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Influence of desiccation and water deficit on the initial development of seedlings of *Tabebuia aurea* (Silva Manso) Beth. Hook. and S. Moore (Bignoniaceae)

Influência da dessecação e déficit hídrico no desenvolvimento inicial de mudas de *Tabebuia aurea* (Silva Manso) Beth. Gancho. e S. Moore (Bignoniaceae)

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Desiccation tolerance mechanisms are one of the main factors related to the ability to survive water deficit conditions imposed by abiotic stress. Thus, the objective of this work was to evaluate the desiccation tolerance and the influence of water deficit on the initial development of *Tabebuia aurea* (Silva Manso) Benth. & Hook.f. ex S. Moore. The seedlings were divided into two treatments the control and those that were submitted to 50% desiccation. The control groups received water daily over a period of 30 days, while the groups that underwent water deficit had water suspension for 14 days, totaling two cycles of water deficit over a period of 30 days. The results of this study indicate that seedlings of *T. aurea* survive desiccation and present less development, whether of the stem, roots, number of leaves, stem diameter when subjected to desiccation and consequent water deficit. Thus, these results indicate that the reduction in early development is related to the perception and attenuation of stressful conditions imposed by the abiotic environment during development.
Keywords: morphology, early development, water suppression.

Os mecanismos de tolerância à dessecação são um dos principais fatores relacionados à capacidade de sobreviver às condições de déficit hídrico impostas pelo estresse abiótico. Assim, o objetivo deste trabalho foi avaliar a tolerância à dessecação e a influência do déficit hídrico no desenvolvimento inicial de mudas de *Tabebuia aurea* (Silva Manso) Benth. & Hook.f. ex S. Moore. As plântulas foram divididas em dois tratamentos o controle e as que foram submetidas a 50% de dessecação. Os grupos controles receberam água diariamente em um período de 30 dias, enquanto os grupos que passaram pelo déficit hídrico tiveram suspensão hídrica por 14 dias, totalizando dois ciclos de déficit hídrico em um período de 30 dias. Os resultados deste estudo indicam que mudas de *T. aurea* sobrevivem à dessecação e apresentam menor desenvolvimento, seja do caule, raízes, número de folhas, diâmetro do caule quando submetidas à dessecação e consequente déficit hídrico. Assim, esses resultados indicam que a redução no desenvolvimento inicial está relacionada à percepção e atenuação das condições estressantes impostas pelo ambiente abiótico durante o desenvolvimento.
Palavras-chave: morfologia, desenvolvimento inicial, supressão hídrica.

1. INTRODUCTION

The ability of organisms to resist damage by rehydration of tissues after loss of water to the environment is known as tolerance to desiccation. Water content below 0.1 g is maintained in desiccation tolerant organisms without promoting damage to cell membranes [1, 2]. During evolution, due to the emergence of roots and water transport tissue, this tolerance became less common in the vegetative part of angiosperms. However, it is still one of the most important adaptation skills for seeds, especially those that are in a seasonal environment with low rainfall that can be found in seedlings of some species [2-4].

Desiccation tolerance is obtained at the end of the maturation stage and usually lost during germination [5]. As seed metabolism increases, the mechanism that makes seeds resistant to desiccation is deactivated [6, 7]. Therefore, this is one of the explanations for seedlings of some species not tolerating water loss during their development. However, seeds produced by different plant species present different behaviors in terms of desiccation [8]. Although some species are not tolerant to water loss after radicle protrusion, seedlings of the species *Sesbania virgata* (Cav.) Pers, *Bauhinia forficata* Link, *Senna multijuga* (Rich.) Irwin et Barn and *Tabebuia aurea* (Silva Manso) Benth. & Hook.f. ex S. Moore are tolerant of desiccation [9-11].

The ability of seedlings to tolerate water loss to the environment may characterize a high capacity of survival, even in environments with higher water restrictions [11]. In semi-arid environments, such as Caatinga, a seasonally dry tropical forest, rain events at short intervals of time promote deficit conditions in all phases of plant development. In the initial development, the seedlings of *Tabebuia aurea* (Silva Manso) Benth. & Hook.f. ex. S. Moore can attenuate stress via stomatic regulation with higher production of proline and antioxidant enzymes, with these conditions also resulting in a lower biomass accumulation [12].

