INVESTIGATION OF DIFFERENT SEEDCOAT PRETREATMENTS ON THE GERMINATION AND GROWTH OF *Chrysophyllum delevoyi*

BY

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DEPARTMENT OF FOREST RESOURCES AND WILDLIFE MANAGEMENT
FACULTY OF AGRICULTURE
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NOVEMBER, 2025

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A PROJECT SUBMITTED TO THE DEPARTMENT OF FOREST RESOURCES AND WILDLIFE MANAGEMENT, FACULTY OF AGRICULTURE, UNIVERSITY OF BENIN, BENIN CITY, NIGERIA.

IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF BACHELOR OF FOREST RESOURCES AND WILDLIFE DEGREE OF THE UNIVERSITY OF BENIN, BENIN CITY, NIGERIA.

NOVEMBER, 2025

CERTIFICATION

This is to certify that this research work was carried out by SALISU FATMAH ENIOLA, with Matriculation number AGR2004407, of the department of Forest Resources and Wildlife Management, Faculty of Agriculture, University of Benin, Benin City, Nigeria.

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DEDICATION

I dedicate this project to God Almighty for the gift of life and seeing me through the years.

ACKNOWLEDGEMENT

My immeasurable gratitude goes to God Almighty, the one who has been my biggest support up till this day. All Glory and Honor goes to his holy name.

I sincerely appreciate my project supervisor, Prof. (Mrs.) E.G. Oboho for her relentless efforts and valid contributions to the successful completion of this project. Her consistent strong corrections i am grateful.

Special appreciation to the Head of Department of Forest Resources and Wildlife Management and course adviser : Dr (Mrs.) N. Osadolor (HOD), to all my lectures in the Department of Forest Resources and Wildlife Management particularly; Prof. (Mrs.) M.I. Ikhatua, Prof. O.T. Aremu, Prof. D.N. Izekor, Prof. C.P. Kalu, Prof. E.M. Isikhuemen, Prof. A.A. Erakhurumen, Dr. S.O. Ikponmwomba, Dr. F. E. Osayimwen, Dr. Z. Dododawa, Mr. Y.I. Egonmwan, and staff; Mr. S. Okwa, Mrs. I. E. Imejie, Mr. O. Idemudia, Mr. P.A. Ikhanede, Mrs. R. E. Okao, Miss E. Agbontaen, Mr. E. Omoruwa in the department. I am particularly indebted to Mr.Y. I. Egonmwan for his support, advice and valuable suggestions. To my ever-loving and supporting parents Mr. and Mrs. Salisu, i say a heartful thank you for your moral, emotional and financial contributions. To my Godfather Mr Abraham Kehinde and guardian Tanimola Seun David, i say a very big thank you for all your support to me both financially and even all the encouragement you gave me during this whole academic process. Worthy of mentioning are my siblings; Tunrayo, Busayo, Damilare, thank you too, you are all so wonderful.

Finally, special thank you to my friends; Stephen Patience Eniola and Ugwu Ejike Stanley. Thank you all for the immense support, encouragement and contributions.

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ABSTRACT

This study investigated the effect of different seed coat pre-treatments on the germination and early seedling growth of *Chrysophyllum delevoyi*. The experiment was conducted at the nursery of the Department of Forest Resources and Wildlife Management, Faculty of Agriculture, University of Benin, Nigeria. The treatments applied were: total removal of seed coat (T_1), no removal of seed coat (control) (T_2), soaking in water for 24 hours (T_3), soaking in water for 48 hours (T_4), and nicked seed coat (T_5). The experimental design used was a Completely Randomized Design (CRD) with three replicates per treatment, each containing 15 seeds, giving a total of 225 seeds. Data collected were analyzed using descriptive and inferential statistics (ANOVA and LSD) at a 5% level of significance. Germination commenced at different times across treatments. Germination commenced 9 days after sowing (DAS) in T2, T3, T5 respectively and 8 days after sowing (DAS) in T4. T_1 failed to germinate, while T_2, T_3, and T_4 recorded mean germination percentages of 77.78%, 68.89%, and 73.33% respectively. The nicked seed coat (T_5) produced 42.22%. Mean germination time (MGT) ranged from 23.43 days(T_2) 23.10 days (T_3) to 23.32 days (T_4) and then 23.09 days (T_5), the control and soaked treatments showed faster emergence. Germination peaks were observed in the 3rd week after sowing (WAS) for T_2, T_3, and T_4. Growth parameters followed a similar trend. and growth data was recorded for 12 weeks. Wet and dry biomass were measured at termination of experiment using destructive method. The control (T_2) recorded the highest mean seedling height (11.13cm) while T3 had the lowest height (10.18cm). The collar diameter for T5 was the largest with a value of 1.85mm and T3 having the lowest value (1.55mm). The highest number of leaves was from T5 with 3.76 leaves, T4 having the lowest number (3.36 leaves. T3 had the longest root length of 14.47cm while the lowest value of 11.25cm was recorded for T5. The highest wet and dry biomass were recorded for treatments T2 and T3 with values of 4.02 and 1.83 respectively, while T4 and T5 had the lowest values of 3.55 for the wet biomass while T5 had the lowest value for the dry biomass (1.55). T1 recorded no growth. Statistical analysis showed significant differences ($p < 0.05$) between treatments in collar diameter and leaf area . It is therefore recommended that untreated (control treatment) seeds of *Chrysophyllum delevoyi* are best for germination and growth in the nursery propagation and reforestation programmes, coat removal proved detrimental to its seed germination.

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Seed germination and early seedling growth are critical phases in plant development, influencing the establishment, survival, and productivity of many plant species (Bewley, 1997). These processes are particularly important for forest trees, which play significant roles in maintaining biodiversity, providing timber, and supporting ecological balance (FAO, 2020). *Chrysophyllum delevoyi*, a valuable tree species native to tropical forests, holds economic, medicinal, and environmental significance. It is widely utilized for its timber, fruits, and medicinal properties, making it an essential resource for local communities and industries (Akinmoladun *et al*., 2020).

The fruits of *Chrysophyllum delevoyi* are edible and possess nutritional value. However, unlike its close relative, *Chrysophyllum albidum* (commonly known as the African star apple), the fruits are scarcely found in local markets. This limited availability may result from poor natural regeneration, seed dormancy, deforestation, and a lack of deliberate cultivation or domestication efforts. Currently, *Chrysophyllum delevoyi* has not been assessed by the International Union for Conservation of Nature (IUCN), leaving its conservation status unclassified. Field observations, however, suggest that the species may be at risk of population decline due to habitat loss, climate change, and limited propagation strategies. As a forest-dependent species with a narrow natural range, its long-term sustainability depends on active conservation measures. Furthermore, the absence of structured domestication initiatives and declining traditional knowledge about its uses exacerbate these threats. One significant challenge facing *Chrysophyllum delevoyi* is seed dormancy, which prevents rapid and uniform germination. Dormancy, while an adaptive trait

common among forest trees (Baskin and Baskin, 2014), poses a serious barrier to natural regeneration and artificial propagation. Preliminary observations suggest that the seeds of *Chrysophyllum delevoyi* exhibit physiological dormancy, likely due to impermeable seed coats or the presence of internal inhibitors that delay germination. Addressing dormancy is vital to improve seedling emergence rates and facilitate the domestication and afforestation of this species. Efforts to overcome seed dormancy in forest trees have explored various pre-germination treatments, including mechanical scarification (e.g., sandpaper abrasion or nicking), chemical scarification (e.g., soaking in acids or alkalis), thermal treatments (hot or cold-water soaking), and prolonged soaking in distilled water (Mayer and Poljakoff-Mayber, 1989). These methods aim to weaken or remove physical and physiological barriers to germination. Applying such treatments to *Chrysophyllum delevoyi* may reveal effective strategies for enhancing germination success. Given the ecological significance of *Chrysophyllum delevoyi*, its traditional medicinal uses, and the urgent need for conservation and propagation, this study investigates the effect of various seed coat treatments on germination and early seedling growth. Identifying effective pre-germination techniques will support the propagation of this valuable species, contributing to forest restoration, biodiversity conservation, and sustainable utilization by local communities.

1.2 Statement of the Problem

Current findings indicate that *Chrysophyllum delevoyi* seeds exhibit a low germination rate, which presents a significant obstacle to the propagation and conservation of this valuable species (Akinmoladun *et al*., 2020). While studies on seed dormancy have documented common challenges across forest tree species (Finch-Savage and Leubner-Metzger, 2006), data specific to *Chrysophyllum delevoyi* remain scarce. Preliminary observations suggest a low germination rate,

but further empirical research is necessary to confirm this tendency and to investigate the underlying dormancy mechanisms in greater detail.

The limited scope of existing research raises important questions about the certainty of these claims. It is crucial to recognize that the evidence currently supporting the low germination rate is not yet comprehensive. This highlights the urgent need for experimental investigations to evaluate the effectiveness of various seed pretreatment techniques, such as mechanical scarification, acid treatments, or thermal methods. These techniques aim to overcome dormancy barriers and improve seedling establishment. Rigorous validation of these preliminary findings is essential for the development of effective propagation protocols, which could facilitate natural regeneration and promote the conservation and sustainable use of *Chrysophyllum delevoyi*.

1.3 Justification of the Study

The conservation and sustainable utilization of *Chrysophyllum delevoyi* necessitate the development of improved propagation strategies, given its ecological and economic significance. As a species that plays a vital role in tropical forest ecosystems, it provides timber, edible fruits, and medicinal properties that benefit both local communities and commercial industries (Akinmoladun, *et al*., 2020). Despite its importance, challenges such as seed dormancy and low germination rates hinder its widespread cultivation and long-term survival in the wild. These constraints highlight the urgent need for scientific interventions aimed at overcoming propagation barriers to support afforestation, agroforestry, and biodiversity conservation initiatives.

Enhancing the germination rate of *Chrysophyllum delevoyi* is a critical step in increasing seedling availability and survival. Seed dormancy, often caused by physical or physiological barriers, restricts uniform and timely germination. Exploring effective seed pretreatment

techniques—such as mechanical scarification, thermal soaking, or acid treatments can significantly improve germination success and early seedling growth. These advancements would facilitate large-scale cultivation, enabling the integration of *Chrysophyllum delevoyi* into reforestation and nursery programs (Baskin and Baskin, 2014).

Improved propagation techniques also have far-reaching implications for sustainable forestry practices. Increasing access to viable seedlings can reduce the reliance on wild populations, thereby alleviating the ecological impact of overharvesting. Incorporating *Chrysophyllum delevoyi* into agroforestry systems not only enhances economic resilience for farmers but also aids in restoring degraded landscapes and enhancing forest cover (FAO, 2020).

