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GERMINATION AND EARLY GROWTH PERFORMANCE OF *KHAYA SENEGALENSIS* (DESR.) A. JUSS. UNDER VARYING LIGHT INTENSITIES

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ABSTRACT

This study assessed the effects of four pre-sowing treatments seeds: dewinging and soaking, dewinging only, soaking only, and untreated seeds control; on germination dynamics over 19 days. The study also determined the effect of four light intensity regimes (100%, 75%, 50% and 25% of full sunlight) on early growth, chlorophyll content, and biomass allocation in seedlings, over eighteen weeks. The main effects of period of experiment, pre-sowing treatment and their interactions were significantly different for germination rate ($p < 0.001$). Dewinging alone produced the most rapid and synchronised germination, confirming primarily physical seed dormancy. Light intensity significantly influenced seedling height ($p = 0.006$), with seedlings under 25% light attaining the highest height (2.205 ± 0.172 cm). In addition, leaf area was significantly affected ($p < 0.001$) by light intensity and nearly doubled under 25% light (560.95 cm^2), when compared with 100% light intensity (284.61 cm^2). Chlorophyll content showed a progressive inverse relationship with irradiance, and this was consistent with shade acclimation. The species is confirmed as a non-pioneer light demander with a juvenile shade tolerance optimum of 25-50% of full sunlight. A two-stage nursery protocol --seed dewinging followed by cultivation under 50% shade is recommended for producing high-quality seedlings for reforestation.

Keywords: *Khaya senegalensis*; seed dewinging; shade tolerance; light intensity; biomass allocation

INTRODUCTION

Khaya senegalensis (Desr.) A. Juss., commonly known as African mahogany, is among the most economically and ecologically significant hardwoods in sub-Saharan Africa. Its dense, reddish-brown timber commands high value in domestic and international markets, with applications spanning furniture, cabinetry, boat construction, flooring and decorative veneers (Nikiema and Pasternak, 2008; Orwa *et al*., 2009). The species is equally valued in traditional medicine, agroforestry and urban amenity planting across the West African savanna belt (Poonguzhali and Josmin, 2025). Despite this importance, *Khaya senegalensis* is listed as vulnerable on the IUCN Red List owing to overexploitation, selective logging and progressive habitat degradation (IUCN, 2017; Adjahossou *et al*., 2018). The natural regeneration and recovery of the species is constrained by landscape disturbance, seed predation, inter-specific competition and unsuitable soil conditions (Egbewole *et al*., 2018). Thus, artificial nursery propagation is a primary strategy essential for restoring the species population through plantation establishment. However, successful propagation depends on a clear understanding of seed germination requirements and the response of seedlings to light variability.

The seeds of *Khaya senegalensis* have a winged structure that facilitates wind dispersal, but also may restrict imbibition and soil-seed contact. This creates a physical barrier that could inhibit rapid germination (Adji *et al*., 2023). Thus, it has been suggested that dewinging be used as a pre-sowing treatment. But, the comparative evidence on the differences and similarities between mechanical wing removal (dewinging) and seed soaking remain limited (Egbewole *et al*., 2018). Furthermore, while *Khaya senegalensis* is mainly classified as light-demanding (Sokpon and Ouinsavi, 2002), empirical information on shade tolerance and optimal nursery irradiance for effective seedling growth remain insufficient. In addition, chlorophyll content and leaf area are sensitive photomorphogenic indicators that provide empirical information on seedling quality and post-transplant establishment (Cruz *et al*., 2016; Valladares and Niinemets, 2008).

The objectives of this study were to evaluate the effect of four pre-sowing treatments on the germination dynamics of *Khaya senegalensis* seeds, to determine the influence of varying light intensities on seedling height, collar diameter, and leaf production, to characterise the effect of

shading on foliar chlorophyll content, and to quantify biomass accumulation and leaf area responses along the light gradient. The findings provide practical, evidence-based nursery protocols for the large-scale propagation of this species across Nigeria and West Africa.

