Evaluation of the resistance to water stress of the two (2) agroforestry species in nurseries *Gmelina arborea* and *Jatropha curcas*in Faranah

Abstract

One of the main abiotic limitations in tropical agroforestry and nursery production systems is water stress or drought. The purpose of this study is to assess how *Gmelina arborea*and*Jatropha curcas* a fast-growing agroforestry tree species reacts to various watering schedules in nursery settings. To evaluate its resistance to water deficit,germination, important physiological and growth parameters are assessed. The findings suggestthe correlation patterns confirm the significant impact of water deficiency on physiological integrity. Under stressful circumstances, leaf necrosis significantly increased.The model explained 91.7% of the growth rate variance ($p < 0.0001$), and stressed seedlings showed reduced elongation and biomass accumulation. Collar diameter is significantly impacted by a lack of water. Its variability was explained by stress level ($p < 0.0001$) with 98.8%, suggesting a considerable reduction in stem thickening under situations of high stress.Additionally, there was a substantial correlation between stay-green and plant height, indicating that chlorophyll retention promotes seedling growth.The results guide the choice of species for plantations in water-limiting locations and nursery hardening.

Introduction

The intensification of climate change and its effects on ecosystems and the resources available for forest growth and productivity have been exacerbated by ongoing global warming (López Aguirre and Barrios Trilleras, 2024). Water supply for forests is limited by the ongoing water stress and droughts that many forest ecosystems are currently experiencing. which are predicted to become more frequent and severe (Plomion, 2016).Forest production. growth rates. and resource usage efficiency are all impacted by water constraints (Berner, 2017).Given the current state of climate change and the growing global population. environmental problems are increasingly amplified in industrialized countries. In developing countries. these problems are characterized by rising temperatures, irregular rainfall, drought, etc.

Reduced soil water availability and hot, dry weather are the main causes of water deficits.Thishas a significant impact on plant development, yield, and productivity by continuously losing water through transpiration and evaporation (Crespoet al., 2011).The frequency and distribution of rainfall, evaporative demands, and soil moisture storage capacity are just a few of the variables that affect how severe a drought will be (Jaleel, 2009). The research on agroforestry plants resistant to water stress may be a solution for agricultural development and environmental protection.Among these plants,*Gmelina arborea* (Verbenaceae) and *Jatropha curcas*(Euphorbiaceae) have already shown performance under certain conditions.

Gmelina arborea is a plant that have a capacity to adapt to many tropical settings, its quick growth. and its high-quality wood for a variety of applications make it a significant forest species(Rojaset al., 2012).Reduced water loss through natural processes is guided by plant physiological strategies in response to microclimatic cycles. One such strategy is stomatal closure, which lowers water loss through transpiration while also limiting CO_2 entry. This lowers the rate of photosynthesis and the translocation of photoassimilates to various plant organs. thereby lowering the pressure gradient required for nutrient entry through the root (Breda et al.,2006;Sachan et al., 2020).*Jatropha curcas* has become a versatile plant in the last ten years. being successfully used to produce biofuel and extract chemicals that are important in the pharmaceutical. agricultural. and industrial sectors. It can be used to revitalize underutilized mining sites and neglected territories (Solís-Ramoset al., 2023; Agganganet al., 2013; González-Chávezet al., 2017).*J. curcas* can reduce soil deterioration, desertification, and deforestation and thrives in regions with severe climates conditions and minimal precipitation (Niuet al., 2012).In order to increase the value of drought-affected land, afforestation practices should be prioritized in these places. This can be achieved by cultivating and planting drought-specific species that are economically significant. The objective of the current study was to examine how *Gmelina arborea* and *Jatropha curcas*performed under drought stress in in nursery conditions.

Materiel et method

Experimental site and Plant material

In the nursery. pot culture experiments were carried out.The experiment was performed at Hight Institute of Agronomic and Veterinary of Faranah. Two species (*Gmelina arborea* and *Jatropha curcas*) were selected to conduct the experiment. The seeds were collected from Faranah region. The studies were conducted before first shower of rainfall (From December to April).