However, the effects of the combination between water deficit and desiccation are not yet known, because the desiccation tolerance pattern is related to the environment in which seeds and seedlings develop. Understanding the limits of desiccation tolerance in species and environmental factors promote this capacity, which is of great ecological importance since it can help in the choice of species used for ecological recovery [13]. In addition, the study of tolerance to desiccation in seedlings and the relationship with the water deficit conditions that are found in the environment in which they develop will contribute to the propagation of species and reintroduction into restoration programs. In this sense, the objective of this work was to evaluate the tolerance to desiccation and the influence of water deficit on the initial development of the seedlings of *Tabebuia aurea* (Silva Manso) Benth. & Hook.f. ex S. Moore. We believe that *T. aurea* seedlings will be more tolerant to water deficit after desiccation and that the combination of these two factors will influence seedling development.

2. MATERIALS AND METHODS

2.1 Studied species and seed collection site

The species *Tabebuia aurea* (Silva Manso) Beth. Hook. and S. Moore is a member of the family Bignoniaceae, commonly known as caraibeira, craibeira, ipê-amarelo, ipê-do-cerrado (Figure 1), this species has a wide distribution being present in Caatinga domains, on the two banks of temporary rivers in the Northeast of the semiarid region of Brazil, and also in the phytophysiognomic domains of Mata Seca and cerradão in the Cerrado [14, 15]. At the time of reproduction, the interactions are quite frequent and intensified, for the flowers are pollinated by several species of insects present in the region, contributing to the maintenance of ecosystem services [15-17].

Tabebuia aurea seeds were collected in the municipality of Canindé do São Francisco in the state of Sergipe, a region with an average annual rainfall of 521 mm of rain per year and average annual temperature of 25.3 °C. So, according to Köppen and Geiger this region is classified as type BSh. Seeds of ripe fruits from 20 matrices were collected, and in the same region 30kg of soil were also collected for the assembly of the experiment. The seeds were taken for processing at the Seed Physiology Laboratory (LAFISE) of the Federal University of Sergipe for the removal of the valves (carpelo) and the septum (Figure 1). Soon after processing they were kept in a cold chamber at 5 °C until the experiments were carried out.

2.2 Desiccation curve

To determine the seed desiccation curve, initially 400 seeds were placed to germinate in 2 plastic trays (40 x 30 cm) containing 200 seeds each, the trays were lined with paper towels and moistened with distilled water. Soon after, the seeds were kept in the germination room at room temperature in the photoperiod light of 12h. At this stage, the root protrusion germination criterion with up to 10 mm was used. We selected 100 seeds with a radicle of 10 mm, in which they were subdivided into 4 replicates of 25 seeds to determine the desiccation curve. Then, the germinated seeds had the initial weight measured on the analytical scale. The four replications were taken to a greenhouse oven at a temperature of 40 °C, and the samples were weighed at 60 min intervals, this procedure was repeated until there was no further variation for three consecutive weighing, ensuring that the material was completely desiccated.

