

Practical Approaches to Germination and Conservation of Endangered Plants: A Study at the University of Benin, Nigeria

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DOI: <https://doi.org/10.62154/ajasfr.2025.019.01018>

Abstract

The germination and conservation of endangered and under-documented plant species in Nigeria are hindered by several practical challenges, particularly during the seedling and early developmental stages. Most of these species exhibit low germination percentages and weak seedling vigor when cultivated outside their native ecosystems. This difficulty is compounded by limited ecological and physiological data, especially on dormancy behavior and moisture sensitivity. Given the mounting pressures from deforestation, unsustainable harvesting, and habitat degradation, improving early-stage propagation has become a critical component of effective plant conservation strategies. This study tested nine species under standardized nursery conditions to assess germination success and early growth performance. These included six endangered species: *Allanblackia floribunda*, *Picralima nitida*, *Pterocarpus santalinoides*, *Buchholzia coriacea*, *Xylopia aethiopica*, and *Lophira alata*, and three widely cultivated reference species: *Terminalia catappa*, *Cola millenii*, and *Coffea canephora*. Each species was planted in three replicates, and parameters such as germination rate, seedling height, and a qualitative vigor score based on seedling morphological quality were recorded. Germination results for the endangered species were generally low, ranging from about 20% to 40%, and the seedlings that emerged tended to show weak development. This may be linked to dormancy issues, seed recalcitrance, or sensitivity to moisture and temperature changes during early growth stages. By contrast, the reference species had higher germination 60% to 85%, and more vigorous seedlings. The results show that standard propagation techniques are not adequate for these threatened species. Many may require seed pre-treatment, carefully timed sowing, and regulated conditions. Tailored propagation strategies are essential for conservation and forest restoration in Nigeria.

Keywords: Germination, Seedling Vigor, Endangered Species, Propagation Techniques, Ex-Situ Conservation.

Introduction

Native plant species in Nigeria are disappearing faster than ever before, and this is strongly linked to ongoing environmental damage across the country (Osawaru, Ogwu and Ahana, 2022). Although species loss can occur naturally over time, the current pace is largely a

result of human activities such as land conversion, deforestation, and industrial expansion (Purvis, 2019).

In rainforest zones, activities such as logging and farmland expansion have removed large sections of forest cover, placing serious pressure on species like *Afzelia africana* and *Khaya senegalensis* (Eludoyin, Dappa and Kokei, 2021; Bamigboye et al., 2022). Similar pressures are evident in mangrove and riverine ecosystems, where oil drilling, dam construction, and coastal development continue to degrade habitats that support native plant populations (Ndinwa and Akpafun, 2012).

A more urgent concern is that many of these species remain poorly studied and undocumented. Several are widely used in local communities and play important ecological roles, yet if they disappear without being formally recorded, both their scientific value and cultural significance may be lost permanently (Pimm et al., 2014).

This situation calls for a more structured and deliberate approach to plant conservation in Nigeria. Efforts must move beyond designated reserves and public awareness campaigns to include focused scientific research, effective protection of native habitats, genuine community involvement, and enforcement of existing environmental laws (FAOLEX Database, 2015). Without proper coordination across these areas, more species will continue to disappear, often unnoticed, and without the chance of recovery.

Factors Contributing to Species Endangerment

1. Habitat Loss

The loss of natural habitats remains one of the most persistent pressures on native plant populations in Nigeria (FAOLEX Database, 2015; Anwadike, 2020). Agricultural expansion, urban development, and industrial activities have steadily reduced vegetation cover, breaking once-continuous habitats into scattered fragments. These fragmented landscapes often fail to meet the ecological needs of many native species, particularly those with narrow habitat preferences. In areas such as the Middle Belt and the forest zones of southern Nigeria, the widespread conversion of land to monoculture agriculture has almost entirely displaced native plant communities (Agumagu, Marchant and Stringer, 2025). Forests that once held a layered complexity of ferns, understory herbs, climbing plants, and tall canopy trees have been reduced to isolated pockets of vegetation. As these systems lose their structural and environmental integrity, species dependent on specific levels of humidity, shade, or soil composition gradually disappear. This pattern is evident in the lowland rainforests of Ondo and Delta states, where species such as *Enantia chlorantha* and *Milicia excelsa* are no longer found in areas they once occupied extensively (Eludoyin, Dappa and Kokei, 2021).

2. Over-Collection

The pressure from human collection has pushed many wild plants toward extinction. In many communities, plants are still used in traditional healing, food preparation, and cultural

practices. However, increased demand, combined with fewer areas left untouched by development, has led to unsustainable harvesting. In some parts of Enugu and Osun, plants like *Sphenostylis stenocarpa* and *Aframomum melegueta* are being collected faster than they can reproduce (Adewale and Abberton, 2024; Omokhua, Fredrick and Eyekpeggha, 2019). These species often grow in specific microhabitats and have slow growth cycles, making it hard for populations to recover once depleted. Some collectors even uproot entire plants, destroying their ability to regenerate (Heinrich, 2001). This form of pressure, when left unmanaged, leads to local extinction and the loss of ecological roles that these species play.

3. Invasive Species and Diseases

The introduction of foreign plants and pests, whether deliberate or accidental, has reshaped several ecosystems in Nigeria. Some invasive plants compete aggressively with native species for light, nutrients, and space (Borokini, 2011). They also alter the physical structure of habitats, making it difficult for indigenous species to thrive. For example, *Chromolaena odorata*, introduced for erosion control, now dominates fallow lands across southern Nigeria and suppresses native herbs and shrubs (Uwalaka and Muoghalu, 2021). In the northern drylands, invasive grasses like *Prosopis juliflora* have altered grazing systems and reduced native plant diversity (Bezaredie, Tadesse and Tadesse, 2023). Fungal infections and parasitic weeds, such as *Striga hermonthica*, have also spread across many cropping systems, harming both cultivated and wild plants (Douthwaite et al., 2007). These threats often spread quickly and are hard to contain once established.

4. Environmental changes

Recent shifts in temperature regimes and rainfall patterns across Nigeria are placing additional strain on native plant populations (Nzeh et al., 2016). Altered climatic conditions have disrupted key physiological processes such as flowering phenology, germination timing, and spatial distribution (Haider, 2019). In the Sahel, prolonged dry spells now occur with greater frequency, reducing habitat suitability for moisture-sensitive species such as *Parkia biglobosa* (Elagib, Ali and Musa, 2024; Omonhinmin et al., 2024). In forested zones, changes in ambient humidity and thermal conditions are driving gradual shifts in species assemblages, with some taxa moving to higher elevations or deeper forest interiors in response (Akindele and LeMay, 2006). Yet habitat fragmentation continues to obstruct such movements, limiting the adaptive capacity of many species and increasing the risk of extinction of native flora (Fahrig et al., 2019).

These threats do not act in isolation. For example, when natural habitats are cleared or fragmented, invasive species often gain a foothold more easily. At the same time, climate change can increase the spread of plant diseases and reduce the ability of already stressed plant populations to recover (Liu et al., 2024). If conservation efforts are delayed, there's a real risk that some native species could vanish before we fully understand their ecological roles or economic importance.

Conservation Strategies and Efforts

Tackling the challenges facing Nigeria's native plant species calls for practical strategies that are based on scientific research and aligned with local realities. Conservation goes beyond a one-time intervention, it involves a mix of protective measures, habitat restoration efforts, and supportive policies that can help preserve plant diversity while also considering the needs of the local communities.

5. Protected Areas

The few remaining areas where native plant species in Nigeria persist with minimal disturbance are largely found within protected forest zones. When effectively managed, these areas serve as important refuges from broader environmental pressures (Alegbeleye et al., 2024). Notable examples include the Cross River National Park and the Okomu Forest Reserve, both established to safeguard species-rich forests and threatened native flora (Adetola and Adetoro, 2014). However, many of these reserves face persistent challenges, including inadequate funding, insufficient staffing, and weak enforcement of conservation regulations (Anwadike, 2020). Strengthening plant conservation efforts will require expanding the protected area network to encompass additional high-biodiversity regions, particularly in the Middle Belt and mangrove zones, while investing in infrastructure and promoting active engagement with local communities.