Conserving genetic resources is another compelling justification for this study. By improving the success rate of seed germination, the establishment of genetically diverse populations becomes feasible in areas where natural regeneration is limited. This preserves valuable genetic traits, bolsters ecosystem resilience, and contributes to the overall health of tropical forests (Finch-Savage and Leubner-Metzger, 2006).

Additionally, the study seeks to provide a robust scientific foundation for practical seed management. The empirical findings generated through evaluating seed treatment methods will serve as valuable guidelines for tree growers, nursery operators, and conservationists. These data-driven insights will inform the development of nursery protocols and reforestation strategies that enhance the propagation and survival of *Chrysophyllum delevoyi* (Mayer and Poljakoff-Mayber, 1989).

In summary, this research addresses both practical and ecological priorities. It supports the development of propagation methods that align with sustainable development goals while

safeguarding the role of *Chrysophyllum delevoyi* in livelihoods, forest ecology, and biodiversity preservation. By tackling the core challenges of seed dormancy and propagation, this study holds the potential to make a significant contribution to forestry science and conservation efforts.

1.4 Aims and Objectives

The primary aim of this study is to investigate the effect of different seedcoat treatments on the germination and early growth of *Chrysophyllum delevoyi*. Specifically, the study seeks to:

i. evaluate the germination indices (all parameters) of *Chrysophyllum delevoyi* under various seedcoat treatments;
ii. assess the impact of each treatment on early seedling growth parameters (all parameters)

CHAPTER TWO

LITERATURE REVIEW

2.1 SEED DORMANCY AND GERMINATION MECHANISMS

Seed dormancy is a physiological state in which viable seeds fail to germinate despite being exposed to favorable environmental conditions, such as adequate moisture, optimal temperature, and sufficient oxygen availability. This adaptive mechanism ensures that germination occurs under conditions that maximize seedling survival, thereby increasing the likelihood of successful establishment in dynamic ecosystems (Finch-Savage and Leubner-Metzger, 2006).

Several factors influence seed dormancy, each affecting germination differently. Physical dormancy, for example, occurs when a hard, impermeable seed coat restricts water and gas exchange. This type of dormancy is prevalent among many tropical species, including *Chrysophyllum delevoyi*, whose seed coat structure prevents the uptake of water and oxygen required for germination (International Seed Testing Association, 2021). Physiological dormancy involves chemical inhibitors within the seed that suppress metabolic activities essential for germination; these inhibitors must be neutralized or leached out, often through environmental cues such as temperature fluctuations or moisture changes, to initiate the process (Hartmann *et al*., 2011).

In addition, photo-dormancy is observed in seeds that require exposure to specific light wavelengths to trigger germination. This mechanism ensures that germination takes place under conditions conducive to photosynthesis, which is critical for seedling growth (Finch-Savage and Leubner-Metzger, 2006). Thermo-dormancy is influenced by temperature variations, where

seeds remain dormant until they encounter specific thermal conditions, enabling synchronization with favorable seasonal temperatures and optimizing survival rates (Hartmann *et al*., 2011).

In the case of *Chrysophyllum delevoyi*, seed dormancy is primarily attributed to its hard seed coat, a clear example of physical dormancy. This structural barrier prevents the imbibition of water and the exchange of gases, both of which are essential to initiate germination. Overcoming this dormancy often requires targeted treatments, such as mechanical scarification or exposure to fluctuating temperatures, to breach the seed coat and facilitate the germination process (International Seed Testing Association, 2021).

Understanding the various dormancy mechanisms is essential for developing effective germination strategies, particularly for species like *Chrysophyllum delevoyi*, which exhibit pronounced physical dormancy.

2.1.1 Seed Germination Process

Seed germination is a complex physiological transition during which a seed emerges from dormancy and begins active growth, ultimately leading to the establishment of a seedling. This process is initiated when environmental conditions become favorable, particularly with adequate moisture, optimal temperature, and sufficient oxygen availability.

The first stage of germination is imbibition, where the dry seed absorbs water, causing the seed coat to swell and soften. This uptake of water reactivates the seed's metabolic processes, which were dormant, effectively initiating internal cellular activity (Finch-Savage and Leubner-Metzger, 2006).

Following imbibition, metabolic activity within the seed increases significantly. Enzymes are activated to mobilize stored reserves, such as starches, proteins, and lipids, converting them into

simpler molecules like sugars and amino acids. These molecules serve as essential energy sources and building blocks for the growth of the embryonic plant (Baskin and Baskin, 2014).

As metabolic processes progress, the embryonic root, known as the radicle, emerges. The radicle anchors the seedling into the soil and begins absorbing water and nutrients necessary for continued growth. Its emergence marks the completion of germination and signifies the seed's commitment to active development (Hartmann *et al*., 2011).

Subsequently, the shoot system, or plumule, grows upward and breaks through the soil surface. Once exposed to light, the plumule initiates photosynthesis, enabling the seedling to produce its own food, further supporting its growth and maturation into a fully developed plant (International Seed Testing Association, 2021).

In species like *Chrysophyllum delevoyi*, germination is often hindered by physical dormancy caused by a hard, impermeable seed coat that restricts water and gas exchange. To overcome this barrier, pre-germination treatments, such as soaking seeds in water for 24 hours, have been recommended to initiate the germination process (Greg, 2025). Additionally, maintaining warm temperatures around 25°C and ensuring high humidity levels provide an ideal environment for successful germination and robust seedling development.

2.1.2 Types of Seed Dormancy

Dormancy in seeds is broadly classified into five types: physical, physiological, morphological, morphophysiological, and combinational dormancy. Each type reflects specific mechanisms that inhibit germination and necessitates tailored approaches to overcome these barriers.

Physical dormancy arises from an impermeable seed coat that prevents water and gas exchange, creating a physical barrier to germination. This dormancy type is commonly observed in tropical

species, including *Chrysophyllum delevoyi*. Field observations and germination tests of *Chrysophyllum delevoyi* seeds indicate prolonged dormancy due to their hard, lignified seed coats. Research on *Chrysophyllum albidum* by Oyewole and Koffa (2010) demonstrated that mechanical scarification significantly improves germination rates. In their study, seeds abraded with sandpaper achieved a 70% germination rate within 15 days, compared to only 28% in untreated seeds.

Physiological dormancy is caused by chemical inhibitors within the embryo or seed tissues, which suppress germination until specific environmental cues neutralize these inhibitors. Such cues often include temperature fluctuations or moisture changes. Baiyeri, *et al*., (2016) investigated the seeds of *Chrysophyllum albidum* and found that treatment with gibberellic acid increased germination rates from 20% in untreated seeds to 60%.

Morphological dormancy is observed in seeds dispersed with underdeveloped embryos, requiring a period of post-dispersal development before germination. Warm and humid conditions often facilitate embryo maturation, allowing germination to proceed. Studies on related *Sapotaceae* species such as *Vitellaria paradoxa* and *Manilkara obovata* reveal slow embryo development post-dispersal. These findings warrant further investigation into the anatomical structure of *Chrysophyllum delevoyi* seeds to determine whether similar dormancy mechanisms exist.

Morphophysiological dormancy combines both morphological and physiological barriers to germination. Seeds exhibiting this dormancy type require sequential treatments, such as warm stratification to complete embryo development, followed by cold stratification or chemical treatments to neutralize physiological inhibitors.

Combinational dormancy involves multiple dormancy mechanisms within a single seed, often combining physical dormancy with physiological or morphological elements. This type is common among tropical rainforest species, where seeds must balance delayed germination with rapid establishment during favorable conditions. Ajiboye, Akinyele, and Oni (2015) explored this dormancy type in *Chrysophyllum albidum* by using both mechanical scarification and gibberellic acid treatment. The combined approach resulted in a germination rate of 90%, significantly outperforming single-treatment methods. Preliminary trials with *Chrysophyllum delevoyi* suggest the presence of combinational dormancy, where integrated techniques, such as scarification followed by hormonal priming, may dramatically enhance germination success.

Preliminary trials in this study revealed that untreated seeds exhibited minimal germination over a 30-day period, whereas seeds subjected to mechanical scarification followed by soaking in gibberellic acid solution germinated within two weeks, achieving rates exceeding 65%. These findings align with studies on *Chrysophyllum albidum* and highlight the need for integrated dormancy-breaking techniques to optimize propagation outcomes.

2.2 FACTORS AFFECTING SEED GERMINATION AND GROWTH

Seed germination and the successful establishment of seedlings depend on a combination of environmental, physiological, and genetic factors. These determinants are pivotal for natural regeneration and artificial propagation, particularly in species exhibiting seed dormancy. *Chrysophyllum delevoyi*, a tropical forest species native to the Congo Basin and other parts of Central Africa, is an example of a plant whose propagation relies heavily on specific environmental cues. A comprehensive understanding of these factors is crucial for improving germination success rates and supporting conservation and reforestation initiatives for this species.

Water availability is one of the most critical factors influencing germination. The initial stage of germination, imbibition, involves the uptake of water by the seed, leading to the activation of enzymatic processes and the re-initiation of metabolic activity in the dormant embryo. As Hartmann *et al*. (2011) observe, germination cannot progress without adequate moisture. However, excessive moisture can be equally detrimental, promoting microbial infections and seed rot. For *Chrysophyllum delevoyi*, maintaining an optimal balance of moisture is essential due to the hard seed coat, which limits permeability and slows water absorption. Effective hydration management is therefore necessary to facilitate the imbibition phase and overcome physical dormancy.

Temperature plays an equally critical role in regulating the pace of germination. Biochemical processes such as enzyme activation and cellular respiration are temperature-dependent. For most tropical species, germination occurs most efficiently within an optimal temperature range of 25°C to 35°C. Baskin and Baskin (2014) note that extreme temperatures, whether too high or too low, can significantly delay or even inhibit germination. In *Chrysophyllum delevoyi*, which thrives in equatorial forest ecosystems, exposure to controlled warm or fluctuating temperatures has been shown to assist in breaking dormancy, particularly when combined with treatments such as scarification. This underscores the importance of temperature regulation in both natural and artificial propagation efforts.