MATERIALS AND METHODS

Study Area

The study was conducted at the Nursery Unit of the Department of Forest Production and Products, and the Soil Resources Laboratory, Department of Soil Science, University of Ibadan, Nigeria (latitudes 7° 26' 850"- 7° 27' 087" N and longitudes 3° 53' 552"- 3° 53' 899" E; elevation 205-227 m asl). Ibadan experiences a humid tropical climate with a bimodal rainfall pattern, with peak rainfall in June-July and September-October, mean annual rainfall of approximately 1,420 mm, relative humidity of 60-82%, and temperatures ranging from 18.1 to 34.4°C (Sangotegbe *et al*., 2015).

Seed Source and Pre-Sowing Treatments

One thousand seeds of *Khaya senegalensis* were collected from mature trees at the Federal College of Wildlife Management, Niger State, Nigeria (Northern Guinea savanna belt) and transported to the University of Ibadan for preparation. Seeds were divided into four groups (250 each) and subjected to: (i) dewinging and soaking in water at room temperature for 24 hours; (ii) dewinging only; (iii) soaking for 24 hours; and (iv) untreated seeds (control). Seeds were sown in germination baskets containing heat sterilised topsoil and monitored daily for 19 days. Germination was considered complete when no further germination occurred over six consecutive days.

Experimental Design and Seedling Establishment

For the germination experiment, a completely randomised design with four pre-sowing treatments (250 seeds each) was adopted. For the early growth assessment, 100 uniformly growing seedlings

were transplanted individually into 10 cm diameter polyethene bags containing sterilised topsoil and randomly assigned to four light intensities (25 seedlings per treatment): 100% full sunlight (0L); 75% light (one-layer mesh net, 1L); 50% light (two-layer mesh net, 2L); and 25% light (three-layer mesh net, 3L), following the method described by Olajuyigbe and Akande (2016). Then, 150 ml of water was applied daily to each seedling during the experiment.

Data Collection and Statistical Analysis

Germination variables; cumulative germination percentage, germination rate, days to first germination, and time spread were computed following AOSA (1983) and ISTA (2015). Seedling height, collar diameter and number of fully expanded leaves were recorded forthnightly over sixteen weeks. At the end of the experiment, seedlings were destructively harvested, separated into leaf, stem, and root fractions, and oven-dried at 70°C for 72 hours to constant dry weight for biomass determination.

Leaf area was determined by the direct planimetric (grid-based tracing) method: fresh leaves were placed on graph sheets, the leaf outline was traced, and the number of grid squares (cm^2) enclosed by each tracing was counted to obtain leaf area, with the mean of five replicates per treatment taken as the leaf area value (Brewer *et al*., 2022).

Fresh leaf samples from five replicates per treatment were analysed using a UV Spectrophotometer (INESA model) at 643 nm and 663 nm wavelength to determine chlorophyll content in the Soil Resources Laboratory, Department of Agronomy, University of Ibadan.

Data on germination rate, seedling height, collar diameter and leaf area were analysed using one-way ANOVA; significant means were separated by Duncan's Multiple Range Test at $p < 0.05$, level of significance.

RESULTS

Germination Response to Pre-Sowing Treatments

The main effects of time of experiment ($p < 0.001$), pre-sowing treatment ($p = 0.004$) and their interaction ($p < 0.001$) were significant in their influence on germination rate (Table 1). Germination commenced approximately 12 days after sowing, with treatment-specific peaks occurring between Days 13 and 17 and germination declining to near zero by Day 19. Dewinged seeds showed rapid and relatively synchronised germination, whereas seeds that were both dewinged and soaked showed a later but more pronounced germination pulse. The single-intervention treatments produced intermediate patterns between the control and the combined treatment (Figure 1).

Table 1. Analysis of Variance for the germination rate of *Khaya senegalensis* seeds

Source of Variation	Sum of Squares	df	MS	F	p-value
Time of experiment	0.6865	6	0.1144	24.473	< 0.001*
Pre-sowing Treatment	0.0659	3	0.0219	4.702	0.004*
Time of experiment x Pre-sowing Treatment	0.4942	18	0.0274	5.873	< 0.001*
Error	0.6545	140	0.0046		