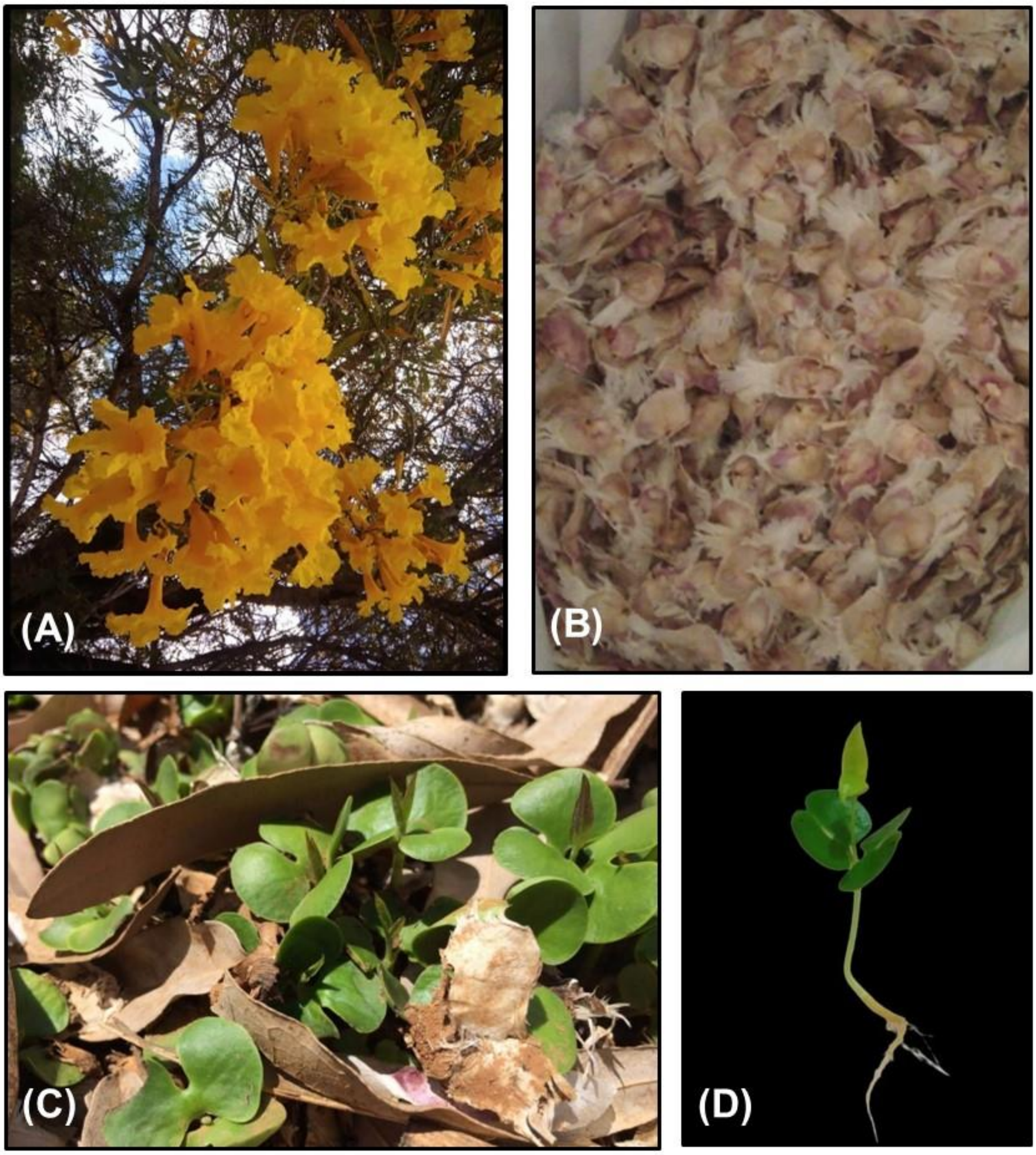

Figure 1: Morfological characteristics of Tabebuia aurea *(Silva Manso) Benth. & Hook. ex. S. Moore (Bignoniaceae). In which (A): peak flowering of the species in December; (B): seed beneficiation in the Seed Physiology Laboratory (LAFISE); (C): seedlings found close to adult individuals of the species; (D) seedlings presenting its of cotyledons, hemotylus, hypocotyl, radicle and root hair*.

2.3 Measurement and Experimental Design

For the setup of desiccation tolerance experiments in *T. aurea* seedlings, 160 seedlings with 10 mm radicle were selected, in which they were subjected to desiccation until reaching 50% of the pre-established water content in the curve. For the control treatment, 160 other seedlings that did not passthrough desiccation were used. After the procedure, they were subdivided into 80 replicates with 4 germinated seeds each that were placed for resumption of development in substrate containing washed sand, Caatinga soil and bovine manure in the ratio of 3:3:1, at this stage of the experiment the replicates received daily water, maintaining the humidity of the field capacity for 7 days until the resumption of growth, after acclimatization, only 1 seedling was maintained per repetition, and the others were eliminated by thinning (Figure 2).

For the treatment of water deficit, seedlings were divided into 4 groups with 20 replications each, in which they were: control without water deficit (WTD), control with water deficit (WHD), desiccated seedlings without water deficit (DWTD) and desiccated seedlings with water deficit (DWHD). The control groups received water daily in a period of 30 days, while the groups that went through the water deficit had water suspension for 14 days, totaling two cycles of water deficit in a period of 30 days, after the end of this first period, measure 1 (M1) was performed (Figure 2). Soon after the seedlings were submitted to water deficit treatments, all treatments received a watering suspension for 15 days, and after this second period, measure 2 (M2) was performed (Figure 2). After the end of the second water deficit period, irrigation was resumed during a 10-day recovery period and measure 3 (M3) was performed.

2.4 Statistical analyses

After 37 days after germination [measure 1 (M1)] for the resumption of growth, the morphological parameters were analyzed, namely: the number of leaves (NF), stem diameter (DC) and stem length (CPA). Assessments were repeated after the second period of water deficit [measure 2 (M2)] and after recovery [measure 3 (M3)] (Figure 2). At 62 days, the length of the roots and the root-stem ratio was measured.

