



Morphophysiological responses to drought in *Ouratea fieldingiana* (Gardner) Engl. (Ochnaceae), a species endemic to the semiarid savannas of Brazil

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ABSTRACT

Increased frequency and duration of droughts are projected due to climate change, with northeastern Brazil's semi-arid region being one of the most affected globally. These changes in rainfall are expected to be particularly harmful to seedlings, impacting plant species' population dynamics. We conducted a greenhouse experiment to assess how different water deficit levels affect the performance and morphophysiological responses of seedlings of *Ouratea fieldingiana* (Ochnaceae), a plant species endemic to the northeastern coast of Brazil. We hypothesized that higher water deficits would lead to significant reductions in seedling growth and alterations in morphophysiological traits. Overall, the seedlings demonstrated slow development, characterized by increased root allocation, fewer leaves, and a reduced leaf area ratio (LAR). Water stress further decreased growth, number of leaves, and relative water content (RWC%) while increasing floating leaf asymmetry (FLA). Furthermore, *O. fieldingiana* seedlings displayed limited capacity to acclimatize to very severe conditions, with all seedlings succumbing within the first 15 days. We conclude that severe water limitation may compromise the recruitment and survival of *O. fieldingiana* under prolonged drought scenarios, posing a significant risk to natural populations in the face of climate change.

Keywords: Coastal savanna, ecophysiology, morphophysiological traits, semiarid, water stress

Introduction

Climatic conditions, notably water availability, play a crucial role in the distribution of plant species across natural environments (Bernacchi & Vanlooche, 2015; Tshwene-Mauchaza & Aguirre-

Gutiérrez, 2019). However, global climate change predictions for this century indicating hotter, drier, and more unpredictable conditions affect the fine relationship between plants and the environment, putting a considerable portion of biodiversity at risk worldwide (Pachauri *et al.*,

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2014). The Brazilian semi-arid regions are among the most sensitive to climate change, experiencing a progressive increase in aridity over time (Walther *et al.*, 2002; Salvatierra *et al.*, 2017).

The Northern Coast of the Brazilian Northeast (NCBN), situated between Rio Grande do Norte and Maranhão states, is geographically located in an ecotonal region where the domains of Caatinga, Cerrado, and Atlantic Forest converge. This convergence fosters the formation of a floristic-vegetation complex rich in biodiversity, harboring species characteristic of each biome (Matias & Nunes, 2001; Freitas & Matias, 2010; Moro *et al.*, 2011; Castro *et al.*, 2012). The NCBN lies within the semi-arid zone, characterized by seasonal and irregular rainfall (Brasil, 2002; Ab'Sáber, 2006). Therefore, plant species in NCBN areas are naturally subjected to significant variations in water availability due to irregular rainfall patterns. Despite this, little is known about the response of plant growth and functional characteristics to changes in soil water availability in species that occur in the NCBN, especially those endemic to this environment.

The establishment of seedlings represents a critical phase in the life cycle of plants and determines both the distribution and the abundance of species in plant communities (Armstrong & Westoby, 1993; Harrison & laForgia, 2019). Soil water availability is an important environmental filter that affects individual plant performance, strongly influencing seedling growth and mortality across contrasting natural ecosystems (Baskin & Baskin, 2014; Westerband *et al.*, 2019; Li *et al.*, 2020). Thus, under limitations in water availability, plants can have strategies that favor the absorption of water by the roots and that minimize loss through the leaves. This can result in a significant increase in root growth relative to shoot growth, negatively impacting the plant's aboveground development (Aidar *et al.*, 2015; Pezzopane *et al.*, 2015; Silva *et al.*, 2017). The elongation of secondary roots, as well as root hairs, has been described in the literature as an adaptive response of plants in conditions of low water potential (Larcher, 2000;

Jackson *et al.*, 2007). In addition, in conditions of water limitation, the reduction in the number of leaves, in the leaf area and specific leaf area (SLA - leaf area per unit of leaf mass) has been strongly related to the efficiency in the use of resources and the tolerance to environmental stresses, mainly to water stress (Ackerly *et al.*, 2000; Poorter, 2009; Wright *et al.*, 2017; Souza *et al.*, 2018). Although plants exhibit functional responses to water stress, their ability to make morphophysiological adjustments depends on genetic factors and phenotypic plasticity, both of which are intrinsic to the species. This capacity is also influenced by the intensity and duration of the drought (Carvalho, 2005; Ferreira *et al.*, 2015; JinHang *et al.*, 2019).