** Significant at $p < 0.05$; df = degrees of freedom; MS = mean square.*

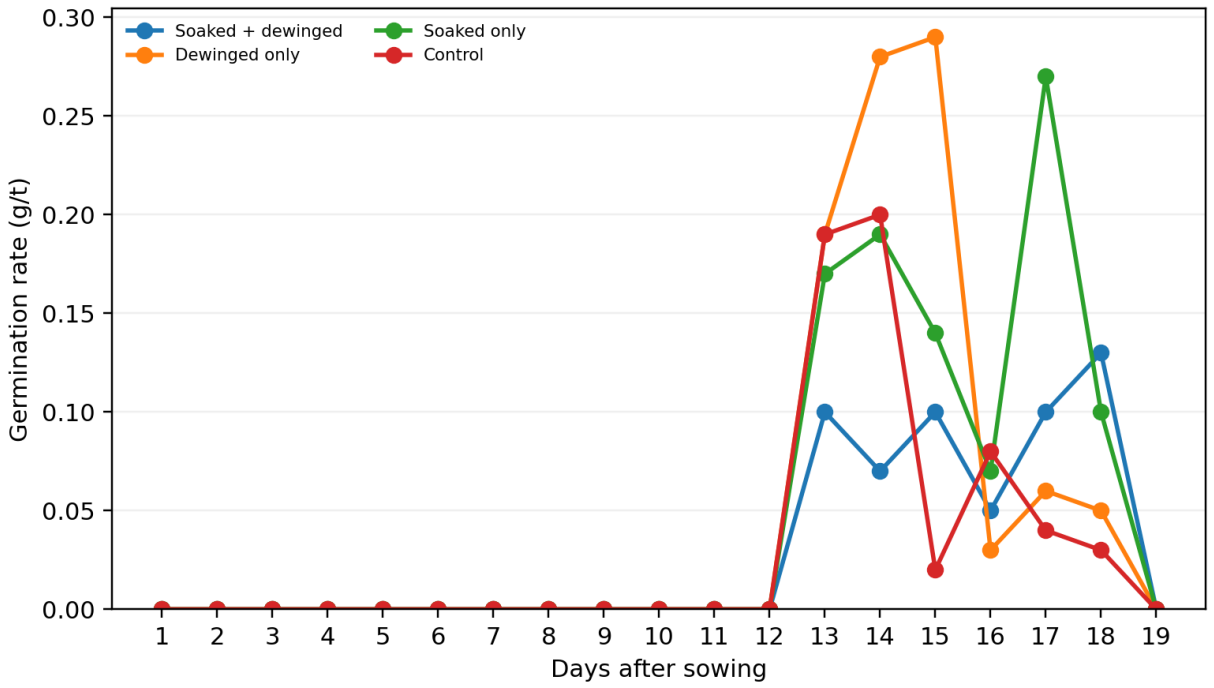

Figure 1. Effect of pre-sowing treatments on germination rate of *Khaya senegalensis* seeds

Seedling Height

Light intensity significantly affected seedling height ($p = 0.006$; Tables 2 and 3). Seedlings under 25% light intensity(3L) attained the highest mean height (2.205 ± 0.172 cm), significantly exceeding those under 75% light (1L: 1.615 ± 0.074 cm). Seedlings under 50% (2L: 1.930 ± 0.112 cm) and 100% (0L: 1.915 ± 0.087 cm) light had intermediate mean heights and were statistically similar to the other groups.

Table 2. Analysis of Variance for the effect of varying light intensity on early growth parameters of *Khaya senegalensis*

Variables	Source of Variation	Sum of Squares	DF	MS	F	P
	Light intensity	34.864	3	11.621	4.214	0.006
Height (cm)	Error	2195.025	796	2.758		
	Total	2229.889	799			
	Light intensity	1.364	3	0.455	0.234	0.873
Number of leaves	Error	1548.485	796	1.945		
	Total	1549.849	799			
	Light intensity	0.935	3	0.312	1.261	0.287
Collar Diameter (mm)	Error	196.601	796	0.247		
	Total	197.535	799			

** Significant at $p < 0.05$; ns = not significant; SS = sum of squares; df = degrees of freedom; MS = mean square.*

Table 3. Mean height of *Khaya senegalensis* seedlings under varying light intensities over sixteen weeks

Treatment	Light Intensity (%)	Mean Height (cm)	Grouping
0L	100	1.915 ± 0.087	ab
1L	75	1.615 +/- 0.074	b
2L	50	1.930 +/- 0.112	ab
3L	25	2.205 +/- 0.172	a

Means followed by different letters differ significantly at $p < 0.05$ (Duncan's Multiple Range Test).