6. ex-situ Conservation

For plant species that are already nearing extinction or confined to highly restricted natural habitats, conservation efforts outside their original environments have become increasingly necessary (Lee, 2023). In Nigeria, this form of conservation is supported through a combination of seed storage, living plant collections, and laboratory-based propagation techniques. The National Centre for Genetic Resources and Biotechnology (NACGRAB), based in Ibadan, plays an important role in this regard. It focuses on the collection, preservation, and study of genetic materials from both cultivated and wild plant species across the country (National Centre for Genetic Resources and Biotechnology, 2025). Through its work, genetic diversity is being safeguarded in crops such as *Vigna subterranea* (Bambara groundnut) and *Cola acuminata*, which hold agricultural and cultural importance in various Nigerian communities (Lee, 2023). In addition, botanical gardens located in Zaria and Lagos function as live repositories for rare medicinal and ornamental plants, many of which are no longer commonly found in their native ecosystems (Isah, Ahmed, and Aliyu, 2019).

7. Restoration Ecology

In many parts of Nigeria, the restoration efforts towards reclaiming degraded ecosystems have become an increasingly urgent priority, especially where native vegetation has been cleared for farming, grazing, or settlement. The process is often gradual and requires a combination of actions, including replanting indigenous species, addressing soil erosion,

and removing invasive plants that disrupt natural regeneration. In northern Nigeria, collaborative efforts by local communities and environmental agencies aim to reintroduce native trees and shrubs into degraded dryland areas (Bodunde, 2023). These initiatives focus on restoring vegetation cover, stabilising soil conditions, and enhancing the ecological functions that support long-term landscape resilience. Restoration efforts that prioritise native species over exotics have shown greater effectiveness in re-establishing key ecological functions, including pollinator activity, nutrient cycling, and moisture retention (IITA, 2024). As these ecosystems recover, surrounding rural communities gain renewed access to essential plant-based resources such as firewood, wild foods, and medicinal plants (Flood, Mahon, and McDonagh, 2022).

8. Legislation and Policy

Laws and policies form the backbone of any serious conservation effort. Nigeria is a signatory to several international agreements, including the Convention on Biological Diversity and the Nagoya Protocol, both of which outline guidelines for the use and equitable sharing of genetic resources (CBD, 2025). At the national level, legal instruments like the Endangered Species Act of 1985 and the Forestry Act are intended to safeguard plant species, though enforcement practices are often uneven (Federal Ministry of Trade, 1985). Community-led conservation, supported by local councils and traditional leaders, is beginning to gain ground (Simire, 2023). Where communities understand the ecological and economic value of biodiversity, voluntary compliance tends to be more effective than top-down enforcement. Initiatives that encourage sustainable harvesting and agroforestry practices further support conservation goals by reducing reliance on wild plant populations while maintaining local livelihoods (Simons and Leakey, 2004).

Taken together, these strategies reflect a growing recognition that plant conservation in Nigeria must go beyond documentation and awareness. It must be embedded in practice, on farms, in policies, in schools, and in the landscapes themselves.

Statement of the Problem

Efforts to conserve endangered and under-documented plant species in Nigeria are often hindered by a lack of practical knowledge about how these species behave during germination and early seedling development. While much attention has been given to habitat loss and ecological threats, fewer studies have addressed the propagation challenges that occur outside natural environments. Standard nursery methods, commonly used for cultivated species, tend to overlook the specific needs of plants with dormancy issues, recalcitrant seeds, or narrow habitat preferences. As a result, many threatened native species continue to record poor germination outcomes and weak seedling performance when raised under controlled conditions. This limits the success of restoration programs, reduces the availability of planting stock, and risks the loss of species before they are fully understood or documented. Addressing these challenges requires an approach

that is grounded in field observation, nursery experimentation, and species-specific propagation techniques.

Objective

The main objective of this research was to develop a practical approach for conserving endangered plant species in Nigeria, focusing on the early stages of propagation under nursery conditions. The study examined the germination responses and seedling growth of selected native species to identify key environmental and biological factors influencing their survival. It also tested propagation methods that could be adapted for use in resource-limited settings, with attention to seed viability, nursery management, and transplant readiness. In addition to technical trials, the research aimed to strengthen species documentation and build propagation skills among young conservationists working in under-resourced but biodiversity-rich areas. Findings from this work are intended to support future conservation efforts and highlight the ecological relevance of lesser-known native plants.

Materials And Methods

Study Sites

The study took place across four distinct sites in Edo State, Nigeria. Each site served a specific role within the research workflow, including soil sampling, substrate preparation, experimental cultivation, and ecological monitoring.

Faculty of Agriculture Farm Site, University of Benin

The farm site, located within the University of Benin, Ugbowo Campus, Benin City (6.4004° N, 5.6231° E), lies within a transitional rainforest zone and is characterised by fertile lateritic soils suitable for seedling media preparation. This site served exclusively as the origin point for soil and organic compost used in the nursery. Topsoil was manually collected from selected plots with visible organic cover, then air-dried under natural conditions. Once dried, the soil was sieved using a fine mesh and thoroughly mixed with well-decomposed organic matter. The resulting blend was packed into polybags for nursery use. No planting or seed propagation was carried out at this site; all activities were limited to soil preparation.



Figure i: A lecture at the Faculty of Agriculture, University of Benin, on the procedure for preparing nursery beds.



Figure ii: Mixing soil with manure to enrich the nursery bed.

Botanical Garden Facility, University of Benin

This botanical garden, located within the University of Benin, Ugbowo Campus, Benin City (6.3337° N, 5.6001° E), served as the core experimental site where the germination trials and growth monitoring were done. Nursery beds were prepared on-site, and all stages of the study, such as seed sowing, germination observation, transplanting, and growth tracking, were carried out under natural sunlight and ambient environmental conditions. The garden provided semi-controlled, open-air conditions ideal for consistent monitoring of seedling responses, offering a stable environment for assessing early plant development outside of natural habitats.

Field Site: Ogba Zoo and Nature Park

Selected seedlings were transplanted at Ogba Zoo to evaluate their performance in a semi-natural environment characterized by mixed canopy cover. This site, located in Benin City, Edo State (6.2880° N, 5.5879° E), spans approximately 60 hectares within a transitional rainforest zone. In addition to hosting transplant trials, the park also served as a primary seed collection site for several species used in the study. Regular site visits were conducted to monitor seedling survival, assess ecological compatibility, and document plant responses to variations in light availability and soil conditions.