Under low soil moisture conditions, water flow within plants is reduced, and transpiration rates can exceed root water absorption, negatively impacting plant water status (López *et al.*, 2022; Koehler *et al.*, 2023). Relative water content (RWC) of plants serves as a reliable and cost-effective indicator of water status, widely used in the literature (Bussotti *et al.*, 2002; Silva *et al.*, 2010; Díaz-Barradas *et al.*, 2020). This measurement indicates the water content in the leaves. As the water deficit worsens, plants undergo protoplasmic dehydration, which negatively impacts photosynthesis as well as their morphological and biomechanical properties (Kaiser, 1987; Kampowski *et al.*, 2018). Another measure that can reflect water stress in plants is floating leaf asymmetry (FLA), which assesses small random variations in the bilateral symmetry of morphological traits. This tool, widely used to evaluate developmental instabilities in both plants and animals, represents minor random variations in bilateral symmetry (Palmer & Strobeck, 1986; Souza *et al.*, 2005). As the level of stress increases, bilateral asymmetry in organisms also tends to rise (Palmer & Strobeck, 1986; Beasley *et al.*, 2013). Although various environmental factors can contribute to asymmetry, studies such as Fair & Breshears (2005) suggest that water stress can influence developmental stability during leaf formation.



In light of current climate changes that are altering precipitation patterns, particularly in Brazilian semi-arid ecosystems (Walther *et al.*, 2002; Salvatierra *et al.*, 2017), studying the relationships between environmental variables and plant adaptive responses is essential. This knowledge is crucial for understanding the evolutionary processes that ensure the maintenance of ecosystems and biodiversity in the face of potential global climate changes (Hooper *et al.*, 2012; Cardinale *et al.*, 2012; Garcia *et al.*, 2014; Arruda *et al.*, 2018). The present study aimed to evaluate the morphophysiological responses of *Ouratea fieldingiana* (Gardner) Engl. (Ochnaceae) seedlings, endemic to the coastal savannas of northeastern Brazil, under different water regimes. We hypothesized that varying water deficit levels would affect the performance of *O. fieldingiana* seedlings and influence their morphophysiological responses. Specifically, we predicted that higher water deficit intensity would lead to decreased seedling growth, number of leaves, and relative water content (RWC%) while increasing root-to-shoot ratio and floating leaf asymmetry (FLA).

Material and Methods

Species and study area

Ouratea fieldingiana, popularly known in Portuguese as batiputá, is a tree-shrub plant of 2 to 4 m in height, endemic to the coastal savannas of northeastern Brazil (Chacon & Yamamoto, 2015). The plant is semi-deciduous, with flowering occurring from August to February and peak fruiting from November to February (Forzza *et al.*, 2010). *Ouratea fieldingiana* has great cultural and economic importance for the traditional communities, being used for several purposes, such as in human and animal nutrition, the manufacture of artifacts, medicines, healing practices, and rituals. (Pinto *et al.*, 2019). In addition, the oil extracted from the seeds of *O. fieldingiana* has pharmacological potential as a pharmaceutical input (Pinto, 2017). Despite the

socio-environmental importance, little is known about the biology/ecology of the species and reports from traditional communities describe a reduction in natural populations and the rate of natural regeneration of *O. fieldingiana*.

The *O. fieldingiana* population assessed in this study is located in a coastal savannah area in the Acaraú municipality (2°53'20.64" S 40°6'47.52" O), in the extreme western region of Ceará State, Brazil. The climate of the region is seasonal, classified as AW tropical hot semi-arid mild with an average temperature between 26 ° to 28 ° C (Fig. 1) (Alvares *et al.*, 2013). Rainfall is concentrated between January to May (summer-autumn), with approximately 90% of the annual precipitation occurring during this period. The historical average annual rainfall is 1147 mm (INMET, 2019; FUNCEME, 2019). Specimens of *O. fieldingiana* were collected, herbarized, and deposited in the Herbarium Prof. Francisco José de Abreu Matos at the Universidade Estadual Vale do Acaraú (HUVA), under registration number 27399.

Seed collection, germination, and seedling production

In March 2020, mature seeds of *O. fieldingiana* were directly collected from the dispersal point of 20 reproductively mature individuals ranging in height from 2 to 3 meters. All the selected *O. fieldingiana* individuals for this study had well-developed canopies and were in good phytosanitary condition (*e.g.* without lianas or parasitic plants). The collected seeds were taken to the Laboratório de Botânica e Ecologia Vegetal (LABEV) of the Instituto Federal de Educação, Ciência e Tecnologia do Ceará (IFCE / Campus Acaraú), where they were processed manually. During the process, seeds of similar size and free from deformities, predation, or signs of pathogens were selected.