0L = 100%; 1L = 75%; 2L = 50%; 3L = 25% sunlight.

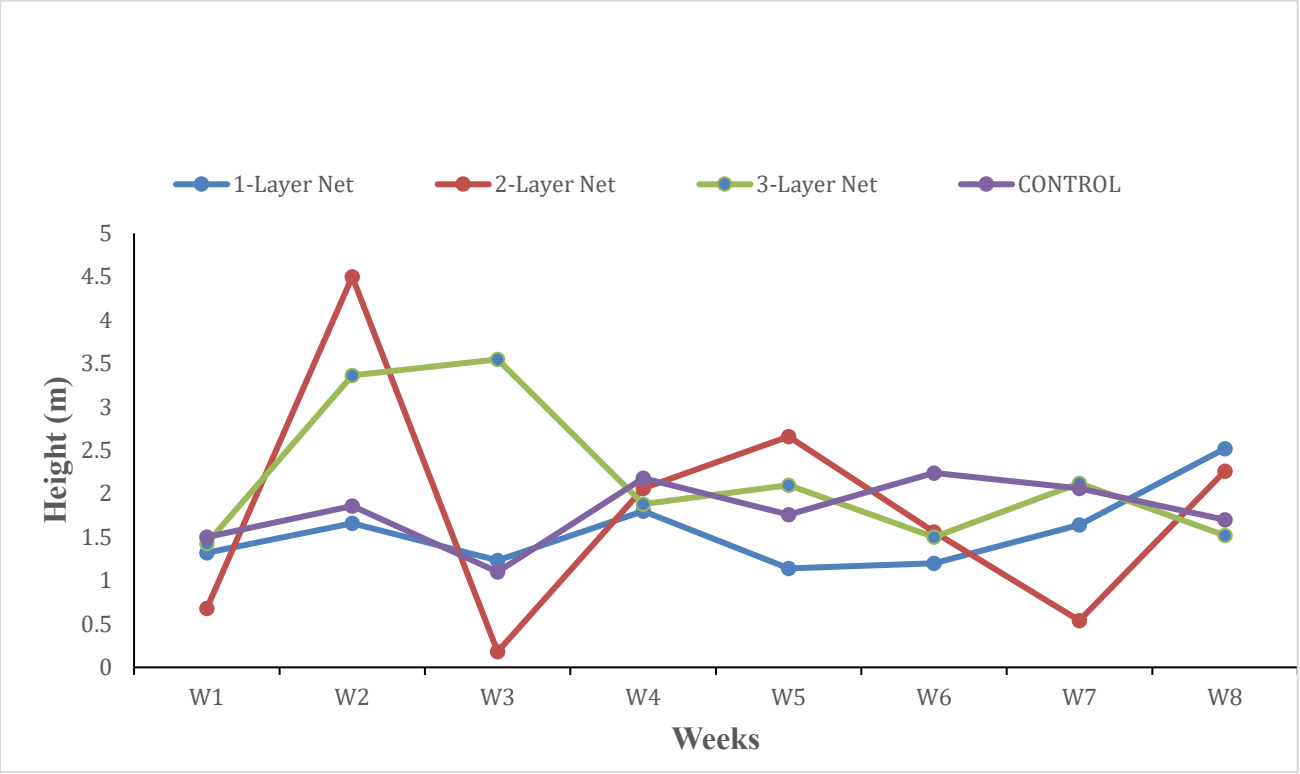

Figure 2: Effect of varying light intensity on *Khaya senegalensis* seedlings height

Number of Leaves and Collar Diameter

Light intensity had no significant effect on the number of leaves ($p = 0.873$) or collar diameter ($p = 0.287$; Table 2). The recorded sampling-period trends are presented in Figures 3 and 4 the weekly progression of leaf production revealed that seedlings under full sunlight (0L) and 75% light (1L) maintained a relatively stable but subdued rate of leaf production approximately 2 leaves over sixteen weeks, while seedlings under 50% (2L) and 25% (3L) light showed more pronounced increases in leaf production over time, particularly from Week 4 onwards. The effect of light intensity on collar diameter was not significant over the eighteen-week experimental period ($p = 0.287$; Table 2) the weekly progression data (Figure 4) revealed a biologically consistent directional trend: seedlings under 50% light (2L) showed a greater increase in collar diameter during the latter weeks of the experiment compared to those under 75% and full sunlight, which maintained a more gradual, stable diameter increment throughout the study period. Seedlings under 25% light showed an intermediate collar diameter trajectory.