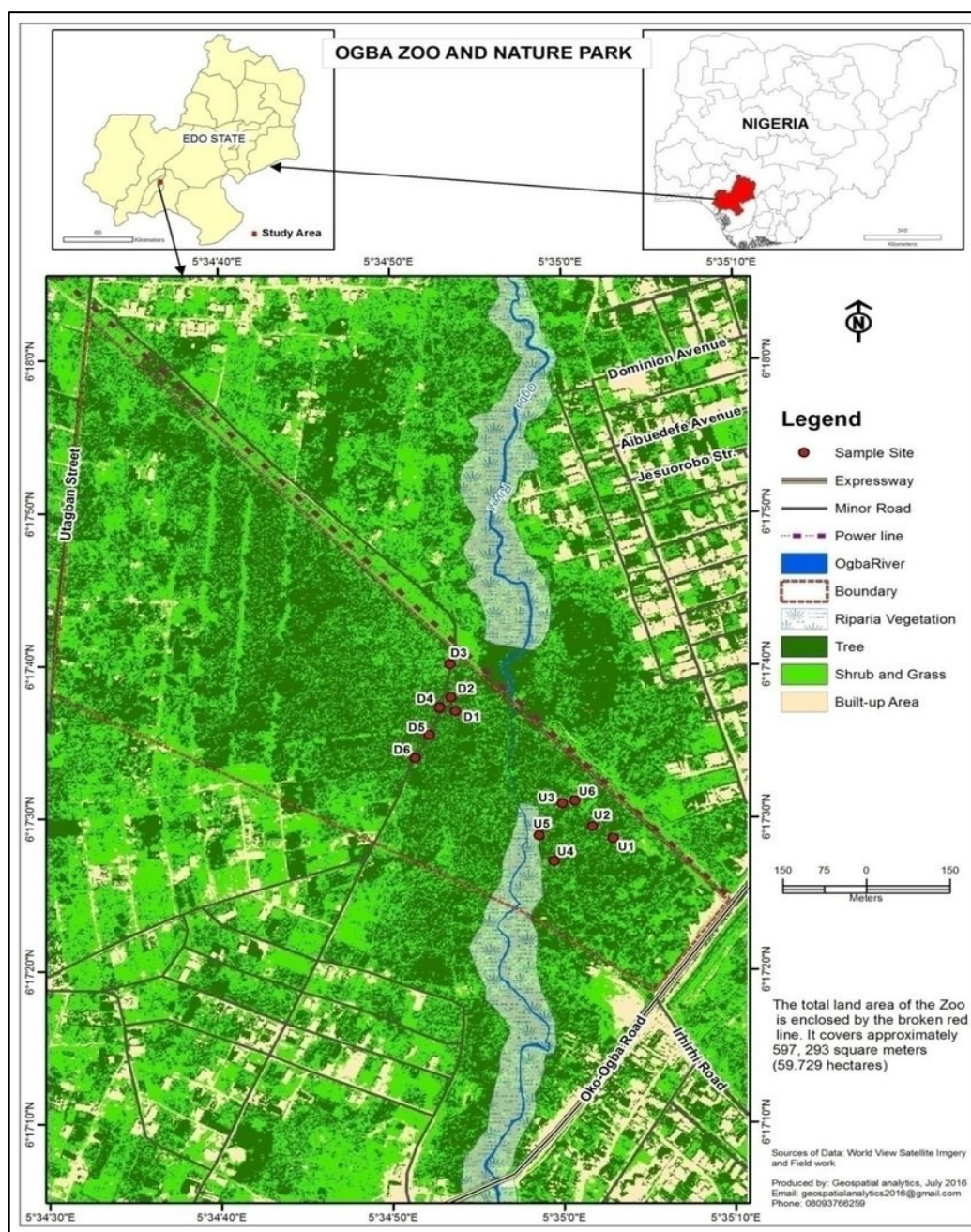


Figure 1: Vegetation map of Ogba Zoo and Nature Park, Benin City, Edo State, showing

natural zones and sampling areas used in the collection of seeds for germination and conservation trials. Disturbed (D1–D6) and undisturbed (U1–U6) sections are marked, alongside surrounding cleared and developed areas.

Source: Adapted from Emmanuel Izaka Aigbokhan (2016)

Field Site: Okomu Forest Reserve, Ovia South-West

Okomu Forest Reserve, located in Ovia South-West Local Government Area of Edo State (6.3127° N, 5.2336° E), spans over 1,000 km² and forms part of the remaining lowland rainforest in southwestern Nigeria. This site was used to observe native plant populations within an undisturbed natural habitat and served as a reference point for understanding ecological conditions and natural community structures. Guided excursions were conducted to identify, document, and monitor the in-situ status of species included in the propagation trials. The reserve provided a valuable ecological baseline for comparing nursery-raised individuals with their naturally occurring counterparts.

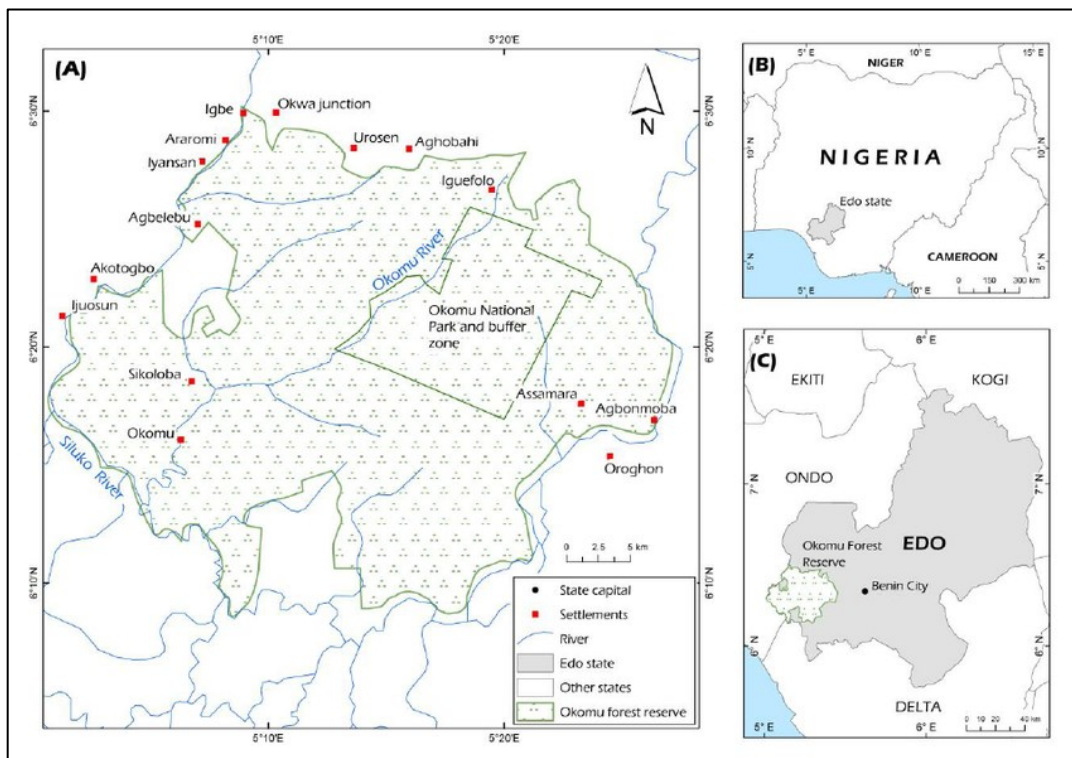


Figure 2: Map of Okomu Forest Reserve and surrounding settlements in Edo State, Nigeria. Panel A shows the spatial layout of Okomu National Park and its buffer zone, including rivers, local communities, and boundary delineations. Panel B indicates the national location of Edo State within Nigeria, while Panel C highlights the position of Okomu Forest Reserve within Edo State relative to Benin City.

Source: Adapted from Onojeghuo, A. & Onojeghuo, A. (2015).

Equipment

The fieldwork required a range of manual tools and transport aids suited for nursery preparation, transplanting, sample collection, and data recording.

- i. **Cutlass** – Used for site clearing, removal of undergrowth, and light soil excavation.
- ii. **Hoe** – Applied in loosening soil during collection, marking bed lines, and preparing transplant spots.
- iii. **Rake** – Used to level the soil surface after hoeing and to remove plant debris.
- iv. **Spade and Shovel** – Employed in soil excavation, compost mixing, and polybag filling.
- v. **Sieve (Fine Mesh)** – Used to refine soil texture by removing stones, twigs, and coarse fragments.
- vi. **Watering Can** – Essential for regulating moisture levels in nursery beds and post-transplant periods.
- vii. **Wheelbarrow** – Used extensively for transporting soil and organic matter across collection and nursery sites.
- viii. **Polybags** – Black polybags served as containers for soil and were used in raising seedlings at the nursery.
- ix. **Garden Fork** – Used in deeper soil loosening and even mixing of compost with base soil.
- x. **Secateurs and Pocket Knife** – Utilized for trimming and harvesting plant material during both propagation and field observation.
- xi. **Measuring Tape and Wooden Pegs** – Employed in layout marking and spacing regulation during transplanting.
- xii. **Buckets and Bowls** – Used to transport seedlings, water, and samples in small batches.
- xiii. **Field Bags and Backpacks** – Used to carry recording sheets, plant samples, and equipment to off-campus sites.
- xiv. **Herbarium Press and Newspapers** – Used for drying and preserving plant samples for taxonomic referencing.
- xv. **Hand Lens** – Used for inspecting seed viability, early germination signs, and leaf morphology.
- xvi. **Notebooks and Field Data Sheets** – Employed for systematic recording of daily observations such as number of germinated seeds, leaf count, plant height, and transplant survival rate.

Logistics and Site Movement

All transportation of materials, seedlings, and tools between sites was carried out manually and via commercial vehicles. Soil-filled polybags were conveyed from the Faculty of Agriculture to the Botanical Garden. Field visits to Ogba Zoo and Okomu Forest were organised through scheduled trips, during which equipment and seedlings were

transported securely in sealed containers and padded crates to prevent damage during transit.

Preparation of Nursery Beds

The nursery bed preparation was guided by both theoretical training and hands-on practical sessions held at the Faculty of Agriculture, University of Benin. Emphasis was placed on proper soil conditioning and sanitation to ensure optimal conditions for germination and seedling development.

Soil Preparation

Topsoil and decomposed organic manure were sourced directly from the Faculty's farm site. The materials were sieved manually to remove large particles, roots, and debris. A mixing ratio of 2:1 (two parts topsoil to one part well-rotted manure) was applied. The soil was turned thoroughly using spades and garden forks until a consistent texture was achieved. This mix was selected to provide adequate aeration, moisture retention, and nutrient content required for seed germination.