Immediately after field collection, 200 seeds were selected. These seeds were subjected to disinfestation in a solution of 1% sodium hypochlorite for 2 minutes and rinsed with water afterward. The seeds were allocated to germinate in trays lined with filter paper moistened with



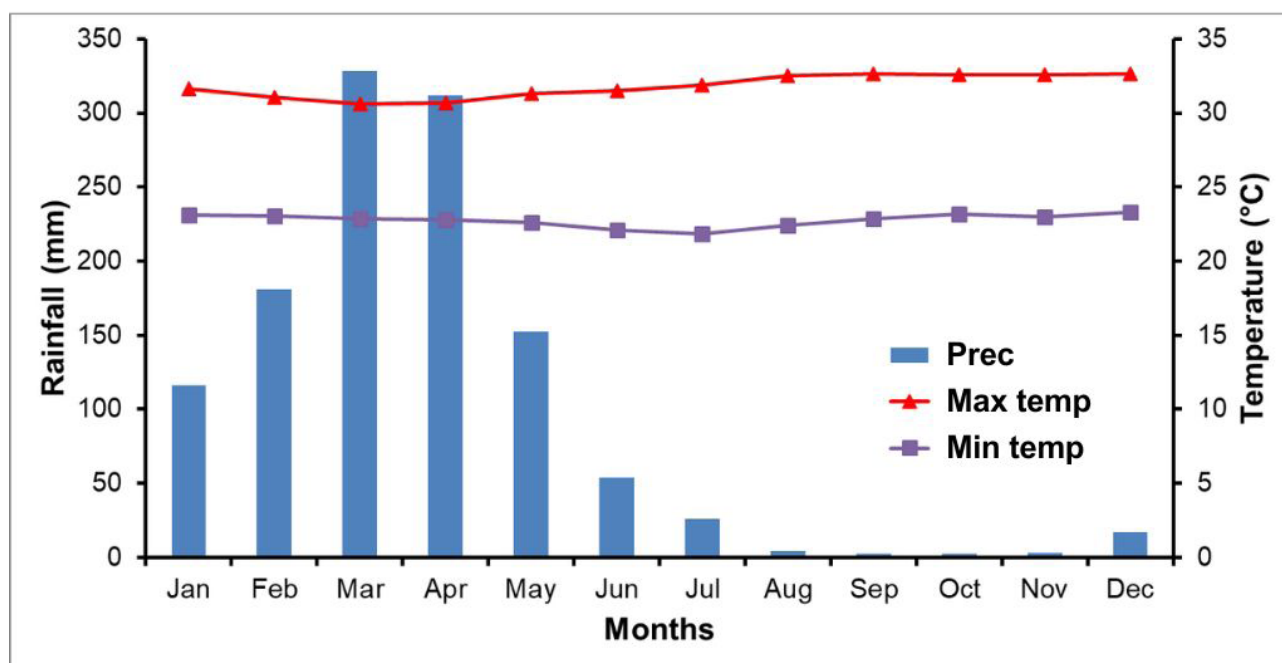


Figure 1. Historical average monthly rainfall and temperature in Acaraú-CE.

distilled water in a dark chamber at room temperature. Germination started on the 10th day and occurred synchronously and uniformly during the evaluation period. The seeds showed high germination, about 90% of the seeds germinated under these conditions. After germination, the seedlings were placed in pots with approximately 0.2 L filled with sandy soil from the collection site. Before planting, the soil was thoroughly sieved to remove rocks, roots, and other debris, ensuring a uniform substrate. The sandy soil used as the substrate had a loose texture, allowing for proper drainage, and was selected to simulate the natural conditions in which *O. fieldingiana* typically grows. The pots with the seedlings were randomly placed in a greenhouse under full sun, avoiding mutual shading. The seedlings were watered daily until the field capacity of the soil for 2 months. After this period, the seedlings reached approximately 4 cm in height and were used in the water deficit experiments.

Water treatments

For the water stress experiment, 50 seedlings were transplanted into pots ~ 0.5 L filled with completely dry organic substrate (3:1 mixture of organic substrate enriched with nutrients

and sand), marked, randomly arranged on the benches, and eventually rearranged avoiding shading mutual.

Previously, the field capacity of the soil was evaluated and the height and diameter of the stem of all seedlings used in this experiment were measured. The seedlings used in the different treatments exhibited normal development and showed no differences in height ($F = 0.01$; $P = 0.99$) and stem diameter ($F = 0.01$; $P = 0.98$) at the beginning of the experiment. Immediately after transplanting the seedlings, differentiation of water treatments was initiated. The seedlings were subjected to five water availability treatments, which were divided into 10%, 20%, 40%, 80%, and 100% of soil field capacity (FC%). Ten seedlings were used per treatment. Daily and always at the same time, between 8 and 10 a.m., the pots with the seedlings were weighed, to check the amount of water consumed and, later, the volumes were added to maintain the water capacity of each treatment (Cabral *et al.*, 2004). Simultaneously, seedling mortality was evaluated.