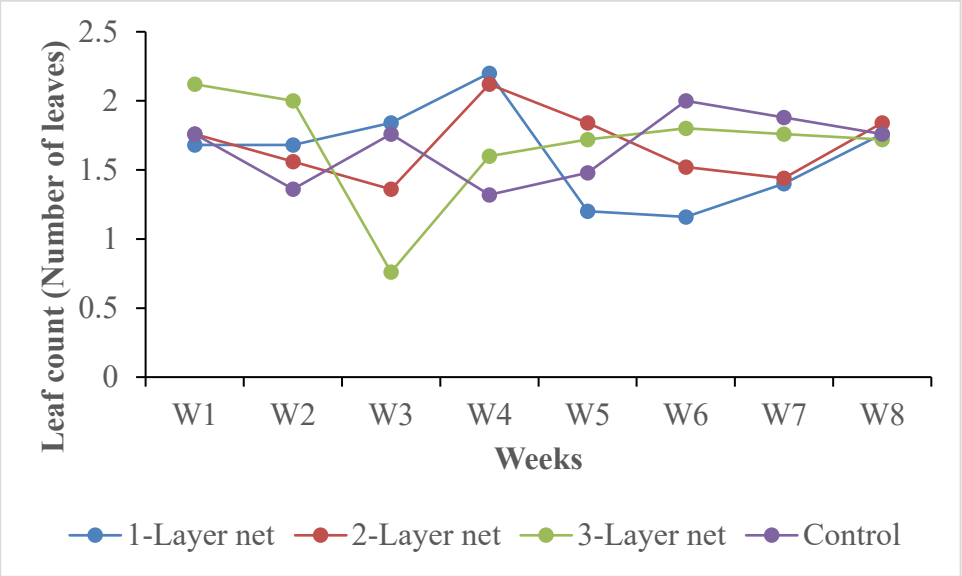

Figure 4. Effect of varying light intensity on number of leaves of *Khaya senegalensis* seedlings

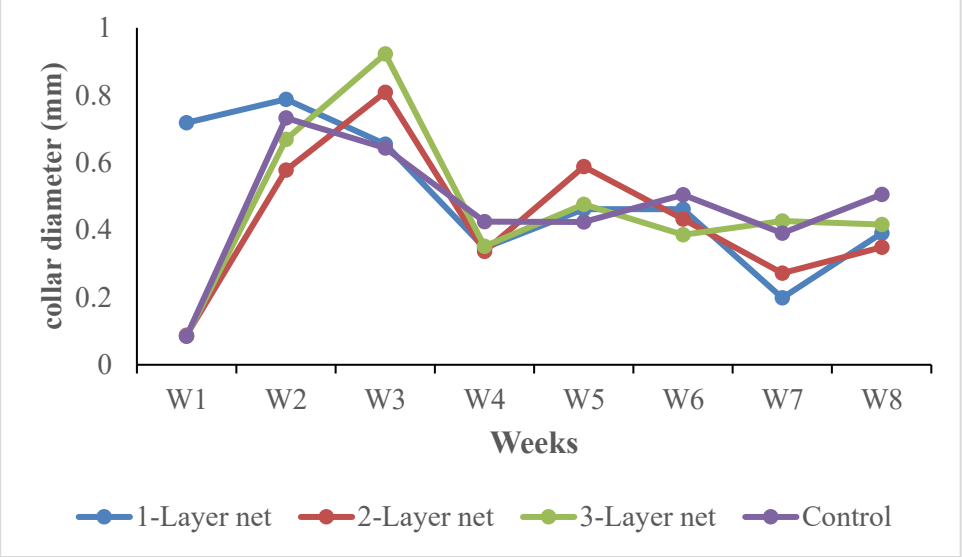

Figure 5. Effect of varying light intensity on collar diameter of Khaya senegalensis seedlings.