Data normality and homogeneity of variances were verified using the Shapiro-Wilk and Levene tests. The results of morphological parameters were submitted to factorial variance analysis a priori, with three factors (time, water deficit and desiccation) and the results of length of roots to Factorial Variance Analysis, with two factors (water deficit and desiccation) and the means compared with the Tukey´s test for the two analyses performed. All analyses were performed in STATISTICA 13 with $\alpha = 5\%$ [18].

3. RESULTS

The time at which the seedlings of *T. aurea* reached 50% of its water content was in 14 hours of desiccation (Figure 3a). Unlike most angiosperms that did not tolerate desiccation after germination, *T. aurea* seedlings tolerated a 50% reduction in their water content and, after tissue rehydration, continued their development.

The desiccation of *T. aurea* seedlings affected their development, even under favorable conditions. The seedlings showed a reduction in their growth both after undergoing desiccation, as well as after being subjected to water restriction. The combination of these two factors during development further accentuated the difference in assessed growth rates.

The results for the growth parameters evaluated showed that there were not significant reductions in control conditions, after seedlings were submitted to water deficit conditions. In addition, the number of leaves in the control did not decrease after passage through water deficit conditions (Figure 3b). However, the combination of desiccation and seedling water deficit led to significant reductions when compared to the control at all times evaluated. Only in the desiccation treatment without water deficit the plants showed no difference in the number of leaves when compared to the control after recovery.

Water deficit conditions together with desiccation promoted a significant reduction in stem length. Desiccation has the same effect in relation to the length of the plants of the species observed in the water deficit. The combination of the two stress factors led to a significant reduction of the mentioned parameter, thus, smaller seedlings were observed (Figure 3c).