Moisture Conditioning

Dry propagation medium was gradually moistened by adding clean water during mixing to ensure uniform moisture distribution. Moisture was assessed manually by pressing a small amount between the fingers; it was judged suitable if it held its shape without releasing water. The prepared medium was then left undisturbed for one week to encourage microbial activity and stabilise nutrient content before use.

Bag Filling and Drainage

After conditioning, the soil mixture was filled into black nursery poly bags. Drainage holes were created at the base of each bag using a sharp knife to create room for the removal of excess water to minimise waterlogging. The prepared polybags, which served as nursery bags, were filled to approximately two-thirds of their capacity and arranged on leveled ground under partial shade within the Botanical Garden of the Department of Plant Biology and Biotechnology.

Pre-Planting Watering

To further stabilize the soil and encourage microbial balance, the filled nursery bags were watered consistently over 7 days before seeds were introduced. Watering was done using watering cans with fine nozzles to avoid compacting the soil surface.

Experimental Design

Each of the nine species evaluated, six endangered and three control, was sown in three replicates, with approximately seven seeds per replicate (totaling 20 seeds per species). Each seed was planted in a separate nursery bag, arranged uniformly across the nursery

bed. This design ensured statistical validity and allowed for accurate comparisons of germination rates and seedling performance across species. Replicates were evenly spaced and managed under identical environmental conditions to minimize variability and bias in the results.

Thinning and Early Management

After germination began, multiple seedlings occasionally emerged from the same nursery bag due to closely sown seeds or split cotyledons. To prevent overcrowding and ensure uniform development, thinning was conducted during the second week after emergence. In each case, only the most vigorous seedling per bag was retained, while others were carefully removed to minimize root disturbance. This step helped reduce competition for light, moisture, and nutrients, allowing for more accurate assessment of individual seedling growth across all replicates.

Germination Percentage Calculation

For consistency, a total of 20 seeds were sown for each species (distributed evenly across three replicates). Germination percentage was calculated using the formula:

Germination (%) = (Number of seeds germinated / Total seeds sown) × 100

For example, if 6 out of 20 seeds germinated for a particular species, the germination rate would be 30%. This standardized approach allowed for direct comparison of germination success across all species tested under uniform nursery conditions.

Seedling Assessment

To evaluate early growth performance, a seedling vigor score was assigned to each species based on visual and morphological criteria. The assessment was qualitative but standardized across all replicates. Scores ranged from 1 (very weak seedling structure, chlorosis, stunted growth) to 3 (robust, upright posture, healthy leaf development, uniform growth). Observations were made weekly, and final scores were averaged per species to generate a comparative index. This scale was adapted from general seedling morphological quality indicators referenced in the abstract.

i. Seed Collection and Pre-Germination Handling

Seeds and fruits were collected from nine native plant species with varying conservation statuses, spanning endangered, vulnerable, and non-threatened categories. Species selection was guided by ecological relevance, ethnobotanical importance, and observed decline in wild populations. Field collection was conducted across multiple sites in southern Nigeria, including the University of Benin campus, Ogba Zoological Garden, Ile-Ife, and the Okomu Forest Reserve. Species such as *Picralima nitida* and *Allanblackia floribunda* were prioritized due to their restricted distribution and vulnerability to overharvesting, while

Terminalia catappa, *Pterocarpus santalinoides*, and *Coffea canephora* served as control species due to their wider range and stable populations.

Collections were timed to coincide with peak fruiting seasons to ensure seed physiological maturity. Samples were hand-harvested from mature, phenotypically healthy individuals, labeled with species name, site, and date, and transported in perforated paper bags to allow aeration and prevent microbial growth.

Seeds were manually harvested, rinsed with distilled water, and then left to dry naturally at room temperature (25–28°C) for 24 to 48 hours. Sorting criteria included seed integrity, uniformity in size, and absence of visible fungal infection or mechanical damage. Only viable and visually healthy seeds were retained for germination trials. The collection covered a range of ecological guilds, including forest canopy trees (*Lophira alata*, *Xylopia aethiopica*), understory medicinal species (*Picralima nitida*, *Buchholzia coriacea*), and multipurpose agroforestry trees (*Cola millenii*, *Terminalia catappa*). The table below summarizes the species planted and their respective collection locations:

Table 1. Study Species and Collection Locations

PLANT/SEEDS	COMMON NAME	LOCATION	SPECIES STATUS
<i>Terminalia catappa</i>	Indian Almond	University of Benin	Control (Not Endangered)
<i>Picralima nitida</i>	Akuamma	Ile-Ife	Endangered
<i>Pterocarpus santalinoides</i>	Mututu	Ogba Zo	Control (Not Endangered)
<i>Cola millenii</i>	Monkey Cola	Ogba Zoo	Under Pressure
<i>Allanblackia floribunda</i>	Tallow Tree	Ogba Zoo	Vulnerable
<i>Xylopia aethiopica</i>	Guinea Pepper	Okomu Forest Reserve	Vulnerable (Regionally)
<i>Lophira alata</i>	Red Ironwood Tree	Okomu Forest Reserve	Vulnerable (IUCN)
<i>Buchholzia coriacea</i>	Wonder Kola	Okomu Forest Reserve	Near Threatened / Concern
<i>Coffea canephora</i>	Robusta Coffee	Ile-Ife	Control (Not Endangered)



Figure 5: Collecting seeds from Okomu Forest Reserve.

Seed Storage and Viability

Seed storage formed a crucial component of the conservation strategy employed in this study, ensuring that the collected seeds retained physiological viability before the commencement of germination trials. Given the diversity of species involved, seed storage protocols were adapted to reflect the physiological characteristics of each seed type, particularly their desiccation tolerance and storage behavior, ranging from orthodox to recalcitrant.

- **Storage Categorization**

Seeds were categorized into two functional groups based on intended storage duration: active and base collections. Active collections consisted of seeds allocated for immediate germination trials and nursery propagation, while base collections were reserved for medium to long-term preservation in accordance with ex-situ conservation protocols. Categorization was informed by species-specific traits, including seed moisture content, desiccation tolerance, and ecological life history.

- **Storage Conditions and Protocols**

For active storage, orthodox seeds were surface-cleaned, air-dried under ambient conditions (25–30°C), and stored in sealed containers, either airtight jars or zip-lock bags, at approximately 5°C. Desiccants such as silica gel were incorporated into storage vessels to maintain low humidity and reduce the risk of microbial contamination. This condition was maintained until sowing commenced, typically within 3–6 weeks of post-collection. Base collections were subjected to lower temperature regimes, ranging between –15°C and –20°C, simulating sub-zero conservation conditions used in seed banks. Although this

project lacked access to ultra-low cryogenic systems such as liquid nitrogen chambers (-196°C), relevant knowledge was acquired through literature review and institutional collaboration. Where possible, moisture content was reduced to 5–7% before cold storage to ensure cellular stability during extended preservation. These procedures were informed by international seed conservation guidelines (e.g., FAO/IPGRI Genebank Standards).

Seeds of *Allanblackia floribunda* and *Lophira alata* were not included in long-term storage trials, as their recalcitrant nature makes them highly sensitive to drying and freezing. Instead, they were kept in moist, aerated containers under shaded conditions and processed shortly after collection to reduce the risk of viability loss. Because these seeds deteriorate quickly, they were prioritised for immediate germination trials within their natural viability period.

Storing each species according to its physiological characteristics helped maintain seed quality and provided more accurate data for developing appropriate propagation methods, especially for species whose seeds are difficult to conserve through conventional storage.

- **Viability Monitoring**

To assess seed viability, germination trials were carried out under nursery conditions using samples from each storage batch. In each test, seeds were sown to track germination rates, the time taken for emergence, and the consistency of sprouting across species. Temperature during the trials ranged from 20°C to 30°C , with watering and light exposure adjusted to reflect the ecological preferences of each species. Partial sunlight was provided in most cases, while moisture levels were maintained through regular monitoring.

- **Maintenance and Replenishment**

Seedlings that germinated successfully were maintained in the nursery under regular monitoring. These individuals grew to maturity and were subsequently used as a source of seeds for future propagation cycles. This approach supported the replenishment of seed stocks and helped maintain genetic continuity across successive trials.

Results

The research systematically assessed germination behavior and early growth patterns in nine indigenous plant species identified as rare, vulnerable, or lacking sufficient documentation. All species were exposed to uniform nursery conditions, and experiments were conducted in triplicate to ensure data reliability. Observations focused on germination percentage, seedling vigor, and early morphological traits. Results differed markedly across species, reflecting inherent biological variability. The outcomes for endangered species are summarized below.