After experiment initiation, fortnightly the seedlings were measured for the increase in height and stem diameter. The stem diameter was measured with a digital caliper at ground

level and height using a transparent ruler with the zero point positioned at ground level, going up to the apical bud. After 90 days, the experiment was completed and the morphophysiological traits related to the allocation of biomass and leaves were evaluated. For this, the seedlings were removed and washed under running water, separating roots and shoots. Subsequently, the different parts of the seedlings were packed in paper bags and placed in an oven at 70 °C until they reached constant dry weight.

Prior to shoot biomass measurement, three leaves per seedling were collected for analysis of leaf morphophysiological traits. These leaves were immediately weighed on a precision scale to determine fresh mass and photographed alongside a millimeter ruler for later determination of leaf area (LA in cm²), leaf length (LL in cm), and leaf width (LW in cm) using the ImageJ software (Schneider *et al.*, 2012). From the leaf length and width data, the LL / LW ratio was calculated. Floating leaf asymmetry (FLA) was also calculated considering the central rib as the axis of symmetry using the difference between the right (LR) and left (LL) widths of the leaf blade ($FLA = |LR - LE|$). After being photographed, the leaves were soaked in water for 24 hours and weighed, thus obtaining turgid leaf weight. Soon, after obtaining the turgid weight, the leaves were stored in paper bags and placed in an oven at 70 °C until they reached the constant leaf dry weight. Finally, we calculated the relative water content in percentage ($RWC\% = [(fresh\ mass - dry\ mass) / (saturated\ mass - dry\ mass)] \times 100$); the specific leaf area (SLA; leaf blade area per unit dry leaf mass; in cm²g⁻¹) and leaf area ratio (LAR; leaf blade area per unit total dry mass of the individual; in cm²g⁻¹).

Data analysis

We started the analyses by evaluating the effect of water treatments on the mortality of *O. fieldingiana* seedlings through survival analysis (Crawley, 2013). For this analysis, we used the *survival* package (Therneau, 2024). Survival analysis is indicated to assess the probability of an event occurring over a period of time,

avoiding temporal pseudo-replication (Souza *et al.*, 2015). In this case, seedling mortality within each treatment was used as a response variable, while time (days after starting water treatment with seedling death) was the explanatory variable.

To test the relationship between the morphophysiological traits of *O. fieldingiana* with the different water treatments, Generalized Linear Models (GLM) were built using Gaussian error distribution for each response variable, according to the model's criticism (Crawley, 2013), we used the RT4Bio package (Reis *et al.*, 2015). We built models to assess the effect of water treatments on seedling growth over time. In this case, the height and diameter of the seedling stem were used as response variables, while water treatments and time (days after starting water treatment) were the explanatory variables. Finally, the effect of water treatment on traits related to biomass allocation for roots shoots and leaves was evaluated, which were used as response variables and water treatments were the explanatory variables. The models were compared using the F test, and contrast analysis was used to group the water treatments (Crawley, 2013).

All the models created were compared with the null model, and the minimum adequate model was adjusted with the omission of non-significant terms. The adequacy of the models was tested through waste analysis (Crawley, 2013). All data from this study were analyzed using the R software (R Core Team, 2013).

Results

The survival of *O. fieldingiana* seedlings over time was affected by water treatments ($X^2 = 154.45; P < 0.001$). All seedlings submitted to the most severe water availability treatments (10 and 20% of FC) died within the first 15 days of the experiment (Fig. 2). Consequently, these groups were excluded from subsequent analyses. The treatments of water availability of 40%, 80%, and 100% of the FC had mortality between 30 and 40% of the analyzed seedlings, without varying in the mortality time between these treatments (Fig. 2).