Chlorophyll Content

Figure 5 illustrates the inverse relationship between light intensity and foliar chlorophyll concentration across the four treatments. Seedlings under 25% and 100% light intensities accumulated the highest chlorophyll concentrations, while the lowest occurred under 75% light. This

indicates a robust and reproducible physiological response to the light gradient imposed in this experiment.

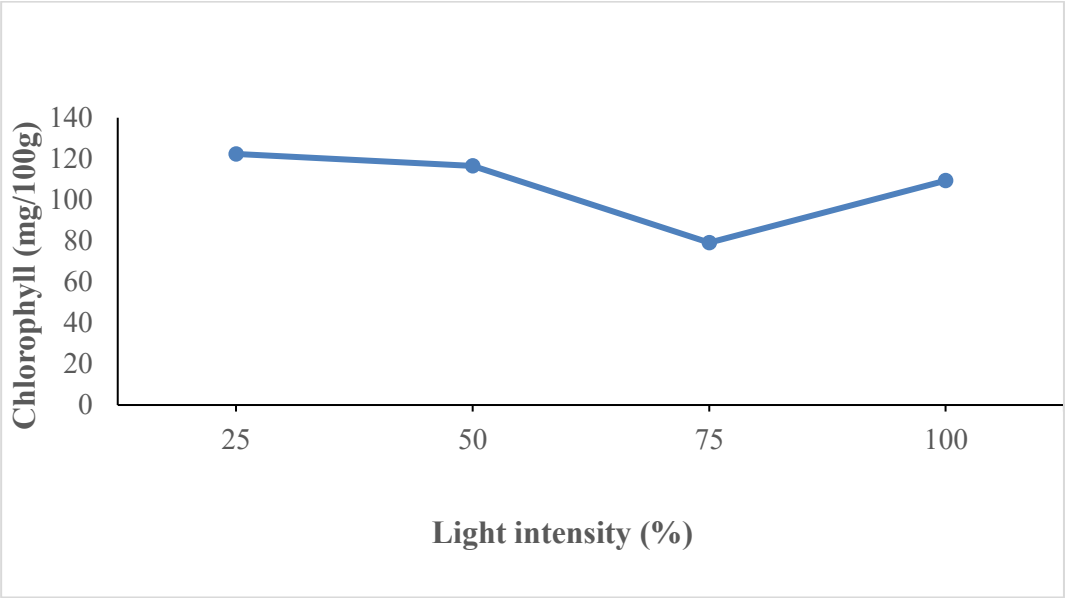

Figure 6: Chlorophyll content of *Khaya senegalensis* seedlings under varying light intensities.

Biomass Allocation and Leaf Area

The effect of light intensity on biomass allocation was directionally consistent but statistically not significant (Table 4). Leaf biomass was greatest under 25% light intensity (1.671 ±0.196 g) and lowest under 100% (1.200 ±0.102 g). Stem biomass was highest under 100% LI (1.943 g) and 75% light (1.914 g). Root biomass was highest under 75% in contrast light intensity exerted a highly significant effect on total leaf area ($p < 0.001$; Figure 6). In contrast, light intensity had a significant effect on leaf area measurements. Seedlings under 25% light intensity had a leaf area of 560.95 cm2 almost doubled that of 100% light (284.61 cm2). Seedlings under 50% (339.59 cm2) and 75% (339.34 cm2) light achieved statistically similar intermediate values, both significantly greater than the control but significantly less than the 25% treatment.

Table : Effect of varying light intensity on biomass allocation of *Khaya senegalensis* seedlings

Treatment	Light (%)	Leaf Biomass (g)	Stem Biomass (g)	Root Biomass (g)

0L	100	1.200 +/- 0.102 b	1.943 +/- 0.154	2.429 +/- 0.297
1L	75	1.414 +/- 0.118 ab	1.914 +/- 0.232	3.071 +/- 0.217
2L	50	1.286 +/- 0.116 ab	1.514 +/- 0.195	2.514 +/- 0.218
3L	25	1.671 +/- 0.196 a	1.886 +/- 0.293	2.700 +/- 0.260

0L = 100%; 1L = 75%; 2L = 50%; 3L = 25% sunlight. Within the Leaf Biomass column, means followed by different letters differ at $p < 0.05$. Stem and root biomass differences were not statistically significant ($p > 0.05$).