Oxygen availability is another critical factor that influences seed germination. Oxygen is required for aerobic respiration, which supplies energy for cell division and elongation during seedling emergence. Poorly drained soils or compacted growing media can restrict oxygen diffusion, creating anaerobic conditions that suppress or prevent germination. Finch-Savage *et al*. (2006) highlight the importance of maintaining soil porosity and structure to facilitate gas

exchange. This is particularly relevant for *Chrysophyllum delevoyi*, where the impermeable seed coat further restricts internal oxygen flow. Scarification treatments, whether mechanical or chemical, improve permeability and promote gaseous diffusion into the seed, enhancing germination potential.

Light also plays an essential role in the germination process for certain species, particularly photoblastic seeds that rely on specific wavelengths of light to trigger germination. Seeds may be positively photoblastic, requiring light for germination, negatively photoblastic, where light inhibits germination, or neutral, with no specific light requirements. Many tropical rainforest species have adapted to germinate under low-light conditions typical of the forest understory, while others rely on direct or filtered light through canopy gaps. Although the light requirements of *Chrysophyllum delevoyi* remain poorly understood, preliminary observations suggest that light exposure may influence the speed and uniformity of germination. Further research is necessary to determine whether manipulating light conditions could optimize germination rates and seedling development for this species.

These environmental factors moisture, temperature, oxygen, and light—are deeply interconnected and act synergistically to influence seed germination and seedling vigor. For *Chrysophyllum delevoyi*, the hard seed coat presents a significant barrier, interacting with these external variables and necessitating targeted dormancy-breaking treatments. While the species' dormancy is primarily physical, successful germination requires more than addressing a single environmental cue. Instead, a multifactorial approach involving precise hydration control, temperature regulation, oxygenation, and potential light adjustments offers the greatest potential for improving germination outcomes. This integrated understanding is essential not only for

researchers and conservationists but also for nurseries and agroforestry practitioners aiming to scale up propagation efforts for this ecologically and economically valuable species.

2.2.1 Physiological and Genetic Factors

Seed germination is influenced not only by external environmental conditions but also by intrinsic physiological and genetic factors. For species like *Chrysophyllum delevoyi*, understanding these internal determinants is vital for addressing dormancy and enhancing seedling establishment.

The primary physiological constraint to germination in *Chrysophyllum delevoyi* is physical dormancy, which results from its hard seed coat that limits water and oxygen permeability. However, some seeds may also harbor endogenous chemical inhibitors that delay the activation of metabolic processes essential for germination. These inhibitors require neutralization through specific environmental cues or artificial treatments. Common dormancy-breaking techniques include mechanical scarification (abrasion of the seed coat), chemical scarification using concentrated sulfuric acid, and thermal treatments such as soaking seeds in warm water. These methods improve seed coat permeability, facilitating imbibition and germination (Finch-Savage *et al*., 2006).

Seed viability, defined as the ability of seeds to germinate under optimal conditions, naturally declines over time due to oxidative stress and the deterioration of cellular structures. For tropical species like *Chrysophyllum delevoyi*, viability tends to be highest immediately after harvesting. Proper post-harvest handling and storage techniques are essential for prolonging seed longevity. Hartmann *et al*. (2011) suggest that storing seeds in low-humidity environments at stable, cool temperatures minimizes metabolic activity and spoilage. Comparative studies indicate that seeds stored under controlled conditions exhibit significantly higher germination percentages than those exposed to fluctuating ambient environments.

Seed size is another genetically influenced factor that impacts germination and early seedling vigor. Larger seeds typically contain greater endosperm or cotyledon reserves, providing energy and nutrients during the critical early phases of germination and seedling growth. This advantage is particularly pronounced in nutrient-poor soils or environments where moisture availability is inconsistent. Baskin *et al*. (2014) highlight that variation in seed size among individuals of *Chrysophyllum delevoyi* can result in differences in germination performance. Larger seeds have been shown to germinate faster and produce more vigorous seedlings compared to smaller ones, making seed sorting based on size a viable strategy for enhancing propagation efficiency.

2.3 SEED COAT TREATMENTS AND THEIR EFFECTS ON GERMINATION

Seed coat treatments play an essential role in overcoming dormancy, particularly in seeds with hard, impermeable coats. These methods are crucial for facilitating seed imbibition, oxygen diffusion, and embryo activation, all of which are prerequisites for germination. Many tropical and subtropical species face seed dormancies due to physical barriers, making seed coat treatments a vital intervention for enhancing propagation success. *Chrysophyllum delevoyi*, a tropical fruit tree, is one such species with physical dormancy caused by its hard testa. Other notable examples include *Acacia senegal*, *Parkia biglobosa*, *Tamarindus indica*, and *Albizia lebbeck*, which have shown improved germination responses following specific seed coat modifications (Baskin and Baskin, 2014; Bewley *et al*., 2013; Danthu *et al*., 2003).

Mechanical scarification is among the most commonly employed techniques to address physical dormancy. It involves physically disrupting the seed coat using tools such as sandpaper or scalpels. Studies on *Parkia biglobosa* and *Albizia lebbeck* demonstrate that nicking or abrading the seed coat significantly enhances water uptake and subsequent germination (Danthu *et al*.,

2003). While effective, mechanical treatments require precision to avoid damaging the embryo, particularly in small-seeded species.

Chemical scarification uses corrosive agents, such as concentrated sulphuric acid (H_2SO_4), to chemically erode the seed coat. This method is particularly effective for seeds with highly lignified coats. Research on *Tamarindus indica* and *Prosopis africana* revealed substantial germination improvements following immersion in sulphuric acid for controlled periods (Hartmann *et al*., 2011; Musa *et al*., 2017). However, careful management is crucial, as overexposure to acids can harm the embryo, reducing seed viability.

Hot water soaking offers a simpler, safer alternative for softening hard seed coats. Seeds are submerged in hot water at temperatures ranging from 50°C to 100°C for 5 to 20 minutes, followed by cooling. Studies on *Acacia nilotica* and *Tamarindus indica* showed significant increases in germination rates following hot water treatment, although effectiveness depends on exposure time and seed coat hardness (Musa *et al*., 2017). Water soaking at ambient temperatures (25°C to 40°C) mimics natural hydration cycles and is less invasive. Although less effective for hard-seeded species, this method benefits seeds with milder dormancy or chemical inhibitors. For example, *Khaya senegalensis* showed moderate germination improvements following prolonged soaking in lukewarm water (Adewusi *et al*., 2018).

Stratification is another dormancy-breaking technique, often used for species exhibiting morphophysiological dormancy. Cold stratification replicates winter conditions by storing seeds at low temperatures (4°C–10°C) for several weeks, while warm stratification involves maintaining seeds at moderate temperatures to stimulate biochemical processes. While cold stratification has proven effective for species such as *Faidherbia albida* and *Garcinia kola*

(Baskin and Baskin, 2014), warm stratification benefits species like *Vitex doniana* that exhibit layered dormancy mechanisms (Finch-Savage *et al*., 2006).

Seed coat treatments have profound effects on germination. A key outcome is accelerated germination due to improved water and oxygen permeability, which reactivates metabolic processes. Acid-scarified *Albizia lebbeck* seeds, for instance, initiated germination within three days compared to untreated seeds, which took over two weeks (Bewley *et al*., 2013). Improved seedling development is another benefit. Treated seeds often yield seedlings with robust root and shoot systems, as observed in *Tamarindus indica* and *Parkia biglobosa*, where treated seeds showed a 30–50% increase in seedling height and leaf number within six weeks of planting (Musa *et al*., 2017; Danthu *et al*., 2003).

Seed coat treatments also significantly reduce dormancy periods, making them essential for time-sensitive propagation efforts. This is especially important in agroforestry systems involving *Chrysophyllum delevoyi*, where synchronized germination supports uniform canopy development.

In summary, seed coat treatments are indispensable for enhancing germination in hard-seeded species. Mechanical abrasion, chemical soaking, and thermal exposure have demonstrated effectiveness across a range of tropical species, including *Chrysophyllum delevoyi*, *Tamarindus indica*, *Acacia senegal*, and *Parkia biglobosa*. Tailoring these treatments to align with species-specific needs and ecological requirements ensures optimal germination outcomes and supports the successful propagation and conservation of indigenous species.

2.4 PREVIOUS RESEARCH ON GERMINATION ENHANCEMENT TECHNIQUES

Extensive research has been conducted to evaluate germination enhancement techniques for seeds that exhibit dormancy challenges. These studies have provided valuable insights into the

effects of various pre-treatment methods on germination rates, seed viability, and early seedling development. For numerous tropical and subtropical plant species, dormancy traits pose significant obstacles to propagation, making it essential to identify effective strategies for dormancy alleviation.

2.4.1 Germination Enhancement in Hard-Coated Seeds

Hard-coated seeds are prevalent among species in the Fabaceae and *Sapotaceae* families. These seeds often display physical dormancy due to hard seed coats that resist water and oxygen permeability, which are critical for germination. Notable examples include *Parkia biglobosa*, *Tamarindus indica*, *Albizia lebbeck*, *Prosopis africana*, and *Acacia nilotica*, all of which possess seed coats that are considered physically tougher than those of *Chrysophyllum delevoyi*. Research has therefore focused on pre-treatment strategies to weaken these barriers and stimulate germination.

Mechanical scarification is a widely utilized technique to address physical dormancy in hard-coated seeds. Methods such as nicking, sanding, or cutting the seed coat have proven effective for initiating water uptake and germination. Sanches *et al*. (2017) reported that mechanical scarification improved germination rates by up to 85% across various tropical forest tree species. Similarly, Aduradola and Muibat (2020) demonstrated that scarification of *Chrysophyllum albidum* seeds significantly increased germination speed and produced more vigorous seedlings compared to untreated seeds. For species such as *Albizia lebbeck* and *Parkia biglobosa*, removal or abrasion of the outer seed layer has consistently enhanced germination outcomes (Danthu *et al*., 2003).

Chemical scarification has also emerged as a reliable method, particularly for seeds with highly lignified coats. Concentrated sulphuric acid (H_2SO_4) is commonly used to chemically erode the seed coat and facilitate germination. Garcia *et al*. (2018) observed marked improvements in germination rates among rainforest tree species after immersing seeds in sulphuric acid for five minutes. Ojo and Adewale (2021) similarly reported that optimized exposure times (between 5 and 10 minutes) improved germination rates in *Chrysophyllum* species. This technique has shown great effectiveness in species like *Prosopis africana* and *Tamarindus indica* (Musa *et al*., 2017; Hartmann *et al*., 2011). However, overexposure to acids can harm embryos and compromise seed viability, necessitating precise control during treatment.