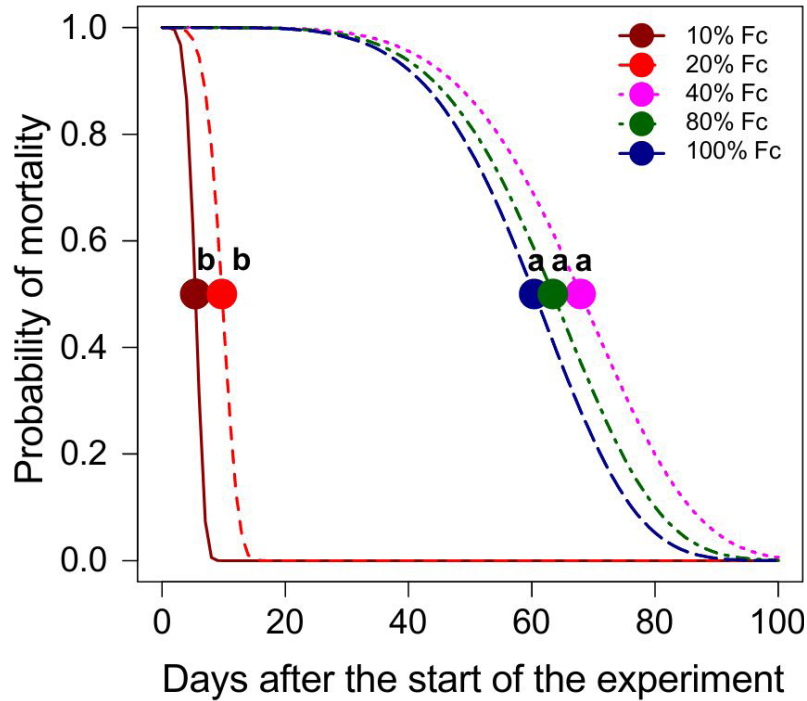


Figure 2. Time to seedling mortality for *Ouratea fieldingiana* in different water conditions. Points indicate the time required for mortality of 50% of the seedlings in different water conditions. Different letters represent statistical ($p < 0.05$) differences by contrast analysis among treatments.

At the end of the experiment, after 5 months of cultivation, the seedlings had a height between 4.5 and 7.3 cm (Table S1). Water stress significantly affected seedling growth over time (Table 1). The effects of water treatments on the height and diameter of the seedling stem were clear between the 30th and the 45th day after the beginning of the experiment (Fig. 3). Seedlings of treatments with 80 and 100% of FC showed statistical similarity in GLM for height, with final average values of 6.1 cm and 6.2 cm ($F=1.00$; $P=0.32$), respectively, and stem diameter, with final average values of 2.54 mm and 2.62 mm ($F=0.01$; $P=0.91$), respectively. Seedlings submitted to treatment

with 40% FC showed a growth reduction of 25% for height and 20% for stem diameter when compared to treatments with 80 and 100% FC.

Our results indicate that water stress affected the biomass partition in *O. fieldingiana* (Fig. 4). Seedlings submitted to water treatments of 40% of FC showed higher root biomass (Fig. 4A) and greater investment in root/shoot ratio (Fig. 4D) when compared to the treatments with 80 and 100% of FC, which did not differ between them. Seedlings subjected to water stress of 40% FC showed root biomass up to 2.5 times greater than seedlings subjected to treatment with 80% FC and about 5 times the seedlings under treatment

Table 1. Deviance analysis of complete models to test the effects of water treatments and time on early development of *Ouratea fieldingiana*.

Response variable	Explanatory variable	DF	Deviance	Deviance residual	F	P
Height	Treatment	2	5.89	131.63	5.41	<0.01
	Time	1	25.63	106.00	47.02	<0.001
	Treatment *Time	2	5.16	100.84	4.73	<0.01
Stem diameter	Treatment	2	1.31	48.21	5.82	<0.01
	Time	1	26.40	21.81	235.17	<0.001
	Treatment *Time	2	1.04	20.77	4.64	<0.05