Treatments and Experimental design

The experiment was performed with polythene bags of standard size filled with a substrate composed of potting soil (75%) and sand (25%).In order to observe the effects of drought stress on *Gmelina arborea* and *Jatropha curcas*, the watering was performed for everyday (V1), every two days (V2) and every three days (V3).The variants correspond to the following factorial treatments: E1V1:*Gmelina arborea* (every day); E1V2:*Gmelina arborea* (each 2 days);E1V3:*Gmelina arborea* (each 3 days);E2V1:*Jatropha curcas* (every day); E2V2:*Jatropha curcas* (each 2 days) and E2V3:*Jatropha curcas*(each 3 days).The experimental design used is a Complete Randomized Block FactorialDesign with 3 repetitions and 6 factorial treatments.

Morphological parameters

The measurements taken during daily cycles. The parameters evaluated were:

- Germination rate was calculated with the following formula

$$GR = \frac{\text{number of germinated seeds}}{\text{number of seeds sown}} x100$$

- The plant height.growth rate and collar diameter were determined by measurement;
- The size of leaves (SL) was calculated as described by Montgomery(1911)with SL = Leaf length × Leaf width × 0.8

Assessment of water stress

The parameters "Stay green" character and Leaf necrosis were evaluated. The "Stay green" (SG) character the behavior of a plant that remains green while under water stress by developing mechanisms that allow it to maintain its turgor despite the water deficit. The rate was determined $SG = \frac{\text{number of plants remaining green}}{\text{total number of plants}} x100$. The Leaf necrosis (LN) is caused by a prolonged and more or less severe effect of drought on plants, their intensity. and their degree of drought resistance. The rate was calculated with the following formula:

$$LN = \frac{\text{number of necrotic plants}}{\text{total number of plants}} x100$$

Statistical Analysis

The data were statistically analyzed usingGenStat Release 12.1.By comparing computed F values with tabular Fvalues, an Analysis of Variance (ANOVA) table was created and considerable variation between the various treatments was found. After determining the critical difference (CD) at 1% significance levels, a pairwise comparison of the chosen treatments was carried out.

Results

Statistical analysis of parameters

The analysis of variance results shows water stress significant (P <0.01) effect on Germination rate,stay green,leaf necrosis, growth rate andcollar diameter.Contrary, theleaf surface and growth rate were not significant (P <0.01) indicated that to two parameters were not affected by the stress (table 1).

Table 1: Analysis of Variance (ANAOVA) of parameters

	Germination rate	**Stay green**	**LeafNecrosis**	**Plant height**	**Leaf surface**	**Growth rate**	**Collar diameter**
R^2	0.990	0.937	0.866	0.487	0.344	0.917	0.988
F	246.103	35.805	15.529	2.280	1.257	26.656	190.165
Pr > F	< 0.0001	< 0.0001	< 0.0001	0.112	0.343	< 0.0001	< 0.0001

Effects of water stress on germination, stay green and leaf necrosis

The germination performance of the species under study was considerably impacted by water stress. With an R^2 of 0.990, germination rate demonstrated a very robust response to water deficit, meaning that water stress level accounted for 99% of its variability.The effect was highly significant ($F = 246.103$; $p < 0.0001$). Similarly, water stress had a significant impact on the stay-green trait, which represents the retention of leaf chlorophyll ($R^2 = 0.937$; $F = 35.805$; $p < 0.0001$). Greater water (everyday) caused seedlings to undergo chlorosis and lose their green coloration more quickly (Photo 1).Under stressful circumstances, leaf necrosis significantly increased. The regression model demonstrated a high correlation between moisture availability and tissue death, explaining 86.6% of necrosis variability ($R^2 = 0.866$; $F = 15.529$; $p < 0.0001$).Under stress conditions, leaf necrosis significantly increased. The regression model demonstrated a high correlation between moisture availability and tissue death, explaining 86.6% of necrosis variability ($R^2 = 0.866$; $F = 15.529$; $p < 0.0001$). for the

Photo 1. *Gmelina arborea*and *Jatropha curcas*in vegetation

The rates of germination differed greatly between treatments (Figure 1). *Gmelina arborea* under 2 and 3 days once watering had the highest values, both of which reached 100%, suggesting ideal conditions for seedling emergence in these treatments. Though marginally lower than Gmelina, *Jatropha curcas* under once watering 2 and 3 days likewise displayed great germination rates (96.29%). On the other hand, both species showed the lowest germination rates under watering everyday treatment (74.07%), indicating that this treatment was less conducive to seed activation and emergence. These findings show that, independent of species, once watering in 2 and 3 days conditions significantly increase seed germination, whereas watering everyday seems to be limiting for early seedling establishment.