Hot water soaking has been evaluated for its ability to reduce seed coat hardness by causing micro-fractures through thermal expansion and contraction. Ajiboye and Olayemi (2019) found that soaking seeds in water at 50–60°C for 30 minutes significantly enhanced germination rates for tropical trees like *Tamarindus indica* and *Acacia nilotica*. However, exposure to temperatures exceeding 80°C can damage internal seed structures, as noted by Martins *et al*. (2020). Positive results from hot water treatments have been consistently observed for species such as *Albizia lebbeck* and *Parkia biglobosa* when temperatures and soaking durations are carefully regulated (Bewley *et al*., 2013).

Research into germination enhancement techniques has revealed that dormancy in tropical forest species can be mitigated through various interventions. By employing methods such as mechanical scarification, chemical treatment, thermal exposure, stratification, hormonal stimulation, and controlled ageing, researchers have demonstrated that both physical and physiological dormancy types can be overcome. For species like *Chrysophyllum delevoyi*,

tailoring these approaches to its specific dormancy traits ensures optimal germination and supports sustainable propagation practices.

2.5 TAXONOMY DESCRIPTION OF *Chrysophyllum delevoyi*

2.5.1 Botanical Description of *Chrysophyllum delevoyi*

Chrysophyllum delevoyi belongs to the family *Sapotaceae* , which comprises numerous tropical trees of ecological and economic significance. Native to the rainforests of West and Central Africa, this species thrives in lowland moist forests, where it plays a key role in maintaining ecosystem diversity and providing resources for local communities. It is known as omumu or ekpiro in Benin language.

Taxonomic Classification of *Chrysophyllum delevoyi*

- **Kingdom**: Plantae
- **Phylum**: Angiosperms
- **Class**: Eudicots
- **Order**: Ericales
- **Family**: *Sapotaceae*
- **Genus**: *Chrysophyllum*
- **Species**: *Chrysophyllum delevoyi* De Wild

Morphologically, *Chrysophyllum delevoyi* is a medium- to large-sized evergreen tree, reaching heights of up to 25 meters. It features a straight, often fluted bole that supports a rounded or broadly spreading crown. The lower portion of the trunk is frequently buttressed—a common

adaptation in tropical trees that provides structural support in wet and competitive forest environments (De Wildeman, 1926; Voorhoeve, 1979). The bark is grayish-brown to dark brown with a textured, fissured surface. When incised, it exudes a characteristic milky latex, typical of many *Sapotaceae* species, which is thought to deter herbivores and pathogens (De Wildeman, 1926).

Its leaves are simple, alternate, and arranged in tight clusters at the terminal ends of branches. They are elliptical to oblong, with an acuminate apex and a cuneate to attenuate base. Leaf dimensions vary widely, with lengths ranging from 15 to 35 centimeters and widths from 5 to 13 centimeters. The adaxial (upper) surface is smooth and glabrous, while the abaxial (lower) surface is densely covered with appressed hairs that give it a golden-brown appearance. This characteristic pubescence underpins the etymology of the genus name *Chrysophyllum*, derived from the Greek words "chrysos" (golden) and "phyllon" (leaf) (Govaerts *et al*., 2001). The leaves also exhibit a prominent venation pattern, with a robust midrib and 20 to 25 lateral veins that curve and loop near the margin, contributing to mechanical strength and efficient water transportation (Ekeke, *et al*., 2021).

Its small, cream-colored, fragrant flowers are borne in clusters, emerging from the axils of leaves or along specialized warty projections on older branches. Each flower is borne on a short pedicel, about 4.5 millimeters long, and is covered with a delicate ferrugineous pubescence. The calyx consists of broadly ovate sepals that protect the floral bud prior to anthesis, while the corolla forms a creamy white tubular structure with densely ciliate, rounded lobes. Microscopic examination reveals a subcorneal ovary covered in dense pilosity and a slender style approximately 3 millimeters in length. These floral characteristics are essential for species

identification and influence the reproductive biology of the tree by attracting pollinators such as bees and butterflies (Hemsley, 1966).

Its fruits, classified as drupes, transition from green to vibrant orange or orange-yellow as they mature. The fruits vary in shape, ranging from ovoid to pyriform or subglobose, and can reach up to 6 centimeters in diameter. Each fruit contains one to five seeds embedded in a sweet, nutritious pulp, which appeals to both wildlife and humans. A notable feature of the seeds is their hard, impermeable testa, which imposes physiological dormancy. While this dormancy mechanism is advantageous for regulating seedling emergence in the wild, it poses challenges for natural and artificial propagation (Ekeke *et al*., 2021)

2.5.2 Ethnobotanical Uses of *Chrysophyllum delevoyi*

Although this species has received less research attention compared to its close relative *Chrysophyllum albidum*, ethnobotanical studies and local knowledge have documented its diverse applications, particularly in food, medicine, craftsmanship, and spiritual practices.

The fruit of *Chrysophyllum delevoyi* is edible and widely consumed by local communities. Its sweet taste and nutritional value make it an important dietary component. Ethnobotanical research in Côte d'Ivoire conducted by N'Guessan, Kouassi, and Zirihi (2009) revealed that the fruit is harvested from wild trees and eaten raw as a seasonal food source. In regions with limited access to commercial markets, the fruit contributes substantially to household nutrition, particularly during periods of food scarcity. Its pulp, rich in natural sugars, serves as a vital energy source for both children and adults.

Traditional medicine utilizes various parts of *Chrysophyllum delevoyi* for herbal remedies. The bark is commonly boiled to prepare decoctions that are used to treat fever, dysentery, diarrhoea,

and stomach pain. Neuwinger (2000) reported that these remedies remain integral to primary healthcare systems in the Congo Basin and surrounding areas. The leaves are also highly valued in folk medicine; when crushed and applied topically, they are used to treat skin infections, boils, rashes, and minor wounds. These applications are based on the belief that *Chrysophyllum delevoyi* possesses anti-inflammatory and antimicrobial properties, a characteristic shared by many members of the *Sapotaceae* family, as supported by Burkill (1985).

In addition to its medicinal and nutritional significance, *Chrysophyllum delevoyi* provides durable timber that is highly valued for domestic construction and woodcraft. Rural communities in Central Africa use the wood to produce pestles, mortars, canoes, stools, and door frames. Its strength, resistance to termite infestation, and general durability make it suitable for a range of subsistence-level construction needs. Lemmens, *et al*., (2012) documented the selective felling of the tree for carpentry and toolmaking, highlighting its utility in these applications.

Cultural and spiritual beliefs surrounding *Chrysophyllum delevoyi* further enhance its ethnobotanical importance. In forest-edge communities of Gabon and Cameroon, the tree is often associated with ancestral spirits and traditional protection rituals. Jonathan *et al*., (2024) reported that the species is preserved in sacred groves during farm clearing, reflecting its role in spiritual practices and ecological stewardship. It is believed to offer protection from harm and misfortune, underscoring its integration into cultural identity and indigenous ecological knowledge systems.

Documenting and incorporating local knowledge into scientific propagation strategies can contribute to biodiversity conservation and support community development efforts.

2.5.3 Ecological Distribution and Habitat

Chrysophyllum delevoyi is primarily distributed across the tropical rainforests and semi-deciduous woodlands of Central and West Africa. Its natural range includes countries such as Nigeria, Cameroon, Gabon, and the Democratic Republic of the Congo, Fischer *et al*. (2010). The species thrives in humid climatic conditions, characterized by annual rainfall ranging from 1,500 to 3,000 millimeters and consistent ambient temperatures of 25 to 32 degrees Celsius.

Chrysophyllum delevoyi demonstrates a strong adaptation to specific edaphic conditions. It thrives in deep, well-drained soils enriched with organic matter, which are commonly found in alluvial and lateritic regions. These soils provide essential nutrients and effective water management, both of which are critical for sustaining growth in tropical environments. The species is typically found at altitudes ranging from 100 to 1,500 meters above sea level, indicating its adaptability to a variety of altitudinal gradients and soil types (Govaerts *et al*., 2001).

Light availability also plays a pivotal role in the establishment and development of *Chrysophyllum delevoyi*. While its seedlings can tolerate shaded conditions during early growth stages, the species requires full sunlight to achieve optimal growth and maturity. This transition from shade tolerance to a preference for full sunlight reflects its ability to adapt to dynamic forest environments, where light conditions often fluctuate due to natural disturbances or canopy openings.

Its extensive root system contributes to soil stabilization, minimizing erosion and enhancing water retention within the ecosystem. Additionally, its rapid growth rate facilitates significant carbon sequestration, making it an important species for mitigating climate change (Bachman *et al*., 2024). The fruits of *Chrysophyllum delevoyi* serve as a valuable food source for various animal species, aiding in seed dispersal and natural regeneration. Concurrently, its fragrant,

cream-colored flowers attract key pollinators such as bees and butterflies, ensuring effective pollination and promoting genetic diversity within tropical ecosystems.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Location of the Experiment Site

The experiment was conducted in the nursery of the Department of Forest Resources and Wildlife Management at the University of Benin, Faculty of Agriculture, located in Ugbowo, Benin City, Edo State, Nigeria. The GPS location of the nursery is Latitude 6°24[1] and Longitude 5°37[1] and on Altitude 134 m (ASL). The vegetation of Benin City area is that of tropical lowland and rain forest, and the climatic condition has a bimodal rainfall pattern with long and sometimes short periods of uncertain rainfall and an annual mean of about 2300mm. The temperature is about 25.1°C (Egharevba *et al*., 2005). The common trees found here are *Triplochiton Scleroxylon, Milicia excelsa, etc.*

The studies were done in two phases namely: Germination phase and Growth phase.

3.2 Germination Study

3.2.1 Pot Filling and Stacking

Medium-sized polythene pots were used. These pots were filled with a well-prepared potting medium consisting of garden topsoil and was sieved thoroughly to remove extraneous materials

(stones, dead roots, sticks, etc.) and neatly filled into each poly pot. After filling, the pots were arranged systematically. There were five (5) treatments, each treatment had three replicates (A, B, and C), and each replicate consisted of 15 poly pots, resulting in a total of 45 pots per treatment and 225 pots in total for the entire experiment. The stacked poly pots were watered for one week

so as to allow weed seeds still present to grow out and were removed before the seeds were sown.

Plate 3.1 Nursery plots

3.2.2 Seed Sourcing, Preparation, and Testing

Mature and ripe fruits of *Chrysophyllum delevoyi (*Plate 3.2) were obtained from a Okomu national park. The fruits were selected based on physical appearance, maturity, and absence of visible defects or pest damage. Each fruit was carefully opened and seeds extracted. On average, each fruit contained three seeds. The seeds were manually separated and sorted. Only seeds that

appeared plump, undamaged, and uniform in size were selected to reduce variability and enhance consistency across treatments.