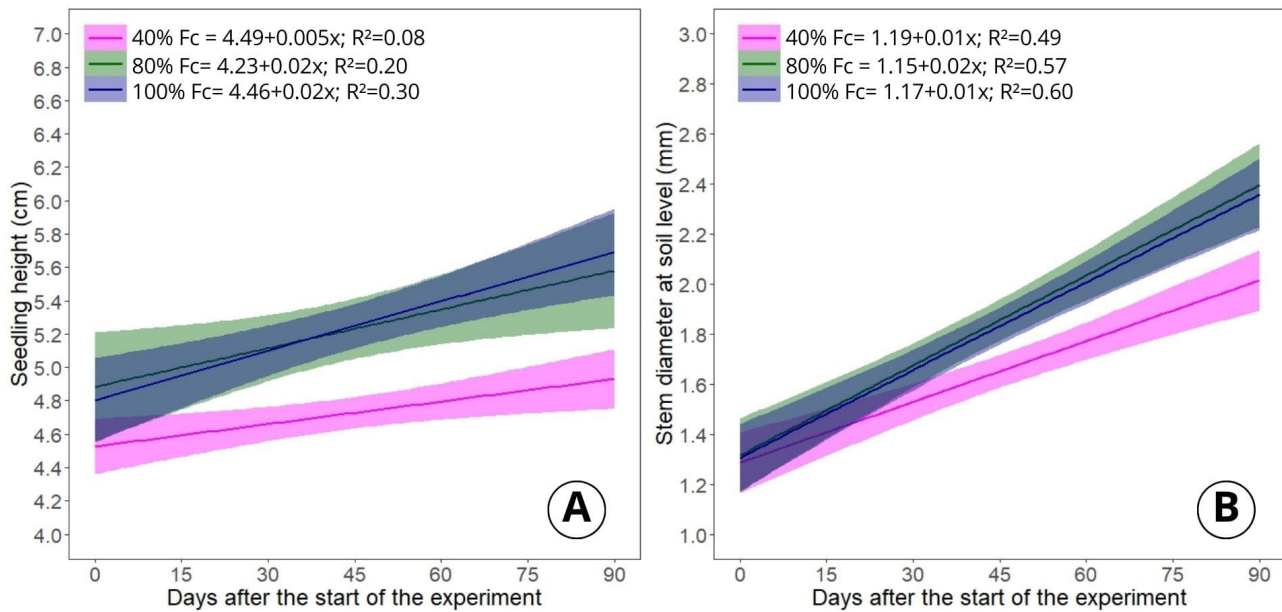


Figure 3. A) Height and B) stem diameter of *Ouratea fieldingiana* seedlings submitted to different water conditions.

of 100% FC. There was no significant effect of water stress on shoot biomass (Fig. 4B) and total seedling biomass (Fig. 4C).

Most of the leaf morphophysiological traits of *O. fieldingiana* seedlings evaluated in this study were not affected by water availability (Table 2). The leaf area, leaf length, leaf width, LL / LW ratio, and SLA were not affected by water stress treatments. However, the LAR and number of leaves were significantly lower in the seedlings

submitted to treatment with 40% FC when compared to treatments with 80 and 100% FC, which did not differ between them. In addition, leaves from seedlings subjected to treatment with 40% FC showed a higher level of water stress, with lower RWC% and greater floating leaf asymmetry (FLA) when compared to treatments with greater water availability, which also did not differ between them.

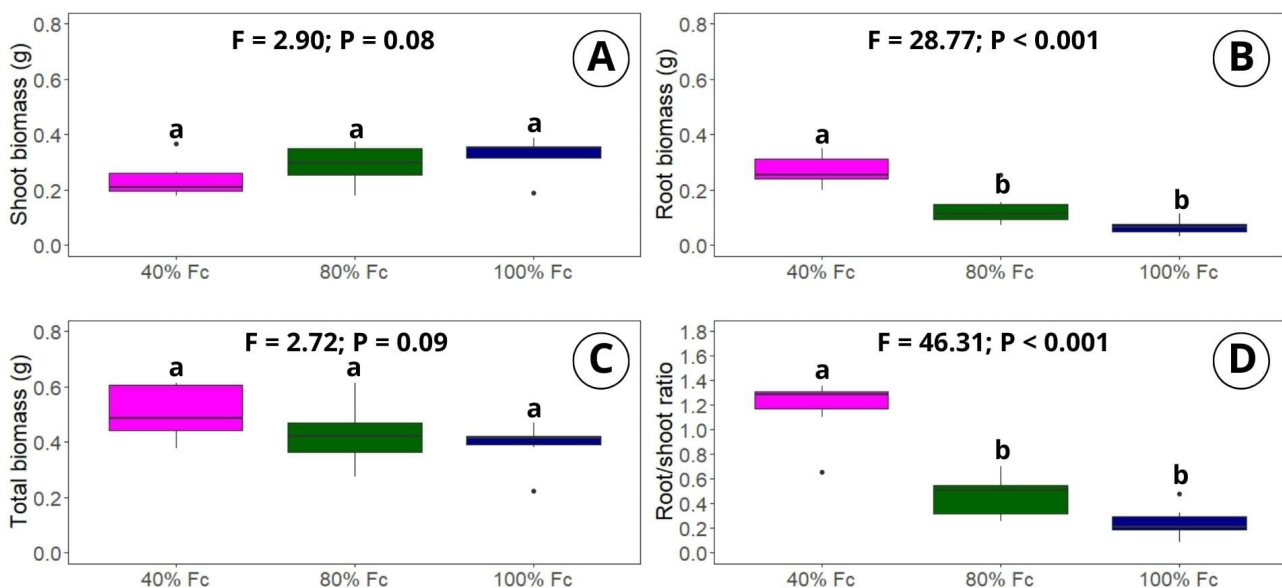


Figure 4. Effects of water availability on the allocation of biomass in seedlings of *Ouratea fieldingiana* to: A) Root biomass (g); B) Shoot biomass (g); C) Total biomass (g); D) Root/shoot ratio. The mean values and standard error for each water treatment are shown. Different letters indicate a significant difference between the treatments studied via contrast analysis ($p < 0.05$).