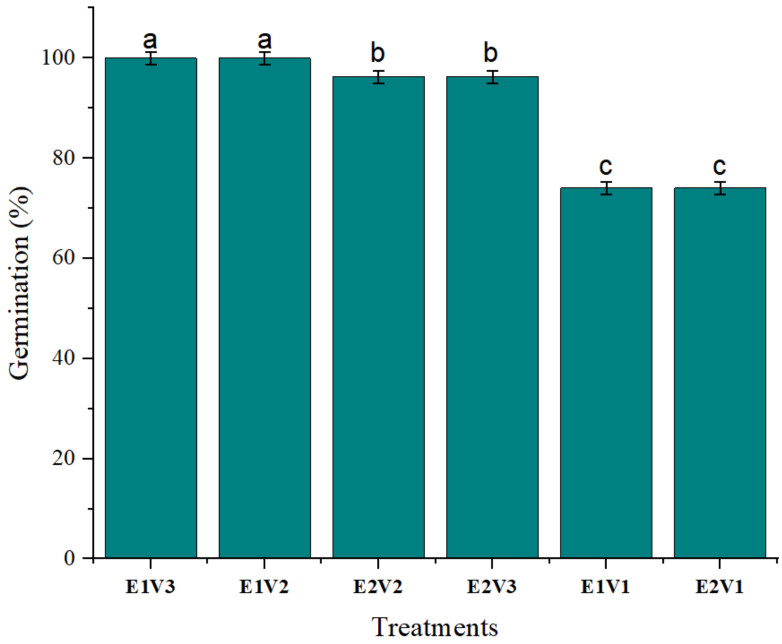

Figure 1: Effect of water stress on the Germination

Both stay-green percentage and leaf necrosis showed significant variations across treatments (figure 2). Under once watering in three days, *Gmelina arborea* (88.88%) and *Jatropha curcas* (80.55%) had the greatest stay-green values, suggesting that seedlings under once watering in 3 days are better able to retain functioning leaf under water constraint. Both species under watering every day, on the other hand, displayed 0% stay-green, indicating that this treatment significantly reduced leaf functioning and hastened senescence.The results of leaf necrosis revealed an inverse trend. *Jatropha curcas* every day watering (88.88%) and once watering every 2 days (80.55%) showed the highest levels of necrosis, indicating significant physiological damage under stress. In contrast, *Gmelina arborea* every day watering (12.63%) and *G. arborea* once watering every 2 days (44.44%) had the lowest necrosis values, indicating that Gmelina has stronger tolerance mechanisms under certain treatments.