Plate 3.2 *Chrysophyllum delevoyi* fruits and seeds

The selected seeds were cleaned under running water to remove residual fruit pulp, followed by air-drying for 2 days to eliminate surface moisture and reduce microbial contamination. This drying process also allowed the seeds to stabilize before treatment.

After drying, the seeds were divided into five equal groups corresponding to the five seed coat treatments. Each group contained 45 seeds, further subdivided into three replicates of 15 seeds each (Replicates A, B, and C).

Before planting, the seeds were subjected to their respective pre-treatment methods *(*Plate 1a-1c) which aimed to overcome potential seed coat-imposed dormancy and improve germination performance. All treated seeds were sown immediately after treatment to avoid spoilage and to maintain uniform treatment conditions.

Plate 1a: Nicked seed of *Chrysophyllum delevoyi*

Plate 1b: Seeds of *Chrysophyllum delevoyi* soaked for 24-hours

Plate 1c: *Chrysophyllum delevoyi* seeds soaked for 48-hours

3.3 Description of Seed Coat Treatments

The seeds of *Chrysophyllum delevoyi* were subjected to five different seed coat treatments aimed at evaluating their effect on germination and early seedling growth. Each treatment was meant to modify or bypass dormancy-related barriers imposed by the seed coat. The treatments were as follows:

1. **Total Removal of Seed Coat (T1)**

In this treatment, the entire seed coat was manually removed using a sterile scalpel. The naked seeds were then immediately planted in moistened poly pots.

2. **No Removal of Seed Coat (Control)(T2)**

Seeds in this group were planted without any form of pre-treatment. The seed coat was left intact to serve as the control, helping to assess the natural germination ability of untreated seeds under the same environmental conditions.

3. **Soaking for 24 Hours(T3)**

Seeds were soaked in clean, room-temperature water for **24 hours**. After soaking, the seeds were removed, and planted immediately. This treatment was intended to soften the seed coat and initiate metabolic activity.

4. **Soaking for 48 Hours(T4)**

Similar to the 24-hour soaking, but extended to **48 hours**. This longer soaking duration was hypothesized to further soften the seed coat and possibly increase the germination rate compared to shorter soaking.

5. **Nicked Seed Coat (T5)**

The seeds in this treatment were scarified by making a small cut on the seed coat using a sterile nail cutter, without damaging the embryo. The nicking was done near the radicle end to facilitate water absorption and radicle protrusion. Seeds were then planted immediately.

Each treatment was applied to **45 seeds (15 per replicate × 3 replicates)**, and all seeds were planted under uniform conditions to ensure a fair comparison of germination and growth responses. Watering was done daily except when rain fell. Weeding was carried out as and when due.

Plate 3.3 Layout of the treatment arrangements

3.4 Data Collection

The experiment was monitored daily, when seeds germinated, they were counted and recorded. Germination parameters investigated were;

Date of sowing: date of sowing varied according to treatments. T1 was sown on the 13th of May, 2025; T2 was sown on the 13th of May, 2025; T3 was sown on the 14th of May, 2025; T4 was sown on the 15th of May, 2025 and T5 was sown on the 13th of May, 2025.

Date of emergence: Emergence was recorded as the number of days from sowing to the day when the seedling first became visibly established above the soil surface. First emergence was recorded 8 days after sowing for T4, 9 days after sowing for treatments T2, T3 and T5, while there was no recorded emergence for T1.

Number of emergences: total number of emerged seedlings were counted and recorded everyday

Germination Percentage: The number of emerged seedlings were divided by the total number of seeds sown and all multiplied by 100.

Germination percentage = $\frac{number\ of\ emerged\ seedlings}{nmber\ of\ seeds\ sown}$ X 100

Mean germination time: calculated by multiplying number of germinations per day by the day number all divided by the total number of germinated seeds.

Mean germination time: $\frac{\Sigma(nXd)}{\Sigma n}$

Where:

n = number of seeds germinated

d = time (in days) of germination

Germination period: Total time taken for the seed to complete the germination process.

Germination period = Last germination day – first germination day

Germination rate index: total number of germinated seeds out of the total number of sown seeds.

Germination rate= $\frac{Number\ of\ seeds\ germinated}{total\ of\ seeds\ sown}$

Germination peak: Highest number of seeds germinated in days/ weeks

The growth parameters measurement was taken for 12 weeks and included:

Seedling height (cm): this was done by measuring from the root collar to the tip (apical part) of the seedlings using a ruler graduated in centimeters. The data were collected once every week.

Number of leaves: this was done by counting the number of leaves on each seedling taken once every week.

collar diameter(mm): this was done using a thread. A thread was wrapped around the collar to measure the circumference, then the thread was measured with a ruler and the value recorded.

Leaf area (cm^2): this was carried out at the termination of study and the areas of leaves were determined using a graph book and tracing the shapes of the leaves of the paper, thereafter the number of boxes were counted in the traced leaves in the graph for each seedling and multiplied by the area of each box ($0.04cm^2$) and then approximate mean leaf area of each seedling determined.

Wet biomass (g): this was also carried out at the termination of the study using a very sensitive electronic weight scale to measure the total weight of each selected seedling. A total of twelve (12) seedlings were used with each treatment having three (3) seedlings removed from garden top soil and cleaned to remove soil particles before weighing.

Dry biomass (g): tagged seedlings used for the wet biomass were used for this. And they were wrapped neatly in aluminum foil and then placed in an oven set at 65^oC for 4 hours, when removed from the oven to cool before measuring the weight of each seedling using a very sensitive electric scale.

Root length: this was done at the termination of the study by measuring the root length of twelve (12) selected seedlings, three from each treatment, used for the biomass study. Measurement was from the collar to the root tip using a ruler graduated in centimeters (cm). The measurement

gotten were used to calculate the shoot/ root length ratio with the shoot length of seedlings by dividing the root length by the shoot length.

3.5 Experimental Design

The experimental design employed for this study was the Completely Randomized Design (CRD), suitable for nursery-based pot experiments where environmental conditions are relatively uniform. Each of the five seed coat treatments was replicated three times, with each replicate containing 15 poly pots, giving a total of 225 seeds used across the entire experiment.

Each replicate was carefully arranged in a 3-row by 15-column grid, and the position of each treatment within the nursery was randomly assigned to minimize positional bias and environmental influence. The data collected was analyzed using one way Analysis or Variance (ANOVA)

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Germination of *Chrysophyllum delevoyi*

The germination type exhibited by *Chrysophyllum delevoyi* is epigeal (Plate 4.1).

Plate 4.1: *Chrysophyllum delevoyi* seedling showing epigeal germination

Germination commenced 9 days after sowing (DAS) in T2, T3, T5 respectively and 8 days after sowing (DAS) in T4.

The observed results for the various germination parameters are presented on Table 4.1, figure 4.1.

Treatment 1(T1): There was no observed germination throughout the study period.

Treatment 2(T2) :(Control) Thirty-five (35) germinated seeds, corresponding to a germination percentage of 77.8%. The mean germination time was 23.7 days, max germination was 2 per day, a germination period of 23.67 days, with a germination rate of 0.35 and peak germination in the 3rd week.

Treatment 3(T3): Thirty-one (31) seeds germinated giving a germination percentage of 68.9%. The mean germination time 23.1 days, max germination was 2 per day, the germination period of 25.67 days, with a germination rate 0.30 and peak germination in the 3rd week.

Treatment 4(T4): Thirty-three (33) germinated seeds with a germination percentage of 73.3%. The mean germination time was 23.3 days, max germination was 2 per day, the germination period of 22.33 days, with a germination rate of 0.37 and peak germination in the 2nd week.

Treatment 5 (T5): Nineteen (19) seeds germinated, representing a germination percentage of 42.2%. The mean germination time was 23.1 days, max germination was 1per day, a germination period of 23.33 days, with a germination rate of 0.27 and peak germination in the 2nd week.

Table 4.1: Germination characteristics of *Chrysophylum delvoyi* under different seedcoat treatments

Treatment	Number germinated	Germination percentage (%)	Mean germination time (MGT, days)	Max germination (per day)	Germination period (days)	Germination rate	Peak germination (week)
T1	0	0.0	-	-	-	-	-
T2	35	77.8	23.43	2	23.67	0.35	3
T3	31	68.9	23.10	2	25.67	0.30	3
T4	33	73.3	23.32	2	22.33	0.37	2
T5	19	42.2	23.09	1	23.33	0.27	2

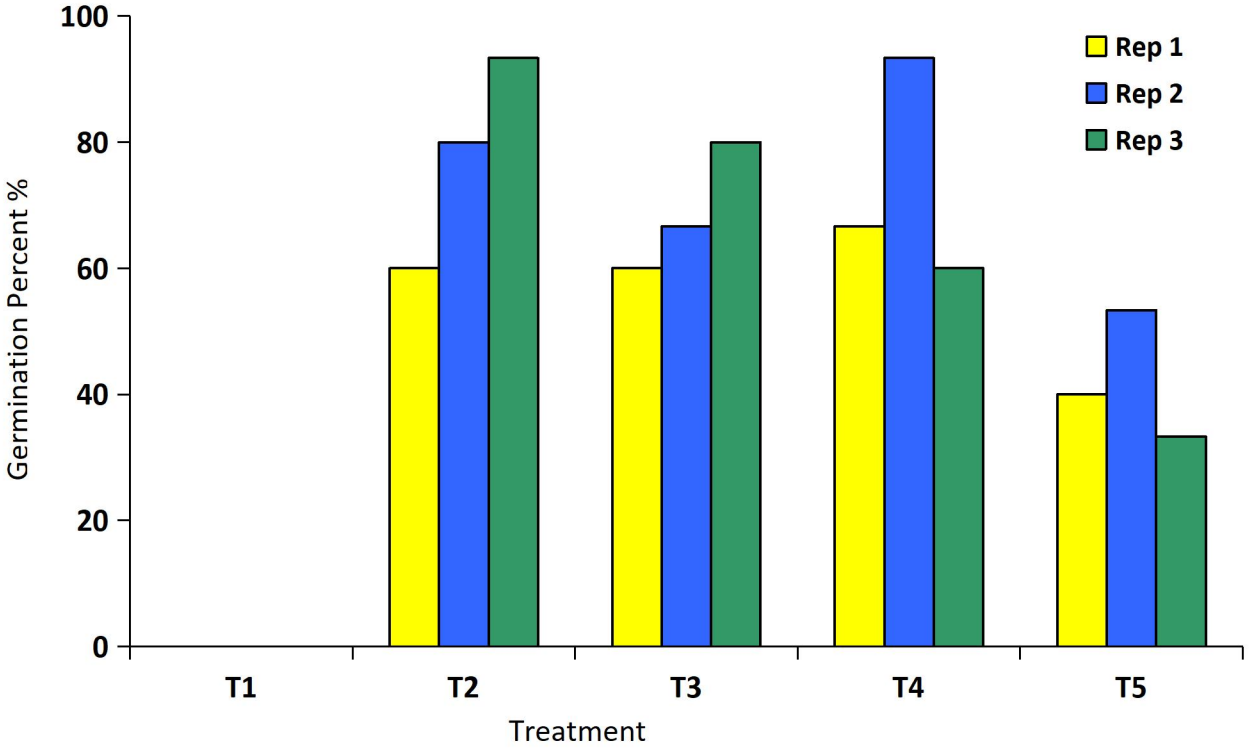

Figure *4.1.* Germination Percentage of *Chrysophyllum delevoyi* replicates under different treatments

GERMINATION PERCENTAGE OF *Chrysophyllum delevoyi*

The results given in descending order of magnitude are as follows:

The control T2 recorded the highest mean germination percentage (77.78%) closely followed by T4 with mean germination of (73.33%) and T3 with a mean germination of (68.89%) and T5 with a mean germination of 42.22%. T2, T3 and T4 are significantly different from T5. T1 had no germination (Table 4.2).

