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Ecophysiology of Khaya grandifoliola C. DC. Under Two Distinct Microclimatic Conditions

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Abstract
The species *Khaya grandifoliola C.DC.*, known as African mahogany, has good size and large increment of wood. However, there are few studies of this kind in Brazilian areas, there is a need to point their climatic preferences. Thus, this study aimed to evaluate the initial growth mahogany in two different microclimate, being: environment A com the mean values of temperature and relative humidity $30°C$ and 73%; environment B with average values of $25°C$ and 86%. The seedlings were planted in pots of 21.5 liters in 90 days and evaluated in inside greenhouses with controlled temperature and humidity. Plant growth was characterized by measuring total dry matter and physiological parameters (photosynthesis, transpiration and stomatal conductance). At the end of the experiment, all parameters analyzed, we noted a higher growth of species in the environment with average values of $25°C$ and 86%. The study generated information relevant to the ecology and indications of climatic preferences of the species.

Keywords
Air Temperature — Relative Humidity — Environmental Preferences — Plant Morphology

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1. Introduction

Forests, across all continents, provide essential services and products that support economic, environmental, and social development. In South America, they sustain productive chains while facing significant conservation challenges (Salas et al., 2016). In Europe, forests are valued for their ecosystem services and are integrated into payment for ecosystem services policies (Europe, 2019; Nolander; Lundmark, 2024). In Oceania, they balance economic exploitation with environmental conservation (Kanowski; Edwards, 2021). In Africa, participatory forest valuation strengthens local and sustainable management (Ali et al., 2025).

In Brazil, the planted forest sector is predominantly dominated by two genera: *Eucalyptus* and *Pinus* (Sanqueta et al., 2018; Andrade; Oliveira, 2016). However, this scenario highlights the need for diversification with species of high economic potential and superior wood quality. In this context, the genus *Khaya*, popularly known as African mahogany, has attracted increasing interest within the Brazilian forestry sector. Among the factors driving this growing appreciation are the high commercial value of its wood, moderate density, ease of seedling production, and good performance under different edaphoclimatic conditions (Silva et al., 2023).

In Brazil, the most cultivated species of the genus *Khaya* are *K. grandifoliola*, *K. senegalensis* A. Juss., and *K. anthotheca* (Welw.) C. DC., with emphasis on the Northern and Southeastern regions, which concentrate the largest planted areas (Silva; Barreira, 2022). The growing interest among rural producers is associated with positive projections of economic return at the end of the production cycle. However, the scarcity of scientific studies on the cultivation of these species limits the development of reliable technical guidelines for their establishment and proper management (Laudares et al., 2023).

Climatic factors such as temperature, relative humidity, precipitation, wind, and solar radiation exert a strong influence on plant growth and development. Moreover, these elements can directly affect growth rates and the survival of forest stands, as the distribution of tree species is closely associated with regional microclimatic conditions (Silva et al., 2023; Oliveira et al., 2019). In addition, microclimatic variations interfere with essential physiological processes, such as photosynthesis and respiration, thereby impacting species performance (Brito et al.,

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2018).

Despite the scarcity of specific studies on the ecophysiology of *Khaya* spp., research involving other forest species, such as *Eucalyptus*, has demonstrated how environmental variables influence plant physiological responses. Recent studies reinforce that successful silviculture depends on understanding the interactions among climate, soil, and forest species (Silva et al., 2023).

The expansion of African mahogany plantations into non-traditional areas in Brazil, such as subtropical regions (20 to $24°C$) and semi-arid regions in the Northeast (28 to $32°C$), faces challenges due to the limited understanding of the species' ecophysiology (Elli et al., 2020). In addition, climate change poses risks to both commercial and non-commercial forests in Brazil, with an increasing occurrence of extreme events such as heat waves, frosts, and droughts. Projections indicate a temperature increase of $2°C$ and a reduction of up to 15% in precipitation in central Brazil, the main region for commercial forest cultivation (Elli et al., 2020). This climate change scenario may render future African mahogany cultivation unsuitable in this area.