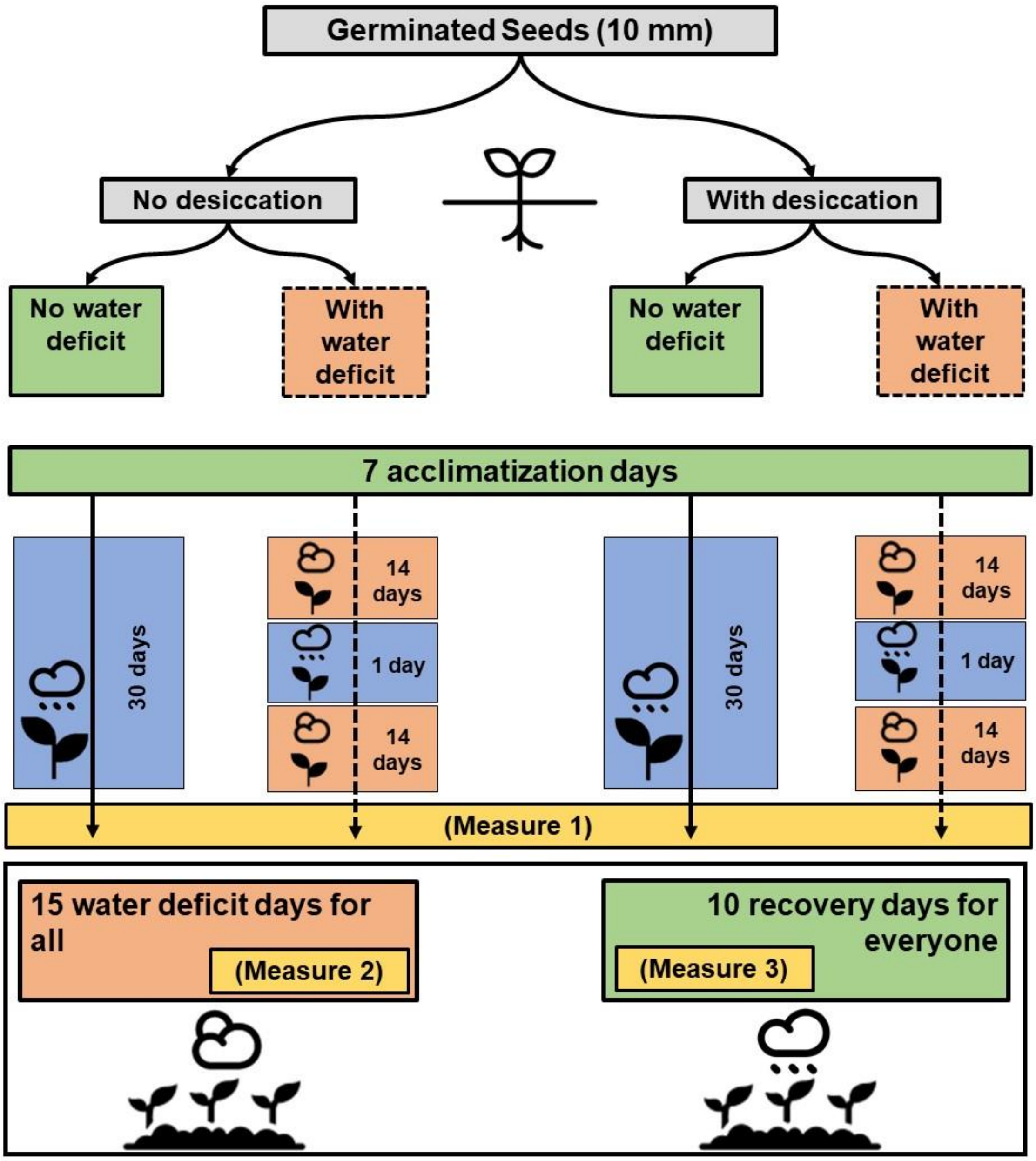

Figure 2: An experimental design of the seedlings that were submitted to desiccation and their morphological evaluations, having these been performed in 3 moments. Measure 1 occurred 37 days after germination, measure 2 took place 52 days after germination and measure 3 took place 62 days later.

In addition to the reduction in shoot and number of leaves, in the control the stem diameter was affected during the period of water restriction, presenting a similar behavior to the treatment submitted only to desiccation. The passage through desiccation and irrigation cycles led to a significant reduction in the stem diameter when compared to other treatments (Figure 3d).

In the studied population, a reduction in the subterranean part (root) can be observed both in the passage through desiccation, and in those that were submitted only to water deficit (Figure 3e). In the root and stem ratio, we can observe that it remained high even in the seedlings that were submitted to desiccation and water deficit. The reduction in this ratio occurs in seedlings that did not undergo desiccation, but were submitted to water deficit (Figure 3f). A significant reduction was observed in the combination of tissue water loss associated with subsequent water restriction during development. Therefore, it can be observed that all plant growth was affected by these factors studied in the present study.