Table 4.2 Germination percentage of *Chrysophyllum delevoyi*

SN	T 2	T 3	T 4	T 5
Replicate A	60	60	66.67	40
Replicate B	80	66.67	93.33	53.33
Replicate C	93.33	80	60	.33.33
Total	233.33	206.67	220	126.66
Mean	77.78a	68.89a	73.33a	42.22b

LSD=26.59

Means with same letters are not significantly different statistically

MEAN GERMINATION TIME OF *Chrysophyllum delevoyi*

The mean germination time varied across treatments. T5 had the highest mean germination time (34.62 days), followed by T2with a mean germination time of 24.43 days, then T4 with a mean germination time of 23.32 days. T3 had a mean germination time of 23.10 days, while T1 had none (Table 4.3).

Table 4.3 Mean Germination Time of *Chrysophyllum delevoyi* in days

SN	T 2	T 3	T 4	T 5
Replicate A	22.00	18.22	27.20	23.33
Replicate B	21.92	27.50	20.86	53.33
Replicate C	26.36	23.58	21.89	27.20
Total	70.28	69.30	69.95	103.36
Mean	23.43a	23.10a	23.32a	34.62a

LSD=16.19

Means with same letters are not significantly different statistically

NUMBER OF GERMINATED SEEDS OF *Chrysophyllum delevoyi*

The highest mean number of seeds germinated value of 11.67 was obtained from T2, followed by T4 with 11.00, followed by T3 with 10.33 and T5 with 6.33. T2, T3, T4 are significantly different from T5 (Table 4.4).

Table 4.4 Number of germinated seeds of *Chrysophyllum delevoyi*

SN	T 2	T3	T4	T 5
Replicate A	9.00	9.00	10.00	6
Replicate B	12.00	10.00	14.00	8
Replicate C	14.00	12.00	9	5
Total	35.00	31.00	33.00	19
Mean	11.67b	10.33b	11.00b	6.33a

LSD=3.99

Means with same letters are not significantly different statistically

GERMINATION PERIOD OF *Chrysophyllum delevoyi*

The highest mean germination period value of 25.67 was obtained from T3, followed by T2 with 23.67, then T4 with 22.33 and T5 with 22.25 (Table 4.5).

Table 4.5 Germination period of *Chrysophyllum delevoyi*

SN	T 2	T 3	T 4	T 5
Replicate A	27.00	25.00	20.00	27.00
Replicate B	22.00	25.00	27.00	18.75
Replicate C	22.00	27.00	20.00	21.00
Total	71.00	77.00	67.00	66.75
Mean	23.67a	25.67a	22.33a	22.25a
LSD=6.27				

Means with same letters are not significantly different statistically

GERMINATION RATE OF *Chrysophyllum delevoyi*

The highest mean germination rate value of 0.37 was obtained from T4, followed by T2 with 0.35, the T3 with 0.30 and T5 with 0.27. There was no significant difference in the treatments (Table 4.6).

Table 4.6 Germination rate of *Chrysophyllum delevoyi*

SN	T 2	T 3	T 4	T 5
Replicate A	0.32	0.26	0.27	0.22
Replicate B	0.35	0.29	0.52	0.38
Replicate C	0.39	0.34	0.32	0.20
Total	1.06	0.89	1.11	0.80
Mean	0.35a	0.30a	0.37a	0.27a
LSD=0.16				

Means with same letters are not significantly different statistically

GERMINATION PEAK OF *Chrysophyllum delevoyi*

The highest mean germination peak value of 2.00 was obtained from T2, followed by T3 and T4 having 1.67 and T5 with 1.33. There was no significant difference in the treatment (Table 4.7).

Table 4.7 Germination peak of *Chrysophyllum delevoyi*

SN	T 2	T 3	T4	T5
Replicate A	2.00	2.00	2.00	1.00
Replicate B	2.00	1.00	2.00	2.00
Replicate C	2.00	2.00	1.00	1.00
Total	6.00	5	5.00	4.00
Mean	2.00a	1.67a	1.67a	1.33a
LSD=0.95				

Means with same letters are not significantly different statistically

GERMINATION TREND OF *Chrysophyllum delevoyi*

Germination trends across treatments revealed the timing and consistency of seedling emergence, this is a regular germination pattern.

Germination began within 9th and 11th days after sowing. Most germination events were completed within 27 days after which no new seedlings emerged.

The germination trend is shown on Figure 4.2. The trend exhibited is regular.

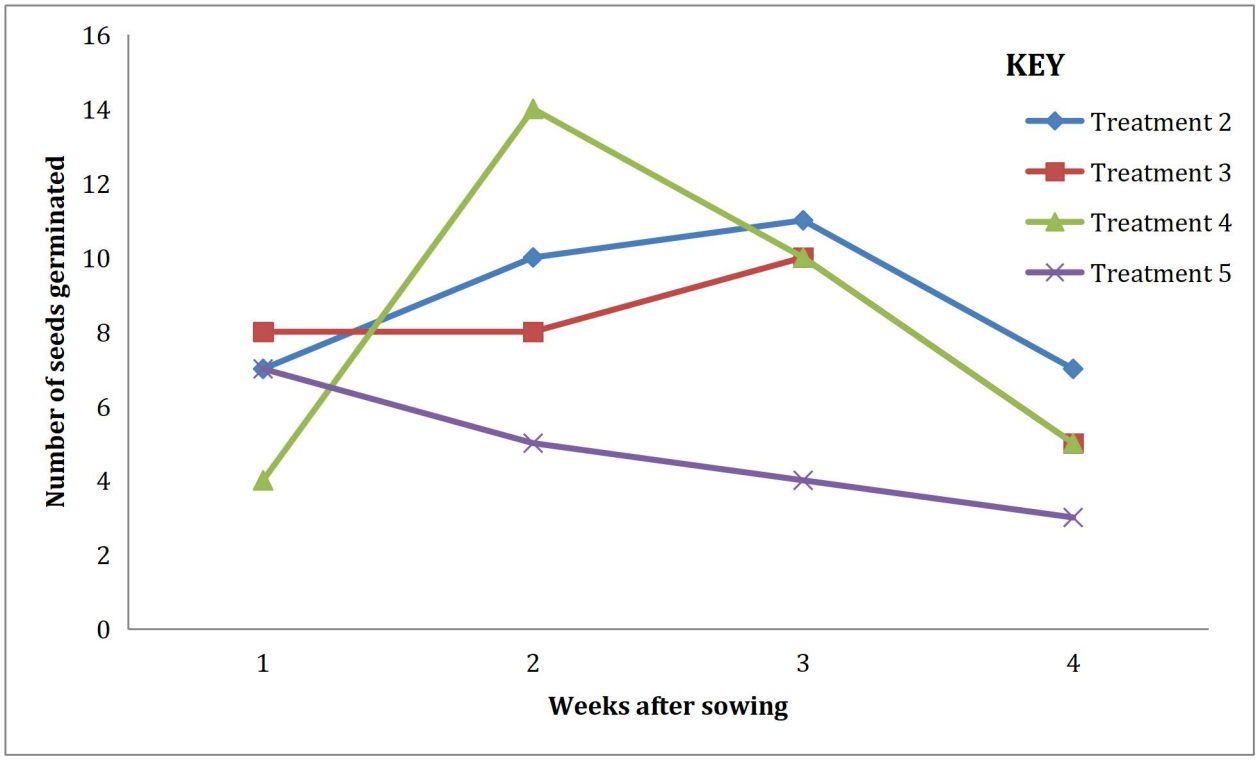

Figure 4.2: Germination trend of *Chrysophyllum delevoyi*

4.2 GROWTH PARAMETERS:

Measurement started 4 weeks after germination and termination of study was 12 weeks after sowing. The mean growth parameter values of *Chrysophyllum delevoyi* seedlings are recorded on (Table 4.8).

Table 4.8 Mean Growth parameters values of *Chrysophyllum delevoyi* seedlings

Treatment	Seedling height	Collar diameter	Number of leaves	Leaf area	Root length	Wet biomass	Dry biomass
T1	-	-	-	-	-	-	-
T2	11.13	1.78	3.73	20.96	14.50	4.02	1.70
T3	10.18	1.55	3.62	38.01	14.87	3.73	1.83
T4	10.56	1.78	3.36	28.49	13.00	3.35	1.57
T5	10.49	1.85	3.76	20.40	11.25	3.35	1.55
LSD	1.25	0.22	0.44	6.88	5.72	1.50	0.65

4.2.1 Seedling Height (cm) of *Chrysophyllum delevoyi*

The result in descending order of magnitude are as follows; T2 recorded the highest mean height (11.13 cm), closely followed by T4 with a mean height of 10.56 cm, and T5 with a mean height of 10.49 cm, and T3 produced a mean height of 10.18cm. T1 did not germinate so there was no growth value. There was no significant difference between the treatments (Table 4.8). Representative seedlings under each seedcoat treatments are shown on (Plate 4.3). The mean weekly growth rate was 0.87cm, value is low meaning that the seedling has slow growth rate in its early stage.