In this context, the objective of this study was to evaluate the influence of two distinct microclimatic conditions on the initial growth and physiological responses of *K. grandifoliola*.

2. Materials and Methods

2.1 Characterization of the Environments

The study was conducted in a climate-controlled greenhouse with regulated temperature and air humidity, located in the experimental area of the Department of Forest and Wood Sciences at the Center for Agricultural Sciences of the Federal University of Espírito Santo (CCA-UFES), in the municipality of Jerônimo Monteiro, ES, Brazil.

Two environments with different climatic conditions were established (Figure 1), each equipped with meteorological stations containing sensors for air temperature and relative humidity (Vaisala, model CS500). Data were collected and stored using a datalogger (Campbell Scientific, model CR10X). The reading interval was ten seconds, and mean data were recorded every 15 minutes throughout the entire experimental period.

The vapor pressure deficit (VPD) was calculated based on the estimation of saturation vapor pressure (es) and actual vapor pressure (ea), according to Pereira et al. (2002). The VPD was obtained from the difference between these variables.

2.2 Installation and Analyses

Seedlings of *K. grandifoliola* at the initial developmental stage, at nursery dispatch age (90 days after sowing), were used. The seedlings were transplanted into 21.5-L pots with holes at the bottom to allow drainage of excess water and were arranged on metal benches measuring 3.0 × 1.20 × 1.0 m in length, width, and height, respectively. Substrate moisture was maintained close to field capacity, and the substrate consisted of soil collected from a depth of 10–50 cm from a Red-Yellow Latosol, with appropriate acidity correction and fertilization adjusted according to its chemical composition.

The experiment was conducted in two environments with different atmospheric demands: environment A, with mean air temperature and relative humidity values of $30°C$ and 73%, respectively; and environment B, with mean values of $25°C$ and 86%. Figure 1 shows the variation in mean air temperature throughout the day in both environments during the entire experimental period. To characterize the physiological responses of the plants, gas exchange measurements were performed between 8:00 and 10:00 a.m., at 60 days of experimentation, using a portable infrared gas analyzer (IRGA) (ADC Bio-Scientific, model LCi). Net photosynthesis rate, stomatal conductance, and transpiration were determined.

At 45 days and at the end of the 90-day experimental period, the following plant growth measurements were taken: plant height from the base to the apex using a metal ruler graduated in millimeters; stem collar diameter measured with a digital caliper; leaf area determined using a bench-top leaf area meter (Li-Cor Inc., model LI-3100); and dry mass of leaves, stem, branches, and roots determined after drying the material in a forced-air circulation oven at $65°C$ for 72 hours, followed by weighing on an analytical balance.

To characterize the physiological responses of the plants, gas exchange measurements were carried out between 8:00 and 10:00 a.m., at 60 days of experimentation, using a portable infrared gas analyzer (IRGA) (ADC Bio-Scientific, model LCi). Net photosynthesis rate, stomatal conductance, and transpiration were determined.

At the end of the 90-day experimental period, a destructive analysis of the plants was performed to determine total dry mass (sum of leaves, stems, branches, and roots), obtained after drying the material in a forced-air circulation oven at $65°C$ for 72 hours and subsequently weighing it using an analytical balance.

Considering that the greenhouse allows the standardization of environmental conditions, a completely randomized experimental design was adopted, with one species, two environments, and six replicates. The results were subjected to the Shapiro–Wilk normality test