Table 2. Germination Counts per Replicate for Each Species (20 Seeds Total per Species, 3 Replicates of ~6–7 Seeds Each)

Species	Germination Rate (%)	Total Planted	Total Germinated	Replicate 1	Replicate 2	Replicate 3
<i>Terminalia catappa</i>	85	20	17	6	6	5
<i>Cola millenii</i>	70	20	14	5	5	4
<i>Coffea canephora</i>	60	20	12	4	4	4
<i>Picralima nitida</i>	30	20	6	2	2	2
<i>Pterocarpus santalinoides</i>	25	20	5	2	2	1
<i>Allanblackia floribunda</i>	20	20	4	2	1	1
<i>Xylopia aethiopica</i>	35	20	7	3	2	2
<i>Lophira alata</i>	40	20	8	3	3	2
<i>Buchholzia coriacea</i>	30	20	6	2	2	2

This table presents the number of seeds that successfully germinated per replicate, out of a total of 20 seeds planted for each species under uniform nursery conditions.

Allanblackia floribunda

The germination rate recorded was 20%. Emergent seedlings exhibited weak morphology and limited growth.

Picralima nitida

A germination rate of 30% was observed. Most seedlings displayed chlorosis and resisted development beyond the cotyledon stage.

Pterocarpus santalinoides

Germination rate stood at 25%, with sparse, uneven emergence. Seedlings showed poor structure and low survival beyond early growth.

Buchholzia coriacea

This species achieved a 30% germination rate. Seedling mortality was high, with weak overall development.

Xylopia aethiopica

Recorded a germination rate of 35%. Seedlings were slow to establish and demonstrated low vigor.

Lophira alata

The highest among the endangered group, *L. alata*, reached a 40% germination rate. Seedling emergence was moderate, though structural robustness remained low.

Control Species Performance (Non-Endangered)

Observations for non-endangered species under identical nursery conditions revealed higher germination success and seedling vigor compared to endangered counterparts. The results for the control species are as follows:

Terminalia catappa

Germination rate was 85%. Seedlings attained a mean height of 12 cm during the monitoring period and showed uniform development.

Cola millenii

A germination rate of 70% was recorded. Average seedling height reached 10 cm with consistent emergence and no visible signs of stress.

Coffea canephora

Germination rate was 60%. Seedlings reached a mean height of 8 cm and maintained healthy foliar development throughout the early growth phase.

Table 3. Comparative Germination Rate, Seedling Height, and Vigor Score Across Endangered and Control Plant Species (n = 3 per species)

	Endangered (Mean ± SD)	Control (Mean ± SD)
Germination Rate	31.20 ± 20.19%	79.30 ± 1.02%
Seedling Height	4.98 ± 4.01 cm	12.96 ± 1.49 cm
Vigor Score	1.75 ± 0.87	3.00 ± 0.00

Source: Data generated from nursery trials (2021)

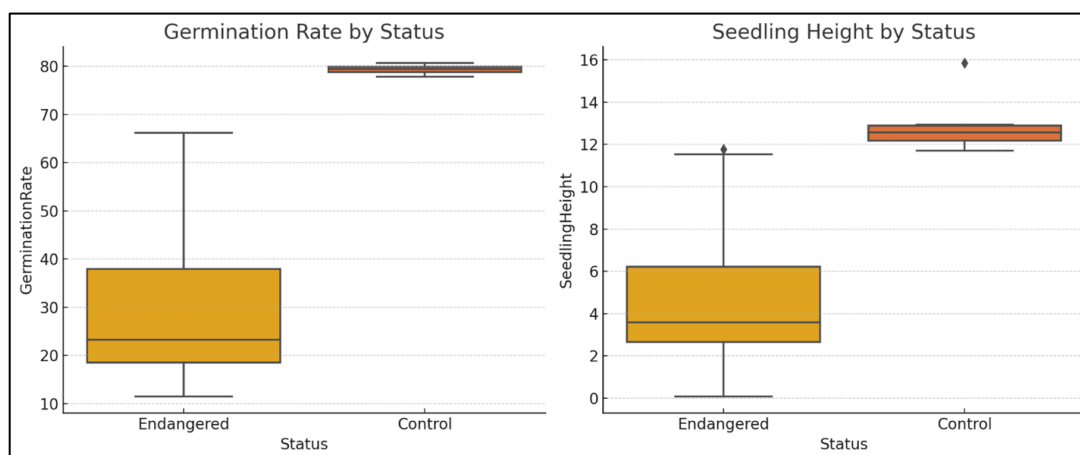


Figure 6: Comparative Summary of Germination Rate, Seedling Height, and Vigor Score Across Endangered and Control Plant Species.

Each species is represented with three key parameters: germination rate (%), average seedling height (cm), and qualitative vigor score (1–3 scale).

- X-axis: Plant Species
- Y-axis: Germination Rate (%), Seedling Height (cm), and Vigor Score (categorical scale)
- Legend: Colour bars differentiate between endangered species and reference/control species

Table 4. Qualitative Assessment of Germination and Seedling Vigor by Species

Species	Common Name	Conservation Status	Germination Rate (%)	Mean Seedling Height (cm)	Seedling Vigor
<i>Terminalia catappa</i>	Indian Almond	Control	85	12	High
<i>Cola millenii</i>	Monkey Cola	Control	70	10	Moderate–High
<i>Coffea canephora</i>	Robusta Coffee	Control	60	8	Moderate
<i>Picralima nitida</i>	Akuamma	Endangered	30	3	Low
<i>Pterocarpus santalinoides</i>	Mututu	Endangered	25	2.5	Very Low
<i>Allanblackia floribunda</i>	Tallow Tree	Endangered	20	2	Very Low
<i>Xylopia aethiopica</i>	Guinea Pepper	Endangered	35	4	Low
<i>Lophira alata</i>	Red Ironwood Tree	Endangered	40	5	Low
<i>Buchholzia coriacea</i>	Wonder Kola	Endangered	30	3	Very Low

Source: Data generated from nursery trials (2021)

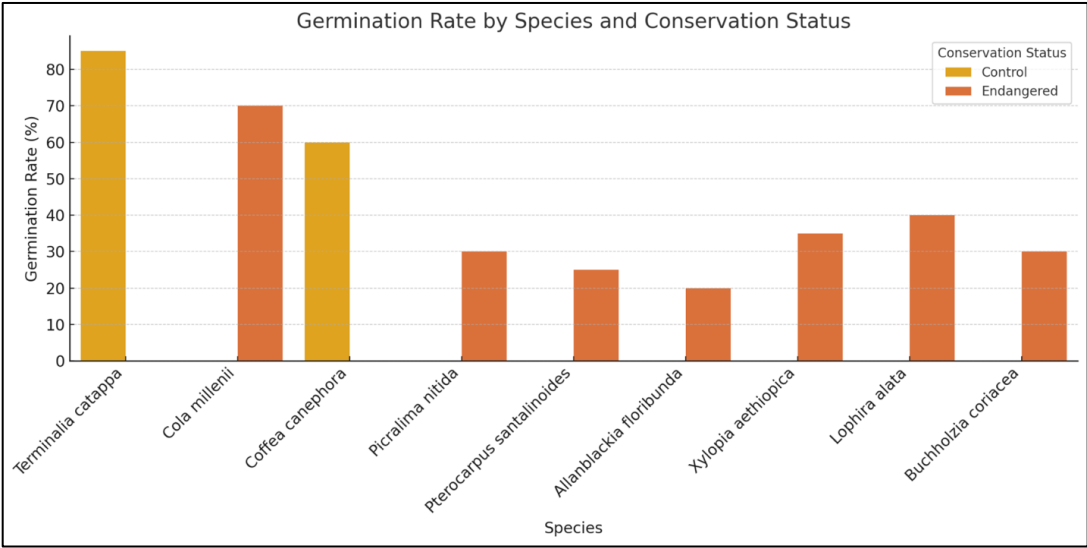


Figure 7: Germination Rate by Species and Conservation Status

This chart compares average seedling height (cm) and germination rate (%) across all species assessed.

- X-axis: Plant Species
- Y-axis: Height (cm) and Germination Rate (%)
- Legend: Bars indicate seedling height (left axis) and germination rate (right axis)

Discussion

The nursery trials revealed noticeable differences among species in germination rates, seedling vigor, and early growth characteristics (Liu et al., 2023). These variations likely result from species-specific traits such as dormancy type, environmental sensitivity, and ecological adaptation, as well as differing levels of human impact (Bewley et al., 2013). The findings show that a single propagation method is not suitable for all species. Some may respond better to treatments like scarification, cold stratification, or hormone application, depending on their seed physiology. In addition, several of the threatened species showed poor performance under nursery conditions, suggesting that in-situ conservation alone may not be enough. This highlights the importance of combining nursery-based propagation with field protection to improve their survival prospects (IUCN SSC, 2014).