Table 2. Effect of water conditions on leaf traits of *Ouratea fieldingiana*. Mean values and standard error (in brackets) are shown. Different letters after mean and standard deviation indicate significant differences among water treatments in contrast analysis in generalized linear models ($P < 0.05$).

Leaf traits	Water conditions		
	40% CC	80% CC	100% CC
Leaf length	2.41 (0.14)a	2.52 (0.35)a	2.13 (0.06)a
Leaf width	1.05 (0.08)a	1.05 (0.05)a	0.86 (0.05)a
Leaf length / width ratio	2.45 (0.25)a	2.40 (0.31)a	2.49 (0.13)a
Leaf área	1.93 (0.16)a	2.11 (0.32)a	2.25 (0.06)a
Number leaf	8.29 (0.78)b	11.17 (0.54)a	10.86 (0.51)a
SLA	123.09 (10.82)a	137.30 (10.39)a	136.94 (6.67)a
LAR	3.44 (0.38)b	5.78 (0.79)a	7.48 (0.38)a
RWC%	60.13 (3.58)b	77.17 (2.14)a	82.16 (4.19)a
FLA	0.06 (3.32 ⁻³)a	0.03 (3.83 ⁻³)b	0.03 (4.73 ⁻³)b

Discussion

In this study, we investigated the effects of varying water availability levels on the growth and morphophysiological responses of *O. fieldingiana*, an endemic species found in the Brazilian semiarid coastal savannas. Our findings indicate that water limitation had a negative impact on the performance of *O. fieldingiana*. Seedlings subjected to low water availability conditions exhibited higher mortality rates, reduced growth, decreased number of leaves, and decreased relative water content (RWC%), as well as increased fluctuating leaf asymmetry (FLA). These results support our hypothesis and align with previous studies that have reported similar effects of water stress on other plant species occurring in the Brazilian semiarid region (Figueirôa *et al.*, 2004; Silva *et al.*, 2010; Ferreira *et al.*, 2015).

Notably, we observed complete mortality of all *O. fieldingiana* seedlings subjected to severe water stress levels of 10% and 20% of field capacity (FC). The initial developmental conditions of seedlings, as well as their genetic characteristics and levels of phenotypic plasticity, can influence their ability to acclimatize to unfavorable water conditions (Smedt *et al.*, 2012; JinHang *et al.*, 2019). Plants that develop under conditions of limited water availability in the soil tend to exhibit greater capacity for development and establishment in the face of water stress conditions (Dias-Filho *et al.*, 1989; Alves *et al.*, 2020). Li *et al.* (2020)

have demonstrated that not only the amount but also the timing of water availability can strongly influence seedling performance, as well as their underlying morphology and physiology. In our experiment, *O. fieldingiana* seedlings were initially cultivated under favorable water conditions, hindering their acclimatization to water-restricted conditions. The water conditions experienced by *O. fieldingiana* seedlings in our study resemble those in their natural habitat. The region where the species occurs receives rainfall concentrated between January and May, accounting for approximately 90% of the total annual rainfall, with a long dry period. The high mortality rates observed in the 10% and 20% FC treatments in our experiment may represent a limitation to recruitment in natural conditions, particularly in the context of advancing arid conditions towards the Northeast of Brazil (PBMC, 2014; Marengo *et al.*, 2017, Soares *et al.*, 2021).

In addition to the complete mortality observed in the treatments with 10% and 20% FC, *O. fieldingiana* seedlings subjected to 40% FC conditions exhibited a significant reduction in RWC% and increased FLA. It is important to note that the initial development conditions of the seedlings in this experiment were carried out without water limitation, which may have influenced stomatal control. This could have led to increased transpiration rates and made it more difficult for the plants to replenish water due to the limited soil moisture in the 40% FC

treatment. The absence of water stress in the early stages of seedling development can result in enhanced stomatal conductance, and increasing transpiration under subsequent water restrictions (Chaves *et al.*, 2009). While plants can restore their water status under conditions of sufficient water availability in the soil, this may not occur under water-limited conditions, leading to irreversible damage (Calbo & Moraes, 1997; Slot & Poorter, 2007; Bento *et al.*, 2016). Many plants partially close their stomata during periods of high evaporative demand when exposed to water deficit, to avoid excessive water loss (Ferreira *et al.*, 2015; Scalón *et al.*, 2020). Moreover, the increased fluctuating leaf asymmetry observed in seedlings subjected to the 40% FC treatment further indicates water stress. Under conditions of environmental stress, organisms have a reduced capacity to correct small developmental errors, which can manifest as leaf asymmetry, as demonstrated in our study (Palmer & Strobeck, 1986; Beasley *et al.*, 2013).