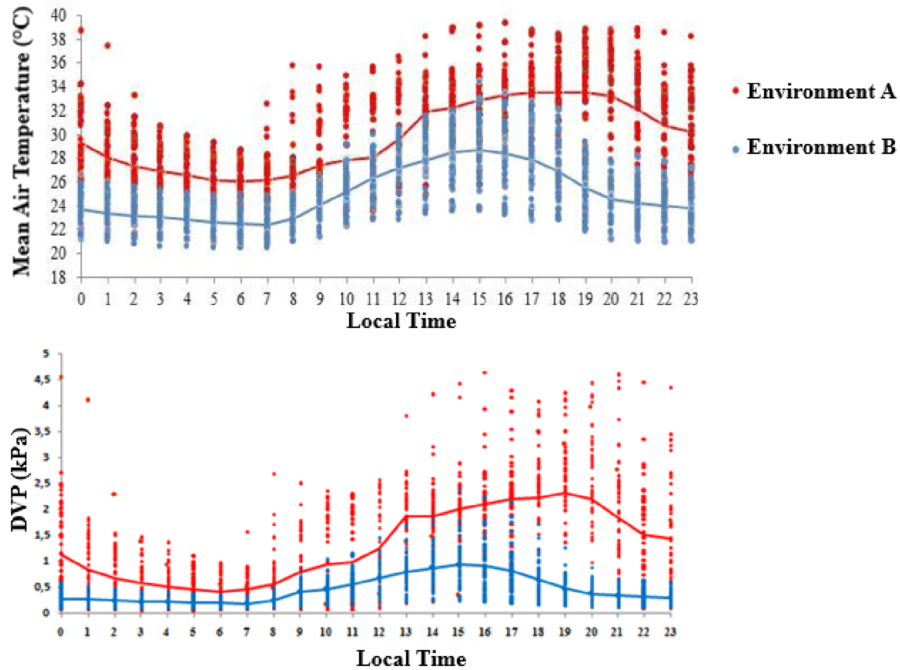

Figure 1. Daily fluctuation of mean air temperature (A) and vapor pressure deficit (VPD) recorded inside the greenhouse for the two environments during the period from December 15, 2012, to March 14, 2013, in Jerônimo Monteiro, ES, Brazil.

and Bartlett's test for homogeneity of variances. When significant, means were compared using Student's *t*-test at the 5% probability level, using the Sisvar statistical software.

3. Results and Discussion

To meet the growing global demand for energy, fiber, and food, agricultural and forest production is projected to double by 2050 (FAO, 2018). However, climate change poses significant challenges to achieving this goal, as high temperatures and drought periods have already caused adverse effects on forests worldwide (Freitas et al., 2021). This challenge requires a comprehensive understanding of the ecophysiological responses of tree species to environmental conditions. One species of particular interest in this context is African mahogany, especially due to its high economic and ecological value.

The evaluation at 45 days showed no statistical differences in the growth of African mahogany. However, at the end of the experiment (90 days), the environments influenced plant growth differently, and the analyzed variables showed statistically significant differences between environments A and B. The environments were characterized by mean vapor pressure deficit (VPD) values of 1.29 kPa and 0.46 kPa for environments A and B, respectively. These external factors are directly related to the physiology of *Khaya* spp. The distinct responses highlighted plant behavior under environmental stress and enabled the identification of the species with greater initial growth under the studied microclimatic conditions, as shown in Figure 2.

Total dry mass was higher in environment B (Figure 2), indicating that *K. grandifoliola* exhibited better development under the microclimatic conditions of lower temperature associated with high relative humidity. These conditions favored the photosynthetic processes of *K. grandifoliola*. In plant ecophysiology, dry mass production occurs when the carbon not consumed by respiration is allocated to growth (Larcher, 2006). In this process, the amount of radiant energy reaching the light-harvesting complex of the photosystems may lead to gains or losses in the efficiency of photochemical reactions (Lemos Filho, 2000).

