcis* in response to reduced soil water availability, and highlight the importance of considering biomass allocation and differential growth between plant parts when studying the ecology and viability of using certain plant species in fragile and conserved ecosystems.

Several studies highlight the negative effect of water stress on germination and development of tree species, such as *Guazuma ulmifolia* Lam. (Scalon et al., 2011); *Jatropha curcas* L. (Moura et al., 2016), *Tectona grandis* L. f. (Freitas et al., 2017), *Mimosa scabrella* Benth (Avrella et al., 2019), *Tabebuia roseoalba* (Ridl.) Sandwith, *Handroanthus chrysotrichus* and *H. impetiginosus* (Mart. ex DC.) Mattos (Valdovinos et al., 2021), *Peltophorum dubium* (Spreng.) Taub. (Ramos et al., 2022), *Hylocereus* spp. (Carvalho et al., 2022), *Sesbania virgata* (Cav.) Pers (El Id & Santos Junior, 2023), *Toona ciliata* M. Roem. var. australis (Campos de Sá et al., 2023), and *Tecoma stans* (L.) Kunth (Ferreira et al., 2024), emphasizing that this environmental factor affect the hydrolysis of seed reserves, root elongation, and cell wall synthesis.

In a situation of water deficit, the shoot triggers several processes in response to this lack of water, such as a reduction in photosynthetic activity, which is linked to the transpiration process; as a result, there will be a reduction in leaf expansion. The reduction or inhibition of leaf expansion reduces carbon and energy consumption, and a greater proportion of the plant's photoassimilates can be allocated to the underground system, where they can support the continued growth of this structure. This root growth is sensitive to the water status of the soil, and in some cases these roots may extend towards a region of higher water potential (Kerbauy, 2019; Moura et al., 2016; Scalon et al., 2011; Taiz et al., 2024). In a condition of water stress, another situation that often occurs, is when the translocation of photosynthates to new growth areas becomes affected; therefore, studies with species with greater plasticity in relation to abiotic stresses are necessary when the objective is to re-establish new areas, facilitating their conquest and colonization in new environments (Ramos et al., 2022; Campos de Sá et al., 2023; Taiz et al., 2024; Tasca et al., 2024). It is worth highlighting the importance of studies focused on abiotic stresses in the germination and development of plants, which can contribute positively to understanding their possible environmental impacts when present as stressors in ecosystems (Stefanello et al., 2023), since it has been confirmed that, among environmental factors, water is a key resource for maintaining these environments.

4 FINAL CONSIDERATIONS

Handroanthus chrysotrichus showed sensitivity to water shortage, with inhibition in the germination process and initial development from -0.4 to -1.0 MPa. However, these parameters remained viable between water potentials of 0 MPa to -0.2 MPa.

Thus, it was possible to understand how this environmental factor interferes with the physiology of this species, specifically the germination process and early development, considering that this species is sensitive to water stress and probably develops ecological strategies to withstand water shortages in its distribution regions, and/or when used in ecological restoration programs under specific conditions.

Furthermore, new studies that include other environmental factors and/or different methodologies and analyses are necessary to establish the best growth conditions for *H. chrysotrichus*.

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Authorship contributions

1 – Julia Savegnago Binotto
Degree in Biological Sciences at the Universidade Federal de Santa Maria
https://orcid.org/0009-0001-8469-1368 • binottojulia5@gmail.com
Contribution: Conceptualization, Data Curation, Formal Analysis, Investigation, Methodology, Writing – Original Draft

2 – Gabriela Neves Righi Corrêa
Degree in Biological Sciences at the Universidade Federal de Santa Maria
https://orcid.org/0009-0001-3443-4443 • gabrielanevesrighi@gmail.com
Contribution: Conceptualization, Data Curation, Formal Analysis, Investigation, Methodology

3 – Raquel Stefanello
Biologist, PhD in Agronomy at the Universidade Federal de Santa Maria
https://orcid.org/0000-0003-3079-2099 • raquelstefanello@yahoo.com.br
Contribution: Conceptualization, Data Curation, Formal Analysis, Investigation, Methodology, Supervision, Project administration, Writing – original draft | Writing – review & editing

4 – Silvane Vestena
Biologist, PhD in Agricultural Sciences at the Universidade Federal de Viçosa
https://orcid.org/0000-0002-9797-1211 • silvanevestena@gmail.com
Contribution: Conceptualization, Data Curation, Formal Analysis, Investigation, Methodology, Supervision, Project administration, Writing – original draft | Writing – review & editing

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