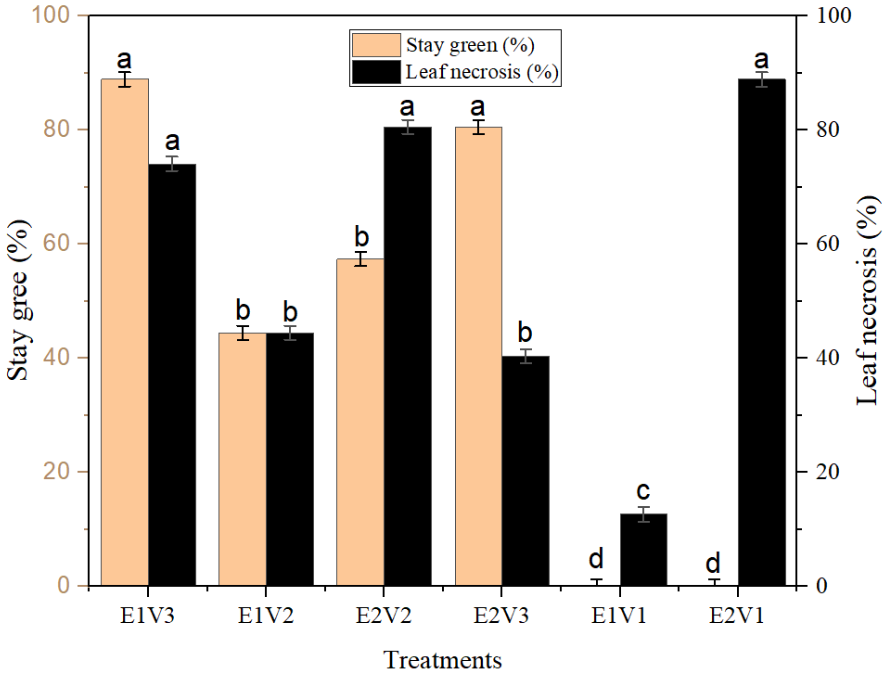

Figure 2: Impact of water stress on stay green and leaf necrosis

Effects stress water on Morphological Growth Parameters

Water stress had a minor impact on plant height, although it was not statistically significant (R^2 = 0.487; F = 2.280; p = 0.112). This reveals that plant height is not a reliable indication of stress in the species and shows a considerable degree of variability across seedlings. Similarly, leaf surface was not significantly sensitive to the stress gradient (R^2 = 0.344; F = 1.257; p = 0.343). Although leaf area tended to decrease under water deficit, but the variation was not sufficiently consistent to generate a statistically supported trend.Growth rate, on the contrary, responded strongly and significantly to water stress. Stressed seedlings exhibited decreased elongation and biomass accumulation, and the model accounted for 91.7% of growth rate variance (R^2 = 0.917; F = 26.656; $p < 0.0001$). Water deficiency also has a significant impact on collar diameter. Stress level accounted for 98.8% of its variability (R^2 = 0.988; F = 190.165; $p < 0.0001$), indicating a significant decrease in stem thickening under extreme stress conditions.

There were notable differences in plant height between treatments. *Jatropha curcas* watering once in 3 days produced the tallest seedlings (34.73 cm), suggesting that this treatment promoted vertical development in spite of water deprivation. *Gmelina arborea* watering once in 3 days (30.83 cm) and *G. arborea* watering once in 2 days (28.91 cm) had the next highest values, whereas *J. curcas* watering every day (22.83 cm) had the lowest plants. Overall, these findings indicate that whereas watering every day was linked to slower development in both species, watering once in 3 days circumstances encouraged more shoot elongation (figure 3).Leaf surface area values were comparatively constant for all species and circumstances, and they did not differ as much between treatments. *Gmelina arborea* watering once in 3 days (69.847 cm^2) and *G. arborea* watering once in 2 days(54.653 cm^2) had the biggest leaf surfaces, indicating improved leaf expansion under these treatments. In contrast, *J. curcas* watering once in 3 days (38.837 cm^2) and *J. curcas* watering every day (41.280 cm^2) had the lowest leaf surface values. These results imply that under the same conditions, *Gmelina arborea* retained larger and more developed foliage than *Jatropha curcas*, which may indicate that more resources were allocated to leaf development (figure 3).

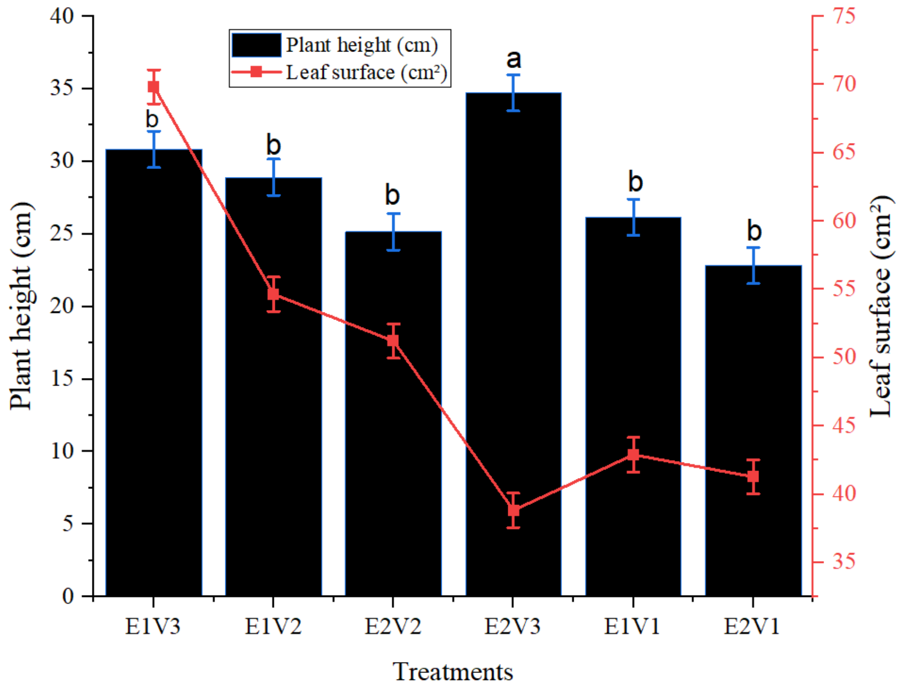

Figure 3: Effects stress waterplant height and leaf surface

The two species' disparate growth tactics are highlighted by the statistical discrepancies between them (figure 4):

- *Gmelina arborea*: minimal sensitivity to watering frequency, rapid height development, and weak radial expansion.
- *Jatropha curcas*: enhanced biomass accumulation with frequent irrigation, robust stem diameter development, and delayed height growth.