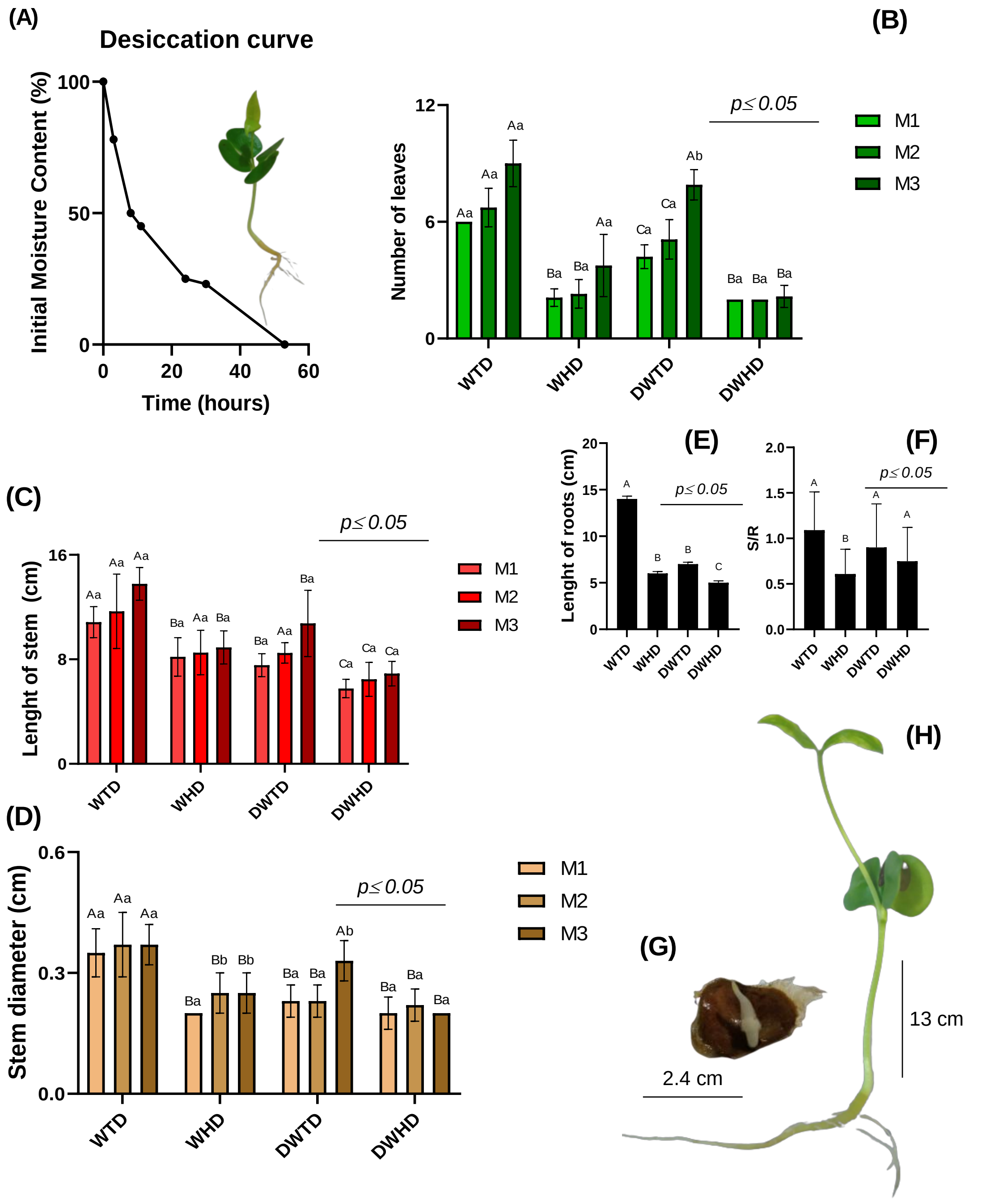

Figure 3: (A) Seedlings drying curve of Tabebuia aurea *(Silva Manso) Benth & Hook.f. ex S. Moore (Bignoniaceae). (B) Number of leaves of* T. aurea*; (C) Length of stem of* T. aurea *and (D) Steam diameter of* T. aurea *submitted to control without water deficit (WTD), control with water deficit (WHD), desiccated seedlings without water deficit (DWTD) and desiccated seedlings with water deficit (DWHD) and measure after recovery. (E) Length of roots of* T. aurea *and (F) Ratio root and stem submitted to control without water deficit (WTD), control with water deficit (WHD), desiccated seedlings without water deficit (DWTD) and desiccated seedlings with water deficit (DWHD) and measure after recovery. (G) Seed of* T. aurea *and (H) Seedling of* T. aurea*. Data shown represent means ± standard error. Different letters indicate significant differences between treatments according to Tukey test at P < 0.05. Upper case indicates differences between treatments and lowercase letters indicate differences within the same treatments.*

4. DISCUSSION

Tolerance to desiccation is a remarkable skill of orthodox seeds. In the group of angiosperms this capacity decreases as the seed absorbs water and expresses germination [12]. *Bowdichia virgilioides* Kunth (Fabaceae) *Enterolobium contortisiliquum* (Vell.) Morong (Fabaceae) and *Handroanthus impetiginosus* (Mart. Ex DC.) Mattos (Bignoniaceae) reduced their germination process from an average of 60% before root protrusion to 0% with root growth when submitted to desiccation. As the germination process progressed, a decrease in the ability to restore tolerance to desiccation of these species was also observed [19]. However, seedlings of *T. aurea* with up to 10 mm of radicle resumed development after desiccation and still endured subsequent water deficit.

Water restriction is one of the environmental factors that most affects plant growth and productivity, as well as influences the persistence, distribution and establishment of plant species [20, 21]. However, the seedlings of *T. aurea* showed a rapid recovery to decrease the availability of water in the soil and tissues, which indicates an adaptation to environments subject to periodic water stress, and that it has already been observed by Silva (2014) [22] when submitting *T. aurea* seedlings to water deficit for 21 days.

Our results demonstrate differences in response in the studied population when compared to other study by Zhang et al. (2012) [23], who, when studying the growth of young plants of *T. aurea* submitted to water deficit, observed that there was no significant difference in the number of leaves in the period of 60 days. In the present study, this reduction occurred in a period of 30 days of water restriction. Recent studies show a reduction in the number of leaves with the increase in water deficit [23-25]. The reduction in the number of leaves is beneficial in situations of water restriction since it reduces temperature stress and consequently the high conductance of the leaf surface that can lead to an increase in transpiration [26].