Plate 4.3: Representative seedlings of *Chrysophyllum delevoyi* under each seedcoat treatments

Table 4.9 Seedling height *Chrysophyllum delevoyi* at 12 Weeks After Sowing

SN	T2	T3	T 4	T5
Replicate A	11.80	9.35	10.23	9.71
Replicate B	11.00	10.05	10.49	10.85
Replicate C	10.60	11.13	10.96	10.91
Total	33.40	30.53	31.68	31.47
Mean	11.13a	10.18a	10.56a	10.49a

LSD=1.25

Means with the same letters are not significantly different statistically

4.2.2 Number of Leaves of *Chrysophyllum delevoyi*

The number of leaves per seedling also varied across treatments. T5 produced the highest mean number of leaves (3.76 leaves), followed by T2 with 3.73 leaves followed by T3 with 3.62. T4 recorded a mean of 3.36 leaves, while T1 had none. However, there was no significant difference between the treatments (Table 4.9).

Table 4.10 Number of leaves *Chrysophyllum delevoyi* at 12 Weeks After Sowing

SN	T 2	T 3	T 4	T 5
Replicate A	3.83	3.85	3.51	3.90
Replicate B	3.68	3.20	3.28	3.48
Replicate C	3.68	3.82	3.28	3.90
Total	11.19	10.87	10.07	11.28
Mean	3.73a	3.62a	3.36a	3.76a

LSD=0.44

Means with same letters are not significantly different statistically

4.2.3 Collar Diameter (mm) of *Chrysophyllum delevoyi*

The highest mean collar diameter value was from T5 with 1.85mm, followed by T4 and T2 both having values 1.78 mm respectively, and T3 with 1.55mm. while T1 had no measurable diameter due to lack of germination. The values were significantly different from each other (Table 4.10).

Table 4.11 Collar diameter *Chrysophyllum delevoyi* at 12 Weeks After Sowing

SN	T 2	T3	T 4	T 5
Replicate A	1.90	1.49	1.74	1.78
Replicate B	1.83	1.46	1.73	1.93
Replicate C	1.60	1.70	1.88	1.83
Total	5.33	4.65	5.35	5.54
Mean	1.78a	1.55c	1.78ab	1.85ab

LSD=0.22

Means with same letters are not significantly different statistically

4.2.4 Leaf Area (cm²) of *Chrysophyllum delevoyi*

The highest mean leaf area value of 38.01cm^2 was obtained from T3 followed by T4 with 28.49cm^2, followed by T2 with 20.96cm^2 and T5 with 20.40cm^2. There was significant difference for leaf area and all the mean values were statistically different from each other except for T2 and T5 (Table 4.11).

Table 4.12 Leaf Area (cm2) *Chrysophyllum delevoyi* at 12 Weeks After Sowing

Replicate	T2	T3	T4	T 5
A	20.16	34.84	31.44	19.88
B	25.08	40.00	22.26	19.32
C	17.64	39.20	31.76	22.00
Total	62.88	114.03	85.47	61.20
Mean	20.96c	38.01a	28.49b	20.40c

LSD=6.88

Means with the same letters are not significantly different statistically

4.2.5 Root Length (cm) of *Chrysophyllum delevoyi*

The highest mean root length value of 14.87 was obtained from T3 followed by T2 with 14.50, then T4 with 13cm and T5 with 11.25. There was no significant difference between root length values.

Table 4.13 Root length of *Chrysophyllum delevoyi* at 12 Weeks After Sowing

SN	T2	T 3	T 4	T5
Replicate A	14.00	15.20	11.50	12.00
Replicate B	20.00	13.15	12.75	9.00
Replicate C	9.50	16.25	14.75	12.75
Total	43.50	44.60	39.00	33.75
Mean	14.50a	14.87a	13.00a	11.25a

LSD=5.72

Means with same letters are not significantly different statistically

4.2.6 Seedling Biomass (g) of *Chrysophyllum delevoyi*

Wet Biomass (g) of *Chrysophyllum delevoyi*

The highest mean wet biomass value of 4.04g was obtained from T2, followed by T3 with 3.73, followed by T4 with 3.55 and T5 with 3.55. Numerically, there was significant difference between the values except for T4 and T5 which were similar (Table 4.12).

Table 4.14 Wet biomass *Chrysophyllum delevoyi* at 12 Weeks After Sowing

SN	T 2	T3	T 4	T5
Replicate A	3.84	4.44	4.59	2.37
Replicate B	3.85	2.99	2.59	3.91
Replicate C	4.38	3.76	2.86	3.78
Total	12.07	11.19	10.04	10.06
Mean	4.02a	3.73a	3.55a	3.55a

LSD=1.50

Means with same letters are not significantly different statistically

Dry Biomass (g) of *Chrysophyllum delevoyi*

The highest mean dry biomass value of 1.83g was obtained from T3, followed by T2 with 1.7g. T4 and T5 had a dry biomass value of 1.57g and 1.55g respectively. Values were not significantly different (Table 4.13).

Table 4.15 Dry biomass *Chrysophyllum delevoyi* at 12 Weeks After Sowing

SN	T 2	T 3	T 4	T 5
Replicate A	1.47	2.17	1.91	1.03
Replicate B	2.04	1.67	1.45	1.66
Replicate C	1.58	1.66	1.36	1.96
Total	5.09	5.50	4.72	4.65
Mean	1.70a	1.83a	1.57a	1.55a

LSD=0.65

Means with the same letters are not significantly different statistically

4.3 DISCUSSION

Chrysophyllum delevoyi seeds exhibited epigeal germination. Gbadamosi and Oni (2004) similarly observed this type of germination with *Enanta clarenta* where the seedcoat encapsulated the emerging seed leaves for a long time. Thus, limiting the development of the seedlings until the seedcoat were shed. The germination of the seeds of *Chrysophyllum delevoyi* proved to be successful in T2, T3, T4, T5, with T2 having highest numerical mean value, meaning that is the best treatment for *Chrysophyllum delevoyi*. T2 produced the best germination performance in *Chrysophyllum delevoyi,* indicating that the seedcoat does not impose a significant barrier to water absorption(imbibition) and embryo emergence. This result suggests that the seedcoat is sufficiently permeable for normal germination, and therefore contradicts previous postulations that *C. delevoyi* seeds possesses strong seedcoat-imposed dormancy. T1 did not germinate due to the attraction of insect to the naked seeds, the seeds fragrance attracted insects that ate all of them. Oboho and Urughu (2010) observed that de-coated seeds of *Garcinia kola* gave the highest germination percentage (83%). The difference observed in this study could be due among other factors to the fact that *Garcinia kola* exhibited hypogeal germination. *Chrysophyllum delevoyi* on the other hand exhibits epigeal germination. At emergence, the cotyledons are raised above the soil making germination discernible. In some species like *Gambeya albida, Terminalia ivorensis*, *Hunteria umbelata*, and *Terminalia superba,* these cotyledons do not fall off but become the first proper leaves of the seedlings (Oboho, 2014).

Chrysophyllum delevoyi developed a longer root system than shoot in early growth stage, this is because taproot system is important for water and nutrients exploitation from the soil to support the entire plant's demand. A well-developed root system increases seedling stability and survival before the shoot grows tall.

Chrysophyllum delevoyi had slow mean weekly growth rate of 0.87cm. There was no significant difference in the growth response of seedlings in the seedling height, root length, wet and dry biomass in relation to seedcoat treatment but there was in collar diameter and leaf area. Tinsea *et al*., (2014) observed that there was no significant difference in the shoot, root length, fresh and dry weights of the seedlings of *Tamarindus indica* obtained from three different sources. Similarly, the poor growth response observed in treatments CR (coat removal), PC (partial cracking of seeds), 7H (70% sulphuric acid), 8H (80% sulphuric acid), supports the report of Ehiagbanare and Onyibe (2007) who also recorded poor growth with treatment with mechanical scarification and zero germination with no growth in treatment with H2SO4 in *Tetracarpidium conophorum* seeds. These could probably mean that the seedcoat plays an important protective role in seedling early growth as noted by Oboho (2015) who stated that for *Gambeya albida* which had epigeal germination and foliaceous seedlings, the seedcoat (testa) plays very crucial protective role during the germination, early growth and survival of the seedlings.

In general, T2 had better germination and growth indices compared to other treatments. Therefore, there is no need to pretreat *Chrysophyllum delevoyi* seeds before sowing.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The study found that the germination and early growth of *Chrysophyllum delevoyi* depend greatly on the seedcoat treatment applied before sowing.

The experiment has revealed that T2 (control and no treatment) exhibited better germination and growth for *Chrysophylum delevoyi.*

Therefore, this affordable and environmentally friendly approach is well-suited for forestry nurseries, reforestation efforts and conservation programmes, promoting the sustainable propagation and long-term preservation of this important forest species.

5.2 RECOMMENDATIONS

Based on the findings from the study, the following recommendations were made;

1. Fresh seeds are recommended for germination of this species.
2. For successful germination and early growth of *Chrysophylum delevoyi,* control treatments (untreated seeds) should be adopted as a standard method of sowing and raising the species in the nursery.
3. Future research should be done on *Chrysophyllum delevoyi* particularly in the area of improving the growth rate, shorten the rotation age and enlist people's participation in its cultivation.

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APPENDIX

ANOVA KEY

DF= degree of freedom

SS= sum of squares

MS= mean square

FCal= F Statistic Calculated

Ftab= F tabulated (critical values)

Sig= Significance (p-value)

Germination percentage ANOVA table

Sv	Df	Ss	Ms	Fcal	Ftab
Treatment	3	2,296.72	765.57	3.83	4.07
Error	8	1,596.94	199.62		
Total	11	3,893.66			

Treatments were not significantly different ($\alpha = 0.05$)

H_0: $\mu_1 = \mu_2 = \mu_3 = \mu_4 = \mu$ i.e. treatment means equal to overall population mean.

H_1: $\mu_1 \neq \mu_2 \neq \mu_3 \neq \mu_4 \neq \mu$ i.e. treatment means not equal to overall population mean.

H_0: $\alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = 0$ i.e. treatments have no effect on the seedlings germination percentage

H_1: $\alpha_1 \neq \alpha_2 \neq \alpha_3 \neq \alpha_4 \neq 0$ i.e. treatments have effect on the seedlings germination percentage

ANOVA table of Mean germination time

Sv	Df	Ss	Ms	Fcal	Ftab
Treatment	3	340.99	113.66	1.54	4.07
Error	8	591.73	73.97		
Total	11	932.72			

Treatments were not significantly different ($\alpha = 0.05$)

H_0: $\mu_1 = \mu_2 = \mu_3 = \mu_4 = \mu$ i.e. treatment means equal to overall population mean.