A. Comparative Germination and Early Growth Performance

Among the species tested, *Terminalia catappa* recorded the highest germination success at 85%, with seedlings reaching an average height of 12 cm. This strong outcome reflects the species’ ecological flexibility and ability to perform well across diverse environmental conditions (Ramanan et al., 2024). Its consistent growth under nursery conditions reinforces its role as a control species, offering a dependable benchmark for comparing

more vulnerable taxa. The rapid and uniform seedling establishment observed further supports its suitability for use in reforestation and agroforestry projects.

Cola millenii and *Coffea canephora* also showed positive nursery responses, with germination rates of 70% and 60%, respectively. Though not listed as endangered, both species demonstrated stable growth patterns and reliable emergence, reinforcing their value in propagation programmes. The performance of *C. millenii* in particular suggests its potential for integration into conservation-agriculture initiatives, especially in regions where its natural populations are under local pressure (Adebola, 2011). Meanwhile, the relatively strong outcome for *C. canephora*, a species long subjected to domestication and breeding efforts, reflects the benefits of selection and its generally resilient physiology (Bopoko et al., 2024).

In contrast, all of the endangered and vulnerable species tested recorded considerably lower germination rates, generally between 20% and 40%, and showed uneven or weak seedling development. These outcomes point to the challenges of using uniform nursery methods for species that have specific germination requirements. Factors such as dormancy, moisture sensitivity, and dependence on narrowly defined habitat conditions likely contributed to their poor performance, traits often seen in species with recalcitrant seeds (Berjak & Pammenter, 2013). The results reinforce the need for customised propagation techniques tailored to each species' biology, especially in cases where conservation and restoration efforts are taking place outside their natural environments.

B. Endangered Species Constraints and Ecophysiological Implications

Allanblackia floribunda had the poorest results in this study, with only 20% of seeds germinating. Its low success is likely tied to its recalcitrant seed nature, which limits how long seeds remain viable and narrows the timeframe for sowing (Ofori et al., 2011). Many of the seedlings also failed to survive, which may be due to how sensitive the species is to changes in humidity and temperature, even under controlled nursery conditions. These observations suggest that *A. floribunda* seeds should be sown immediately after harvest and may require tighter environmental control or treatments like gibberellic acid to improve germination (Gayatri et al., 2021).

Picralima nitida and *Pterocarpus santalinoides* also performed poorly, with germination rates of 30% and 25%, respectively. Both plants are very important plants that are valued for their ethnobotanical relevance, but their seedlings showed signs of etiolation and failure of their cotyledon, possibly due to dormancy or missing environmental cues like alternating light and temperature (Gbadamosi, 2013; Fredrick et al., 2021). In the case of *P. santalinoides*, its hard seed coat may have played a role, which is typical for members of the Fabaceae family (Wen et al., 2024). These results point to the need for species-specific treatments such as scarification or heat exposure before sowing.

Buchholzia coriacea and *Xylopia aethiopica* both recorded moderate germination (30% and 35%) but showed weak seedling establishment (Ekeke, Ariwaodo & Enwongo-Abasi, 2021;

Johnson & Murray, 2018). Both species come from shaded rainforest environments, and their poor performance suggests that the nursery conditions may not have matched their native habitat requirements. Factors like light intensity, temperature, and humidity likely affected their growth.

Although *Lophira alata* achieved a slightly higher germination rate of 40%, the seedlings grew slowly and remained small. This could be linked to poor nutrient uptake or restricted root growth. Its hard seed coat also suggests it might benefit from pre-sowing treatments such as mechanical scarification or gibberellic acid, as shown in other tropical hardwood species (Kouakou et al., 2016).

C. Ecological and Conservation Implications

Germination trials showed that control species performed noticeably better than the endangered ones. Species like *Terminalia catappa* and *Coffea canephora*, which are more commonly cultivated and adapted to a range of environments, responded well under the trialed nursery conditions. The endangered species, however, struggled to germinate. Many of them are ecologically specialised or have dormancy challenges that likely contributed to their poor performance (Yang et al., 2025).

For species at risk, successful propagation depends on a closer understanding of their seed behavior. Techniques such as scarification, stratification, embryo removal, or the use of gibberellic acid could help improve germination in some cases (Li, Guan & Probert, 2007). Many of the endangered species in this study showed high mortality and poor seedling development, even after germination. This suggests that standard nursery conditions may not meet their ecological needs. Some of these plants may rely on specific microclimates, soil conditions, or biological interactions that are difficult to replicate outside their native habitats. For such species, propagation should be paired with habitat-based strategies, including in-situ trials and restoration of natural growing conditions (Haven et al., 2006; Bhatt, Gallacher & Souza-Filho, 2020). This approach is especially important in regions like Nigeria's rainforest belt, where many threatened species are native and face growing pressure from land-use change and overharvesting (Enuoh & Ogogo, 2018).

Limitation and Future Direction

While this study provided useful insights, a few limitations likely affected the results. First, the number of seeds tested per species was relatively small, which made it difficult to detect finer trends in germination and seedling development. All species were grown under the same nursery conditions to allow comparison, but these conditions may not have suited the specific ecological needs of every species, especially those that grow in more specialised habitats.

Another limitation was the use of a uniform sowing protocol without applying species-specific seed pre-treatments. Many tropical forest species require dormancy-breaking techniques like scarification or stratification, and the absence of these treatments may have contributed to the low germination rates observed in some cases. Seed origin and handling

after collection were not fully standardised either, which could have affected seed quality and early seedling growth.

Finally, the study focused only on early-germination development. It did not track longer-term growth or stress responses, which means we do not have information on how well these species would perform beyond the nursery phase. Also, physiological traits like chlorophyll content or biomass accumulation were not measured, so the assessment of seedling health was limited to height and emergence rates.

Future studies should take a more species-specific approach to germination and early growth, building on the patterns observed in this preliminary work. A key area for improvement is the use of targeted pre-treatments. These could include methods like physical scarification, temperature conditioning (hot or cold water treatments), or applying plant hormones such as gibberellic acid to improve germination, especially in species with dormancy issues.

Environmental conditions in future trials should also be adjusted more precisely. Controlling variables such as humidity, light exposure, temperature, and soil composition can help recreate the native conditions that some species may require. This would make it easier to refine nursery protocols based on each species' specific needs.

Beyond early germination, it will be important to extend the observation period to track survival, growth rates, and stress responses over time. Monitoring seedlings beyond the nursery phase, both in controlled environments and in field trials, can give better insight into their adaptability and suitability for reintroduction.

Seed storage and viability also deserve more focused study, particularly for species that are sensitive to drying or have a short shelf life. Understanding how quickly seed quality declines under different conditions could help inform seed banking strategies and improve ex-situ conservation planning.

There is also value in exploring the genetic and physiological traits that influence seed viability and early growth. Tools such as genetic diversity assessments or tests for stress tolerance markers could help identify stronger seed sources and support more reliable propagation.

Lastly, the success of any conservation work will depend on strong collaboration. Working closely with local communities, forestry departments, and conservation agencies will be essential to apply these research findings in real-world restoration projects and habitat protection programs.

By addressing these areas, future research can strengthen the foundation for species-specific propagation and help improve the conservation outlook for rare and endangered plants in Nigeria and similar environments.

Conclusion

This study explored the germination patterns and early growth of nine tropical plant species, including several that are threatened or not well documented. By growing all

species under the same nursery conditions, the results highlighted clear differences in how each one responded. While commonly cultivated species such as *Terminalia catappa* and *Cola millenii* performed well, most of the endangered species struggled to germinate and showed weak seedling development.

These outcomes reflect the challenges of using standard propagation methods for species that have specialised seed traits or narrow habitat preferences. The low success rates among endangered species suggest that more attention is needed in designing propagation protocols that match their biological and ecological requirements.

Although this was a preliminary investigation, the findings point to practical steps that can be taken to improve conservation outcomes. These include adjusting environmental conditions in the nursery, applying seed pre-treatments where needed, and combining propagation work with broader efforts such as habitat restoration and seed banking. Further research should also look beyond germination, focusing on long-term seedling survival and field performance.

Protecting rare and threatened plant species will require a combination of technical knowledge, fieldwork, and collaboration with communities and conservation agencies. This study contributes to that effort by providing early evidence that can help guide future propagation and conservation strategies, especially in regions like Nigeria, where many of these species are under increasing pressure.