Plants are subjected to a combination of high temperature and full sunlight (Alves, 1998), resulting in conditions of high atmospheric demand, as observed in Microclimates 2 and, especially, 3. Under this scenario, extreme temperatures affect the functioning of the oxygen-evolving system (Yamashita and Butler, 1968), leading to the release of manganese ions from the complex. Consequently, the limitation of photosynthesis due to the

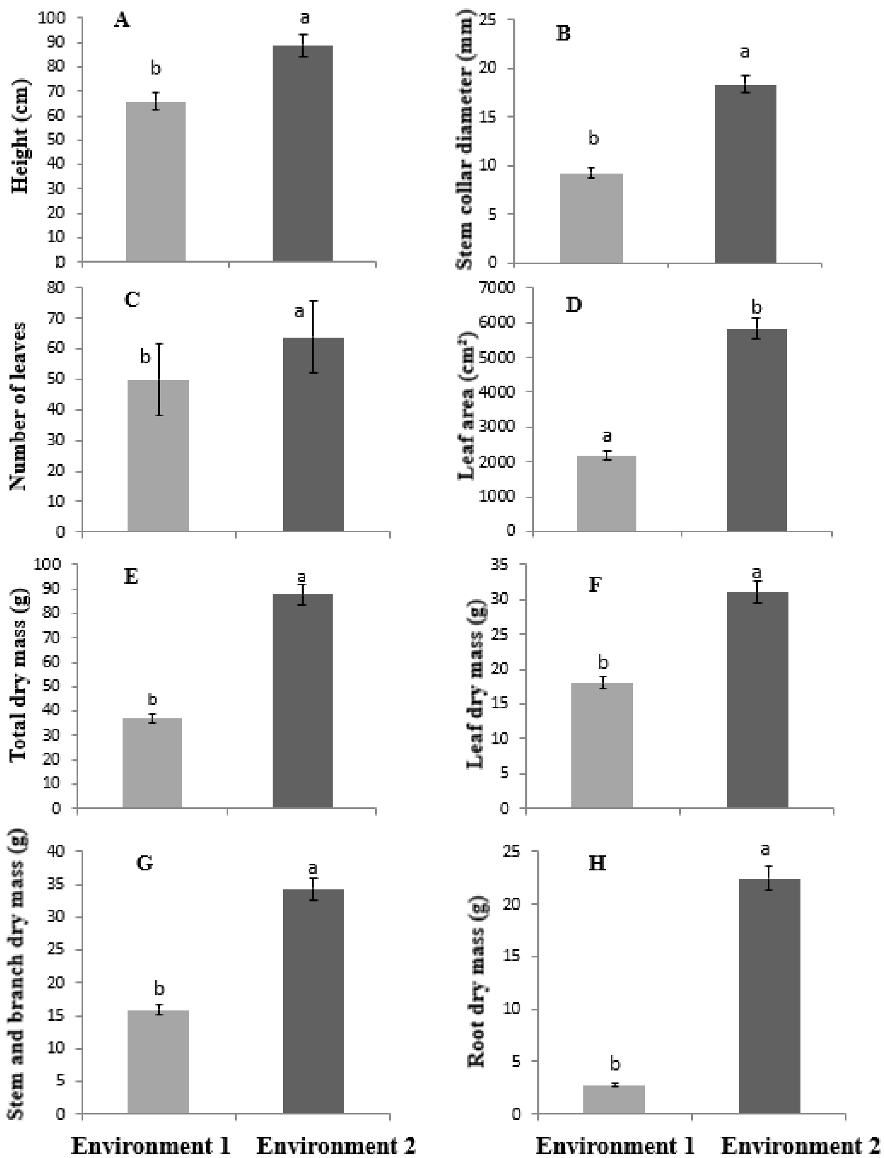

Figure 2. Mean values of height (A), stem collar diameter (B), number of leaves (C), leaf area (D), total dry mass (E), leaf dry mass (F), stem and branch dry mass (G), and root dry mass (H) of *Khaya grandifoliola* at the end of the experiment.

Rubisco regeneration rate includes constraints on the enzymes of the cycle responsible for regenerating Rubisco from triose phosphate. In addition, limitations occur in the electron transport rate as well as in the production, export, and utilization of sucrose (Woodrow, 1988).

The influence of different climatic variables on the ecophysiological responses of forest species has been increasingly investigated in recent studies (Silberstein et al., 2003; Lane et al., 2004). These studies primarily highlight the importance of microclimate in plant productivity and in the efficiency of compound assimilation.