During the water deficit, the seedlings suffered a reduction in the shoot and roots in response to water restriction from the early stages of treatment. This is because, the continuity of growth depends on the pressure of turgidity, expansion and cell division [27] whose main effect of water deficit is the reduction of growth [28]. In addition, reducing growth is a survival strategy in an environment with low water availability [28].

The cycles of water suppression and desiccation alone led to results, in part, similar to those found by Cabral et al. (2004) [17] and Zhang et al. (2012) [23]. During periods of water restriction, seedlings tend to invest more in the growth of the underground part to the detriment of the aerial part Cabral et al. (2004) [17], found that the length of the underground part was greater than the length of the stem and this response is adaptive, being common in plants submitted to water deficit, making it advantageous to obtain water in the soil. This is because the differential investment aims to increase the water absorption area and maintain the organism's physiology. However, the present study showed a reduction in the underground part, demonstrating that every plant reduced its size to withstand the conditions imposed on it.

The combination of desiccation and water deficit during development results in a reduction in the growth of *T. aurea* seedlings. Reducing growth can be a strategy to avoid water loss, in this case, from the shoot. However, this reduced growth also affected root development and, consequently, water uptake by the seedlings. Despite the reduced growth, the seedlings did not die during the drought and continued their development after the recovery period.

5. CONCLUSION

The results of this research show that the development of *T. aurea* seedlings that came from seeds that underwent desiccation resulted in a significant reduction in all morphological parameters evaluated in this study, which indicates that the reduction in initial development is related to the attenuation of stressful conditions. Thus, desiccation tolerance acts as an initial stress marker that prepares seedlings for establishment in the studied species.