References

- Adebola, P. O. (2011). Cola. *Springer EBooks*, 63–71. https://doi.org/10.1007/978-3-642-21201-7_4
- Adetola, B. O., & Adetoro, A. O. (2014). Threats to biodiversity conservation in Cross River National Park, Nigeria. *International Journal of Conservation Science*, 5(4).
- Adewale, D. B., & Abberton, M. T. (2024). African yam bean (*Sphenostylis stenocarpa*). *Potential Pulses*, 14–38. <https://doi.org/10.1079/9781800624658.0002>
- Agianaku, O. F., & Aigbokhan, E. I. (2018). Flora of Ogba Zoo and Nature Park, Benin City, Nigeria: I. Vegetation Structure. *Nigerian Journal of Botany*, 31(1).
- Agumagu, O. O., Marchant, R., & Stringer, L. C. (2025). Land use and land cover change dynamics in the Niger Delta region of Nigeria from 1986 to 2024. *Land*, 14(4), 765. <https://doi.org/10.3390/land14040765>
- Akindele, S. O., & LeMay, V. M. (2006). Development of tree volume equations for common timber species in the tropical rain forest area of Nigeria. *Forest Ecology and Management*, 226(1-3), 41–48. <https://doi.org/10.1016/j.foreco.2006.01.022>
- Alegbeleye, O. M., Rotimi, Y. O., Shomide, P., Oyediran, A., Ogundipe, O., & Akintunde-Alo, A. (2024). Land use land cover (LULC) analysis in Nigeria: A systematic review of data, methods, and platforms with future prospects. *Bulletin of the National Research Centre/Bulletin of the National Research Center*, 48(1). <https://doi.org/10.1186/s42269-024-01286-z>
- Anwadike, B. (2020). Biodiversity Conservation in Nigeria: Perception, challenges and possible remedies. *Current Investigations in Agriculture and Current Research*, 8(4). <https://doi.org/10.32474/ciacr.2020.08.000293>
- Bamigboye, S. O., Odewo, S. A., Jimoh, M. O., Lasisi, I. A., & Momo, B. O. (2022). Studies on extinction risk of genus *Azelia* in Nigeria from biogeographical perspective. *Zenodo (CERN European Organization for Nuclear Research)*. <https://doi.org/10.5281/zenodo.7028007>

- Berjak, P., & Pammenter, N. W. (2013). Implications of the lack of desiccation tolerance in recalcitrant seeds. *Frontiers in Plant Science*, 4. <https://doi.org/10.3389/fpls.2013.00478>
- Bewley, J. D., Bradford, K. J., Hilhorst, H. W. M., & Nonogaki, H. (2013). *Seed physiology of development, germination and dormancy*. Springer.
- Bezaredie, D., Tadesse, Z., & Tadesse, Z. (2023). Effects of *Prosopis juliflora* on plant diversity on rangeland in Shilabo district, Somali regional state, Ethiopia. *Heliyon*, 9(3), e14049. <https://doi.org/10.1016/j.heliyon.2023.e14049>
- Bhatt, A., Gallacher, D. J., & Souza-Filho, P. R. M. (2020). Germination strategies of annual and short-lived perennial species in the Arabian desert. *Journal of Arid Land*, 12(6), 1071–1082. <https://doi.org/10.1007/s40333-020-0023-8>
- Bodunde, D. (2023, September 5). *Borno launches tree planting campaign to tackle desertification*. Thecable. https://www.thecable.ng/orno-launches-tree-planting-campaign-to-tackle-desertification/?utm_source=chatgpt.com
- Bopoko, B., Broeckhoven, I., Verbist, B., Stoffelen, P., & Trefon, T. (2024). The history of robusta coffee cultivation in the Tshopo province, democratic republic of the Congo. *African Journal of Social Issues*, 7(1), 450–466. <https://doi.org/10.4314/ajosi.v7i1.29>
- Borokini, T. I. (2011). Invasive alien plant species in Nigeria and their effects on biodiversity conservation. *Tropical Conservation Science*, 4(1), 103–110. <https://doi.org/10.1177/194008291100400110>
- CBD. (2025). *Nigeria – country profile*. Convention on Biological Diversity. <https://www.cbd.int/countries/profile/?country=ng>
- Douthwaite, B., Schulz, S., Olanrewaju, A. S., & Ellis-Jones, J. (2007). Impact pathway evaluation of an integrated *Striga hermonthica* control project in Northern Nigeria. *Agricultural Systems*, 92(1-3), 201–222. <https://doi.org/10.1016/j.agry.2006.03.007>
- Ekeke, C., Ariwaodo, J., & Enwongo-Abasi, E. E. (2021). Morphological and anatomical studies on *Buchholzia coriacea* Engl. (Capparaceae) endemic to West Africa. *Jordan Journal of Natural History*, 8(2), pp.25-34. https://www.rscn.org.jo/uploaded_files/journal/6764075ccb8491734608732.pdf
- Elagib, N. A., Ali, M. M. A., & Musa, A. A. (2024). Intensifying droughts render more Sahel drylands unsuitable for cultivation. *The Science of the Total Environment*, 176390–176390. <https://doi.org/10.1016/j.scitotenv.2024.176390>
- Eludoyin, O. S., Dappa, D. I., & Kokei, P. N. (2021). Impact of logging on non-timber forest products in a rainforest ecosystem of Cross River State, Nigeria. *Journal of Research in Forestry, Wildlife and Environment*, 13(4), pp.66-76.
- Enuoh, O. O. O., & Ogogo, A. U. (2018). Assessing tropical deforestation and biodiversity loss in the Cross River rainforest of Nigeria. *Open Journal of Forestry*, 08(03), 393–408. <https://doi.org/10.4236/ojf.2018.83025>
- Fahrig, L., Arroyo-Rodríguez, V., Bennett, J. R., Boucher-Lalonde, V., Cazetta, E., Currie, D. J., Eigenbrod, F., Ford, A. T., Harrison, S. P., Jaeger, J. A. G., Koper, N., Martin, A. E., Martin, J.-L., Metzger, J. P., Morrison, P., Rhodes, J. R., Saunders, D. A., Simberloff, D., Smith, A. C., & Tischendorf, L. (2019). Is habitat fragmentation bad for biodiversity? *Biological Conservation*, 230, 179–186. <https://doi.org/10.1016/j.biocon.2018.12.026>
- FAOLEX Database. (2025). *National biodiversity strategy and action plan 2016-2020*. Fao.org. <https://www.fao.org/faolex/results/details/en/c/LEX-FAOC168968/>
- Federal Ministry of Trade. (2023). *Endangered species (control of international trade and traffic) Act, 1985*. PolicyVault.Africa. <https://www.policyvault.africa/policy/endangered-species-control-of-international-trade-and-traffic-act-1985/>