Overall, the findings indicate that*J. curcas* grows a stronger and more resilient stem, particularly under ideal watering conditions, while *G. arborea* is better suited for quick canopy formation. These results are crucial for species selection in dryland agroforestry, plantation management, and reforestation, when water availability and growth goals differ.

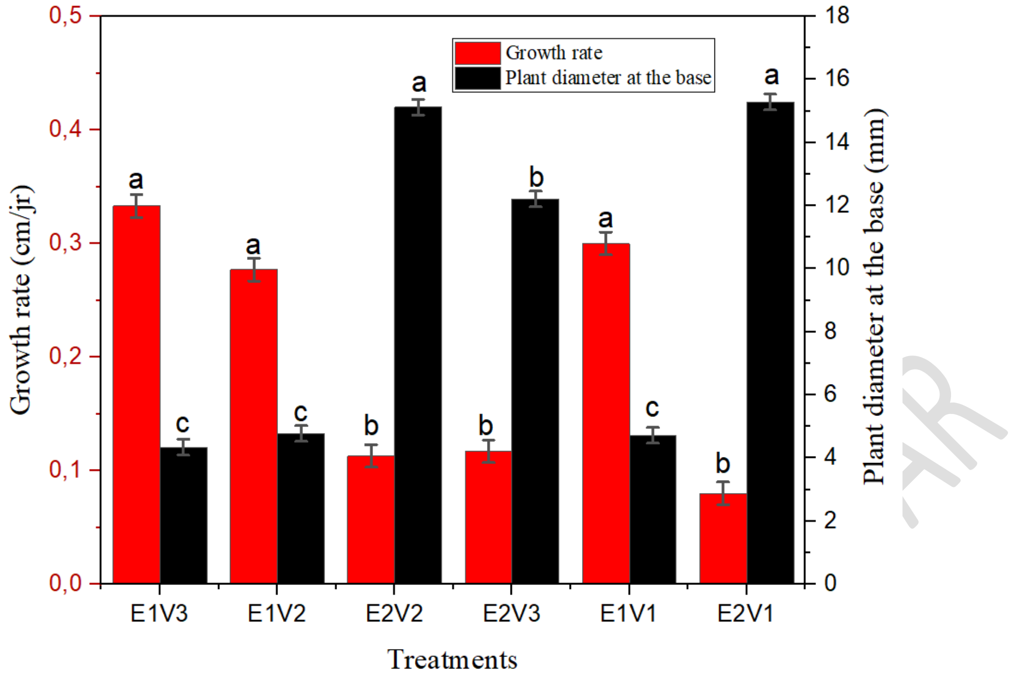

Figure 4: Evaluation of growth rate and plant diameter collar

Correlation among growth and physiological variables

Strong correlations between the measured qualities were shown by the correlation matrix. Stay-green (r = 0.899), plant height (r = 0.644), and leaf surface (r = 0.600) were all positively connected with germination rate, suggesting that seedlings with strong early vigor tended to retain bigger leaf area and greener foliage. Additionally, there was a substantial correlation (r = 0.779) between stay-green and plant height, indicating that chlorophyll retention promotes seedling growth.Plant height (r = -0.360) and growth rate (r = -0.465) were negatively linked with leaf necrosis, indicating that tissue damage lowers overall seedling performance. Growth rate and collar diameter had a very high negative association (r = -0.978), suggesting that stressed seedlings prefer elongation over stem thickening as a compensatory response. Growth rate and leaf surface had a moderate correlation (r = 0.645), indicating that seedlings with larger leaves often grow more quickly under mild stress (table 2). Overall, the correlation patternsconfirm the significant impact of water deficiency on physiological integrity (necrosis, chlorosis), which subsequently affects biomass allocation and growth dynamics.