The *O. fieldingiana* seedlings exhibited slow development, as even after 5 months of cultivation, their height did not exceed 7.3 cm. These results align with the initial development patterns observed in other coastal vegetation species (Zamith & Scarano, 2004; Fidalgo *et al.*, 2009), indicating that this growth pattern may be an adaptive trait in response to the high luminosity, water stress, and nutrient-poor soils found in these ecosystems (Henriques *et al.*, 1986; Magnago *et al.*, 2010). In this context, plants with slow growth rates invest their limited resources in developing robust root systems, allowing them to efficiently explore the soil for water and nutrients (Comas *et al.*, 2013). Additionally, slow growth can be advantageous in water-stressed environments as it reduces the overall water requirements of the plant (Freschet *et al.*, 2018). Thus, species adapted to this environment tend to employ conservative development strategies and various ecophysiological adaptations that enhance their survival (Gessler *et al.*, 2007; Pires *et al.*, 2012). However, chronic photoinhibition and reduced energy dissipation capacity pose limitations to

plant development in this semiarid environment (Scarano *et al.*, 2002).

When exposed to moderate water limitation (40% FC), *O. fieldingiana* seedlings demonstrated adaptive trait adjustments in response to water stress, primarily through increased investment in the root system, reduced number of leaves, and decreased leaf area ratio (LAR). The increased investment in the root system enhances the water absorption area in the soil, while the reduction in leaf area minimizes water loss through transpiration, thereby delaying cellular dehydration processes (Aranda *et al.*, 2015; Silva-Pinheiro *et al.*, 2016). These adaptive strategies involve a complex trade-off aimed at minimizing water loss, but they also negatively affect photosynthesis, limiting biomass production due to reduced CO₂ fixation and light interception, thereby impeding the growth and development of several plant species (Silva *et al.*, 2010; Ferreira *et al.*, 2015; Cerqueira *et al.*, 2015; Savi *et al.*, 2017).

Projections indicate that the semiarid region, where *O. fieldingiana* occurs, will be among the areas most impacted by climate change (Marengo *et al.*, 2017; Soares *et al.*, 2021). Average temperatures are expected to rise by up to 4.5°C, with a 50% reduction in rainfall and more frequent, prolonged droughts (PBMC, 2014). These changes are likely to exacerbate regional water deficits and contribute to intensifying desertification in certain areas (Walther *et al.*, 2002; PBMC, 2014; Salvatierra *et al.*, 2017). Our experiment revealed a limited capacity for *O. fieldingiana* seedlings to adapt to the severe water conditions anticipated for the semi-arid region. The high mortality rate observed in seedlings subjected to the lowest water availabilities (10% and 20%) within the first 15 days of the experiment reinforces this conclusion and raises concerns about the viability of natural populations under ongoing climate change. Given this scenario, the ability to adjust morphophysiological traits in response to environmental conditions represents an important mechanism for individuals to cope with environmental fluctuations, thus playing a crucial role in preventing local extinctions in the



face of climate change (Matesanz *et al.*, 2010; Hoffmann & Sgró, 2011; Lázaro-Nogal *et al.*, 2015). Our findings suggest that *O. fieldingiana*, as an endemic species, may be particularly vulnerable to the rapid environmental changes predicted for this century.

In summary, our study provides evidence that water availability can significantly influence seedling performance and underlying morphophysiological traits. The recruitment of *O. fieldingiana*, a key endemic species in the coastal savannas of northeastern Brazil, may be constrained by future severe and prolonged drought events. To gain a better understanding of how *O. fieldingiana* and other species in these ecosystems might respond to projected climate change scenarios, further studies incorporating water limitation and prolonged drought events are needed.

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Authors' Contributions

Matheus Lopes Souza – Roles: Conceptualization, Formal analysis, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

Renata Kécia de Oliveira – Roles: Roles: Conceptualization, Methodology, Visualization, Writing – original draft.

Ingrid H'Oara Carvalho Vaz da Silva – Roles: Conceptualization, Methodology, Visualization, Writing – original draft.

Rafaela Camargo Maia – Roles: Conceptualization, Methodology, Supervision, Visualization, Writing – original draft.

Conflict of Interest

We declare that there are no conflicts of interest (personal, scientific, commercial, political, or financial) in the article.

Supplementary Material

The following online material is available for this article:

Table S1. Development of seedlings of *Ouratea fieldingiana* in different water conditions.

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