- Flood, K., Mahon, M., & McDonagh, J. (2022). Everyday resilience: Rural communities as agents of change in peatland social-ecological systems. *Journal of Rural Studies*, 96, 316–331. <https://doi.org/10.1016/j.jrurstud.2022.11.008>
- Fredrick, C., Ekeke, B. A., Omokhua, G. E., & Alex, A. (2021). Assessment of the effect of cutting length on sprout and growth of *Pterocarpus santalinoides* l'hérit. ex DC. *Journal of Applied Life Sciences International*, 1–9. <https://doi.org/10.9734/jalsi/2021/v24i930256>
- Gayatri, G. P., Kumar, K. G. A., Nair, P. S., & Pillai, M. S. (2021). GA/ABA antagonism in the physiology of seed germination in the recalcitrant and vulnerable tree- *vateria indica* L. *Indian Journal of Agricultural Research, Of*. <https://doi.org/10.18805/ijare.a-5729>
- Gbadamosi, A. E. (2013). Germination biology of *Picralima nitida*(Stapf) under pretreatments. *Greener Journal of Biological Sciences*, 3(1), 013–020. <https://doi.org/10.15580/gjbs.2013.1.110912247>
- Haider, H. (2019). *Climate change in Nigeria: Impacts and responses*. <https://www.preventionweb.net/publication/climate-change-nigeria-impacts-and-responses>.
- Haven, K., Vitt, P., Maunder, M., Guerrant, E. O., & Dixon, K. (2006). Ex-situ plant conservation and beyond. *BioScience*, 56(6), 525. [https://doi.org/10.1641/0006-3568\(2006\)56\[525:espcab\]2.0.co;2](https://doi.org/10.1641/0006-3568(2006)56[525:espcab]2.0.co;2)
- Heinrich, M. (2001). Applied ethnobotany. people, wild plant use and conservation,. *Journal of Ethnopharmacology*, 77(2-3), 265–266. [https://doi.org/10.1016/s0378-8741\(01\)00282-3](https://doi.org/10.1016/s0378-8741(01)00282-3)
- IITA. (2024). *Cultivating resilience and wealth: The role of indigenous trees in Nigeria's future*. International Institute of Tropical Agriculture. <https://www.iita.org/news-item/cultivating-resilience-and-wealth-the-role-of-indigenous-trees-in-nigerias-future>
- IPBES. (2019). *Global assessment report on biodiversity and ecosystem services IPBES Secretariat*. IPBES. <https://www.ipbes.net/node/35274>
- Isah, Y. P., Ahmed, J., & Aliyu, H. (2019). Survey on exotic plant species in Ahmadu Bello University, Zaria Botanical Garden. *FUW Trends in Science & Technology Journal*.
- IUCN. (2015). *International union for conservation of nature IUCN species survival commission guidelines on the use of ex-situ management for species conservation*. <https://portals.iucn.org/library/sites/library/files/documents/2014-064.pdf>
- Johnson, D. M., & Murray, N. A. (2018). A revision of *Xylopia* L. (Annonaceae): The species of tropical Africa. *PhytoKeys*, 97, 1–252. <https://doi.org/10.3897/phytokeys.97.20975>
- Kouakou, K. L., Kouakou, C., Koffi, K. K., Dao, J., Beugré, Baudoin, J.-P., & Bi, Z. (2016). Effect of mechanical scarification and gibberellins (GA3) on seed germination and growth of *Garcinia kola* (Heckel). *Journal of Applied Biosciences*, 103(103), 9811–9818. <https://doi.org/10.4314/jab.v103i1.3>
- Lee, H. (2023). Ex-situ conservation efforts for plant diversity protection with a focus on seeds. *The Open Agriculture Journal*, 17(1). <https://doi.org/10.2174/18743315-v17-230822-2023-15>
- Li, A.-R., Guan, K.-Y., & Probert, R. J. (2007). Effects of light, scarification, and gibberellic acid on seed germination of eight *Pedicularis* species from Yunnan, China. *HortScience*, 42(5), 1259–1262. <https://doi.org/10.21273/hortsci.42.5.1259>
- Liu, D., Yang, J., Tao, L., Ma, Y., & Sun, W. (2023). Seed germination and seedling growth influenced by genetic features and drought tolerance in a critically endangered maple. *Plants*, 12(17), 3140. <https://doi.org/10.3390/plants12173140>
- Liu, J., Chen, M., Wang, L., Liu, T., Jin, X., Yu, F.-H., & Zhang, Y. (2024). Habitat fragmentation differentially affects invasive and native plant diversity in a human-dominated wetland island system. *Plant Diversity*. <https://doi.org/10.1016/j.pld.2024.09.003>
- Lopoukhine, N., Crawhall, N., Dudley, N., Figgis, P., Karibuhoye, C., Laffoley, D., Londoño, J. M., MacKinnon, K., & Sandwith, T. (2012). Protected areas: Providing natural solutions to 21st-century challenges. *Surveys and Perspectives Integrating Environment and Society*, 5(2), 117–131.
- National Centre for Genetic Resources and Biotechnology. (2025). *About us – NACGRAB*. [Nacgrab.gov.ng](https://www.nacgrab.gov.ng/about-one/). <https://www.nacgrab.gov.ng/about-one/>

- Ndinwa, C. C. G., & Akpafun, S. (2012). Environmental Impacts of Oil Exploration and Exploitation in the Niger Delta of Nigeria. *Journal of Environmental Management and Safety*, 3(1), 159–183.
- Nzeh, E. C., Uke, P. C., Attamah, N., Nzeh, D. C., & Agu, O. (2016). Climate change and agricultural production in Nigeria: A review of status, causes and consequences. *Nigerian Agricultural Policy Research Journal (NAPReJ)*. <https://doi.org/10.22004/ag.econ.292062>
- Ofori, D. A., Peprah, T., Cobbinah, J. R., Atchwerebour, H. A., Osabutey, F., Tchoundjeu, Z., Simons, A. J., & Jamnadass, R. (2025). Germination requirements of *Allanblackia parviflora* seeds and early growth of seedlings. *New Forests*, 41(3), 337–348. <https://doi.org/10.1007/s11056-011-9252-1>
- Omokhua, G. E., Fredrick, C., & A Eyekpegaha. (2019). Germination and seedling growth response of *Aframomum melegueta* K. Schum to different pre-treatments. *Journal of Research in Forestry, Wildlife and Environment*, 11(3), 72–80.
- Omonhinmin, C. A., Taiwo, N. S., Okonkwo, P. B., Ajayi, I. M., Paul Akinniyi Akinduti, Aworunse, O. S., Ibukun Ajiboye, Taiwo, O. S., Bosede Temitope Adekeye, Olubukola Oziegbe, Bello, A. O., Eze Frank Ahuekwe, Oyekanmi, J., Olanrewaju Olufowobi, Margaret Ikhiwili Oniha, Oyewumi Oshamika, Ejoh, S. A., Adewale, A. G., Akinnola, O. O., & Oranusi, S. U. (2024). Dataset on rbcL-based intra-specific diversity and population structure of *Parkia biglobosa* (Jacq.) in Nigeria. *Data in Brief*, 110146–110146. <https://doi.org/10.1016/j.dib.2024.110146>
- Onojeghuo, A. O., & Onojeghuo, A. R. (2015). Mapping forest transition trends in Okomu Reserve using Landsat and UK-DMC-2 satellite data. *South African Journal of Geomatics*, 4(4), 486. <https://doi.org/10.4314/sajg.v4i4.9>
- OSAWARU, M. E., OGWU, M. C., & AHANA, C. M. (2022). Current status of plant diversity and conservation in Nigeria. *Nigerian Journal of Life Sciences (ISSN: 2276-7029)*, 3(1), 168–178. <https://doi.org/10.52417/njls.v3i1.120>
- Patrick.Tonissen. (2019). *A million threatened species? Thirteen questions and answers*. IPBES Secretariat. <https://www.ipbes.net/news/million-threatened-species-thirteen-questions-answers>
- Pimm, S. L., Jenkins, C. N., Abell, R., Brooks, T. M., Gittleman, J. L., Joppa, L. N., Raven, P. H., Roberts, C. M., & Sexton, J. O. (2014). The biodiversity of species and their rates of extinction, distribution, and protection. *Science*, 344(6187), 1246752–1246752. <https://doi.org/10.1126/science.1246752>
- Ramanan S, S., Arunachalam, A., Singh, R., & Verdiya, A. (2024). Tropical almond (*Terminalia catappa*): A holistic review. *Heliyon*, 11(1), e41115. <https://doi.org/10.1016/j.heliyon.2024.e41115>
- Simire, M. (2023). *NCF, NABU launch three-year project to boost livelihood of eight communities in Cross River - Environews - latest environment news, climate change, renewable energy*. EnviroNews - Latest Environment News, Climate Change, Renewable Energy. https://www.environewsnigeria.com/ncf-nabu-launch-three-year-project-to-boost-livelihood-of-eight-communities-in-cross-river/?utm_
- Simons, A. J., & Leakey, R. R. B. (2004). Tree domestication in tropical agroforestry. *Agroforestry Systems*, 61-62(1-3), 167–181. <https://doi.org/10.1023/b:agfo.0000028997.74147.f9>
- Uwalaka, N. O., & Muoghalu, J. I. (2021). Ecological impact of *Chromolaena odorata* (L.) King and Robinson on native plant communities and soil seed bank in Ile-Ife, Nigeria. *African Journal of Ecology*, 59(2), 572–581. <https://doi.org/10.1111/aje.12848>
- Wen, Z., Lu, X., Wen, J., Wang, Z., & Chai, M. (2024). Physical seed dormancy in legumes: Molecular advances and perspectives. *Plants*, 13(11), 1473–1473. <https://doi.org/10.3390/plants13111473>
- Yang, Y., Luo, L., Zhu, L., Cheng, Y., Yuan, M., Ruan, X., & Zhao, K. (2025). Complex seed dormancy in *Parrotia subaequalis*: Identification, breaking mechanisms, and conservation strategies for an endangered species in China. *Plants*, 14(3), 452–452. <https://doi.org/10.3390/plants14030452>