Table 2. Correlation matrix

Variables	Germination rate	Stay green	LeafNecrosis	Plant height	Leaf surface	Growth rate	Collar diameter
Germination rate	**1**	**0.899**	0.157	0.644	0.600	0.192	-0.185

Stay_green	**0.899**	**1**	0.181	**0.779**	0.539	0.124	-0.100
LeafNecrosis	0.157	0.181	**1**	-0.360	0.315	-0.465	0.580
Plant height	0.644	**0.779**	-0.360	**1**	0.162	0.236	-0.327
Leaf surface	0.600	0.539	0.315	0.162	**1**	0.645	-0.530
Growth rate	0.192	0.124	-0.465	0.236	0.645	**1**	**-0.978**
Collardiameter	-0.185	-0.100	0.580	-0.327	-0.530	**-0.978**	**1**

Discussion

The study findings show that water stress has a substantial impact on seedlings physiological and morphological development,with notable effects on germination, growth rate, collar diameter, necrosis, and chlorophyll retention. These results are in line with several research on the drought sensitivity of tropical agroforestry species, especially fast-growing hardwoods like *Gmelina arborea*.

The strong effect of water deficit on germination ($R^2 = 0.990$) confirms that early developmental stages are highly sensitive to water availability.Similar findings have been reported by a number of writers, who point out that insufficient moisture decreases radicle emergence, inhibits imbibition, and delays enzyme activation (Bewley et al., 2013). According to Valverde et al. (2021), *Gmelina arborea* exhibited limited tolerance at early developmental stages, as evidenced by a considerable fall in germination percentage under lower watering frequency.

A key characteristic associated with delayed leaf senescence is the stay-green feature, which allows the plant to sustain photosynthetic activity for a longer period of time under early and terminal drought. Early leaf senescence, decreased chlorophyll content, and ultimately low maize production are caused by reduced water availability (Kathirvelan et al., 2025).Thus, the strong association between germination and stay-green found in this study is indicative of the normal physiological reactions of stressed seedlings.A promising strategy to increase crop thermotolerance and production stability is the stay green trait, which is characterized by delayed senescence and sustained photosynthetic activity under stress (Shricharan and Kumar 2025).

Under water stress, leaf necrosis significantly increased, demonstrating that oxidative stress and turgor loss caused by a water shortage cause structural damage in tissues. Similar patterns have been observed in tropical deciduous species, where extended dryness causes leaf abscission and marginal necrosis (Chaves et al., 2003). According to Valverde et al. (2021), *Gmelina arborea* had severe drought-induced necrosis, with tissue damage closely linked to reduced photosynthesis and compromised water transport. Thus, the correlations between necrosis, plant height, and growth rate found in this study are in line with recognized physiological disturbances. Niu and al. (2012)demonstrated that the growth and leaf development of Jatropha plants cultivated in greenhouses were considerably decreased by saline stress and insufficient irrigation.

Water stress caused moderate and nonsignificant responses in plant height and leaf surface, indicating that these characteristics are less accurate predictors of early drought impacts. This trend aligns with the findings of Ngidlo (2017), who observed that *Gmelina arborea* seedlings may sacrifice lateral expansion and stem thickening in order to sustain height elongation under stress. Rather than biomass buildup, height growth under water stress frequently represents a survival strategy meant to improve access to light.

Strong positive correlations between germination, stay-green, leaf surface, and plant height were found by the correlation analysis.The findings of Valverde et al. (2021), who demonstrated that increasing tissue damage dramatically lowers photosynthetic efficiency and growth in *Gmelina arborea* seedlings, are consistent with the negative link between leaf necrosis and growth rate.The very strong negative correlation (r = -0.978) between growth rate and collar diameter is one noteworthy discovery, indicating a shift in biomass allocation toward vertical elongation at the expense of radial development. In order to preserve a competitive edge in the face of water scarcity, plants prioritize shoot elongation, which is reflected in this trade-off (Blum, 2011). Under water stress, *Gmelina arborea* and other Meliaceae and Verbenaceae species have been shown to exhibit such allocation patterns.

Conclusion

Overall, the findings of this study are consistent with the body of knowledge about the responses of tropical agroforestry species to drought.The significant impacts of water stress on physiological markers and the variable effects on morphological traits demonstrate the complexity of drought resistance mechanisms. Collar diameter and growth rate may be helpful early indicators of water stress for nursery management due to their great sensitivity. However, because they could mask underlying stress effects, plant height and leaf area should be interpreted with caution.

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