6. ACKNOWLEDGEMENT

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7. BIBLIOGRAPHIC REFERENCES

1. Alpert P. The Limits and frontiers of desiccation-tolerant life. Integ Comp Biol. 2005;45(5):685-95. doi: 10.1093/icb/45.5.685
2. Oliver MJ, Farrant JM, Hilhorst HW, Mundree S, Williams B, Bewley JD. Desiccation tolerance: avoiding cellular damage during drying and rehydration. Ann Rev Plan Biol. 2020;71:435-60. doi: 10.1146/annurev-arplant-071219-105542
3. Dekkers BJ, Costa MCD, Maia J, Bentsink L, Ligterink W, Hilhorst HW. Acquisition and loss of desiccation tolerance in seeds: from experimental model to biological relevance. Planta. 2015;241(3):563-77. doi: 10.1007/s00425-014-2240-x
4. Oliver MJ, Tuba Z, Mishler BD. The evolution of vegetative desiccation tolerance in land plants. Plant Ecol. 2000;151(1):85-100. doi: 10.1023/a:1026550808557
5. Bewley J, Bradford KJ, Hilhorst HWM, Nonogaki H. Seeds: Physiology of Development. New York (US): Springer-Verlag; 2013.
6. Castro LE, Guimarães CC, Faria JMR. Physiological, cellular and molecular aspects of the desiccation tolerance in *Anadenanthera colubrina* seeds during germination. Braz J Biol. 2017;77:774-80. doi: 10.1590/1519-6984.00616
7. Dickie JB, Prichard HW. Systematic and evolutionary aspects of desiccation tolerance in seeds. In: Black M, Pritchard HW, editors. Desiccation and survival in plants: drying without. New York (US): CABI Publishing; 2002. p. 239-59.
8. Masetto TE, Faria JMR, Queiroz SEE. Avaliação da qualidade de sementes de cedro (*Cedrela fissilis* - Meliaceae) pelo teste de raios X. Ciên Agrotec. 2008;32:1708-12. doi: 10.1590/S1413-70542008000600004
9. Masetto TE, Faria JMR, Fraiz ACR. Loss and re-establishment of desiccation tolerance in the germinated seeds of *Sesbania virgata* (Cav.) (Pers.). Acta Sci Agro. 2015;37:313-20. doi: 10.4025/actasciagron.v37i3.19373
10. Rodrigues AC, Alvarenga AAD, Ribeiro DE, Guimarães RM, Alves E, Silva Junior JMD. Reindução da tolerância à dessecação em sementes de *Bauhinia forficata* Link (Fabaceae). Cerne. 2015;21:579-86. doi: 10.1590/01047760201521041377
11. Ribeiro DE, Alvarenga AAD, Martins JR, Rodrigues A, Maia VO. Germinação e reindução da tolerância à dessecação em sementes de *Senna multijuga* (Rich.) Irwin et Barn. Ciên Flores. 2016;26:1133-40. doi: 10.5902/1980509825031
12. Freire FCDJ, Silva-Pinheiro JD, Santos JS, Silva AGLD, Camargos LSD, Endres L, et al. Proline and antioxidant enzymes protect *Tabebuia aurea* (Bignoniaceae) from transitory water deficiency. Rodriguesia. 2022;73:1-13. doi: 10.1590/2175-7860202273031
13. Tweddle JC, Dickie JB, Baskin CC, Baskin J. Ecological aspects of seed desiccation sensitivity. J Ecol. 2003;91(2):294-304. doi: 10.1046/j.1365-2745.2003.00760.x
14. Lorenzi H. Árvores brasileiras: Manual de identificação e cultivo de plantas arbóreas nativas do Brasil. 2. ed. Nova Odessa (SP): Editora Plantarum; 2008.
15. Soares JJ, Oliveira AKMD. O paratudal do pantanal de Miranda, Corumbá-MS, Brasil. Rev Árv. 2009;3:339-47. doi: 10.1590/2175-7860202273031
16. Silva MD, Queiroz LD. A família Bignoniaceae na região de Catolés, Chapada Diamantina, Bahia, Brasil. Sit Sér Ciê Biol. 2003;3(1/2):3-21. doi: 10.1590/2175-7860201869243
17. Cabral EL, Barbosa DCDA, Simabukuro EA. Crescimento de plantas jovens de *Tabebuia aurea* (Manso) Benth. & Hook. f. ex S. Moore submetidas a estresse hídrico. Acta Bot Bra. 2004;18:241-51. doi: 10.1590/S0102-33062004000200004
18. StatSoft South America [Internet]. Brasil; 2022 [citado em 24 jan de 2022]. Disponível em: http://www.statsoft.com.br
19. Maia J, Dekkers BJW, Provart NJ, Ligterink W, Hilhorst HWM. The re-establishment of desiccation tolerance in germinated *Arabidopsis thaliana* seeds and its associated transcriptome. PLoS one. 2011;6(12):e29123. doi: 10.1371/journal.pone.0029123
20. Sadras VO, Milroy SP. Limiares de água no solo para respostas de expansão foliar e troca gasosa: uma revisão. Pes Cult Cam. 1996;47:253-66.
21. Smith MD, Wilcox KR, Power SA, Tissue DT, Knapp AK. Assessing community and ecosystem sensitivity to climate change–toward a more comparative approach. J Veget Scien. 2017;28(2):235-7. doi: 10.1111/jvs.12524

22. Silva EE. Produção de mudas de *Tabebuia aurea* (manso) Benth. & Hook. f. ex. s. moore (Bignoniaceae) com qualidade em diferentes embalagens e substratos. Con-Ciên Tec. 2014;8(2):1-12. doi: 10.21439/conexoes.v8i2.638
23. Zhang Y, Equiza MA, Zheng Q, Tyree MT. Factors controlling plasticity of leaf morphology in *Robinia pseudoacacia* L. II: the impact of water stress on leaf morphology of seedlings grown in a controlled environment chamber. Ann For Sci. 2012;69(1):39-47. doi: 10.1007/s13595-011-0134-7
24. Egea G, Nortes PA, Domingo R, Baille A, Pérez-Pastor A, González-Real MM. Almond agronomic response to long-term deficit irrigation applied since orchard establishment. Irrig Scien. 2013;31:445-54. doi: 10.1007/s00271-012-0322-8
25. Leigh A, Sevanto S, Close JD, Nicotra AB. The influence of leaf size and shape on leaf thermal dynamics: does theory hold up under natural conditions? Plant, Cell & Environment. 2017;40(2):237-48. doi: 10.1111/pce.12857
26. Taiz L, Zeiger E. Plant Physiology. 3rd ed. Sunderland (GB): Sinauer Associates; 2004.
27. Larcher W. Ecofisiologia vegetal. 1. ed. São Paulo (SP) Rima Artes e Textos; 2004.
28. Bhadouria R, Singh R, Srivastava P, Raghubanshi, AS. Understanding the ecology of tree-seedling growth in dry tropical environment: a management perspective. Energy, Ecology and Environment. 2016;1(5):296-309. doi: 10.1007/s40974-016-0038-3