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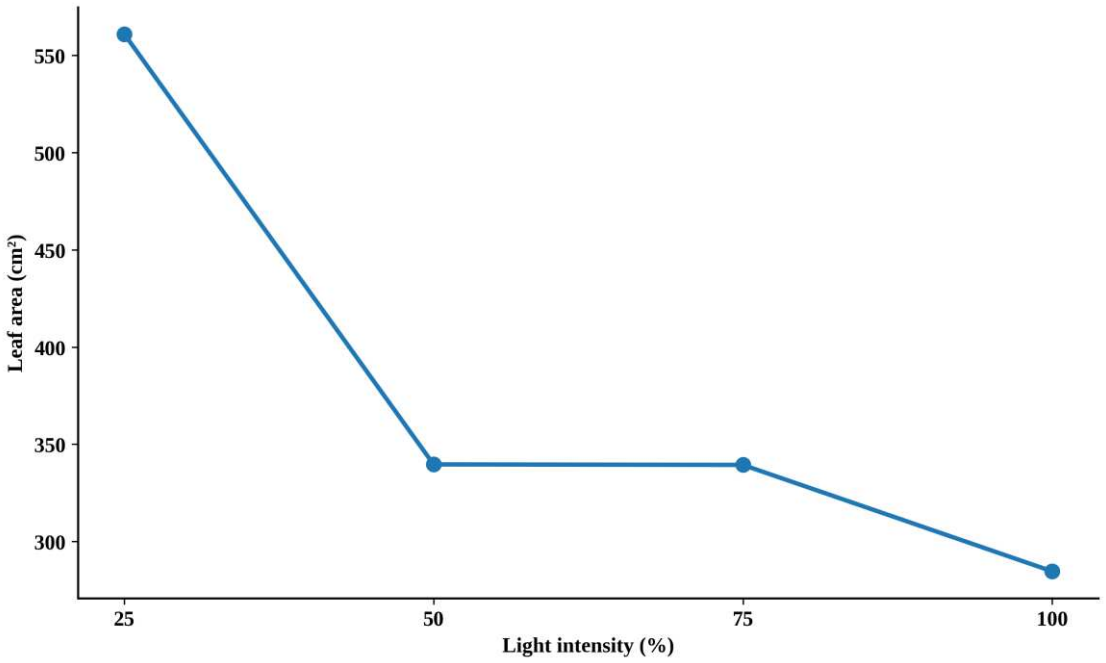

Figure 7: Effect of varying light intensity on total leaf area of *Khaya senegalensis* seedlings ($p < 0.001$)

DISCUSSION

Germination Response to Pre-Sowing Treatments

The interaction effect of time of experiment with pre-sowing treatment ($p < 0.001$) revealed that dewinging and soaking influence the timing, rate, and duration of germination in *Khaya senegalensis*. day germination lag suggested that the moderately hard seed coat restricted water uptake and imbibition before radicle emergence. This lag time was similar to the 10-14day period reported for the species (Egbewole *et al*., 2018; Ogunwusi and Ogunwusi, 2017). The rapid synchrony of germination in dewinged seeds confirmed that the papery wing functions primarily as a physical barrier impeding imbibition and soil-seed contact, rather than serving as a physiological dormancy mechanism. Wing morphology has been reported as a major factor influencing germination of *Khaya senegalensis* (Adji *et al*., 2023). Yao *et al*. (2024), opined that seed coat manipulation was an important strategy for enhancing seed propagation of Khaya species. However, the moderate germination observed in the untreated control implied that partial physical dormancy occurred in the species. These observations were consistent with the species' life history as a wind-dispersed savanna tree in tropical ecologies (Sacande *et al*., 2004).

Consequently, combining dewinging with soaking had no additive benefit and produced a delayed germination pulse. Thus, soaking was a redundant process once the wing barrier had been removed, and may slightly retard radicle emergence through over-hydration. Dewinging is therefore recommended as the sole pre-sowing intervention. This is a simple, low-cost, equipment-free, and immediately applicable operation in community nurseries and smallholder forestry outfits, without the need for chemical inputs or specialised infrastructure.