When analyzing these physiological responses, higher gas exchange values were also observed in environment B. Thus, Figure 3 shows that stomatal conductance, photosynthesis, and transpiration were greater under the milder microclimatic conditions (Environment B).

Atmospheric demand associated with adequate soil water availability leads to high gas exchange rates. However, each species has a specific capacity to balance water absorption by the roots, its translocation throughout the plant, and water loss through transpiration. In this case, in the present study, water uptake was likely insuffi-

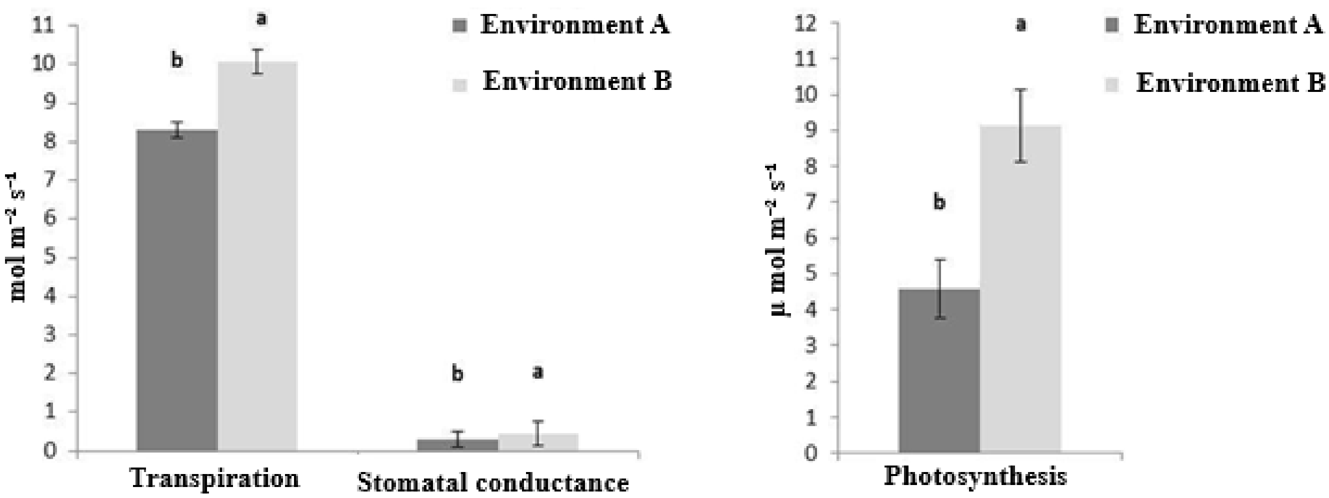

Figure 3. Transpiration, stomatal conductance, and photosynthesis of *K. grandifoliola* plants at 90 days of experimentation in a climate-controlled greenhouse under higher temperature (Environment A) and intermediate temperature (Environment B) conditions, in Jerônimo Monteiro, ES, Brazil.

cient to compensate for water loss via transpiration under the environment with higher atmospheric demand. This resulted in lower stomatal conductance in this treatment and, consequently, reduced photosynthetic and transpiration rates.

The data from the present study corroborate the climatic characteristics of the region of origin of African mahogany, which is characterized by high relative humidity associated with moderate temperature ranges, helping to explain the species' preference for environment B.

Forests are particularly vulnerable to the adverse effects of high temperatures. Understanding how African mahogany and other tree species respond and adapt to these challenges is essential to ensure resilient forest management under climate change scenarios. The results of this study highlight the urgent need to address the combined threats of drought and heat events, as well as their potential consequences for forest production.

4. Conclusion

The development of *K. grandifoliola* proved to be sensitive to different microclimatic conditions after 90 days of growth. For all analyzed parameters, the species showed a preference for the environment with mean values of $25°C$, 86%, and 0.46 kPa for air temperature, relative humidity, and vapor pressure deficit, respectively. These results provide valuable information for sustainable forest management and for understanding the potential impacts of climate change on African mahogany.

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Author Statements

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