H_1: $\mu_1 \neq \mu_2 \neq \mu_3 \neq \mu_4 \neq \mu$ i.e. treatment means not equal to overall population mean.

H_0: $\alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = 0$ i.e. treatments have no effect on the seedlings mean germination time

H_1: $\alpha_1 \neq \alpha_2 \neq \alpha_3 \neq \alpha_4 \neq 0$ i.e. treatments have effect on the seedlings mean germination time

ANOVA table of Number of germinated seeds

Sv	Df	Ss	Ms	Fcal	Ftab
Treatment	3	51.77	17.26	3.84	4.07
Error	8	35.98	4.50		
Total	11	87.75			

Treatments were not significantly different ($\alpha = 0.05$)

H_0: $\mu_1 = \mu_2 = \mu_3 = \mu_4 = \mu$ i.e. treatment means equal to overall population mean.

H_1: $\mu_1 \neq \mu_2 \neq \mu_3 \neq \mu_4 \neq \mu$ i.e. treatment means not equal to overall population mean.

H_0: $\alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = 0$ i.e. treatments have no effect on the seedlings number germinated

H_1: $\alpha_1 \neq \alpha_2 \neq \alpha_3 \neq \alpha_4 \neq 0$ i.e. treatments have effect on the seedlings number germinated

ANOVA table of Germination period

Sv	Df	Ss	Ms	Fcal	Ftab
Treatment	3	23.01	7.67	0.69	4.07
Error	8	88.36	11.05		
Total	11	111.37			

Treatments were not significantly different ($\alpha = 0.05$)

H_0: $\mu_1 = \mu_2 = \mu_3 = \mu_4 = \mu$ i.e. treatment means equal to overall population mean.

H_1: $\mu_1 \neq \mu_2 \neq \mu_3 \neq \mu_4 \neq \mu$ i.e. treatment means not equal to overall population mean.

H_0: $\alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = 0$ i.e. treatments have no effect on the seedlings germination period

H_1: $\alpha_1 \neq \alpha_2 \neq \alpha_3 \neq \alpha_4 \neq 0$ i.e. treatments have effect on the seedlings germination period

ANOVA table of Germination rate

Sv	Df	Ss	Ms	Fcal	Ftab
Treatment	3	0.0189	0.0063	0.84	4.07
Error	8	0.0603	0.0075		
Total	11	0.0792			

Treatments were not significantly different ($\alpha = 0.05$)

H_0: $\mu_1 = \mu_2 = \mu_3 = \mu_4 = \mu$ i.e. treatment means equal to overall population mean.

H_1: $\mu_1 \neq \mu_2 \neq \mu_3 \neq \mu_4 \neq \mu$ i.e. treatment means not equal to overall population mean.

H_0: $\alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = 0$ i.e. treatments have no effect on the seedlings germination rate

H_1: $\alpha_1 \neq \alpha_2 \neq \alpha_3 \neq \alpha_4 \neq 0$ i.e. treatments have effect on the seedlings germination rate

ANOVA table of Germination peak

Sv	Df	Ss	Ms	Fcal	Ftab
Treatment	3	0.68	0.23	0.92	4.07
Error	8	2.01	0.25		
Total	11	2.69			

Treatments were not significantly different ($\alpha = 0.05$)

H_0: $\mu_1 = \mu_2 = \mu_3 = \mu_4 = \mu$ i.e. treatment means equal to overall population mean.

H_1: $\mu_1 \neq \mu_2 \neq \mu_3 \neq \mu_4 \neq \mu$ i.e. treatment means not equal to overall population mean.

H_0: $\alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = 0$ i.e. treatments have no effect on the seedlings germination peak

H_1: $\alpha_1 \neq \alpha_2 \neq \alpha_3 \neq \alpha_4 \neq 0$ i.e. treatments have effect on the seedlings germination peak

ANOVA table of Plant height

Sv	Df	Ss	Ms	Fcal	Ftab
Treatment	3	2.16	0.72	1.63	4.07
Error	8	3.54	0.44		
Total	11	5.70			

Treatments were not significantly different ($\alpha = 0.05$)

H_0: $\mu_1 = \mu_2 = \mu_3 = \mu_4 = \mu$ i.e. treatment means equal to overall population mean.

H_1: $\mu_1 \neq \mu_2 \neq \mu_3 \neq \mu_4 \neq \mu$ i.e. treatment means not equal to overall population mean.

H_0: $\alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = 0$ i.e. treatments have no effect on the seedlings height

H_1: $\alpha_1 \neq \alpha_2 \neq \alpha_3 \neq \alpha_4 \neq 0$ i.e. treatments have effect on the seedlings height

ANOVA table of Number of Leaves

Sv	Df	Ss	Ms	Fcal	Ftab
Treatment	3	0.30	0.10	1.83	4.07
Error	8	0.27	0.05		
Total	11	0.57			

Treatments were not significantly different ($\alpha = 0.05$)

H_0: $\mu_1 = \mu_2 = \mu_3 = \mu_4 = \mu$ i.e. treatment means equal to overall population mean.

H_1: $\mu_1 \neq \mu_2 \neq \mu_3 \neq \mu_4 \neq \mu$ i.e. treatment means not equal to overall population mean.

H_0: $\alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = 0$ i.e. treatments have no effect on the seedlings number of leaves

H_1: $\alpha_1 \neq \alpha_2 \neq \alpha_3 \neq \alpha_4 \neq 0$ i.e. treatments have effect on the seedlings number of leaves

ANOVA table of collar diameter

Sv	Df	Ss	Ms	Fcal	Ftab
Treatment	3	0.15	0.05	3.65	4.07
Error	8	0.11	0.01		
Total	11	0.26			

Treatments were not significantly different ($\alpha = 0.05$)

H_0: $\mu_1 = \mu_2 = \mu_3 = \mu_4 = \mu$ i.e. treatment means equal to overall population mean.

H_1: $\mu_1 \neq \mu_2 \neq \mu_3 \neq \mu_4 \neq \mu$ i.e. treatment means not equal to overall population mean.

H_0: $\alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = 0$ i.e. treatments have no effect on the seedlings collar diameter

H_1: $\alpha_1 \neq \alpha_2 \neq \alpha_3 \neq \alpha_4 \neq 0$ i.e. treatments have effect on the seedlings collar diameter

ANOVA table of Root length

Sv	Df	Ss	Ms	Fcal	Ftab
Treatment	3	24.47	8.16	0.89	4.07
Error	8	73.71	9.21		
Total	11	98.18			

Treatments were not significantly different ($\alpha = 0.05$)

H_0: $\mu_1 = \mu_2 = \mu_3 = \mu_4 = \mu$ i.e. treatment means equal to overall population mean.

H_1: $\mu_1 \neq \mu_2 \neq \mu_3 \neq \mu_4 \neq \mu$ i.e. treatment means not equal to overall population mean.

H_0: $\alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = 0$ i.e. treatments have no effect on the seedlings root length

H_1: $\alpha_1 \neq \alpha_2 \neq \alpha_3 \neq \alpha_4 \neq 0$ i.e. treatments have effect on the seedlings root length

ANOVA table of Shoot length

Sv	Df	Ss	Ms	Fcal	Ftab
Treatment	3	2.21	0.74	0.40	4.07
Error	8	14.62	1.83		
Total	11	16.83			

Treatments were not significantly different ($\alpha = 0.05$)

H_0: $\mu_1 = \mu_2 = \mu_3 = \mu_4 = \mu$ i.e. treatment means equal to overall population mean.

H_1: $\mu_1 \neq \mu_2 \neq \mu_3 \neq \mu_4 \neq \mu$ i.e. treatment means not equal to overall population mean.

H_0: $\alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = 0$ i.e. treatments have no effect on the seedlings shoot length

H_1: $\alpha_1 \neq \alpha_2 \neq \alpha_3 \neq \alpha_4 \neq 0$ i.e. treatments have effect on the seedlings shoot length

ANOVA table of Leaf Area

Sv	Df	Ss	Ms	Fcal	Ftab
Treatment	3	610.31	203.44	15.22	4.07
Error	8	106.96	13.37		
Total	11	717.27			

Treatments were not significantly different ($\alpha = 0.05$)

H_0: $\mu_1 = \mu_2 = \mu_3 = \mu_4 = \mu$ i.e. treatment means equal to overall population mean.

H_1: $\mu_1 \neq \mu_2 \neq \mu_3 \neq \mu_4 \neq \mu$ i.e. treatment means not equal to overall population mean.

H_0: $\alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = 0$ i.e. treatments have no effect on seedlings leaf area

H_1: $\alpha_1 \neq \alpha_2 \neq \alpha_3 \neq \alpha_4 \neq 0$ i.e. treatments have effect on the seedlings leaf area

ANOVA table of Wet Biomass Seedlings

Sv	Df	Ss	Ms	Fcal	Ftab
Treatment	3	0.94	0.31	0.50	4.07
Error	8	5.06	0.63		
Total	11	6.00			

Treatments were not significantly different ($\alpha = 0.05$)

H_0: $\mu_1 = \mu_2 = \mu_3 = \mu_4 = \mu$ i.e. treatment means equal to overall population mean.

H_1: $\mu_1 \neq \mu_2 \neq \mu_3 \neq \mu_4 \neq \mu$ i.e. treatment means not equal to overall population mean.

H_0: $\alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = 0$ i.e. treatments have no effect on seedlings wet biomass

H_1: $\alpha_1 \neq \alpha_2 \neq \alpha_3 \neq \alpha_4 \neq 0$ i.e. treatments have effect on the seedlings wet biomass

ANOVA table of Dry Biomass of Seedlings

Sv	Df	Ss	Ms	Fcal	Ftab
Treatment	3	0.15	0.05	0.42	4.07
Error	8	0.97	0.12		
Total	11	1.12			

Treatments were not significantly different ($\alpha = 0.05$)

H_0: $\mu_1 = \mu_2 = \mu_3 = \mu_4 = \mu$ i.e. treatment means equal to overall population mean.

H_1: $\mu_1 \neq \mu_2 \neq \mu_3 \neq \mu_4 \neq \mu$ i.e. treatment means not equal to overall population mean.

H_0: $\alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = 0$ i.e. treatments have no effect on seedlings dry biomass

H_1: $\alpha_1 \neq \alpha_2 \neq \alpha_3 \neq \alpha_4 \neq 0$ i.e. treatments have effect on the seedlings dry biomass