Seedling Growth Responses to Light Intensity

The significant effect of light on height growth ($p = 0.006$), with greatest height under 25% light, is consistent with the shade avoidance syndrome, where seedlings exposed to a reduced red:far-red light ratio allocate proportionally more carbon to vertical elongation (Smith and Whitelam, 1997). Previous studies have reported superior height growth for Khaya species under moderate shade. Thus, *Khaya senegalensis* is classified as a moderately shade-tolerant species at the juvenile stage (Oni, 1987; Keay, 1989). Usually, full sunlight and excessive irradiance cause elevated vapour

pressure deficit which induces stomatal closure and restrict carbon assimilate availability, in spite of high photon flux density (Valladares and Niinemets, 2008). The collar diameter and number of leaves did not differ probably because of the developmental priority of height establishment over radial growth in young tropical hardwood seedlings (Onyekwelu *et al*., 2014). Furthermore, diameter differentiation is expected to become statistically significant over longer monitoring periods (Yahaya *et al*., 2016).

Chlorophyll Content and Shade Acclimation

The inverse relationship between irradiance and chlorophyll content reflected the shade acclimation phenomenon. On one hand, low irradiance causes seedlings to up-regulate chlorophyll biosynthesis, particularly for chlorophyll b in order to maximise light-harvesting efficiency and sustain carbon fixation (Taiz *et al*., 2015). On the other hand, high irradiance causes excess photon flux to generate reactive oxygen species within chloroplasts. This drives photoprotective down-regulation through reduction of chlorophyll antenna size and upregulation of carotenoid synthesis via the xanthophyll cycle (Demmig-Adams and Adams, 1992). These patterns are consistent with tropical species and confirm that full-sun conditions are physiologically supra-optimal for the development of photosynthetic apparatus of juvenile Khaya senegalensis (Ojo *et al*., 2021).

Biomass Allocation and Leaf Area Plasticity

The near doubling of leaf area under 25% light (560.95 cm2 vs. 284.61 cm2 in full sun; $p < 0.001$) was a striking morphological response, which demonstrated the considerable phenotypic plasticity of K. senegalensis in leaf architecture. This results in the production of thinner leaves with higher specific leaf area, and the maximization of photosynthetic surface area per unit carbon invested (Chazdon and Fetcher, 1984; Valladares and Niinemets, 2008). The directional biomass trends which include; deep shade promoting leaf area expansion, 75% light producing highest root biomass, and full sun maximising stem biomass, were ecologically coherent responses consistent with optimal partitioning theory (Poorter *et al*., 2012). The high root biomass under 75% light

suggests incipient water stress driving greater belowground carbon allocation to enhance water acquisition (Silva, 2010). While 25% light produced the strongest individual growth response, the resulting tall, thin-leaved seedlings may be structurally fragile under field conditions. The 50% shade treatment, produced the most balanced combination of height, collar diameter trajectory, moderate leaf area, and favourable chlorophyll physiology, and is recommended as the optimal practical nursery treatment (Cruz *et al*., 2016; Grossnickle, 2012).

5. CONCLUSION

This study established that seed dormancy in *Khaya senegalensis* was primarily physical, and effectively addressed by dewinging alone. The species is confirmed as a non-pioneer light demander with significant juvenile shade tolerance and an optimal nursery irradiance range of 25-50% of full sunlight. Seedlings under 25% light intensity produced the strongest individual growth responses for height, chlorophyll, and leaf area, while 50% shade was recommended as the practical nursery standard, yielding seedlings with the balanced morphology and physiology most conducive to successful field establishment. Consequently, a two-stage nursery protocol, seed dewinging followed by cultivation under 50% shade nets for at least eighteen weeks, with graduated hardening to full sun prior to outplanting is recommended for the large-scale, cost-effective propagation of this IUCN Vulnerable-listed species. The study provides a robust, evidence-based framework for improving *Khaya senegalensis* propagation, increasing its sustainable management and ecological restoration across Nigeria and the broader West African sub-region.

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Authors contributions

All authors conceptualized the research idea **Akinyode I. T.** carried out the experimental procedure and prepared the manuscript; **Olajuyigbe S. O** supervised the experimental procedure, corrected and edited the manuscript.

Conflict of interest

On behalf of all authors, the corresponding author states that there's no *conflict-of-interest*

Ethics, Consent to Participate, and Consent to Publish declarations: not applicable.

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